Annual Report 2017

Jožef Stefan Institute, Ljubljana, Slovenia

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Jožef Stefan Institute, Ljubljana, Slovenia

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INTRODUCTION

European research and technological development policy is set out to build Europe as a leading, knowledge-based society. Particularly during the last economic crisis, however, there were significant differences among the EU Member States. The more developed countries, being aware of the importance of this area, increased their investments, while some others, generally the poorer countries, decided to reduce their spending, despite the recommendations of the European Commission. This has contributed to a widening of the gap between the technologically more- and less-developed regions of Europe.

Unfortunately, Slovenia is among those countries that, due to negative financial flows, decided to shrink their innovation potential, particularly with respect to public research and the research infrastructure. What is unusual about this, is that European institutions are pointing out the importance of public investments in research, in particular in relation

Director of the Jožef Stefan Institute, Prof. Jadran Lenarčič (left), Director of the National Institute of Chemistry, Prof. Gregor Anderluh, and Director of Arnes, Marko Bonač, M. Sc., signed a letter of intent to cooperate in the Slovenian supercomputer network SLING on the 26th of April 2017 at the National Institute of Chemistry. (Photo: Jernej Stare)

to the productivity of the economy, which is one of the negative features of Slovenian development. Last year, for the first time in many years, the Slovenian government proposed raising funds for research in 2018. Although additional funding would be very welcome, many years of cutbacks cannot be easily repaired.

The fundamental development issue for Slovenian research organizations is how to remain internationally comparable and competitive. The Jožef Stefan Institute builds its research excellence on a long-standing tradition of international cooperation and exchanges, and the involvement of young researchers, who have a lot of inspiration and commitment. Therefore, in spite of the modest conditions for work, this year we can again boast of excellent research results, which are demonstrated by high-level scientific publications or in development achievements in cooperation with the economy. On this occasion, I would like to thank all my colleagues for their efforts and their valuable contributions.

Prof. Jadran Lenarčič
Director of the Jožef Stefan Institute

A BRIEF HISTORY OF THE JOŽEF STEFAN INSTITUTE

1946
~ Decision taken by the Slovenian Academy of Science and Arts to build a Physics Institute

1949
~ Research connected to the peaceful use of atomic energy started, financed by the Federal Government

1952
~ Institute renamed the Jožef Stefan Physics Institute and moved to new laboratories on its present site

1954
~ The betatron and an electron microscope installed as the institute's first major pieces of equipment

1956
~ Van de Graaff accelerator, constructed at the institute, started operation

1958
~ Institute reorganised and new fields of activity defined: nuclear physics, solid-state physics, chemistry, and radiobiology

1959
~ Institute renamed the Jožef Stefan Nuclear Institute. The major source of income was provided by the Yugoslav Atomic Energy Commission

Mass spectrometer at the JSI (about 1960)

1962
~ One of the first compounds of a noble gas, XeF_6, synthesised at the institute
~ The first computer for research, ZUSE Z 23, installed

1966
~ Nuclear research reactor TRIGA starts operation

1968
~ Yugoslav Atomic Energy Commission ceases to operate; The Republic of Slovenia becomes the institute's dominant source of research funding

1969
~ Institute is renamed as the Jožef Stefan Institute

1970
~ University of Ljubljana becomes a co-founder of the Jožef Stefan Institute, together with the Federal Executive Council

1971
~ A new unit, INOVA, established with the aim of applying the institute's expertise and output to productive use in the national economy

Institute buildings after the opening in 1953

1972
~ New computer Cyber 72 purchased, and the Republic Computer Centre established as an independent unit of the Jožef Stefan Institute

1974
~ Collaboration with the international centre CERN in the field of high-energy physics started
~ SEPO group for evaluating environmental interventions is established

1976
~ First Yugoslav 8-bit processor computer DARTA 80

1979
~ Contract defining cooperation between the Jožef Stefan Institute and the Nuclear Power Plant Krško is signed
~ First robot in Slovenia is constructed

1982
~ Ecological Laboratory with Mobile Unit established as a special unit of the Slovenian Civil Protection Organisation

1983
~ Stefin, a cysteine proteinase inhibitor named after Jožef Stefan, isolated and its primary structure determined

The Reactor Centre, Podgorica, built in 1966

1985

~ "2000 New Young Researchers" project established by the Slovenian Research Council

~ Centre for Hard Coatings established by the Jožef Stefan Institute and the firm SMELT

The beginnings of robotics at the JSI, in 1985

1987

~ INEA established by the Jožef Stefan Institute as an independent company to promote technology transfer in the fields of cybernetics and energy management

1989

~ Milan Čopič Nuclear Training Centre established

1990

~ The first Slovenian supercomputer, CONVEX, installed at the Jožef Stefan Institute

1992

~ New technology centres established by the Ministry of Science and Technology

~ Jožef Stefan Institute restructured by the Slovenian Government as a public research institution

~ Jožef Stefan Technology Park founded, later to become the Ljubljana Technology Park

1995

~ Jožef Stefan Institute is a co-founder of the international postgraduate school for environmental sciences, the Nova Gorica Polytechnic

~ Research institutes in Velenje, ERICo and Valdoltra established by the Institute

1997

~ 3.5-MeV electrostatic accelerator, TANDETRON, installed

1999

~ Jožef Stefan Institute celebrates its 50th anniversary

2003

~ Jožef Stefan International Postgraduate School established

2004

~ Jožef Stefan Institute is chosen as the coordinator of four Research Centres of Excellence

2007

~ Nanomanipulation of single atoms using low-temperature scanning tunneling microscope

~ New ERDA/RBS beamline installed at the TANDETRON accelerator at the Microanalytical center

2015

~ New research infrastructure, including new and renovated laboratory and office space with high-tech instrumentation for environmental research

High-tech instrumentation for environmental research at the JSI in 2015

FORMER DIRECTORS

Prof. Anton Peterlin, Founder and first Director of the Jožef Stefan Institute, 1949–1955
Karol Kajfež, 1955–1958
Lucijan Šinkovec, B. Sc., 1959–1963
Prof. Milan Osredkar, 1963–1975
Prof. Boris Frlec, 1975–1984
Prof. Tomaž Kalin, 1984–1992
Prof. Danilo Zavrtanik, 1992–1996
Prof. Vito Turk, 1996–2005

Prof. Anton Peterlin,
first Director of the Jožef Stefan Institute

Jožef Stefan Institute

ORGANISATION OF THE JOŽEF STEFAN INSTITUTE

BOARD OF GOVERNORS

DIRECTOR

SCIENTIFIC COUNCIL

RESEARCH DEPARTMENTS

Physics

Theoretical Physics (F-1)
Prof. Svjetlana Fajfer
Low and Medium Energy Physics (F-2)
Prof. Primož Pelicon
Thin Films and Surfaces (F-3)
Asst. Prof. Miha Čekada
Surface Engineering and Optoelectronics (F-4)
Prof. Miran Mozetič
Solid State Physics (F-5)
Prof. Igor Muševič
Complex Matter (F-7)
Prof. Dragan Dragoljub Mihailović
Reactor Physics (F-8)
Asst. Prof. Luka Snoj
Experimental Particle Physics (F-9)
Prof. Marko Mikuž

Chemistry and Biochemistry

Inorganic Chemistry and Technology (K-1)
Asst. Prof.Gašper Tavčar

Physical and Organic Chemistry (K-3)
Prof. Ingrid Milošev

Electronic Ceramics (K-5)
Prof. Barbara Malič

Nanostructured Materials (K-7)
Prof. Spomenka Kobe

Synthesis of Materials (K-8)
Prof. Darko Makovec

Advanced Materials (K-9)
Prof. Danilo Suvorov

Biochemistry, Molecular and Structural Biology (B-1)
Prof. Boris Turk
Molecular and Biomedical Sciences (B-2)
Prof. Igor Križaj
Biotechnology (B-3)
Prof. Janko Kos
Environmental Sciences (O-2)
Prof. Milena Horvat

Electronics and Information Technology

Automation, Biocybernetics and Robotics (E-1)
Prof. Aleš Ude
Systems and Control (E-2)
Dr. Vladimir Jovan
Artificial Intelligence Laboratory (E-3)
Prof. Dunja Mladenić
Open Systems and Networks (E-5)
Prof. Borka Jerman Blažič
Communication Systems (E-6)
Prof. Mihael Mohorčič
Computer Systems Department (E-7)
Asst. Prof. Gregor Papa
Knowledge Technologies (E-8)
Prof. Nada Lavrač
Intelligent Systems (E-9)
Prof. Matjaž Gams

Reactor Techniques and Energetics

Reactor Engineering (R-4)
Prof. Leon Cizelj

CENTRES

Reactor Centre (RIC)
Prof. Borut Smodiš
Networking Infrastructure Centre (NIC)
Vladimir Alkalaj, M. Sc., dr. Jan Jona Javoršek
Science Information Centre (SIC)
Dr. Luka Šušteršič
Energy Efficiency Centre (EEC)
Stane Merše, M. Sc.
Centre for Knowledge Transfer in Information Technologies (CT-3)
Mitja Jermol, M. Sc.
Milan Čopič Nuclear Training Centre (ICJT)
Dr. Igor Jenčič
Centre for Electron Microscopy and Microanalysis (CEMM)
Prof. Miran Čeh
Centre for Technology Transfer and Innovation (CTT)
Dr. Špela Stres, MBA, LLM
Smart Cities and Communities Centre (CSC & C)
Martin Pečar, B. Sc.
Center Factory of the Future (CFoF)
Rudi Panjtar, B. Sc.
Microanalytical Instrumental Centre (MIC)
Prof. Primož Pelicon

Combined Atomic Microscope (UHV-AFM/STM)
Prof. Maja Remškar
Helium Liquifier with Superconducting Magnet and Helium Regeneration System
Prof. Janez Dolinšek
Mass Spectrometry Centre
Dr. Dušan Žigon
National Centre for Microstructure and Surface Analysis
Prof. Miran Čeh
National Centre for High Resolution NMR Spectroscopy
Prof. Janez Dolinšek
Centre for Protein Structure
Prof. Dušan Turk
Nanolitography and Nanoscopy
Prof. Dragan Dragoljub Mihailović
For Experimental Particle Physicis in International Laboratories
Prof. Marko Mikuž
Hot Cells Facility
Prof. Borut Smodiš
Video-conferencing Centre
Dr. Dušan Gabrijelčič

ADMINISTRATION, SERVICES AND SUPPORT UNITS

Administration and Services

Legal and Personnel (U-2)
Katja Novak, LL. B.
Sales and Purchase Department (U-3)
Darko Korbar, M. Sc., MBA
Finance and Accounting (U-4)
Regina Gruden, M. Sc.
Service for Business Informatics (U-5)
Jože Kašman, B. Sc.
Technical Services (TS)
Aleš Cesar, B. Sc.

Support Units

Radiation Protection Unit (SVPIS)
Matjaž Stepišnik, M. Sc.
Quality Assurance (QA)
Dr. Andrej Prošek
Workshops
Franc Setnikar, B. Sc.

PARTICIPATION IN THE REGIONAL DEVELOPMENT OF RESEARCH

Ljubljana Technology Park Ltd.

University of Nova Gorica

Jožef Stefan International Postgraduate School

Technology Centres

Nanotesla Institute Ljubljana

Development Centre for Hydrogen Technologies

Technology Centre for Production Automation, Robotics and Informatics (ARI)

Security Technology Competence Centre (SETTCE)

Centres of Excellence

Nanocenter - Center of Excellence in Nanoscience and Nanotechnology

Centre of Excellence for Integrated Approaches in Chemistry and Biology of Proteins (CIPKeBiP)

Centre of Excellence NAMASTE

Centre of Excellence for Polymer Materials and Technologies (PoliMaT)

EN-FIST Centre of Excellence

CEBIC Centre of Excellence for Biosensors, Instrumentation and Process Control

CO NOT: Centre of Excellence for Low-Carbon Technologies

Centre of Excellence for Space Sciences and Technologies SPACE-SI

MANAGEMENT

DIRECTORATE

BOARD OF GOVERNORS

SCIENTIFIC COUNCIL

INTERNATIONAL ADVISORY BOARD

STAFF QUALIFICATIONS

1949-2017

Legend:
- Ph. D. Degree
- M. Sc., B. Sc. Degree
- Total Staff

Year	Ph. D.	M. Sc., B. Sc.	Total Staff
1949			7
1950	2	6	13
1951	5	9	44
1952	3	18	81
1953	5	18	114
1954	6	24	138
1955	10	27	174
1956	12	34	215
1957	3	68	273
1958	15	69	291
1959	15	90	335
1960	17	93	350
1961	19	96	367
1962	22	121	375
1963	24	120	400
1964	26	133	444
1965	55	116	457
1966	54	116	443
1967	55	116	412
1968	57	116	403
1969	56	117	420
1970	58	135	452
1971	66	145	480
1972	73	152	515
1973	77	149	534
1974	92	159	558
1975	103	200	593
1976	108	196	634
1977	109	193	632
1978	122	216	687
1979	119	210	630
1980	130	225	652
1981	133	255	675
1982	135	256	667
1983	137	280	702
1984	143	293	732
1985	143	316	749
1986	147	347	813
1987	174	349	852
1988	191	372	895
1989	200	385	909
1990	218	379	895
1991	218	403	858
1992	264	295	809
1993	227	278	744
1994	247	237	707
1995	250	235	703
1996	264	225	707
1997	270	225	705
1998	287	236	731
1999	301	231	733
2000	318	224	743
2001	323	219	739
2002	343	212	742
2003	363	224	768
2004	363	232	770
2005	369	265	799
2006	370	279	818
2007	358	321	854
2008	377	336	860
2009	351	372	882
2010	365	410	929
2011	432	417	981
2012	420	425	962
2013	434	388	961
2014	429	389	962
2015	448	395	955
2016	469	387	958
2017	455	406	961

RECIPIENTS OF THE JSI AWARDS AND TITLES

HONORARY MEMBERS

Prof. Robert Blinc✠, President of the Scientific Council of the Jožef Stefan Institute from 1992 to 2007 (1933 - 2011)

Prof. Jean-Marie Dubois, Institut Jean Lamour, CNRS - Centre National de la Recherche Scientifique, Paris and Université Lorraine, Nancy, France

Prof. Boris Frlec, Director of the Jožef Stefan Institute from 1975 to 1984

Prof. Robert Huber, Nobel Prize Winner, Max-Planck-Institut für Biochemie, Munich, Germany

Prof. Milan Osredkar✠, Director of the Jožef Stefan Institute from 1963 to 1975 (1919 - 2003)

Prof. Anton Peterlin✠, Founder and First Director of the Jožef Stefan Institute from 1949 to 1955 (1908 - 1993)

Prof. Vito Turk, Director of the Jožef Stefan Institute from 1996 to 2005

ASSOCIATE MEMBERS

Prof. David C. Ailion, University of Utah, Salt Lake City, Utah, USA

Prof. Neil Bartlett✠, University of California, Berkeley, California, USA

Prof. John H. Beynon, University of Wales Swansea, Swansea, United Kingdom

Prof. Wolfram Bode, Max-Planck-Institut für Biochemie, Munich, Germany

Prof. Oscar D. Bonner✠, University of South Carolina, Columbia, South Carolina, USA

Dr. Horst Borrmann, Max-Planck-Institut für chemische Physik fester Stoffe, Dresden, Germany

Prof. Henrik Buchowsky, Politechnika Warszawska, Warszawa, Poland

Prof. Rüdiger Dillmann, Karlsruher Institut für Technologie, Karlsruhe, Germany

Prof. Joseph W. Doane, Liquid Crystal Institute, Kent State University, Kent, Ohio, USA

Prof. Hans Fritz, Universität München, Munich, Germany

Prof. Oskar Glemser✠, Universität Göttingen, Göttingen, Germany

Prof. Paul Hagenmuller✠, Université de Bordeaux I, Bordeaux, France

Prof. John Holloway, University of Leicester, Leicester, United Kingdom

Prof. Rudolf Hoppe✠, Universität Giessen, Giessen, Germany

Prof. Robert J. Jaeger✠, National Institute on Disability and Rehabilitation Research, US Department of Education, Washington, D. C., USA

Prof. Nikola Kallay✠, University of Zagreb, Zagreb, Croatia

Prof. Nobuhiko Katunuma, Tokushima Bunri University, Tokushima, Japan

Prof. Raymond Kind, ETH, Zurich, Switzerland

Prof. Jože Koller, University of Ljubljana, Faculty of Chemistry and Chemical Technology, Ljubljana, Slovenia

Prof. Rüdiger Mews, Universität Bremen, Bremen, Germany

Prof. Donald Michie✠, Edinburgh University, Edinburgh, United Kingdom

Dr. Fani Milia, National Centre for Scientific Research "Demokritos", Athens, Greece

Prof. Tsuyoshi Nakajima, Aichi Institute of Technology, Toyota, Japan

Prof. Vincenzo Parenti - Castelli, University of Bologna, Bologna, Italy

Prof. Herbert W. Roesky, Universität Göttingen, Göttingen, Germany

Prof. John A. Rupley, The University of Arizona, Tucson, Arizona, USA

Prof. Findlay E. Russell, The University of Arizona, Tucson, Arizona, USA

Prof. Hugo V. Schmidt, Montana State University, Bozeman, Montana, USA

Prof. Lev A. Shuvalov✠, Institute for Crystallography, Russian Academy of Sciences, Moscow, Russia

Prof. Neil W. Tanner✠, University of Oxford, Oxford, United Kingdom

Dr. Alain Tressaud, Institut de Chimie de la Matière Condensée de Bordeaux, CNRS, Pessac, France

Prof. Vlado Valković, Zagreb, Croatia

Prof. John Waugh, M.I.T., Cambridge, Massachusetts, USA

EMERITUS SCIENTISTS

Prof. France Bremšak✠

Prof. Mihael Drofenik

Prof. Peter Gosar

Prof. Darko Jamnik

Prof. Gabrijel Kernel

Prof. Borut Mavko

Prof. Miodrag V. Mihailović✠

Prof. Raša Matija Pirc

Prof. Marjan Senegačnik✠

Prof. Saša Svetina

Prof. Boštjan Žekš

Prof. Boris Žemva

EXTERNAL ADVISERS

Prof. Savo Bratoš, Université Pierre et Marie Curie, Paris, France

Marko Bulc, B. Sc., Ljubljana, Slovenia

Prof. Davorin Dolar✠, Slovenian Academy of Sciences and Arts, Ljubljana, Slovenia

Zdravko Gabrovšek, B. Sc., Slovenia

Prof. Dušan Hadži, National Institute of Chemistry, Ljubljana, Slovenia

Prof. Karl A. Müller, *Nobel Prize Winner*, IBM Research Laboratory, Zurich, Switzerland

Prof. Bogdan Povh, Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Dr. Lev Premrú✠, Lek, d. d., Ljubljana, Slovenia

Prof. Momčilo M. Ristić, Academy of Science of Serbia, Belgrade, Serbia

Milan Slokan✠, M. Sc., Ljubljana, Slovenia

Prof. dr. Petar Strohal, Zagreb, Croatia

Dr. Novak Zuber, Nuclear Regulatory Commission, Washington D. C., USA

Prof. Črt Zupančič, Ludwig-Maximillians-Universität, Munich, Germany

Prof. Andrej Župančič✠, Slovenian Academy of Sciences and Arts, Ljubljana, Slovenia

INTERNATIONAL COOPERATION

Multilateral international cooperation	No. of projects
H2020 (EUROPEAN INSTITUTE OF INNOVATION AND TECHNOLOGY, EXCELLENT SCIENCE, EURATOM, INDUSTRIAL LEADERSHIP, SOCIETAL CHALLENGES, SPREADING EXCELLENCE AND WIDENING PARTICIPATION, SCIENCE WITH AND FOR SOCIETY)	133
7. FP (COOPERATION: HEALTH, FOOD, AGRICULTURE/FISHERIES, BIOTECHNOLOGY, INFORMATION COMMUNICATION TECHNOLOGIES, NANOSCIENCES + NANOTECHNOLOGIES, MATERIALS + NEW PRODUCTION TECHNOLOGIES, ENERGY, ENVIRONMENT AND CLIMATE CHANGE, TRANSPORT (INCLUDING AERONAUTICS), SOCIO-ECONOMIC SCIENCES + THE HUMANITIES, SPACE, SECURITY; IDEAS: FRONTIER RESEARCH (EUROPEAN RESEARCH COUNCIL); PEOPLE: MARIE CURIE FELLOWSHIPS; CAPACITIES: RESEARCH INFRASTRUCTURES, SMEs, REGIONS OF KNOWLEDGE, RESEARCH POTENTIAL, SCIENCE AND SOCIETY, INCO (HORIZONTAL), DEVELOPMENT OF POLICIES) AND 7. FP - EURATOM	28
ESI	26
OTHERS (COST, IAEA, IEE, JRC, ESA, NATO, CIP, CEF, MED, EMPIR, LIFE+, SCOPES...)	183
TOTAL	**370**

Bilateral cooperation	No. of projects		Bilateral cooperation	No. of projects
Argentina	1		Japan	6
Austria	2		Macedonia	3
Bosnia and Herzegovina	2		Montenegro	2
China	5		Russia	5
Germany	3		Serbia	10
France	16		Turkey	3
Croatia	8		USA	27
Hungary	2		**TOTAL**	**98**
India	3			

INTERNATIONAL COOPERATION AGREEMENTS

In 2017, international cooperation agreements were signed between the Jožef Stefan Institute and:

1. Agenzia Regionale per la Protezione dell«Ambiente del Friuli Venezia Giulia (ARPA FVG), Palmanova (UD), Italy (F2)

2. Kazan Scientific Center of the Russian Academy, The Kazan E. K. Zavoisky Physical-Technical Institute (KPhTI), Kazan, Russia (F7)

3. SCK • CEN - Studiecentrum voor Kernenergie/ Centre d«Etude de l«Energie Nucleaire, Brussels, Belgium (F8)

4. ICTP - Centro Internazionale di Fisica Teorica Abdus Salam, Trieste, Italy (O2)

5. The Chinese Academy of Sciences, Institute of Hydrobiology, Wuhan, Hubei Province, P. R. China; Fujian Normal University, Fujian, P. R. China; National Cheng Kung University, Tainan City, Taiwan; Third Institute of Oceanography, State Ocean Administration, P. R. China; University of Malaya, Institute of Earth Science, Kuala Lumpur, Malaysia; Zoological Institute of the Russian Academy of Sciences, St. Petersburg, Russia; Institute of Fish Resources, Varna, Bulgaria; National Institute of Oceanography and Experimental Geophysics, Sgonico (Trieste), Italy; CNR, Institute for Coastal Marine Environment, Napoli, Italy (O2)

6. Masaryk University, Brno, Czech Republic; National Research Council (CNR), Rome, Italy; Aristotle University, Thessaloniki, Greece; Slovak Medical Universityin Bratislava, Bratislava, Slovak Republic; Lancaster University, Lancaster Environmental Centre, Lancaster, Great Britain (O2)

7. Al-Farabi Kazakh National University, Almaty, Republic of Kazakhstan (O2)

8. Scientific and Production Center for Preventive Medicine of the Ministry of Health of the Kyrgyz Republic, Bishkek, Kyrgyz Republic (O2)

COOPERATION WITH HIGHER-EDUCATION ESTABLISHMENTS

FULL-TIME FACULTY MEMBERS

Professors

1. **Prof. Denis Arčon**, University of Ljubljana, Faculty of Mathematics and Physics
2. **Prof. Iztok Arčon**, University of Nova Gorica
3. **Asst. Prof. Rok Bojanc**, University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies
4. **Prof. Janez Bonča**, University of Ljubljana, Faculty of Mathematics and Physics
1. **Asst. Prof. Marko Bračko**, University of Maribor, Faculty of Chemistry and Chemical Engineering
2. **Prof. Ivan Bratko**, Academician, University of Ljubljana, Faculty of Computer and Information Science
3. **Prof. Milan Brumen**, University of Maribor, Faculty of Education
4. **Prof. Dean Cvetko**, University of Ljubljana, Faculty of Mathematics and Physics
5. **Prof. Mojca Čepič**, University of Ljubljana, Faculty of Education
6. **Prof. Martin Čopič**, University of Ljubljana, Faculty of Mathematics and Physics
7. **Prof. Janez Dolinšek**, University of Ljubljana, Faculty of Mathematics and Physics
8. **Prof. Irena Drevenšek Olenik**, University of Ljubljana, Faculty of Mathematics and Physics
9. **Prof. Svjetlana Fajfer**, University of Ljubljana, Faculty of Mathematics and Physics
10. **Prof. Bojan Golli**, University of Ljubljana, Faculty of Education
11. **Prof. Boštjan Golob**, University of Ljubljana, Faculty of Mathematics and Physics
12. **Prof. Tomaž Gyergyek**, University of Ljubljana, Faculty of Electrical Engineering
13. **Asst. Prof. Branko Kavšek**, University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies
14. **Prof. Igor Klep**, University of Ljubljana, Faculty of Mathematics and Physics
15. **Prof. Samo Korpar**, University of Maribor, Faculty of Chemistry and Chemical Engineering
16. **Prof. Janko Kos**, University of Ljubljana, Faculty of Pharmacy
17. **Prof. Stanislav Kovačič**, University of Ljubljana, Faculty of Electrical Engineering
18. **Prof. Samo Kralj**, University of Maribor, Faculty of Education
19. **Prof. Peter Križan**, University of Ljubljana, Faculty of Mathematics and Physics
20. **Prof. Brigita Lenarčič**, University of Ljubljana, Faculty of Chemistry and Chemical Technology
21. **Prof. Marko Mikuž**, University of Ljubljana, Faculty of Mathematics and Physics
22. **Prof. Igor Muševič**, University of Ljubljana, Faculty of Mathematics and Physics
23. **Prof. Uroš Petrovič**, University of Ljubljana, Biotechnical Faculty, University of Nova Gorica, School of Environmental Sciences, School for Viticulture and Enology
24. **Prof. Rudolf Podgornik**, University of Ljubljana, Faculty of Mathematics and Physics
25. **Asst. Prof. Tomaž Podobnik**, University of Ljubljana, Faculty of Mathematics and Physics
26. **Prof. Peter Prelovšek**, University of Ljubljana, Faculty of Mathematics and Physics
27. **Prof. Saša Prelovšek Komelj**, University of Ljubljana, Faculty of Mathematics and Physics
28. **Prof. Anton Ramšak**, University of Ljubljana, Faculty of Mathematics and Physics
29. **Prof. Boris Rogelj**, University of Ljubljana, Faculty of Chemistry and Chemical Technology and Faculty of Pharmacy, University of Maribor, Faculty of Medicine, Faculty of Health Sciences
30. **Prof. John Shawe-Taylor**, University College London, Centre for Computational Statistics and Machine Learning
31. **Asst. Prof. Lea Spindler**, University of Maribor, Faculty of Mechanical Engineering
32. **Prof. Simon Širca**, University of Ljubljana, Faculty of Mathematics and Physics
33. **Prof. Žiga Šmit**, University of Ljubljana, Faculty of Mathematics and Physics
34. **Prof. Borut Štrukelj**, University of Ljubljana, Biotechnical Faculty and Faculty of Pharmacy, University of Maribor, Faculty of Medicine
35. **Prof. Tanja Urbančič**, University of Nova Gorica
36. **Prof. Nataša Vaupotič**, University of Maribor, Faculty of Education
37. **Prof. Katarina Vogel-Mikuš**, University of Ljubljana, Biotechnical Faculty
38. **Prof. Danilo Zavrtanik**, University of Nova Gorica
39. **Prof. Marko Zgonik**, University of Ljubljana, Faculty of Mathematics and Physics
40. **Prof. Primož Ziherl**, University of Ljubljana, Faculty of Mathematics and Physics

Assistants and researchers

1. **Dr. Jure Leskovec**, Stanford University, Palo Alto, California, USA
2. **Dr. Tomaž Rejec**, University of Ljubljana, Faculty of Mathematics and Physics

PART-TIME FACULTY MEMBERS

Professors

1. **Prof. Jan Babič**, University of Ljubljana, Faculty of Electrical Engineering and IPS, Ljubljana
2. **Asst. Prof. Andreja Benčan Golob**, IPS, Ljubljana
3. **Prof. Ljudmila Benedik**, University of Ljubljana, Faculty of Chemistry and Chemical Technology, Faculty of Mathematics and Physics and IPS, Ljubljana
4. **Asst. Prof. Aleš Berlec**, University of Ljubljana, Faculty of Pharmacy
5. **Prof. Slavko Bernik**, IPS, Ljubljana
6. **Asst. Prof. Anton Biasizzo**, IPS, Ljubljana
7. **Prof. Vid Bobnar**, IPS, Ljubljana
8. **Prof. Marko Bohanec**, University of Nova Gorica, School of Enginnering and Management and IPS, Ljubljana
9. **Asst. Prof. Klemen Bučar**, University of Ljubljana, Faculty of Mathematics and Physics
10. **Prof. Leon Cizelj**, University of Ljubljana, Faculty of Mathematics and Physics
11. **Prof. Uroš Cvelbar**, IPS, Ljubljana
12. **Prof. Miran Čeh**, University of Ljubljana, Faculty of Chemistry and Chemical Technology and IPS, Ljubljana
13. **Asst. Prof. Nina Daneu**, IPS, Ljubljana
14. **Prof. Marko Debeljak**, IPS, Ljubljana, University of Ljubljana, University of Primorska, University of Nova Gorica
15. **Asst. Prof. Tadej Debevec**, University of Ljubljana, Faculty of Sport
16. **Asst. Prof. Goran Dražič**, IPS, Ljubljana

17. **Prof. Jean-Marie Dubois**, IPS, Ljubljana
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REVENUES JSI (€) AND NUMBER OF PROJECTS

	2017	Contribution 2017	2016	Contribution 2016	Index 2017/2016	No. of Projects in 2017
National Agencies and Ministries	32,265,588	67.9 %	29,844,964	63.4 %	108.1	363
National Market	5,725,866	12.0 %	5,244,775	11.1 %	109.2	355
International Market	9,183,505	19.3 %	11,645,413	24.7 %	78.9	312
Other Revenues	359,533	0.8 %	340,525	0.7 %	105.6	
TOTAL	**47,534,492**	**100.0 %**	**47,075,677**	**100.0 %**	**101.0**	**1030**

Revenues 2016/2017 (€M))
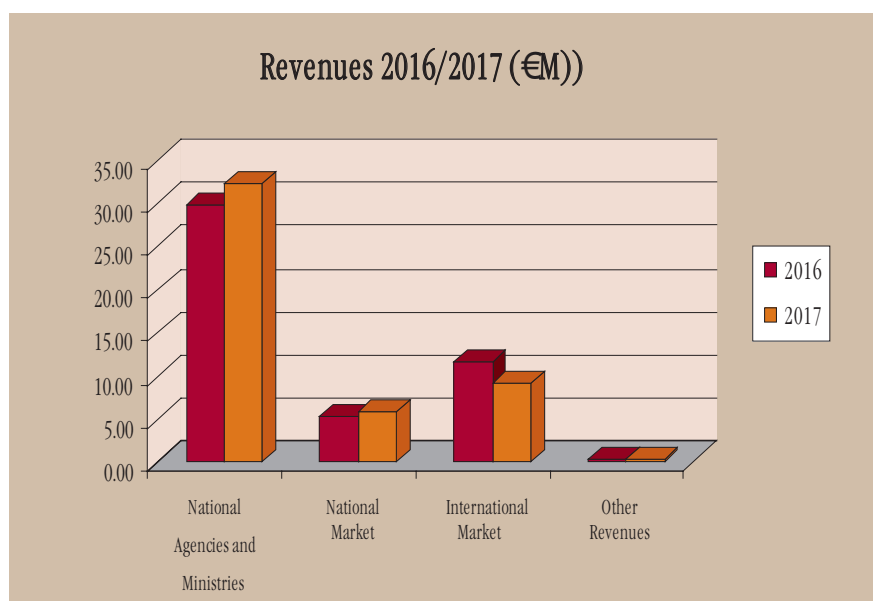
POSTGRADUATES FINANCED   1985-2017

by Slovenian Research Agency
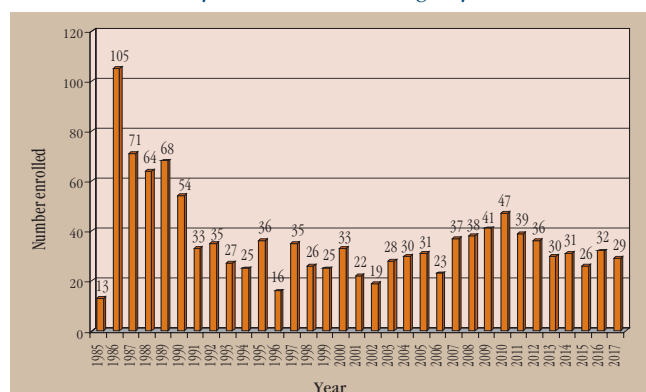
by Industry

JSI UNDERGRADUATE SCHOLARSHIPS

1977-2017

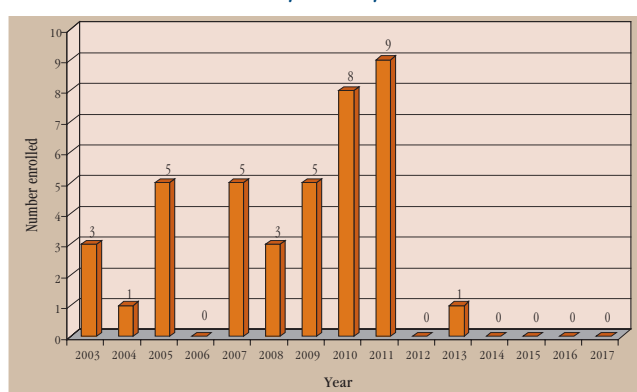| Year	FMF		FKKT UNI LJ	FKKT UNI MB	NTF	FDV	FA	BF	FE and FRI	Other UNI LJ	FG and FERI	UNG	IPS	Total
	Physics	Mathematics												
... 1982	115	38	100						50	12				315
1983	10	1	5						9		1			26
1984	11	3	7					1	12		1			35
1985	18	4	6					1	19		1			49
1986	16	8	4						22	2				52
1987	20	8	4						23	2				57
1988	26	7	8					1	27	2				71
1989	26	6	10					1	19	3	1			66
1990	26	5	11					2	25		1			70
1991	23	2	9					2	24	2	1			63
1992	22	3	16					3	17	1				62
1993	21	1	15					3	13	1				54
1994	7	1	8					3	6					25
1995	2		9					3	5					19
1996	2		9					3	5					19
1997	2		12					1	4		1			20
1998	1		6					1	7		1			16
1999	2		7					4	7					20
2000	1		5					3	9					18
2001	3		13					3	10					29
2002	4		20					3	10					37
2003	3		18					2	12	1				36
2004	4		17					1	15	1	2	2		42
2005	3		12			1		2	19		2	1		40
2006	2		12			1		1	17		2	2		37
2007	3		14			1		2	18		2	1		41
2008	2	1	13	3		1		2	15		1	1		39
2009	2	1	17	4		1		5	16		1	2		49
2010	2		11	5	2	1	1	3	10		1	2	5	43
2011	2	1	11	5	4	1	1	4	7		1		6	43
2012	2		10	6	3	1		3	6				5	36
2013	3	2	3	2	1		1		2	2			6	22
2014	14	6	3		2		1		3	2			1	32
2015	21	6	4		1				9	1			10	52
2016	16	2	5						7	1			15	46
2017	11	2	4					2	7				12	38
TOTAL	448	108	438	25	13	8	4	65	486	33	20	11	60	1719

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NTF	Faculty of Natural Sciences and Engineering, University of Ljubljana	**FERI**	Faculty of Electrical Engineering and Computer Science, University of Maribor
FDV	Faculty of Social Sciences, University of Ljubljana	**UNG**	University of Nova Gorica
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PATENTS GRANTED

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16. Milena Horvat, Ermira Begu, Yaroslav Shlyapnikov, Andrej Stergaršek, Peter Frkal, Jože Kotnik
Flow device
SI25182 (A), Slovenian Intellectual Property Office, 30. 10. 2017.

ART EXHIBITIONS AT THE JSI

Matej Rukavina, 16 January-10 February
Teja Tegelj, 13 February-16 March
Riko Debenjak, 20 March-20 April
Vida Slivniker, 24 April-18 May
Brane Širca, 22 May-15 June
Irena Majcen, 19 June-14 July
Vinko Prislan, 17 July-8 September
Jošt Snoj, 11 September-12 October
Mojca Zlokarnik, 16 October-8 November
Rajko Bizjak, 13 November-7 December
Iskra Beličanska and Boštjan Plesničar, 11 December-11 January 2018

Jošt Snoj at the opening of his exhibition

REVIEW OF PUBLICATIONS

FOR 2017

Department	Original Articles*	Books	Patent Appl. and Grants	Ph. D. Theses
Department of Theoretical Physics (F-1)	67	1		1
Department of Low and Medium Energy Physics (F-2)	90	1		
Department of Thin Films and Surfaces (F-3)	25			1
Department of Surface Engineering and Optoelectronics (F-4)	53		3	
Department of Solid State Physics (F-5)	125	3	4	5
Department for Complex Matter (F-7)	47		7	
Department of Reactor Physics (F-8)	92	2		
Department of Experimental Particle Physics (F-9)	134	1		1
Department of Inorganic Chemistry and Technology (K-1)	46		2	1
Department of Physical and Organic Chemistry (K-3)	18			
Electronic Ceramics Department (K-5)	52		3	1
Department for Nanostructured Materials (K-7)	58			3
Department for Synthesis of Materials (K-8)	20			1
Department for Advanced Materials (K-9)	19			1
Department of Biochemistry, Molecular and Structural Biology (B-1)	24		2	2
Department of Molecular and Biomedical sciences (B-2)	13			
Department of Biotechnology (B-3)	27		2	1
Department of Environmental Sciences (O-2)	104	2	1	4
Department of Automation, Biocybernetics and Robotics (E-1)	68		1	
Department of Systems and Control (E-2)	31	1	1	1
Artificial Intelligence Laboratory (E-3)	25			1
Laboratory for Open Systems and Networks (E-5)	15			1
Department of Communication Systems (E-6)	41			
Computer Systems Department (E-7)	19			
Department of Knowledge Technologies (E-8)	76	2		3
Department of Intelligent Systems (E-9)	60	2		
Department of Reactor Engineering (R-4)	61	1		1
Reactor Infrastructure Centre (RIC)	8	1		
Networking Infrastructure Centre (NIC)	2			
Energy Efficiency Centre (EEC)	13			
Centre for Electron Microscopy and Microanalysis (CEMM)	14			1
Milan Čopič Nuclear Training Centre (ICJT)	3			
Radiation Protection Unit (SVPIS)	2	1		
Centre for Technology Transfer and Innovation (CTT)	2			
Center for Smart Cities and Communities (CSC&C)	1			
Center Factory of the Future (CFoF)	3		1	
Jožef Stefan Institute	1319	16	22	29

* Articles in Journals and Conference Proceedings, and Chapters in Books

COMPLETED THESES

UNTIL 2017

Year	Ph. D. Theses		Year	Ph. D. Theses
…1999	524		2009	30
2000	36		2010	33
2001	31		2011	31
2002	29		2012	47
2003	41		2013	56
2004	31		2014	51
2005	22		2015	44
2006	22		2016	42
2007	26		2017	29
2008	29		TOTAL	1154
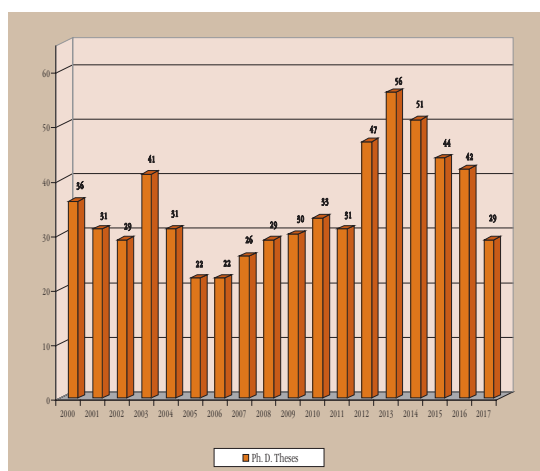
AWARDS AND APPOINTMENTS

AWARDS MADE TO JSI RESEARCHERS BY THE REPUBLIC OF SLOVENIA

Medal of Merit

Borka Džonova Jerman Blažič

Borut Pahor, President of the Republic of Slovenia, awarded Borka Džonova Jerman Blažič with the Medal for Services, for her contribution to the development of the Internet and computer communications.

Prof. Borka Džonova Jerman Blažič is awarded by Borut Pahor, President of Republic of Slovenia, with the Medal of Merit

Zois Award and Zois Certificate of Recognition

Slobodan Žumer

Presented with the Zois Award for lifetime achievements for his research in soft-matter physics

Anton Kokalj

Presented with the Zois Certificate of Recognition for significant achievements in the molecular modelling of chemical processes on metal surfaces

Puh Certificate of Recognition

Pavle Boškoski, Bojan Musizza, Andrej Debenjak and the Domel company (Damjan Demšar, Jernej Tomažin, Janez Urh, Miha Kržišnik in Marjan Kavčič)
Presented with the Puh Certificate of Recognition for an adaptive system for the quality control of blowers and production tracking

Roman Trobec, Viktor Avbelj, Matjaž Depolli, Aleksandra Rashkovska Koceva, Gregor Kosec, Tomaž Krištofelc, Klemen Bregar, Ivan Tomašić
Presented with the Puh Certificate of Recognition for a miniature personal device with an on-board ECG sensor for the long-term measurement of heart rhythm called Savvy ECG

JSI AWARDS AND APPOINTMENTS

Honorary Member of the Jožef Stefan Institute

Vito Turk

Honorary Member of the Jožef Stefan Institute: academician Prof.Vito Turk

The Jožef Stefan Golden Emblem Prize

presented to the following for doctoral theses with high impact :

Luka Leskovec

Hadronic resonances from lattice QCD

Petra Galer

Synthesis, transformation and behaviour of phenyl substituted derivatives of 1,3-diketones

Marinka Žitnik

Learning by Fusing Heterogeneous Data

The winners of the Jožef Stefan Golden Emblem Prize: Dr. Petra Galer, Dr. Marinka Žitnik and Dr. Luka Leskovec

The Jožef Stefan Roll of Honour

was awarded for their successful contribution for developing new high-tech products based on scientific and technological achievements of the Jožef Stefan Institute:

Boris Simončič and Saving, d.o.o., Ljubljana

Anton Konda and Jože Štupar, Keko Oprema, d.o.o., Žužemberk

JSI Director's fund

Mojca Otoničar, Hana Uršič, Marko Vrabelj

for the project entitled Laboratory for the ultracool preparation of complex oxides – ULTRACOOL

OTHER SELECTED AWARDS TO JSI RESEARCHERS

Viktor Avbelj, co-mentor, received a Prešeren award with the students Ada Lazar and Špela Likar, Ljubljana, University of Ljubljana, for research work on "Application of wireless electrocardiogram in hospitalised patients"

Matic Bergant, Krka Prize, Novo mesto, Slovenia, 47th Krka Prizes, "Determination of meglumine by derivatization with sodium naphthoquinone sulfonate and high performance liquid chromatography"

Jani Bizjak, Matjaž Gams, Hristijan Gjoreski, Anton Gradišek, Luka Stepančič, best paper, Melbourne, Australia, 2nd International Workshop on Biomedical Informatics with Optimization and Machine Learning in Conjunction with the 26th International Joint Conference on Artificial Intelligence, Smartwatch for Active Ageing as Part of an Open EU Framework

Marko Bohanec, was made a "Fellow and Distinguished Scholar" by the International Institute for Applied Knowledge Management.

Andraž Bradeško, ranked among the best posters at the 2017 IEEE International Symposium on Applications of Ferroelectrics (ISAF), Atlanta, USA, Institute of Electrical and Electronics Engineers (IEEE)

Martin Breskvar, Matej Petkovič and Blaž Škrlj were in the winning team of the HackElect 2017 hackathon. With methods such as predictive classification trees and deep neural networks they were the only team that managed to predict electricity consumption for each household appliance in various time frames.

Mišel Cevzar, The Satena award for the best presentation selected by a committee of journalists, Ljubljana, Slovenia, Fitts' Law for Human-Human Collaborative Reaching Task; Best presentation award chosen by the scientific committee, Ljubljana, Fitts' Law for Human-Human Collaborative Reaching Task; Award for the best poster selected by the audience, Ljubljana, Fitts' Law for Human-Human Collaborative Reaching Task

Mojca Čepič, Award for outstanding achievements in higher education of Republic Slovenia

Urška Gabor, Award for best oral presentation in the young researchers' section at the 15th Conference & Exhibition of the European Ceramic Society (ECerS 2017), Budapest, Hungary, European Ceramic Society, "Mechanism of the formation of $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ thin layers using the PLD technique"

Lojze Gačnik, Best Student Presentation Award, Montreal, Canada, 7th International k0-Users' Workshop, "Effect of control rod insertion on the TRIGA neutron spectrum and the determination of elemental concentrations with k0-INAA"

James Alexander Hodson, Jack Treynor Prize from the Institute for Quantitative Research in Finance, New York, USA, Q Group, Trading on Talent: Human Capital and Firm Performance; Second place in the 2017 PanAgora Asset Management, Boston, USA PanAgora Asset Management, Trading on Talent: Human Capital and Firm Performance

Uroš Jagodič, M. R. Ejtahadi, S. M. Hashemi, M. R. Mozaffari, Igor Muševič, and Miha Ravnikar, EPS Poster Prize for the best PhD student poster, Ljubljana, LIQUIDS 2017, Fractal Nematic Colloids

Eva Jarc, Best poster Award (Second place), 12th Meeting of the Slovenian Biochemical Society, Bled, 23 September 2017

Matej Kocen, Best Oral Presentation Award at the 25th International Conference on Materials and Technology, 25 ICM&T, Portorož, Slovenia, 16–19 October 2017 for the contribution "Inhibition of W grain growth in W-based material for fusion application (CM)" (co-authors: Petra Jenuš, Saša Novak, Andreja Šestan).

Rok Kocen, Best Scientific Presentation Award at the Joint Students' Conference of the Jožef Stefan International Postgraduate School and Young Researchers Day in the field of Chemistry, Materials, Biochemistry and Environment at the Jožef Stefan Institute for

the contribution "3D printing biomaterials for regenerative medicine", Ljubljana, 19–20 April 2017; "Science in front of the Microphone" Award given by SATENA - Slovenian Academic Society for Science and Engineering for the Best short presentation of PhD Thesis at the Joint Students' Conference of the Jožef Stefan International Postgraduate School and Jožef Stefan Institute, Ljubljana, 19 April 2017

The winners from JSI of Zois Award and Zois Certificate of Recognition and Puh Certificate of Recognition

Tomaž Kos was awarded with the PCT technology network award (Process Control Technology) for his Master's thesis entitled "Measurement system for automated low-frequency and high-temperature characterization of dielectric materials".

Nejc Košnik, Slovenian research agency award "Excellency in science" awarded for the publication of a review article Physics of leptoquarks in precision experiments and at particle colliders, Phys.Rept. 641 (2016) 1-68;

Marko Kovač, Competition FLL-First Lego League Slovenia - 2nd award for the project of Growing Engineers (coach of the team Marko Kovač); overall 4th place in the competition.

Primož Koželj, The Young Scientist Best Oral Presentation, Athens, Greece, C-MAC Days 2017, Eutectic CoCrFeNiZrx High-Entropy Alloys: Magnetism Complicated by the Microstructure of a "Real" Multiphase HEA

Gregor Kramberger, Erik Margan, award for technical improvements, Multi-channel small ionization flow meter and MOSFET and PIN dosimeter sensor, Ljubljana, Jožef Stefan Institute, Department of Environmental Science, Ljubljana, Slovenia

Rok Krpan, Best young author paper award (NENE2017 conference, Bled, Slovenia), Nuclear Society of Slovenia, Simulation of a low-momentum steam jet interaction with a light gas layer in a containment facility

Aleš Lapanje, Jaz Zrimec, Best Poster Award in the Early Stage Scientist Category, Valencia, Spain, Federation of European Microbiological Societies FEMS 2017, "DNA Structural Alignment Algorithm Can Predict Plasmid Mobility and Host Range by Locating DNA Substrates for Plasmid Transfer"

Zorica Latinović, Best poster Award (First place), 12th Meeting of the Slovenian Biochemical Society, Bled, 23 September 2017

Jure Leskovec, Best paper award, Portland, USA, CSCW 2017, Anyone Can Become a Troll: Causes of Trolling Behaviour in Online Discussions; Best paper award honourable mention, Perth, Australia, WWW 2017, An Army of Me: Sockpuppets in Online Discussion Communities; Best paper runner-up, Portland, USA, CSCW 2017, Toeplitz Inverse Covariance-Based Clustering of Multivariate Time Series Data

Nikola Ljubešić, Yves Scherrer (University of Geneva) won the CLIN2017 Shared Task on Normalising Historical Text with their CSMtiser tool, which was developed within the national basic research project JANES and the national research infrastructure CLARIN.SI.

Anja Mahne Opatič, Best Poster Award, Bologna, Italy, 5th MS Food Day, "A preliminary traceability model for tomato using analysis of stable isotopes, elemental content and chemical markers"

Matej Martinc, Iza Škrjanec, Katja Zupan, and Senja Pollak, The approach for author profiling has been ranked second among 22 groups in the PAN2017 competition, which this year focused on Gender and Language Variety Identification on Twitter.

Aleksander Matavž, award for presentation and poster, Ljubljana, 9. IPSSC Conference, Inkjet Printing Thin-Film Electronic Devices from Solution-Based Inks; 1st place award for contribution in an individual section, Portorož, 25. ICM&T, Inkjet Printing of Metal-Oxide-Based Electronic Devices

Polona Megušar, Biotechnical Faculty Prešeren Prize 2017, Biotechnical Faculty, University of Ljubljana, Ljubljana, Characterisation of antimicrobial and anti-adhesive activity of mushrooms aqueous extracts, 21 December 2017

Ana Mitrović, Krka Prize, Novo mesto, Slovenia, Role of cysteine cathepsins B and X and their inhibitors in epithelial-mesenchymal transition of tumour cells, 13 October 2017

Bojan Nemec, Leon Žlajpah, Aleš Ude, Best paper in Intelligent Robotics, Hong Kong, China, International Conference on Advanced Robotics (ICAR), Door Opening by Joining Reinforcement Learning and Intelligent Control

Jerca Pahor, Krka Awards 2017 for under- and post-graduate research works

Tjaša Parkelj, 2nd place Award for oral presentation in young researchers section at the 25th International Conference on Materials and Technology, Portorož, Metals and Technology (IMT): "Different approaches to the preparation of Sr buffered Si (001) surfaces using pulsed laser deposition"

Jan Ravnik, Best poster award at the conference PIPT6, Sendai, Japan, Conference Scientific Committee, Time evolution of a phase transition to a stable photoinduced state in 1T-TaS2; Best poster award at the International School and Workshop on Electronic Crystals ECRYS-2017, Cargese, France, Conference Scientific Committee, Reaching a Hidden State in Half a Picosecond.

Boris Rogelj, Lapanje Award, Bled, Slovenian Biochemical Society, for exceptional achievements in biochemical science, 21 September 2017

Ljupka Stojčevska Malbašić, Best poster award at the conference ICFSI 2017, Hannover, Germany, Conference Scientific Committee, Study of the photoinduced hidden state in 1T-TaS2 single crystals doped with selenium by means of time-resolved photoemission spectroscopy.

Luka Suhadolnik, Miran Čeh, Best Innovation Award at the 10th International Conference on Technology Transfer, IJS, Ljubljana, Slovenia, 9–13 October 2017

Tomaž Šef, Gold recognition for product innovation, Slovenia, Chamber of Crafts Gorenjska, "Text-to-Speech Synthesizer eBralec", 14 June, 2017

Matej Tekavčič, Boštjan Končar, Ivo Kljenak, Best poster award (ICONE25 conference, Shanghai, China), American Society of Mechanical Engineers, Liquid inlet boundary effect on the simulation of liquid waves in vertical air-water churn flow

Roman Trobec, Viktor Avbelj, Matjaž Depolli, Aleksandra Rashkovska Koceva, Gregor Kosec, Tomaž Krištofelc, Klemen Bregar, Ivan Tomašić, A golden award of Celjski sejem, Celje, Celjski sejem; FOR: a miniature personal device with an on-board ECG sensor for long-term measurement of heart rhythm Savvy ECG - an important achievement in the field of mobile health

Eva Vidak, Prešeren Award at the University of Ljubljana, Ljubljana, Slovenia, 6 December 2017, Preparation of recombinant human caspase-1 and identification of its extracellular substrates

Primož Ziherl, an outstanding research result at the University of Ljubljana in 2017; University of Ljubljana, article Dotera, T., Bekku, S., Ziherl, P. Bronze-mean hexagonal quasicrystals. Nature Materials 16 (2017), 987-993.

Slobodan Žumer, elected Fellow of the American Physical Society, USA, American Physical Society (APS), for theoretical contributions to the soft condensed matter physics of liquid-crystal systems

Kristina Žužek Rožman, Finalist for the Best Mentor 2016 Award, given by Young Academy Association in cooperation with the Slovenian Research Agency (ARRS), Ljubljana, Slovenia, 22 March 2017

KNOWLEDGE TRANSFER

The JSI pays a lot of attention to furthering its links with industry. In keeping with European aims and the objectives of the Slovenian government, the JSI organized several important meetings on the subject of cooperation with enterprises and industry. In this way the JSI introduced a new method of cooperation, showing industry and the public that it is aware of its leading role, not only in research but also in the transfer of knowledge into practice.
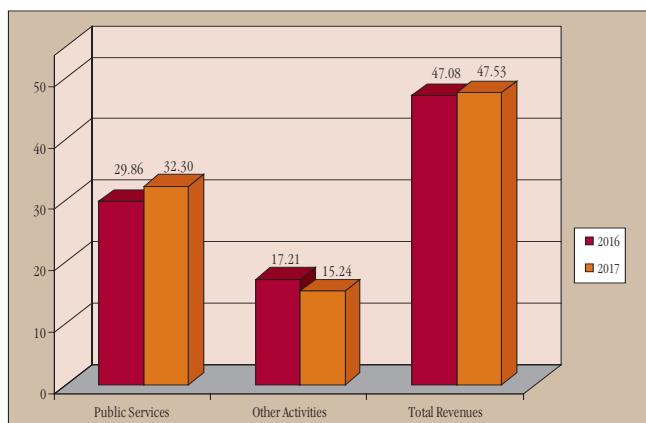
R & D PROJECT PARTNERS

1. Administration of the Republic of Slovenia for Food Safety,Ljubljana
2. Administration of the RS for Civil Protection and Disaster Relief, Ljubljana
3. Agency for Radwaste Management, Ljubljana
4. Alpineon, Ltd., Ljubljana
5. Amebis, Ltd., Kamnik
6. Balder, optoelectronic elements and measuring systems, Ltd., Ljubljana
7. Bioiks, Ltd., Ljubljana
8. BTC, d.d., Ljubljana
9. Cankarjev dom, Ljubljana
10. Cinkarna Celje, Celje
11. Comtrade, Ltd., Ljubljana
12. Časnik Finance, Ltd., Ljubljana
13. Danfoss Trata, Ltd., Ljubljana
14. DOMEL, Ltd., Železniki
15. Ecological Engineering Institute, Maribor
16. ELES, Ltd., Electricity Transmission System Operator, Ljubljana
17. Elgoline Ltd, Cerknica
18. Elvez, Ltd., Višnja Gora
19. Energetika Ljubljana, Ltd., Ljubljana
20. Energetika Maribor Ltd., Maribor
21. Energy Agency, Maribor
22. Eti, Ltd., Izlake
23. GEN energija, Krško
24. Generali zavarovalnica, d.d. Ljubljana, Ljubljana
25. Geopolis, Ltd., Ljubljana
26. Gorenje gospodinjski aparati, d.d., Velenje
27. Gorenje surovina, Ltd., Maribor
28. Hidria AET, Ltd., Tolmin
29. Inea, Ltd., Ljubljana
30. Institute of Occupational Safety, Ljubljana
31. Institute of Oncology Ljubljana, Ljubljana
32. Instrumentation Technologies, d.d., Solkan
33. Iolar, Ltd., Ljubljana
34. Iskratel, Ltd., Kranj, Kranj
35. J.P. Vodovod kanalizacija, Ltd., Ljubljana
36. Jožef Stefan International Postgraduate School (IPS), Ljubljana
37. JP CČN Domžale-Kamnik, Ltd., Domžale
38. Keko Equipment Ltd., Žužemberk
39. KMZ - Zalar Miran s.p., Ljubljana
40. Knauf Insulation, Ltd., Škofja Loka, Škofja Loka
41. Kolektor Group, Ltd., Idrija
42. Komunala Novo mesto, Ltd., Novo mesto
43. KOTO, Ltd., Ljubljana
44. Krka, tovarna zdravil, d.d., Novo mesto
45. Krško Nuclear Power Plant, Krško
46. Lek , d.d., Ljubljana
47. Ljubljanske mlekarne, d.d., Ljubljana
48. Luka Koper, d. d., Koper
49. Medical Dentistry, Ljubljana
50. Melamin, Kočevje
51. Metrology Institute of the Republic of Slovenia, Ljubljana
52. Milan Vidmar Electric Power Research Institute, Ljubljana
53. Ministry of Education, Science and Sport, Ljubljana
54. Ministry of Higher Education, Science and Technology, Ljubljana
55. Ministry of Infrastructure, Ljubljana
56. Ministry of Public Administration, Ljubljana
57. Ministry of the Environment and Spatial Planning, Ljubljana
58. Nanocut, Ltd., Hrastnik
59. National Institute of Biology (NIB), Ljubljana
60. National Institute of Chemistry, Ljubljana
61. Nela razvojni center, Ltd., Železniki
62. Občina Idrija, Idrija
63. Občina Zagorje ob Savi, Zagorje ob Savi
64. Optotek, Ltd., Ljubljana
65. Petrol, d.d., Ljubljana
66. Petrol energetika, Ltd., Ravne na Koroškem
67. Pharmahemp, Ltd., Ljubljana
68. Pivovarna Laško Union, Ltd., Ljubljana
69. Plinovodi, Ltd., Ljubljana
70. Podkrižnik, Ltd., Ljubno ob Savinji
71. Razvojni center eNeM Novi Materiali, Ltd., Zagorje ob Savi
72. Reodom, Ltd., Grosuplje
73. Saving trgovina in storitve, Ltd., Ljubljana
74. Sberbank banka, d.d., Ljubljana
75. Slovenian Biochemical Society, Ljubljana
76. Slovenian Environment Agency, Ljubljana
77. Slovenian Nuclear Safety Administration, Ljubljana
78. Slovenian Radiation Protection Administration, Ljubljana
79. Slovensko društvo ljubiteljev kemije, Ljubljana
80. Statistical Office of the Republic of Slovenia, Ljubljana
81. Swatycomet, Ltd., Maribor
82. Šoštanj Thermal Power Plant, Ltd, Šoštanj
83. Štore Steel, Ltd., Štore
84. Technology Park Ljubljana, Ljubljana
85. The Academic and Research Network of Slovenia (ARNES), Ljubljana
86. The Agricultural Institute of Slovenia, Ljubljana
87. Tosama, Ltd., Domžale
88. UniCredit Banka Slovenija, d.d., Ljubljana
89. University of Ljubljana, Biotechnical Faculty, Ljubljana
90. University of Ljubljana, Faculty of Maritime Studies and Transport, Portorož
91. University of Ljubljana, Faculty of mathematics and physics, Ljubljana
92. University of Ljubljana, Faculty of Natural Sciences and Engineering, Ljubljana
93. University of Maribor, Faculty of Chemistry and Chemical Engineering, Maribor
94. University of Maribor, Faculty of Energy Technology, Maribor
95. VOC Celje, d.d., Celje
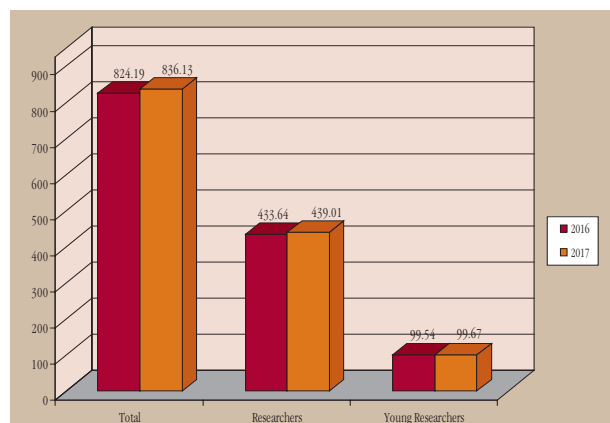96. XLAB, Ltd., Ljubljana
97. ZEL-EN, Ltd., Krško
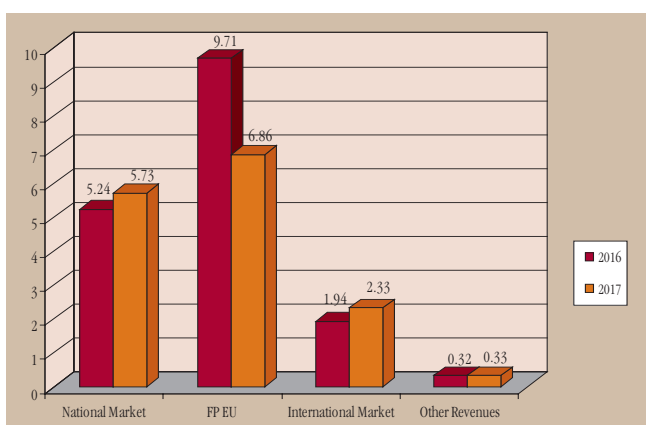
INSTITUTE IN NUMBERS 2016–2017
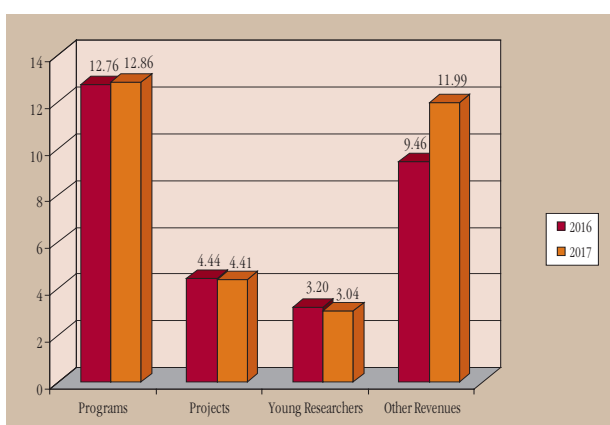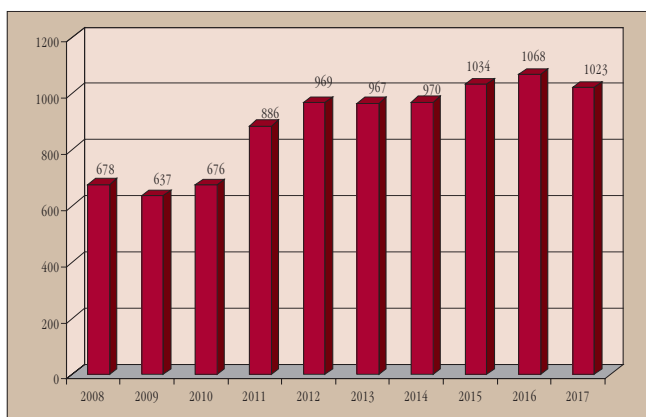
COMPARISON OF REVENUES (€M)

Public Services: 2016 29.86, 2017 32.30
Other Activities: 2016 17.21, 2017 15.24
Total Revenues: 2016 47.08, 2017 47.53

EMPLOYEES (FTE)

Total: 2016 824.19, 2017 836.13
Researchers: 2016 433.64, 2017 439.01
Young Researchers: 2016 99.54, 2017 99.67

REVENUES FROM OTHER ACTIVITIES (€M)

National Market: 2016 5.24, 2017 5.73
FP EU: 2016 9.71, 2017 6.86
International Market: 2016 1.94, 2017 2.33
Other Revenues: 2016 0.32, 2017 0.33

REVENUES FROM PUBLIC SERVICES (€M)

Programs: 2016 12.76, 2017 12.86
Projects: 2016 4.44, 2017 4.41
Young Researchers: 2016 3.20, 2017 3.04
Other Revenues: 2016 9.46, 2017 11.99

NUMBER OF PUBLICATIONS IN THE WEB OF SCIENCE*

2008 678, 2009 637, 2010 676, 2011 886, 2012 969, 2013 967, 2014 970, 2015 1034, 2016 1068, 2017 1023

* retrieved 26 July 2018

NUMBER OF CITATIONS IN THE WEB OF SCIENCE*

2008 11648, 2009 13107, 2010 15094, 2011 17381, 2012 21432, 2013 23190, 2014 25907, 2015 28325, 2016 32117, 2017 33462
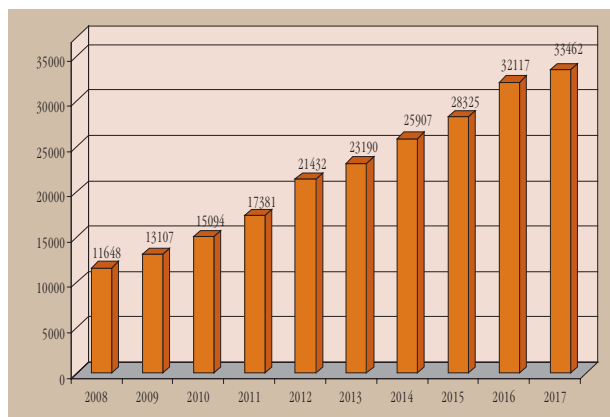
* retrieved 26 July 2018

RESEARCH DEPARTMENTS

DEPARTMENT OF THEORETICAL PHYSICS

F-1

In 2017 members of the program group THEORY OF NUCLEUS, ELEMENTARY PARTICLES AND FIELDS have continued with research in the area of hadronic physics, quantum chromodynamics, effective field theory of electroweak decays of mrsons, unified theory and precise calculation in the three-body systems.

We found an indication for a new symmetry ($SU(4)$) of quantum chromodynamics at high temperatures, which is larger than the well-known chiral symmetry ($SU(2)L \times SU(2)R$). This was established through observation of unexpected degeneracies of the correlatoration functions computed using lattice QCD. We established for the first time the multi-hadron states in the channel with the proton quantum numbers using lattice QCD. We constructed operators for simulating the scattering of two hadrons with arbitrary spin on the lattice.

We examined the methodology currently employed by the experimental analyses in estimating the dominant Standard Model backgrounds in di-photon searches at the LHC. We showed that close to the high-energy tails of the distributions, estimates of the jet faking backgrounds relying on functional extrapolations or Monte Carlo estimates of the challenging photon-jet contributions introduce a large uncertainty. We confronted the indications of lepton flavour universality violation observed in semi-tauonic B meson decays with new physics searches using high-pT tau leptons at the LHC. We also considered measurements of exclusive rare semi-tauonic b-hadron decays at a future high-energy circular electron-positron collider (FCC-ee). We designed a search strategy for the Standard Model four top production at the LHC in the same-sign dilepton and trilepton channels.

Within a Grand Unified Theory we proposed a mechanism for the generation of neutrino masses via a one-loop Feynman diagram involving quarks and two species of leptoquarks. We have shown that the same two leptoquarks can explain the measured values of lepton universality violation in decays of B mesons, B -> K l l, and partly also in B -> D l nu. We have demonstrated that the most important is the S_3 leptoquark contribution to R_K in B -> K l l decays, while the contribution of $\widetilde{R}_2$ leptoquark to B -> D l nu is strongly bounded.

We considered the minimal unified theory with the SO(10) gauge group. We showed that the Yukawa sector has 3 Higgs fields, the real 10 and 120 dimensional and the complex 126 dimensional. We checked that it correctly describes all the masses and mixing angles of the Standard Model light fermions. The model predicts a Pati-Salam intermediate scale and the dominant proton decay to charged pion and antineutrino or neutral pion and positron.

Collider signals of Higgs bosons related to the spontaneous origin of heavy Majorana neutrino mass were studied in detail. Production through the Higgs portal in the gluon fusion channel allows for a number of events in $gg \rightarrow \Delta \rightarrow NN$ as well as $h \rightarrow \Delta\Delta \rightarrow 4N$, signalling the breaking of lepton number by two or even four units. In both cases the displaced vertices can be present and serve as a discriminating variable; the resulting sensitivity New Physics scale extends well beyond 10 TeV.

Head:
Prof. Svjetlana Fajfer

- **We found an indication for a new symmetry of quantum chromodynamics at high temperatures, which is larger than the well-known chiral symmetry.**
- **We confronted the indications of lepton flavour universality violation observed in semi-tauonic B meson decays with new physics searches using high pT tau leptons at the LHC.**
- **We have proposed a Grand Unified Theory realization that contains a suitable leptoquark state to accommodate the R_K anomaly.**
- **We proposed the minimal SO(10) unified theory and predicted the consequences for low-energy physics.**
- **We proposed new searches for heavy Majorana neutrinos at colliders in Higgs-mediated channels, where it is possible to discover the breaking of lepton number by two or even four units.**

Some outstanding publications in the past three years

1. Faroughy, Darius A., Greljo, Admir, Kamenik, Jernej. Confronting lepton flavor universality violation in B decays with high-pT tau lepton searches at LHC. *Physics letters. Section B*, ISSN 0370-2693. [Print ed.], 2017, vol. 764, str. 126-134, doi: 10.1016/j.physletb.2016.11.011. [COBISS.SI-ID 29977127]
2. Doršner, Ilja, Fajfer, Svjetlana, Faroughy, Darius A., Košnik, Nejc. The role of the S3 GUT leptoquark in flavor universality and collider searches. *The journal of high energy physics*, ISSN 1029-8479, 2017, vol. 2017, no. 10, str. 188-1-188-31, doi: 10.1007/JHEP10(2017)188. [COBISS.SI-ID 30917159]
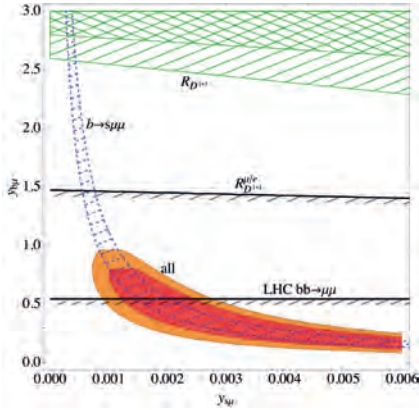
Figure 1: Constraints on the S3 Yukawa couplings due to RD (green), RK (blue). Regions above the hatched horizontal lines are excluded due to measurements of RD in light leptons and measurements of pp -> mu mu scattering at LHC.
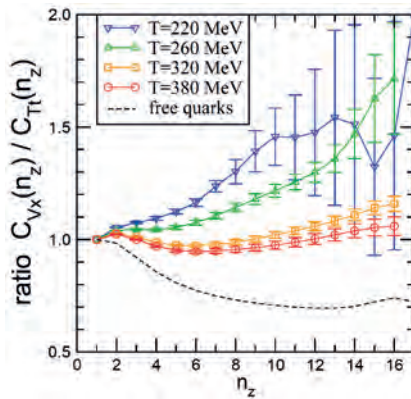

Figure 2: The figure shows that the ratio of two correlation functions approaches to one as the temperature is increased. These two correlators are not related by the chiral transformations, so their degeneracy indicates the presence of a larger symmetry (SU(4)) of QCD at T ' 380 MeV. Correlators are calculated with lattice QCD, where nz denotes the distance between the source and sink in z-direction.
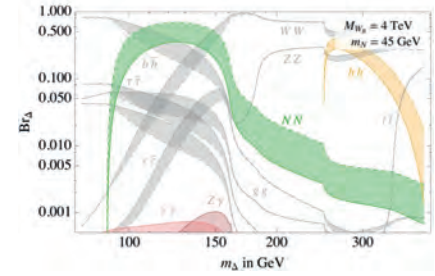

Figure 3: Branching ratios of Δ to a pair of Majorana neutrinos (green) with mN = 45 GeV, pairs of Higgs (red) and other SM particles in grey, $\gamma\gamma$ in pink and $Z\gamma$ in purple.

3. Babu, K. S., Bajc, Borut, Saad, Shaikh. Yukawa sector of minimal SO(10) unification. *The journal of high energy physics*, ISSN 1029-8479, 2017, vol. 2017, no. 2, str. 136-1-136-24, doi: 10.1007/JHEP02(2017)136. [COBISS.SI-ID 31027751]

4. Rohrhofer, C., Aoki, Y., Cossu, G., Fukaya, H., Glozman, Leonid Ya., Hashimoto, Shoji, Lang, Christian B., Prelovšek, Saša. Approximate degeneracy of J = 1 spatial correlators in high temperature QCD. *Physical review. D*, ISSN 2470-0010, 2017, vol. 96, iss. 9, str. 094501-1-094501-6, graf. prikazi, doi: 10.1103/PhysRevD.96.094501. [COBISS.SI-ID 3147876]

5. Rohrhofer, C., Aoki, Y., Cossu, G., Fukaya, H., Glozman, Leonid Ya., Hashimoto, Shoji, Lang, Christian B., Prelovšek, Saša. Approximate degeneracy of J = 1 spatial correlators in high temperature QCD. *Physical review. D*, ISSN 2470-0010, 2017, vol. 96, iss. 9, str. 094501-1-094501-6, graf. prikazi, doi: 10.1103/PhysRevD.96.094501. [COBISS.SI-ID 3147876]

The group of SOLID STATE THEORY AND STATISTICAL PHYSICS has been investigating the equilibrium and non-equilibrium properties of materials with strongly correlated electrons, nanosystems, as well as the properties of complex networks.

For localization in disordered many-body interacting systems we introduced an analytical theory, based on a self-consistent treatment of density fluctuations. With increasing disorder it reveals the transition to localization, but also the sub-diffusion in the ergodic regime. We also published an invited overview on correlations and transport in models of many-body localization. In collaboration with the experimentalists we analysed the muon-spin resonance and nuclear-relaxation results in the low-temperature phase of 1T-TaS_2 and proposed their interpretation in terms of a novel quantum spin-liquid state, with results published in Nature Physics. Based on the analysis obtained for a single hole in the one-dimensional t-J model we have shown that electron-magnon interaction delocalizes the particle in a system with strong charge disorder. In contrast, when disorder couples to spin degrees of freedom, the systems undergoes a complete many-body localization. There can even exist two distinct localization transitions whereby with increasing disorder localization first occurs in the spin sector while a further increase of disorder localizes also charges.

In collaboration with the experimentalists we analysed the muon-spin resonance and nuclear-relaxation results in the low-temperature phase of 1T-TaS_2 and proposed their interpretation in terms of a novel quantum spin-liquid state, with results published in Nature Physics.

The article was published in Physical Review Letters.

By studying the model of doped Mott insulators we showed that the anomalous behaviour of the electrical resistivity at high temperatures can be understood by much more basic quantity called charge susceptibility, while the diffusion plays a minor role. This will improve our understanding of the normal phase of the high-temperature superconductors by measurements of this susceptibility.

We studied the physics of long-lived excitations in hybrid semiconductor-superconductor devices. In collaboration with experimental groups from France and Denmark we determined the phase diagrams of devices consisting of one

and two quantum dots. We also investigated the super-current in spin-split quasi-ballistic point contact in an InAs nanowire, where we also observed a 0.7 anomaly. We devised methods to study defects in Mott insulators using real-space dynamical mean-field theory. We applied this technique to study simplified models of a domain wall in 1T-TaS2.

Within the research of statistical physics of complex systems and networks we have studied dynamic critical phenomena in two classes of interacting systems. In models of magnetic memory devices, we have studied the domain-wall motion through the sample during the magnetization reversal by the applied magnetic field. We have mapped the accompanying Barkhausen noise into series of mathematical graphs. By applying the concepts of self-organized criticality of physical systems, we have analysed the empirical data of social interactions designed to create collective knowledge. Our analysis revealed the dynamical signatures of self-organized criticality in these empirical data, due to specific knowledge-sharing constraints in the meaningful interactions among the participants.

We investigated the role of electronic interactions on the transport properties of iron under Earth-core conditions. These results are of seminal importance to understand the physical mechanism of the Earth's magnetic field. We initiated the investigation of the role of spin-orbit coupling in transition-metal oxides where we obtained the first results within a model investigation of the three-orbital quantum impurity problem with the Kanamori interaction and spin-orbit coupling. In order to obtain accurate enough solutions we employed a numerical renormalization group method that we adapted for the problems with spin-orbit coupling
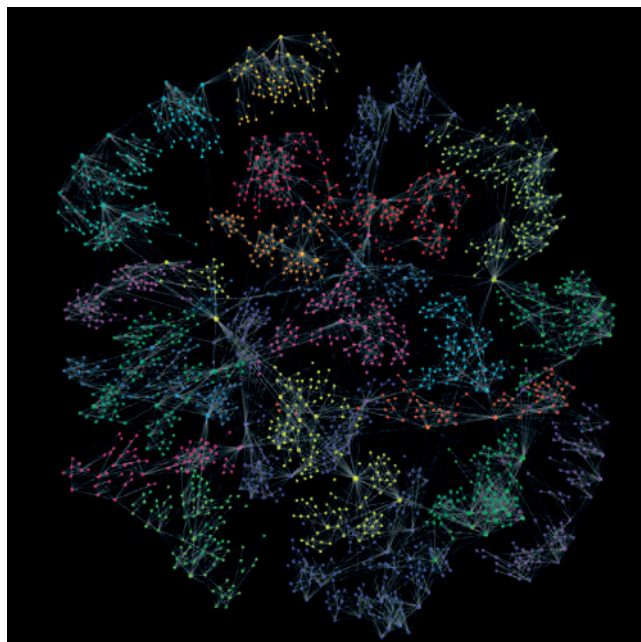

Figure 4: The network of connections between the system's states in the phase space corresponding to fluctuations in the initial segment of the hysteresis loop during magnetization reversal with an external field (Barkhausen noise).

Some outstanding publications in the past three years

1. Klanjšek, Martin, Zorko, Andrej, Žitko, Rok, Mravlje, Jernej, Jagličić, Zvonko, Kumar Biswas, Pabitra, Prelovšek, Peter, Mihailović, Dragan, Arčon, Denis. A high-temperature quantum spin liquid with polaron spins. Nature physics, ISSN 1745-2473, [in press] 2017, 7 str., doi: 10.1038/nphys4212. [COBISS.SI-ID 30689319]

2. Lemut, Gal, Mierzejewski, Marcin, Bonča, Janez. Complete many-body localization in the t-J model caused by a random magnetic field. *Physical review letters*, ISSN 0031-9007. [Print ed.], 2017, vol. 119, iss. 24, str. 246601-1-246601-6, graf. prikazi, doi: 10.1103/PhysRevLett.119.246601. [COBISS.SI-ID 3160676]

3. Pourovskii, Leonid, Mravlje, Jernej, Georges, Antoine, Simak, S. I., Abrikosov, I. A. Electron-electron scattering and thermal conductivity of iron at Earth›s core conditions. New journal of physics, ISSN 1367-2630. [Online ed.], 2017, vol. 19, str. 073022-1-073022-9, doi: 10.1088/1367-2630/aa76c9/meta. [COBISS.SI-ID 30731303]

Figure 5: Represents the difference between charge disorder and spin disorder. Figure is reproduced from the reference: Phys. Rev. Lett. 119, 246601 (2018).

The group for THEORETICAL BIOPHYSICS AND SOFT MATTER PHYSICS investigated polyelectrolytes, liquid crystals, colloids, and phospholipid and biological membranes.

In the past year we were involved in the analysis of intermolecular interactions and structural order in high-density DNA mesophases by the application of advanced molecular dynamics techniques, generalizations of the mean field theory of electrostatic interactions in colloids, and analysis of the distribution and properties of the electrostatic charge residing on proteins and their complexes such as virus capsids. We developed an electrostatic model of proteins, which includes the pH dependence of their charges. Using this model, we studied both the pH dependence of the electrostatic multipole moments in proteins and the pH dependence of charges on viral capsid proteins, where the charge is concentrated on the tail ends of the proteins. We also continued with studies of the genome folding of RNA viruses and the effect of mutations on them, where we designed experiments that will check the predictions of our studies.

We proposed a new structural model for the twist-bend nematic phase.

Figure 6: Schematic cross-section of a simulation box with cylindrical resolution regions: atomistic (AT), hybrid (HY), and coarse-grained (CG). The Na^+ and Cl^- atoms are shown in green and blue, respectively.

Figure 7: Surface structure of human serum albumin, superimposed onto a circumscribed sphere with projected multipole expansion of the surface-charge distribution.
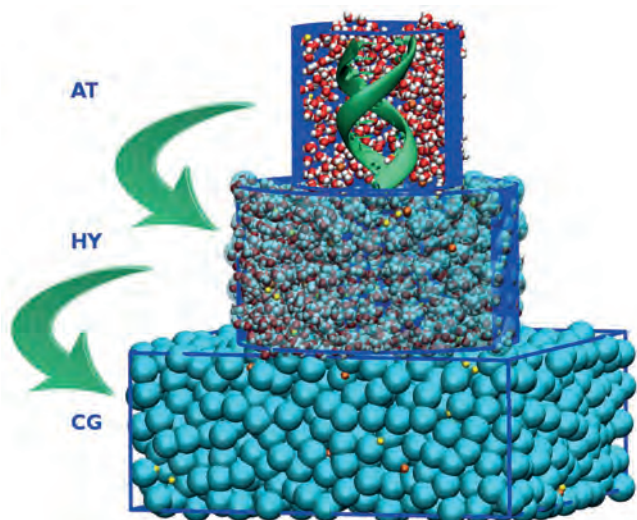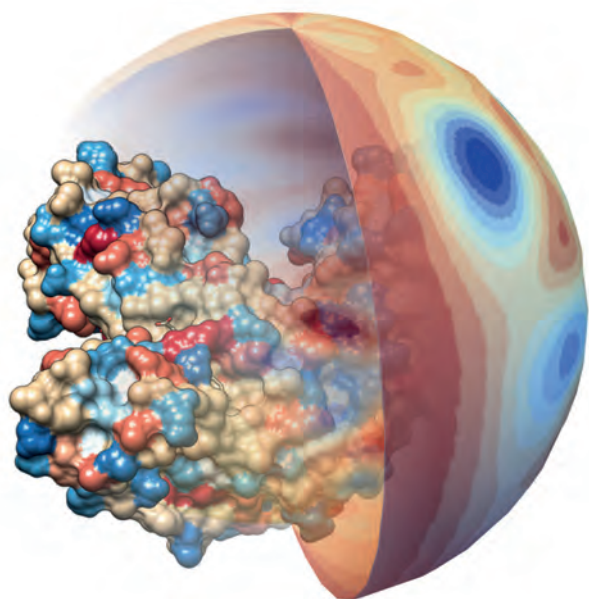
We proposed a new type of two-dimensional quasicrystal, which has a hexagonal rotational symmetry and is based on the so-called bronze mean. The existence of a disordered version of this quasicrystal was numerically confirmed in an ensemble of particles with a hard-core/square-shoulder interaction. We also studied the detailed structure of a quasicrystal with an eighteen-fold symmetry formed by such particles. We computed the phase diagram of elastic spheres and we showed that it contains several types of non-close-packed lattices at large densities, which is somewhat counterintuitive.

We used resonant soft x-ray scattering at the carbon K-edge to study periodic structures of phases with orientational order of the molecules but a homogenous distribution of the electron density. We modelled the scattering pattern, assuming a structure of each phase. By comparing theoretical and experimental results, we proposed a new structural model for the twist-bend nematic phase and we showed that the type of the blue phase can be determined if polarization effects are taken into account. We analysed relaxation modes in ferroelectric liquid crystals with an emphasis on polar relaxation modes. We also studied the anti-chiroclinic effect, that is, consequences of added chiral dopants to polar smectics formed of bent core molecules, which demonstrate a phase transition to a tilted anti-chiral smectic phase upon lowering the temperature.

Also studied were the controlled reversible shape transformations of lipid vesicles in a microfluidic diffusion chamber driven by the intercalation of suitable shape-modifying molecules from solution into the vesicle membrane. We showed that the observed shapes can be interpreted using the area-difference-elasticity theory. We interpreted the cell-to-cell variability in isogenic cell populations using an analogy between the processes of vesicle self-reproduction and cell self-replication. We propose that during cell self-replication, the balance between processes of cell growth and division also relies on causal relations between the corresponding cellular variables. In addition, we explored the effect of the deformability of red blood cells on blood flow around the bifurcation in a human carotid artery. We developed a protocol for the maximization of the density of entropy production in stationary two-step enzyme reactions and we tested it using data for glucose isomerase.

Some outstanding publications in the past three years

1. Dotera, Tomonari, Bekku, Shinichi, Ziherl, Primož. Bronze-mean hexagonal quasicrystal. *Nature materials*, ISSN 1476-1122, 2017, vol. 16, no. 16, str. 987-992, doi: 10.1038/NMAT4963. [COBISS.SI-ID 30811175]

2. Zavadlav, Julija, Podgornik, Rudolf, Praprotnik, Matej. Order and interactions in DNA arrays : multiscale molecular dynamics simulation. *Scientific reports*, ISSN 2045-2322, 6 Jul. 2017, vol. 7, art. no. 4775, str. 1-11, ilustr. doi: 10.1038/s41598-017-05109-2. [COBISS.SI-ID 3105124]

3. Salamonczyk, Miroslaw, Vaupotič, Nataša, Pociecha, Damian, Wang, Cheng, Zhu, Chenhui, Górecka, Ewa. Structure of nanoscale-pitch helical phases : blue phase and twist-bend nematic phase resolved by resonant soft X-ray scattering. *Soft matter*, ISSN 1744-683X, [in press] 2017, 6 str., doi: 10.1039/c7sm00967d. [COBISS.SI-ID 30804519]

Awards and appointments

1. Dr Nejc Košnik: Nejc Košnik: Slovenian research agency award "Excellency in science" awarded for the publication of a review article Physics of leptoquarks in precision experiments and at particle colliders, Phys.Rept. 641 (2016) 1-68;

2. Dr Luka Leskovec: Zlati znak Jožefa Stefana za leto 2017 za doktorsko disertacijo: Hadronske resonance v kromodinamiki na mreži;

3. Prof. Mojca Čepič, Award for outstanding achievements in higher education of Republic Slovenia;
4. Prof. Primož Ziherl, an outstanding research result at the University of Ljubljana in 2017; University of Ljubljana, article Dotera, T., Bekku, S., Ziherl, P. Bronze-mean hexagonal quasicrystals. Nature Materials 16 (2017), 987-993.

Organization of conferences, congresses and meetings

1. New physics at the junction of flavor and collider phenomenology, Portorož, Slovenia, 18-21 April 2017
2. Trans-European School of High Energy Physics, Cerklje na Gorenjskem, Slovenia, 13-20 July 2017
3. 10th Liquid Matter Conference, Ljubljana, Slovenia, 17-21 July 2017
4. Selected topics in high energy physics, Belica, Slovenia, 11-13 October 2017
5. Nonequilibrium Phenomena in Quantum Systems, Krvavec, Slovenia, 17-20 December 2017
6. 12th Christmas Biophysics Workshop, Golte, Slovenia, 11-12 December 2017

INTERNATIONAL PROJECTS

1. COST CA15108; Connecting Insights in Fundamental Physics (FUNDAMENTALCONNECTIONS)
    Prof. Jernej Fesel Kamenik
    Cost Office
2. COST CA16201; Unraveling New Physics at the LHC through the Precision Frontier
    Asst. Prof. Miha Nemevšek
    Cost Office
3. H2020 - ITN - COLLDENSE; Hybrid Colloidal Systems with Designed Response
    Prof. Primož Ziherl
    European Commission
4. Search for Composite Higgs Models at the LHC
    Prof. Jernej Fesel Kamenik
    Slovenian Research Agency
5. Strong Electronic Correlations and Superconductivity
    Asst. Prof. Rok Žitko
    Slovenian Research Agency
6. From Flavor Anomalies to Signals in High-pT Searches
    Prof. Jernej Fesel Kamenik
    Slovenian Research Agency
7. Dark Side of the Higgs Boson
    Prof. Jernej Fesel Kamenik
    Slovenian Research Agency
8. Relaxation Dynamics in Correlated Systems With Multiple Degrees of Freedom
    Prof. Janez Bonča
    Slovenian Research Agency

9. Tools for Studying Systems with Extreme Correlations
    Asst. Prof. Rok Žitko
    Slovenian Research Agency

RESEARCH PROGRAMS

1. Theory of the condensed matter and statistical physics
    Prof. Janez Bonča
2. Theoretical physics of nuclei, particles and fields
    Prof. Svjetlana Fajfer
3. Biophysics of polymers, membranes, gels, colloids and cells
    Prof. Rudolf Podgornik

R & D GRANTS AND CONTRACTS

1. Thermodynamics of dissipative nanosystems
    Dr. Jure Kokalj
2. The many-impurity problem
    Asst. Prof. Rok Žitko
3. New physics implications of scalar resonances at the LHC
    Prof. Jernej Fesel Kamenik
4. High-resolution optical magnetometry with cold cesium atoms
    Asst. Prof. Rok Žitko

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4. Prof. Mojca Čepič*
5. *Dr. Ilja Doršner, left 01.10.17*
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8. Prof. Bojan Golli
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13. Asst. Prof. Jernej Mravlje
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21. Prof. Nataša Vaupotič*
22. Prof. Primož Ziherl*

23. Asst. Prof. Rok Žitko
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25. *Dr. Matej Krajnc, left 01.10.17*
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29. Darius Alexander Faroughy Carias, B. Sc.
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32. Alen Horvat, B. Sc.
33. Urša Skerbiš Štok, B. Sc.
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35. Lara Ulčakar, B. Sc.
36. *Luiz Henrique Vale Silva, B. Sc., left 01.09.17*
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37. Jan Skolimowski, B. Sc.
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38. Nevenka Hauschild

Note:

* part-time JSI member

BIBLIOGRAPHY

Original Article

1. A. Allerdt, Rok Žitko, A. E. Feiguin, "Nonperturbative effects and indirect exchange interaction between quantum impurities on metallic (111) surfaces", *Physical review. B*, **95**, 23, 235416, 2017.
2. Ezequiel Alvarez, Darius A. Faroughy, Jernej Kamenik, Roberto Morales, Alejandro Szynkman, "Four tops for LHC", *Nucl. phys, Sect. B*, **915**, 19-43, 2017.
3. Labrini Athanasopoulou, Primož Ziherl, "Phase diagram of elastic spheres", *Soft matter*, **13**, 7, 1463–1471, 2017.
4. K. S. Babu, Borut Bajc, Shaikh Saad, "Yukawa sector of minimal SO(10) unification", *J. high energy phys.*, **2017**, 2, 136, 2017.
5. Ralf Blossey, A. C. Maggs, Rudolf Podgornik, "Structural interactions in ionic liquids linked to higher-order Poisson-Boltzmann equations", *Phys. rev., E*, **95**, 6, 060602, 2017.
6. Janez Bonča, Marcin Mierzejewski, "Delocalized carriers in the t - J model with strong charge disorder", *Physical review. B*, **95**, 21, 214201, 2017.
7. Luca Di Luzio, Jernej Kamenik, Marco Nardecchia, "Implications of perturbative unitarity for scalar di-boson resonance searches at LHC", *The European physical journal. C*, **77**, 1, 30, 2017.
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11. Ilja Doršner, Svjetlana Fajfer, Darius A. Faroughy, Nejc Košnik, "The role of the S_3 GUT leptoquark in flavor universality and collider searches", *J. high energy phys.*, **2017**, 10, 188, 2017.
12. Ilja Doršner, Svjetlana Fajfer, Nejc Košnik, "Leptoquark mechanism of neutrino masses within the grand unification framework", *The European physical journal. C*, **77**, 417, 2017.
13. Tomonari Dotera, Shinichi Bekku, Primož Ziherl, "Bronze-mean hexagonal quasicrystal", *Nature materials*, **16**, 16, 987-992, 2017.
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15. W.-V. van Gerven Oei, D. Tanasković, Rok Žitko, "Magnetic impurities in spin-split superconductors", *Physical review. B*, **95**, 8, 085115, 2017.
16. Matjaž Gomilšek, Martin Klanjšek, Rok Žitko, Matej Pregelj, Fabrice Bert, Philippe Mendels, Y. Li, Qiming M. Zhang, Andrej Zorko, "Field-induced instability of a gapless spin liquid with a spinon fermi surface", *Phys. rev. lett.*, **119**, 13, 137205, 2017.
17. Vanja Hatić, Boštjan Mavrič, Nejc Košnik, Božidar Šarler, "Simulation of direct chill casting under the influence of a low-frequency electromagnetic field", *Appl. math. model.*, f. 1-40, 2017.
18. Jacek Herbrych, Jure Kokalj, "Effective realization of random magnetic fields in compounds with large single-ion anisotropy", *Physical review. B*, **95**, 12, 125129, 2017.
19. Alen Horvat, Leonid Pourovskii, Markus Aichhorn, Jernej Mravlje, "Theoretical prediction of antiferromagnetism in layered perovskite Sr_2TcO_4", *Physical review. B*, **95**, 20, 205115, 2017.
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22. Jernej Kamenik, Gilad Perez, M. Schlaffe, Andreas Weiler, "On the challenge of estimating diphoton backgrounds at large invariant mass", *The European physical journal. C*, 77, 2, 126, 2017.
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29. Gal Lemut, Marcin Mierzejewski, Janez Bonča, "Complete many-body localization in the t-J model caused by a random magnetic field", *Phys. rev. lett.*, **119**, 24, 246601, 2017.
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32. Tomer Markovich, David Andelman, Rudolf Podgornik, "Surface tension of acid solutions: fluctuations beyond the non-linear Poisson-Boltzmann theory", *Langmuir*, **33**, 1, 34-44, 2017.
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34. Žiga Osolin, Rok Žitko, "Fine structure of the spectra of the Kondo lattice model: two-site cellular dynamical mean-field theory study", *Physical review. B*, **95**, 3, 035107, 2017.
35. Lokendra Poudel, Rudolf Podgornik, Wai-Yim Ching, "The hydration effect and selectivity of alkali metal ions on poly(ethylene glycol) models in cyclic and linear topology", *J. phys. chem., A Mol. spectrosc. kinet. environ. gen. theory*, **121**, 24, 4721-4731, 2017.
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43. Tomonori Shirakawa, Takami Tohyama, Jure Kokalj, Sigetoshi Soto, Seiji Yunoki, "Ground-state phase diagram of the triangular lattice Hubbard model by the density-matrix renormalization group method", *Physical review. B*, **96**, 20, 205130, 2017.
44. Bosiljka Tadić, Marija Mitrović, Roderick Melnik, "Mechanisms of self-organized criticality in social processes of knowledge creation", *Phys. rev., E*, **96**, 3, 032307, 2017.
45. Lara Ulčakar, Anton Ramšak, "Exact analysis of gate noise effects on non-adiabatic transformations of spin-orbit qubits", *New journal of physics*, **19**, 093015, 2017.
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47. Julija Zavadlav, Rudolf Podgornik, Matej Praprotnik, "Order and interactions in DNA arrays: multiscale molecular dynamics simulation", *Sci. rep.*, **7**, 4775, 2017.
48. Rok Žitko, Michele Fabrizio, "Non-Fermi-liquid behavior in quantum impurity models with superconducting channels", *Physical review. B*, **95**, 8, 085121, 2017.

SHORT ARTICLE

1. Maja Poklinek Čančula, Mojca Čepič, "A spreading shadow in color", *Phys. teach.*, **55**, 9, 586, 2017.

PUBLISHED CONFERENCE CONTRIBUTION (INVITED LECTURE)

1. S. Bekku, Primož Ziherl, Tomonari Dotera, "Origin of 18-fold quasicrystal", In: *Proceedings of the 13th International Conference on Quasicrystals, 18-23 September 2016, Kathmandu, Nepal*, (Journal of physics, Conference series, **809**), 1, 012003, 2017.
2. Mojca Čepič, "Introduction of current scientific results to education: experiences from the case of liquid crystals", In: *Key competences in physics teaching and learning: selected contributions from the International Conference GIREP EPEC 2015, Wrocław Poland, 6-10 July 2015*, (Springer Proceedings in Physics, **190**), Tomasz Greczyło, ed., Ewa Dębowska, ed., 2017, 41-54.
3. Jernej Kamenik, "Interplay between LHC and flavor physics", In: *The 3rd International Symposium, on "Quest for the Origin of Particles and the Universe", KMI 2017, 5-7 January 2017, Nagoya*, (Proceedings of science, **294**), 032, 2017.

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1. K. S. Babu, Borut Bajc, Miha Nemevšek, Z. Tavartkiladze, "Trinification at the TeV scale", In: *CETUP* 2016: Workshop on Neutrino Physics and Unification, Near Detector Physics and Dark Matter, 6 June-15 July 2016, Lead/Deadwood, South Dakota, USA*, (AIP Conference Proceedings, **1900**), Barbara Szczerbinska, ed., 020002, 2017.
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3. Mojca Čepič, "Inquiry based learning of new research findings in science and identification of gifted students", *ESERA conference*, 1518, 2017.
4. Luca Di Luzio, Jernej Kamenik, Marco Nardecchia, "Perturbative unitarity bounds on di-boson scalar resonances", In: *5th International Conference on New Frontiers in Physics, July 6-14, 2016, Crete, Greece*, A. Wrońska, ed., *EPJ Web conf.*, **164**, 07026, 2017.
5. Svjetlana Fajfer, "Scalar (or vector) leptoquarks in B meson anomalies", In: *Capri 2016 - Interplay of flavour physics with electroweak symmetry breaking: proceedings of the Sixth Workshop on Theory, Phenomenology and Experiments in Flavour Physics, Anacapri, Italy, 11-13 June 2016*, (Nuclear and particle physics proceedings, **285/286**), Giulia Ricciardi, ed., 81-86, 2017.
6. Bojan Golli, "The Roper resoannce - a genuine three quark or dynamically generated resonance?", In: *Proceedings of the Mini-Workshop Advanced in Hadronic Resonance, Bled, Slovenia, July 2-9, 2017*, Bojan Golli, ed., Mitja Rosina, ed., Simon Širca, ed., *Blej. del. fiz.*, **18**, 1, 76-81, 2017.
7. Jerneja Pavlin, Mojca Čepič, "Hydrogels in the classroom", In: *Key competences in physics teaching and learning: selected contributions from the International Conference GIREP EPEC 2015, Wrocław Poland, 6-10 July 2015*, (Springer Proceedings in Physics, **190**), Tomasz Greczyło, ed., Ewa Dębowska, ed., 2017, 191-201.
8. Peter Prelovšek, "The finite temperature Lanczos method and its applications", In: *The physics of correlated insulators, metals and superconductors: lecture notes of the Autumn School on Correlated Electrons 2017, Forschungszentrum Jülich, 25-29 September 2017*, (Schriften des Forschungszentrums Jülich, Reihe Modeling and Simulation, **7**), Eva Pavarini, ed., Jülich, Forschungszentrum, 2017, 7.1-7.23.
9. Bosiljka Tadić, Miroslav Andjelković, "Algebraic topology of multi-brain graphs: methods to study the social impact and other factors onto functional brain connections", In: *Belgrade Bioinformatics Conference 2016, 20-24 June 2016, Belgrade, Serbia: proceedings*, Nenad Mitić, ed., Belgrade, Faculty of Mathematics, 2017, 134-140.
10. Bosiljka Tadić, Miroslav Andjelković, Neelima Gupte, "Structure of simplicial complexes of graphs representing magnetization-reversal time series", In: *Proceedings of the Perspectives in Nonlinear Dynamics 2016: 24th - 29th July, 2016, Berlin, DE*, (Indian academy of sciences conference series, **1**), Bangalore, Indian Academy of Science, 2017, 1, 77-83.

INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

1. Bosiljka Tadić, Milovan Šuvakov, David Garcia, Frank Schweitzer, "Agent-based simulations of emotional dialogs in the online social network MySpace", In: *Cyberremotions: collective emotions in cyberspace*, (Understanding complex systems), Janusy A. Hołyst, ed., [S. l.], Springer, 207-229.

UNIVERSITY, HIGHER EDUCATION OR HIGHER VOCATIONAL EDUCATION TEXTBOOK

1. Rok Žitko, *Kvantne in računalniške tehnologije*, (Zbirka izbranih poglavij iz fizike, **51**), Ljubljana, DMFA - založništvo, 2017.

MENTORING

1. Matej Krajnc, *Mechanics of epithelial tissues:* doctoral dissertation, Ljubljana, 2017 (mentor Primož Ziherl).

DEPARTMENT OF LOW AND MEDIUM ENERGY PHYSICS

F-2

The Department of Low and Medium Energy Physics conducts research in the field of atomic and nuclear physics. The knowledge acquired in basic research is exploited for numerous applications, including radiological monitoring of the environment, in materials research, fusion, biology, energy storage, medicine, pharmacology, environment and archaeometry. The research is executed with our own experimental equipment, consisting of ion accelerator and beamlines, dedicated detectors of ionizing radiation, experimental setups for atomic physics and calibrated radiation fields. In addition, researchers from the department are granted access to large scientific installations worldwide, including accelerators, synchrotrons, free-electron lasers, fusion reactors and plasma guns.

Head:
Prof. Primož Pelicon

In 2017 we have continued our intense engagement at the three-spectrometer facility of the Mainz Microtron (MAMI) with measurements of parity-violating electron scattering with transversely polarized electrons (*Schlimme et al. Nucl. Inst. Meth. A 2017*). These studies represent an attempt to understand the fundamental symmetries of hadronic physics, exploiting observables sensitive to transverse polarization instead of the usual longitudinal polarization that probes the strangeness content of the nucleon. We have completed our analysis of the data obtained using a new experimental method based on initial-state radiation (ISR) in elastic e–p scattering that relies on the virtually perfect knowledge of the radiative tail of the elastic peak to access the proton charge form factor at extremely small momentum transfers. These results contribute to the resolution of the famed "proton radius puzzle", and although we were not able to ascertain the correct radius to a desired precision yet, we managed to validate the radiative corrections far away from the elastic line and provide the first measurements of the proton electric form factor during momentum transfers as low as 0.001 $(GeV/c)^2$ (*Mihovilovič et al. Phys. Lett. B 2017*). We completed a study of the proton polarization components in neutral-pion electroproduction of the Roper resonance (*Štajner et al. Phys. Rev. Lett. 2017*), as well as the analysis of charged-pion electroproduction close to the threshold (*Friščić et al. Phys. Lett. B 2017*).

Our work at the Thomas Jefferson National Accelerator Facility (Jefferson Lab) has been focused on the preparations for running a comprehensive group of experiments using a tritium target. This effort will be a unique opportunity to explore ^{3}H, the mirror nucleus of ^{3}He, and thereby impose severe constraints on state-of-the-art theories of nuclear many-body systems, in particular relating to the aspect of isospin symmetry. One of our major collaborative achievements at Jefferson Lab was the finalization of the analysis of a deeply virtual Compton scattering (DVCS) process on the proton (*Defurne et al. Nature Comm. 2017*). Our recent analyses on the electric and magnetic form factor of the proton at high momentum transfers have been updated with additional data sets (*Puckett et al. Phys. Rev. C 2017*), and the results published on the first measurement of nonpolarized, semi-inclusive, deep-inelastic scattering cross-sections from a ^{3}He target (*Yan et al. Phys. Rev. C 2017*).

In 2017 we studied the nuclear reaction between protons and deuterons at the JSI ion accelerator. The proton energy was in the range relevant for Big-Bang nucleosynthesis, i.e., between 50 and 300 keV. The reaction between the protons and deuterons produces ^{3}He and its rate determines the abundance ratio between deuterium and ^{3}He in the Universe. This ratio is today determined accurately and could be a good test of conditions after the Big Bang, if only its cross-section was known as accurately as the ratio. As deuterium targets we used implanted graphite and titanium. In graphite targets we observed a small number of electrons emitted instead of gamma rays (*Lipoglavšek et al, Phys. Lett. B 2017*).

We have started with the development of several detection systems for the international research centre FAIR in Darmstadt, Germany. We engaged in the stabilization of an electrostatic lens system for the multiple reflection time-of-flight mass spectrometer of the Super-FRS experiment. The other activity is dedicated to the design and
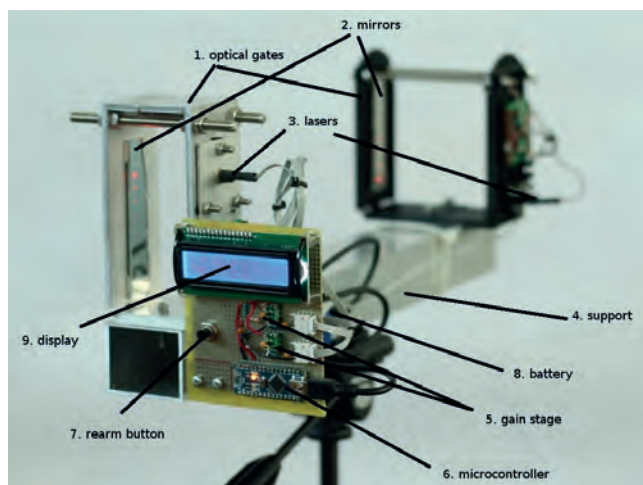

Figure 1: Optical ballistic chronometer designed and constructed by Ajda Tuševski as part of her diploma project under the supervision of assist. prof. dr. Matjaž Vencelj.

1: $n \leftrightarrow p$
2: $n(p,\gamma)d$
3: $d(d,p)t$
4: $d(p,\gamma)^3He$
5: $d(d,n)^3He$
6: $^3He(n,p)t$
7: $t(d,n)^4He$
8: $d(d,\gamma)^4He$
9: $^3He(d,p)^4He$
10: $t(\alpha,\gamma)^7Li$
11: $^3He(\alpha,\gamma)^7Be$
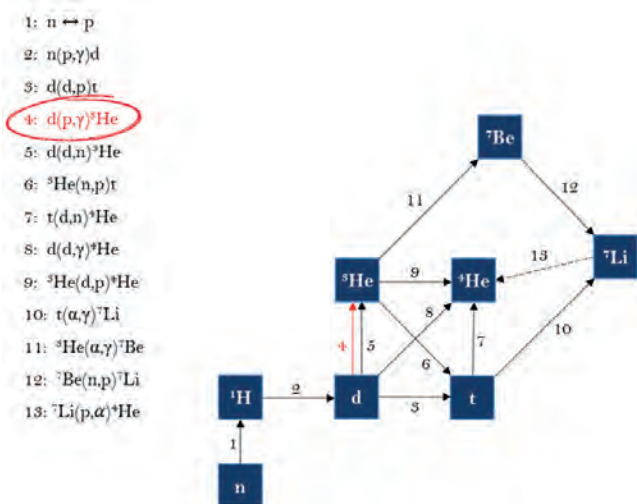12: $^7Be(n,p)^7Li$
13: $^7Li(p,\alpha)^4He$

Figure 2: The most important nuclear reaction network during Big-Bang nucleosynthesis. The reaction between protons and deuterons, studied at the JSI tandem accelerator, is coloured red.

optimization of an optical readout for the BGO scintillation detectors for the high-resolution DEGAS spectrometer of the DESPEC experiment.

We continued the innovation work at the field of instrumentation in medical physics. A US patent No. 9,881,708 titled "Radiation area monitor device and method" was granted for our work done in collaboration with colleagues from Oak Ridge and the AiSense company. We continue the tradition of popular final-year projects for students of physics, designed to arm the students with a rich spectrum of technical competences, such as optical ballistic chronometer (Figure 1).

The Division of Ionizing Radiation Measurements was conducting the environmental radioactivity monitoring of the living environment in Slovenia, regular Krško Nuclear Power Plant (KNPP) off-site environmental radioactivity monitoring, independent verification of the regular environmental radioactivity monitoring around KNPP, monitoring of radioactivity in fodder, central radioactive waste repository radiological monitoring, monitoring of the radioactivity in drinking water, material characterizations, calibrations of the radiation gauges and measurements of the personal and environmental doses by thermoluminescent dosimeters. The listed laboratories active in the dosimetry of ionizing radiation are accredited according the standard SIST EN ISO/IEC 17025 and successfully performed during international intercomparisons in 2017.

In 2017 we continued our intensive collaboration with the Metrology Institute of the Republic of Slovenia (MIRS). As a designated institution and as the holder of the national standard for the field of ionizing radiation, we continued the activities on projects from EU funding EMRP projects: "Metrology for radiological early warning networks in Europe" (ENV57 MetroERM) and "Preparedness – Metrology for mobile detection of ionising radiation following a nuclear or radiological incident". In the MetroERM project the main deliverable was the design and construction of a high-volume flow-rate air-pump with an embedded spectrometric system for identification of the radionuclides in the case of an incidental release. The device was successfully completed, and successfully tested at NPL, UK, and ENEA, Italy.
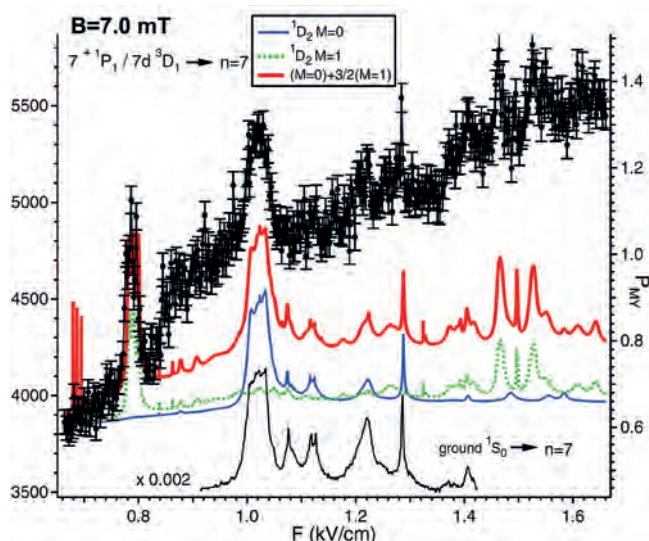

Figure 3: Measured metastable atom yield and modelled PMY trends as a function of a DC electric field strength F when 1s7s manifold of states is populated by a radiative decay of 7+ 1P1 and 7d 3D1 doubly excited states when helium gas is in the homogeneous magnetic field of 7 mT (Žitnik et al, Phys. Rev. A 2017).

In 2017 we developed a dedicated method for the analysis of the melamine resins and input raw materials to determine the fraction of raw materials bio-origin. The work was carried out for the Melamin company in Kočevje. In November 2017 we organized a two-day specialized workshop with the title "Calibrations and provision of metrological traceability in SSDL" for the staff of Krško Nuclear Power Plant. Members of the Infrastructure Group also took part in regular drills and special tasks with the radiological mobile unit ELME.

In the field of basic atomic physics we have published a map of avoided crossings of $1s7l$ energy levels in helium, pointing out their coordinates in terms of a DC electric field and magnetic field amplitude (Žitnik *et al. PRA 2017*). In this so-called anticrossing spectrometry, the mapping resolution is limited only by a field definition in the target volume. In our experiment the resolution was better than 10^{-3}, allowing us to detect very weak multi-level interactions by observing the yield of metastable helium atoms upon broadband excitation of the states with the synchrotron light. We have also performed extensive calculations that show very good agreement with the experimental ''spectra'' of singly and even doubly excited states. We have also published theoretical work about a two-colour photo-excitation scheme of even parity auto-ionizing resonances in helium where we are interested mainly in the dependence of electrons and ions on the wavelength of the IR laser when an odd resonance in the vicinity is simultaneously photo-excited by XUV light, obtained by high harmonic generation on the gaseous target

(*Mihelič et al. Jour. Phys. B 2017*). With group from the Laboratory of Quantum Optics of the University of Nova Gorica we have already performed the pilot measurements for such an experiment with the HHG source CITIUS. At the GALAXIES beamline of SOLEIL synchrotron we have observed TEOE Auger decay in choromethanes and in HCl, thus confirming the existence of his rare relaxation channel in simple molecules. We have further developed codes for simulating the passage of strong light pulses through the gas. In particular, we were studying the superfluo-

rescence phenomena in the 1s2p-1s2s transition and the SASE process for the resonant photoexcitation of doubly excited states in helium. We were developing an in-house magnetic bottle experiment with electron impact excitation where we are now able to generate 1 ns long electron pulses and pass them to the target region.

In the field of high-energy resolution x-ray spectroscopy, an experiment has been performed at ID26 beamline at ESRF synchrotron (Grenoble) in collaboration with the group from the National Institute of Chemistry in Ljubljana. *In-operando* RIXS measurements at the sulphur 1s edge collected from the cathode of the magnesium-sulphur (Mg-S) battery have been used to characterize sulphur compounds build up electrochemically during the discharge process. Mg-S represents one of the most promising electrochemical couples for the sulphur-based high-energy-density batteries. Mg-S batteries are still in the very early stage of research and development, our experiment is one of the first *in-situ* characterizations and will contribute significantly towards a detailed understanding of the electrochemical processes within the battery and the mechanism of operation. We have expanded methods for studying electrochemical processes within sulphur-based batteries towards proton-induced high-energy-resolution x-ray emission spectroscopy (HR-PIXE), which is performed in our home laboratory using a proton beam from the JSI accelerator. The Kα and Kβ x-ray emission spectra on reference polysulfide standards Li_2S_n (n=2, 4, 6, 8) were measured, the latter being synthesized by colleagues from the National Institute of Chemistry. In combination with modelling, based on density functional theory, the recorded emission spectra will form a reference dataset that can be later employed for the analysis of sulphur compounds produced in battery during charge/discharge. A detailed analysis of measured *in-operando* RIXS and XANES spectra on Mg-S battery during discharge has been performed, yielding relative amounts of separate sulphur compounds produced electrochemically within the cathode during the discharge. The electrochemical conversion of sulphur with magnesium proceeds through the formation of polysulphides dissolved in the electrolyte. This is followed by the precipitation towards the end of the discharge leading to the formation of the MgS final sulphur compound. We have also shown that the electrochemically precipitated MgS has a different local structure from the MgS synthesized in the lab. The results of this work, explaining the operation of Mg-S batteries, were published in late 2017 (*Robba et al. Chem. Mater. 2107*).

In collaboration with the group from UPMC in Paris we have also published the reconstruction of the potential energy surface of the dissociative I 3d^{-2} double-core-hole state in CH_3I molecule and determined its lifetime (*Marchenko et al., Phys. Rev. Lett. 2017*). The reconstruction is based on the combination of resonant inelastic x-ray scattering and resonant Auger spectroscopy. Such a combination of two spectroscopic techniques providing complementary information is a novel experimental method to obtain information on the lifetime and potential energy surface of dissociative core-hole states in molecules excited with hard x-ray radiation. In the field of high-energy-resolution x-ray spectroscopy combined with proton target excitation (HR-PIXE) at the Microanalytical center IJS, we have published the main operational parameters and the characterization of the new emission spectrometer combining polycapillary X-ray optics and a flat crystal diffraction (*Kavčič et al., NIM B 2017*).

In 2017, the group for x-ray absorption spectroscopy gained 7-week-long beamtimes at four synchrotrons: ESRF (beamlines BM30b, ID26), PETRA III DESY (beamlines P64 and P65), ALBA (beamline CLAESS) and ELETTRA (beamline XAFS). In collaboration with the Institute for chemistry, Ljubljana we performed *in-operando* XANES experiments on high-energy-density Mg-sulphur. In collaboration with Biotechnical Faculty of University
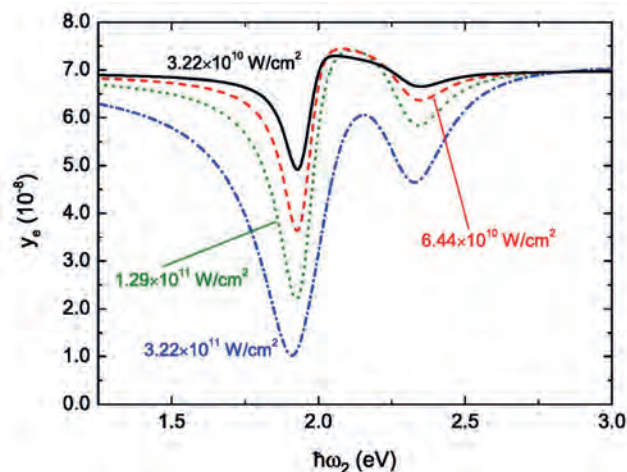
Figure 4: *Total electron yield in the region of the 2a and 2b 1Se resonance states. The photon energy of the 35-fs-long probe pulse is resonant with the transition to the 2a 1Po resonance at 60.14 eV. At high intensities, the contributions of the 2b (1.9 eV) and 2a 1Se (2.3 eV) resonance states overlap due to the laser-induced broadening (Mihelič et al. Jour. Phys. B 2017).*

Figure 5: *Scheme showing deuterium accumulation around helium implantation zone (up) and deuterium depth profiles on helium implanted sample and on the reference sample after annealing at 450 K (down) (Markelj et al. Nucl. Fus. 2017).*

Figure 6: 2 MV tandem accelerator of the Jožef Stefan Institute with four beamlines (Foto M. Verč).
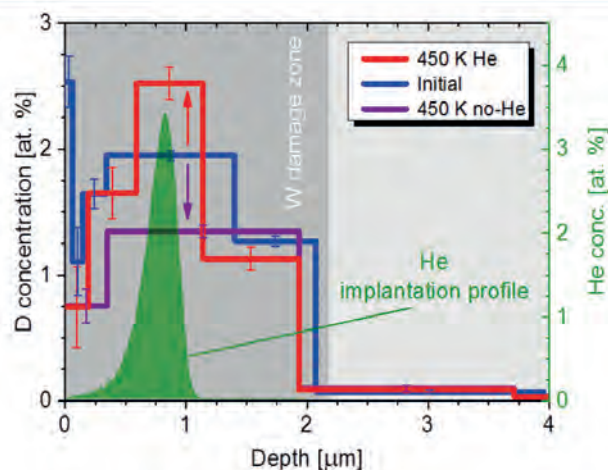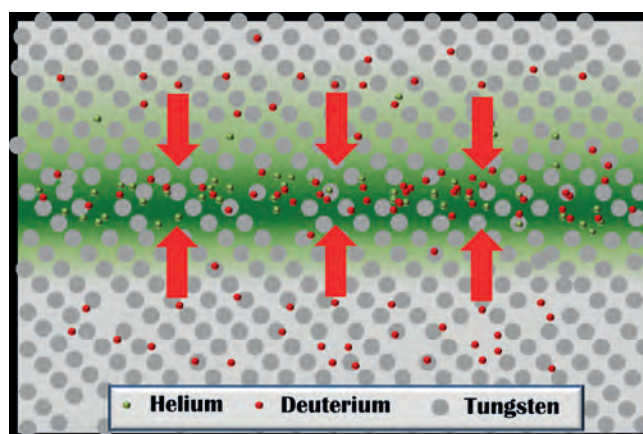
of Ljubljana, we performed XAS experiments at PETRA III, ALBA and at ESRF to determine the distribution of pollutant elements (Se, Hg, Cd, Pb), Ag nanoparticles and essential elements (Zn. Cu, Ni, Mn, Fe) in the cells of edible mushrooms and liver tissue of snails, feeding on the mushrooms, to elucidate the molecular and cellular mechanisms inducing the tolerance to the noxious metal cations and their transport to a food chain, or the mechanism of accumulation of essential elements in edible parts of the plants (*Baldi et al. Chemosphere 2017, Kovačec et al. Chemosphere 2017, Kodre et al. Environ. Exp. Bot. 2017*). In collaboration with the University of Nova Gorica and the Institute of Chemistry Ljubljana, we continued long-term projects, which involve XANES and EXAFS measurements on catalytic materials SiO_2 and CeO_2 doped with Cu in operando during a catalytic reaction at 400ºC, and on TiO_2 and SiO_2 photocatalytic materials doped with Cu and/or Zr, Sn, Mn, or Zn at room temperature. The valence of the dopants and their atomic neighbourhood are determined, to elucidate their catalytic properties. The materials aim to commercial applications such as photo catalysis for water cleaning, adsorbents and ion traps, as well as solid heterogeneous catalysts (*Čižmar et al. Catalysis Today 2017, Jovanovič et al. Jour. Am. Chem. Soc. 2017*). In collaboration with the University of Maribor we published a final analysis of edge profiles and multi-electron photo-excitations in the K shell photo-absorption spectra of gaseous hydrides of 3p elements and their homologues (*Hauko et al. Rad. Phys. Chem. 2017*).

Within our collaboration at the ALOISA and ANCHOR/HASPES beamlines (Laboratorio IOM CNR) operating at the Elettra synchrotron facility in Trieste, Italy, we studied the electronic structure and transport properties at hybrid organic interfaces and nanostructured materials. In particular, model organic–inorganic interfaces from well-defined perylenediimide stacks (PTCDI) were prepared and studied with resonant photoemission spectroscopy, revealing an unexpected length dependence of excited-state charge-transfer dynamics for surface-confined PTCDI ensembles (*Mazaheripour et al. Mater. Horiz. 2017*). Using resonant Auger spectroscopy we further examined the coupling of Boroxine-based molecules, which may be adopted as building blocks in the synthesis of covalent organic frameworks (COFs), to the Au substrate. We evidenced the crucial role of oxygen endgroups in establishing efficient pathways for ultrafast electron transport at the hybrid interface (*Toffoli et al. Chem. Sci. 2107*).

Figure 7: elemental maps of the periprosthetical tissue, removed during the failed hip-prosthesis replacement surgery. Wear particles containing titanium and vanadium were identified in titanium and vanadium elemental maps (Fokter et al., Jour. Mech. Beh. Biom. Mat. 2017).

The material properties were studied with measurements of the magnetic and electric hyperfine fields using Mössbauer spectroscopy. We studied $FePO_4$ catalysts for the synthesis of methanol from methane with the addition of O_2, N_2O and H_2O oxidants. We determined the phase changes in fresh, reduced and spent catalysts. The Mössbauer spectra revealed the change of the initial ferric orthophosphate, $FePO_4$ (tdm), to divalent metal form, iron(II) pyrophosphate ($Fe_2P_2O_7$); thereafter, the reactivity was governed by the interaction (strength) with the individual oxidizing agents. The Mössbauer data showed that the $Fe_2P_2O_7$ phase is a dominating phase in the reduced catalyst, while its amount decreases five times after oxidation with O_2, due to the formation of the catalytically active α-phase. The characterization of the used catalysts under different oxidant atmospheres provided a new understanding of phase isolation relative to specific oxidants, to form methanol from methane. The use of N_2O and H_2O as oxidants allowed the formation of the α-phase, while reducing the formation of the $Fe_2P_2O_7$ phase. The reaction using only O_2 showed the formation of the less-active β-phase, which was strongly suppressed in N_2O and H_2O atmosphere (*Dasireddy et al. Hyperfine Inter. 2017*). Cu-Fe oxide catalysts for partial CO oxidation (POX) in H_2-rich process streams have been studied. The Mössbauer data of the Cu and Fe loaded catalyst showed three well-defined sextets belonging to the tetrahedral and octahedral sites of Fe^{3+} ions. In cooperation with industrial partners we have investigated the properties of frozen solutions of magnetic materials. We have developed a method that allows Mössbauer measurements on frozen solutions. We have characterised the superparamagnetic materials in solutions and determined their blocking temperature. We have improved the sensitivity of our Mössbauer
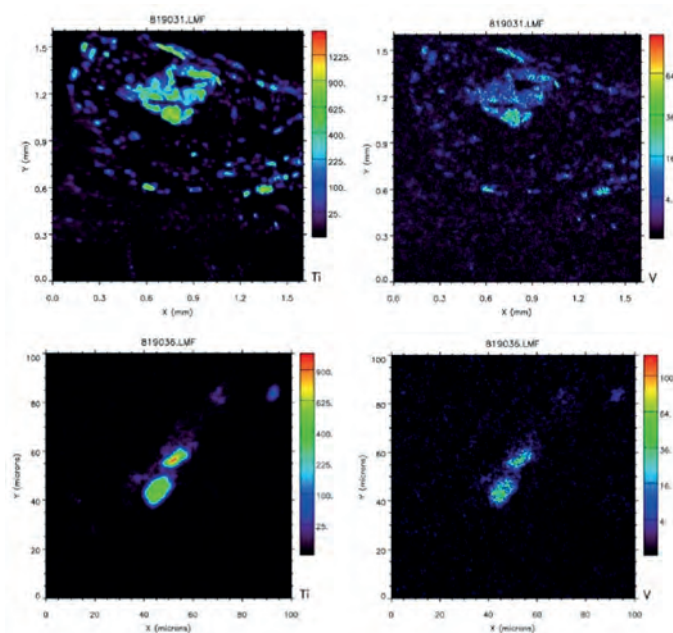
spectrometer to be able to measure spectra on glassy samples with only 0.1% Fe. In cooperation with the National Institute of Chemistry we started to investigate the properties of metal organic frameworks with different Al/Fe ratios. We have performed in-operando measurements of high current charge/discharge cycles in LiFePO$_4$ batteries.

In 2017 we continued with fusion-related research, coordinated by EUROfusion Consortium within the Work Package on "Preparation of efficient Plasma-Facing Component (PFC) operation for ITER and DEMO". Our research focuses on the study of hydrogen-isotope retention in tungsten material, which is considered to be the most suitable material for plasma-facing components in future fusion reactors. On the way to understanding the recycling and hydrogen isotope (HI) retention in plasma facing materials at particle fluxes up to 10^{24} s^{-1}m^{-2}, we need to understand the basic processes such as transport in a non-perfect material with lattice defects, the effect of interstitial impurity atoms on defect evolution and the role of surface on HI uptake and release. Lattice defects, produced by the neutrons from fusion DT reaction with the energy of 14 MeV and by the ions from the fusion plasma, act as trapping sites for HIs with high de-trapping energy as compared to the energy of diffusion between solute interstitial sites. For this purpose benchmark experiments are needed. Here, D atoms are only a tool to detect and pin down the nature of defects: their de-trapping energy for HI and the evolution with sample temperature with and without presence of HI. For this purpose we used the specific installation at JSI where samples are exposed to low-energy HI atoms with typical fluxes in the range of 10^{19} at. m^{-2}s^{-1}. The atoms populate the traps induced by 20 MeV W ion irradiation, which is one of the possible ways of simulating irradiation by 14 MeV neutrons. In 2017 we published two papers with results of the rate equation models (*Markelj et al. J. Nucl. Mater. 2017, Založnik et al. Phys. Scr. 2017*) that enabled us to pin down the nature of traps and detrapping energies (*Hodille et al. Nucl. Fus. 2017*), parameters for the surface processes and energy barrier for inward diffusion *(Založnik et al. Jour. Nucl. Mat. 2017).* This helped us to explain the differences between low-energy atom loading versus few (ten) eV ion/plasma exposure and set the basis to predict the influence of neutrals on HI retention at orders of magnitude higher fluxes as well as in remote areas in future fusion applications (*Hodille et al. Phys. Scr. 2017*).

The influence of He on D transport and retention in W was studied in a joint experiment with the group from Max-Planck Institut für Plasmaphysik, Garching (*Markelj et al. Nucl. Fus. 2017*). Recent experiments investigating the plasma-surface interaction of He-seeded deuterium (D) plasmas with tungsten (W) have resulted in a reduced D retention compared with pure D plasmas. A possible explanation for the reduced retention is that implanted He might create a diffusion barrier for D transport, thus reducing D uptake in the W bulk during plasma exposure. In this paper we for the first time unambiguously confirmed that helium does not act as a diffusion barrier in tungsten, but attracts deuterium and locally increases deuterium trapping. After the sample heating at 450 K the deuterium accumulated around helium implantation zone whereas no such effect was observed on the reference sample without implanted helium. Using rate-equation modelling we have quantitatively explained the measured deuterium depth profiles. These results bolster confidence in theoretical calculations, predicting that more hydrogen isotopes can be stored around a He-cluster zone.

We have also performed mass spectrometry measurements with pure ammonia and deuterium. We have provided new data for the thermal decomposition of these molecules on a hot tungsten surface. The interaction of ammonia and hydrogen (H$_2$ and D$_2$) was studied by flowing pure gas or a gas mixture through a hot tungsten capillary. The composition of the gas after passing the capillary was analysed by mass spectrometry as a function of capillary temperature. Specific temperatures were identified where changes in mass spectra took place, indicating thermal decomposition and isotope exchange channels (*Markelj et al, JVST 2107*).

The tandem accelerator at the Jožef Stefan Institute delivered over 3500 hours to the users from the field of fusion, biology, medicine, nuclear astrophysics, materials and energy research. In 2017, we completed the upgrade of the in-air beamline. A quadrupole magnetic doublet was inte-
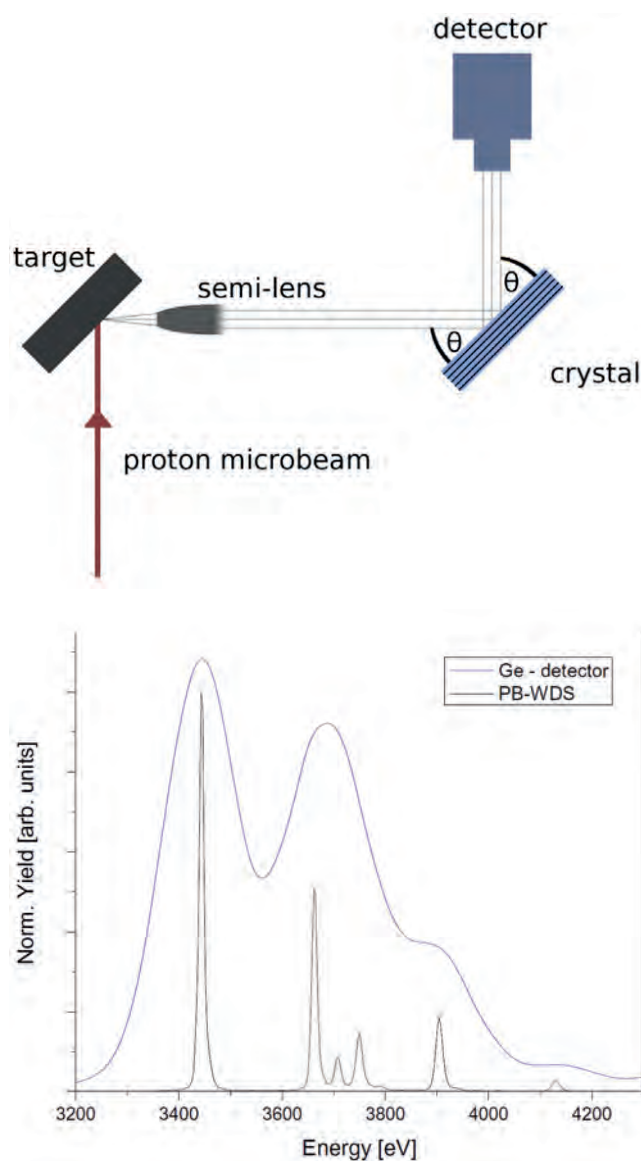

Figure 8: Shematics of the JSI Parallel Beam Wavelength Dispersive X-ray Spectrometer (PW-WDS) combining polycapillary X-ray optics and a flat crystal diffraction (up). A comparison of the Sn L PIXE spectra recorded with the PB-WDS spectrometer and the high-purity Ge solid state detector (down). (Kavčič et al, Nucl. Instr. Meth. B 2017).

grated along with the micrometre-driven slits to form in-air proton beam with a size below 50 micrometres. In this way, it enables high lateral resolution for applications where elemental profiles at the scale of tens of micrometres are sought for, and the analysed objects are too sensitive to be inserted into the vacuum. By micro-PIXE technique, we executed a number of projects for the users from biology, where slices of biological tissue were analysed and quantitative elemental images obtained. The application of micro-PIXE in medical research in collaboration with University Clinical Centre Maribor revealed the presence of wear metallic particles in the surrounding tissue after the hip prosthesis replacements *(Fokter et al., Jour. Mech. Beh. Biom. Mat. 2017)*. In addition, we engaged for the first time with the quantitative analysis of the protein samples, where we determined the number of metallic centres in the protein molecules. The work has been carried out in collaboration with Jagiellonian University in Krakow. Additional progress has been achieved for the nuclear microprobe in the development of the MeV-SIMS method. In collaboration with Ithemba Labs we identified several pharmaceutical substances accumulated in human-hair samples, including lithium *(Cloete et al., Anal. Meth. 2017)*. Besides the conventional approach with the pulsed primary beam, we successfully implemented the detection of each individual primary ion, and managed to implement MeV-SIMS with continuous primary beam. Successful scans of plant and human tissue samples demonstrated subcellular resolution of this novel technique of Mass Spectroscopy Imaging, with lateral resolution of 800 nanometres. Additional efforts were invested to also improve the mass resolution of the associated mass spectrometer.

In the field of archaeometry with in-air proton beam we continued our research of archaeologic glass. This year we analysed a series of prehistoric glass beads from the Slovenian sites, selected systematically from the entire first millennium BC. We found that only the most ancient were made of glass that contained mixed alkalis, while all the others used flux made of Egyptian natron. This suggests a widespread commerce with raw glass already in prehistory. We further analysed examples of classic Greek small coinage and confirmed the findings obtained by isotopic analyses that the Athens minted coins exclusively from silver obtained from the mines of Laurion. Using the discriminant analysis, we identified the counterfeits. Numismatic research was extended to the Celtic coins from Slovenia. Since these coins are known to be made of rather inhomogeneous metals, we combined PIXE results with the measurements of prompt neutron activation analysis in Budapest. Among our international collaborations, we continued studies of glass from medieval Bosnia and Dalmatia and glass from the post-Roman settlement Jelica in Serbia. In Prague, we used XRF to analyse pigments in the book of Sigmund Herberstein held in Czech Republic, and compared them to the book held in Slovenia. We further contributed to the exhibition Past under the Microscope in the National Museum of Slovenia.

Organization of conferences, congresses and meetings

1. EEP'17, 3–6 July 2017, Bled
2. NUSTAR week 2017, 25–29 September 2017, Ljubljana
3. Joint Annual Meeting of WP JET2 and WP PFC, Ljubljana, 20–23 November 2017, Ljubljana

INTERNATIONAL PROJECTS

1. Calibrations
   Matjaž Mihelič, M. Sc.
2. TLD Dosimetria
   Boštjan Črnič
3. Extraction of Tantalum and Niobium from Ores
   Dr. Marijan Nečemer
   Prg Ltd.
4. FAIR Detectors
   Prof. Matej Lipoglavšek
   Gsi Helmholtzzentrum
5. MetroERM; Metrology for Radiological Early Warning Networks in Europe
   Dr. Toni Petrovič
   Euramet E.v.
6. EMPIR; Preparedness - Metrology for Mobile Detection of Ionising Radiation Following a Nuclear or Radiological Incident
   Dr. Toni Petrovič
   Euramet E.v.
7. EMPIR; AEROMET - Aerosol Metrology for Atmospheric Science and Air Quality
   Prof. Matjaž Žitnik
   Euramet E.v.
8. COST CM1204: XUV/X-Ray Light and Fast Ions for Ultrafast Chemistry (XLIC)
   Prof. Matjaž Žitnik
   Cost Office
9. Hydrogen Retention in Self-damaged and He Irradiated Tungsten Alloys in Fusion Devices; Plasma-Wall Interaction for Irradiated Tungsten and Tungsten Alloys in Fusion Devices
   Asst. Prof. Sabina Markelj
   IAEA - International Atomic Energy Agency
10. RC 18353/R2; Dual Imaging of Biological Samples with MeV SIMS and PIXE Analysis; Development of Molecular Concentration Mapping Techniques using MeV Focussed Ion Beams
    Asst. Prof. Klemen Bučar
    IAEA - International Atomic Energy Agency
11. RC 18186/R2; Application of Synchrotron Radiation in Studies of Environmental Impact on Biological Organisms; Experiments with Synchrotron Radiation for Modern Environmental and Industrial Applications
    Prof. Katarina Vogel-Mikuš
    IAEA - International Atomic Energy Agency
12. COST CA16117 - ChETEC; Chemical Elements as Tracers of the Evolution of the Cosmos
    Prof. Matej Lipoglavšek
    Cost Office
13. Training Fees for Mr. Andrii Kholodyuk, STEP
    Asst. Prof. Benjamin Zorko
    Ictp - Centro Internazionale Di Fisica Teorica
14. Enhancing Nuclear Analytical Techniques to Meet the Needs of Forensic Sciences; Forensics with Nuclear Methods: Art and Food Forgery, Drugs in Hair
    Prof. Primož Pelicon
    IAEA - International Atomic Energy Agency
15. H2020 - CONCERT; European Joint Programme for the Integration of Radiation Protection Research
    Asst. Prof. Benjamin Zorko
    European Commission
16. H2020 - TRANSAT; TRANSversal Actions for Tritium
    Asst. Prof. Sabina Markelj
    European Commission

17. H2020-EUROfusion-Plasma Facing Components-1-IPH-FU, EUROFUSION
Asst. Prof. Sabina Markelj
European Commission
18. H2020 EUROfusion - Education-ED-FU
Prof. Primož Pelicon
European Commission
19. Electron Scattering Studies of 3H/3He Mirror Nuclei
Prof. Simon Širca
Slovenian Research Agency
20. 2017 Interim Meeting of MODARIA IIWG3; Technical Meeting of MODARIA IIWG3
Asst. Prof. Benjamin Zorko
Slovenian Research Agency
21. General Meeting of the 21st International Conference on Radionuclide Metrology and its Applications
Dr. Matjaž Aleš Korun
Slovenian Research Agency

RESEARCH PROGRAMS

1. Archaeological and Archaeometric Research of Portable Archaeological Heritage
Prof. Žiga Šmit
2. Object and Prestige; taste, status, power (Researches of the material culture in Slovenia)
Dr. Marijan Nečemer
3. Structure of hadronic systems
Prof. Simon Širca
4. Studies of atoms, molecules and structures by photons and particles
Prof. Matjaž Žitnik

R & D GRANTS AND CONTRACTS

1. Vegetation and hydrology of Ljubljansko barje in the past, present and future a consequence of succession, human impact or climatic fluctuations?
Dr. Marijan Nečemer
2. Triggering forbidden phenomena with twisted light and particles beams
Prof. Matjaž Žitnik
3. Redox active organic materials for electrical energy storage
Asst. Prof. Matjaž Kavčič
4. Stable isotopes in the study of the impact of increasing CO2 levels on C and Hg cycling in coastal waters
Prof. Katarina Vogel-Mikuš
5. BEST: Barley stress tolerance
Prof. Primož Pelicon
6. EMRP, MetroERM - Metrology for Radiological Early Warning Networks in Europe
Dr. Toni Petrovič
7. Different Analyses; Reference Materials
Dr. Jasmina Kožar Logar
8. Irradiation and Analysis of Nano SiC Samples in the Year 2017
Asst. Prof. Benjamin Zorko
9. Sampling and determination of U-238, Ra-225, Ra-228, Pb-210, Th-228 and K-40 in drinking water
Branko Vodenik, M. Sc.
10. XRF Analyses
Dr. Marijan Nečemer
11. Vacuum Chamber
Dr. Peter Kump
12. Determination of tritium
Dr. Jasmina Kožar Logar
13. Calibrations
Matjaž Mihelič, M. Sc.
14. Alfa/Beta and H-3 Analyses
Dr. Jasmina Kožar Logar
15. C-14 Analyses
Dr. Romana Krištof

NEW CONTRACTS

1. Operational monitoring of radioactivity in the surrounding of NEK in RS in 2017
Asst. Prof. Benjamin Zorko
Ministry of the Environment and Spatial Planning
2. Measurements of tritium in VOP-1/06, V-12/77 and V-7/77
Asst. Prof. Benjamin Zorko
Nuklearna Elektrarna Krško d. o. o.
3. Dteremination of biocomponents in melamine resines and their input materials
Dr. Romana Krištof
Melamin Kemična Tovarna d. d.
4. Annex No. 16 to the contract on performing activities and fulfillment of obligations of holder of national standard in the field of ionising radiation
Matjaž Mihelič, M. Sc.
Ministry of Education, Science and Sport
5. Ecology laboratory with mobile unit
Prof. Matej Lipoglavšek
Ministry of Defence
6. Maintenance of radiological emergency preparedness for a period of 5 years (2012-2017)
Prof. Matej Lipoglavšek
Nuklearna Elektrarna Krško
7. Sale and transfer of intellctual property rights share over a joint invention
Asst. Prof. Matjaž Vencelj
Instrumentation Technologies, d. d.
8. Analyses of atmospheric releases in 2015, 2016 and 2017
Asst. Prof. Benjamin Zorko
Nuklearna Elektrarna Krško
9. Off-site radiological monitoring of the Krško Nuclear Power Plant in2016 and 2017
Asst. Prof. Benjamin Zorko
Nuklearna Elektrarna Krško d. o. o.
10. Monitoring of radioactivity in the living environment in Slovenia 2016
Asst. Prof. Benjamin Zorko
Ministry of the Environment and Spatial Planning
11. Monitoring of radioactivity in drinking water in Republic of Slovenia in 2016 and 2017
Asst. Prof. Benjamin Zorko
Ministry of Health
12. Independent control over regular radiological monitoring of NPP Krško 2016
Asst. Prof. Benjamin Zorko
Ministry of the Environment and Spatial Planning
13. Services based on the Ionising Radiation Protection and Nuclear Safety Act
Boštjan Črnič
Monitoring of radioactivity in drinking water in Republic of Slovenia
Asst. Prof. Benjamin Zorko
Ministry of Health
14. Measurement of gross alpha and beta activities in drinking waters in Republic of Slovenia
Dr. Jasmina Kožar Logar
Ministry of Health
15. Central radioactive waste repository radiological monitoring CSRAO 2017
Dr. Marijan Nečemer
Arao, Ljubljana
16. Independent control over regular radiologocal monitoring of NPP Krško 2017
Asst. Prof. Benjamin Zorko
Ministry of the Environment and Spatial Planning
17. Sampling and analysis of gamma and beta emitters in fodder in the year 2017
Asst. Prof. Benjamin Zorko
Ministry of Agriculture, Forestry and Food
18. Mössbauer spectra and blocking temperature determination for formulated iron suspension
Dr. Darko Hanžel
Lek d. d.
19. Comparison study between different formulated iron powder samples using Mössbauer spectroscopy
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20. Central radioactive waste repository radiological monitoring CSRAO 2018
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VISITORS FROM ABROAD

1. Giscard Honore Sonkwa Monthe, Yaoundé University, Yaoundé, Cameroon, 8 March–2 June 2017
2. Nikola Bošković, Faculty of Technical Sciences, Novi Sad, Serbia, 13 March–25 April 2017
3. Andrii Kholodiuk, Institute for Safety Problems of NPP, Kiev, Ukraine, 22 May–20 August 2017
4. Prof. Dr. Stanley Lutts and Marie Lucyx, Université catholique de Louvain, Louvain-la-Neuve, Belgium, 21 June 2017
5. Dr. Paulo Jobim, UFGRS, Porto Alegre, Brazil, 11 September 2017–10 September 2018
6. Dr. Carla Eliete Iochims Dos Santos, UFGRS, Porto Alegre, Brazil, 11 September 2017–10 September 2018
7. Prof. Dr. Tahar Ghnaya, Centre de Biotechnologie de Borj Cedria, Hammam-Lif, Tunisia, 6–13 November 2017

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37. Mojca Gantar
38. Sandi Gobec
39. Mirko Ribič, B. Sc.

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. A1 Collaboration, Patrick Achenbach *et al.* (39 authors), "Beam helicity asymmetries in $K^+\Lambda$ electroproduction off the proton at low Q^2", *The european physical journal. A, Hadrons and nuclei*, **53**, 198, 2017.

2. Giuliana Aquilanti, Marco Giorgetti, Robert Dominko, Lorenzo Stievano, Iztok Arčon, Nicola Novello, Luca Olivi, "Operando characterization of batteries using x-ray absorption spectroscopy: advances at the beamline XAFS at synchrotron Elettra", *J. phys., D, Appl. phys.*, **50**, 7, 1-12, 2017.

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5. Karen Jacqueline Cloete, Boštjan Jenčič, Žiga Šmit, Mitja Kelemen, Kwezikazi Mkentane, Primož Pelicon, "Detection of lithium in scalp hair by time-of-flight secondary ion mass spectrometry with high energy (MeV) primary ions", *Analytical methods*, **9**, 36, 5249-5253, 2017.

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UNIVERSITY, HIGHER EDUCATION OR HIGHER VOCATIONAL EDUCATION TEXTBOOK

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1. Marta Debeljak, *Investigation of plant mercury and selenium metabolism using various imaging techniques:* doctoral dissertation, Ljubljana, 2017 (mentor Katarina Vogel-Mikuš; co-mentor Johannes Teun van Elteren).
2. Helena Fajfar, *Analysis of glass, metal and mineral samples of cultural heritage objects with proton meam in the air:* doctoral dissertation, Ljubljana, 2017 (mentor Žiga Šmit).
3. Samo Štajner, *Analysis of Roper resonance N(1440) in pion electroproduction process $p(e, e'p)\pi^0$:* doctoral dissertation, Ljubljana, 2017 (mentor Simon Širca).

DEPARTMENT OF THIN FILMS AND SURFACES

F-3

The main research field of the department is the development, deposition and characterization of hard protective PVD coatings, while research is also conducted in other fields of thin films and surface physics. The basic research is concentrated on the study of the physical and chemical properties of various multicomponent, multilayer and nanostructured coatings. Among the applied research, different coatings are developed for the protection of tools for various production processes in industry.

Head:
Asst. Prof. Miha Čekada

In the previous year we completed a set of research activities on nanostructured hard coatings, which had lasted for several years. The nanostructured character can be induced in two ways. The first option is to use quick substrate rotation during the deposition in order to ensure the periodic deposition of two separate layers with a low layer thickness (of the order of a few tens of nanometers); these structures are called nanolayer coatings. A case example of our research is the AlTiN/TiN coating. The second option is to use certain deposition parameters that cause a spontaneous phase separation during the coating growth, which in turn promotes the formation of a nanocomposite structure. These are the nanocomposite coatings with a grain size of a few tens of nanometers. In our case we worked on the TiAlSiN-based coating, which includes nanocrystalline TiAlN grains and amorphous Si_3N_4.

While in the previous years these coatings were investigated from a more basic-science point of view, in the last year the emphasis was on application. We successfully completed an applied research project in collaboration with the Faculty of Mechanical Engineering (University of Ljubljana) and an industrial partner (EMO Orodjarna), where the applicability of these coatings was tested in practice. We found that by far the best performance in hard milling was when using the TiAlSiN nanocomposite coating; however, the nanolayer coating AlTiN/TiN contributed only a negligible improvement compared to the standard single-layer TiAlN coating. Part of research was made in collaboration with foreign partners from Turkey (University of Bartin) and Serbia (University of Novi Sad), which were oriented towards studies of the tribological properties and tests of using these coatings for milling of nickel alloys (Inconel).

In the previous year we were also substantially engaged in the protection of tools for die casting. With the previously mentioned partners from the University of Novi Sad we investigated the tribological properties of CrN and TiAlN coatings for the protection of die casting components in comparison with uncoated tools. The experiment was envisaged based on the dynamics of tool extraction after sinking into the aluminium alloy melt. We found that the surface topography has a far more important influence than its chemical composition; the best results were obtained on polished coatings. In a more applied character, these results are partly implemented in the project Gostop, which is conducted in the scope of the "Smart specialization strategy" (priority area "Factories of the future"). Our role in this project is to develop coatings for the protection of die casting tools. There are 6 research and 13 industrial partners in the project. Yet another M.Sc. work is connected to die casting; in this case we analysed the wear of trimming tools for components, produced by aluminium die casting.

The tribological analyses were also conducted at a more basic level. The friction coefficient and related tribological properties do not depend only on the chemical composition of the components in contact; the surface topography, surrounding atmosphere and experiment duration also play a role. We put an emphasis on the running-in phase, i.e., the initial part of the experiment where we evaluated the influence of the initial condition on the tribological test performance. The coating's surface topography contains the growth defects, protrusions on the spots of carbide inclusions and eventual mechanical surface post-treatment. We tested several different combinations and found that the last-stage coating polishing step has the most pronounced influence on the tribological properties.

We use different vacuum techniques for the deposition of thin films. Magnetron sputtering is among the more widespread in industry and laboratories. With this technique plasma is used to transform the solid material (target) into the vapour phase, which in turn condenses on the substrate surface in the form of a thin film. In the magnetron plasma there are complex
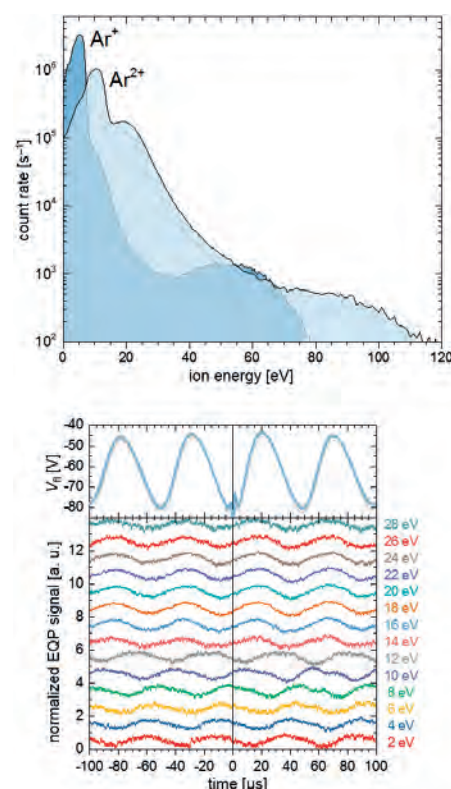

Figure 1: Energy distribution of Ar⁺ and Ar²⁺ ions in magnetron plasma (above). Time-resolved measurements of the floating potential (V_{fl}) and mass spectrometer signals of individual ion energies (below). The period of the floating potential changes and the mass spectrometer signals is the same; however, the phase shift depends on the ion energy. Using these measurements we conclude that argon ions are accelerated by the electric field, which is caused by the ionization zones.
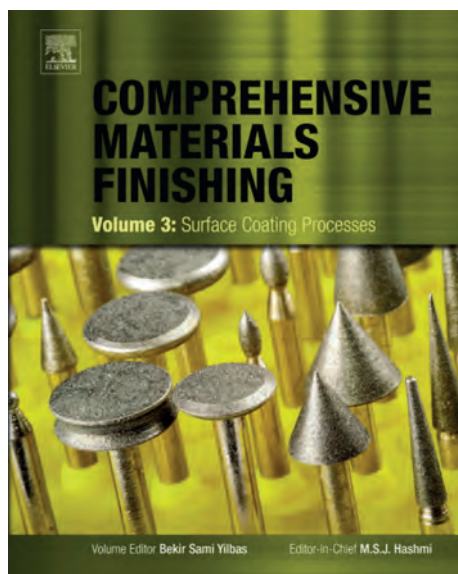
Figure 2: Cover of the book "Comprehensive Materials Finishing", Vol. 3 (Surface Coating Progresses), published by Elsevier in 2017. Our co-worker Dr Peter Panjan is the co-author of the chapter "Hard Coatings on Cutting Tools and Surface Finish".
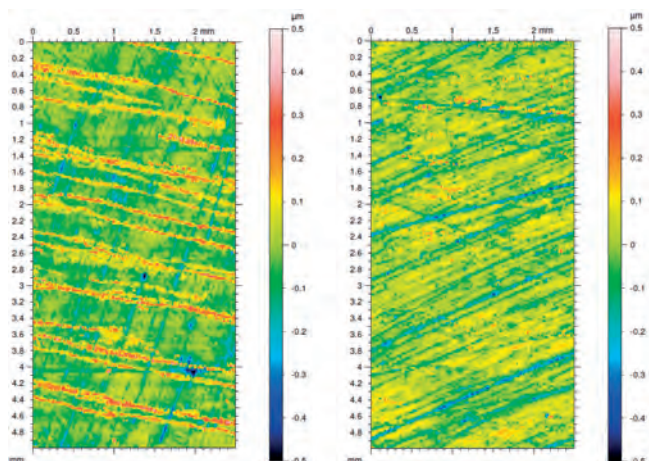

Figure 3: Surface topography of tungsten test tiles after plasma treatment in a tokamak. The damage on the bare tungsten surface (left) is much more pronounced than on the WN coating (right)

magnetic and electric fields; they cause a complicated movement of the charged particles. The consequence of such a movement is a spatially inhomogeneous plasma, which in magnetron systems forms the so-called ionization zones. In the last few years several research groups have tried to understand the formation mechanism and properties of these inhomogeneities. The ionization zone shape, their number and dynamics depend a lot on the pressure, discharge parameters and type of cathode power supply (i.e., DC or pulsed).

In the previous year our co-worker Dr Matjaž Panjan investigated the transport of ions in magnetron plasma, which is not a fully understood process. Mass spectrometry was used; it is a method enabling the measurement of the energy distribution of individual ions. He performed these measurements at the Lawrence Berkeley National Laboratory in USA. The time dependence of ions, coming from the plasma into the spectrometer was observed and compared to the movement of ionization zones. The dynamics of ionization zones was evaluated by measuring the floating potential and using a high-speed camera. The measurements showed that the high-energy ions get their energy (several 10 eV) from the electric field, which is formed by the ionization zones. This is an important result as the high energy of sputtered atoms/ions is crucial for the growth of dense thin films. Such films generally have superb mechanical, optical, electrical, and other physical and chemical properties.

Looking from a broader perspective, the department was until recently using several types of PVD processes: triode sputtering, magnetron sputtering and electron-beam evaporation. For the deposition of coatings for our industrial partners, magnetron sputtering was predominantly used; this process type was also used to deposit the majority of samples upon which various research was made. However, nowadays the hard protective coating segment is dominated by the cathodic arc evaporation technique; we came across this technique only indirectly, via common projects with foreign partners. To overcome this drawback, and also needed to renew our hardware used for servicing the industrial partners, we purchased a new unit for deposition of coatings using cathodic arc. It was constructed by the German company KCS Europe, and is based on the technology of the Japanese company Kobe steel.

The above presented activities belong to the core activities of the department, i.e., the research and development of hard protective coatings. To a minor extent we are also active in other fields of the physics and chemistry of thin films and surfaces. For the previous year we would like to emphasize the surface topography analytics of tungsten nitride thin films, which had been previously deposited on test tiles. They were later subjected to a plasma in a fusion reactor. Based on a comparison of the same sample (before/after plasma treatment) we found which places on the surface are more prone to arcing and what kind of consequences there are on the material surface. This work was done within the Eurofusion project in collaboration primarily with the Max Planck Institute of Plasma Physics, Garching, Germany. There are several other department activities worth mentioning:

- topographic evaluation of the damage during the laser ablation of surfaces, with a special emphasis on multilayer structures (Al/Ti, AlTiN/TiN)
- deposition of multilayer Si/C structures for the study of diffusion processes
- study of morphological and magnetic properties of hematite
- deposition of thin films of transparent conductive materials (GITO)

This work was made in collaboration with the following research partners: Vinča Institute of Nuclear Sciences, Belgrade, Serbia; Hungarian Academy of Sciences, Budapest, Hungary; Faculty of Electrical Engineering, Ljubljana, Slovenia, and in a minor extent with several other institutions.

In addition to the above-mentioned research projects we performed several analyses for various Slovenian companies: Cetis, EMO Orodjarna, Hella Saturnus, Iskra mehanizmi, Kolektor Sikom, Kovinos, LTH Castings and Phos.

Some outstanding publications in the past year

1. M. Panjan, A. Anders, Plasma potential of a moving ionization zone in DC magnetron sputtering. *Journal of applied physics*, 121 (2017) 6, 063302-1–063302-17
2. P. Panjan, A. Drnovšek, J. Kovač, M. Čekada, M. Panjan, Oxidation processes in vanadium-based single-layer and nanolayer hard coatings. *Vacuum*, 138 (2017), 230–237

INTERNATIONAL PROJECTS

1. H2020-EUROfusion-Plasma Facing Components-1-IPH-FU, EUROFUSION
   Dr. Matjaž Panjan
   European Commission
2. H2020 EUROfusion - Medium Size Tokamak Campaigns-MST1-FU
   Dr. Matjaž Panjan
   European Commission
3. Microstructure, Morphology and Magnetism of Natural Hematite Crystallites and its Geological Significance
   Dr. Matjaž Panjan
   Slovenian Research Agency
4. Studies of Fundamental Processes in Magnetron Sputtering
   Dr. Matjaž Panjan
   Slovenian Research Agency

RESEARCH PROGRAM

1. Thin film structures and plasma surface engineering
   Asst. Prof. Miha Čekada

R & D GRANTS AND CONTRACTS

1. Antibacterial Nanostructured Surfaces for Biological Applications
   Asst. Prof. Miha Čekada
2. Understanding plasma processes and thin film growth in High Power Impulse Magnetron Sputtering
   Dr. Matjaž Panjan
3. Development and production of taylor made milling tools, coatings and corresponding manufacturing technologies in individual tooling industry
   Asst. Prof. Miha Čekada
4. Building blocks, tools and systems for the Factories of the Future – GOSTOP
   Asst. Prof. Miha Čekada

VISITORS FROM ABROAD

1. Carsten Uder, Dirk Prinz, CemeCon AG, Würselen, Germany, 18.–26. 4. 2017
2. Marin Tadić, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 7.–18. 8. 2017
3. Jelena Petruša, University of Zagreb, Zagreb, Croatia, 2. 10. – 31. 12. 2017
4. Dr. Rainer Cremer, Taha Hamoudi, KCS Europe GmbH, Monschau, Germany, 27.–30. 11. 2017
5. Marin Tadić, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 18.–22. 12. 2017

STAFF

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11. Tomaž Sirnik

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PUBLISHED CONFERENCE CONTRIBUTION

1. Aleksander Drenik, Daniel Allegre, Sebastijan Brezinšek, Alfonso de Castro, Uron Kruezi, Martin Oberkofler, Matjaž Panjan, Gregor Primc, T. Reichbauer, Matic Resnik, Volker Rohde, Michael Seibt, P. A. Schneider, T. Wauters, Rok Zaplotnik, the ASDEX-Upgrade and EUROfusion MST teams and JET contributors, "Evaluation of the plasma hydrogen isotope content by residual gas analysis at JET and AUG", In: *The 16th International conference on plasma-facing materials and components for fusion applications (PFMC-16),* Düsseldorf, May 2017, *Phys. scr.*, vol 2017, T170, 014021, 2017.

2. Aleksander Drenik, Daniel Allegre, Sebastijan Brezinšek, Alfonso de Castro, Uron Kruezi, Gerd Miesl, Miran Mozetič, Martin Oberkofler, Matjaž Panjan, Gregor Primc, Matic Resnik, Volker Rohde, Michael Seibt, Francisco L. Tabares, Rok Zaplotnik,The ASDEX-Upgrade team, the EUROfusion MST team and the JET contributors, "Detection of ammonia by residual gas analysis in AUG and JET", In: *Proceedings of the 29th Symposium on Fusion Technology (SOFT-29)*, Prague, Czech Republic, September 5-9, 2016, *Fusion Eng. Des.*, **124**, 239-243, 2017.

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5. Pal Terek, Lazar Kovačević, Aleksandar Miletić, Dragan Kukuruzović, Branko Škorić, Aljaž Drnovšek, Peter Panjan, "Ejection performance of coated core pins intended for application on die casting tools for aluminium alloys procesing", In: *Serbiatrib '17: proceedings*, 15th International Conference on Tribology SERBIATRIB '17, 17-19 May 2017, Kragujevac, Serbia, Slobodan Mitrovic, ed., Kragujevac, University of Kragujevac, Faculty of engineering, Serbian Tribology Society, 2017, 382-220.

MENTORING

1. Aljaž Drnovšek, *The influence of atmosphere and surface topography of PVD hard coatings on their tribological properties:* doctoral dissertation, Ljubljana, 2017 (mentor Miha Čekada).

DEPARTMENT OF SURFACE ENGINEERING AND OPTOELECTRONICS F-4

The research program is associated with vacuum science, technology and applications. The main activities are focused on plasma science, the modification of advanced biomedical materials and products for improved biocompatibility, the characterization of inorganic, polymer and composite materials with different thin films on the surface, the modification and characterization of fusion-relevant materials, the thermodynamics of trapped gases and methods for sustaining an ultra-high-vacuum environment, vacuum optoelectronics, and basic research in the field of surface and thin-film characterization by electron and ion spectroscopy techniques.

The advanced plasma reactors available in our labs as well as at our partners in Slovenia and abroad were used for tailoring the surface properties of solid and liquid materials. The surfaces and thin films were characterized by various complementary techniques, which allow us to understand the complex mechanisms involved in plasma–surface interactions. The analytical equipment for the surface and thin-film analyses was upgraded with two important innovations. First, there was an Auger electron spectrometer, model JAMP 7830F, produced by Jeol company. This instrument replaced a 40 years old Auger electron spectrometer, model SAM 545A, which remained operable until the new instrument was commissioned. The recently installed Auger JAMP 7830F instrument is a combination of a field-emission electron microscope with a high lateral resolution and an Auger electron spectrometer. The instrument operates in ultra-high vacuum and allows us to analyse accurately the composition of surfaces, thin films and nanostructures within a region of a few nm. Sputtering with an argon-ion gun allows for the removal of the surface layer and thus depth profiling up to a depth of around 1 micrometre.

Another important improvement in our analytical equipment was the upgrade of the ToF SIMS ION-TOF.5 instrument, an advanced mass spectrometer for the precise surface characterization or organic and inorganic materials. This instrument was upgraded with a new sputter ion gun, model DCS, produced by the ION TOF company, which allows for high-precision analyses of thin films of thicknesses between a few nanometres and a few micrometres. A new ion gun performs the bombardment of the sample surface with either Ar^+, O_2^- or Cs^+ ion beams at low kinetic energies (from 0.5 to 2 keV) and high sputtering rates up to 1 nm/s. Such performances are the consequence of highly focused beams. In this way a controlled removal of the surface layers can be obtained. The simultaneous mass analysis of emitted secondary ions from a sample surface allows us to measure the depth distribution of the elements in thin films and multilayer structures. Such depth profiles can be measured with a very high depth resolution (a few nm) and high sensitivity for the detection of elements, even in the ppm region. Both new instruments in our laboratory will also make possible advanced studies of diffusion phenomena in thin solid films, atomic transport through internal interfaces of multilayer structures and analyses of the depth distribution of elements, dopants and impurities. Thanks to these two recent upgrades of our analytical equipment we will continue and extend our decades-long tradition in high-quality surface and thin-film analyses.

Photo-catalysts offer several promising applications, such as hydrogen evolution via water splitting, CO_2 reduction and the removal of organic pollutants from water. Due to its high photocatalytic activity and chemical stability, low cost, water insolubility and nontoxicity, TiO_2 has been widely applied, studied and identified as the best photocatalyst for the decomposition of pollutants present in an aqueous medium. The drawbacks of TiO_2 are a wide band-gap energy and fast electron-hole recombination. Many different attempts have been tested to overcome

Head:
Prof. Miran Mozetič

The analytical equipment for surface and thin-film analyses was upgraded with two important additions, an Auger electron spectrometer and an ion gun for the ToF-SIMS spectrometer.
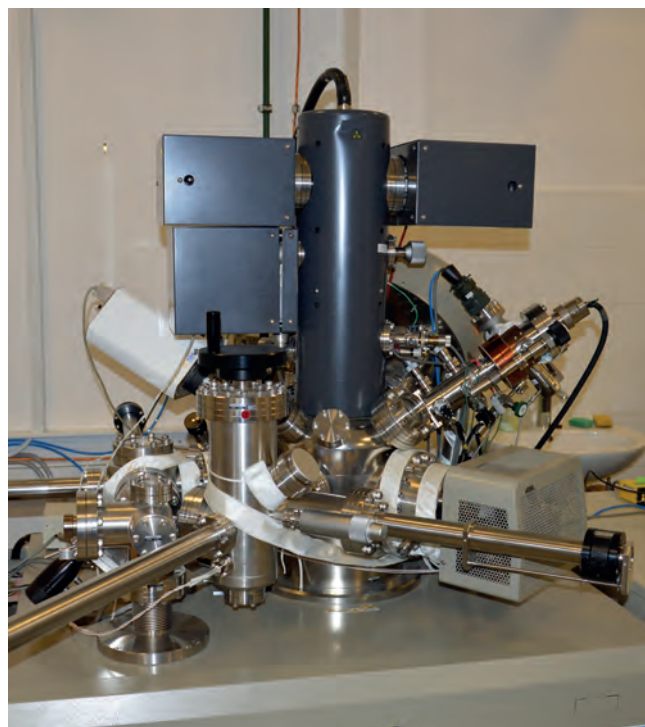

Figure 1: Auger electron spectrometer installed in 2017 enables the precise analyses of surfaces, thin films and nanostructures with depth and lateral resolutions of a few nm and about 20 nm, respectively.
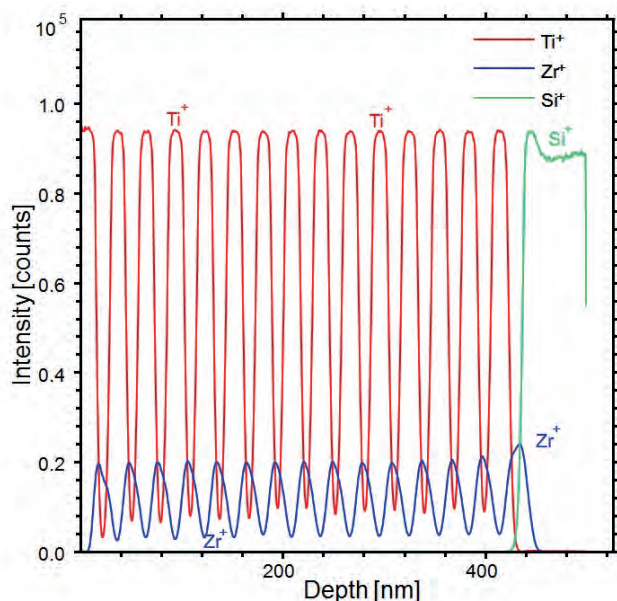
Figure 2: High-quality SIMS analysis can be recognized by sharp interfaces between layers in a multilayer structure of 30 layers of Ti(15 nm)/Zr(15 nm) on Si substrate.

the drawbacks of TiO_2, such as doping TiO_2 with other metal or non-metal elements or coupling with different semiconductors. Modifying TiO_2 with carbon materials, like carbon nanotubes and graphene, has attracted a lot of attention due to an exceptionally high electron mobility in carbon. In collaboration with National Institute of Chemistry from Ljubljana we performed a study on photo-catalysis from composite materials of TiO_2 nanorods and reduced graphene oxide (rGO) with nominal loadings of rGO from 4 to 20 wt. %. The composites were prepared by hydrothermal synthesis. We investigated in detail how the increasing amount of rGO influences the structural and electrical properties, and how this manifests itself in the photocatalytic activity. Our group performed precise XPS analyses of the chemical composition, chemical bonding and electronic structure of the composite materials. In this way we found that the charge separation in TiO_2+rGO composites is related to a perfect matching of TiO_2 and rGO valence band maxima. As a consequence, the electron-hole recombination in composites was slower, resulting in more electrons and holes being able to particicpate in the photocatalytic reaction. Degradation rates of pollutants in water in photocatalytic experiments correlated well with the XPS and other results.

The graphene decorated with catalytic nanoparticles represents an attractive material for electro-catalysis, providing it is oriented vertically on a substrate so that the effective surface area becomes enormous. With our colleagues from the National Institute of Chemistry we investigated the possibility of using carbon nanowalls (CNWs) for increasing the stability of electrodeposited nanocatalysts, which is a major task for future industrial applications. The most common degradation mechanism is the loss of active surface area due to nanoparticle growth via coalescence/agglomeration. We proposed a particle confinement strategy via carbon nanowall deposition to overcome the degradation of the catalyst's nanoparticles. With a CNW-modified electrode a much better stability was obtained compared to the non-modified electrode. IL-SEM images before and after 15,000 ageing cycles confirmed the superior stability of the CNW-protected Ag nanocatalyst exhibiting no agglomeration or coalescence. The graphene structure acts as a barrier for particle migration and cluster formation. This strategy can be considered as a general way to prevent coalescence/agglomeration of metallic nanoparticles for any electrochemical reaction and other applications beside electro-catalysis and thus increase the long-term stability of nanoparticles.

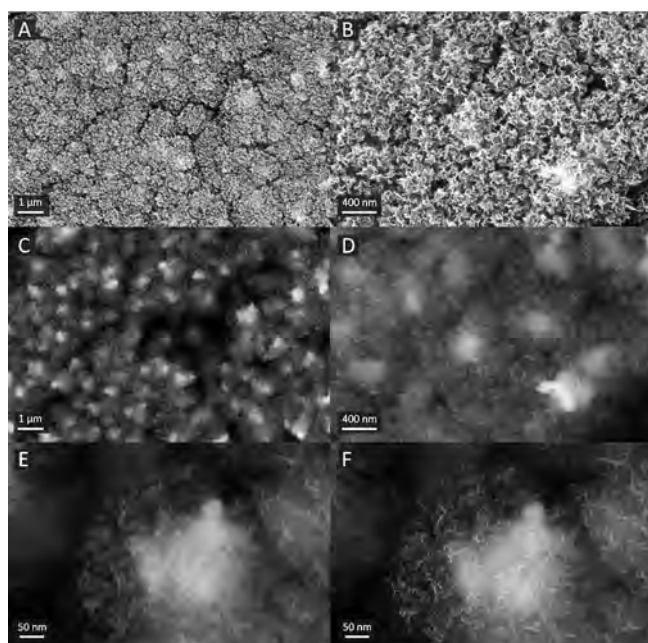Since one of the greatest challenges in the commercialization of graphene and its derivatives is the production of high-quality material in bulk quantities at low price and in a reproducible manner, we were also closely collaborating with the University of Lisbon on this topic. The main focus area was the synthesis of pure graphene and carbon nanowalls. Our results demonstrated that a microwave plasma-enabled synthesis exhibits a great potential for a scalable route that would enable the continuous, large-scale fabrication of freestanding graphene and nitrogen-doped graphene sheets. The method's crucial advantage relies on harnessing unique plasma mechanisms to control the material and energy fluxes of the main building units on the atomic scale. By tailoring the high-energy density plasma environment, a controllable selective synthesis of high-quality graphene sheets at 2 mg/min yield with prescribed structural qualities was achieved. The method demonstrated the great promise for the large-scale fabrication of graphene and its derivatives, and is a cost-effective alternative to the presently used chemical methods. A fruitful collaboration on this topic resulted in a successful EU Horizon 2020 FET-Open project "Pegasus".

Titanium is commonly used for body implants, and can be coated with a nanostructured oxide film to improve its properties. A novel approach for the modification of titanium alloys used for vascular implants (stents) was studied. It is well known that the biological response of a stent is still far from optimal, mainly due to restenosis. Currently, the restenosis presents the main drawback on all metal stents, as it occurs in more than 33% of the cases. Stents can be divided on bare metal stents

Figure 3: SEM images of Ag nanoparticles on a CNW electrode obtained with different detectors before degradation cycles (A-E). (F) - after 15,000 cycles.

(BMS) and drug-eluting stents (DES). With DES the problems of allergenic reactions as well as the risks of restenosis are lowered, as DES release anti cell-proliferative, immunosuppressive or anti-thrombogenic drugs, which inhibit the proliferation of smooth muscle cells and reduce thrombus formation. However, it was shown that DES also inhibits normal endothelium growth, which potentially leads to thrombosis. Thus the aim of our work was to alter the surface properties of stents in order to reduce platelet adhesion and at the same time improve the endothelial cell proliferation without the need to use drug-eluting coatings. The stents were coated with titanium oxide nanotubes. By altering the conditions of electrochemical anodization, nanotubes of different diameter and length were fabricated. The as-deposited coating was further treated with an oxygen plasma in order to obtain super-hydrophilic surface finish, which significantly influenced the proliferation of endothelial cells (HCAECs). Furthermore, a significant decrease in the activation and adhesion of platelets was observed on these surfaces, which reduces the possibilities for undesired thrombotic reactions. Due to the applicability of our results, the innovative approach was protected by filing a patent application. A contract for collaboration with the Swiss company Rontis, one of the leading producers of vascular stents, was signed.

Low-pressure gaseous plasma can also be used for modifying the surfaces of biomedical materials made from polymers. While the best anti-thrombogenic material is a coating made from heparin, such coatings are difficult to apply because they are quickly removed in a real environment, so we just functionalized the polyethylene terephthalate surface with sulfonate groups in order to mimic heparin. We used inductively coupled plasma in mixtures of SO_2 and O_2. X-ray photoelectron spectroscopy and atomic force microscopy showed weak functionalization of the samples' surfaces with sulphur-containing groups and revealed the highly altered morphology of plasma-treated samples. The samples were then incubated with human umbilical vein endothelial cells (HUVECs) and various biological tests were performed. The biocompatibility demonstrated a well-pronounced maximum versus gas composition, which correlated well with the development of the surface morphology. The best proliferation was observed in the case of nearly the same amounts of both mentioned gasses what was explained by the formation of $-SO_x$ radicals on the surface of the polyethylene terephthalate – similar to the groups in heparin. Such a surface finish seems to be stable so the innovative treatment with SO_2/O_2 plasma represents an interesting alternative to classic heparin coatings.

Atmospheric pressure plasmas, especially atmospheric pressure plasma jets (APPJs), offer new possibilities in medical applications, such as the treatment of cancer cells and wound treatment. Furthermore, APPJs also proved to be useful in various fields of dentistry, including the surface modifications of dental implants, adhesion of protective materials to teeth, caries treatment, endodontic treatment and tooth bleaching. Our study was focused on the stability of the chemical surface modification of the human dental enamel and dentine by using helium single-electrode multiple-harmonic APPJs. Modification of the enamel and dentine surface was observed using contact-angle measurements and X-ray photoelectron spectroscopy. The results of this study showed increased wettability of the enamel and dentine, increased Ca/P ratio, which was close to an ideal ratio for the highest volume of re-mineralization, and an increased O/C ratio, which confirmed the oxidation of transparent organic matrix in the enamel – one of the major processes in tooth bleaching.

Use of atmospheric pressure plasmas was also extended to other areas of biomedical research. We explored atmospheric pressure plasma depositions of antibacterial coatings, the treatment of model wounds, decontamination of natural toxins and the selective deactivation of cancer cells. Biomedical applications of plasma require its efficacy for specific purposes, whereas its safety is equally important. These safety aspects of cold plasma with simple atmospheric pressure plasma jet produced with helium gas were evaluated in skin damage on a
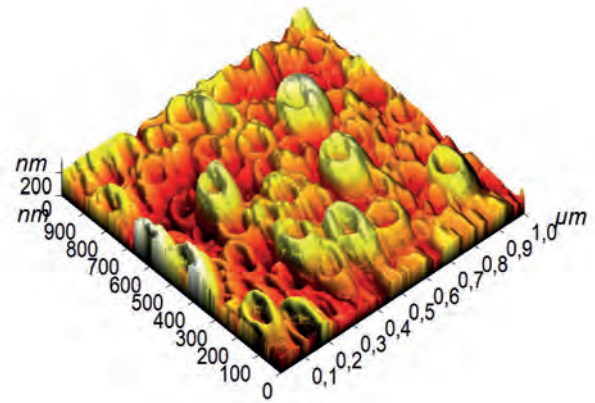

Figure 4: Titanium oxide nanotubes of diameter 100 nm, as observed by atomic force microscopy (AFM).
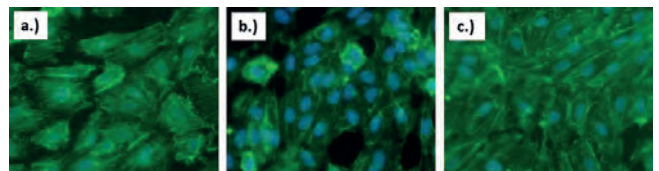

Figure 5: Fluorescent images of endothelial cells (HCAEC) on a Ti foil (left), as synthesized TiO_2 nanotubes (middle) and plasma treated TiO_2 nanotubes.
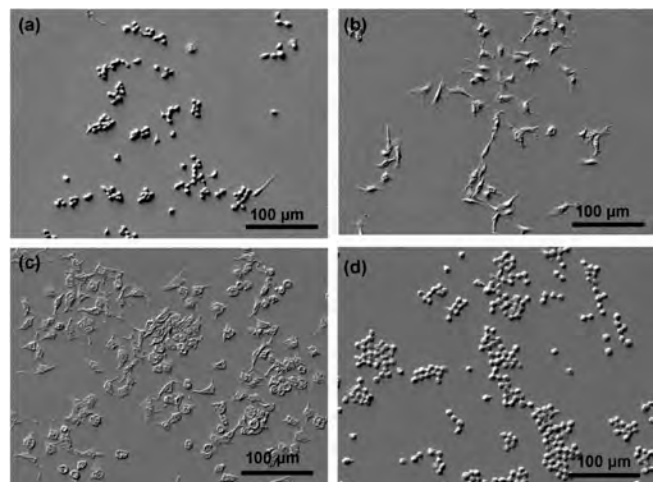

Figure 6: SEM images of cells on PET surfaces treated in various SO_2 + O_2 mixtures after 24 hours of incubation: (a) 100% SO_2; (b) 90% SO_2 + 10% O_2; (c) 60% SO_2 + 40% O_2; (d) 10% SO_2 + 90% O_2.

Figure 7: Cover image of Applied Physics Reviews with our illustration.

mouse, for different durations of exposure and gas-flow rates. The extent of skin damage was systematically evaluated using a stereomicroscope, labelling with fluorescent dyes, histology, infrared imaging and optical emission spectroscopy. The analyses revealed early and late skin damages as a consequence of plasma treatment, and were attributed to the direct and indirect effects of plasma. The results indicate that direct skin damage progresses with longer treatment times and increasing gas flow rates. With increasing flow rates, the temperature of the treated skin increases and so do the reactive oxygen and nitrogen species (RONSs). The direct effects depended on plasma parameters, whereas the secondary effects were rather independent of the discharge parameters and related to the diffusion of RONS. Thermal effects and skin heating were related to plasma coupling and were separated from the effects of RONS. It was demonstrated that a cumulative treatment with a helium plasma jet could lead to the skin damage. Our results provide guidance for researchers working on atmospheric pressure plasma jets for skin treatments worldwide.

Atmospheric pressure plasma was also used as a tool for the removal of mycotoxins, which are secondary metabolites produced by several filamentous fungi. These toxins frequently contaminate our food, and can result in human diseases affecting vital systems such as the nervous and immune systems. Intensive food production is contributing to the incorrect handling, transport and storage of the food, resulting in increased levels of mycotoxin contamination. Mycotoxins are structurally very diverse molecules necessitating versatile food-decontamination approaches, which are grouped into physical, chemical and biological techniques. Our new and promising approach demonstrated a high mycotoxin destruction efficiency as compared to classic techniques.

Similarly, we used plasma treatment as an alternative therapy for bone cancer, either primary or metastatic. The classic treatments are difficult to implement and not always effective. An alternative therapy could be cold plasma generated at atmospheric pressure, which has already demonstrated selective anti-tumour action in a number of carcinomas and in rather rare brain tumours. An atmospheric pressure plasma jet was employed to validate its selectivity towards osteosarcoma cells versus human mesenchymal stem cells. Effects on cells during the direct interaction of plasma jet with cells were compared with indirect interaction when only the liquid medium was treated and subsequently added to the cells. The delayed effects led to 100% bone cancer cell death through apoptosis stages, while healthy cells remained almost fully viable and unaffected by the treatment. The high efficiency of the indirect treatment indicates that an important role is played by the RONS in the gaseous plasma, which are transmitted into the liquid phase, which in turn led to lethal and selective action towards osteosarcoma cells. These initial findings might open another pathway for the treatment of metastatic bone disease with a minimal invasive approach.

In recent years we occasionally participated in fusion experiments in the two European tokamaks: JET and ASDEX-U. JET (Joint European Torus) is currently the biggest operating fusion reactor in the world, located in the Culham Centre for Fusion Energy in Oxfordshire, UK. ASDEX-U is a divertor tokamak located in the Max-Planck-Institut für Plasmaphysik, Garching, and it is Germany's second largest fusion device after the newly-built stellarator Wendelstein 7X in Greifswald. Our main interest was the investigation of ammonia production in nitrogen-seeded fusion-plasma discharges. The detection of ammonia with Residual Gas Analysers (RGA), mounted either in the tokamak divertor or the mid-plane, was impeded by the presence of water and methane, which, in a mixed hydrogen-deuterium system, leave signatures in the same range of the mass spectra. We suggested a new statistical model and fitting procedure, and applied it successfully to experimental data from

Figure 8: Average values of H/(H+D) ratios from the sub-divertor Penning gauge, H-alpha divertor spectroscopy and RGA hydrogen as well as methane signals in JET discharges.

nitrogen-seeded campaigns at ASDEX-U and JET. Our novel method of RGA spectra analysis was also used for the evaluation of the hydrogen isotope content at both tokamaks.

Tritium retention studies in future nuclear fusion reactors represent an important activity as maximum tolerated absorbed tritium dose determines the reactor's lifetime. To avoid risky experiments with radioactive tritium, many experiments are performed using hydrogen or deuterium instead. To compensate for the lower detection capability of these two hydrogen isotopes, all contributions which influence the accuracy of the results should be well recognized. In our very precise measurements of hydrogen permeation through impermeable

membranes or in Thermal Desorption Spectroscopy (TDS) experiments, we determined hydrogen/deuterium absorption within oxide layers of an ultra-high-vacuum system. Pressure measurements were performed by non-ionizing gauges as we had to eliminate unacceptably high influence of positively charged gaseous ions. We performed hydrogen exposures at conditions that simulated true conditions in fusion reactors. Results were applied in fusion-related studies of mixed Be/W layers with oxygen and carbon. Namely, the formation of Be/W layers during plasma operation is evident from JET experiments and the retention of tritium in these layers should be predictable. Unfortunately, mixed Be/W layers in a real device will also contain oxygen and carbon, which further increases the number of chemical states for hydrogen retention. Several samples of mixed layers on pure tungsten substrates were investigated by TDS cycles performed up to 700°C.

Some outstanding publications in the past three years

1. Žerjav, G., et al., Improved electron-hole separation and migration in anatase TiO_2 nanorod/reduced graphene oxide composites and their influence on photocatalytic performance. *Nanoscale*, 2017, 9(13): p. 4578-4592.

2. Vanrenterghem, B., et al., Increase of electrodeposited catalyst stability via plasma grown vertically oriented graphene nanoparticle movement restriction. *Chemical Communications*, 2017, 53(67): p. 9340-9343.

3. Tatarova, E., et al. Towards large-scale in free-standing graphene and N-graphene sheets. *Scientific reports*, 2017, 7: p. 10175-1-10175-15.

4. Recek, N., et al., Cell Proliferation on Polyethylene Terephthalate Treated in Plasma Created in SO_2/O_2 Mixtures. *Polymers,* 2017. 9(3): p. 82.

5. Šantak, V., et al., Surface Treatment of Human Hard Dental Tissues with Atmospheric Pressure Plasma Jet. *Plasma Chemistry and Plasma Processing*, 2017. 37(2): p. 401-413.

6. Hojnik, N., et al., Mycotoxin decontamination of food: cold atmospheric pressure plasma versus "classic" decontamination. *Toxins* 2017, 9(5): p. 151-1-151-19,

7. Canal, C., et al., Plasma-induced selectivity in bone cancer cells death. *Free Radical Biology & Medicine*, 2017, 110: p. 72-80

8. Baranov, O., et al., Plasma under control: advanced solutions and perspectives for plasma flux management in material treatment and nano-synthesis. *Applied physics reviews*, 2017, 4: p. 041302-1-041302-33

9. Drenik, A., et al., Detection of ammonia by residual gas analysis in AUG and JET. *Fusion Engineering and Design*, 2017, 124: p. 239-243.

10. Nemanič, V., et al., Hydrogen interactions with oxidized austenitic stainless steel. *Journal of vacuum science & technology. A*, 2017, 35(2): p. 2017/35-1-2017/35-6.

Patent granted

1. Marián Lehocký, Petr Stloukal, Vladimír Sedlarik, Petr Humpolíček, Alenka Vesel, Miran Mozetič, Rok Zaplotnik, Gregor Primc, Dana Kreizlová, Zařízení pro generování UV záření a způsob generování tohoto záření, CZ306584 (B6), Úřad Průmyslového Vlastnictví, 15. 03. 2017.

INTERNATIONAL PROJECTS

1. COST TD1208; Electrical Discharges with Liquids for Future Applications; COST Training School on Liquid Discharges
   Prof. Uroš Cvelbar
   Cost Office

2. NATO Grant; SPS 984555; Atmospheric Pressure Plasma Jet for Neutralisation of CBW
   Prof. Uroš Cvelbar
   Nato - North Atlantic Treaty Organisation

3. COST CA15114; Anti-Microbal Coating Innovations to prevent Infectious Diseases (AMICI)
   Prof. Uroš Cvelbar
   Cost Office

4. COST TD1305; Improved Protection of Medical Devices Against Infection (IPROMEDAI)
   Dr. Martina Modic
   Cost Office

5. H2020 - PEGASUS; Plasma Enabled and Graphene Allowed Synthesis of Unique nano Structures
   Prof. Uroš Cvelbar
   European Commission

6. H2020-EUROfusion-Plasma Facing Components-1-IPH-FU, EUROFUSION
   Asst. Prof. Rok Zaplotnik
   European Commission

7. H2020 EUROfusion - Education-ED-FU
   Prof. Miran Mozetič
   European Commission

8. H2020 EUROfusion - Medium Size Tokamak Campaigns-MST1-FU
   Asst. Prof. Rok Zaplotnik
   European Commission

9. Sniffing for Carcinogenic Substances - Research for Toxic Gas Molecule Sensing with Networks of Carbon Nanowalls
   Prof. Uroš Cvelbar
   Slovenian Research Agency

10. Biocompatible Nanostructured Tetragonal Zirconium Oxide Thin Films with Alternative Stabilization Dopants
    Prof. Miran Mozetič
    Slovenian Research Agency

11. Innovative Method for Synthesis of Thin Absorption Films for Photovoltaics
    Asst. Prof. Alenka Vesel
    Slovenian Research Agency

12. Sterilization of Heat-sensitive Materials with Innovative Plasma Source of UV Radiation
    Prof. Miran Mozetič
    Slovenian Research Agency

13. Dust in Plasmas (DIP)
    Prof. Miran Mozetič
    Slovenian Research Agency

14. Making Luminescent C-dots and GQDs Based on Atmospheric Pressure Microplasma-Liquid Interaction
Prof. Uroš Cvelbar
Slovenian Research Agency
15. Quantitative Depth Profiling of Ultra-Thin Films
Asst. Prof. Janez Kovač
Slovenian Research Agency
16. Catalytic Activity of Nanomaterials for Elimination of Sulfur
Prof. Uroš Cvelbar
Slovenian Research Agency
17. Determination of Neutral-Atom Densities in Large Plasma Reactors
Prof. Miran Mozetič
Slovenian Research Agency
18. Plasma Assisted-Deposition of Antibacterial Coatings and their Testing
Dr. Martina Modic
Slovenian Research Agency
19. Plasma-Assisted Design of Multifunctional Carbon Nanowalls Bio-Sensor
Prof. Uroš Cvelbar
Slovenian Research Agency
20. Membership Chair of ECS - Division Dielectric Science and Technology Electrochemical Society
Prof. Uroš Cvelbar
Slovenian Research Agency
21. Innovative Coatings for Bare Metallic Vascular Stents for Reduction of Restenosis and Acceleration of Natural Endothelization
Prof. Miran Mozetič
Slovenian Research Agency
22. Consequences of electron emission from hot plasma-facing components in nuclear fusion reactors
Prof. Miran Mozetič
Slovenian Research Agency

RESEARCH PROGRAMS

1. Vacuum technique and materials for electronics
Dr. Vincenc Nemanič
2. Thin film structures and plasma surface engineering
Prof. Miran Mozetič

R & D GRANTS AND CONTRACTS

1. Nanoscale engineering of the contract interfaces for green lubrication technology
Asst. Prof. Janez Kovač

2. Multifunctional electrospunned nanofibers development and dynamic interaction studies with pathogen bacteria
Prof. Miran Mozetič
3. Understanding plasma processes and thin film growth in High Power Impulse Magnetron Sputtering
Prof. Uroš Cvelbar
4. Plasma-assisted wound treatment and topical introduction of molecules
Prof. Uroš Cvelbar
5. New generation of superior creep resistant steels with nanoparticles modified microstructure
Prof. Uroš Cvelbar
6. Interaction between fully dissociated moderately ionized ammonia plasma and glass-fiber reinforced polymers
Prof. Miran Mozetič
7. Nanostructures and related composites for detection of hazardous gaseous molecules
Prof. Uroš Cvelbar
8. Functionalization of polymer cardiovascular implants for optimal hemocompatibility
Asst. Prof. Alenka Vesel
9. Advanced hydrodesulphurisation with catalyst nanomaterials
Prof. Uroš Cvelbar
10. Advanced hemocompatible surfaces of vascular stents
Dr. Ita Junkar
11. Evaluation of the range of plasma parameters suitable for nanostructuring of polymers on industrial scale
Prof. Miran Mozetič
12. Selective plasma oxidation of FeCrAl alloys for extended-lifetime of glow plugs for diesel engines
Asst. Prof. Janez Kovač
13. Food for future - F4F
Asst. Prof. Alenka Vesel
14. Potential of biomass for development of advanced materials and bio-based products
Dr. Ita Junkar
15. Building blocks, tools and systems for the Factories of the Future – GOSTOP
Prof. Miran Mozetič
16. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
Prof. Miran Mozetič
17. Development of nanostructured biosensors for diagnosis/treatment of cancer and surfaces with antibacterial
Prof. Miran Mozetič
18. Novel type of antibacterial coatings on textile materials and plastics with controllable release of antibacterial agent
Prof. Uroš Cvelbar
19. Hydrogen Permeation Measurements on PVD-Coated Eurofer
Dr. Vincenc Nemanič
20. Tof-SIMS surface spectrometry
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VISITORS FROM ABROAD

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9. Dr Kenji Ishikawa, University of Nagoya, Nagoya, Japan, 6–8 July 2017
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SHORT ARTICLE

1. Zdenka Peršin, Tanja Pivec, Miran Mozetič, Karin Stana-Kleinschek, "Sol-gel/Ag coating and oxygen plasma treatment effect on synthetic wound fluid sorption by non-woven cellulose material", *Tekstilec*, **60**, no. 1, 25-28, 2017.

PUBLISHED CONFERENCE CONTRIBUTION (INVITED LECTURE)

1. Anton Nikiforov *et al.* (11 authors), "Plasma deposition of antibacterial nano-coatings on polymeric materials", In: *Plasma nano science and technology*, P. Mascher, ed., Uroš Cvelbar, ed., *ECS transactions*, **77**, 3, 53- 61, 2017.

PUBLISHED CONFERENCE CONTRIBUTION

1. Aleksander Drenik, Daniel Allegre, Sebastijan Brezinšek, Alfonso de Castro, Uron Kruezi, Martin Oberkofler, Matjaž Panjan, Gregor Primc, T. Reichbauer, Matic Resnik, Volker Rohde, Michael Seibt, P. A. Schneider, T. Wauters, Rok Zaplotnik, the ASDEX-Upgrade and EUROfusion MST teams and JET Contributors, "Evaluation of the plasma hydrogen isotope content by residual gas analysis at JET and AUG", In: *The 16th International conference on plasma-facing materials and components for fusion applications (PFMC-16)*, Düsseldorf, May 2017, *Phys. scr.*, vol 2017, T170, 014021, 2017.
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INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

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PATENT APPLICATION

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PATENT

1. Marián Lehocký, Petr Stloukal, Vladimír Sedlarik, Petr Humpolíček, Alenka Vesel, Miran Mozetič, Rok Zaplotnik, Gregor Primc, Dana Kreizlová, *Zařízení pro generování UV záření a způsob generování tohoto záření,* CZ306584 (B6), Úřad Průmyslového Vlastnictví, 15. 03. 2017.

DEPARTMENT OF SOLID STATE PHYSICS F-5

Our research program focuses on the study of the structure and dynamics of disordered and partially ordered condensed matter at the atomic and molecular levels with a special emphasis on phase transitions. The purpose of these investigations is to discover the basic laws of physics governing the behaviour of these systems, which represent the link between perfectly ordered crystals on one side and amorphous matter, soft condensed matter and living systems on the other. Such knowledge provides the key to our understanding of the macroscopic properties of these systems and is an important condition for the discovery and development of new multifunctional materials, nanomaterials and biomaterials for new applications. An important part of the research program is devoted to the development of new experimental methods and techniques in the field of magnetic resonance, magnetic resonance imaging, fluorescence micro-spectroscopy, scanning tunnelling, electronic and atomic force microscopy, as well as dielectric relaxation spectroscopy and dynamic specific heat measurements.

Head:
Prof. Igor Muševič

The experimental techniques used are:

- One- (1d) and two-dimensional (2d) nuclear magnetic resonance (nmr) and relaxation, as well as quadrupole (nqr) resonance and relaxation,
- Multi-frequency nmr in superconducting magnets of 2t, 6t and 9t, as well as the dispersion of the spin–lattice relaxation time t_1 via field cycling,
- Nuclear double resonance and quadrupole double resonance such as ^{17}o–h and ^{14}n-h,
- Fast field cycling NMR relaxometry,
- Frequency-dependent electron paramagnetic resonance (epr) and 1d and 2d pulsed epr and relaxation,
- MR imaging and micro-imaging,
- Measurement of the electronic transport properties,
- Magnetic measurements,
- Fluorescence microscopy and micro-spectroscopy,
- Linear and non-linear dielectric spectroscopy in the range 10^{-2} Hz to 10^9 Hz,
- Electron microscopy and scanning tunnelling microscopy,
- Atomic force microscopy and force spectroscopy,
- Dynamic specific heat measurements.

The research program of the Department of Solid State Physics at the Jožef Stefan Institute is performed in close collaboration with the Department of Physics at the Faculty of Mathematics and Physics of the University of Ljubljana, Institute of Mathematics, Physics and Mechanics and the J. Stefan International Postgraduate School. In 2017, the research was performed within three research programs:

- Magnetic resonance and dielectric spectroscopy of smart new materials
- Physics of Soft Matter, Surfaces and Nanostructures
- Experimental Biophysics of Complex Systems

I. Program group "Magnetic resonance and dielectric spectroscopy of smart new materials"

The research of the program group "Magnetic resonance and dielectric spectroscopy of smart new materials" focused on the study of physical phenomena in condensed matter at the atomic and molecular levels. The purpose of the investigations was to discover the basic laws of physics governing the behaviour of the investigated systems. The attained knowledge provides the key to understanding the microscopic and macroscopic properties of various types of solids and is an important condition for the discovery and development of new multifunctional materials and nanomaterials for novel technological applications.

In our research, we used the following experimental techniques:

- Nuclear magnetic resonance (NMR), electron paramagnetic resonance (EPR) and nuclear quadrupole resonance (NQR),
- Nuclear double resonance ^{17}O–H and ^{14}N–H,

- Fast field cycling NMR relaxometry,
- Linear and non-linear dielectric spectroscopy in the range 10^{-2} Hz to 10^9 Hz,
- Frequency-dependent ac calorimetry,
- Measurement of electrical and thermal transport coefficients,
- Magnetic measurements.

The research program was performed in close collaboration with the Department of Physics at the Faculty of Mathematics and Physics of the University of Ljubljana, Institute of Mathematics, Physics and Mechanics, and the J. Stefan International Postgraduate School.

In 2017, members of the program group published 42 original scientific papers in international peer-reviewed scientific journals. Among these, one paper was published in *Nature Chemistry* IF = 25.9, one in *Nature Physics* IF = 22.1, one in *ACS Nano* IF = 13.9, and two in *Physical. Review Leter.* IF = 8.5.

The research group has discovered new quantum spin order in quantum spin liquids and the first magnetic superconductor for potential use in spintronics and quantum computing. It has developed new electronic elements for printed electronics, discovered a new material with a giant electrocaloric effect for the development of refrigerators of a new generation and found a new catalyst material based on titanate nanotubes for aldol condensation.

The investigations were focused on the following research fields:

Quantum magnetism

Martin Klanjšek, Andrej Zorko and Denis Arčon, in collaboration with researchers from Slovenia and the UK, experimentally studied the spin dynamics of the layered material 1T-TaS$_2$. As each layer of the material in the charge-density wave state below 210 K exhibits a frustrated, triangular lattice of magnetic spins, it has been descibed as a possible platform for the realization of the enigmatic quantum spin-liquid (QSL) state for the past 40 years. To confirm this prediction, the authors conducted nuclear quadrupole resonance and muon-spin-relaxation experiments, which indeed revealed that the spins show gapless QSL dynamics and no long-range magnetic order, at least down to 70 mK. Canonical T^2 power-law temperature dependence of the spin relaxation dynamics characteristic of a QSL is observed down to 55 K. Below this temperature, a new gapless state is observed, signifying a new quantum spin order emerging from the QSL. The discovery was published in M. Klanjšek, A. Zorko, R. Žitko, J. Mravlje, Z. Jagličić, P. Kumar Biswas, P. Prelovšek, D, Mihailovic, D. Arčon. A high-temperature quantum spin liquid with polaron spins. *Nature Physics* 13 (2017), 1130.

Figure 1: Low-temperature spin state of 1T-TaS$_2$ with the arrangement of the "Star-of-David" spin singlets (red shaded areas) in a spatially random manner. This state still exhibits a gapless behaviour for the low-energy spin excitations (blue arrows).

Matjaž Gomilšek, Martin Klanjšek, Matej Pregelj and Andrej Zorko, in collaboration with partners from China and France, discovered instability in an enigmatic quantum spin liquid with a spinon Fermi surface. They showed that its magnetic excitation (spinons), which are equivalents of electrons with spin but no charge, form pairs in a magnetic field. This process is analogous to the formation of Cooper pairs in superconductors. The discovery of a "magnetic superconductor" could be important in the fields of spintronics and quantum computing and was published in M. Gomilšek, M. Klanjšek, R. Žitko, M. Pregelj, F. Bert, P. Mendels, Y. Li, Q. M. Zhang, A. Zorko. Field-induced instability of a gapless spin liquid with a spinon fermi surface. *Physical Review Letters* 119 (2017), 137205.

Figure 2: Illustration of the spinon-pairing instability observed in the kagome antiferromagnet Zn-brochantite. The process is a magnetic analogue of Cooper pairing in superconductors.

Matej Pregelj, Andrej Zorko, and Denis Arčon, in collaboration with partners from Germany, Russia and Switzerland, explored the thermodynamic properties of the layered compound CuNCN using heat-capacity measurements and investigated the corresponding thermal atomic motions by means of neutron scattering. They complemented the experiments using a combination of density-functional calculations, phonon analysis and analytic theory. In this way they established the existence of a soft flexural mode – bending of the layers, characteristic for the material structure – that reflects in the phonon spectrum of CuNCN by giving characteristic temperature-dependent contributions to the heat capacity and atomic displacement parameters. The agreement with the neutron data allowed them to extract a residual – on top of the lattice – presumably spinon contribution to the heat capacity, speaking in favour of the spin-liquid picture of the electronic phases of CuNCN. Their discovery was published in A. L. Tchougréeff1, R. P. Stoffel, A. Houben, P. Jacobs, R. Dronskowski, M. Pregelj, A. Zorko, D. Arčon, O. Zaharko. Atomic motions in the layered copper pseudo-chalcogenide CuNCN indicative of a quantum spin-liquid scenario. *Journal of Physics: Condensed Matter 29* (2017), 235701.

Andrej Zorko and Matjaž Gomilšek, in collaboration with partners from Croatia, USA and France, employed a combination of complementary torque magnetometry and electron spin resonance techniques to investigate single
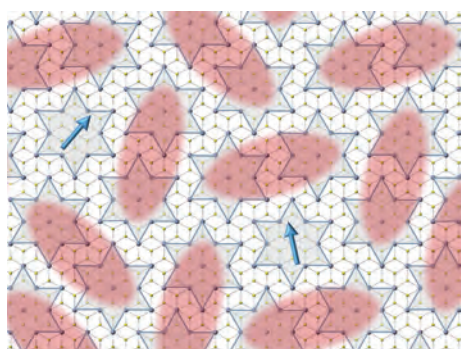
crystals of herbertsmithite, the closest realization to date of a quantum kagome antiferromagnet featuring a spin-liquid ground state. Their discovery of a magnetic response that contradicts the threefold symmetry of the ideal kagome lattice was shown to originate from a global structural distortion that might be related to the establishment of a spin-liquid ground state. These results were published in A. Zorko, M. Herak, M. Gomilšek, J. van Tol, M. Velázquez, P. Khuntia, F. Bert, P. Mendels. Symmetry reduction in the quantum kagome antiferromagnet herbertsmithite. *Physical Review Letters* 118 (2017), 017202. Andrej Zorko collaborated with researchers from Croatia, France and USA on a synthesis and characterization of a novel hetero-tetranuclear compound $[Cr_2(bpy)_4(\mu\text{-}O)_4Nb_2(C_2O_4)_4]\cdot3H_2O$ (bpy = 2,2′-bipyridine). It was found that it consists of a square-shaped macrocyclic $\{Cr_2(\mu\text{-}O)_4Nb_2\}$ core in which Cr^{III} and Nb^V ions are alternately bridged by oxo ions and three uncoordinated water molecules. The resulting magnetic structure corresponds to weakly interacting chromium dimers. The results were published in M. Jurić, L. Androš Dubraja, D. Pajić, F. Torić, A. Zorko, A. Ozarowski, V. Despoja, W. Lafargue-Dit-Hauret, X. Rocquefelte. Experimental and Theoretical Investigation of the Anti-Ferromagnetic Coupling of Cr_{III} Ions through Diamagnetic $-O-Nb^V-O-$ Bridges. *Inorganic Chemistry* 56 (2017), 6879.

Magnetism of the CoCrFeNiZr$_x$ eutectic high-entropy alloys

We have investigated the magnetism of CoCrFeNiZr$_x$ (x = 0.4–0.5) eutectic high-entropy alloys (HEAs) in relation to their microstructure by XRD, SEM, magnetization, specific heat and electrical resistivity measurements. Two structural phases develop in the CoCrFeNiZr$_x$ HEAs, a Zr-free fcc solid solution and a Zr-containing C15 Laves-phase intermetallic compound (Fig. 4), where in both phases the magnetic transition elements Co, Cr, Fe and Ni substitute each other in a random-like manner. Two magnetic structures coexist in the CoCrFeNiZr$_x$ HEAs. The first is a disordered ferromagnetic (FM) phase that develops in the interior of large dendrites of the fcc solid solution and in some larger lamellas of this phase. The second phase is superparamagnetic-like and originates from the remaining spins of the fcc solid-solution fraction, located at the surfaces and in the interfaces, and from all spins of the C15 Laves-phase fraction. The magnetism of multi-phase HEAs containing magnetic elements cannot be described as a compositional average of the magnetic properties of the constituent phases.

The results of the study were published in S. Vrtnik, S. Guo, S. Sheikh, A. Jelen, P. Koželj, J. Luzar, A. Kocjan, Z. Jagličić, A. Meden, H. Guim, H.J. Kim, J. Dolinšek. Magnetism of CoCrFeNiZrx eutectic high-entropy alloys. *Intermetallics* 93 (2017), 122.

Study of nanostructured materials and materials with a large electrocaloric effect for solid-state cooling applications:

We showed by direct measurements the existence of a large electrocaloric effect in thick-film multilayers of PMN-10PT, as well as in bulk lead-free materials. In addition, we demonstrated that these materials can survive many fields. The patent application, which was bought by the company Gorenje d.d. in 2016, has been awarded an EU patent in 2017 (*EP 3027980 BI*): B. Malič, H. Uršič, M. Kosec, S. Drnovšek, J. Cilenšek, Z. Kutnjak, B. Rožič, U. Flisar, A. Kitanovski, M. Ožbolt, U. Plaznik, A. Poredoš, U. Tomc, J. Tušek. Method for electrocaloric energy conversion: patent application US 2016/0187034 A17700. [S. l.]: United States Patent Office, 30. 6. 2016. The results of the study were published in Z. Kutnjak, R. Pirc. Specific heat anomaly in relaxor ferroelectrics and dipolar glasses. *Journal of Applied Physics* 121 (2017), 105107. B. Asbani, Y. Gagou, J.-L. Dellis, M. Trček, Z. Kutnjak, M. Amjoud, A. Lahmar, D. Mezzane, M. El Marssi. Lead-free $Ba_{0.8}Ca_{0.2}Te_xTi_{1-x}O_3$ ferroelectric ceramics exhibiting high electrocaloric properties. *Journal of Applied Physics* 121 (2017), 064103.

We also demonstrated that the gold nanoparticles can stabilize periodic defect structures, studies of which were published in M. Trček, G. Cordoyiannis, B. Rožič, V. Tzitzios, G. Nounesis, S. Kralj, I. Lelidis, E. Lacaze, H. Amenitsch, Z. Kutnjak. Twist-grain boundary phase induced by Au nanoparticles in a chiral liquid-crystal host. *Liquid Crystals* 44 (2017), 1575. B. Rožič, J. Fresnais, C. Molinaro, J. Calixte, S. Umadevi, S. Lau-Truong, N. Felidj, T. Kraus, F. Charra, V. Dupuis, T. Hegmann, C. Fiorini-Debuisschert, B. Gallas, E. Lacaze. Oriented gold nanorods and gold nanorod chains within smectic liquid-crystal topological defects. *ACS Nano* 11 (2017), 6728.
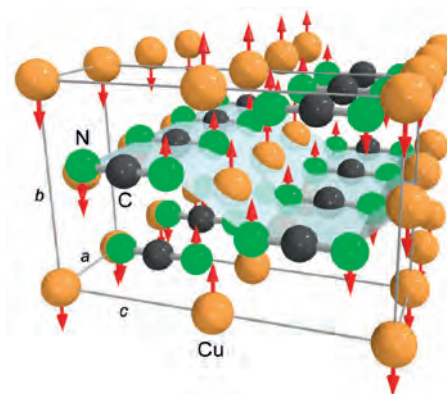
Figure 3: The crystal structure of CuNCN with Cu in dark-orange, C in black and N in green. The half-transparent surface is a guide for the eye to highlight the layered structure of the material. Γ point eigenvectors of the flexural vibration mode are depicted using arrows. These eigenvectors are clearly dominated by the rotations of the NCN^{2-} moieties around the a axis, accompanied by the parallel motions of the Cu atoms. Contributions in the c direction are small and no a components are present.

Figure 4: Microstructure of the CoCrFeNiZrx eutectic high-entropy alloy obtained by SEM backscattered electrons.

Figure 5: Texture of stabilized TGBA phase by gold particles. Front schematics show nanoparticle agglomeration in defect dislocation lines.

Figure 6: Surface –OH groups that are in a bridging configuration are crucial for high catalytic activity.
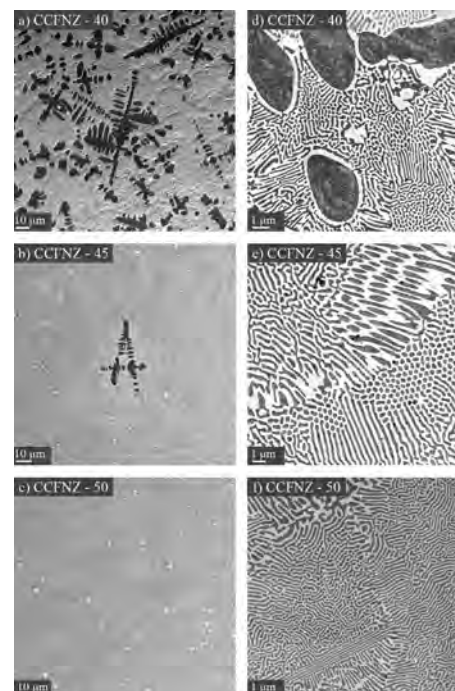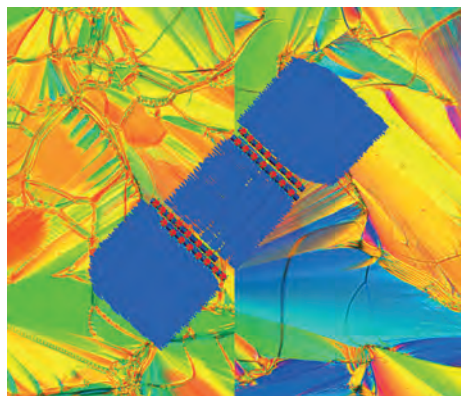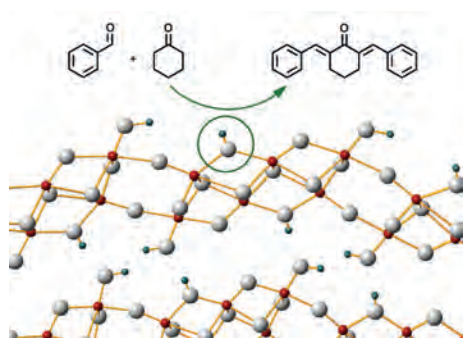

Figure 7: The impact of the ink–substrate interactions on the morphology and definition of the printed pattern. The indium-zinc oxide (IZO) ink (prepared by dissolving $In(NO_3)_3$ and $Zn(NO_3)_2$ in a solvent mixture of 2-methoxyethanol and 1,3-propanediol in a 45:55 volume ratio) spreads completely on the bare glass due to strong interactions (left). By implementing a PMMA layer, the interactions become weak and the pattern breaks into individual droplets (right). A precise adjustment of the interactions between the ink and the substrate by a partial decomposition of the polymeric layer enables printing with a high resolution (middle). The results of the study were published in A. Matavž, V. Bobnar, B. Malič. Tailoring ink-substrate interactions via thin polymeric layers for high-resolution printing. Langmuir 33, (2017), 11893.

Research of the catalytic properties of 1D titanate nanostructures

In research of the applicative properties of nanostructured materials in the field of catalysis, Melita Sluban and Polona Umek with colleagues from the universities of Ljubljana and Bucharest successfully catalysed aldol condensation with protonated titanate nanotubes. This is a 'green' alternative to the present reaction performance at the industrial level, where stoichiometric amounts of homogeneous catalyst are used and the catalyst cannot be recycled. With protonated titanate nanotubes, catalytic amounts of the material sufficed for the reaction progress, the catalyst was reused several times and was efficient in a large-scale experiment. The study *Protonated titanate nanotubes as solid acid catalyst for aldol condensation* was published in the *Journal of Catalysis* 346 (2017), 161169.

Robust preparation procedure for the production of thermomechanically active composite soft materials

The group of B. Zalar and A. Rešetič has developed a robust preparation procedure for the production of thermomechanically active composite soft materials on the basis of main-chain liquid-crystal elastomers. By employing cryogenic planetary ball milling as well as by determining the degree of orientational order of thermomechanically active microparticles in the polymer matrix via deuteron quadrupole-perturbed nuclear magnetic resonance, they have achieved a thermomechanical response of approximately 100%, an elastic modulus of the order of 1 MPa, and a high structural homogeneity of both the prepolymerization resin and of the cross-linked composite. This is an important step towards the application of polymer dispersed liquid-crystal elastomers in additive manufacturing technologies.

Tailoring ink-substrate interactions via thin polymeric layers for high-resolution printing

The surface properties of a substrate are among the most important parameters in the printing technology of functional materials, determining not only the printing resolution but also the stability of the printed features. We showed that the wetting of a substrate and, consequently, the quality of the printed pattern can be mediated through the deposition of polymeric layers that are a few nanometres thick. In particular, we introduced a thermal decomposition of the poly(methyl–methacrylate) (PMMA) layer on glass substrates as a method for precisely adjusting the surface properties, which is used to optimize the print quality and the resolution. The practical applicability of this procedure was exemplified by three ink–substrate systems, which originally exhibited poor printing performance: (i) a tantalum oxide based ink on indium tin oxide coated glass, (ii) a ferroelectric $Pb(Zr,Ti)O_3$ ink on a platinized silicon substrate, and (iii) a silver nanoparticle ink on an alumina substrate.

Inkjet printing of metal-oxide-based transparent thin-film capacitors

We have fabricated transparent thin-film capacitors by inkjet printing solution-based inks onto glass substrates. The all-printed capacitors, composed of indium-zinc oxide electrodes and tantalum oxide-based dielectric, were ∼100 nm thick and showed a uniform thickness. Electrical measurements revealed the stable performance of the capacitors at frequencies up to ∼1 kHz, while at higher frequencies the dielectric response is governed by a non-negligible resistivity of the printed electrodes. Good dielectric performance as well as the low leakage current density of our capacitors indicate that inkjet printing can be used to produce all-printed, high-quality electronic elements. The results of the study were published in A. Matavž, B. Malič, V. Bobnar. Inkjet printing of metal-oxide-based transparent thin-film capacitors. *Journal of Applied Physics* 122 (2017), 214102.

Development of multilayer ceramic elements for electrocaloric cooling

Electrocaloric (EC) cooling elements, composed of five 60-μm-thick layers of the relaxor-ferroelectric $0.9Pb(Mg_{1/3}Nb_{2/3})O_3–0.1PbTiO_3$ ceramics with internal platinum electrodes, were synthesized. We have shown that with careful processing of these multilayer (ML) elements, including the mechanochemical synthesis of the powder, slurry formulation, tape casting, and ML fabrication, a similar EC response (ΔT_{EC} values above 2 K over a broad temperature range) of the ML elements can be achieved as for state-of-the-art bulk ceramic elements. Moreover, a study of their EC stability revealed a fatigue-less behaviour, which justifies the

choice of relaxor multilayers as working bodies in EC cooling devices, where the material should withstand numerous electric field cycles with high amplitudes.

Molecular dynamics of 1-ethyl-3-methylimidazolium triflate ionic liquid studied by ^{1}H and ^{19}F nuclear magnetic resonance

The molecular dynamics of an ionic liquid (IL) composed of 1-ethyl-3-methylimidazolium cation and triflate (trifluoromethanesulfonate) anion, abbreviated as [Emim][TfO] (Fig. 5), was studied by NMR spectroscopy. By measuring the temperature-dependent high-field ^{1}H and ^{19}F spin-lattice relaxation (SLR) rates, the frequency-dependent ^{1}H and ^{19}F SLR dispersion curves using fast-field-cycling relaxometry and the temperature-dependent ^{1}H and ^{19}F diffusion constants, and utilizing the fact that the primary NMR-active nucleus on the Emim cation is ^{1}H, whereas on the TfO anion it is ^{19}F, the cationic and anionic dynamics were studied separately. A single theoretical relaxation model has successfully reproduced all the experimental data of both types of resonant nuclei. Upon cooling, [Emim][TfO] exhibits a super-cooled liquid phase between 256 K and the crystallization temperature 227–222 K, as also confirmed by differential scanning calorimetry (DSC) experiments. The existence of the supercooled liquid region in the [Emim][TfO] IL should be taken into account when using this IL for a specific application.

The results of the study were published in M. Wencka, T. Apih, R. Cerc Korošec, J. Jenczyk, M. Jarek, K. Szutkowski, S. Jurga, J. Dolinšek. Molecular dynamics of 1-ethyl-3-methylimidazolium triflate ionic liquid studied by 1H and 19F nuclear magnetic resonance. *Physical Chemistry Chemical Physics* 19 (2017), 15368.

Figure 8: Schematic presentation of the ionic liquid [Emim][TfO] molecule.

[14]N NQR lineshape in nanocrystals: An *ab-initio* investigation of urea

One of the ^{14}N NQR uses is also the identification and quantification of nitrogen-containing molecular crystals in heterogeneous compounds, e.g., discriminating between crystalline and amorphous structures, between polymorphs, hydrates and anhydrates, co-crystals, and others. In the bulk, the ^{14}N NQR resonances are very narrow, less than 1 kHz wide, so the parameter of interest is only the frequency, which is compound- and crystal structure specific. In nanocrystals we still expect to observe the ^{14}N NQR resonances, although some size effects, which would prevent this observation, cannot be excluded. Namely, nitrogen nuclei close to the surface experience a different environment than those in the bulk. As a result, their individual NQR frequency will be shifted from the bulk frequency, which will eventually result in broadening or perhaps a shift of the whole resonance. This would then limit the detection of the nanocrystals when non-accounted for. The failure to detect some nanocrystals, e.g., smaller ones, but not the larger ones, can have serious consequences for the interpretation of otherwise simple ^{14}N NQR spectra and could undermine the reputation of NQR as being non-sensitive to the physical form of the sample. This problem has become relevant for ^{14}N NQR spectroscopy only recently, when pharmaceutical substances, which are often nitrogen-containing molecular crystals, became increasingly more often prepared as nanocrystals embedded in some sort of matrix. In order to provide some insight into the subject, we theoretically investigated the size-lineshape relationship of the ^{14}N NQR resonance in urea nanocrystals with *ab-initio* techniques. We have considered nanocrystals with two geometries: (i) a sphere and (ii) a cube, with characteristic sizes between 5 and 100 nm. Our calculations suggest that there is a dramatic difference between the linewidths for the two geometries. For spheres, we find a steep drop in linewidths at ∼10 nm; at 5 nm the linewidth is ∼11 kHz, whereas for sizes above 20 nm the linewidth is practically negligible (<100 Hz). For cubes, on the other hand, we find a steady 1/size decrease, from 12 kHz at 10 nm to 1.2 kHz at 100 nm. The study was published in A. Gregorovič. [14]N NQR lineshape in nanocrystals: An *ab-initio* investigation of urea. *The Journal of Chemical Physics* 146 (2017), 194306.

Figure 9: Two representative ^{14}N NQR spectra and the corresponding size-linewidth dependence for two nanocrystal geometries: (i) spheres (open blue circles) and (ii) cubes (open red squares). The representative spectra are calculated for a nanocrystal size of 100 unit cells.

Mesoporous Gadollinium-Doped TiO_2 Nanobeads: Theragnostic Potential for Cancer Diagnosis and Tratment

The current study presents the synthesis, characterization, and performance of novel biocompatible and multifunctional Gd-doped TiO_2 in the sub-micrometre range, intended with a potential for cancer-cells tracking and killing. Our results, obtained by a collaboration of five University of Ljubljana faculties, the "J. Stefan Institute", and universities of Hannover, Upsaala, and St. Petersburg, demonstrated high reactive oxygen species photogeneration capacity and photocatalytic activity of the TiO_2 nanobeads doped with a low concentration of Gd. At the same
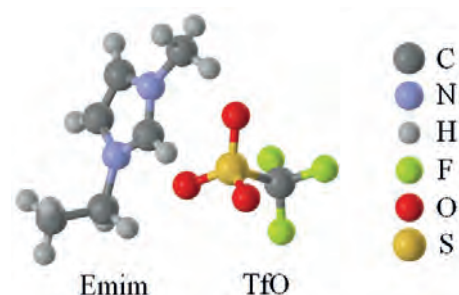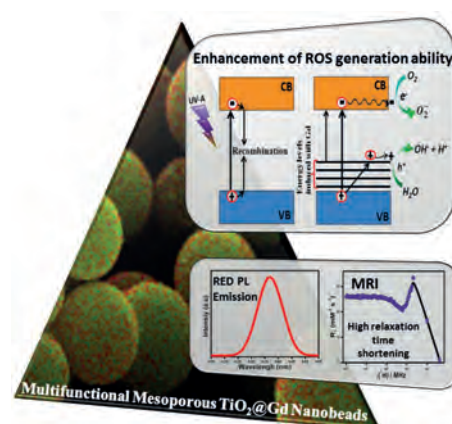

Figure 10: TiO_2 nanobeads doped with a low concentration of Gd.

time, the material functions as an optical imaging and magnetic resonance imaging (MRI) contrast agent, making it very interesting for future theragnostic applications. The study was published in

R. Imani, R. Dillert, D. W. Bahnemann, M. Pazoki, T. Apih, V. Kononenko, N. Repar, V. Kralj-Iglič, G. Boschloo, D. Drobne, T. Edvinsson, A. Iglič. Multifunctional Gadolinium-Doped Mesoporous TiO$_2$ Nanobeads: Photoluminescence, Enhanced Spin Relaxation, and Reactive Oxygen Species Photogeneration, Beneficial for Cancer Diagnosis and Treatment. *Small* 13 (2017), 1700349.

II. Research programme "Physics of Soft Matter, Surfaces, and Nanostructures"
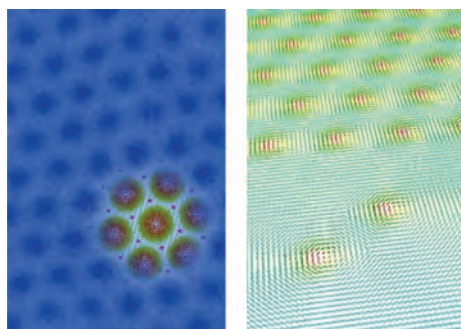

Figure 11: Optical image of the half-skyrmion lattice and simulation of the director field of the half-skyrmion lattice and individual defects.

The investigations of the research program *"Physics of Soft Matter, Surfaces, and Nanostructures"* focus on novel complex soft-matter systems and surfaces with specific functional properties. We investigated in particular liquid-crystalline elastomers and dendrimers as novel multifunctional materials, nematic colloids, molecular motors, soft-matter photonic crystals and novel synthetic or self-assembled micro- and nano-structures. The aim of the program is to understand the structural and dynamical properties of these systems, their interactions, their function at the molecular level, and self-assembly mechanisms in soft matter. The underlying idea is that it is possible to understand complex mechanisms, such as self-assembly, on a macroscopic level, using a simplified physical picture and models. In order to provide a comprehensive approach to the problem, the programme combines both experimental and theoretical investigations, supported by modelling and simulations. Special emphasis is given to the possible electro-optic and medical applications.

Skyrmions in a thin layer of a highly chiral nematic

Using a high-precision optical microscope we have shown that swirl-like structures known as half-Skyrmions are spontaneously formed in thin chiral liquid crystalline films that in bulk form blue phases. At a certain temperature they assemble into a two-dimensional hexagonal lattice that exhibits strong fluctuations (A. Nych, J. Fukuda, U. Ognysta, S. Žumer, I. Muševič. Spontaneous formation and dynamics of half-skyrmions in a chiral liquid-crystal film, *Nature Physics* 13 (2017), 1215). With numerical modelling of the structures and optical images, we confirmed a spontaneous formation of the skyrmion lattice in thin layers of blue phase II, predicted several years ago (*Nature Communications* (2011)), but until now observed only in chiral magnets and Bose-Einstein condensates. We also showed that the swirl-like single skyrmion structure in the cholesteric environment is always accompanied by two singular defects to neutralize the skyrmion topological charge. The study gives direct insights into the nature of topological condensed matter, which is one of the hot topics of current material physics research.

Spontaneous formation of half skyrmions in very thin layers of blue phases and the existence of defects with topological charges equal multiples of the unit charge in chiral nematic drops have been demonstrated. Fractal topological states in nematic colloids and coupling orientational and velocity fields in nematic microfluidics have been realized. We have succeeded in tagging living cells with microlasers. A system that allows for the simultaneous creation of two Bose-Einstein condensates was developed.

Topology of droplets with chiral nematic liquid crystals

We used the extended fluorescent confocal polarizing microscopy (FCPM) method, which was developed at the JSI, to characterise temperature quench-induced metastable director structures in chiral nematic droplets with homeotropic anchoring. In this way metastable states with multiple unit charge topological defects with a total topological charge of +1 are accessible. These defects are stabilized by chiral structures called cholesteric bubbles, which are related to skyrmions in chiral magnets. Some of the metastable structures include the newly discovered topological defects with a higher than unity topological charge. These defects form complex topological structures akin to molecules, and are interesting as building blocks for self-assembly with different symmetries (G. Posnjak, S. Čopar and I. Muševič. Hidden topological constellations and polyvalent charges in chiral nematic droplets. *Nature Communications* 8 (2017), 14594).

Figure 12: Point defects with higher topological charge in chiral nematic droplets.

Fractal nematic colloids

The generation of fractal topological states in nematic fluids was demonstrated (S. M. Hasheimi, U. Jagodič, M. R. Mozaffari, M. R. Ejtehadi, I. Muševič, and M. Ravnik, *Fractal nematic colloids, Nature Community* 8 (2017), 12106). For fractal colloidal particles in nematic liquid crystals numerical modelling based on mesoscopic phenomenological free-energy minimization with finite elements was used. On the experimental side two-photon laser polymerization was

used to produce colloidal particles in the shape of fractal Koch snowflakes, which were then observed with optical microscopy techniques. The research was a combinations of numerical modelling and performed at the Faculty of Mathematics and Physics at the University of Ljubljana, with support from the group at Sharif University of Technology, and experiments, which were performed at the Department of Condensed Matter Physics at the Jožef Stefan Institute.

Topological defects in thin nematic films:

We studied experimentally and theoretically the structures of strongly charged topological defects in nematic liquid crystals confined to thin films. We determined the conditions for which defects decay into their elementary units. The defects were enforced experimentally using an AFM inscribed nematic patterns into confining plates. In theoretical modelling we used Landau-de Gennes mesoscopic modelling. The obtained results are interesting from the fundamental perspective. Namely, topological defects might represent "particles" of nature if fields are viewed as elementary entities of nature. The results were published in B. S. Murray, S. Kralj, C. Rosenblatt. Decomposition vs. escape of topological defects in a nematic liquid crystal. *Soft Matter* 13 (2017), 8442. S. Kralj, B. S. Murray, C. Rosenblatt. Decomposition of strongly charged topological defects. *Physical Review* E 95 (2017), 04702.

Figure 13: Nematic topological states stabilized by fractal Koch-star colloidal particles.

Nematic microfluidics: Cross-talk between topological defects in orientational and velocity fields

Mutual interaction between the topological defects in the velocity field and the topological defects in the nematic orientational field in the microfluid junctions was demonstrated using a combination of experiments, numerical simulations and analytical model, the result of which was published in L. Giomi, Ž. Kos, M. Ravnik, A. Sengupta. Cross-talk between topological defects in different fields revealed by nematic microfluidics. *Proceedings of the National Academy of Sciences of the United States of America* 114 (2017), E5777.

This result is one of the first contributions in the direction of understanding multi-field topology. The work was presented also at the 14th European Liquid Crystals Conference in Moscow, where Ziga Kos was awarded the best poster prize. The work is a result of a collaboration between IJS, FMF UL, Leiden University (Netherlands) and ETH (Switzerland). In details we also studied defects in a junction of three orthogonal cylindrical pores for different flow regimes: Ž. Kos, M. Ravnik, S. Žumer. Nematodynamics and structures in junctions of cylindrical micropores, *Liquid Crystals* 44 (2017), 2161.

Figure 14: An enforced topological defect of charge 6 decays into 12 elementary defects, which are assembled at the confining boundary. This phenomenon is analogous to a Faraday cavity effect in electrostatics.

Improved method of simulating the polarized images

We developed a simple method of simulating polarized micrographs of director fields in optically anisotropic materials. Jones matrix formulation allows the variation of different parameters, such as the focusing depth and numerical aperture of the microscope objective. We tested the method by comparing experimental polarized micrographs of chiral nematic droplets with simulated images, calculated from director fields that were reconstructed from FCPM experimental data (*Liquid Crystals 44 (2017),* 679-687). We also used FCPM to characterize the localized chiral structures that are formed in homeotropic films of chiral nematic under the influence of an alternating electric field. The localized chiral structures behave as quasiparticles and form hexagonal arrays, and because of their bistability they can be used as switchable difractive optical devices (A. Varanytsia, G. Posnjak, U. Mur, V. Joshi, D. Kelsey, I. Muševič, S. Čopar, LC Chien. Topology-commanded optical properties of bi-stable electric-field-induced torons in cholesteric bubble domains, *Scientific Reports* 7 (2017), 16149).

Optothermally driven colloidal transport in a confined nematic liquid crystal

We demonstrate the transport of microparticles by the rapid movement of a laser spot in a thin layer of a nematic liquid crystal. The transport is achieved by fluid flow, caused by two different mechanisms. The thermo-viscous expansion effect induces colloidal transport in the direction opposite to the laser movement, whereas thermally induced local melting of the liquid crystal pulls the particles in the direction of the laser movement. We demonstrate control of the colloidal transport by changing the speed of the laser trap movement and the laser power (M. Škarabot, N. Osterman, I. Muševič. Optothermally driven colloidal transport in a confined nematic liquid crystal. *Soft Matter 13* (2017), 2448-2452).
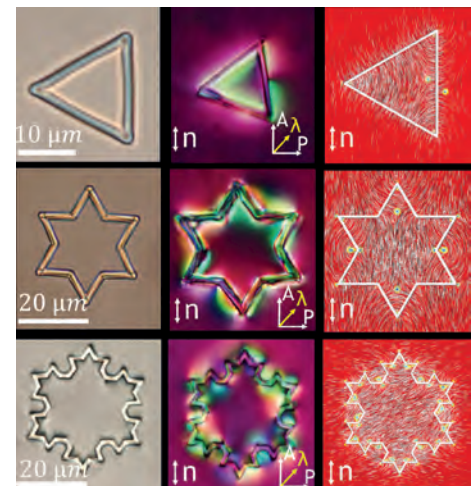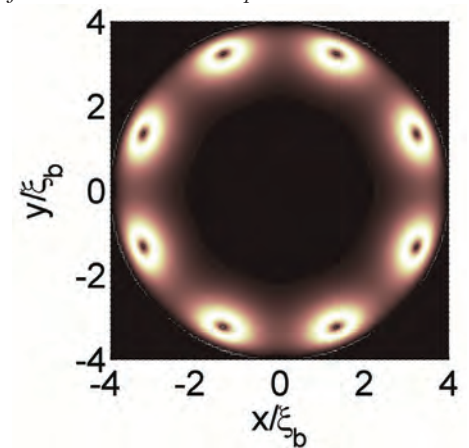

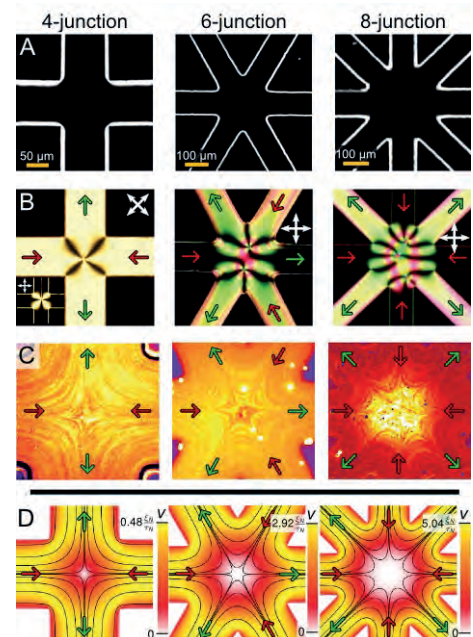*Figure 15: Emergence of nematic topological defects and hydrodynamic singularities at a microfluidic junction*
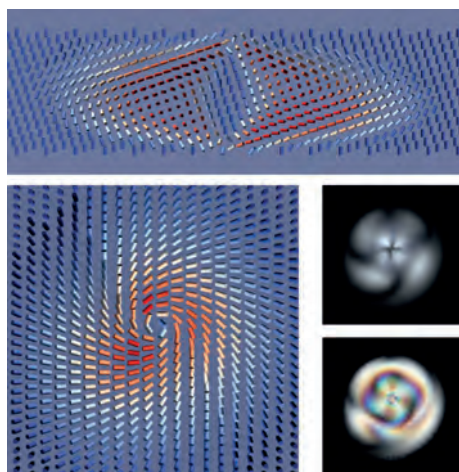
Figure 16: FCPM method allows the reconstruction of director fields from experimental data. The images show localized chiral structures in thin homeotropic layers.
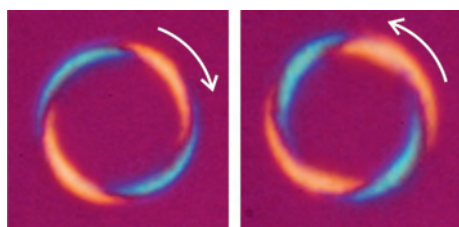

Figure 17: Circulation of the laser spot induces hydrodynamic flow in liquid crystal.
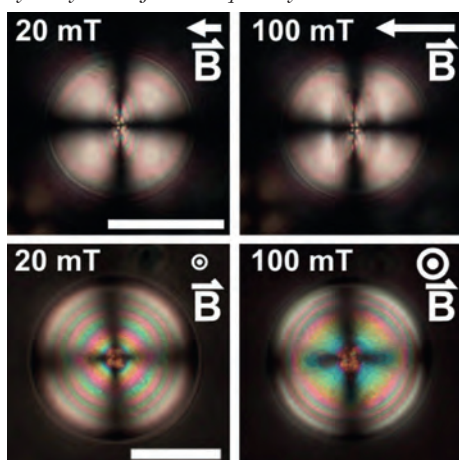

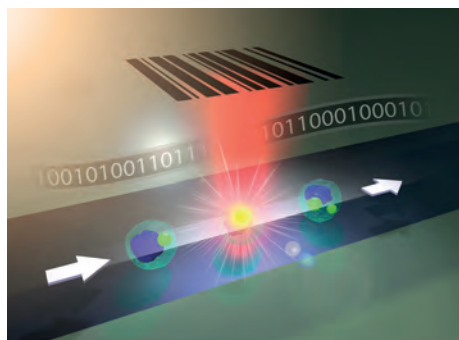*Figure 18: Elastic distortions in a ferromagnetic nematic droplet due to magnetic field.*

Figure 19: Cells containing small lasers inside a microfluidic channel. The lasers are used as barcodes to tag the cells.

Magnetic-field tuning of whispering-gallery-mode lasing from ferromagnetic nematic liquid-crystal microdroplets.

We show that microdroplets made of fluorescently dyed ferromagnetic nematic liquid crystals can act as whispering-gallery-mode lasers that can be tuned by an external magnetic field. It causes elastic distortions in the otherwise radial droplet director field. The laser wavelengths can be shifted towards red or blue, depending on the experimental geometry, the shift amounts to approximately 1 nm per 100 mT (M. Mur, J. Sofi, I. Kvasić, A. Mertelj, D. Lisjak, V. Niranjan, I. Muševič, S. Dhara. Magnetic-field tuning of whispering gallery mode lasing from ferromagnetic nematic liquid crystal microdroplets. *Optics Express* 25 (2017), 1073-1083).

Bio-lasers

We have implanted photonic devices such as lasers and optical waveguides into biological systems. The integration of optical devices with biological systems enables a more accurate study of biological processes, diagnostics and targeted medical treatments. We have implanted the lasers into various tissues, including skin, eye and blood (M. Humar et al., *Optica* 4 (2017), 1080-1085). Lasers were also made of materials that are already approved for medical use, which will expedite their use for medical purposes. We have employed lasers inside cells for cell tagging (M. Humar et al., *Lab Chip* 17 (2017), 2777-2784). Each laser within a cell emits light with a slightly different fingerprint that can be easily detected and used as a bar code to tag the cell. With careful laser design, up to a trillion cells (1,000,000,000,000) could be uniquely tagged, enabling unique tagging of every single cell in the human body. Tagging will facilitate the study of cell migration, including cancer metastasis.

Molecular motors

We investigated the breaking of mirror symmetry in the embryonic development of the model organism zebrafish. For some time it has been known that the transfer of molecular chirality to the macroscale is mediated by cilia, whose beating induces a circular fluid flow. However, the question of how the cells detect this flow has remained unanswered. In collaboration with experimental groups from Strasbourg and Paris we precisely mapped the cilia in a number of embryos and used the data to test the possible hypotheses. We showed that the flows are too weak and too inhomogeneous for mechanical detection. On the other hand, the flow-mediated transport of signalling particles allows robust side determination, consistent with the reliability found in nature (R.R. Ferreira, A. Vilfan, F. Jülicher, W. Suppato, J. Vermot. Physical limits of flow sensing in the left-right organizer. *eLife* 6 (2017), e25078).

Tungsten oxide nanowires as electron field emitters

We investigated the field-emission characteristics of randomly oriented W_5O_{14} nanowires (U. Gallo, C. Ciceroni, A. D. Carlo, F. Brunetti, J. Jelenc, M. Saqib, A, Varlec, M. Remškar. Synthesis and field emission characteristics of W5O14 nanowires film. *Microelectronic Engineering* 170 (2017), 44-48). The work function of single W_5O_{14} nanowires was determined by Kelvin microscopy in UHV and ranges from 4.23 to 4.36 eV. Due to the relatively low electrical resistance and specific surface structure, these single-crystal nanowires enabled a good current density at a low electric field. The low turn on electric field can be justified from the combined effect of the high enhancement factor and the nanowires work function that is lower than the typical values of the carbon nanotubes. The long-term stability test showed that the nanowires can continuously emit electrons for more than 100 h, showing characteristics comparable with carbon nanotubes.

Low-friction nanomaterials

We used transition-metal dichalcogenide nanoparticles to improve the tribological properties of lubricants. The results shown synergetic interactions between the MoS_2 nanotubes with anti-wear and detergents additives, a slight synergy with extreme-pressure additives and antagonistic interactions with dispersants (A. Tomala, M. Rodriguez Ripol, C. Gabler, M. Remškar, M. Kalin. Interactions between MoS2 nanotubes and conventional additives in model oils. *Tribology International*, 110 (2017) 140-150). Under extreme pressure conditions all the selected additives provide synergistic effects with MoS_2 nanotubes. Under reciprocating sliding, the MoS_2 nanotubes show superb anti-wear properties in combination with any of the selected additives.

Nano safety

We have reported on the results of the uptake of platinum nanoparticles by two plants: arugula and escarole (E. Kranjc, D. Mazej, M. Regvar, D. Drobne, M. Remškar. Foliar surface free energy affects platinum nanoparticle adhesion, uptake, and translocation from leaves to roots in arugula and escarole. *Environmental Science: Nano* 5 (2017), 520-532). Our results showed that arugula and escarole internalized and translocated the Pt NPs from leaves to roots and from roots to leaves. The leaves of both plants accumulated higher concentrations of Pt due to the lack of a physical barrier between the leaves and NPs deposited on the leaves in a form of a dispersion. These findings suggest the need to include air quality as a factor in discussions of food safety and urban gardening.

Growth and characterization of thin layers of transitional metal oxides

In collaboration with the PLD group of the Advanced Materials Department we grew ordered 4-to-100-nm thin films of $SrRuO_3$ on STO. Strontium ruthenates display a variety of electronic properties due to the interplay between electronic correlations and structure related degrees of freedom. Growing thin layers on various substrates allows us to fine-tune the strain in these layers and thus control the properties. We characterized the samples using Scanning Tunnelling Microscopy and Spectroscopy at temperatures as low as 1K. The surfaces appear partially ordered and the electronic properties of the films resemble those of bulk samples.

Quasicrystals

We have shown that icosahedral quasicrystal structures can also be properly described by cyclic twinning at the unit-cell level (A. Prodan, R. Dušić Hren, M. Van Midden, H. Van Midden, E. Zupanič. The equivalence between unit-cell twinning and tiling in icosahedral quasicrystals. *Scientific Reports* 7 (2017), 12474). Simulated diffraction patterns of the multiply twinned rhombohedra are in full accord with the experimental diffraction patterns and can be indexed by means of classical three-dimensional crystallography. Our alternative approach is fully compatible with the rather complicated descriptions in hyper-space.

Ultra-cold atoms

We can simultaneously create two separate Bose-Einstein condensates of caesium atoms. By confining them to a narrow, quasi one-dimensional channel and fine-tuning the interaction between the atoms, they can be turned into solitons, i.e., stationary states that maintain their shape during propagation. With a sudden change of interaction between the atoms in an elongated Bose-Einstein condensate, multiple solitons can be created at once, forming a so-called soliton train. We set the solitons in motion and observed their propagation and interactions with neighbouring solitons.

III. Research program "Experimental biophysics of complex systems and imaging in biomedicine«

The programme group "**Experimental biophysics of complex systems and imaging in biomedicine**" combines the research of processes and structures of biological systems by developing new advanced experimental techniques of super-resolution microscopies, micro-spectroscopies and nanoscopies as well as new imaging techniques. Our research is mainly focused on the response of molecular and supramolecular structures to interactions between materials and living cells as well as between light and living cells. We are interested in molecular events and physical mechanisms with which these events are causally connected, time scales, conditions and the applied value of the investigated mechanisms, especially for use in medicine and in the field of healthcare in general. With the development of new coupled super-resolution and spectroscopic techniques we want to open new possibilities to investigate biological systems and from there open up new possibilities for designing medical materials and devices, for diagnostics, therapy and tissue regeneration, representing key challenges due to the population aging. The investment into the new super-resolution STED system opened up a variety of fluorescence microscopy approaches: STED
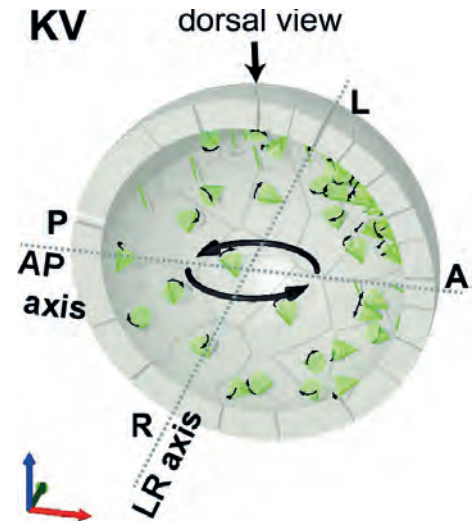
Figure 20: Schematic presentation of cilia motion in vesicle.
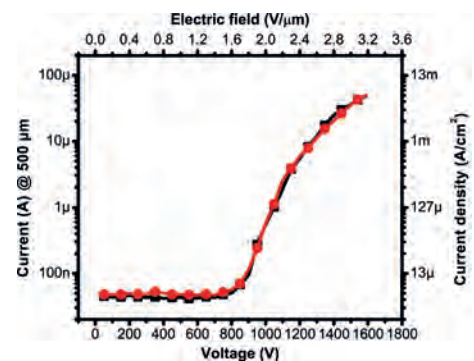
Figure 21: Emission current of nanowire and corresponding current density as a function of electric field.
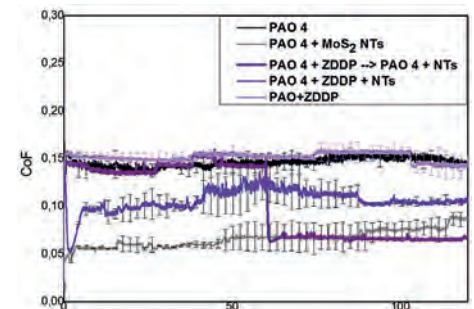
Figure 22: Adding nanoparticles decreases the friction coefficients of lubricants.

STED microscopy allowed us to directly observe a molecular event of lipid wrapping in the living pulmonary epithelium for the first time together with the subsequent uncontrolled relocation of the epithelial membranes across a lung's air-blood barrier. Using a special spectral analysis we developed a method and filed a patent for the identification of porous vessels in the retina on the basis of the analysis of retinal auto-fluorescence.
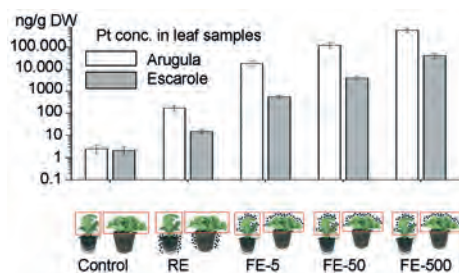
Figure 23: Platinum concentrations of arugula and escarole leaves after Pt NP foliar exposure (FE) or root exposure (RE).
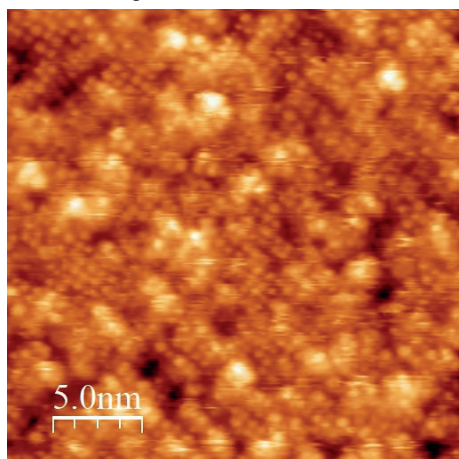
Figure 24: STM image of partially ordered surface of 10-unit-cell thick film of SrRuO₃
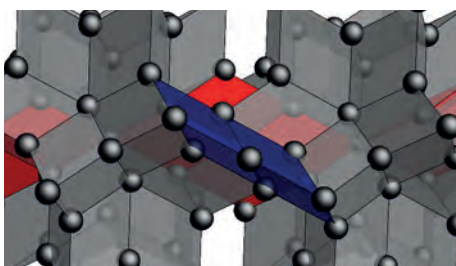
Figure 25: Stacking of two rhombic hexecontahedra, each composed of 20 twinned prolate rhombohedra, and 2 oblate rhombohedra.
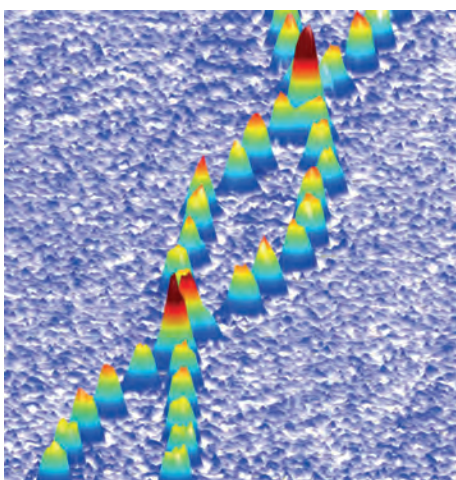
Figure 26: Colliding matter-wave solitons made of two independent Bose-Einstein condensates of caesium atoms.

microscopy and two-photon (2PE) microscopy, multichannel spectrally resolved fluorescence lifetime imaging (spFLIM), fluorescence microspectroscopy (FMS). These, coupled with optical tweezers, can be used to examine the interactions between materials, nanomaterials and cell lines and the phenomena involved such as lipid wrapping, membrane disintegration, and cellular membrane translocation bypassing conventional signalling pathways. We also introduced a method that enables monitoring of the electric field in tumours in the treatment of cancer with electroporation, and further developed a method of multi-parametric magnetic resonance imaging for the characterization of food and medicines and various industrial processes. High-resolution magnetic resonance imaging can monitor the effectiveness of surface treatments, the formation and dissolution of gels as well as measure the diffusion in confined geometries with the use of modulated gradients.

In 2017 the group carried out perhaps the most important change in the past two decades - **the introduction of nonlinear super-resolution live microscopy to monitor changes in supramolecular structures in living systems**, based on an investment in new equipment of high value – **two-photon STED microscope with spFLIM detector** (€0.9m). The introduction of the new scientific field has been encouraged by: the first stable STED microscopes with open hardware and software support becoming commercially available in 2015, the expressed international need for super-resolution live microscopy as part of the H2020 SmartNanoTox project to explore interactions between nanomaterials and cells, in particular the identification of molecular initiating events, and the possibility to build new LBF/F5 optical laboratories within LBF, F5 and IJS, and to renew the LBF preparatory laboratories for the controlled execution of experiments. With the introduction of the new field we transferred most of the necessary knowledge about STED microscopy as quickly as possible by **establishing a lasting cooperation with prof. Eggeling from the University of Oxford**. Prof. Eggeling contributed to the development of the STED concept along with Prof. Stefan Hell, who later received the Nobel Prize for STED microscopy. In September 2017 a training workshop for all interested researchers on the subject of new advanced microscopies with emphasis on the STED microscopy was organized by us and the Eggeling Group. The introduction of the new field has shown **remarkable results** only few months after the launch of the new system. Namely, in the framework of the H2020 project and the P1-0060 program, we directly observed a molecular event of lipid wrapping in the lung epithelium by STED microscopy, which we could previously observe only indirectly using many other methods. The paper is under evaluation in a high-impact-factor journal.

The production of new materials is growing and their impact on health is often unexplored. For example, the relationship between the inhalation of nanoparticles (NPs) and cardiovascular disease has long been known, but the molecular mechanisms themselves are not yet known. In order to explain possible causal relationships, we used various advanced observation techniques, such as super-resolution STED fluorescence microscopy and microspectroscopy, fluorescence fluctuation measurement techniques and electron microscopy. We have shown (i) that TiO_2 NP decreases the integrity of the lipid membranes; (ii) that, when exposed to TiO_2 NP, the membrane of living lung epithelial cells decays and wraps around the surface of TiO_2, and (iii) the most important, we have been the first to **observe that membrane wrapped NPs easily diffuse and are therefore able to relocate the epithelial membrane pieces** away from non-mobile epithelial cells. By inhalation, such NPs can reach the lung's air-blood barrier, a 500-nm-thin layer of the lung epithelial and capillary endothelial cells. Therefore, the formation of mobile, membrane enveloped NPs can be responsible for transmission of membrane anchored blood factors that activate blood coagulation, which can lead to systemic inflammation and the progression of cardiovascular disease (paper submitted for publication).

To track nanoparticles in a living organism, the NP must be fluorescently labelled. However, since NP labelling can lead to experimental artefacts, we have designed and tested **an NP labelling protocol that is suitable for metal oxides in general** on TiO_2 NP. The protocol contains several steps: 1) initial characterization of input material with morphology measurements (TEM) and surface-charge measurements (ξ-potential); 2) confirmation of a linker bound to the NP surface with the FTIR method and ξ-potential; 3) validation of the labelling and characterization of desorption of the probe by measurements of fluorophore concentrations and the use of the FCS method; 4) final characterization of the sample with TEM, ξ-potential and optionally with the STED method (paper in preparation).

For *in-vitro* tests, nanoparticles are usually fluorescently labelled with organic fluorophores that can be degraded by cell enzymes. Thus, the labelling is usually unstable *in vivo*. In order to avoid this, we synthesized **TiO_2 NPs that contain europium** and have the characteristic peak of europium's emissions at 615 nm. We successfully localized europium-doped TiO_2 NPs *in vitro* in LA4 mouse epithelium cells and *ex vivo* in mouse lungs using the FMS method.

In collaboration with the same laboratory, we also upgraded the **fluorescence microspectroscopy with environmentally sensitive probes to determine the local molecular properties of biological membranes**. Most of these probes are relatively photo-unstable, which has until now restricted their use in combination with new microscopic methods that exceed the diffraction limit of the spatial resolution. In the last year we identified three compounds that are also useful for STED super-resolution microscopy, the discovery we reported in a reputable scientific journal *Biophysical Journal*. **The three-fold improvement in local resolution compared to conventional confocal microscopy** has made it possible to unequivocally **detect transient heterogeneity in the membrane structure of cellular vesicles** near the critical point of lipid mixing phases and **determine the fine differences in the composition of membranes of endocytic vesicles**. We will use the same method to study the interactions of nanoparticles and biological membranes.

Activities in the field of the **interaction of light with biological systems** were focused on two topics. The first was **imaging of the vascular structures in retina after using laser photocoagulation**. The experiments have shown that non-coagulated red blood cells can be spectrally distinguished from the ones located in the emerging blood clots forming on the surface of damaged vessels. The second topic was a study of the possibility of **using membrane structures as wave guides for targeted light transmission**. The tilted focused laser beam was illuminating one end of the cellular structure of epithelial cells with the intensity of light being gathered at the other end, the process repeated through full rotation.

Figure 27: STED panorama of TiO_2 nanotubes (with diameter of 10 nm labelled with Alexa 647, red colour) interact with membranes (labelled with CellMask, green colour) close to the upper surface of the living LA4 lung epithelial cell layer. On the zoom-ins, nanoparticles can be located coated with lipids (co-localization within 30 nm precision, identified with yellow-orange colours).

The concepts of molecular imaging based on FMS and the life-time analysis (FLIM) of the retina auto-fluorescence to identify local changes in tissue properties have also been developed. The algorithms in the FMS image-analysis software have been optimized. **Based on the developed technology, we have applied for a European patent.** The described concepts can also be transferred to the development of an increased contrast in endoscopic imaging based on (auto) fluorescence. The usefulness of these approaches was also demonstrated in the field of **polymer interactions with biological systems**. Natural biodegradable fibrin material was used to fabricate porous scaffolds as substitute tissues for tissue-engineering applications. Measurements of cell adhesion were performed on erythrocytes with confocal and super-resolution STED microscopy, exploiting the auto-fluorescence signal of erythrocytes and a signal of fluorescently labelled fibrin networks. **The position and density of the cells in the resulting polymeric fibrin network** have been identified and we were able to distinguish individual fibrin threads of 100 nm thickness.

Characterization of nanomaterials by magnetic resonance

Nanoparticles also play an important role in tumour treatments based on tumour hyperthermia. We have been involved in the development of new hybrid $FePt/SiO_2/Au$ nanoparticles for the treatment of tumours with photo-thermal ablation. For the developed particles, it was shown that they also have similar properties as standard MRI contrast agents. This property allows us to trace them in the human body by means of MRI. This is important for treatment, since in this way it can be confirmed that the concentration of nanoparticles in the targeted tumour is sufficient so that the photo-thermal ablation treatment can be expected to be successful.

The results of the research were published in the article N. Kostevšek, I. Abramovič, S. Hudoklin,M. Erdani-Kreft, I. Serša, A. Sepe, J. Vidmar, S. Šturm, M. Spreitzer, J. Ščančar, S. Kobe, K. Žužek Rožman. Hybrid FePt/SiO2/Au nanoparticles as theranostic tool: in vitro photo-thermal treatment and MRI imaging. *Nanoscale* 10 (2018), 1308.

Electroporation treatment monitoring

Results of our previous studies on electroporation monitoring by MRI, where we developed a method for electric field measurement in the tumour during the delivery of electroporation pulses, were upgraded with the Peleg-Fermi model of cell death. With this model, we can predict the cell-death probability in different tumour parts based on the map of the electric field in the tumour during the electroporation pulse. Consequently, the overall success of the tumour treatment by electroporation can be predicted as well.

The results of this research were published in the article M. Kranjc, S. Kranjc, F. Bajd, G. Serša, I. Serša, D. Miklavčič. Predicting irreversible electroporation-induced tissue damage by means of magnetic resonance electrical impedance tomography. *Scientific Reports* 7 (2017), 1-10.
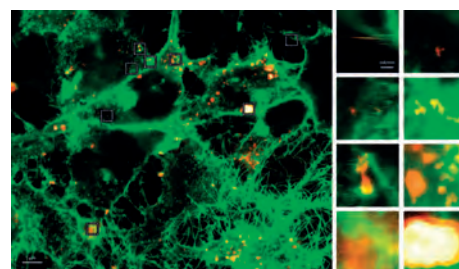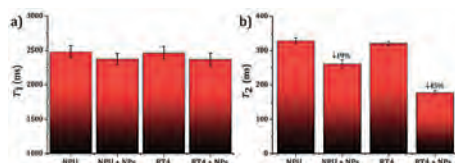
Figure 28: NMR relaxation times T1 and T2 of healthy cells (NPU) and cancer cells (RT4) and of both types of cells incubated with hybrid FePt/SiO2/Au nanoparticles at a concentration of 100 μgml for 24 h (in Kostevšek et al. Nanoscale, 2017).

Figure 29: MRI pulse sequence for measuring the electric field in electroporation (a) and the procedure for calculating the electric field in the tumour from measurements of the current density and known geometry of the sample and electrodes (M. Kranjc et al., Scientific reports, 2017).

Advanced methods for translational dynamics measurements

In materials with an internal structure, such as porous materials, diffusion is anomalous. In these cases, the diffusion coefficient can be measured as a function of the time of diffusion, as the ratio between the mean square displacement and the time of diffusion, or by its frequency equivalent, which is called the diffusion spectrum. In our past research we have shown that the diffusion spectra can be measured using the CPMG sequence of RF pulses in a constant magnetic field gradient, provided that only the signal of the direct coherence path is detected. In the study, published in the article below, we showed how the restriction to the direct coherent path can be overcome (I. Serša, F. Bajd, A. Mohorič. A study of the effects of different echo processing on the diffusion spectra measured by the CPMG sequence in a constant gradient. *Microporous and Mesoporous Materials* [in press] (2017), 4.)

Use of magnetic resonance in wood science

Magnetic resonance imaging is a very efficient method for water detection in biological systems, which certainly includes wood. The role of water in wood is multi-layered. In a living wood tissue, this is associated with its vitality, but in wood as a building material, moisture is an essential factor in wood decay. In the MRI laboratory we were involved in the doctoral work of student Mojca Žlahtič Zupanc, who studied by MRI the effectiveness of different wood coatings on prevention of the water penetration into typical Slovenian wood species. She also received the "Jesenko" award for the best postgraduate student of the Biotechnical Faculty in 2017. From these measurements a scientific article was published in M. Žlahtič Zupanc, U. Mikac, I. Serša, M. Merela, M. Humar. Distribution and penetration of tung oil in wood studied by magnetic resonance microscopy. *Industrial Crops and Products* 96 (2017), 149.

Our research has been supported by a number of international projects financed by the European Union. It was also supported within the bilateral Slovenian–USA, Slovenian–German and Slovenian–Greek and other scientific cooperations. In 2017, the Department had cooperation with 108 partners from Slovenia and abroad. Among them:

- The high magnetic field centres in Grenoble, France, and Nijmegen, The Netherlands
- The high magnetic field centre at the University Florida, Tallahassee, Florida, USA
- The ETH, Zürich, Switzerland
- The Ioffe Institute in St. Petersburg, Russia
- The University of Duisburg, the University of Mainz and the University of Saarbrucken in Germany
- The University of California, the University of Utah and the Liquid Crystal Institute, Kent, Ohio, USA
- National Institute for Research in Inorganic Materials, Tsukuba, Japan
- NCSR Demokritos, Greece
- Institut für Biophysik und Nanosystemforschung OAW, Graz, Austria
- Bioénergétique et Ingénierie des Protéines, CNRS Marseille, France
- Architecture et Fonction des Macromolécules Biologiques, CNRS Marseille, France
- The Max Delbruck Center for Molecular medicine in Berlin
- The Dartmouth Medical School, Hanover, NH, USA
- The Mayo Clinic, Rochester, USA
- Kyung Hee University, Suwon, Korea
- Technische Universität Ilmenau, Ilmenau, Germany
- Elettra Sincrotrone Trieste, Trieste, Italy
- University of North Carolina at Chapel Hill
- Max-Delbrück-Centrum für Molekulare Medizin (MDC)

made the above studies possible.

Some outstanding publications in 2017

1. M. Klanjšek, A. Zorko, R. Žitko, J. Mravlje, Z. Jagličić, P.K. Biswas, P. Prelovšek, D. Mihailović, D. Arčon. A high-temperature quantum spin liquid with polaron spins. *Nature Physics* 13 (2017), 1130–1134.
2. Y. Takabayashi, M. Menelaou, H. Tamura, N. Takemori, T. Koretsune, A. Štefančič, G. Klupp, A.J.C. Buurma, Y. Nomura, R. Arita, D. Arčon, M.J. Rosseinsky, K. Prassides. π-electron $S = 1/2$ quantum spin-liquid state in an ionic polyaromatic hydrocarbon. *Nature Chemistry* 9 (2017), 635–643.
3. B. Rožič, J. Fresnais, C. Molinaro, J. Calixte, S. Umadevi, S. Lau-Truong, N. Felidj, T. Kraus, F. Charra, V. Dupuis, T. Hegmann, C. Fiorini-Debuisschert, B. Gallas, E. Lacaze. Oriented gold nanorods and gold nanorod chains within smectic liquid crystal topological defects. *ACS Nano* 11 (2017), 6728–6738.

4. A. Zorko, M. Herak, M. Gomilšek, J. van Tol, M. Velázquez, P. Khuntia, F. Bert, P. Mendels. Symmetry reduction in the quantum Kagome antiferromagnet Herbertsmithite. *Physical Review Letter* 118 (2017), 017202.

5. M. Gomilšek, M. Klanjšek, R. Žitko, M. Pregelj, F. Bert, P. Mendels, Y. Li, Q. M. Zhang, A. Zorko. Field-induced instability of a gapless spin liquid with a spinon Fermi surface. *Physical Review Letter* 119 (2017), 137205.

6. L. Giomi, Ž. Kos, M. Ravnik, and A. Sengupta. Cross-talk between topological defects in different fields revealed by nematic microfluidics. *Proceedings of the National Academy of Sciences of the United States of America* 114 (2017), E5771-E5777.

7. S. M. Hasheimi, U. Jagodič, M. R. Mozaffari, M. R. Ejtehadi, I. Muševič, and M. Ravnik, Fractal nematic colloids. *Nature Communications* 8 (2017), 12106.

8. G. Posnjak, S. Čopar and I. Muševič. Hidden topological constellations and polyvalent charges in chiral nematic droplets. *Nature Communications* 8 (2017), 14594.

9. A. Nych, Jun-ichi Fukuda, U. Ognysta, S. Žumer, I. Muševič. Spontaneous formation and dynamics of half-skyrmions in a chiral liquid-crystal film. *Nature Physics* 13 (2017), 1215.

10. E. Sezgin, F. Schneider, V. Zilles, I. Urbančič, E. Garcia, D. Waithe, A.S. Klymchenko, C. Eggeling. Polarity-Sensitive Probes for Superresolution Stimulated Emission Depletion Microscopy. *Biophysical Journal* 113 (2017), 1321-1330.

11. M. Kranjc, S. Kranjc, F. Bajd, G. Serša, I. Serša, D. Miklavčič. Predicting irreversible electroporation-induced tissue damage by means of magnetic resonance electrical impedance tomography. *Scientific Reports* 7 (2017*)*, 1-10.

Some outstanding publications in 2016

1. A. Rešetič, J. Milavec, B. Zupančič, V. Domenici, B. Zalar. Polymer-dispersed liquid crystal elastomers. *Nature Communications* 7 (2016), 13140.

2. M. Jeong, M. Klanjšek et al. Dichotomy between attractive and repulsive tomonaga-luttinger liquids in spin ladders. *Physical Review Letters* 117 (2016), 106402.

3. F. E. Annanouch, P. Umek et al. Aerosol-assisted CVD-grown PdO nanoparticle-decorated tungsten oxide nanoneedles extremely sensitive and selective to hydrogen. *ACS Applied Materials & Interfaces* 8 (2016), 10413.

4. H. Uršič, V. Bobnar, B. Malič, C. Filipič, M. Vrabelj, S. Drnovšek, Jo Younghun, M. Wencka, Z. Kutnjak. A multicaloric material as a link between electrocaloric and magnetocaloric refrigeration. *Scientific Reports* 6 (2016), 26629.

5. M. Igarashi, P. Jeglič, A. Kranjc, R. Žitko, T. Nakano, Y. Nozue, D. Arčon. Metal-to-insulator crossover in alkali doped zeolite. *Scientific Reports* 6 (2016), 18682.

6. G. Posnjak, S. Čopar, I. Muševič. Points, skyrmions and torons in chiral nematic droplets. *Scientific Reports* 6 (2016), 26361.

7. L. E. Aguirre, A. de Oliveira, D. Seč, S. Čopar, P. L. Almeida, M. Ravnik, M. H. Godinho, S. Žumer. Sensing surface morphology of biofibers by decorating spider silk and cellulosic filaments with nematic microdroplets. *Proceedings of the National Academy of Sciences of the United States of America* 113 (2016), 1174.

8. S. Nizamoglu, M. Humar et al. Bioabsorbable polymer optical waveguides for deep-tissue photomedicine. *Nature Communications* 7 (2016), 10374.

9. S. Cho, M. Humar, N. Martino, S. H. Yun. Laser Particle Stimulated Emission Microscopy. *Physical Review Letter* 117 (2016), 193902.

10. B. Nitzsche, E. Dudek, L. Hajdo, A. A. Kasprzak, A. Vilfan, S. Diez. Working stroke of the kinesin-14, ncd, comprises two substeps of different direction. *Proceedings of the National Academy of Sciences of the United States of America* 113 (2016), E6582.

Some outstanding publications in 2015

1. M. Sluban, P. Umek, Z. Jagličić, J. Buh, P. Šmitek, C. Bittencourt, P. Guttmann, M.-H. Delville, D. Mihailović, D. Arčon. Controlling disorder and superconductivity in titanium oxynitride nanoribbons with anion exchange. *ACS Nano* 9 (2015), 10133.

2. M. Pregelj, A. Zorko, O. Zaharko, H. Nojiri, H. Berger, L. Chapon, D. Arčon. Spin-stripe phase in a frustrated zigzag spin-1/2 chain. *Nature Communications* 6 (2015), 7255.

3. M. Klanjšek, D. Arčon, A. Sans, P. Adler, M. Jansen, C. Felser. Phonon-modulated magnetic interactions and spin Tomonaga-Luttinger liquid in the p-orbital antiferromagnet CsO_2. *Physical Review Letters* 115 (2015), 057205.

4. R. H. Zadik, A. Potočnik, P. Jeglič, D. Arčon, et al. Optimized unconventional superconductivity in a molecular Jahn-Teller metal. *Science Advances* 1 (2015), e1500059.

5. M. Pregelj, A. Zorko, M. Gomilšek, et al. Controllable broadband absorption in the mixed phase of meta-magnets. *Advanced Functional Materials* 25 (2015), 3634.

6. M. Nikkhou, M. Škarabot, S. Čopar, M. Ravnik, S. Žumer, I. Muševič. Light-controlled topological charge in a nematic liquid crystal. *Nature Physics* 11 (2015), 183.

7. S. Čopar, U. Tkalec, I. Muševič, S. Žumer. Knot theory realizations in nematic colloids. *Proceedings of the National Academy of Sciences of the United States of America* 112 (2015), 1675.

8. R. Podlipec, J. Štrancar. Cell-scaffold adhesion dynamics measured in first seconds predicts cell growth on days scale - optical tweezers study. *ACS Applied Materials & Interfaces* 7 (2015), 6782.

9. T. Koklič, R. Chattopadhyay, R. Majumder, B. R. Lenz. Factor Xa dimerization competes with prothrombinase complex formation on platelet-like membrane surfaces. *Biochemical Journal* 467 (2015), 37.

10. Z. Arsov, U. Švajger, J. Mravljak, S. Pajk, A. Kotar, I. Urbančič, J. Štrancar, M. Anderluh. Internalization and accumulation in dendritic cells of a small pH-activatable glycomimetic fluorescent probe as revealed by spectral detection. *ChemBioChem* 16 (2015), 2660.

Awards and appointments

1. Jani Bizjak, Matjaž Gams, Hristijan Gjoreski, Anton Gradišek, Luka Stepančič: best paper, Melbourne, Australia, 2nd International Workshop on Biomedical Informatics with Optimization and Machine Learning in Conjunction with 26th International Joint Conference on Artificial Intelligence, Smartwatch for Active Ageing as Part of an Open EU Framework

2. Uroš Jagodič, M. R. Ejtahadi, S. M. Hashemi, M. R. Mozaffari, Igor Muševič, Miha Ravnikar: EPS Poster Prize for the best PhD student poster, Ljubljana, LIQUIDS 2017, Fractal Nematic Colloids

3. Primož Koželj: The Young Scientist Best Oral Presentation, Athens, Greece, C-MAC Days 2017, Eutectic Co-CrFeNiZrx High-Entropy Alloys: Magnetism Complicated by the Microstructure of a "Real" Multiphase HEA

4. Aleksander Matavž: award for presentation and poster, Ljubljana, 9. IPSSC Conference, Inkjet Printing Thin-Film Electronic Devices from Solution-Based Inks

5. Aleksander Matavž: 1st place award for contribution in an individual section, Portorož, 25. ICM&T, Inkjet Printing of Metal-Oxide-Based Electronic Devices

6. Slobodan Žumer: elected Fellow of the American Physical Society, USA, American Physical Society (APS), for theoretical contributions to the soft condensed matter physics of liquid crystal systems

7. Slobodan Žumer: Zois Award for lifetime achievements of the Republic of Slovenia, November 23, 2017

Organization of conferences, congresses and meetings

1. 10th Liquid Matter Conference, LIQUIDS 2017, Ljubljana, 16–21 July 2017

2. Exploring the Molecular World By Advanced Fluorescence Microscopy Approaches, JSI, 12–14 September 2017

3. Alpine NMR Workshop, Recent Advances in NMR Methods and Applications to Materials, Bled, 21–24 September 2017

Patent granted

1. Barbara Malič, Hana Uršič, Marija Kosec, Silvo Drnovšek, Jena Cilenšek, Zdravko Kutnjak, Brigita Rožič, Uroš Flisar, Andrej Kitanovski, Marko Ožbolt, Uroš Plaznik, Alojz Poredoš, Urban Tomc, Jaka Tušek, Method for electrocaloric energy conversion, EP3027980 (B1), European Patent Office, 18. 10. 2017.

2. Luka Drinovec, Griša Močnik, Anthony D. A. Hansen, Method and apparatus for the analysis of materials, US9671324 (B2), US Patent and Trademark Office, 06. 06. 2017.

3. Griša Močnik, Anthony D. A. Hansen, Jeffrey R. Blair, Method for automatic performance diagnosis and calibration of a photometric particle analyzer, US9804082 (B2), US Patent Office, 06. 06. 2017.

INTERNATIONAL PROJECTS

1. MERCK - AFM Investigations
   Asst. Prof. Miha Škarabot
   Merck Kgaa

2. Kimberly-Clark - confidential project
   Prof. Igor Muševič
   Kimberly-clark

3. 7FP - SIMDALEE2; Sources, Interaction with Matter Detection and Analysis of Low Energy Electrons 2
   Prof. Maja Remškar
   European Commission

4. 7FP - LIVINGLASER; A Laser made Entirely of Living Cells and Materials derived from Living Organisms
   Prof. Igor Muševič
   European Commission

5. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Prof. Maja Remškar
   European Commission

6. COST MP1308; Towards Oxide Based Electronics (TO-BE)
   Aleksander Matavž
   Cost Office

7. COST CA15107; Multi-Functional Nano-Carbon Composite Materials Network

Dr. Polona Umek
Cost Office

8. COST CA15209; European Network on NMR Relaxometry
Prof. Tomaž Apih
Institut Jožef Stefan

9. COST CA16109; Chemical On-Line Composition and Source Apportionment of Fine Aerosol
Asst. Prof. Griša Močnik
Cost Office

10. COST CA16218; Nanoscale Coherent Hybrid Devices for Superconducting Quantum Technologies
Dr. Abdelrahim Ibrahim Hassanien
Cost Office

11. COST CA16221; Quantum Technologies with Ultra-Cold Atoms
Dr. Peter Jeglič
Cost Association Aisbl

12. H2020 - SmartNanoTox; Smart Tools for Gauging Nano Hazards
Prof. Janez Štrancar
European Commission

13. H2020 - ENGIMA; Engineering of Nanostructures with Giant Magneto-Piezoelectric and Multicaloric Functionalities
Prof. Zdravko Kutnjak
European Commission

14. Investigating Catalytic and Physical Properties of CuGdCa Alloys
Prof. Tomaž Apih
Slovenian Research Agency

15. Aromatic Polymers with Ultrahigh Breakdown Field Strength, Low Dielectric Loss, and High Electric Energy Density
Prof. Zdravko Kutnjak
Slovenian Research Agency

16. Investigation of Complex Materials for Hydrogen Storage
Prof. Janez Dolinšek
Slovenian Research Agency

17. Lipid Wrapped Gold Nanoparticles and Activity of Factor Xa
Prof. Janez Štrancar
Slovenian Research Agency

18. Crystal and Electronic Structure of NbS3 Phases
Dr. Erik Zupanič
Slovenian Research Agency

19. Lead-Free (Ba0.8Ca0.2)1-xLa2x/3TiO3 Based Electrocaloric Materials for New Dielectric Cooling Technologies
Prof. Zdravko Kutnjak
Slovenian Research Agency

20. Stabilisation of Networks of Topological Defects
Prof. Samo Kralj
Slovenian Research Agency

21. Superconductivity and Magnetism: Two Faces of Electron Correlations in Carbon- and Fe-Based Superconductors
Prof. Denis Arčon
Slovenian Research Agency

22. Radiative forcing of desert mineral dust and PM10 concentrations over Southern Europe
Prof. Maja Remškar
Slovenian Research Agency

RESEARCH PROGRAMS

1. Magnetic resonance and dielectric spectroscopy of „smart" new materials
Prof. Janez Dolinšek
2. Physics of Soft Matter, Surfaces and Nanostructures
Prof. Slobodan Žumer
3. Experimental Biophysics of Complex Systems
Prof. Janez Štrancar

R & D GRANTS AND CONTRACTS

1. Topology and Photonics of Liquid Crystal Colloids and Dispersions
Prof. Igor Muševič

2. Intra-pocket-targeted nanomedicines for treatment of periodontal disease
Prof. Maja Remškar
3. The textural analysis of spatiotemporal changes for breast lesions diagnosis on ultrafastbreast MRIs
Prof. Igor Serša
4. High-Entropy Alloys
Dr. Stanislav Vrtnik
5. Metamaterials from liquid crystal colloids
Prof. Miha Ravnik
6. Sensor technologies in diagnostics and monitoring of cultural heritage buildings
Prof. Janez Dolinšek
7. Thermophoretic guidance, accumulation and sorting of biomolecules in microfluidic devices
Asst. Prof. Andrej Vilfan
8. New advanced electrocaloric materials for novel environmentally-friendly dielectric refrigeration technology
Prof. Zdravko Kutnjak
9. Role of Calcium and lipid membranes in survival of critically ill patients
Dr. Tilen Koklič
10. Multifunctional materials for actuator and cooling devices
Prof. Zdravko Kutnjak
11. Correlated electrons in cnofined molecular systems
Prof. Denis Arčon
12. High-resolution optical magnetometry with cold cesium atoms
Dr. Peter Jeglič
13. Integrated multi-channel artificial nose for vapor trace detection
Prof. Igor Muševič
14. Performance of wood and lignocelolosic composites in outdoor applications
Prof. Igor Serša
15. Advanced electrocaloric energij conversion
Prof. Zdravko Kutnjak
16. Biopharmaceuticals: sensor for aggregation of protein particles based on liquid crystals
Prof. Miha Ravnik
17. Micro-electromechanical and electrocaloric layer elements
Prof. Zdravko Kutnjak
18. Microspectroscopy-based optimization of the effects of laser pulses on the retina
Prof. Janez Štrancar
19. Domain engineered ferroelectric ceramic layer elements for efficient energy harvesting and energy conversion applications
Prof. Zdravko Kutnjak
20. Building blocks, tools and systems for the Factories of the Future – GOSTOP
Prof. Janez Štrancar
21. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
Prof. Igor Muševič
22. SCOPES; Spin-liquid and Spin-ice States in Frustrated Rare-earth and Transition Metal Spinels
Dr. Matej Pregelj
Snf- Swiss National Science Foundation
23. Irradiation and Analysis of Nano SiC Samples in the Year 2017
Prof. Vid Bobnar
National Nuclear Research Center
24. Inkjet Printing of PZT Test Structures and Piezoelectric Characterization of Thin Films Double-Beam Laser Interferometer Measurement
Prof. Vid Bobnar
Epcos Ohg
25. LIQUIDS 2017
Prof. Igor Muševič
Cankarjev dom, Ljubljana

NEW CONTRACTS

1. Release of water soluble substances, conservation of antioxidant capacity and qualitative evaluation of plant cell damage after blending
Dr. Tilen Koklič
Bsh Hišni Aparati d. o. o.
2. MRI scanning of samples
Prof. Igor Serša
Krka, Tovarna Zdravil, d. d.

VISITORS FROM ABROAD

1. Doctoral student Benjamin Daniel, Institute of Scientific Instruments, Brno, the Czech Republic, 2 January to 21 March 2017
2. Prof. Valentina Domenici, University of Pisa, Department of Chemistry and Industrial Chemistry, Pisa, Italy, 29 January to 4 February 2017
3. Dr Carla Bittencourt, University of Mons, Mons, Belgium, 9–17 March 2017
4. Dr Deepak Venkateshvaran, University of Cambridge, Optoelectronics Group, Cavendish Laboratory, Cambridge, Great Britain, 31 March 2017
5. Dr Lachezar Komitov and his business partner from Tridentic Holding AB, Kimberly-Clark, Gothenburg, Sweden, 6–8 April 2017
6. Prof. Tom Lancaster, University of Durham, Durham, Great Britain, 9–22 April 2017

7. Filippo Caracciolo, University of Pavia, Pavia, Italy, 2 May to 14 June 2017
8. Dr Stefan Fölsch, Paul Drude Institute for Solid State Electronics, Berlin, Germany, 4–7 May 2017
9. Dr Bouchra Asbani, University of Picardie Jules Verne, Laboratory of Condensed Matter Physics, Amiens, France, 7–20 May 2017
10. Mutsuo Igarashi, Gunma National College of Technology, Department of Applied Physics, Maebashi, Japan, 22–28 May 2017
11. Prof. Katsumi Tanigaki, Tohoku University, Department of Physics, Graduate School of Science, Sendai, Miyagi, Japan, 1–3 June 2017
12. doctoral student Milijana Savić, Vinča Nuclear Institute, Belgrade, Serbia, 10–14 July 2017
13. Prof. Jun-Ichi Fukuda, Kyushu University, Fukuoka, Japan, 11–16 July 2017
14. Mutsuo Igarashi, Gunma National College of Technology, Department of Applied Physics, Maebashi, Japan, 11–21 August 2017
15. Dr Magdalena Wencka, Institute of Molecular Physics, Polish Academy of Sciences, Poznan, Poland, 14–18 August 2017
16. Nikita Derets, Ioffe Physical-Technical Institute of the Russian Academy of Sciences, Saint Petersburg, Russia, 4–6 September 2017

17. Prof. John Georg Seland, University of Bergen, Bergen, Norway, 25 September to 1 October 2017
18. Dr Anna V. Ryzhkova, ASML Holding, Eindhoven, the Netherlands, 16 October to 11 November 2017
19. Dr Igor Lukyanchuk, University of Picardie Jules Verne, Laboratory of Condensed Matter Physics, Amiens, France, 25–31 October 2017
20. Dr Masoomeh Hashemi, Sharif University of Technology, Department of Physics, Tehran, Iran, 1 November 2017 to 31 January 2018
21. Dr Sharmisthe Ghosh, DST-INSPIRE Faculty, University of Calcutta, Kolkata, India, 5–11 November 2017
22. Dr Jakub Malohlava, Faculty of Medicine and Dentistry, Palacky University in Olomouc, Department of Medical Biophysics, Olomouc, Czech Republic, 26 November to 8 December 2017
23. Dr Venkata Subba Rao Jampani, University of Luxembourg, Physics and Materials Science Research Unit, Luxembourg, Luxembourg, 13 December 2017
24. Dr Mildred Quintana, The Autonomous University of San Luis Potosí, San Luis Potosí, Mexico, 19–21 December 2017
25. Dr Yaovi Gagou, University of Picardie Jules Verne, Laboratory of Condensed Matter Physics, Amiens, France, 19–22 December 2017

STAFF

Researchers
1. Prof. Tomaž Apih
2. Prof. Denis Arčon*
3. Asst. Prof. Zoran Arsov
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36. *Dr. Franci Bajd, left 13.11.17*
37. Dr. Primož Koželj
38. Dr. Mitja Krnel
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41. Dr. Nikola Novak
42. Dr. Rok Podlipec
43. Dr. Gregor Posnjak
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45. Dr. Brigita Rožič
46. Dr. Anna Ryzhkova

47. Dr. Maja Trček*
48. Dr. Iztok Urbančič
49. Dr. Jernej Vidmar*
50. Dr. Bojana Višić
51. Dr. Stanislav Vrtnik
Postgraduates
52. Nikita Derets
53. Matjaž Gomilšek, B. Sc.
54. Urška Gradišar Centa, B. Sc.
55. Saša Harkai, B. Sc.
56. Dr. Matjaž Humar
57. Uroš Jagodič, B. Sc.
58. Nejc Janša, B. Sc.
59. Tilen Knaflič, B. Sc.
60. Marta Lavrič, B. Sc.
61. Janez Lužnik, B. Sc.
62. Hana Majaron, B. Sc.
63. Bojan Marin*, M. Sc.
64. Aleksander Matavž, B. Sc.
65. Tadej Mežnaršič, B. Sc.
66. Maruša Mur, B. Sc.
67. Luka Pirker, B. Sc.
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72. *Dr. Luka Drinovec*, left 01.07.17*
73. Dr. Maja Garvas
74. Dr. Andreja Jelen
75. Boštjan Kokot, B. Sc.
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77. Jože Luzar, B. Sc.
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79. Dražen Ivanov
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84. Silvano Mendizza
85. Janja Milivojević
86. Ana Sepe, B. Sc.
87. Marjetka Tršinar

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Alen Ajanović, Jaka Konda, Gašper Fele-Žorž, Anton Gradišek, Matjaž Gams, Ana Peterlin, Karolina Počivavšek, Mojca Matičič, "Application for sexually transmitted infection risk assessment", *Informatica (Ljublj., Tisk. izd.)*, **41**, 2, 253-254, 2017.

2. Cristobal Alessandri, Sara Fathipour, Huamin Li, Iljo Kwak, Andrew Kummel, Maja Remškar, Alan Seabaugh, "Reconfigurable electric double layer doping in an MoS_2 nanoribbon transistor", *IEEE trans. electron devices*, **64**, 12, 5217-5222, 2017.

3. Fatima Ezahra Annanouch, Sergio Roso, Zouhair Haddi, Stella Vallejos, Polona Umek, Carla Bittencourt, Christopher Blackman, T. Vilic, Eduard Llobet, "p-Type PdO nanoparticles supported on n-type WO_3 nanoneedles for hydrogen sensing", *Thin solid films*, **618**, part B, 238-245, 2017.

4. Bouchra Asbani, Y. Gagou, J. -L. Dellis, Maja Trček, Zdravko Kutnjak, M. Amjoud, A. Lahmar, D. Mezzane, Mimoun El Marssi, "Lead free $Ba_{0.8}Ca_{0.2}Te_xTi_{1-x}O_3$ ferroelectric ceramics exhibiting high electrocaloric properties", *J. appl. phys.*, **121**, 6, 064103, 2017.

5. Franci Bajd, Martin Škrlep, Marjeta Čandek-Potokar, Igor Serša, "MRI-aided texture analyses of compressed meat products", *J. food eng.*, **27**, 108-118, Aug. 2017.

6. M. Becerril-Valle, E. Coz, Andre S. H. Prevot, Griša Močnik, Spyros N. Pandis, A. M. Sánchez de la Campa, A. Alastuey, E. Díaz, R. M. Pérez, B. Artíñano, "Characterization of atmospheric black carbon and co-pollutants in urban and rural areas of Spain", *Atmos. environ.*, **169**, 36-53, 2017.

7. Jani Bizjak, Anton Gradišek, Luka Stepančič, Hristijan Gjoreski, Matjaž Gams, "Intelligent assistant carer for active aging", *EURASIP J. Adv. Signal Process.*, **2017**, 76, 2017.

8. Jože Buh, Aleš Mrzel, Andrej Kovič, Viktor V. Kabanov, Zvonko Jagličić, Stanislav Vrtnik, Primož Koželj, Dragan Mihailović, "Phase slip and telegraph noise in $\delta-$MoN nanowires", *Phys., C Supercond.*, **535**, 24-29, 2017.

9. Romana Cerc Korošec, Polona Umek, Alexandre Gloter, Jana Padežnik Gomilšek, Peter Bukovec, "Structural properties and thermal stability of cobalt- and chromium-doped $\alpha-MnO_2$ nanorods", *Beilstein j. nanotechnol.*, **8**, 1032-1042, 2017.

10. Sarah Marie Denkhaus, Malte Vögler, Nikola Novak, Jürgen Rödel, "Short crack fracture toughness in $(1-x)(Na_{1/2}Bi_{1/2})TiO_{3-x}BaTiO_3$ relaxor ferroelectrics", *J. Am. Ceram. Soc.*, **100**, 10, 4760-4769, 2017.

11. Mitja Drab, Ekaterina Gongadze, Luka Mesarec, Samo Kralj, Veronika Kralj-Iglič, Aleš Iglič, "The internal and external dipole moment of a water molecule and orientational ordering of water dipoles in an electric double layer", *Elektrotehniški vestnik*, **84**, 5, 221-234, 2017.

12. Luka Drinovec, Asta Gregorič, Peter Zotter, Robert Wolf, Emily Anne Bruns, Andre S. H. Prevot, Jean-Eudes Petit, Olivier Favez, Jean Sciare, Ian J. Arnold, Rajan K. Chakrabarty, Hans Moosmüller, Filep Ágnes, Griša Močnik, "The filter loading effect by ambient aerosols in filter absorption photometers depends on the mixing state of the sampled particles", *Atmos. meas. tech.*, **10**, 3, 1043-1059, 2017.

13. Alexander Dubtsov, Sergey V. Pasechnik, Dina V. Shmeliova, Aleš Iglič, Samo Kralj, "Influence of polar dopant on internal configuration of azoxybenzene nematic-in-water droplets", *Liq. cryst.*, **45**, 3, 388-400, 2017.

14. G. K. Elyashevich, D. V. Novikov, I. S. Kuryndin, Andreja Jelen, Vili Bukošek, "Ordering effects and percolation in the structure formation process of the oriented polyolefin porous films", *Acta chim. slov. (Print ed.)*, **64**, 4, 980-987, nov. 2017.

15. Rita R. Ferreira, Andrej Vilfan, Frank Jülicher, Willy Suppato, Julien Vermot, "Physical limits of flow sensing in the left-right organizer", *eLife (Cambridge)*, **6**, 25078, 2017.

16. Lovro Fulanović, Silvo Drnovšek, Hana Uršič, Marko Vrabelj, Danjela Kuščer, Kostja Makarovič, Vid Bobnar, Zdravko Kutnjak, Barbara Malič, "Multilayer $0.9Pb(Mg_{1/3}Nb_{2/3})O_3-0.1PbTiO_3$ elements for electrocaloric cooling", *J. Eur. Ceram. Soc.*, **37**, 2, 599-603, 2017.

17. Lovro Fulanović, Jurij Koruza, Nikola Novak, Florian Weyland, Barbara Malič, Vid Bobnar, "Fatigue-less electrocaloric effect in relaxor $Pb(Mg_{1/3}Nb_{2/3})O_3$", *J. Eur. Ceram. Soc.*, **37**, 15, 5105-5108, 2017.

18. Ulisse Gallo, C. Ciceroni, A. D. Carlo, F. Brunetti, Janez Jelenc, Muhammad Saqib, Ana Varlec, Maja Remškar, "Synthesis and field emission characteristics of W_5O_{14} nanowires film", *Microelectron. eng.*, **170**, 44-48, 2017.

19. Luca Giomi, Žiga Kos, Miha Ravnik, Anupam Sengupta, "Cross-talk between topological defects in different fields revealed by nematic microfluidics", *Proc. Natl. Acad. Sci. U. S. A.*, **114**, 29, E5771-E5777, 2017.

20. Matjaž Gomilšek, Martin Klanjšek, Rok Žitko, Matej Pregelj, Fabrice Bert, Philippe Mendels, Y. Li, Qiming M. Zhang, Andrej Zorko, "Field-induced instability of a gapless spin liquid with a spinon fermi surface", *Phys. rev. lett.*, **119**, 13, 137205, 2017.

21. Anton Gradišek, Gašper Slapničar, Jure Šorn, Mitja Luštrek, Matjaž Gams, Janez Grad, "Predicting species identity of bumblebees through analysis of flight buzzing sounds", *Bioacoustics (Berkhamsted)*, **26**, 1, 63-76, 2017.

22. Alan Gregorovič, " ^{14}N NQR lineshape in nanocrystals: an ab initio investigation of urea", *J. chem. phys.*, **146**, 19, 194306, 2017.

23. Manabu Hagiwara, Yoshitaka Ehara, Nikola Novak, Neamul H. Khansur, Azatuhi Ayrikyan, Kyle Webber, Shinobu Fujihara, "Relaxor-ferroelectric crossover in $(Bi_{1/2}K_{1/2})TiO_3$ origin of the spontaneous phase transition and the effect of an applied external: origin of the spontaneous phase transition and the effect of an applied external", *Physical review. B*, **96**, 1, 014103, 2017.

24. Rana R. Haikal, Ahmed B. Soliman, Muhammad Amin, Stavros G. Karakalos, Youssef S. Hassan, Ahmed M. Elmansi, Inas H. Hafez, Mohamed R. Berber, Abdou Hassanien, Mohamed H. Alkordi, "Synergism of carbon nanotubes and porous-organic polymers (POPs) in C_2 fixation: one-pot approach for bottom-up assembly of tunable heterogeneous catalyst", *Appl. catal., B Environ.*, **207**, 347-357, 2017.

25. Saša Harkai, Milan Ambrožič, Samo Kralj, "Impact of diffusion limited aggregates of impurities on nematic ordering", *Physica, A*, **467**, 249-256, 2017.

26. S. M. Hashemi, Uroš Jagodič, M. R. Mozaffari, M. R. Ejtehadi, Igor Muševič, Miha Ravnik, "Fractal nematic colloids", *Nature communications*, **8**, 12106, 2017.

27. Song-Jeng Huang, Wei-Yi Peng, Bojana Višić, Alla Zak, "Al alloy metal matrix composites reinforced by WS_2 inorganic nanomaterials", *Mater. sci. eng., A Struct. mater.: prop. microstruct. process.*, **709**, 290-300, 2017.

28. Matjaž Humar, Anja Dobravec, Xiangwei Zhao, Seok Hyun Andy Yun, "Biomaterial microlasers implantable in the cornea, skin, and blood", *Optica*, **4**, 9, 1080-1085, 2017.

29. Matjaž Humar, Avinash Upadhya, Seok Hyun Andy Yun, "Spectral reading of optical resonance-encoded cells in microfluidics", *Lab chip*, **17**, 16, 2777-2784, 2017.

30. Matjaž Humar, Seok Hyun Andy Yun, "Whispering-gallery-mode emission from biological luminescent protein microcavity assemblies", *Optica*, **4**, 2, 222-228, 2017.

31. Mutsuo Igarashi, Peter Jeglič, Tadej Mežnaršič, Takehito Nakano, Yasuo Nozue, Naohiro Watanabe, Denis Arčon, "Thermally activated motion of sodium cations in insulating parent low-silica X zeolite", *J. Phys. Soc. Jpn.*, **86**, 7, 075005, 2017.

32. Roghayeh Imani, Ralph Dillert, Detlef W. Bahnemann, Meysam Pazoki, Tomaž Apih, Veno Kononenko, Neža Repar, Veronika Kralj-Iglič, Gerrit Boschloo, Damjana Drobne, Tomas Edvinsson, Aleš Iglič, "Multifunctional gadolinium-doped mesoporous TiO_2 nanobeads ephotoluminescence, enhanced spin relaxation, and reactive oxygen species photogeneration, beneficial for cancer diagnosis and treatment", *Small*, **13**, 20, 1-11, 2017.

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MENTORING

1. Slavko Buček, *Hysteretic Behaviour of Lebwohl-Lasher Rotors:* doctoral dissertation, Maribor, 2017 (mentor Samo Kralj).

2. Miha Čančula, *Mutually coupled flow of light and liquid crystal ordering:* doctoral dissertation, Ljubljana, 2017 (mentor Slobodan Žumer; co-mentor Miha Ravnik).

3. Primož Koželj, *Physical properties of high-entropy alloys and their comparison to complex intermetallics:* doctoral dissertation, Ljubljana, 2017 (mentor Janez Dolinšek).

4. Ahmed Kreta, *Nanoscopic study of corrosion dynamics and properties of anticorrosion coatings on copper and aluminium alloys:* doctoral dissertation, Ljubljana, 2017 (mentor Igor Muševič).

5. Mitja Krnel, *Intermetallic compounds with catalytic properties in the systems Ga-Pd and Cu-Gd-Ca:* doctoral dissertation, Ljubljana, 2017 (mentor Janez Dolinšek).

6. Šárka Perutková, *On the role of anisotropy of membrane constituents on the elastic properties of highly curved lipid membranes:* doctoral dissertation, Maribor, 2017 (mentor Veronika Kralj-Iglič; co-mentor Samo Kralj).

7. Gregor Posnjak, *Topological formations in chiral nematic droplets:* doctoral dissertation, Ljubljana, 2017 (mentor Igor Muševič).

8. Maja Trček, *Nanoparticle-induced twist grain boundary phases and electrocaloric effect in liquid crystals:* doctoral dissertation, Ljubljana, 2017 (mentor Zdravko Kutnjak; co-mentor Samo Kralj).

9. Jure Varlec, *Simuliranje adsorpcije vode v mikroporoznih aluminofosfatih:* doctoral dissertation, Ljubljana, 2017 (mentor Gregor Mali; co-mentor Janez Dolinšek).

10. Mojca Žlahtič Zupanc, *Influence of selected environmental factors on moisture dynamics of wood:* doctoral dissertation, Ljubljana, 2017 (mentor Miha Humar; co-mentor Igor Serša).

DEPARTMENT FOR COMPLEX MATTER F-7

The research within the Department of Complex Matter encompasses a variety of research fields, ranging from the synthesis of new materials to fundamental investigations of elementary excitations in complex systems: from nano-biosystems to exotic magnetic systems and superconductors. The experimental methods used are suitably diverse, from synthetic chemistry to femtosecond laser spectroscopy. The research achievements are thus quite diverse, but we are able to report on important discoveries in a number of areas.

The activities in the department can be grouped into a number of thematically inter-related research areas. Nanomaterials science research is focused on investigations into the fundamental properties and applications of semiconducting transition-metal dichalcogenides and molecular nanowires, crossing into the physics and nano-science of macromolecular biological systems, venturing also into fields of quantum molecular electronics and nano-electronics. These and other materials, such as strongly correlated systems, electronically ordered systems and superconductors were investigated using advanced femtosecond spectroscopy techniques. In a number of areas we have introduced new materials, technologies and techniques.

Head:
Prof. Dragan D. Mihailović

Ultrafast studies of electron dynamics in correlated systems

In the last two decades non-equilibrium spectroscopies have evolved from avant-garde studies to crucial tools for expanding our understanding of the physics of strongly correlated materials. The possibility of obtaining simultaneously spectroscopic and temporal information has led to insights that are complementary to (and in several cases beyond) those attainable by studying matter at equilibrium. From this perspective, multiple phase transitions and new orders arising from competing interactions are benchmark examples where the interplay among electrons, lattice and spin dynamics can be disentangled because of the different timescales that characterize the recovery of the initial ground state. For example, the nature of the broken-symmetry phases and of the bosonic excitations that mediate the electronic interactions, eventually leading to superconductivity or other exotic states, can be revealed by observing the sub-picosecond dynamics of impulsively excited states. Furthermore, recent experimental and theoretical developments have made it possible to monitor the time-evolution of both the single-particle and collective excitations under extreme conditions, such as those arising from strong and selective photo-stimulation. These developments are opening the way for new, non-equilibrium phenomena that can eventually be induced and manipulated by short laser pulses.

European Research Council
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Particular emphasis is placed on investigations of phase transitions in time, and most recently into the creation of new states of matter created under non-equilibrium conditions.

The absorption spectra of 2D semiconductors are dominated by excitons with a binding energy of several hundreds of meV. Nevertheless, even single layers show an appreciable photovoltaic effect and work as the active material in high-sensitivity photodetectors, thus indicating some degree of free charge-carrier photogeneration. We perform ultrafast transient absorption spectroscopy on monolayer MoS_2 in a field-effect transistor configuration. We found that even a moderate in-plane electric field of a few kV cm^{-1} can significantly increase the charge-carrier yield from photogenerated hot electron–hole pairs (**2D materials 4, 35017 (2017)**).

The quest for a pairing boson in cuprate high-temperature superconductors is one of the outstanding tasks of solid-state physics. Performing this task we studied in collaboration with University Mainz the superconducting-state depletion process in an electron-doped cuprate $Pr_{1.85}Ce_{0.15}CuO_{4-\delta}$, where the superconducting gap is smaller than the energy of the relevant bosonic excitations. We found that the absorbed energy density required to deplete superconductivity matches the thermodynamic condensation energy when pumping with the above-gap terahertz pulses. In contrast, at near-infrared pumping the required depletion energy density is an order of magnitude higher. These results imply that only a small subset of bosons, which are generated during the relaxation of optically excited carriers, contributes to the pairing, as described in **Phys. Rev. B 95, 085106 (2017)**.

A systematic temperature-dependent study of the femtosecond optical superconducting (SC) state destruction and recovery in $Bi_2Sr_2CaCu_2O_{8+\delta}$ cuprate superconductor by means of the all-optical polarization-sensitive multipulse spectroscopy is presented. At low temperatures and a partial SC state suppression, an anisotropic SC-gap recovery time scale is suggested by the data. The SC state destruction and recovery dynamics are compared to the recent TR-ARPES-inferred SC-gap dynamics and a qualitative agreement is found. Using a phenomenological response function, the
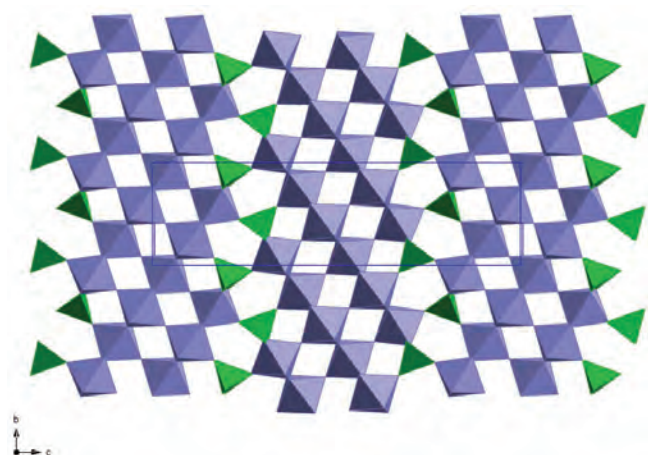
Figure 1: Crystal structure of $(PO_2)_4(WO_3)_{12}$ tungsten bronze showing the WO_6 octahedra and the monophosphate PO_4 tetrahedra projected along the crystallographic a direction.

experimental data are also compared to time-dependent Ginzburg-Landau model simulations, as published **Phys. Rev. B 96, 184522 (2017)**.

All-optical femtosecond relaxation dynamics in a single crystal of monophosphate tungsten bronze $(PO_2)_4(WO_3)_{2m}$ with alternate stacking m=6 of WO_3 layers was studied through the three consequent charge-density-wave (CDW) transitions. Several transient coherent collective modes associated with the different CDW transitions were observed and analysed in the framework of the time-dependent Ginzburg–Landau theory. Remarkably, the interference of the modes leads to an apparent rectification effect in the transient reflectivity response. A saturation of the coherent-mode amplitudes with increasing pump fluence well below the CDW destruction threshold fluence indicates a decoupling of the electronic and lattice parts of the order parameter on the femtosecond timescale, as discussed in **Phys. Rev. B 96, 035429 (2017)**.

Transitions between different charge density wave (CDW) states in quasi-two-dimensional materials may also be accompanied by changes in the inter-layer stacking of the CDW. Using MeV ultrafast electron diffraction, the out-of-plane stacking order dynamics in the quasi-two-dimensional dichalcogenide $1T$-TaS_2 was investigated for the first time. From the intensity of the CDW satellites aligned around the commensurate $l = 1/6$ characteristic stacking order, it is found that this phase disappears with a 0.3-ps time constant. Simultaneously, in the same experiment, the emergence of the incommensurate phase, with a slightly slower 2 ps time constant, is determined from the intensity of the CDW satellites aligned around the incommensurate $l = 1/3$ characteristic stacking order. These results might be of relevance in understanding the metallic character of the laser-induced metastable "hidden" state recently discovered in this compound, as described in **Structural Dynamics 4, 044020 (2017)**.

Ultrafast memory materials

An important new area of research is related to the search for new metastable states that have both fundamental and practical importance. The functionality of computer memory elements is currently based on multi-stability, driven either by locally manipulating the density of electrons in transistors or by switching magnetic or ferroelectric order. Another possibility is switching between metallic and insulating phases by the motion of ions, but their speed is limited by slow nucleation and inhomogeneous percolative growth. Here we demonstrate fast resistance switching in a charge-density wave system caused by pulsed current injection. As a charge pulse

> **The search for a metastable state switched by ultrafast laser pulses or electrical pulses has led to several patent applications and international projects and collaborations.**

travels through the material, it converts a commensurately ordered polaronic Mott insulating state in $1T$–TaS_2 to a metastable electronic state with textured domain walls, accompanied by a conversion of polarons to band states, and concurrent rapid switching from an insulator to a metal. The large resistance change, high switching speed (30 ps) and ultra-low energy per bit opens the way to new concepts in non-volatile memory devices manipulating all-electronic states.

Dual-vortex charge order in a metastable state created by an ultra-fast topological transition in $1T$-TaS_2. Many-body systems in complex materials undergoing non-equilibrium phase transitions may self-organise into ordered metastable emergent states with new and unexpected functionalities. Recent observations of long-living metastable states induced by a single ultra-fast optical pulse gave access to previously unexplored area of non-stroboscopic and real space measurements for systems out of equilibrium. Using large-area scanning tunnelling microscopy we revealed an intricate chiral vortex structure and complex tiling of charged electron domains in the metastable metallic state in 1T-TaS2 created by a non-equilibrium topological transition initiated by a single femtosecond optical pulse. A M Moiré analysis showed that the interference of non-equilibrium nested Fermi surface electrons led to the creation of charge vortices $D^{\rightarrow}$ on a length scale of ~70 nm. On a much smaller scale of ~ 5 nm, domain configurational patterns appear, which show bound vortex-antivortex pairs, discommensurations, domain-wall crossings and kinks, consistent with a rapidly quenched Berezinskii-Kosterlitz-Thouless transition. A long-range ordered state emerges finally through domain phase locking in space,
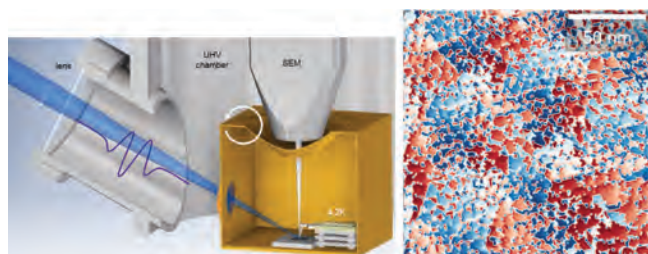
Figure 2: Left – schematic view of the combined scanning tunnelling microscope and scanning electron microscope system with optical access for ultrafast laser pulse excitation used for studies of metastable states in 1T-TaS$_2$; right – clear ordered vortex structure revealed with the Moire' analysis of the phases (red to blue scale: -180 to 180 degrees) of the mesoscale domain structure found in the real space image of the metastable state in 1T-TaS$_2$.

thus supporting the fundamental concept that macroscopic states can be created out of equilibrium. Revealing the detailed mechanism for the transition opens the way to the design of long-range charge-ordered metastable states with intricate emergent properties under controlled non-equilibrium conditions. The paper is currently under review, and the latest preprint can be found at **arXiv: 1704.08149v2**.

Ultra-fast studies of electron dynamics in correlated systems

Optical control of the unusual CDW state in molybdenum oxide Mo_8O_{23}: anomalous stability of the photo-induced phase created at low temperature. Studies of long-lived metastable phases created non-thermally by single ultra-short optical pulse is a way to improve our fundamental understanding of correlated phenomena and to tailor the phase diagram of the system in controlled manner for the practical applications. So far only two materials (1T-TaS2 and strained manganite films) have been found to demonstrate unique long-lived metastable phases induced by a single ultra-short optical pulse. We have discovered a new system - unusual CDW oxide Mo_8O_{23} - that displays such long lived metastability created by single pulse and is more stable than the ground states at room temperature. We performed combined theoretical and experimental studies of the equilibrium and non-equilibrium parts of the unusual CDW oxide Mo_8O_{23}. Particularly, we have studied the transient reflectivity of Mo_8O_{23} over a wide range of temperatures and fluences of pump pulse. The key feature of our low-fluence experimental studies is the polarization-resolved transient reflectivity measurements that allow identification of the different structural phases in and out of equilibrium.

We have discovered a new system with a long-lived metastable phase created by a single ultra-short optical pulse that is more stable than the ground states at room temperature - an unusual CDW oxide Mo_8O_{23}. We performed combined theoretical and experimental studies of the equilibrium and non-equilibrium parts of the unusual CDW oxide Mo_8O_{23}.

We demonstrate switching to a new metastable phase, not present under equilibrium conditions, by high fluence optical pulses and study it, using polarization-resolved transient reflectivity and high-resolution transmission electron microscopy (the latter done in collaboration with colleagues from the K5 department). The manuscripts reporting transient reflectivity studies of equilibrium phase and studies of the new photo-induced phase are under preparation.

Theoretical studies on the nanoscale

We developed a theory of the upper critical field in a BCS superconductor with a nonlocal interaction between the electrons. We have shown that the nonlocal interaction is characterized by the universal dimensionless parameter $k_{F\rho_0}$, where k_F is the Fermi momentum and ρ_0 is the radius of electron-electron interaction. The presence of the external magnetic field leads to the generation of additional components of the order parameter with different angular momenta. This effect leads to the enhancement of the upper critical field above the orbital limiting field. In addition the upward curvature in the temperature dependence of the upper critical field in the clean limit is predicted.

We have developed a theoretical model in order to describe the polaron ordering on a triangular lattice. The model takes into account the short-range attraction between polarons due to lattice deformation and long-range Coulomb repulsion. In addition to that we introduce the modulation due to the charge-density wave ordering. Monte Carlo simulations show that the resulting patterns are similar to that observed in the STM experiments on TaS_2.

We derive the kinetic equations for polaron hopping in organics that explicitly take into account the double occupation possibility and pair intersite correlations. The equations include simplified phenomenological spin dynamics and provide a self-consistent framework for the description of the bipolaron mechanism of the organic magnetoresistance. At low applied voltages the equations can be reduced to effective resistor network that generalizes the Miller-Abrahams network and includes the effect of spin relaxation on the system resistivity. Our theory discloses the close relationship between the organic magnetoresistance and the intersite correlations. Moreover, in the absence of correlations, as in ordered system with zero Hubbard energy, the magnetoresistance vanishes. (**Submitted for publication**)

We have developed a theoretical model in order to describe the polaron ordering on a triangular lattice. The model describes the commensurate ordering of polarons with the doping level n=1/3,1/4,1/7,1/9.1/12,1/13,... It is shown that at intermediate doping the polarons form an amorphous hyper-uniform state. Monte Carlo simulations showed that the resulting patterns are similar to that observed in the STM experiments on TaS_2 (**Submitted for publication**).

Nanomaterials

We investigated the optical and electronic properties of transition-metal dichalcogenides (TMDs) and chalcohalides as well as oxides and carbides synthesized from them, in various low-dimensional forms, in particular atomically thin films, nanoflakes, and nanowires. Moreover, we studied organic nanowires and thin-film coatings and organic perovskite-halide-based solar cells.

Signal modulation in optoelectronics is obtained by the modulation of either the refractive index or the absorbance by an electric field. However, electromodulators have not kept up with the miniaturization of other electronic and optical components. Here we show a strong transverse electro-absorption signal in a monolayer of the two-dimensional semiconductor MoS_2. The electro-absorption spectrum is dominated by an apparent linewidth broadening of around 15% at a modulated voltage of only $V_{pp} = 0.5$ V. Contrary to known variants of the Stark effect, the broadening increases linearly with the applied field strength and arises from a linear variation of the distance between the strongly overlapping exciton and trion resonances. The achievable modulation depths exceeding 0.1 dB nm^{-1} bear the scope for extremely compact, ultra-fast, energy-efficient electro-absorption modulators for integrated photonics, including on-chip optical communication (**2D Materials, 4, 021005 (2017)**. Moreover, we filed a UK *patent application* for the proposed electromodulator device: **GB 1600549.8**.

Monolayer MoS_2 shows an unprecedentedly strong electro-absorption effect with an unusual field dependence.

The photonic properties of an active material originate in the behaviour of photo-excited states, which typically manifests itself on the fs to ps time scales. Here we use femtosecond optical spectroscopy to systematically study photo-excited carrier relaxation in few-layer MoS_2 flakes as a function of the excitation density and sample thickness. We consider two aqueous dispersions of MoS_2 with average layer number of $<N> = 2.5$ and $<N> = 10$ layers, respectively, obtained from liquid-phase exfoliation followed by cascade centrifugation for thickness selection. We find that the primary photogenerated excitons dissociate into free charges, whose fate then depends on the sample thickness: in thin samples, bimolecular coalescence of charges creates indirect excitons, while in thick samples charges are efficiently trapped at local defects. The main difference between the two sample thicknesses is the defect content, which is higher by one order of magnitude in the thick sample, thus causing trapping to dominate over charge coalescence. This work has been published in the journal **2D Materials, 5, 015011 (2018)**.

Perovskite solar cells made using low-cost fabrication techniques have already exceeded the threshold of 20% stabilised efficiency. Thus, they have the potential to enable a reduction in the cost of generating electricity from sunlight in comparison to conventional material systems. Many of the best performing perovskite solar cells use TiO_2 as an electron-selective contact layer. However, TiO_2 usually requires high-temperature sintering, which is related to electrical instabilities in perovskite solar cells, and causes cell performance degradation under full solar spectrum illumination. Here we demonstrate an alternative approach based on the modification of transparent conductive oxide electrodes with self-assembled siloxane-functionalized fullerene molecules, eliminating TiO_2 or any other additional electron transporting layer. We demonstrate that these molecules spontaneously form a homogenous monolayer acting as an electron-selective layer on top of the fluorine-doped tin oxide electrode, minimizing material consumption. We find that the fullerene-modified fluorine-doped tin oxide is a robust, chemically inert, charge-selective contact for perovskite-based solar cells, which can reach 15% of stabilised power conversion efficiency in a flat junction device architecture using a scalable, low-temperature, and reliable process. In contrast to TiO_2, devices employing a molecularly thin functionalized fullerene layer show unaffected performance after 67 h of UV light exposure (**Journal of Materials Chemistry A, 5, 11882 (2017)**.

Tungsten oxide and its associated bronzes (compounds of tungsten oxide and an alkali metal) are well known for their interesting optical and electrical characteristics. We have modified the transport properties of thin WO_3 films by electrolyte gating using both ionic liquids and polymer electrolytes. We were able to tune the resistivity of the gated film by more than five orders of magnitude, and a clear insulator-to-metal transition was observed. To clarify the doping mechanism, we have performed a series of incisive *operando* experiments, ruling out both a purely electronic effect (charge accumulation near the interface) and oxygen-related mechanisms. We propose instead that hydrogen intercalation is responsible for doping WO_3 into a highly conductive ground state and provide evidence that it can be described as a dense polaronic gas (**npj Quantum Materials, 2, 35 (2017)**.

The discovery that oxidatively intercalated graphite can be rapidly expanded by heating or microwave radiation to form a low-density, high-surface-area compound has enabled new applications in foils, threads, packaging and polymer composites. We have intercalated MoS_2 crystals with the quaternary ammonium salt tetrabutyl ammonium hydroxide in a table-top reaction under ambient conditions, producing novel compounds with long-term stability in air. We then rapidly expanded them by two methods: heating and, as a new, alternative process, e-beam irradiation. Both methods expand the MoS_2 within seconds to levels previously not achievable, while leaving it chemically intact (accepted for publication in **Materials Letters (2018)**.

We have demonstrated that ohmic contacts can be prepared on δ-MoN nanowires with ion-beam-induced platinum deposition using a focused-ion-beam microscope, allowing detailed and comprehensive characterization of the superconducting and transport properties of δ-MoN nanowires. Resistance measurements showed a wide normal-to-superconducting transition region. The width of this transition is strongly dependent on the average diameter of the wire. The LAMH fits to the $R(T)$ show a discrepancy that we attribute to the inhomogeniety/granularity of the sample and to the effect of the external noise. Critical current measurements showed a typical

step-like $U(I)$ behaviour. We were able to observe telegraph switching between phase-slip configurations. The supplied current greatly affects the lifetime of the phase slip states, while the addition of a small amount of external noise increases the average switching frequency between the phase slip configurations. The sharpness of the transition between phase slip configurations is also strongly affected by the introduction of external magnetic field. This work has been published in **Physica C: Superconductivity and its Applications, 535, 24-29 (2017)**.

Soft Matter

In cooperation with Nankai University in China we continued investigations of liquid-crystal alignment at the interface with thin polymeric walls that are oriented in a direction perpendicular to the glass substrates. The walls are fabricated by a direct laser writing process based on two-photon polymerization. This method provides micro-structured liquid-crystal alignment in practically oblique configurations, which opens up several possibilities for application in liquid crystalline optical modulators and spatial light filters, microfluidic units based on liquid crystals, etc. The results of this work were reported in **Chinese Optics Letters 15, 070501 (2017)**. Another part of the cooperative research was focused on an investigation of calcium waves-based communication processes between microglial cells. In this study the cells were grown on special platforms with pre-determined spatial patterns and intercellular signal transmission was analysed as a function of the stimulation site on the central cell and as a function of the distance between the central cell and the neighbouring cells. The results of this work were reported in **ACS Applied Materials & Interfaces 10, 2937 (2018)**.

In cooperation with the University of Luxembourg we continued with investigations of the optical properties of 2D arrangements of droplets and shells made of cholesteric liquid crystals. We found that the shells exhibit optical reflection patterns that are much more complex than the patterns generated by the droplets. We showed that the increased complexity results from combined reflections from the inner and the outer interfaces of the shells as well as from multiple reflections between two, three and even more shells. The results were published in **Liquid Crystals 44, 1948 (2017)**.

We continued with investigations of molecular recognition of lipophilic guanosine derivatives in Lagmuir films at the air-water interface. The investigation took place via film balance experiments and Brewster Angle Microscopy (BAM). The results showed that guanosine, despite its strong tendency towards self-assembly, interacts with both complementary and noncomplementary liponucleosides. This indicates that ϖ–ϖ stacking interactions between the aromatic planes of liponucleoside derivatives probably dominate over hydrogen-bonding interactions. The work was reported in **Biochimica et Biophysica Acta (BBA) - General Subjects 1861, 1463 (2017)**.

In cooperation with the University of Vienna we continued investigations of synthetic magneto-active periodic media that might be suitable for application in magnetically tuneable neutron-optical devices. We analysed the diffraction properties of cold neutrons from colloidal crystals doped with superparamagnetic nanoparticles as a function of external magnetic field. The results were published in **The Journal of Physics and Chemistry of Solids 110, 234 (2017)**.

We performed preliminary investigations of the surface properties of magneto-active elastomers. The samples were prepared at the East-Bavarian Technical High School (OTH) in Regensburg. Modifications of surface roughness as a function of applied external magnetic field were determined. We also investigated the effect of magnetic field on the contact angle of sessile water droplets deposited on the material surface. We found that the observed phenomenon of magnetic field-dependent contact angle originates predominantly from the field-induced protrusion of carbonyl iron microparticles from the surface layer, while field-induced roughness modifications are practically unimportant. The work was reported in **Journal of applied polymer science 135, 46221 (2018)**.
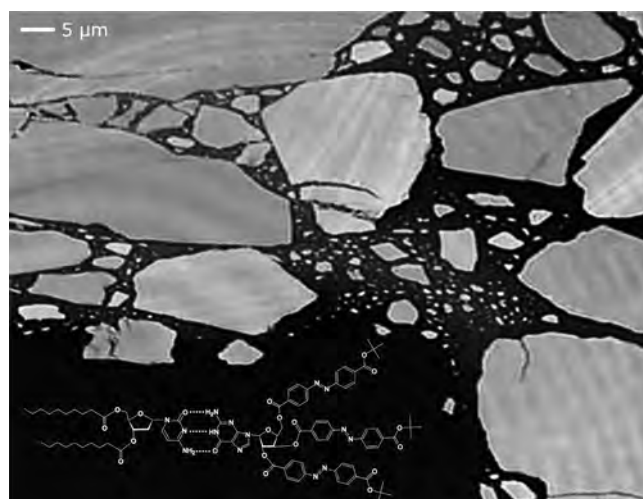
Figure 3: Brewster-angle microscopy image of a broken-up molecular film formed by a mixture of lipophilic guanosine and cytidine derivatives on water (illustrated as bonded via hydrogen bonds in the inset). In contrast to typical Langmuir films, where increasing the available area results in the dissolution of the film, these molecules form rigid flakes and remain together even after the area available to them is increased
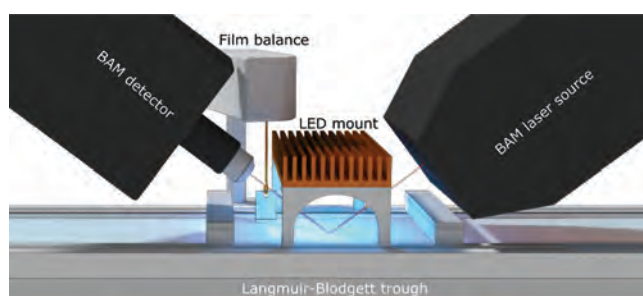
Figure 4: Setup for studying Langmuir films formed by photoactive molecules. LEDs suspended over the water surface emit light that promotes either trans-cis or cis-trans transitions of the deposited molecules. Changes in the film are monitored with a film balance and a Brewster angle microscope.

We showed that a variety of structures of ferromagnetic cholesteric liquid crystals can be controlled using a combination of small magnetic and electric fields.
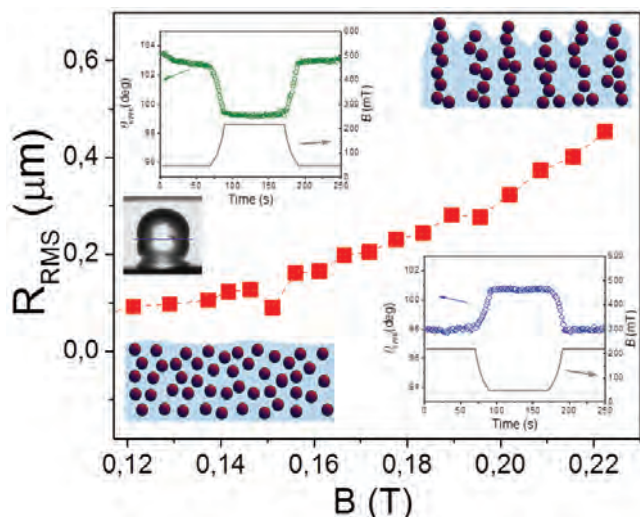
Figure 5: Surface roughness of a magneto-active elastomer as a function of external magnetic field. Insets: Variation of the contact angle of a sessile water droplet deposited on the material surface during variation of the applied magnetic field.

The magnetic response of a ferromagnetic nematic liquid crystal is significantly affected by the dissipative dynamic cross-coupling between the nematic and magnetic order parameters.

Figure 6: Images of structures of ferromagnetic cholesteric liquid crystals, which can be controlled using a combination of small magnetic and electric fields.

In cooperation with the University of Maribor we concluded investigations of the kinetics of water sorption into textile fibres designed for the fabrication of medical textiles. We found that in the case of polyester fibres, the sorption speed obtained from optical videomicroscopy-based analysis focused on single fibres and the sorption speed obtained from the standard measurement method involving macroscale samples are very similar. The results were published in **Materials Research Express 5, 01531 (2018)**.

One of the advantages of anisotropic soft materials is that their structures and consequently their properties can be controlled using moderate external fields. While the control of materials with uniform orientational order is straightforward, the manipulation of systems with complex orientational order is challenging. We showed that a variety of structures of an interesting liquid material, which combine chiral orientational order with ferromagnetic order, can be controlled using a combination of small magnetic and electric fields. In the suspension of magnetic nanoplatelets in chiral nematic liquid crystal, the platelet's magnetic moments orient along the orientation of the liquid crystal and, consequently, the material exhibits a linear response to small magnetic fields. In the absence of external fields, orientations of the liquid crystal and magnetization have a wound structure, which can be either homogeneously helical, disordered, or ordered in complex patterns, depending on the boundary condition at the surfaces and the history of the sample. We demonstrated that by using different combinations of small magnetic and electric fields it is possible to reversibly control the formation of the structures in a layer of the material. In such a way different periodic structures can be explored and some of them may be suitable for photonic applications. The material is also a convenient model system for studies of chiral magnetic structures, as it is a unique liquid analogue of a solid helimagnet (**Sci. Adv. 3, e1701336 (2017)**).

The hydrodynamics of complex fluids with multiple order parameters is governed by a set of dynamic equations with many material constants, of which only some are easily measurable. We studied a unique example of a dynamic magneto-optic coupling in a ferromagnetic nematic liquid, in which the long-range orientational order of liquid crystalline molecules is accompanied by the long-range magnetic order of magnetic nanoplatelets. In collaboration with theoretical physicists from the Department of Mathematics and Physics, University in Ljubljana, University of Bayreuth and MPI for Polymer Research, Mainz, Germany, we investigated the dynamics of the magneto-optical response experimentally and theoretically and found that it is significantly affected by the dissipative dynamic cross-coupling between the nematic and magnetic order parameters. The cross-coupling coefficient determined by fitting the experimental results with a macroscopic theory is of the same order of magnitude as the dissipative coefficient (rotational viscosity) that governs the reorientation of pure liquid crystals. (**Phys. Rev. Lett. 119, 097802 (2017)**).

Nonlinear optics

In the Nonlinear Optics Laboratory we study new materials and their interaction with laser light. In cooperation with North Carolina State University, Raleigh, USA, we study new concepts of compact light sources on the basis of the nonlinear optical conversion of existing lasers into the short wavelengths spectral regions where lasers are not yet available.

AlN is a wide-bandgap semiconductor with emerging applications also in nonlinear and quantum optics.

We study AlGaN waveguides in various geometries that allow for phase-matched second-harmonic generation and therefore give high efficiency. We study modal dispersion in multimode waveguides and specially prepared waveguides with an alternating sign of the nonlinear coefficient that allows quasi phase matching. AlGaN grown by metal-organic chemical vapour deposition (MOCVD) has a great potential for optoelectronic devices emitting and detecting light in the ultraviolet spectrum. It is also transparent for THz

frequencies, making it interesting for new THz applications. New applications in quantum optics are envisioned by writing qubits in nitrogen vacancies.

Biomedical optics

We have participated in the research of nanoparticles which exhibit upconversion fluorescence (UCF; e.g., $Yb^{3+},Tm^{3+}:NaYF_4$). Such nanoparticles have great potential for diagnostic imaging in medicine and new approaches for cell-specific therapy. We have demonstrated that one dedicated amphiphilic coating (TPGS) improves UCF performance and at the same time offers very good protection against nanoparticle dissolution in aqueous media, thus successfully preventing acute cytotoxicity. Such properties are critically important with regard to biocompatibility and the suitability of such nanostructures for biomedical applications. (Collaboration with Department for Materials Synthesis and Department for Inorganic Chemistry and Technology, IJS, and Medical University of Graz, Austria).

Figure 7: Upconversion fluorescence spectra of bare and TPGS-coated nanocrystals ($Yb^{3+},Tm^{3+}:NaYF_4$) in water su-spension upon irradiation at 978 nm (a). The labels indicate the corresponding electronic transitions of Tm^{3+} - see the level diagram in (b).

Our three-dimensional model of light transport in spatially heterogeneous optically scattering structures (Monte Carlo) was used for an analysis of the interaction between intense laser pulses and cutaneous blood vessels containing novel nanostructures with different sizes. These nanostructures were engineered from animal erythrocytes and contained indocyanine green, an FDA-approved infrared absorbing dye. Such biocompatible and safe nanoprobes hold great potential for diagnostic imaging in small animals and possibly human patients. (Collaboration with Beckman Laser Institute and Medical Clinic, University of California at Irvine, and University of California at Riverside, USA).

We have continued with the development of novel biomedical applications based on pulsed photo-thermal radiometry (i.e., time-resolved measurements of laser-induced infrared emission) and diffuse reflectance spectroscopy. By combining these experimental techniques with inverse analysis utilizing a numerical model of light transport in strongly scattering biological tissues (multi-dimensional optimization) we have developed a unique approach to the non-invasive assessment of structure and composition of human skin in vivo. The described methodology was tested by the subtle manipulation of healthy human skin, e.g., by using a blood-pressure cuff.

The same approach was also applied to the characterization of hemodynamics in human volunteers with incidentally obtained bruises (hematomas). The improved understanding of bruise dynamics (in terms of, e.g., hemoglobin mass diffusion coefficient and biochemical decomposition rate) and derived methodology could enable a significantly more accurate determination of the time of injury in forensic investigations. Both studies were supported by an equipment loan from Fotona, d.o.o., Ljubljana.

We have performed an experimental study of hyperthermic lipolysis using an Nd:YAG laser (wavelength 1064 nm) and forced-air cooling in a porcine model ex vivo. The results show that varying the irradiation power density and duration, as well as the cooling power, enables versatile control over the amplitude and shape of the subsurface temperature distribution. The developed numerical model and improved understanding provide a good basis for a further improvement of the laser lipolysis treatment.

We have participated in the development of two types of nanostructures with great potential for applications in biomedical imaging and therapy: The first type involves lanthanide-doped fluoride nanocrystals with polymer coatings and features upconversion fluorescence, the other are derived from animal erythrocytes and contain an infrared-absorbing dye indocyanine green.

Microfluidics

A fundamental requirement for microfluidic experiments is the fabrication of microfluidic arrays. In close collaboration with the Laboratory for Experimental Soft Matter at the Faculty for Mathematics and Physics and Laboratory for Photonics and Laser Systems at the Faculty for Engineering, both University of Ljubljana, we developed a high-precision direct laser micro-structuring system. The developed method, which is highly efficient and precise, uses fibre-laser generated bursts of picosecond light pulses. The set-up allows for the structuring of single micrometre-sized objects with a nanometre resolution. The efficiency of the method was demonstrated on a copper layer and a significant reduction of typical processing time was shown. Bursts of pulses also contribute to the high-quality definition of structure edges and sides. By using bursts instead of single pulses, we are able to use up to ten times less laser energy for microfluidic structuring. The work thus opens a window to utilise compact fibre lasers, reducing the overall system complexity, size and cost (**J. Phys. D: Appl. Phys., vol. 50, 325104 (2017).**
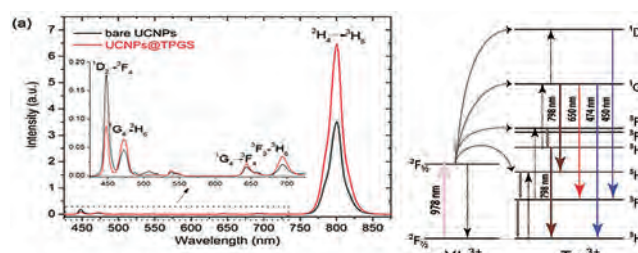
We developed a high-precision direct laser micro-structuring system for surface modification, based on bursts of picosecond laser pulses.

The developed method for laser ablation and surface modification, which is based on using a sequence of weaker laser pulses rather than one stronger one, was also used on silicone. We have shown that by changing the energy of the pulse, pulse position, and the number of pulses in a burst, we can successfully control the crystallinity of the structure. Depending on the parameters, a transition from no observable changes of the silicon at low pulse energies, through amorphisation below the ablation threshold energy, to the ablation with either complete, partial or non-existent amorphisation was observed. Single micrometre-sized areas of desired shape and crystallinity were defined on the silicon surface with sub-micron precision (**Opt. Express, vol. 25, 26356 (2017).**

The described research was part of a postgraduate programme, which was successfully completed with a dissertation entitled *Interaction of short laser pulses with matter during direct micro-structuring.*

Part of the research was carried out in collaboration with the Condensed Matter Physics Department. We focused on observations of optothermal effects, which can transport microparticles in confined liquid crystals. Optical tweezers were used for the rapid movement of a laser beam in a thin layer of a nematic liquid crystal and demonstrated the appearance of fluid flows. The observed phenomenon is caused by two different mechanisms, thermoviscous expansion effects and thermally induced local melting of the liquid crystal. The flow was controlled by a variation of the velocity of the focused laser beam and its intensity. This enabled creation of directed microflows in a channel-free environment (**Soft Matter, vol. 13, 2449 (2017).**

Some outstanding publications in the past year

1. Daniele Vella, Dmitry A. Ovchinnikov, Daniele Viola, Dumitru Dumcenco, Yen C. Kung, Eva Arianna Aurelia Pogna, Stefano Dal Conte, Victor Vega Mayoral, Tetiana Borzda, Matej Prijatelj, Dragan Mihailović, András Kis, Giulio Cerullo, Christoph Gadermaier, "Field-induced charge separation dynamics in monolayer MoS_2", *2D materials*, vol. 4, str. 035017-1-035017-8, 2017, doi: 10.1088/2053-1583/aa7ce0. [COBISS.SI-ID 30699559]

2. M. Beck, Viktor V. Kabanov, Jure Demšar, et al., "Energy dependence of the electron-boson coupling strength in the electron-doped cuprate superconductor $Pr_{(1.85)}Ce_{(0.15)}CuO_{(4-\delta)}$", *Physical review. B*, vol. 95, no. 8, str. 085106-1-085106-8, 2017, doi: 10.1103/PhysRevB.95.085106. [COBISS.SI-ID 30240551]

3. Ivan Madan, Vladimir V. Baranov, Y. Toda, Migaku Oda, T. Kurosawa, Viktor V. Kabanov, Tomaž Mertelj, Dragan Mihailović, "Dynamics of superconducting order parameter through ultrafast normal-to-superconducting phase transition in $Bi_2Sr_2CaCu_2O_{8+\delta}$ from multipulse polarization-resolved transient optical reflectivity", *Physical review. B*, vol. 96, no. 18, str. 184522-1-184522-9, 2017, doi: 10.1103/PhysRevB.96.184522. [COBISS.SI-ID 31049255]

4. Ljupka Stojchevska, Miloš Borovšak, P. Foury-Leylekian, J.-P. Pouget, Tomaž Mertelj, Dragan Mihailović, "Evolution of coherent collective modes through consecutive charge-density-wave transitions in the $(PO_2)_4(WO_3)_{12}$ monophosphate tungsten bronze", *Physical review. B*, vol. 96, no. 3, str. 035429-1-035429-7, 2017, doi: 10.1103/PhysRevB.96.035429. [COBISS.SI-ID 30647847].

5. Le Guyader, L., Chase, T., Reid, A. H., LI, R. K., Svetin, Damjan, Shen, Z.-X., Vecchione, T., Wang, X. J., Mihailović Dragan, Dürr, H. A. Stacking order dynamics in the quasi-two-dimensional dichalcogenide $1T-TaS_2$ probed with mev ultrafast electron diffraction. Structural dynamics, ISSN 2329-7778, 2107, vol. 4, no. 4, str. 044020-1-044020-7, doi: 10.1063/1.4982918. [COBISS.SI-ID 30465319].

6. Daniele Vella, Dmitry A. Ovchinnikov, N. Martino, Victor Vega Mayoral, D. Dumcenco, Y.-C. Kung, Mariarosa Antognazza, András Kis, Guglielmo Lanzani, Dragan Mihailović, Christoph Gadermaier, "Unconventional electroabsorption in monolayer MoS_2", *2D materials*, vol. 4, no. 2, str. 021005-1-021005-9, 2017, doi: 10.1088/2053-1583/aa5784. [COBISS.SI-ID 30218279].

7. Vega Mayoral, Victor, Borzda Tetiana, Vella Daniele, Prijatelj Matej, Pogna Eva Arianna Aurelia, Backes Claudia, Coleman Jonathan N., Cerullo Giulio, Mihailovic Dragan, Gadermaier Christoph. Charge trapping and coalescence dynamics in few layer MoS_2. *2D materials*, ISSN 2053-1583, 2018, vol. 5, no. 1, str. 015011-1-015011-8, doi: 10.1088/2053-1583/aa8d42. [COBISS.SI-ID 30957095].

8. Peter Topolovšek, Francesco Lamberti, T. Gatti, A. Cito, J. M. Ball, Enzo Menna, Christoph Gadermaier, Annamaria Petrozza, "Functionalization of transparent conductive oxide electrode for TiO_2: free perovskite solar cells", *J. mater. chem. A (Print)*, vol. 5, no. 23, str. 11882-11893, 2017, doi: 10.1039/c7ta02405c. [COBISS.SI-ID 30594855].

9. X. Leng, Jure Strle, et al., "Insulator to metal transition in WO_3 induced by electrolyte gating", *npj quantum mater.*, vol. 2, str. 35-2-35-7, 2017, doi: 10.1038/s41535-017-0039-2. [COBISS.SI-ID 30631207].

10. Peter Medle Rupnik, Darja Lisjak, Martin Čopič, Simon Čopar, Alenka Mertelj, "Field-controlled structures in ferromagnetic cholesteric liquid crystals", *Science advances*, vol. 3, no. 10, str. e1701336-1-e1701336-11, 2017, doi: 10.1126/sciadv.1701336. [COBISS.SI-ID 30900775],

11. Tilen Potisk, Daniel Svenšek, Helmut R. Brand, Harald Pleiner, Darja Lisjak, Natan Osterman, Alenka Mertelj, "Dynamic magneto-optic coupling in a ferromagnetic nematic liquid crystal", *Phys. rev. lett.*, vol. 119, no. 9, str. 097802-1-097802-6, 2017, doi: 10.1103/PhysRevLett.119.097802. [COBISS.SI-ID 30734631],

12. Miha Škarabot, Natan Osterman, Igor Muševič, "Optothermally driven colloidal transport in a confined nematic liquid crystal", *Soft matter*, vol. 13, no. 13, str. 2448-2452, 2017, doi: 10.1039/c7sm00136c. [COBISS.SI-ID 30397479]

13. Maruša Mur, Junaid Sofi, Ivan Kvasić, Alenka Mertelj, Darja Lisjak, Vidur Niranjan, Igor Muševič, Surajit Dhara, "Magnetic-field tuning of whispering gallery mode lasing from ferromagnetic nematic liquid crystal microdroplets", *Opt. express*, vol. 25, no. 2, str. 1073-1083, 2017, doi: 10.1364/OE.25.001073. [COBISS.SI-ID 30156583],

14. Jaka Mur, Jaka Petelin, Natan Osterman, Rok Petkovšek, "High precision laser direct microstructuring system based on bursts of picosecond pulses", *J. phys., D, Appl. phys.*, vol. 50, f. 1-7, 2017, http://iopscience.iop.org/article/10.1088/1361-6463/aa7b5a/pdf, doi: 10.1088/1361-6463/aa7b5a. [COBISS.SI-ID 15571227],

15. Joshua M. Burns, Rolf Saager, Boris Majaron, Wangcun Jia, Bahman Anvari, "Optical properties of bio-mimetic probes engineered from erythrocytes", *Nanotechnology (Bristol)*, vol. 28, no. 3, str. 035101-1-035101-12, 2017, doi: 10.1088/1361-6528/28/3/035101. [COBISS.SI-ID 30071591],

16. Plohl Olivija, Kralj Slavko, Majaron Boris, Fröhlich Eleonor, Ponikvar-Svet Maja, Makovec Darko, Lisjak Darja. Amphiphilic coatings for the protection of upconverting nanoparticles against dissolution in aqueous media. *Dalton transactions*, ISSN 1477-9226, 2017, vol. 46, no. 21, str. 6975-6984, doi: 10.1039/c7dt00529f. [COBISS.SI-ID 30501671]

17. Martin Klanjšek, Andrej Zorko, Rok Žitko, Jernej Mravlje, Zvonko Jagličić, Pabitra Kumar Biswas, Peter Prelovšek, Dragan Mihailović, Denis Arčon, "A high-temperature quantum spin liquid with polaron spins", *Nature physics*, 7 str., [in press] 2017, doi: 10.1038/nphys4212. [COBISS.SI-ID 30689319]

18. Damjan Svetin, Igor Vaskivskyi, Serguei Brazovskii, Dragan Mihailović, "Three-dimensional resistivity and switching between correlated electronic states in 1T–TaS21T–TaS2", *Scientific reports*, vol. 7, str. 46048-1-46048-10, 2017, doi: 10.1038/srep46048. [COBISS.SI-ID 30469415],

Some outstanding publications in the year 2016

1. Vaskivskyi, Igor, Mihailović, Ian, Brazovskii, Serguei, Gospodarič, Jan, Mertelj, Tomaž, Svetin, Damjan, Šutar, Petra, Mihailović, Dragan. Fast electronic resistance switching involving hidden charge density wave states. Nature communications, ISSN 2041-1723, 2016, vol. 7, str. 11442 -1-11442 -5, doi: 10.1038/ncomms11442. [COBISS.SI-ID 29594919]

2. Madan, Ivan, Kušar, Primož, Baranov, Vladimir V., Lu-Dac, Mathieu, Kabanov, Viktor V., Mertelj, Tomaž, Mihailović, Dragan. Real-time measurement of the emergence of superconducting order in a high-temperature superconductor. Physical review. B, Condensed matter and materials physics, ISSN 1098-0121, 2016, vol. 93, no. 22, str. 224520-1-224520-8, doi: 10.1103/PhysRevB.93.224520. [COBISS.SI-ID 29645351]

3. Ličen, Matjaž, Majaron, Boris, Noh, Junghyun, Schütz, C., Bergström, Lennart, Lagerwall, Jan P. F., Drevenšek Olenik, Irena. Correlation between structural properties and iridescent colors of cellulose nanocrystalline films. *Cellulose*, ISSN 0969-0239, 2016, vol. 23, iss. 6, str. 3601-3609, ilustr., doi: 10.1007/s10570-016-1066-z.

4. Troha, Tinkara, Drevenšek Olenik, Irena, Webba Da Silva, Mateus, Spindler, Lea. Surface-adsorbed long G-quadruplex nanowires formed by G:C linkages. *Langmuir*, ISSN 0743-7463, 2016, vol. 32, iss. 28, str. 7056-7063, ilustr., doi: 10.1021/acs.langmuir.6b01222

5. Ji, Zhichao, Zhang, Xinzheng, Shi, Bin, Li, Wei, Luo, Weiwei, Drevenšek Olenik, Irena, Wu, Qiang, Xu, Jingjun. Compartmentalized liquid crystal alignment induced by sparse polymer ribbons with surface relief gratings. *Optics letters*, ISSN 0146-9592, 2016, vol. 41, iss. 2, str. 336-339, ilustr., doi: 10.1364/OL.41.000336

6. Geng, Yong, Noh, Junghyun, Drevenšek Olenik, Irena, Rupp, Romano A., Lenzini, Gabriele, Lagerwall, Jan P. F. High-fidelity spherical cholesteric liquid crystal Bragg reflectors generating unclonable patterns for secure authentication. *Scientific reports*, ISSN 2045-2322, 2016, vol. 6, art. no. 26840, 9 str., ilustr., doi: 10.1038/srep26840.

7. Lisjak, Darja, Plohl, Olivija, Vidmar, Janja, Majaron, Boris, Ponikvar-Svet, Maja. Dissolution mechanism of upconverting AYF4:Yb,Tm (A = Na or K) nanoparticles in aqueous media. Langmuir, ISSN 0743-7463, 2016, vol. 32, no. 32, str. 8222-8229, doi: 10.1021/acs.langmuir.6b02675. [COBISS.SI-ID 29679655]

8. Shuai, M., Mertelj, Alenka, Lisjak, Darja, Čopič, Martin, et al. Spontaneous liquid crystal and ferromagnetic ordering of colloidal magnetic nanoplate. *Nature communications*, ISSN 2041-1723, 2016, vol. 7, str. 10394-1- 10394-8, doi: 10.1038/ncomms10394. [COBISS.SI-ID 29253927]

Some outstanding publications in the year 2015

1. Madan, Ivan, Kurosawa, T., Toda, Y., Oda, Migaku, Mertelj, Tomaž, Mihailović, Dragan. Evidence for carrier localization in the pseudogap state of cuprate superconductors from coherent quench experiments. *Nature communications*, ISSN 2041-1723, 2015, vol. 6, str. 6958-1- 6958-6, doi: 10.1038/ncomms7958. [COBISS.SI-ID 28758311]

2. Buh, Jože, Kabanov, Viktor V., Baranov, Vladimir V., Mrzel, Aleš, Kovič, Andrej, Mihailović, Dragan. Control of switching between metastable superconducting states in [delta]-MoN nanowires. *Nature communications*, ISSN 2041-1723, 2015, vol. 6, str. 10250-1-10250-6, doi: 10.1038/ncomms10250. [COBISS.SI-ID 29119015]

3. Shumilin, A. V., Kabanov, Viktor V.. Kinetic equations for hopping transport and spin relaxation in a random magnetic field. *Physical review. B, Condensed matter and materials physics*, ISSN 1098-0121, 2015, vol. 92, no. 1, str. 041206-1- 041206-15, doi: 10.1103/PhysRevB.92.014206. [COBISS.SI-ID 28747047]

4. Medle Rupnik, Peter, Lisjak, Darja, Čopič, Martin, Mertelj, Alenka. Ferromagnetic liquid crystals for magnetic field visualisation. *Liquid crystals*, ISSN 0267-8292, 2015, vol. 42, no. 12, str. 1684-1688, doi: 10.1080/02678292.2015.1049570. [COBISS.SI-ID 28701223]

5. Vaskivskyi, Igor, Gospodarič, Jan, Brazovskii, Serguei, Svetin, Damjan, Šutar, Petra, Goreshnik, Evgeny A., Mihailović, Ian, Mertelj, Tomaž, Mihailović, Dragan. Controlling the metal-to-insulator relaxation of the metastable hidden quantum state in 1T-TaS[sub]2. *Science advances*, ISSN 2375-2548, 2015, vol. 1, no. 6, str. e1500168-1-e1500168-6, doi: 10.1126/sciadv.1500168. [COBISS.SI-ID 28753959]

6. Pogrebna, Anna, Mertelj, Tomaž, Vujičić, Nataša, Cao, Guozhong, Xu, Z. A., Mihailović, Dragan. Coexistence of ferromagnetism and superconductivity in iron based pnictides : a time resolved magnetooptical study. *Scientific reports*, ISSN 2045-2322, 2015, vol. 5, str. 7754-1-7754-7, doi: 10.1038/srep07754. [COBISS.SI-ID 28287783]

7. Vidovič, Luka, Milanič, Matija, Majaron, Boris. Objective characteriza-tion of bruise evolution using photothermal depth profiling and Monte Carlo modeling. Journal of biomedical optics, ISSN 1083-3668, 2015, vol. 20, no. 1, pp. 017001-1-12, doi: 10.1117/1.JBO.20.1.017001. [COBISS.SI-ID 28243495]

8. Lisjak, Darja, Plohl, Olivija, Ponikvar-Svet, Maja, Majaron, Boris. Dissolution of upconverting fluoride nanoparticles in aqueous suspensions. RSC advances, ISSN 2046-2069, 2015, vol. 5, no. 35, str. 27393-27397, doi: 10.1039/c5ra00902b. [COBISS.SI-ID 28445735]

Awards and Appointments

1. Jan Ravnik: Best poster award at the conference PIPT6, Sendai, Japan, Conference Scientific Committee, Time evolution of a phase transition to a stable photoinduced state in 1T-TaS2.
2. Jan Ravnik: Best poster award at the International School and Workshop on Electronic
3. Crystals ECRYS-2017, Cargese, France, Conference Scientific Committee, Reaching a Hidden State in Half a Picosecond.
4. Ljupka Stojčevska Malbašić: Best poster award at the conference ICFSI 2017, Hannover, Germany, Conference Scientific Committee, Study of the photoinduced hidden state in 1T-TaS2 single crystals doped with selenium by means of time-resolved photoemission spectroscopy.

Organization of conferences, congresses and meetings

1. Winter School on Photophysics of Hybrid Interfaces, COST Action Nanospectroscopy MP1302, Ambrož pod Krvavcem, Slovenia 15.–19. 1. 2017.
2. Nonequilibrium Phenomena in Quantum Systems, Ambrož pod Krvavcem, Slovenia, Organisers, 17. 12.-20. 12. 2017.

Patents granted

1. Adolf Jesih, Andrej Kovič, Aleš Mrzel, Method for a synthesis of quasi one-dimensional structures of 4D and 5D (Nb, Mo, Ta, W) transition metals, EP2723524 (B1), European Patent Office, 27. 12. 2017.

2. Marko Kazič, Matjaž Lukač, Laser system and method for the treatment of body tissue, US9610125 (B2), US Patent Office, 04. 04. 2017.

3. Marko Kazič, Matjaž Lukač, A laser system for the treatment of body tissue, EP2818131 (B1), European Patent Office, 09. 08. 2017.

4. Matjaž Lukač, Marko Kazič, Laser system and method for operating the laser system, US9572632 (B2), US Patent Office, 21. 02. 2017.

5. Ljupka Stojchevska, Tomaž Mertelj, Igor Vaskivskyi, Dragan Mihailović, Ultrafast nonvolatile memory, US9589631 (B2), US Patent Office, 07. 03. 2017.

6. Igor Vaskivskyi, Dragan Mihailović, Ian Mihailović, Switchable macroscopic quantum state devices and methods for their operation, US9818479 (B2), US Patent Office, 14. 11. 2017.

INTERNATIONAL PROJECTS

1. Spectra Measurements XANES/EXAFS; Extend Existing Work and Include Completing the Data Analysis and Writing s Paper for Submission to a Referred Journal
   Steven Daniel Conradson
   Areva Mining And Front-end Bg

2. Kimberly-Clark - Development of LCD Shutter in the Year 2017
   Dr. Andrej Petelin
   Kimberly-clark

3. 7FP - MoWSeS; Nanoelectronics based on Two-dimensional Dichalcogenides
   Prof. Christoph Gadermaier
   European Commission

4. 7FP - TRAJECTORY, Coherent Trajectories through Symmetry Breaking Transitions
   Prof. Dragan Dragoljub Mihailović
   European Reasearch Council Executive Agency

5. COST MP1302; NanoSpectroscopy
   Prof. Christoph Gadermaier
   Cost Office

6. The European Upconversion Network - From the Design of Photon-Upconverting Nanomaterials to Biomedical Applications
   Prof. Boris Majaron
   Cost Office

7. COST BM 1205: Biomedicine and Molecular Biosciences
   Prof. Boris Majaron
   Cost Office

8. Winter School e-COST Action MP1302; Winter School on Photophysics of Hybrid Interfaces
   Prof. Christoph Gadermaier
   Cost Office

9. COST CA16101; MULTI-modal Imaging of FOREnsic SciEnce Evidence - tools for Forensic Science
   Prof. Boris Majaron
   Cost Office

10. COST CA16218; Nanoscale Coherent Hybrid Devices for Superconducting Quantum Technologies
    Prof. Viktor Kabanov
    Cost Office

11. COST MP1305; Flowing Matter
    Dr. Mojca Vilfan
    Cost Office

12. H2020 EUROfusion - JET Campaigns-JET1-FU
    Dr. Natan Osterman
    European Commission

13. H2020 - MagNem; Hydrodynamics of Ferromagnetic Nematic Liquid Crystals
    Asst. Prof. Alenka Mertelj
    European Commission

14. H2020 - Umem4QC; Ultrafast Charge Density Wave Memory or Quantum Computing
    Prof. Dragan Dragoljub Mihailović
    European Reasearch Council Executive Agency

15. Neutron Polarizers based on Polymer-nanoparticle Composites
    Prof. Martin Čopič
    Slovenian Research Agency

16. Evaluation of Tissue Depth Characterization in Vivo Using Photothermal Radiometry by Co-registration with Alternative Novel Approaches
    Prof. Boris Majaron
    Slovenian Research Agency

17. Growth and Characterization of Functional 2D Materials based on Graphene and Dichalcogenides
    Asst. Prof. Tomaž Mertelj
    Slovenian Research Agency

18. Micro-Patterned Liquid Crystalline Structures for Application in Microfluidic Devices
    Prof. Irena Drevenšek Olenik
    Slovenian Research Agency

19. Magnetically Reconfigurable Elastomeric Optical Surfaces
    Prof. Dragan Dragoljub Mihailović
    Slovenian Research Agency

20. Photo-Stimulated Phenomena and Dynamical States in the Vicinity of the Phase Transition
    Prof. Viktor Kabanov
    Slovenian Research Agency

RESEARCH PROGRAMS

1. Medical physics
   Dr. Matija Milanič

2. Light and Matter
   Prof. Martin Čopič

3. Dynamics of complex nano-systems
   Prof. Dragan Dragoljub Mihailović

R & D GRANTS AND CONTRACTS

1. Thermophoretic guidance, accumulation and sorting of biomolecules in microfluidic devices
   Dr. Natan Osterman

2. Ultrafast memory devices by molecular beam epitaxy
   Prof. Dragan Dragoljub Mihailović

3. Femtosecond time-resolved scanning tunneling electron microscopy of complex materials
   Prof. Dragan Dragoljub Mihailović

4. Electrically tunable ferromagnetic liquids
   Asst. Prof. Alenka Mertelj

5. Development of gradual optical shutter – OPTIGRAD
   Dr. Luka Cmok

VISITORS FROM ABROAD

1. Valentino Jadriško, Institut za fiziku, Zagreb, Croatia, 23.-25. 1. 2017.

2. Maksim Litskevich, P. N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia, 9. 1.-24. 2. 2017.

3. Victor V. Mayoral, Trinity College Dublin, Dublin, Ireland, 10. 1. 2017-15. 10. 2017.

4. dr. Yoshiaki Uchida, Department of Materials Engineering Science, Graduate School of Engineering Science Osaka University, Japan, 18.-26. 1. 2017.

5. Valentino Jadriško in Borna Pielić, Institut za fiziku, Zagreb, Croatia, 13.-17. 2. 2017.

6. Nikolai Fedotov, Kotel'nikov Institute of Radioengineering and Electronics RAS, Moscow, Russia, 26. 3.-9. 4. 2017.

7. Shaohua Gao, TEDA Applied Physics Institute, Nankai University, China, 8.-21. 5. 2017.

8. Dr. Reinhard Kaindl in dr. Alexander Bluemel, Joanneum Research, Austria, 19. 5. 2017.

9. dr. Tony Raven, Cambridge Enterprise, univerza v Cambridgeu, Great Britain, 11. 5. 2017 (v organizaciji CTT).

10. prof. dr. Istvan Janossy, Institute for Solid State Physics and Optics, Wigner Research Centre, Budapest, Hungary, 5.-9. 6. 2017.

11. prof. dr. Rupert Schreiner in prof. dr. Mikhail Chamonin, iz Ostbayerische Technische Hochschule Regensburg, Germany, 14.-19. 6. 2017.

12. prof. dr. Xinzheng Zhang, TEDA Institute of Applied Physics & School of Physics Nankai University, China, 16.-24. 6. 2017.

13. Sanje Fenkart, University of Vienna, Vienna, Austria, 12.-28. 7. 2017.

14. Mathias Fleisch, University of Vienna, Austria, 12. 7.- 15. 8. 2017.

15. Ivan I. Smalyukh, University of Colorado at Boulder, Department of Physics, Colorado Ave Boulder, USA, 21. 7. 2017.
16. dr. Juergen Klepp, University of Vienna, Austria, 5.-9. 7. 2017.
17. Maksim Litskevich, P. N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia, 26. 7.-25. 8. 2017.
18. Nikita Raginov in Serhii Voloshenuik, Moscow Institute of Physics and Technology, Moscow, Russia, 20. 7.-25. 8. 2017.
19. Yevhenii Vaskivskyi, Department of Experimental Physics of Faculty of Physics, Taras Shevchenko National University of Kyiv, Ukraine, from 1.-31. 7. 2017.

20. dr. Emili Catelli, Dipartimento di Chimica "Giacomo Ciamician", Univerza v Bologni, Italy, 30. 8.-3. 9. 2017.
21. dr. Satoshi Tsuchiya, Department of Applied Physics, Faculty of Engineering, Hokkaido University, Japan, 3. 9. 2017-30. 6. 2018.
22. dr. Rinat F. Mamin, Laboratory of Novel Materials, Kazan Physical- Technical Inst. RAS, Russia, 5. 10.-7. 11. 2017.
23. Željko Rapljenović, Institut za fiziko, Zagreb, Croatia, 15. 11.-17. 11. 2017.

STAFF

Researchers
1. Dr. Steven Daniel Conradson
2. Prof. Martin Čopič*
3. Prof. Irena Drevenšek Olenik*
4. Prof. Christoph Gadermaier
5. Prof. Viktor Kabanov
6. Dr. Matjaž Lukač*
7. Prof. Boris Majaron
8. Asst. Prof. Alenka Mertelj
9. Asst. Prof. Tomaž Mertelj
10. **Prof. Dragan Dragoljub Mihailović, Head**
11. Dr. Matija Milanič*
12. Dr. Aleš Mrzel
13. Asst. Prof. Natan Osterman*
14. Dr. Nerea Sebastián Ugarteche
15. Asst. Prof. Lea Spindler*
16. Dr. Mojca Vilfan
17. Prof. Marko Zgonik*

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18. Dr. Luka Cmok
19. Dr. Andrej Petelin
20. Dr. Anastasia Samodurova
21. *Dr. Ljupka Stojčevska Malbašić, left 01.12.17*
22. Dr. Jure Strle

Postgraduates
23. Patricija Hribar, B. Sc.
24. Andrej Kranjec, B. Sc.
25. Matjaž Ličen, B. Sc.
26. *Luca Moretti, B. Sc., left 01.03.17*
27. Mimoza Naseska
28. *Matej Prijatelj, B. Sc., left 01.11.17*
29. Jan Ravnik, B. Sc.
30. Nina Verdel, B. Sc.
31. *Dr. Luka Vidovič*, left 01.11.17*
32. Jaka Vodeb, B. Sc.
33. **Technical officers**
34. Damjan Svetin, B. Sc.
35. Petra Šutar, B. Sc.

Technical and administrative staff
36. *Sabina Cintauer, B. Sc., 16.10.17, transferred to Department K7*
37. Martina Knavs, B. Sc.
38. Janja Milivojević
39. Laura Petan, B. Sc.

Note:
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2. Tetiana Borzda, *Non-equilibrium electron dynamics in semiconducting transition metal dichalcogenides:* doctoral dissertation, Ljubljana, 2017 (mentor Christoph Gadermaier; co-mentor Viktor Kabanov).
3. Jaka Mur, *Interakcija kratkih laserskih pulzov s snovjo med direktnim mikrostrukturiranjem:* doctoral dissertation, Ljubljana, 2017 (mentor Natan Osterman; co-mentor Rok Petkovšek).
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DEPARTMENT OF REACTOR PHYSICS
F-8

During the past year we have been working mainly on:
- *theoretical, experimental and applied reactor physics*
- *plasma physics*
- *neutron-transport calculations*
- *semiconductor physics*
- *medical physics*

Head:
Asst. Prof. Luka Snoj

In the field of **reactor physics** our activities have been focused on the development of novel methods for research and power-reactor analyses. In collaboration with our CEA – Cadarache colleagues we have performed measurements of the neutron flux and the spectrum in the core of the TRIGA reactor using new miniature fission chambers, coated with neptunium and plutonium. Another experimental campaign with the CEA – Cadarache colleagues has been successfully performed, the main goal of which was the characterization of gamma fields in the TRIGA reactor using thermoluminescent and opto-luminescent detectors (TLD, OSLD), RadFET detectors, a scintillator spectrometer, as well as fission and ionization chambers. The results of the campaign will be used for a validation of the two-step Monte Carlo calculation method, which is being developed at the department and enables the calculation of prompt and delayed gamma transport, occurring from radioactive fissions and product activation in the reactor. It has been shown experimentally that the latter represent a significant part of the total field intensity.

In the framework of the international collaboration project E-SiCure (Engineering Silicon Carbide for Improved Border and Port Security), which is being carried out under the NATO Science for Peace and Security programme, we have begun the development of neutron detectors based on SiC aimed at the detection of fissile material. We have performed a series of irradiations of SiC samples at the TRIGA reactor in order to study neutron-induced defects in SiC material. We have also begun preparations for a prototype detector with a converter layer that will enable enhanced sensitivity to thermal neutrons.

In the field of neutron dosimetry, in collaboration with colleagues from CEA – Cadarache and CEA – Saclay, we are studying radiative neutron capture reactions, in themselves predominantly sensitive to the thermal and resonance neutron energy ranges, which would exhibit a sensitivity shift to epithermal neutron energies in conjunction with the appropriate boron-based thermal neutron filters. In neutron dosimetry the epithermal energy range is very poorly covered because of the small number of radiative capture reactions that have strong resonances at epithermal energies, or threshold reactions with a low energy threshold. An experimental campaign is in preparation at the TRIGA reactor, the aim of which is to measure the reaction rates for 10 identified reactions, using filters made from boron nitride (BN), boron carbide (B4C) and enriched boron carbide 10B4C.

In this year we have continued to actively participate in the two OCED/NEA workgroups, namely, the International Criticality Safety Benchmark Evaluation Project (ICSBEP) and International Reactor Physics Experiment Evaluation Project (IRPhEP), where we have contributed a new evaluation of a benchmark experiment with a UO2F2 solution with a spherical geometry. The experiment is crucial for an analysis of reprocessed-fuel criticality measurements. We have taken part in the workgroup's meetings and helped with an independent review of foreign benchmark experiment evaluations.

Within the framework of the European CHANDA project we were involved in the process of improving nuclear data for the fourth-generation reactor concept MYRRHA. For materials and reactions that significantly influence the uncertainty of integral parameters and have most room for improvement, a comparison between the experimental and evaluated nuclear data was performed.

In 2017 an international group working on the characterization of spent nuclear fuel under the leadership of SKB and SSB was formed and joined by the JSI. In the framework of this currently informal collaboration a so-called "blind test" on measurements of the decay heat of spent nuclear fuel from the Swedish PWR and BWR reactors and the validation of different codes for decay heat calculations will be performed by several European groups. The comparison will include sensitivity and uncertainty analyses with more than 10 independent partners.

Researchers from the Reactor Physics Department also provided technical support for the safe operation of the Krško nuclear power plant (NPP) in 2017. We have independently confirmed a preliminary loading scheme for the fuel cycle 30. A review of the results obtained by a new version of design codes ANC9 has been performed. In the framework of the project financed by the Slovenian Research Agency (co-financed by the NPP Krško) the Mc-

Cord code has been developed. The interface will enable the automatic transfer of the fuel characteristics from the CORD-2 system to the MCNP code for an arbitrary operational state. Preliminary full-core calculations have been executed. Currently, the calibration and verification process is under way. As an authorized expert organization in the field of radiation and nuclear safety we have finalized an independent expertise on a Krško NPP reload safety evaluation for cycle 29. For the Slovenian Nuclear Safety Administration an analysis of the influence of the pressure vessel irradiation on expected NPP Krško lifetime has been performed.

We were also active in the field of **plasma physics** in 2017, especially in connection with fusion. We continued our collaboration in the EUROfusion consortium projects MST1 and MST2. In the former we worked on measurements and the processing of the data related to the turbulent transport in the scrape-off-layer of the TCV tokamak in Lausanne. Together with our partners from University of Innsbruck we performed for the first time kinetic

Figure 1: Neutron flux (upper left) is proportional to the probability that the neutron will reach a certain point in space, while the adjoint neutron flux for a detector (upper right) is proportional to the probability that a neutron from that point in space will reach the detector. Multiplication of the neutron flux and the adjoint neutron flux thus shows the contribution field (lower), which describes the main pathways of these particles. To determine these fields, the deterministic code Denovo was used and the results are useful for accelerating of the Monte Carlo simulations. When combined, different approaches thus lead to better results.

simulations of parallel dynamics of the turbulent transport and which we plan to continue in the following years. The MST2 project, dedicated to development of a new probe head (NPH) to be used in tokamaks of the MST1 programme, has now been ongoing for several years. This year we performed thermo-mechanical calculations of the heat load on the probe head in tokamak conditions together with the Reactor Engineering Department. In both projects we collaborated mostly with researchers from Austria, Denmark and Italy. In 2017 we also became involved in the EUROfusion PFC work package, which deals with the plasma-wall interactions. We performed experimental measurements comparing the results from Langmuir and Ball-pen probes in the COMPASS tokamak together with our colleagues from the University St. Kliment Ohridski from Sofia. In the field of theoretical modelling we continued our work on the one-dimensional two-fluid model of the plasma-wall transition. We also included the energy equation in the model in which we also took into account the heat flux carried by the plasma. We studied what happens if the temperature of the ions is non-zero. We showed that we can get monotonous and non-oscillating solutions if we select the boundary conditions with the proposed method. This method allows the simultaneous correct and self-consistent determination of the ion flux velocity and the electric field on the edge of the system. During their journey towards the wall the ions are initially cooled and then heated. Their temperature reaches a maximum just before the sheath entrance. We also studied the effect of ion-neutral collisions where charge-exchange is present. Such collisions heat the ions. If we also take into account the plasma heat flux we see that the ion flux is almost isothermal, even if the heat conductivity is relatively small.

In the field of **neutron-transport calculations** for fusion reactors co-workers of the Reactor Physics Division have, in collaboration with colleagues from Culham Centre for Fusion Energy, United Kingdom, participated in the calibration of neutron detectors to 14-MeV neutrons. Within this project we participated in the experimental part of the calibration process, simulated the response of neutron detectors to the calibration source – the DT neutron generator – and to the plasma neutron source inside the reactor. With a combination of measurements and calculations we determined the calibration factors for neutron detectors. The computational support was crucial for the successful calibration of the detectors with a target uncertainty of 10%. The calibration process was largely completed by the end of 2017, some additional analyses are needed to determine the final values of the calibration factors in order to improve our understanding of the process and for the reliability of the calculated correction parameters.

In the scope of the European Fusion program, (Fusion for Energy – F4E in EURO fusion) we continued with an international collaboration started over 20 years ago in the field of fusion reactor neutronics, which includes experiments and theoretical research (experimental measurements of tritium production in the JSI TRIGA mark II research reactor on the basis of irradiated Mn samples, validation of neutron and gamma cross sections for copper, sensitivity and uncertainty analysis, preparation and validation of covariance matrices, development of the SINBAD database for experimental data).

During the international conference entitled Mathematics and Computations (M&C 2017) on the island of Jeju in South Korea, a workshop was organized in April of 2017 on the use of the JSI-developed program package XSUN-2017/SUSD3D, which was attended by a significant number of participants.

In the case of the parametric neutron source used to simulate the plasma source we analysed the TT (tritium + tritium) neutron source to be used in the TT campaign at the JET Tokamak. The neutrons generated by this reaction are particularly interesting because the reaction has three important channels, which produce neutrons with different energies, while the intensity of the individual channel is poorly known. Determining the relative intensities
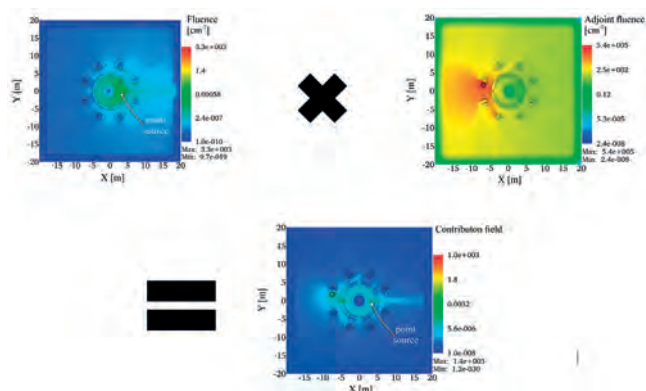
of these three channels will be a goal of the future TT campaign and co-workers of the Reactor Physics Division are involved in calculation support for the experiments. In 2017 we identified suitable detectors (especially activation foils) that could distinguish between different peaks of the TT reaction. The sensitivity of potential detectors, as well as the suitability for the use in a tokamak, were considered.

We have performed calculations of the neutron field in different locations inside the torus. We have collaborated in analyses in support of planned, as well as already performed experiments. Additionally, we have investigated the cause for discrepancies in the predicted low-energy neutron flux levels between calculations obtained using two different computational models. The analyses performed resulted in the identification of errors in one of the computational models, which will significantly improve the accuracy of future analyses.

Colleagues from the F8 department and a colleague from RIC have taken part in a feasibility study for a water-activation experiment at the JET tokamak, which occurs due to the $16O(n,p)16N$ threshold reaction. The experiment will be of great value to the ITER project, as the main coolant in the ITER device will be water, and the presence of $16N$ in significant quantities will present an important radiation-safety constraint in locations in the immediate vicinity of the cooling-system components outside the tokamak itself.

In 2017 we have started performing neutronics analyses in the support of the development of the future fusion power plant DEMO. The work was performed within the framework of the EUROfusion Engineering Grant project, involving the studies of tested or newly developed reactor engineering configurations. The analyses focused on the estimation of the heating of superconducting magnets due to increased neutron and gamma flux in the vicinity of the reactor, which occurs due to the installation of plasma heating systems. The calculations have pointed to appropriate engineering solutions of systems within the equatorial ports and useful radiation shielding strategies, which will be implemented into the upcoming detailed models of the DEMO fusion power plant.

In 2017 we continued with calculations of neutron fluence with hybrid deterministic/Monte Carlo transport codes inside the largest operational fusion tokamak - JET. The simulations were performed in the scope of the JET3-NEXP streaming benchmark experiment project. Calculation results at experimental locations more than 40 m away from the plasma source were compared to experimental results in order to validate computer codes and nuclear data. This work is being performed in a consortium of international institutions including national laboratories from Slovenia, Great Britain, Poland and the USA.

Throughout the year a novel methodology for the detailed simulation of plasma neutron sources in tokamaks has been developed, resulting in the PLANET code. The latter is based on a set of Python and Fortran subroutines, which are implemented into the source code of one of the most advanced Monte Carlo neutron transport computation programs, MCNP. The data on the plasma source is obtained with state-of-the-art plasma transport simulations performed with the TRANSP code, which was developed at the Princeton Plasma Physics Laboratory. Based on the plasma information the neutron spectrum is evaluated using the Swedish DRESS code. With the computed neutron-emissivity profiles, angle of emission and energy the random sampling process is started, resulting in the generation of a weighted neutron source. The PLANET code is currently undergoing further development and optimisation and will be used for the validation of plasma-simulation codes and neutron calibration of detector systems at the JET fusion device. Throughout the project collaborations were established with researchers at PPPL (USA), Uppsala University (Sweden), UNED (Spain) and CCFE (UK).

The research on the **transport of charge in organic semiconductors** arises from our own observations in the past - namely that the cause for more than 20 years old unusual phenomenon of decrease of charge mobility with the increasing external electric field in some metal/organic semiconductor compositions is attributed to empirically determined electrical field strengths at the contact, which is linearly dependent on the external field. According to published experiments, such a dependence of the electric field strength on the boundary layer, as an argument of a previously derived expression - the modulation function of the effective charge mobility - directly lists the negative drift mobility gaps or electrons. Last year research was therefore focused on a physical interpretation of the written empirical function. For this purpose a boundary layer was modelled as an infinite dielectric plane covered with gaps and organic semiconductor electrons at the contact. The previously published electrostatic model of metal/organic semiconductor contact was modified for the surface densities of the surplus charge at the boundary layer. This was done under the assumption that the energy transfer of the density of disordered states of the two charge types (described with the Gaussian function) on the semiconductor is linearly dependent on the external electric field. The calculated electric field of the excess boundary density of the boundary layer is then the shape of the Gaussian function. It also turns out that the linear interpolation of the positive inclination through its transitional point is exactly the same as the empirical expression of the given metal/organic semiconductor composition. As a parallel achievement of the study, the interdependence of the electric field on the metal/organic semiconductor layer and the effective mobility of the charge (gaps or electrons) inside the organic material was observed. In literature the latter is usually assumed but remains an unproven phenomenon.
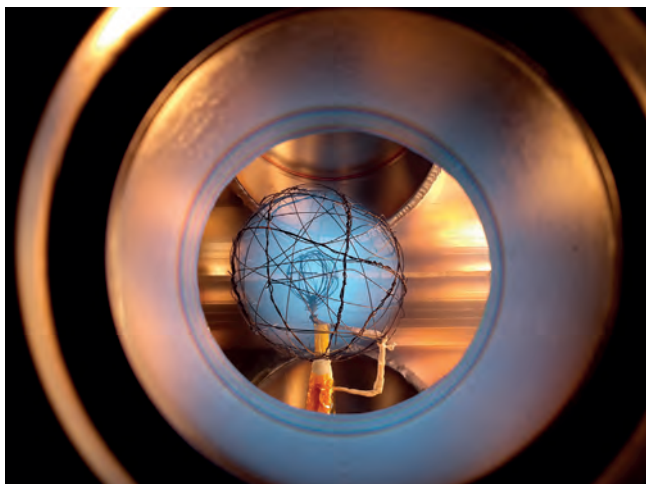
Figure 2: This photograph shows an inverted fireball in the new plasma device in the Laboratory for Plasma Physics, Reactor Physics Department. The inverted fireball is a phenomena achieved by utilizing additional biased grids for the acceleration of the charged particles, causing additional ionization. Thus we are creating a denser, hotter plasma inside the plasma that is electrostatically confined between the grids. Author: Jan Kavčič.

In the field of **medical physics** we continued work on the research areas that we work most actively in recent years: analysis of Positron Emission Tomography (PET) images, image guided cancer treatment and modelling. We also started to work in the field of proton therapy.

We developed a computer model that is used to simulate the response of mice tumours on anti-PD-1 immunotherapy. We verified this model on literature data and we found that it works adequately. Results were presented at an annual meeting of The Society for Immunotherapy of Cancer (SITC) in National Harbor (MD, USA). A manuscript is in preparation. In the future we plan to verify the model with experiments that are already carried out in cooperation with the Department for Experimental Oncology at the Institute of Oncology Ljubljana.

In cooperation with the Institute of Oncology Ljubljana we started prospective immunotherapy study, where patients with metastatic lung tumour after unsuccessful first or second line treatment received pembrolizumab (anti-PD-1 drug). Patients were imaged with CT and FDG PET/CT at timepoints that were planned in the study protocol. Currently, 23 patients were included in the study, but we plan to include 50 patients. The aim of the research is to figure out whether the radiomic analysis of metabolic response, as seen on FDG PET/CT, is a superior methodology for anti-PD-1 response assessment and prediction, as compared to current standards (irRC, iRECIST). Protocol for similar study, where the patients will be treated with durvalumab is currently in preparation.

We worked also on the modelling of proton transport through the dynamic anthropomorphic geometries. Aim of this research was dose calculation for proton therapy, while taking into account all the uncertainties that takes place in real proton therapy. In 2017 we set up a framework for Monte Carlo dose calculations. Besides that, we developed an algorithm for dose calculation in the case of known deformation field. In the following years we plan to develop more advanced methods for an estimation of the deformation fields from medical images (registration methods), sensitivity analysis and experimental verifications.

As in the previous years, we cooperate with the University of Wisconsin – Madison (USA) also in 20017.

Some outstanding publications in the past year

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Organization of Conferences, Congresses and Meetings

1. Conference of Young Generation of Reactor Physics Department (F8), "Jožef Stefan" Institute, Ljubljana, Slovenia, 27. 2. 2017

INTERNATIONAL PROJECTS

1. 7FP - CHANDA; solving CHAllenges in Nuclear Data
   Prof. Ivan Aleksander Kodeli
   European Commission
2. F4E-FPA-327 (PMS-DG): SG04; Conceptual Design and Interface Definitions for the Enabled ITER Radial Gamma-Ray Spectrometer Diagnostic
   Dr. Igor Lengar
   European Joint Undertaking for ITER and the Development of Fusion Energy ('Fusion for Energy')
   F4E-FPA-395-02; Gas Production Experiment and TBM Nuclear Instrumentation
   Prof. Ivan Aleksander Kodeli
   European Joint Undertaking for ITER and the Development of Fusion Energy ('Fusion for Energy')
3. Integral Measurements for the Validation of the Dosimetry Cross Sections; F41031 Testing and Improving the IAEA International Dosimetry Library for Fission and Fusion (IRDFF)
   Prof. Ivan Aleksander Kodeli
   IAEA - International Atomic Energy Agency

4. Benchmarks of Computational Tools against Experimental Data on Fuel Burnup and Material Activation for Utilization, Operation and Safety Analysis of Research Reactors; Activation Rate Benchmark at the JSI TRIGA Mark-II Reactor
   Dr. Vladimir Radulović
   IAEA - International Atomic Energy Agency
5. E-SiCure - Engineering Silicon Carbide for Enhanced Border and Ports Security
   Asst. Prof. Luka Snoj
   Nato - North Atlantic Treaty Organisation
6. Training Fees for IAEA"s Fellow Mr. Francisco Javier Cabrera Orellana, (CHI/16002), from 16 January 2017 to 15 July 2017
   Asst. Prof. Luka Snoj
   IAEA - International Atomic Energy Agency
7. Training Fees for IAEA"s Fellow Ms. Alvie Asuncion Astronomo (PHI/16014), 04.09.2017 - 03.11.2017
   Asst. Prof. Luka Snoj
   IAEA - International Atomic Energy Agency
8. H2020 EUROfusion - Research Unit - Administration and Services RU – FU
   Asst. Prof. Luka Snoj
   European Commission
9. H2020-EUROfusion-Plasma Facing Components-1-IPH-FU, EUROFUSION

Dr. Jernej Kovačič
European Commission

10. H2020-EUROfusion-Exploatation of DT Operation for ITER-JET3-FU
Asst. Prof. Luka Snoj
European Commission

11. H2020 EUROfusion - Education-ED-FU
Asst. Prof. Luka Snoj
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12. H2020 EUROfusion - Medium Size Tokamak Campaigns-MST1-FU
Dr. Jernej Kovačič
European Commission

13. H2020 EUROfusion - JET Enhancements-JET4-FU, EUROFUSION
Dr. Igor Lengar
European Commission

14. H2020 EUROfusion - PMI-PPPT-2-FU: Nuclear data
Prof. Ivan Aleksander Kodeli
European Commission

15. H2020 EUROfusion - Engineering Grants: Fusion Plant Nuclear Analyst - The modelling of the proposed DEMO component designs, testing their performance under reactor conditions and development of new design solutions
Aljaž Čufar, B. Sc.
European Commission

16. Impact of Neutron Irradiation in the Fusion Environment on Tritium Production, Tritium Retention and Nuclear Damage in Plasma Facing Materials
Prof. Ivan Aleksander Kodeli
Slovenian Research Agency

17. Combined Use of Monte Carlo and Deterministic Particle Transport Tools for Fusion Shielding Benchmark Neutronics Studies
Prof. Ivan Aleksander Kodeli
Slovenian Research Agency

18. Multiphysics Validation of High Fidelity Modelling and Simulation for Nuclear Applications
Asst. Prof. Luka Snoj
Slovenian Research Agency

19. Experimental on-line neutron spectra adjustment method using various fission chambers with adequate fissile isotopes
Dr. Gašper Žerovnik
Slovenian Research Agency

20. Eksperimental validation of the gamma flux simulation scheme and measurment techniques by TLD, OSLD and ionization chamber in the mixed neutron-photon high dose rate environment of the JSI TRIGA reactor
Asst. Prof. Luka Snoj
Slovenian Research Agency

21. Mathematical methods for the nuclear data and code validation applied to improved safety of new nuclear reactor core design
Prof. Ivan Aleksander Kodeli
Slovenian Research Agency

22. Consequences of electron emission from hot plasma-facing components in nuclear fusion reactors
Dr. Jernej Kovačič
Slovenian Research Agency

23. Epithermal neutron flux determination and validation of nuclear cross-sections and through activation measurements employing neutron spectrum filters

Prof. Andrej Trkov
Slovenian Research Agency

RESEARCH PROGRAM

1. Medical physics
Prof. Robert Jeraj
2. Reactor Physics
Asst. Prof. Luka Snoj

R & D GRANTS AND CONTRACTS

1. Development of methodology for calibration of neutron detectors with a 14.1 MeV neutron generator - JET fusion reactor case
Asst. Prof. Luka Snoj
2. Development of Computational Tools for the Determination of the Neutron Field in the Containment of a Pressurized Water Reactor
Prof. Andrej Trkov
3. ICERR Agreement for Receiving Affiliate Staff to CEA as a Designated International Center based on Research Reactors, through its Research Centres of Saclay and Cadarache
Asst. Prof. Luka Snoj
Cea - Commissariat A L"energie Atomique Et Aux
4. Experimental Testing of Self-Powered Neutron Detector Assembly for CEA DISCOMS Project
Dr. Vladimir Radulović
Cea List Institute, Dept. Of Metrology,

NEW CONTRACTS

1. Development of Computational Tools for the Determination of the Neutron Field in the Containment of a Pressurized Water Reactor
Prof. Andrej Trkov
Nuklearna Elektrarna Krško d. o. o.
2. Reload Operational Core Analysis, Post Refuelling Nuclear Design Check Tests, PIS and KESS Cycle Specific Data for Future Fuel Cycles (CIKEL 29)
Asst. Prof. Marjan Kromar
Nuklearna Elektrarna Krško d. o. o.
3. Impact of the pressure vessel irradiation on the NPP Krško expected lifetime
Asst. Prof. Marjan Kromar
Ministrstvo za Okolje in Prostor
4. Support for implementation and calculations in the SFDS project
Asst. Prof. Luka Snoj
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5. Reload Operational Core Analysis,Post Refuelling Nuclear Design Check tests, PIS and KFSS Cycle Specific Data for Future Fuel Cycles(Cycle 30)
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1. Dr. Ivana Capan, director of international project ESiCure, "Rudjer Bošković" Institute, Zagreb, Croatia, 6. 1. 2017
2. Lino Šalamon, student, Aix-Marseille University, France, 1. 1.–1. 4. 2017
3. Francisco Javier Cabrera Orellana, IAEA stipend, Chilean Nuclear Energy Commission (CCHEN), Santiago, Chile, 16. 1.–15. 7. 2017
4. Gerard Ratoka Lekhema, Kingdom of Lesotho, and Ryan Olivares, Manila, Philippines, tutees of the EU INSC project, 9. 2.–31. 3. 2017
5. Prof. Michel Giot, UCL, Louvain School of Engineering SST, Louvain-la-Neuve, Belgium, and prof. dr. Abdallah Lyoussi, CEA, France, 1. 3. 2017
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9. Solène Tarride, ERASMUS student exchange programme, National School of Computer Science for Industry and Business (ENSIIE), Évry, France, 5. 6.–25. 8. 2017
10. Dr. Pierre Dossantos, International relations, ENSIIE, University of Evry, Evry, France, 18. 7. 2017

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16. Mathew J. Nancekievill, Ashley R. Jones, University of Manchester, Manchester, United Kingdom; Arran Plant, University of Lancaster, Lancaster, United Kingdom, 28. 11.–29. 11. 2017
17. Iñaki Gomez Alonso, visiting researcher, Astigarra, Irun, San Sebastian, Spain, 1. 12. 2017–30. 9. 2018
18. Loic Barbot in Damien Fourmentel, Alternative Energies and Atomic Energy Commission – CEA, DEN / DER / SPEX / LPE, Cadarache, France, 11. 12.-21. 12. 2017

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BIBLIOGRAPHY

Original Article

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PROFESSIONAL MONOGRAPH

1. Tanja Goričanec, Andrej Trkov, Roberto Capote Noy, *Analysis of the U-238 Livermore pulsed sphere experiments benchmark evaluations*, (INDC(NDS), 0742), Vienna, IAEA, 2017.

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MENTORING

1. Romain Henry, *Neutronic and thermal-hydraulics coupling for simulations of the TRIGA Mark II reactor:* doctoral dissertation, Ljubljana, 2017 (mentor Iztok Tiselj; co-mentor Luka Snoj).

DEPARTMENT OF EXPERIMENTAL PARTICLE PHYSICS F-9

Departmental research is devoted to experimental studies of elementary particles, to reveal the ultimate building blocks of matter and the nature of the interactions between them. Experiments are carried out within large collaborative programmes at international centres for particle physics at CERN near Geneva and at KEK in Tsukuba. The department is also engaged in developing and applying the technologically advanced particle detectors that are demanded by such measurements. Astroparticle physics is an emerging field applying the experimental techniques of particle physics to solve astrophysical problems. Slovenian researchers are participating in measurements of ultra-high-energy cosmic rays with the Pierre Auger observatory spread over a surface of 3000 km² near Malargue in Argentina.

Head:
Prof. Marko Mikuž

In order to reveal the ultimate secrets of nature in the world of elementary particles, accelerators with higher and higher energies are needed. Their cost, both in terms of money and human resources, has grown to the level where they are affordable only as joint international enterprises. Thus, future accelerators will be unique facilities of their kind, the first being the Large Hadron Collider (LHC), just completed at the European Organization for Nuclear Research (CERN) near Geneva. Researchers will exploit this facility to perform experiments in presently inaccessible regions of energy, which, though pushed higher and higher, still remain minute compared to that of the vast blast of the Big Bang that led to the creation of the Universe.

Together with colleagues from the Physics Department of the Faculty of Mathematics and Physics and the Faculty of Electrical Engineering of the University of Ljubljana, and from the Faculty of Chemistry and Chemical Technology of the University of Maribor, we are performing measurements at CERN and the Japanese centre KEK in Tsukuba. We are taking part in two experiments, each conducted as an international collaboration:

- ATLAS at the Large Hadron Collider (LHC) at CERN (3000 researchers, 175 institutions from 38 countries),
- Belle II at the asymmetric electron-positron collider (KEK-B) at KEK (750 researchers, 101 institutions from 22 countries)

In 2017 the ATLAS collaboration published more than 100 scientific papers in the most distinguished scientific journals, bringing the total number of scientific papers published by the collaboration to 700.

In the field of astroparticle physics we are part of the Pierre Auger collaboration (250 researchers, 94 institutions from 17 countries), which uses a giant-scale (3000 km²) observatory near Malargue in Argentina for detection of ultra-high-energy cosmic rays. This endeavour is carried out in collaboration with colleagues from the University of Nova Gorica.

A more detailed report on the 2017 activities follows, focused on the contributions of our researchers:

ATLAS experiment

In 2015 the upgraded Large Hadron Collider (LHC) began its operation at CERN and reached a record centre-of-mass energy of 13 TeV, which marks the beginning of the "Run 2" of LHC operation. In 2016 and 2017 the LHC then exceeded all expectations and facilitated the recording of the largest quantity of data at the ATLAS experiment so far. The amount of the ATLAS experiment proton-proton collision data at 13 TeV in the years 2015-2017 reached the integrated luminosity of 80 fb^{-1} of exceptional data (Fig. 1), which led to the most precise Run 2 searches of new physics beyond the Standard Model hitherto achieved. In the analysed data a considerable number of different theories were excluded and there are some indications for potential new discoveries in the particle physics – however, for confirming or refuting these a larger amount of data needs to be recorded and analysed. Subsequently, the next two years will be full of challenges and expectations of pivotal events. In 2017 the ATLAS collaboration published more than 100 scientific papers [1,2] in the most distinguished scientific

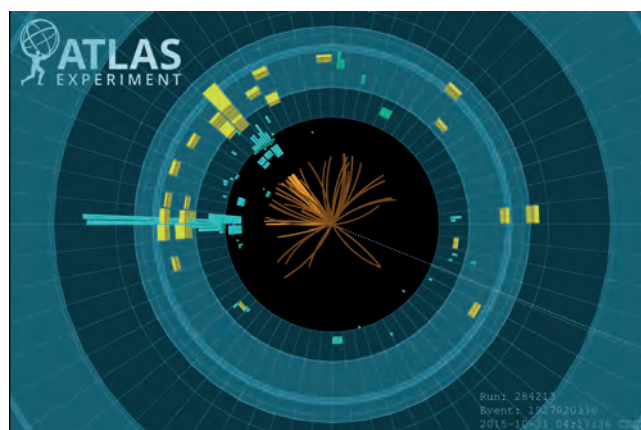*Figure 1: The event display of a proton-proton collision at a centre-of-mass energy of 13 TeV taken in 2017, showing an event candidate for the Higgs boson decaying into heavy b quarks. The ETMiss, shown as a white dashed line, has a magnitude of 294.3 GeV. The two central high-pT b-tagged jets are shown as green and yellow bars corresponding to the energy deposition in the electromagnetic and hadronic calorimeters, respectively.*

journals, bringing the total number of scientific papers published by the collaboration to 700, with more than a hundred further papers in preparation.

The ATLAS Ljubljana group had a leading role in designing, building and operating several beam and radiation monitoring systems, namely: ATLAS Beam Condition Monitor (BCM), Beam Loss Monitor (BLM), Radiation Monitor (RADMON) and Diamond Beam Monitor (DBM). BCM was built to monitor conditions of the LHC beams and issue warnings about unexpected and potentially dangerous situations. In the first part of the LHC operation it served as the main luminosity monitor of ATLAS. BLM on the other hand is solely a safety system and protected the ATLAS Inner Detector from potential damage by LHC beams which fired and extracted LHC beams a few times. RADMON records the doses received by different parts of the ATLAS Inner Detector. Newly built DBM was installed during the last shutdown and was used for the first time in 2015. It is built from a pCVD diamond sensor and a pixel readout chip with pixels of size $250 \times 50\ \mu m^2$. It will provide luminosity measurements complementary to the BCM and other luminosity monitors in ATLAS. Its readout is ready to be tested during the operation with beams. For the High Luminosity upgrade we are developing yet another system to replace the current beam abort and luminosity monitors based on pCVD diamond sensors. The readout chip for the new system is being developed.

> **The new Diamond Beam Monitor (DBM) is built from a pCVD diamond sensor and pixel readout chip with pixels of size $250 \times 50\ \mu m^2$**

The collaboration at ATLAS intends to upgrade the detector in the next decade. The upgraded detector will be able to record the data even at the highest luminosity (5×10^{34} cm^{2}s^{-1}) delivered by the HL-LHC collider (High Luminosity LHC). The inner part of the detector will be replaced by a new tracker of charged particles with sensors based on semiconductor technology. Our department is involved in the development of sensors, readout electronics and support structures. The company ELGOLINE from Podskrajnik is fabricating multilayer flexible circuits, which will serve as the interface between the detector modules and the control electronics.

Belle detector at the asymmetric electron positron collider KEKB at KEK

The experiments Belle and Belle II, operating at the electron positron collider KEKB / SuperKEKB in Tsukuba, Japan, belong to the group of so-called intensity frontier experiments in experimental particle physics. The aim of such experiments is a search for processes and particles (Fig. 2,3), not included in the Standard Model (SM), commonly addressed as New Physics (NP); to do so, extremely precise measurement results are confronted to predictions of the SM. While the latter is considered as a very successful effective theory, it is believed that NP must exist and is responsible – among other things – for the observed matter–antimatter asymmetry in the universe.

Among the most significant results of the Belle collaboration (537 researchers from 91 institutions and 20 countries) in 2017 are measurements of processes in which a b quark decays into a final state composed of an s quark and a photon, and search for the CP symmetry violation in decays of D^0 mesons.

Hadronic processes, in which the quark underlying process is $b \to s\,\gamma$, are forbidden at first order in the framework of the SM. They can proceed through the rare penguin processes (higher order). Due to that, they represent an interesting field of searches for NP. The collaborators at Belle performed a measurement of $B \to K^*\gamma$ decays [3] revealing a statistically significant isospin violation, i.e., a difference between the rates of $B^0 \to K^{*0}\gamma$ and $B^\pm \to K^{*\pm}\gamma$ decays. Within the measurement accuracy, the observed asymmetry is still consistent with the SM prediction. A significantly improved measurement will be possible using the data recorded by the Belle II detector.

> **Research within the Belle II collaboration was focused on the preparation of the early data analyses.**

A related process to $b \to s\,\gamma$ is a process $b \to s\,l^+l^-$, where instead of a photon in the final states one finds a pair of electrons or muons. Belle collaborators performed [4] a full angular distribution study of $B \to K^* l^+ l^-$, where $l = e$ or μ. The results confirm the previously observed discrepancy with respect to the SM predictions, measured by the LHCb experiment [4].

While the CP symmetry violation (violation of symmetry at simultaneous parity transformation and particle/antiparticle replacement) in the system of B meson is experimentally well established, it has not yet been observed in the decays involving D mesons. A measurement of CP asymmetry between D^0 and meson decays into the $K_s^0 K_s^0$ final state has been measured by Belle [Belle 4]. The result is consistent with a null asymmetry and hence in agreement with the SM prediction.

Research within the Belle II collaboration (750 researchers from 101 institutions in 23 countries) was focused on the preparation of the early data analyses. The term early data in this context represents the data to be recorded in the Phase 2 of the Belle II detector's commissioning, in the
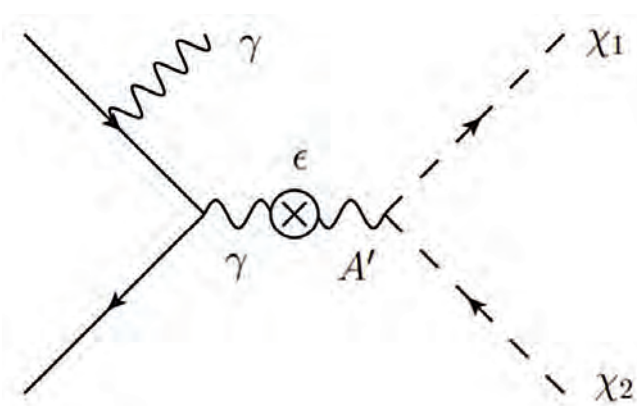

*Figure 2: Feynman diagram of a hypothetical dark photon (A')
production in e+e- collisions, decaying into a pair of light dark-matter
particles ($c_{1,2}$).*

first half of 2018. Due to the absence of the semiconductor vertex detectors in this phase of data taking one of the main fields of measurements will be a search for potential dark-matter constituents. For this purpose many dedicated detailed analyses of simulated data were performed. An example is the search for a dark photon decaying into a pair of light-matter candidates. The latter do not produce a signal in the detector. The experimental signature of such a process (Fig.2), is a single detected photon. The performed simulation analyses shows that already with the data corresponding to an integrated luminosity of 20 fb^{-1} (expected to be recorded during the Phase 2 of Belle II operation) it will be possible to extend the interval of accessible coupling strength between the conventional and the dark photon (Fig.3) by around an order of magnitude with respect to the sensitivities achieved so far. Using the data expected at the end of Belle II running (50 ab^{-1}) this search will be extended for another two orders of magnitude, as can be seen in Fig.2.

Figure 3: Area of sensitivity reach of Belle II in coupling strength and mass of a hypothetical dark photon. The sensitivity using the data at the end of Phase 2 (20 fb-1) and the final Belle II data set (50 ab-1) is shown.

Pierre Auger observatory

The Pierre Auger Observatory is an international cosmic ray observatory in Argentina designed to detect ultra-high-energy cosmic rays: sub-atomic particles traveling nearly at the speed of light and each with energies beyond 10^{18} eV. In the Earth's atmosphere such particles interact with air nuclei and produce various other particles. Secondary particles forming the so-called "air shower" can be detected and measured in order to clarify the origin of the highest-energy primary particles and their properties like energy, arrival direction and the particle type (photons, protons, atomic nuclei). But since these high-energy particles have an estimated arrival rate of just 1 per km^2 per century, the Auger Observatory has created a detection area of 3000 km^2 to be able to record a large number of these events. It is located in the western Mendoza Province, Argentina, near the Andes.

The Pierre Auger Observatory combines two complementary techniques to measure air showers. On their way through the atmosphere the secondary particles stimulate nitrogen molecules in the air to emit fluorescence light. This light is measured with large telescopes. In addition, secondary particles reaching ground level are registered in an array of particle detectors. The latter are water Cherenkov detectors, measuring the light emitted by relativistic particles passing through a water tank.

The Pierre Auger Collaboration has shown that the energy spectrum of cosmic rays exhibits a sharp drop around 10^{20} eV. This drop is compatible with the Greisen-ZatsepinKuz'min (GZK) cut-off caused by the universe becoming opaque due to resonant collisions between ultra-high-energy protons and the photons of the cosmic microwave 2.7 K background radiation. Past measurements by the Pierre Auger Collaboration have already cast some doubt on this explanation, and this year's results further established that the GZK cut-off cannot be the entire story and even the extent of its contribution to the cut-off remains unclear.

Collisions of ultra-high-energy cosmic rays on atmospheric molecules provide hadronic interactions at an energy that exceeds the LHC centre-of-mass energy by one to two orders of magnitude. Although progress was made in incorporating the LHC results, some mysteries were not solved. The number of muons in Monte Carlo simulations is very significantly smaller than the number measured in the experimental data. Also, the depth at which most muons are produced that reach the Earth's surface cannot be described by a Monte Carlo simulation for any reasonable composition mix of cosmic rays.

In September 2017 the Pierre Auger Collaboration reported the first observational evidence that cosmic rays originate from much further away than our Galaxy, by studying more than 30,000 cosmic rays with energies greater than 1 Joule. At higher energies, the rate of the arrival of cosmic rays on top of the atmosphere drastically drops, but deflections are expected to be smaller, so that their arrival directions could possibly point closer to their homeland. By studying the arrival direction of nearly 900 cosmic rays with energies larger than 6 Joules (39 × 10^{18} eV), it is found that about 10% of those cosmic rays cluster within 13° of the directions of starburst galaxies.

The Pierre Auger observatory is currently upgrading its detection capabilities. The key element of the upgrade will be the installation of a plastic scintillator on top of each existing surface detector station. It will provide a complementary measurement of the showers allowing the reconstruction of muons and electromagnetic particles. The surface scintillator detector stations (SSD) will be deployed over the full 3,000-km^2 area of the overall surface detector (SD). To enhance the capabilities of the surface detector, especially for composition measurements, it will be equipped with upgraded electronics with a larger sampling rate and a larger dynamic range.
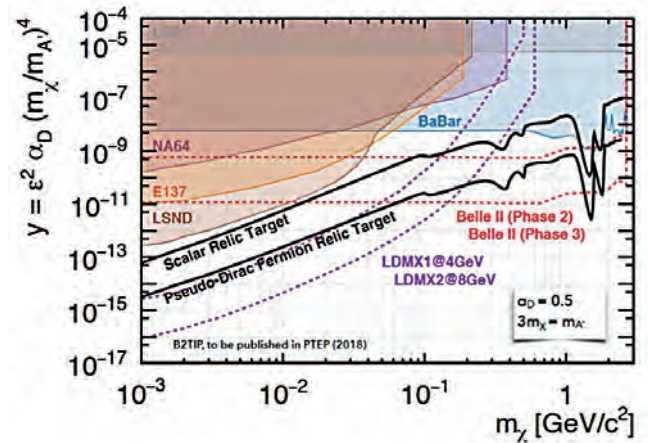
In September 2017 the Pierre Auger Collaboration reported the first observational evidence that cosmic rays originate from much further away than our Galaxy

Distributed computing

The computing resources of SiGNET Tier-2 were increased to 6500 CPU cores and 4.PB of storage space in 2017, while the throughput of the international link to the LHCONE network was upgraded to 30Gb/s. The usage of CPU resources was 95% and the disk storage was at 98%. Most of the computing resources are dedicated to simulation and the deconstruction of data produced with the ATLAS detector and for Monte-Carlo simulation of the Belle II detector. The general purpose NSC cluster at the Jožef Stefan Institute and the computing centre of ARNES are transparently included in the distributed computing infrastructure within WLCG collaboration and EGI infrastructure. The arcControlTower system that manages the job execution at ATLAS experiment computing centres was in collaboration with Faculty of Computing and Information Science adapted to a general purpose system which users can leverage for personal job submission to Slovenian computing centre and enables the quick processing of 100 TB data in few hours.

A four-day "ARC F2F" workshop was organized in November at the Jožef Stefan Institute within the Nordugrid collaboration framework devoted to distributed computing and data-management evolution. As a constitutive member of the Slovenian National Grid Initiative SLING/NGI the site had supported and maintained the Slovenian grid infrastructure together with Arnes. The Slovenian distributed infrastructure incorporates seven clusters from the Jožef Stefan Institute, Arnes, Acrtur, University of Nova Gorica, and several others are in the process of joining with a vision to create a powerful distributed computing infrastructure in Slovenia. The SiGNET is a full member of international organizations EGI/InSPIRE, wLCG and Nordugrid and participated in several joint projects related to support, maintenance and planning of the computing infrastructure as well as the development, distribution and deployment of the distributed computing infrastructure.

Detector development

In 2017 CMOS was officially accepted by the ATLAS collaboration as the technological option for one layer of pixel detectors of the charged particle tracker after the upgrade of LHC to HL-LHC. Measurements of radiation-damage effects on the charge-collection properties in CMOS detectors made by our group contributed significantly to this decision. In 2017 we measured and explained the large effect of thinning and backplane processing on the charge collection in the CMOS detectors after irradiation. In a promising version of CMOS technology detectors are processed on a thin (25 μm) layer of epitaxial silicon, which can be depleted already at reverse bias of few volts. The innovative modification of the doping profile of detector volume resulted in good charge collection with small collection electrode also after irradiation. The small collecting electrode because of its small capacitance lowers the power required by amplification circuitry reducing the load of the cooling system. Our group made complex E-TCT measurements of irradiated detectors and the parameters of design of new detector series were set, based on the results of our measurements. Important results were also obtained from our measurements of CMOS detectors irradiated with protons. Radiation damage caused by protons has a different effect on the performance of detectors than neutrons (Fig.4). Protons contribute significantly to the radiation environment in the ATLAS inner detector so it is necessary to study their effect on detectors that will be operating there.

In the past year we continued the work on development of High Granularity Timing Detector for ATLAS. We took the leading role in radiation studies of Low Gain Avalanche Detectors (LGAD), which are the choice for the sensor technology and were proven to fulfil the requirements of HGTD. We have evaluated thin LGADs from several producers and showed that the performance is similar for all. The dependence of gain on fluence was precisely measured in the entire range of HL-LHC fluences and the measured time resolution (50-60 ps per sensor) was sufficient also at the highest fluences provided <50 μm thick sensors are used. At high fluences the multiplication takes place in silicon bulk as a consequence of large space charge originating from irradiation. This improves the signal rise time and compensates partly for the loss of gain due to acceptor removal in the gain layer. The first measurements of Ga-doped LGADs were performed this year in an attempt to mitigate initial acceptor removal. As a part of sensor development a setup for precise time measurements with LGADs was constructed at JSI.

A multichannel system for simultaneous readout of different dosimetric sensors was further developed. Apart from its use in medical applications the system is used also for precise dosimetric measurement during irradiations at the JSI reactor facility.

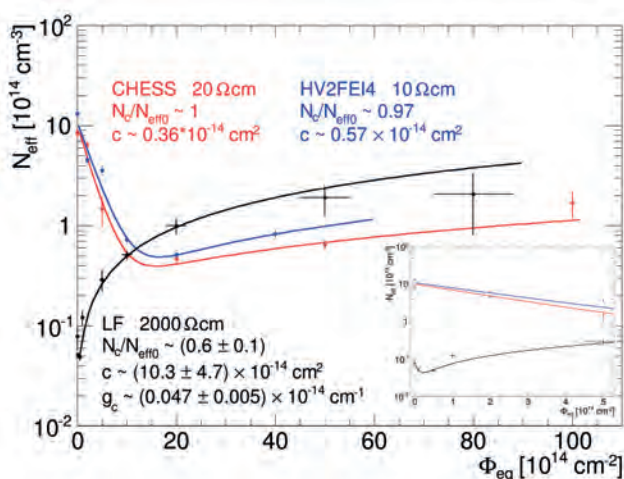**We took the leading role in radiation studies of Low Gain Avalanche Detectors (LGAD)**

Figure 4: Fluence dependence of effective space charge concentration in irradiated CMOS sensor Measurements were made on sensors with different initial dopant concentrations.

We continued with the development of new methods for the detection of annihilation gamma rays in positron emission tomography (PET), one of the most important medical imaging methods. We have already shown that the difference in the time of flight for two gamma rays can be measured with a very high precision of 80ps (FWHM) if a Cherenkov radiator is used as a gamma ray converter instead of a scintillator. With such a resolution, we can directly obtain three-dimensional information on the emission point of the two gamma rays, which substantially reduces the time needed to determine the activity distribution in the patient. While this first result was achieved with a microchannel plate photomultiplier tube (MCP PMT) as the low level light sensor, we have in 2016 continued with the examination of possibilities offered by silicon photomultipliers (SiPM), compact semiconductor based light sensors that can be operated in high magnetic fields (important for the multimodal imaging in combination with MRI), and would be much cheaper. The results have shown that by using single Cherenkov photon hit, a resolution can be achieved that is better than 200 ps; we have also started to investigate how the resolution could be improved in multi-hit cases.

Within the frame of research of particle-physics detectors in medical physics we have performed the characterization of low gain avalanche diodes (LGAD) matrices. The measurements will be used in element selection for a suitability study of a Compton camera with LGAD detectors for proton therapy.

We developed a prototype of an annihilation gamma photon detector with an improved spatial resolution, based on LYSO crystal matrix segmented to cells with sides of 1.5 mm. The prototype is shown in the attached photograph (Fig. 5). Tasks related to the LYSO prototype development and evaluations were also performed.

Figure 5: Flood image taken with LYSO crystals and cell size 1.5 mm x 1.5 mm

Within the CIMA international collaboration consisting of scientists from Ohio State University (OSU), University of Michigan (UM), University of Valencia and JSI we have continued to evaluate the prototype of a high-resolution PET system with silicon detectors at OSU. We have continued the analysis of recorded images.

Within the framework of the European project AIDA 2020 (Advanced European Infrastructures for Detectors at Accelerators) more than 180 irradiations by neutrons were performed at the reactor centre at the request of 22 different institutions. The focus was on the development of components for planned upgrades of the ATLAS, CMS and Belle detectors.

Some outstanding publications in the past year

1. M. Aaboud et al.: (ATLAS collaboration) Phys. Lett. B 765, 11-31 (2017)
2. G. Aad et al.: (ATLAS collaboration) Eur. Phys. Journal C77 (2) (2017)
3. T. Horiguci et al. (Belle Coll.), Phys. Rev. Lett. 119, 191802 (2017)
4. S. Wehle et al. (Belle Coll.), Phys. Rev. Lett. 118, 111801 (2017)
5. I. Mandić, V. Cindro, A. Gorišek, B. Hiti, G. Kramberger, M. Mikuž, M. Zavrtanik, T. Hemperek, M. Daas, F. Hügging, H. Krüger, D.-L. Pohl, N. Wermes and L. Gonella: JINST Vol. 12, (2017)

Awards and Appointments

1. Gregor Kramberger, Erik Margan – award for technical improvements: Multi-channel small ionization flow meter and MOSFET and PIN dosimeter sensor. Ljubljana: Jožef Stefan Institute, Department of Environmental Science, Ljubljana, Slovenia

Organization of Conferences, Congresses and Meetings

1. ARC F2F Workshop 2017, Jožef Stefan Institute, Ljubljana, Slovenia, 28 November – 1 December 20171

INTERNATIONAL PROJECTS

1. COST TD1401; Fast Advanced Scintillator Timing (FAST)
   Prof. Peter Križan
   Cost Office
2. COST CA16108 - VBSCan; Vector Boson Scattering Coordination and Action Framework
   Prof. Borut Paul Kerševan
   Cost Office
3. IAEA Fellowship for Ms Maizura Binti Ibrahim (MAL/15013), 15.8.2016-29.9.2016
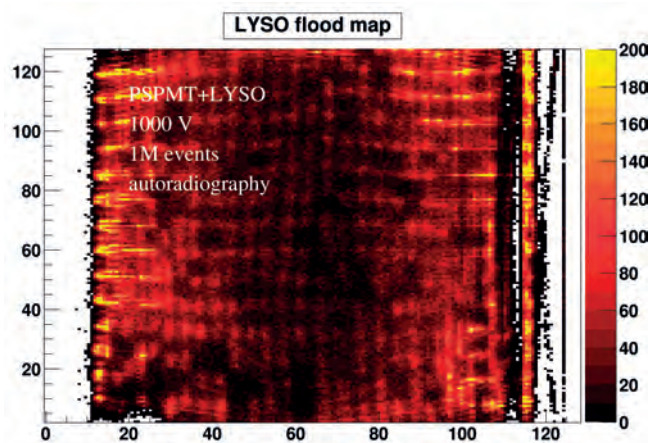
Prof. Marko Mikuž
IAEA - International Atomic Energy Agency
4. H2020 - JENNIFER; Japan and Europe Network for Neutrino and Intensity Frontier Experimental Research
   Prof. Peter Križan
   European Commission
5. H2020 - SCICHALLENGE; Next Generation Science Challenges using Participatory Techniques and Digital Media

Prof. Marko Mikuž
European Commission
6. H2020 - AIDA-2020; Advanced European Infrastructures for Detectors at Accelerators
Prof. Marko Mikuž
European Commission
7. Studies of Silicon Detector Properties by Using Transient Current Technique
Dr. Gregor Kramberger
Slovenian Research Agency
8. Development of Solid State Detectors and Readout Electronics for Experimental Particle Physics and Medical Diagnostics
Dr. Andrej Gorišek
Slovenian Research Agency
9. Development of Silicon Detectors for Medical Applications
Prof. Marko Mikuž
Slovenian Research Agency

RESEARCH PROGRAMS

1. Astroparticle Physics
Prof. Marko Zavrtanik
2. Experimental Particle Physics
Prof. Marko Mikuž

R & D GRANTS AND CONTRACTS

1. History of Doctoral Dissertations by Slovene Candidates in the Austro Hungarian Empire (18721918)
Prof. Boštjan Golob
2. Novel scintillation detectors for precision particle physics experiments
Prof. Peter Križan
3. Collaboration CERN RD-39
Prof. Marko Mikuž
Cern

VISITORS FROM ABROAD

1. Ronald Cintro Shellard, Brasilian Center for Research in Physics, Brazil, 10. 2. 2017
2. Itana Bubanja, Faculty of Science and Mathematics, University of Montenegro, Montenegro, 17. 4. – 28. 4. 2017
3. Leonid Burmistrov, Laboratoire de l'Accelerateur Lineaire, France, 9 .5 . – 12. 5. 2017

4. Collaboration CERN RD-50
Prof. Marko Mikuž
Cern
5. Collaboration DELPHI
Prof. Borut Paul Kerševan
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6. Collaboration ATLAS
Prof. Marko Mikuž
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7. Collaboration CERN RD-42
Prof. Marko Mikuž
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8. Collaborations Belle in Belle II
Prof. Peter Križan
Kek - High Energy Accelerator Research
9. Design, Procurement and QA of Flex-rigid Hybrids
Prof. Marko Mikuž
European Organization For Nuclear Research
10. Irradiations in TRIGA Nuclear Reactor
Prof. Vladimir Cindro
11. Workshoop: 4th FAST WG3/4/5 8-9 January 2018
Prof. Peter Križan
12. Rental of equipment and work space on JSI
Dr. Gregor Kramberger
Particulars d. o. o.

NEW CONTRACTS

1. Calibration of transmission lines
Prof. Vladimir Cindro
Elgoline d. o. o.
2. International Collaboratin of ATLAS - Costs Refundation
Prof. Marko Mikuž
Ministry of Education, Science and Sport

4. Maizura Ibrahim, Malaysian Nuclear Agency, Malaysia, 14. 8. – 30. 9. 2017
5. XiaoQuan Song, Ocean University of China, China, 18. 9. – 19. 9. 2017
6. Marko Miliovanović, Desy Zeuthen, Germany, 26.12. – 28.12.2018

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ORIGINAL ARTICLE

1. AUGER Collaboration, A. Aab *et al.*, "Calibration of the logarithmic-periodic dipole antenna (LPDA) radio stations at the Pierre Auger Observatory using an octocopter", *Journal of instrumentation*, **12**, T10005-0-T10005-37, oct. 2017.
2. AUGER Collaborations, A. Aab *et al.*, "Combined fit of spectrum and composition data as measured by the Pierre Auger Observatory", *Journal of cosmology and astroparticle physics*, **2017**, 1-40, Apr. 2017.
3. AUGER Collaboration, A. Aab *et al.*, "Impact of atmospheric effects on the energy reconstruction of air showers observed by the surface detectors of the Pierre Auger Observatory", *Journal of instrumentation*, **12**, P02006-0-P02006-22, Feb. 2017.
4. AUGER Collaboration, A. Aab *et al.*, "Inferences on mass composition and tests of hadronic interactions from 0.3 to 100 EeV using the water-Cherenkov detectors of the Pierre Auger Observatory", *Phys. rev., D*, **96**, 12, 122003, Dec. 2017.
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6. AUGER Collaboration, A. Aab *et al.*, "Muon counting using silicon photomultipliers in the AMIGA detector of the Pierre Auger Observatory", *Journal of instrumentation*, **12**, 1-23, Mar. 2017.
7. AUGER Collaboration, A. Aab *et al.*, "Observation of a large-scale anisotropy in the arrival directions of cosmic rays above 8×10^{18} eV", *Science (Wash. D.C.)*, **357**, 6357, 1266-1270, sep. 2017.
8. AUGER Collaboration A. Aab, Andrej Filipčič, Gašper Kukec Mezek, Ahmed Saleh, Samo Stanič, Marta Trini, Darko Veberič, Serguei Vorobiov, Lili Yang, Danilo Zavrtanik, Marko Zavrtanik, et al., "Search for photons with energies above 10^18 eV using the hybrid detector of the Pierre Auger Observatory", *Journal of cosmology and astroparticle physics*, **2017**, 1-17, Apr. 2017.
9. AUGER Collaboration, A. Aab *et al.*, "Spectral calibration of the fluorescence telescopes of the Pierre Auger Observatory", *Astropphys.*, **95**, 44-56, 2017.
10. AUGER Collaboration, A. Aab *et al.*, "A targeted search for point sources of EeV photons with the Pierre Auger Observatory", *The astrophysical journal, Letters*, **837**, 2, 1-7, Mar. 2017.
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Published Conference Contribution

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2. Ahmed Mohamed Saleh Hassanin Khalil, *Studies of astrophysical very-high energy gamma-ray emission with the Pierre Auger Observatory:* doctoral dissertation, Nova Gorica, 2017 (mentors Sergey Vorobyev, Danilo Zavrtanik).

DEPARTMENT OF INORGANIC CHEMISTRY AND TECHNOLOGY   K-1

The Department of Inorganic Chemistry and Technology is one of the leading groups in the world for the synthesis of new inorganic compounds containing fluorine. The main research fields are: the synthesis of new coordination compounds with different ligands, the chemistry of noble gases, the chemistry of elements of the main groups, the synthesis of new hybrid materials and inorganic materials with special properties. A great deal of the activity of the group has been devoted to technological, ecological and process-safety issues in Slovenia. The group has already been cooperating closely with Slovenian industry for more than 30 years. It is also active in the field of education and in the field of the promotion of natural sciences among students at colleges and elementary schools.

Head:
Asst. Prof. Gašper Tavčar

The vast experiences of the department in the research field of fluorine inorganic chemistry resulted in chapters in the book "Modern Synthesis Processes and Reactivity of Fluorinated Compounds", the third volume in Elsevier's series "Progress in Fluorine Science Series", which was published in 2017. It describes the photochemical syntheses of various fluorides in anhydrous hydrogen fluoride and was provided by Dr. Zoran Mazej. The book is the third volume of this series and provides information about the latest synthesis routes to fluorocompounds and the involved reaction mechanisms. Special attention is given to the unique reactivity of fluorine and fluorinated media, along with the correlation with those properties to valuable applications of fluorinated compounds.

The $[SbF_6]^-$ anion belongs to the group of weakly coordinating anions and is therefore useful for the preparation of many coordination compounds with various cations. We reported about the crystal structures of $[SbF_6]^-$ compounds, containing hydrated Ag^+, Pd^{2+} and Cd^{2+} cations. Since the $[SbF_6]^-$ anion is resistant to oxidation, it can be used for the preparation of new types of Xe(VI) compounds. The results of the study of the $A^+/[XeF_5]^+/[PnF_6]^-$ (A = Rb, Cs; Pn = Sb, Bi) system were reported in *Eur. J. Inorg. Chem.* (2017). This work was presented in "*Cover Profile*".

The Ag^{2+} cation is among the strongest one-electron oxidizers that is capable of oxidizing O_2 and Xe in the superacidic environment. Because of its reactivity, it is not stable in an aqueous environment. $AgSO_4$ is a unique example of a Ag(II) compound containing F-free anion. Surprisingly, the action of atmospheric moisture on shiny black crystals of $AgSO_4$ generates black powder, which corresponds to $AgSO_4 \times H_2O$. The contribution "*[Ag(OH_2)_2][Ag(SO_4)_2]: the first hydrate of an Ag(II) salt*", where one of the authors is also Z. Mazej (IJS), was published in 2017 in *Chemistry - A European Journal*. It was highlighted on the inner cover page of one of the issues.

Carbon nanotubes, made from carbon atoms arranged in hexagons, are probably the best-known nanotubes. A group of researchers from the USA, Poland and Slovenia (IJS, Z. Mazej) discovered a completely new type of inorganic nanotubes. They contain only silver and fluorine, and – unlike carbon nanotubes – they are made of squares rather than hexagons. If a nanotube would be cut open it would resemble chessboard rather than honeycomb. The research was published in *Dalton Transactions* (2017) and highlighted by the internet chemistry portal *ChemistryViews* (*First Metal Fluoride Nanowire*). An extended experimental study, supported by theoretical calculations, about the structural transitions of silver(II) fluoride under high pressure (up to 40 GPa) was published in a separate contribution in *Inorganic Chemistry* (2017).

In collaboration with the Materials Synthesis Department the degradation of NaYF4:Yb,TmNaYF4:Yb,Tm-based upconversion nanoparticles in phosphate buffered saline solution has been studied and amphiphilic coatings for the protection against dissolution in aqueous media have been suggested.

Reactions of SbF$_3$ with N-heterocyclic carbenes resulted in the preparation of hybrid materials. We have successfully determined the reaction mechanism and the behavior of the system, both in solution and in the solid state with the use of NMR spectroscopy. It has also been shown that the auxiliary ligand (tmen) does not enter the reaction mechanism and does not affect the

The Ag^{2+} cation is among the strongest one-electron oxidizers that is capable of oxidizing O$_2$ and Xe in the superacidic environment
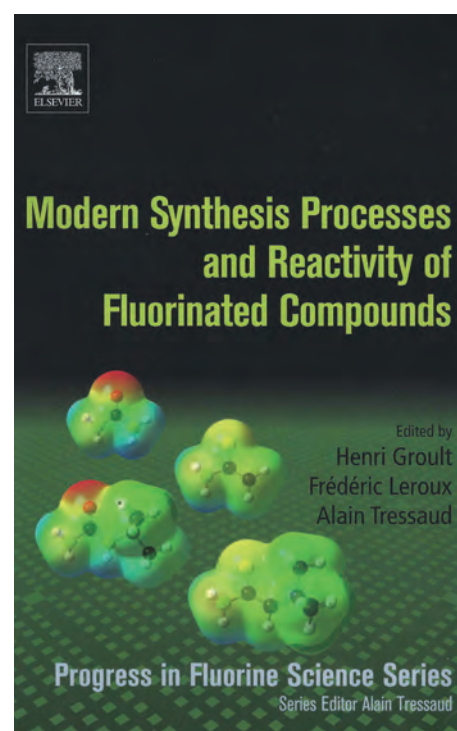
Figure 1: Cover of the book "Modern Synthesis Processes and Reactivity of Fluorinated Compounds", Wiley, 2017; Zoran Mazej contributed the chapter Photochemical Syntheses of Fluorides in Liquid Anhydrous Hydrogen Fluoride

Figure 2: a.) Cover of the European Journal of Inorganic Chemistry No. 21, 2017 (Design cover M. Mazej), b.) Inside Cover of Chemistry of a European journal No. 8, 2017

abnormal rearrangement of the NHC. Such a rearrangement of the NHC ligand is quite rare and has been noticed on the fluoride substrate for the first time. Imidazolium fluoride $[(L^{Dipp})H][F]$ was studied as a good source of fluoride with fluoroacids SiF_4 and GeF_4. We have managed to obtain discrete trigonal bipyramidal SiF_5^- and GeF_5^- anions. Such a geometry of anions is relatively rare compared to the octahedral geometry of anions. Using single-crystal X-ray diffraction we have achieved the first structural determination of a trigonal bipyramidal GeF_5^- anion so far. The ^{19}F NMR spectrum of related species GeF_5^- and GeF_6^{2-} were also studied in organic solvents. Quantum chemical calculations supporting the results were made in cooperation with the Department of Physical and Organic Chemistry. The work was completed by comparing the calculated stability of the trigonal bipyramidal to octahedral species together with the interpretation of the disorder in the crystal structure as a result of the rigid rotation or the Barry pseudo-rotation mechanisms of the prepared anions. This work was published in Inorganic Chemistry (2017) and was also highlighted by the internet chemistry portal *ChemistryViews* (GeF_5^- Anion Characterized).

The interaction of elemental copper with a mixture CCl_4 - DMSO in the presence of an additional ligand was studied. New copper(I) pi-complexes were synthesized and their non-linear optical properties were investigated.

We have continued with the optimization of the solvothermal processes for the preparation of nanostructured metal fluorides. Results additionally confirm the key role of alcoholic solvents on the macrostructure of solid products. Very voluminous aerogels based on AlF_3 are obtained exclusively in cases when the liquid medium contains methanol. Combinations of other alcohols solvents yield products that are more compact. The successful use of SiF_4 for the fluorination of the starting alkoxides opens the way towards the possible direct preparation of mixed AlF_3/SiO_2 materials in the form of aerogels or xerogels. A series of metal fluorides with high surface areas was also prepared as a possible catalyst for the activation of small molecules using related techniques. This research is performed in collaboration with a research group from Poland.

The reaction of the naked fluoride reagent $[(L^{Dipp})H][F]$ with SiF_4 and GeF_4 leads to their elusive, trigonal bipyramidal SiF_5^- and GeF_5^- anions

Solid acids based on $H_3(P(W_3O_{10})_4)$ in pure or doped form exhibit mainly Broensted acidity. The use of these materials as possible (super)acidic catalysts in the conversion of methane was investigated in collaboration with the National Institute of Chemistry. New composite materials were also studied as a possible catalyst. Molybdenum halides intercalated graphite was produced by the intercalation of the $MoCl_5$, $MoBr_3$ and MoI_3 into commercial graphite and phosphoric acid activated pyrolytic graphite processed at the National Academy of Sciences of the Ukraine from cornelian cherry dogwood, a fruit processing waste. The $MoCl_5$ intercalated graphite was of stage 2 and stage 3 and was treated with hydrogen sulfide gas at 1050 K to sulfidise the interlayer molybdenum halides and obtain MoS_2 intercalated graphite, the potentially catalytically active material with improved activity.

Figure 3: Crystal structure of $[(L^{Dipp})_2SbF_2]^+$ cation (Dalton Transactions, 46 (2017) 3338)

Within the process safety topic, in 2017 we researched and published work on the relationships among the safety-performance indicators and the dynamic risk assessments, the evaluation of the quality of safety change management in industrial organizations and on the evaluation of the safety culture among the employees. We continued our technical lead of the international consortium for a consultation project involving an industrial client outside Slovenia. It is about the implementation of the individual elements of the process safety management system within the rather large organization in the oil and gas industry (work continues in 2018 and beyond).

In collaboration with partners a control of the operation of decarbonisation facilities and a supermonitoring of the guarantee measurements of ammonia water flow for unit 6 of the Šoštanj Thermal Power Plant.

A group of partners including the JSI was selected in a public tender of the Slovenian Ministry of the Environment and Spatial Planning for the performance of a public order "Preparation of a guidelines proposal for transition to the circular economy (CE) potentials utilization in Slovenia, and support for stakeholders involvement, and communication of the proposal". In general, the project consisted of visits and motivational workshops in all Slovenian regions, producing a report
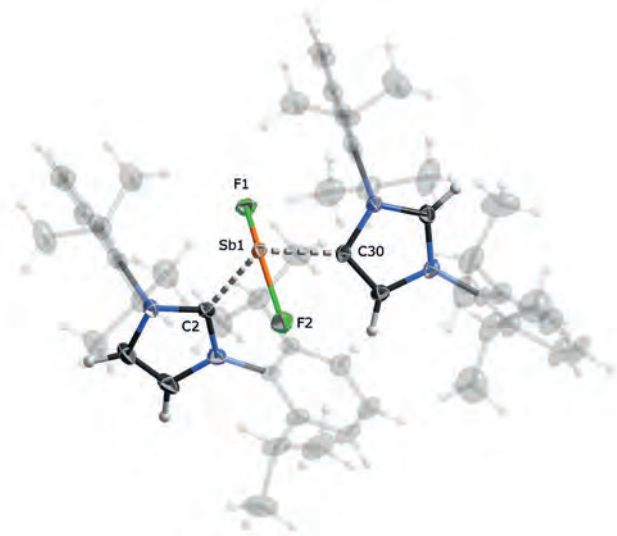
with identified priority areas and potentials for circular solutions in regions, and preparing guidelines for the Government of the Republic of Slovenia in the form of a "Roadmap" document. The role and task of the JSI was to analyze and prepare the appropriate indicators in which to express the goals for the transition to CE, and monitor the transition of the Slovenian economy to CE by following trends of these indicators in-line with the EU CE legal requirements and in comparison with other EU member states. The project started in August 2017 and will finish at the end of April 2018.

The activity in the field of education and the promotion of sciences should be mentioned. Members of the department were actively engaged in the work of the Jožef Stefan International Postgraduate School as lecturers and as mentors to MSc and PhD students. In addition, the School of Experimental Chemistry maintained its very important relations with elementary schools, secondary schools and even kindergartens through experimental courses performed in a specialised laboratory or through direct demonstrations at the schools. With demonstrations of chemical experiments, we participated at the Hokus pokus, Lupa festival and at the Researchers Night. Some of the activities of the School of the Experimental Chemistry were carried out within the project, which is funded by the JSI and the City of Ljubljana.

Figure 4: Structurally characterized discrete GeF_5^- anion (Inorg. Chemistry 56 (2017) 10070)

Some outstanding publications in the past year

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2. B. Alič, M. Tramšek, A. Kokalj, G. Tavčar, Discrete GeF_5^- anion structurally characterized with a readily synthesized imidazolium based naked fluoride reagent, *Inorganic chemistry*, 56 (2017), 10070-10077.

3. Z. Mazej, T. Gilewski, E. A. Goreshnik, Z. Jagličić, M. Derzsi, W. Grochala, Canted antiferromagnetism in two-dimensional silver(II) Bis[pentafluoridooxidotungstate(VI)], *Inorganic chemistry*, 56 (2017) 224-233.

4. B. Alič, A. Štefančič, G. Tavčar, Small molecule activation: SbF3 auto-ionization supported by transfer and mesoionic NHC rearrangement, *Dalton transactions*, 46 (2017) 3338-3346.

5. M. Gerbec, Safety change management - a new method for integrated management of organizational and technical changes, *Safety science*, 100, part B (2017) 225-234.

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INTERNATIONAL PROJECTS

1. Export of the Fluorinated Carbons
   Dr. Zoran Mazej
2. Extraction of Tantalum and Niobium from Ores
   Asst. Prof. Gašper Tavčar
   Prg Ltd.
3. Implementation of Process Safety Management System (PSMS) into NIS j.s.c.
   Prof. Marko Gerbec
   European Virtual Institute For Integrated Risk
4. 7FP - FluoCoorChem; Fluorinated Weakly Coordinating Anions for Coordination Chemistry of Unusual Ligands
   Dr. Matic Lozinšek
   European Commission
5. The Development of a Nondestructive Analytical Method for the Screening of Upconverting Nanoparticles Surface Properties Based on Optical Characterization
   Prof. Maja Ponikvar-Svet
   Slovenian Research Agency

RESEARCH PROGRAM

1. Inorganic Chemistry and Technology
   Asst. Prof. Gašper Tavčar

R & D GRANTS AND CONTRACTS

1. Direct Conversion of Methane to Higher Hydrocarbons Using Superacid Catalysts
   Asst. Prof. Gašper Tavčar
2. CHNS Analysis
   Prof. Maja Ponikvar-svet
3. Analysis of waste acid and H2SiF6 acids
   Asst. Prof. Gašper Tavčar
   Steklarna Rogaška d. o. o.
4. Activity of evaluation to set up a charging station
   Prof. Marko Gerbec
   Istrabenz Plini d.o.o.

NEW CONTRACT

1. A supermonitoring of the guarantee measurements of the Flue Gas Desulphurization Plant of unit 6 of the Šoštanj Thermal Power Plant
   Prof. Maja Ponikvar-svet
   Teš d. o. o.
2. E-Car for students
   Dr. Melita Tramšek
   Alpe Adria Green
3. Consultations services at the update of the formal safety case
   Prof. Marko Gerbec
   Termoelektrarna Brestanica d. o. o.
4. School of experimental chemistry
   Asst. Prof. Gašper Tavčar
   Slovensko društvo ljubiteljev kemije
5. Roadmap: Preparation of a guidelines proposal for Slovenian potentials utilization for the transition to the circular economy
   Asst. Prof. Robert Kocjančič
   Ministry of the Environment and Spatial Planning

VISITORS FROM ABROAD

1. Markus Kauppila, Student exchange, Unwersytet Warszawski, Raahen Ammattiopisto, Raahe, Finland, 18.4. – 26.5. 2017
2. Jakub Czajka in Kacper Koteras, Student exchange, Unwersytet Warszawski, Warsaw, Poland, 5.9. – 18.9. 2017
3. Dr. Rafal Robert Jurczakowski, Cooperation, Unwersytet Warszawski, Warsaw, Poland, 18.9. – 23.9. 2017
4. Justyna Katarzyna Ignaczak, Student exchange, Gdansk University of Tech, Gdansk, Poland, 15.9. – 15.12. 2017

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21. Mira Zupančič

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Review Article

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1. Gabriele Baldissone, Micaela Demichela, Marko Gerbec, Maria Cleva Leva, "Risk-based optimization of operational procedures", In: *Safety & reliability: theory and applications: proceedings of the 27th European Safety and Reliability Conference, ESREL 2017, Portorož, Slovenia, 18-22 June 2017*, Marko Čepin, ed., Radim Briš, ed., Boca Raton, CRC Press, London, Taylor & Francis, 2017, 1763-1768.

2. Marko Gerbec, "Management of technical and organizational changes", In: *Safety & reliability: theory and applications: proceedings of the 27th European Safety and Reliability Conference, ESREL 2017, Portorož, Slovenia, 18-22 June 2017*, Marko Čepin, ed., Radim Briš, ed., Boca Raton, CRC Press, London, Taylor & Francis, 2017, 1595-1602.

3. Marko Gerbec, "Post-ARAMIS project use of the safety climate questinnaire for the process industry", In: *Risk analysis and management - trends, challenges and emerging issue: proceedinngs of the 6th International Conference on Risk Analysis and Crisis Response, (RACR-2017), Ostrawa/Prague, Czech Republic, 5-9 June 2017*, (Communications in cybernetics, systems science and engineering), Aleš Bernatik, ed., Chongfu Huang, ed., Olivier Salvi, ed., Leiden, CRS Press, 2017, 261-275.

4. David Levovnik, Marko Gerbec, "Auditing operational readiness of management of change", In: *Safety & reliability: theory and applications: proceedings of the 27th European Safety and Reliability Conference, ESREL 2017, Portorož, Slovenia, 18-22 June 2017*, Marko Čepin, ed., Radim Briš, ed., Boca Raton, CRC Press, London, Taylor & Francis, 2017, 1659-1666.

5. David Levovnik, Marko Gerbec, "Ocenjevanje pripravljenosti organizacij za izvajanje managementa sprememb v procesni industriji", In: *35. strokovni posvet o poklicni, procesni in požarni varnosti: dvodnevni posvet z mednarodno udeležbo, Portorož 2017, 16.-17. 5. 2017*, Ljubljana, Fakulteta za kemijo in kemijsko tehnologijo, Katedra za poklicno, procesno in požarno varnost, 2017.

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DEPARTMENT OF PHYSICAL AND ORGANIC CHEMISTRY K-3

The basic research of the department is focused on the experimental and theoretical study of various physico-chemical processes at surfaces and in atmospheric chemistry. The main attention in the field of organic chemistry is directed to a green-chemistry approach to the transformation of organic compounds.

Head:
Prof. Ingrid Milošev

Different types of materials were the focus of our research in the field of modern corrosion protection: (i) technological materials and (ii) biomedical materials.

In the area of technological materials we were concentrated primarily on alloys based on aluminium and copper. Aluminium alloys are widely used in different industries and are one of most important materials today, especially in the transportation industry due to the need to reduce vehicle weight and, consequently, to reduce fuel consumption. Traditional ways of corrosion protection for aluminium alloys, i.e., chromate coatings, are not applicable due to ecological restrictions. In the past decade numerous alternatives have been explored, among which the most important are different conversion coatings, sol-gel coatings, superhydrophobic coatings, organic inhibitors, etc. The man goal is to develop environmentally harmless coatings that would achieve the efficiency of chromate coatings in both corrosion protection and adhesion of the organic topcoat. In our laboratory we are investigating several main strategies for the protection of aluminium alloys (series 2xxx, 6xxx and 7xxx), i.e., conversion, sol-gel and hydrophobic coatings.

Before applying any kind of coating, however, it is necessary to pre-treat or appropriately clean the surface of the metal to be coated. The goal of either the pre-treatment or cleaning is to remove any organic and inorganic residues from the surface before treating it with paints or coatings. The effects of mechanical and chemical pre-treatments of AA7075-T6 and AA2024-T3 aluminium alloys were studied in terms of changes in the morphology, composition and wettability of the surface, and of the related corrosion properties in sodium chloride solution. The mechanical treatments tested include grinding under water and non-water diamond polishing. The chemical treatments included etching with sodium hydroxide and with a commercial cleaner and de-smutting in nitric acid. Mechanical water grinding of AA7075-T6 leads to the loss of magnesium, which is preferentially dissolved. The non-water polished surfaces, however, contain a higher proportion of Mg than a water-ground surface. Chemical treatment was carried out using an alkaline NaOH solution and alkaline commercial cleaner, both followed by de-smutting with HNO_3. The treatment with commercial cleaner, however, results in a surface that is morphologically more similar to that of a water-ground sample. Both treated surfaces are hydrophilic.

Two types of conversion coatings are being studied. The first type is rare-earth coatings in the form of cerium and lanthanum nitrates and chlorides. They were used both individually or mixed. Promising results were obtained for coatings containing a mixture of Ce and La chloride salts, which are synergistic and improve the protection compared to individual salts, especially to La alone. Coatings can be prepared either as additives to the corrosion medium, or as individual coatings at the metal surface. In the latter case the procedure is usually stimulated using oxidants such as hydrogen peroxide. The mechanism of formation of conversion coatings includes the progressive precipitation of metal hydroxides from a rare-earth salt solution at the cathodic sites at the metal surface; therefore, blocking the sites of the oxygen reduction reaction. The overall corrosion process is consequently retarded. Another type of conversion coatings studied was a zirconium-based coating prepared from a conversion bath containing zirconium hexafluoride. The coating formation process involves activation of the surface in the acidic fluoride-containing bath

> **Conversion coatings based on rare-earth salts represent an environmentally friendly alternative to toxic and carcinogenic chromate conversion coatings. However, they still do not achieve the efficiency of corrosion protection required to replace the chromate coatings and further formations should be investigated.**
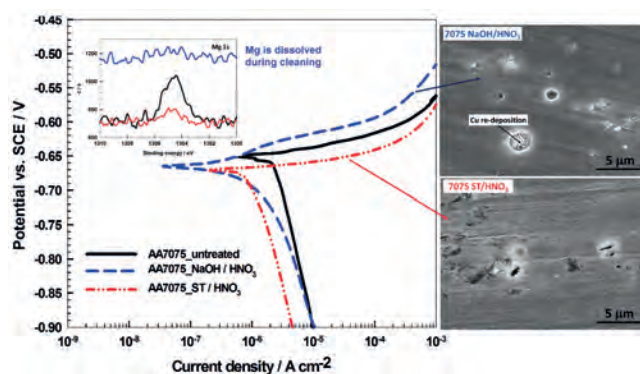
Figure 1: Potentiodynamic polarization curves recorded in 0.1-M NaCl for the aluminium alloy AA7075-T6: ground under water (untreated) and then chemically treated using $NaOH/HNO_3$ and ST/HNO_3 (left panel). X-ray photoelectron spectra shown in inset for Mg 1s signal confirms that the chemical treatment removes magnesium from the surface. Scanning electron microscopy images (right panel) show that copper deposits are formed during chemical cleaning using NaOH, whilst cleaning using less alkaline commercial cleaner preserves a similar morphology to the untreated sample. The study emphasizes the importance of proper chemical cleaning of the surface.

and subsequent deposition at the sites of increased pH. This increase in pH drives the hydrolysis of the fluorometalates to form precipitated hydrated metal oxide layers. The effect of the conversion bath parameters on the efficiency of corrosion protection of Zr-based conversion coating are being studied for aluminium alloys of series 6xxx.

We continue to work on different hybrid sol-gel coatings aiming to protect aluminium alloys in chloride environment. Currently, four types of coatings are being investigated: (i) Hybrid silica sol-gel coatings doped with cerium nitrate are denoted as GTS-Ce coatings. Tetraethyl orthosilicate (TEOS) and organically modified 3-glycidoxypropyl-trimethoxysilane (GPTMS) were used as precursors. Silica SiO_2 (Ludox) particles were added to achieve a barrier properties of coating, while $Ce(NO_3)_3 \cdot 6H_2O$ was added in order to obtain an active corrosion protection. Another type is the so-called TMZ coatings prepared from TEOS and organically modified silicon precursor 3-methacryloxy propyltrimethoxysilane (MAPTMS), which were then mixed with different amounts of zirconium(IV) propoxide (ZTP) chelated using methacrylic acid (MAA). These coatings, denoted as TMZ, offer a high degree of barrier protection. The third type of coating denoted as TMM are polysiloxane hybrid coatings, synthesized from TEOS, MAPTMS and, methyl methacrylate (MMA), and the fourth coatings using GPTMS and ZTP. All these coatings show a high degree a barrier protection due to the formation of a condensed network of Si–O–Si, Si–O–Zr and Si–O–Al bonds, respectively. In the case of GTS-Ce coatings the barrier properties of the silica matrix are combined with the active protection of the cerium nitrate. The mechanism of corrosion protection for these coatings is investigated using electrochemical methods, and long-term immersion testing and testing in a salt-spray chamber. Moreover, these coatings are also subjected to field-testing in the Adriatic Sea. As substrates, two types of aluminium alloys are used of series 6xxx developed by the company Talum d.d. Kidričevo, Slovenia: Al-7Si-0.3Mg and Al-9Si-3Cu. Samples in the form of rectangular plates are mechanically ground and then coated by sol-gel coatings GTS-Ce, TMZ, TMM and ZG using a dip-coating procedure. Uncoated substrates are used as a reference. Uncoated and coated samples were embedded in a Teflon holder and immersed in the Adriatic Sea at the buoy facility (National Institute of Biology, Marine Biology Station Piran). The samples were immersed 2 miles from the coast at a depth of 20 m. Samples were taken out at different time periods (after 1, 3 and 6 months). After the test, the samples were sonicated to remove the biofilm and then analysed subsequently using the following methods: electrochemical measurements including potentiodynamic polarization and electrochemical impedance spectroscopy and surface analytical methods including SEM/EDXS, XPS and ToF-SIMS analyses.

> **Prof. Ingrid Milošev was the guest editor of a special issue of the CORROSION journal devoted to biocorrosion, aiming to emphasize the importance of studies of different aspects of materials used as orthopaedic implants.**

Figure 2: Field-testing of four types of hybrid sol-gel coatings developed in our laboratory: GTS-Ce, TMZ, TMM and ZG was performed at the buoy facility (a) in the Adriatic Sea (National Institute of Biology, Marine Biology Station Piran). Samples were embedded in a Teflon holder (b) and immersed 2 miles from the coast at a depth of 20 m. Samples were taken out at different time periods and analysed for morphological and compositional changes (c).

We continued to work on the project COR_ID within M-Era.Net (European Research Area, an EU-funded network). The main aim of the project *"Design of corrosion resistant coatings targeted for versatile applications" (acronym COR_ID)* is to design and engineer new coatings for aluminum alloys with targeted properties of increased corrosion resistance, specific hydrophobic properties, prolonged service life-time and reduced ecological impact. The project consortium, coordinated by Prof. Ingrid Milošev, comprises researchers from Slovenia, France and Hungary: Department of Physical and Organic Chemistry of the Jožef Stefan Institute, Talum d.d. Kidričevo (partner mag. Dejan Lorber), Chimie ParisTech (CNRS) from Paris (partner Prof. Philippe Marcus) and Eötvös Loránd University from Budapest (partner Prof. József Rábai). The project consortium links scientists from three partner countries and one technological company Talum Kidričevo d.d.) aiming to stimulate advances in basic and applied research and technology transfer. The current state-of-the-art in this field is represented by high-throughput experimental empirical testing of large sets of organic compounds. In contrast to such a trial-and-error approach, a rational design of new corrosion inhibitors would provide a major breakthrough in the field of corrosion protection. The scientific framework should therefore postulate a strategy that will contribute to the increased understanding of corrosion inhibition. One of the possibilities is to use the ICME (Integrated Computational Materials Engineering) principles. The basic relationships between aluminium surface and corrosion inhibitors are therefore addressed, i.e., corrosion inhibitors were designed in such a way as to allow the investigation of the effect of anchor group and the effect of backbone chain on their inhibitive performance on aluminium in chloride solution. The methodological approach was versatile: (i) synthesis

> **As for the bonding of siloxane coatings to Al substrates, our DFT calculations indicate that there has to be at least one monomer sub-unit acting as a "molecular spacer", connecting the two siloxane sub-units chemisorbed to the surface.**

or purchase of organic inhibitors, (ii) preparation of uncoated and inhibitor-coated aluminium samples, (iii) electrochemical measurements, (iv) water contact-angle measurements (v) long-term immersion tests, (vi) surface analytical study by SEM, ToF-SIMS or XPS, and (vii) Density Functional Theory (DFT) modelling. The surface of the aluminium substrates was prepared by alkaline etching to allow easy self-assembling during immersion in ethanol solution of selected corrosion inhibitors. The inhibitors differed in the (i) type of backbone chain, (ii) length of backbone chain, and (iii) type of anchor group. Based on the obtained experimental (electrochemical parameters and composition of the surface layers) and computational (adsorption reaction energies decomposed into inhibitor-surface and lateral inhibitor-inhibitor interactions, adsorption induced changes of electronic structure, etc.) parameters we are aiming to build a predictive model for screening new corrosion inhibitors with targeted properties. The modelling and experiments are therefore combined using an integrative approach.

In the next step selected inhibitors will be tested in a silane matrix, also developed in our laboratory. In this context, we modelled the interactions of various molecular species to aluminium substrates. In the context of elucidating the mechanism by which siloxane-based sol-gel coatings adhere to Al substrates – these coatings are a promising alternative for the replacement of toxic chromate conversion coatings – we studied how the constituents of these coatings behave on the atomistic scale. It is well known that sol-gel synthesis occurs via a hydrolysis/condensation mechanism and a similar mechanism is proposed for the reaction of silanols with the surface. In order to test this hypothesis the adsorption of a model silanol molecule, $CH_3Si(OH)_3$, and its oligomers (up to the trimer) on oxidized and fully-hydroxylated aluminium substrates was modelled. We found that the formation of a single strong bond with the hydroxylated surface via the condensation mechanism (monodentate bonding mode) is exothermic, irrespective of oligomer size. In contrast, the formation of a bidentate bonding mode is exothermic only for the trimer and larger oligomers. The implausibility of the bidentate bonding mode for the monomer and the dimer is due to the strained configurations these small adsorbates have to adopt. This indicates that the commonly used scheme of siloxane-surface bonding where each monomeric siloxane subunit in a polymer binds to a surface metal atom is not to be taken for granted; according to our calculations there has to be at least one sub-unit acting as a "molecular spacer", connecting two monomeric subunits bonded to the surface.

In 2017 we started to work on the M-Era.Net project entitled "*COIN DESC: Corrosion inhibition and de-alloying descriptors*", which is a basic research project targeted at (i) the design of corrosion-resistant copper-based alloy systems by using corrosion inhibitors and at (ii) deepening the mechanistic understanding of corrosion inhibition. The specific objective of the project is to identify physically-sound corrosion inhibition and de-alloying descriptors, depending on the metallic material and environment to which the material is exposed. Such descriptors are mandatory for the construction of a new corrosion inhibitor virtual design framework that will allow a faster and more rational screening of new, specifically designed corrosion inhibitors with superior characteristics. The project consortium consists of four partners from Slovenia, Belgium, Spain, and Netherlands (Department of Physical and Organic Chemistry of Jožef Stefan Institute, Institute for Materials Research of Hasselt University, Department of Physics at Universitat Politècnica de Catalunya, and Materials Science and Engineering at Delft University of Technology). The work on the project started by testing about two dozen molecules from the azole family as potential corrosion inhibitors of copper, zinc and their alloys. Corrosion tests were performed by electrochemical methods, such as polarization resistance measurements and impedance spectroscopy, whereas the bonding of inhibitors to metal surfaces was investigated by means of density functional theory (DFT) computer modelling.

Our investigations also continued in the field of metallic materials used in biomedical applications, specifically orthopaedic implants. Understanding the mechanism of biocorrosion and metal degradation in human body – identification of the metal corrosion and wear products, and their effects on human body – is of paramount importance for the safety and long-term well-being of the patients. Translation of in-vitro mechanisms to in-vivo clinical situation is not straightforward: only the strong combination of knowledge regarding both material properties as well as
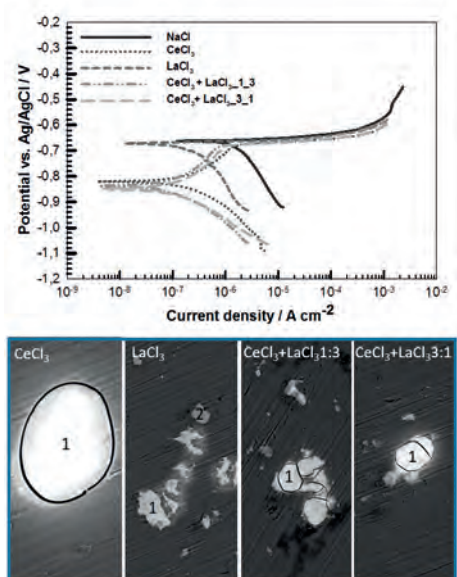
Figure 3: Potentiodynamic polarization curves recorded for aluminium alloy AA7075-T6 in 0.1-M NaCl containing 0.01-M CeCl3, LaCl3, and their mixtures (upper panel). Scanning electron microscopy images recorded in compositional mode after 12 h immersion of AA7075-T6 in 0.1-M NaCl containing different rare-earth salts and their mixture showing deposits of Ce- and La- oxides and hydroxides (lower panel).

For new particle formation in the atmosphere methylamine and formic acid were confirmed to enhance the nucleation rate of the sulphuric acid hydrates.
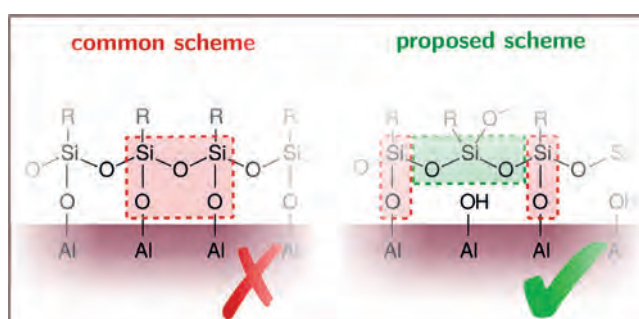
Figure 4: (left) Commonly used scheme for the adhesion of siloxane based sol-gel coatings, where each monomeric siloxane subunit in a polymer binds to a surface metal atom via the Si–O–Al bond is not to be taken for granted; (right) our DFT calculations imply that there has to be at least one sub-unit acting as a "molecular spacer", connecting the two monomeric subunits bonded to the surface.

A new method for direct dehydrative cross-coupling of benzy alcohols and alkenes catalysed with molecular iodine was developed.

clinical conditions enables an understanding of the long-term operating mechanisms. One of the prerequisites to reach this goal is a fruitful collaboration between scientists in the laboratories and orthopaedic surgeons in the operating theatres. Prof. Milošev was the guest editor in the special issue of CORROSION devoted to biocorrosion. It aimed to emphasize the importance of studies of different aspects of materials used as orthopaedic implants. The issues comprised twelve articles and can be divided into two parts: (i) six in-vitro studies and (ii) six retrieval and model clinical studies related to orthopedic implants.

In the field of atmospheric chemistry we studied secondary atmospheric aerosols formation. These mainly originate in the atmosphere from gas-to-particles conversion processes with sulphuric acid as the main driver of new particle formation through binary homogeneous nucleation with water. Both laboratory and field investigations have revealed that only binary chemical components are insufficient to explain the observed nucleation rate in the lower tropospheric regions, thus, the formation of new particles in the atmosphere involves multiple components. Recently, amines and organic acids have been established to enhance the nucleation rate by a few orders of magnitude and we have included methylamine and formic acid as a prototype for amines and carboxylic acids, respectively, in our studies. Physico-chemical characterization of these nucleation events is essential for modelling atmospheric processes.
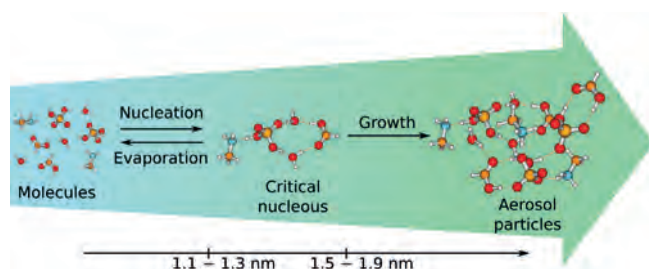
Figure 5: Shematic representation of the transformation from gas molecules through critical nucleous to atmospheric aerosols

In the framework of the Laboratory for Organic and Bioorganic Chemistry we continued the investigation on the application of principles of green chemistry to the transformations of organic compounds C–C bond formation is one of the most fundamental approaches toward molecular diversity in organic synthesis. In pursuit of environmentally friendlier chemical approaches to organic chemistry, we present a new, metal-free method for direct dehydrative cross-coupling of alcohols and alkenes using molecular iodine as a Lewis acid catalyst under solvent-free reaction conditions (Figure). The reaction is atom-economical, tolerant to air and allows a simple synthetic procedure, furnishing C_{sp}^3 – C_{sp}^2 coupling products with yields up to 97%. The method has proved efficient for the coupling of secondary benzyl alcohols with phenyl-substituted alkenes.
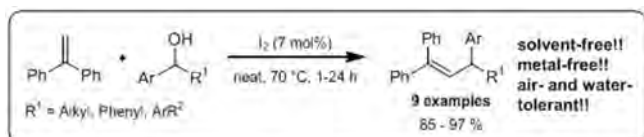

Scheme 1: Direct dehydrative cross-coupling of alcohols and alkenes using molecular iodine as a Lewis acid catalyst under solvent-free reaction conditions

N-halosuccinimides (NXSs) are well-known to be convenient, easily manipulable and low-priced halogenation reagents in organic synthesis. In the present work, *N*bromosuccinimide (NBS) has been promoted as the most efficient and selective catalyst among the NXSs in the reaction of direct esterification of aryl and alkyl carboxylic acids. Comprehensive esterification of substituted benzoic acids, mono, di- and tri-carboxy alkyl derivatives has been performed under solvent-free (SFRC) or high-substrate-concentration reaction conditions (HSCRC). The method is metal-free, air- and moisture-tolerant, allowing a simple synthetic and isolation procedure as well as the large-scale synthesis of aromatic and alkyl esters with yields up to 100%. A protocol for the recycling of the catalyst has been proposed.

We developed a new method for aromatic nitration where nitric acid is activated by fluorinated alcohol, which works as a template catalyst. The template catalyst works like an enzyme, by providing complementary charge to the transition state and thus lowering the energy barrier. We made an evaluation of how our method fulfils the requirements of green chemistry and we compared it with other modern literature methods for the nitration of aromatic compounds. In the evaluation we compared methods with most often used green-chemistry metrics (atom economy, E-factor, etc.) and also by the cost of reagents needed to carry out the reaction. In a collaboration with the Biotechnical Faculty University of Ljubljana we are developing new derivatives of malonic acid as precursors in the biosynthesis of tetracyclines.

Some outstanding publications in the past year

1. U. Tiringer, J. Kovač, I. Milošev, Effects of mechanical and chemical pre-treatments on the morphology and composition of surfaces of aluminium alloys 7075-T6 and 2024-T3, Corros. Sci., 119 (2017), 46-59
2. I. Milošev, From in vitro to retrieval studies of orthopaedic implants, Corrosion, 73 (2017), 1496-1509
3. N. Kovačevič, I. Milošev, A. Kokalj, How relevant is the adsorption bonding of imidazoles and triazoles for their corrosion inhibition of copper?, Corros. Sci. 123 (2017), 25-34
4. S. Tušar, A. Lesar, Hydrogen bonding in the hydroxysulfinyl radical-formic acid-water system: a theoretical study, J. Comput. Chem., 37 (2016), 1611-1625

5.   Š. Možina, S. Stavber, Dual catalysis for the aerobic oxidation of benzyl alcohols - nitric acid and fluorinated alcohol, Eur. J. Org. Chem, 2017 (2017), 448-452

Awards and Appointments

1.   Jerca Pahor: Krka Awards 2017 for under- and post-graduate researchAnton Kokalj: Zois Certificate of recognition for significant achievements in the molecular modeling of chemical processes on metal surfaces in 2017

INTERNATIONAL PROJECTS

1.   K3 - Nano4Life; Know-How License and Cooperation Agreement concluded between Jožef Stefan Institute and Nano4Life Europe; CTT - Nano4Life; Licence Grant
Prof. Ingrid Milošev
Nano4life Europe
2.   EUSpec, COST MP1306; Modern Tools for Spectroscopy on Advanced Materials: A European Modelling Platform
Asst. Prof. Anton Kokalj
Cost Office
3.   H2020 - STEM4youth; Promotion of STEM Education by Key Scientific Challenges and their Impact on Our Life and Career Perspectives
Dr. Peter Rodič
European Commission
4.   H2020 - mCBEEs; Advanced Integrative Solutions to Corrosion Problems Beyond Micro-Scale: Towards Long-Term Durability of Miniaturized Biomedical, Electronic and Energy Systems
Prof. Ingrid Milošev
European Commission
5.   COR_ID: Design of corrosion resistant coatings targeted for versatile applications
Prof. Ingrid Milošev
Ministry of Education, Science and Sport
6.   COIN DESC: Corrosion inhibition and dealloying descriptors
Asst. Prof. Anton Kokalj
Ministry of Education, Science and Sport
7.   Small Services
Prof. Ingrid Milošev

RESEARCH PROGRAMS

1.   Chemistry for sustainable development
Prof. Stojan Stavber
2.   Advanced materials for low-carbon and sustainable societyAdvanced materials for low-carbon and sustainable society
Prof. Ingrid Milošev

R & D GRANTS AND CONTRACTS

1.   Modulation of polyketid synthase complex involved in early and late stages of tetracycline biosynthesis
Prof. Stojan Stavber
2.   Lightweight alloys based on aluminium as materials with increasing potential in transport industry
Prof. Ingrid Milošev
3.   Development of Molecularly Imprinted Polymers and their application in environmental and bio-analysis
Prof. Jernej Iskra

NEW CONTRACTS

1.   Ecology laboratory with mobile unit
Dr. Peter Rodič
Ministry of Defence

VISITORS FROM ABROAD

1.   dr. Bojan Božič, University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, Serbia,1.10.2016-31.3.2017

2.   Dominique Costa, Chemie Paris Tech, Ecole nationale superiore de chemie de Paris, Paris, France, 18.12.-22.12.2017

STAFF

Researchers
1.   Asst. Prof. Anton Kokalj
2.   Dr. Antonija Lesar
3.   Dr. Matic Lozinšek
4.   **Prof. Ingrid Milošev, Head**
5.   Prof. Stojan Stavber
Postdoctoral associates
6.   *Dr. Tina Bakarič, left 01.05.17*
7.   Dr. Peter Rodič
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8.   Klara Čebular, B. Sc.

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12.   Urša Tiringer, B. Sc.
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14.   Damir Hamulić, B. Sc.
15.   Barbara Kapun, B. Sc.
16.   Dolores Zimerl, B. Sc.

BIBLIOGRAPHY

ORIGINAL ARTICLE

1.   Blaž Alič, Melita Tramšek, Anton Kokalj, Gašper Tavčar, "Discrete GeF_5^- anion structurally characterized with a readily synthesized imidazolium based naked fluoride reagent", *Inorg. chem.*, **56**, 16, 10070-10077, 2017.
2.   Paolo Giannozzi *et al.* (50 authors), "Advanced capabilities for materials modelling with Quantum ESPRESSO", *J. phys., Condens. matter*, 29, 46, 465901, 2017.
3.   Anton Kokalj, Takamasa Makino, Michio Okada, "DFT and TPD study of the role of steps in the adsorption of CO on copper: Cu(410) vs Cu(100)", *J. phys., Condens. matter*, **29**, 19, 194001, 2017.

4.   Milica Košević G., Gavrilo Šekularac, Ljiljana Živković, Vladimir Panić, Branislav Ž. Nikolić, "TiO_2 from colloidal dispersion as support in Pt/TiO_2 nanocomposite for electrochemical applications", *Croat. chem. acta*, **90**, 2, 251-258, 2017.
5.   Nataša Kovačević, Ingrid Milošev, Anton Kokalj, "How relevant is the adsorption bonding of imidazoles and triazoles for their corrosion inhibition of copper?", *Corros. sci.*, **124**, 25-34, 2017.
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Review Article

1. Ingrid Milošev, "From in vitro to retrieval studies of orthopedic implants", *Corrosion (Houst., Tex.)*, **73**, 12, 1496-1509, 2017.

Published Conference Contribution

1. Danjela Kuščer, Tina Bakarič, Andre-Pierre Abellard, Julien Bustillo, Marc Lethiecq, Franck Levassort, "High-frequency acoustic characterization of porous lead zirconate titanate for backing applications", In: *2017 IEEE International Ultrasonic Symposium, September 6-9, 2017, Washingtoon, D. C., USA*, Danvers, IEEE = Institute of Electrical and Electronics Engineers, 2017, 4

Mentoring

1. Štefan Možina, *Activation of nitric acid in fluorinated alcohol for aromatic nitration and oxidation of alcohols:* doctoral dissertation, Ljubljana, 2017 (mentor Stojan Stavber; co-mentor Jernej Iskra).

ELECTRONIC CERAMICS DEPARTMENT

K-5

The Electronic Ceramics Department is active in research of the synthesis, properties and applications of materials for electronics and energetics, mainly complex multifunctional materials and structures that can perform multiple functions (multifunctional materials). The materials of interest include ceramic piezoelectrics, ferroelectrics, relaxors, multiferroics and conductive oxides. The emphasis is on the creation of the properties by the synthesis and structure on the nano-, micro- and macro-levels. The group also works on the principles of basic technologies of ceramic pressure sensors, ceramic MEMS and flexible electronics.

Head:
Prof. Barbara Malič

In the framework of **lead-free piezoelectric ceramics** we studied the influence of a material's size scale on its functional properties in collaboration with Technical University Darmstadt, Germany. **Sodium niobate** ceramic samples with different grain sizes, from ~150 nm to ~50 μm, were prepared and analyzed using differential scanning calorimetry, dielectric measurements, and ^{23}Na 3QMAS nuclear magnetic resonance (NMR). A size-induced phase transition from the antiferroelectric phase into the ferroelectric polymorph was observed when the grain size decreased below 270 nm. This size-induced phase transition is attributed to the existence of intragranular stresses, induced by the decreased compensation of the ferroelastic energy during the formation of non-180° domain walls, while decreasing the grain size and the large anisotropy of the thermal expansion, and has not been observed in other ferroic systems.

The piezoelectric response of **BiFeO$_3$** ceramics at elevated temperatures, up to 260 °C, has been revealed for the first time. The distinct temperature dependence of the piezoelectric coefficient and phase was attributed to the so-called Maxwell-Wagner mechanism, arising due to the presence of electrical conductivity at the local scale. The results thus identify conductive paths along domain walls and grain boundaries as the key to controlling the temperature-dependent piezoelectric response of BiFeO$_3$ and possibly other, more complex, BieFO$_3$-based piezoceramics.

By means of combined piezoresponse force microscopy and transmission electron microscopy analyses we studied the synthesis-structure-properties relationship in **Sm$_2$O$_3$-modified BiFeO$_3$ ceramics**. The results, obtained in collaboration with Ural Federal University in Russia, revealed significant differences in the domain structure and local switching behaviour, depending on the processing method used, i.e., standard solid-state reaction versus mechano-chemical processing. Evidence of an electric-field-induced phase transition from anti-ferroelectric Pbam to ferroelectric R3c phase was provided at the local scale. The transition plays an important role in the functional properties of rare-earth-modified BiFeO$_3$ systems.

In collaboration with the Advanced Materials Department we studied the ferroelectric domain structure of BaTiO$_3$ plates prepared by molten-salt synthesis, using piezoresponse force microscopy. We found that both micrometre-sized as well as submicrometre-sized plates exhibit ferroelectric and piezoelectric properties, which opens up new possibilities for the use of such plates in the field of miniature piezoelectric sensors.

Within the activities on **lead-based piezoelectric ceramics** electric-field-induced changes in 1-xPb(Mg$_{1/3}$Nb$_{2/3}$)O$_3$–xPbTiO$_3$ (PMN–xPT) ceramics were studied in order to elucidate the complex electromechanical responses in polycrystalline relaxor-ferroelectric materials. By using combined microscopy and diffraction techniques, we aimed to determine the most significant changes of the crystal and domain structures with an applied electric field in different compositions of the PMN–xPT family.

Later, we constructed the micro-cylinder pumps with piezoelectric actuators based on 0.57Pb(Sc$_{1/2}$Nb$_{1/2}$)O$_3$–0.43PbTiO$_3$ in collaboration
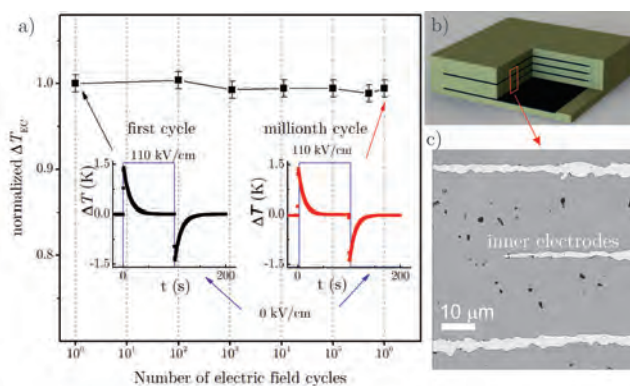
Figure 1: Stability of the electrocaloric effect in multilayer elements of lead magnesium niobate. a) Normalized values of electrocaloric temperature changes (ΔTEC) versus the number of applied electric field cycles. The first and the millionth temperature changes (ΔT) upon electric field of 110 kV/cm are presented in the insest. b) 3D model of multilayer elements c) Microstructure of multilayer element cross-section obtained on a scanning electron microscope.
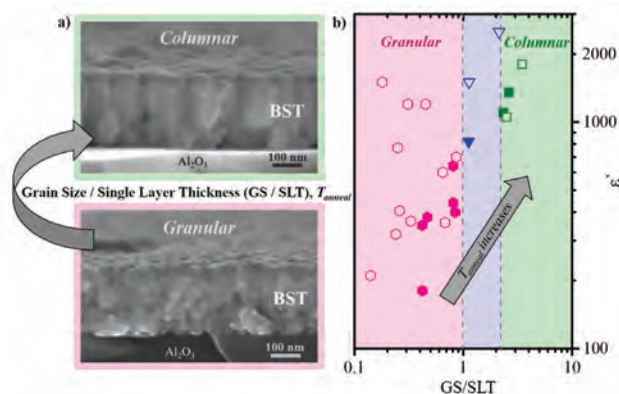
Figure 2: a) Schematic presentation of the evolution of microstructure from granular to columnar in the case of $Ba_{0.5}Sr_{0.5}TiO_3$ (BST) thin films prepared by Chemical Solution Deposition. b) Dielectric permittivity plotted as a function of GS/SLT ratio for various $Ba_xSr_{1-x}TiO_3$, x=0-1, thin films taken from the literature (open symbols) and prepared in the frame of our study (full symbols).

with the Faculty of Electrical Engineering, University of Ljubljana. This was the first time that the relaxor-ferroelectric material has been used in a piezoelectric micropump application.

The **electrocaloric (EC) effect** is defined as the adiabatic temperature change that is induced by the application or removal of an external electric field in a polar material. Cooling technology based on the EC effect has the potential for a broad range of applications, including on-chip cooling and temperature regulation, due to its high efficiency and compactness. Electric fields needed to reach EC temperature changes (DT_{EC}), suitable for applications in cooling technology, at least 2 K, are close to the dielectric breakdown strength of EC bulk ceramic materials, typically about 100 kV/cm. In order to reduce the applied voltage for a given DT_{EC}, we prepared **multilayer cooling elements** of relaxor $Pb(Mg_{1/3}Nb_{2/3})O_3$ (PMN) with internal platinum electrodes by tape-casting and lamination in collaboration with the company KEKO-Equipment, Žužemberk, Slovenia. The thicknesses of the ceramic and platinum layers were about 30 mm and 4 mm, respectively. The **EC effect's stability (EC fatigue)** for multilayer elements was studied in collaboration with Institute of Materials Science, Technische Universität Darmstadt, Germany. The multilayer elements were subjected to 10^6 unipolar cycles at an electric field amplitude of 110 kV/cm. The initially measured EC temperature change of 1.45 K decreased by only 0.01 K upon cycling, exhibiting a fatigue-less behaviour. These results justify the choice of relaxor-based multilayers as the working bodies in EC cooling devices, where the materials should withstand numerous electric field cycles with high electric field amplitudes, sometimes exceeding 100 kV/cm, and therefore, represent another step towards the application of EC ceramic materials in solid-state cooling. (Figure 1)

Further, we studied a **multicaloric effect** in polycrystalline $Pb(Fe_{1/2}Nb_{1/2})O_3$. Ceramics were prepared by the mechano-chemical activation of constituent oxides, followed by sintering at 1000 °C in an oxygen atmosphere. The maximum magnetocaloric temperature change (0.16°C at 50 kOe) was obtained at -271 °C. The pronounced electrocaloric effect was determined at room temperature (0.81 °C at 80 kV/cm), while the maximum value of the electrocaloric temperature change 1.29 °C was obtained near the paraelectric-ferroelectric phase transition (i.e., at 100 °C).

In the frame of the **M-ERA.NET PiezoMEMS** project we continued research of ferroelectric $K_{0.5}Na_{0.5}NbO_3$-based thin films for piezoelectric energy-harvesting applications together with partners from Poland and Romania. By optimizing the chemical composition and solution-based processing of **$K_{0.5}Na_{0.5}NbO_3$** thin films, doped with strontium and manganese, we successfully reduced the leakage current density by almost an order of magnitude, reaching $\approx 2 \cdot 10^{-8}$ A/cm² at the electric field amplitude 100 kV/cm.

In collaboration with Materials and Research Technology Department, Luxembourg Institute of Science and Technology, Luxembourg, we investigated the evolution of the microstructure of tunable ferroelectric **$Ba_{0.5}Sr_{0.5}TiO_3$ (BST) thin films** by Chemical Solution Deposition. The films were prepared on alumina substrates by repeated deposition-drying-pyrolysis-annealing steps at temperatures between 640 °C and 900 °C. The elements of the microstructure, i.e., grain size (GS) and shape, in relation to the thickness of individual layers (SLT), were correlated with the annealing temperature. We found that for our processing conditions the BST films annealed at 640–800 °C had granular microstructures with 10-40-nm large equiaxed grains and with GS/SLT<1. Only at temperatures 880 °C the films consisted of columnar grains with an average lateral grain size of about 90 nm and with GS/SLT>2.5. Such an evolution of the microstructure was explained in the frame of the Microstructural Zone Model for solution-derived thin films. In parallel with the observed changes in the microstructure, the kHz-range dielectric permittivity of the films increased by almost an order of magnitude, from around 180 to 1350, which showed that the model can serve as an effective guideline for designing thin films with tailored functional properties suitable, for example, in microwave-range telecommunications. (Figure 2)

In the frame of the **M-ERA.NET INTcerSEN** project we successfully prepared screen-printed $0.65Pb(Mg_{1/3}Nb_{2/3})O_3$–$0.35PbTiO_3$ **thick films** on metalized **low-temperature co-fired ceramic** (LTCC) substrates. Such substrates are interesting for micro-electro mechanical systems, for example, in piezoelectric sensors and actuators, where functional layers are usually Pb-based perovskites. Special attention was given to the influence of the Au, Ag and Ag/Pd electrode materials coated over the LTCC on the functional properties of the films. The best phase purity, dielectric and piezoelectric properties were obtained in the films on gilded substrates. The piezoelectric coefficient d33 of the films on gilded LTCC substrates was 120 pC/N. (Figure 3)

We investigated the preparation of environmentally benign **thick-film** piezoelectrics based on $K_{0.5}Na_{0.5}NbO_3$ on metalized ceramic substrates using the **electrophoretic deposition method** for applications in high-frequency

Figure 3: Cover of the Informacije MIDEM journal showing the amplitude image of local piezoelectric response in a $0.65Pb(Mg_{1/3}Nb_{2/3})O_3$–$0.35PbTiO_3$ thick film obtained by piezoresponse force microscope. Researchers from the Electronic Ceramics Department are actively involved in the publication as well as the editing of the Informacije MIDEM journal. The department co-organized the 53rd International Conference on Microelectronics, Devices and Materials with the workshop "Materials for Energy Conversion and their Applications: Electrocalorics and Thermoelectrics" MIDEM 2017, which was held at the Jožef Stefan Institute.

ultrasound transducers and energy harvesters. With numerical modelling we demonstrated that the most thickness-uniform deposit is obtained by applying a constant current between two electrodes with similar dimensions separated by a few mm, wheich we confirmed with experiments. After sintering at 1100 °C the 30 µm-thick films exhibited promising dielectric and electromechanical properties, the latter measured in collaboration with researchers from François-Rabelais University Tours, France. The thick films exhibited piezoelectric coefficient d_{33} up to 80 pC/N and thickness coupling factor k_t up to 35 %. (Figure 4)

We proceeded with microstructural investigations of a few µm to several tens of µm thick $BiFeO_3$ films deposited on platinized Al_2O_3. The thick-films were prepared by the **screen-printing method**.

In collaboration with colleagues from the Condensed Matter Department we investigated how the surface properties of a substrate influence the resolution and stability of **inkjet-printed** functional-oxide **nanostructures**. We found that the wetting of an organic-precursor-based ink is easily modified by adjusting the thermal treatment conditions of a few nm thick layer of a polymer deposited on a selected substrate.

As part of the research on conducting oxides for gas sensing in collaboration with University Brescia, Italy and University Guilan, Iran we prepared zinc stannate ceramic targets for RF sputtering of thin films, suitable as active layers for the sensing of ethanol, acetone and nitrogen dioxide.

LTCC (Low Temperature Co-fired Ceramics) and thick-film materials and processes have been investigated for the design and fabrication of microfluidic ceramic systems. The flow rate, the hydrodynamic resistance of the channels and the diodicity of the valves were studied depending on the shape and dimensions of elements and the type of fluidic media. Results are useful in designing various microfluidic components, devices and systems. On this basis and with the cooperation of partners (**Centre of Excellence NAMASTE**, **HIPOT-RR** and **KEKO Equipment**), we successfully integrated pressure and electrochemical sensors into the fluidic system without any degradation of the fluidic properties in the observed channel. (Figure 5)

In collaboration with the company **ETI Elektroelement** d.o.o., Izlake, we processed cordierite ceramics with a reproducible low thermal expansion coefficient and with excellent mechanical properties by sintering in a narrow temperature range, which was achieved by optimisation of the amount and particle size of alumina. The cordierite material, suitable for automatic, large-scale production, was patented.

Some outstanding publications in the past year

1. Rojac, Tadej, Benčan, Andreja, Dražić, Goran, Sakamoto, Naonori, Uršič, Hana, Jančar, Boštjan, Tavčar, Gašper, Makarovič, Maja, Walker, Julian, Malič, Barbara, Damjanović, Dragan. Domain-wall conduction in ferroelectric $BiFeO_3$ controlled by accumulation of charged defects. Nature materials, ISSN 1476-1122, 2017, vol. 16, no. 3, str. 322-327, doi: 10.1038/nmat4799. [COBISS.SI-ID 29936679]

2. Fulanović, Lovro, Koruza, Jurij, Novak, Nikola, Weyland, Florian, Malič, Barbara, Bobnar, Vid. Fatigue-less electrocaloric effect in relaxor $Pb(Mg_{1/3}Nb_{2/3}O_3Pb(Mg_{1/3}Nb_{2/3}O_3$, *Journal of the European ceramic society*, ISSN 0955-2219. [Print ed.], 2017, vol. 37, no. 15, str. 5105-5108, doi: 10.1016/j.jeurceramsoc.2017.06.011. [COBISS.SI-ID 30569511]

3. Matavž, Aleksander, Bobnar, Vid, Malič, Barbara. Tailoring ink-substrate interactions via thin polymeric layers for high-resolution printing. *Langmuir*, ISSN 0743-7463, 2017, vol. 33, no. 43, str. 11893-11900, doi: 10.1021/acs.langmuir.7b02181. [COBISS.SI-ID 30841383]

4. Mercier, Hugo, Malič, Barbara, Uršič, Hana, Hreščak, Jitka, Levassort, Franck, Kuščer, Danjela. Electrophoretic deposition and properties of strontium-doped sodiumpotassium niobate thick films. Journal of the European ceramic society, ISSN 0955-2219., 2017, vol. 37, iss. 16, str. 5305-5313, doi: 10.1016/j.jeurceramsoc.2017.06.030.

Excellent in Science in the field of technology nominated by Slovenian Research Agency! The achievement "Interpretation of electric conductivity of domain walls in bismuth ferrite" ranked in the selection of Excellent in 2017. (T. Rojac, A. Benčan Golob, G. Dražić, H. Uršič Nemevšek, B. Jančar, G. Tavčar, M. Makarovič, J. Walker in B. Malič, Nat. Mater. 16, 3, 2017)
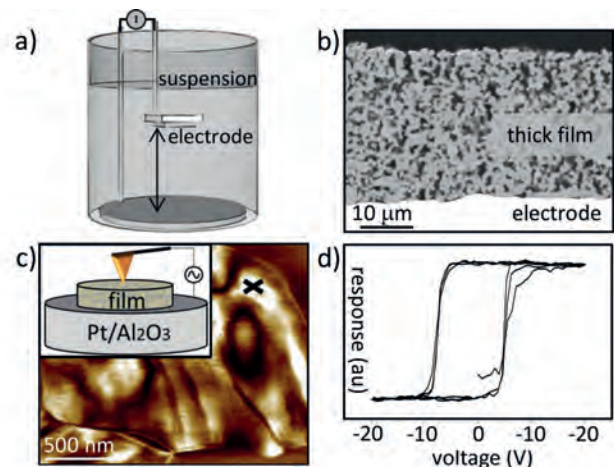
Figure 4: a) Schematic representation of electrophoretic deposition setup.(b) Microstructure of $(K_{0.5}Na_{0.5})_{0.99}Sr_{0.005}NbO_3$ thick film on Pt/ Al_2O_3 obtained by electrophoretic deposition and subsequent sintering at 1100 °C. c) Amplitude image of local piezoelectric response in thick film obtained by piezoresponse force microscope. d) Local hysteresis loop obtained from a selected area on the film (marked by x in panel c).

Relaxor multilayer elements exhibited a fatigue-less electrocaloric (EC) effect even after 10^6 unipolar cycles at an electric field amplitude of 110 kV cm^{-1}, which makes them suitable candidates for the working bodies in EC cooling devices.

Figure 5: Fluidic channel in LTCC structure with integrated pressure sensor.

5. Rojac, Tadej, Damjanović, Dragan. Domain walls and defects in ferroelectric materials. *Japanese journal of applied physics*, ISSN 0021-4922, 2017, vol. 56, no. 10S, str. 10PA01-1-10PA01-4, doi: 10.7567/JJAP.56.10PA01. [COBISS.SI-ID 30744615]

Awards and Appointments

1. Andraž Bradeško: ranked among the best posters at the 2017 IEEE International Symposium on Applications of Ferroelectrics (ISAF), Atlanta, USA, Institute of Electrical and Electronics Engineers (IEEE)
2. Mojca Otoničar, Hana Uršič, Marko Vrabelj: JSI Director's fund for 2017, Ljubljana, JSI Director's Council, for the project entitled Laboratory for the ultracool preparation of complex oxides - ULTRACOOL

Organization of Conferences, Congresses and Meetings

1. MIDEM 2017: 53rd International Conference on Microelectronics, Devices and Materials with the Workshop on Materials for Energy Conversion and their Applications: Electrocalorics and Thermoelectrics, Ljubljana, 4–6 October 2017

Patents granted

1. Ines Bantan, Danjela Kuščer, Janez Holc, Process for manufacturing cordierite ceramics having controlled and reproducible mechanical and thermal properties, EP3115347 (B1), European Patent Office, 01. 11. 2017.
2. Barbara Malič, Hana Uršič, Marija Kosec, Silvo Drnovšek, Jena Cilenšek, Zdravko Kutnjak, Brigita Rožič, Uroš Flisar, Andrej Kitanovski, Marko Ožbolt, Uroš Plaznik, Alojz Poredoš, Urban Tomc, Jaka Tušek, Method for electrocaloric energy conversion, EP3027980 (B1), European Patent Office, 18. 10. 2017.

INTERNATIONAL PROJECTS

1. COST action TO-BE: Towards Oxide-Based Electronics
    Asst. Prof. Hana Uršič Nemevšek
    Cost Office
2. Fabrication and Modelling of Integrated Piezoelectric Structures for High-frequency Ultrasound Applications
    Asst. Prof. Danjela Kuščer Hrovatin
    Slovenian Research Agency
3. Domain Structure of Complex Oxides
    Asst. Prof. Hana Uršič Nemevšek
    Slovenian Research Agency
4. Local Structure of Relaxor Ferroelectrics - The Key to Understanding the Functional properties
    Asst. Prof. Andreja Benčan Golob
    Slovenian Research Agency
5. Piezoelectric Films for Microelectromechanical Systems Based on Environment Friendly Perovskite Materials
    Prof. Barbara Malič
    Slovenian Research Agency

RESEARCH PROGRAM

1. Electronic Ceramics, Nano, 2D and 3D Structures
    Prof. Barbara Malič

R & D GRANTS AND CONTRACTS

1. Photovoltaic cell and module inhomogenity analysis and performance monitoring in power plants through lifetime
    Prof. Barbara Malič
2. New advanced electrocaloric materials for novel environmentally-friendly dielectric refrigeration technology
    Prof. Barbara Malič

3. Multifunctional materials for actuator and cooling devices
    Asst. Prof. Tadej Rojac
4. Advanced electrocaloric energy conversion
    Prof. Barbara Malič
5. Microelectromechanical and electrocaloric layer elements
    Prof. Barbara Malič
6. Ferroelectric ceramic layer elements with designed domain structure for efficient energy harvesting and conversion
    Prof. Barbara Malič
7. Integrated sensors with microfluidic features using LTCC technology
    Asst. Prof. Hana Uršič Nemevšek
    Ministry of Education, Science and Sport
8. Piezoelectric MEMS for efficient energy harvesting
    Prof. Barbara Malič
    Ministry of Education, Science and Sport
9. Inkjet Printing of PZT Test Structures
    Prof. Barbara Malič
    Epcos Ohg
10. Analysis of piezoelectric elements from different producers
    Prof. Barbara Malič
11. Laboratory for the ultracool preparation of complex oxides – ULTRACOOL
    Asst. Prof. Hana Uršič Nemevšek, Dr. Mojca Otoničar

NEW CONTRACTS

1. Consulting on the development of the steatite material, analysis of raw materials and sintered samples, and on-demand consulting on the industrial production process
    Prof. Barbara Malič
    Eti d. d.
2. Research of compatibility of LTCC materials and conductive pastes, with the emphasis on appropriate adhesion of the conductive material on LTCC and on simultaneous densification of both materials
    Prof. Barbara Malič
    Keko - Oprema d. o. o. Žužemberk
3. Ferroelectric ceramic layer elements with planned domain structure for efficient collection and conversion of energy
    Prof. Barbara Malič
    Keko - Oprema d. o. o. Žužemberk

VISITORS FROM ABROAD

1. Agnieszka Monika Paszkowska, Maria Curie-Skłodowska University, Lublin, Poland, 24 October 2016 to 31 March 2017
2. Karolina Szymanek, Maria Curie- Skłodowska University, Lublin, Poland, 24 October 2016 to 31 March 2017

3. Hugo Mercier, University François-Rabelais of Tours, Tours, France, 5–18 February 2017; 9–22 April 2017; 18 May to 2 June 2017 and 18 September to 14 October 2017
4. Dr Gregor Trefalt, University of Geneva, Geneva, Switzerland, 16 February 2017
5. Martina Guliš, University of Zagreb, Zagreb, Croatia, 6 March to 6 June 2017

6. Prof. Dr Jacob L. Jones, North Carolina State University, Raleigh, North Carolina, USA, 7–8 March 2017
7. Stjepan Golubić, M.Sc., Bjelovar University of Applied Sciences, Bjelovar, Croatia, 20–21 March 2017
8. Zoran Vrhovski, M.Sc., Bjelovar University of Applied Sciences, Bjelovar, Croatia, 20–21 March 2017
9. Dr. Soma Dutta, Materials Science Division, National Aerospace Laboratories, Bangalore, Karnataka, India, 31 March to 24 August 2017
10. Allard Mathéo, University François-Rabelais of Tours, Tours, France, 3 April to 23 June 2017
11. Hafsa Znibrat, University François-Rabelais of Tours, Tours, France, 3 April to 23 June 2017
12. Prof. Dr Franck Levassort, University François-Rabelais of Tours, Tours, France, 17–19 May 2017
13. Prof. Dr Isabelle Laffez, University François-Rabelais of Tours, Tours, France, 17–19 May 2017
14. Dr Julian Walker, Pennsylvania State University, USA, 26–30 June 2017
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18. Dr Magdalena Wencka, Institute of Molecular Physics Polish Academy of Sciences, Poznan, Poland, 16 August 2017
19. Prof. Dr Naonori Sakamoto, Research Institute of Electronics, Department of

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20. Ivan Šimunović, Bjelovar University of Applied Sciences, Bjelovar, Croatia, 4 September to 1 December 2017
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24. Dr Denis Orosel, EPCOS OHG A TDK Group Company, Deutschlandsberg, Austria, 28 September 2017
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26. Dr Holger Neubert, Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, Germany, 4–6 October 2017
27. Dr Sylvia Gebhardt, Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, Germany, 4–6 October 2017
28. Dr Xavier Moya, Department of Materials Science & Metallurgy, University of Cambridge, Cambridge, United Kingdom, 4–6 October 2017
29. Prof. Dr Brahim Dkhil, Laboratoire Structures, Propriétés et Modélisation des Solides, Centrale Supélec, Université Paris-Saclay, Châtenay-Malabry, France, 4–6 October 2017
30. Dr Emmanuel Defay, Luxembourg Institute of Science and Technology, Luxembourg, Luxembourg, 4–6 October 2017
31. Ana Čukman, Bjelovar University of Applied Sciences, Bjelovar, Croatia, 27 November 2017 to 23 February 2018

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Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLE

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PATENT

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MENTORING

1. Anže Abram, *Synthesis and characterization of hydrothermally treated and functionalised zinc and aluminium surfaces:* doctoral dissertation, Ljubljana, 2017 (mentor Goran Dražić).

2. Barbara Bertoncelj, *Influence of fiber weight content and fiber distribution on functional properties of glass-fiber reinforced composites:* doctoral dissertation, Ljubljana, 2017 (mentor Barbara Malič; co-mentor Janez Rihtaršič).

3. Viviana Golja, *Migration of nanoparticles from food contact materials:* doctoral dissertation, Ljubljana, 2017 (mentor Saša Novak Krmpotič; co-mentor Goran Dražić).

DEPARTMENT FOR NANOSTRUCTURED MATERIALS K-7

One of our biggest advantages is our interdisciplinary team. The basic and applied research of the Department for Nanostructured Materials includes metals, intermetallic alloys, biomaterials, ceramic materials and minerals. Our research encompasses conventional processing as well as the development of new technologies and methods for preparing new materials with advanced properties. It includes experimental and theoretical investigations of structures, analyses of chemical compositions at the atomic level, and measurements and calculations of physical properties, all of which help us to improve the properties of micro- and nanostructured materials.

Head:
Prof. Spomenka Kobe

Magnetic Materials

One of the research topics of the **Marie Skłodowska-Curie Action European Training Network (DEMETER)** is the **recycling of critical raw materials**. We successfully produced novel permanent magnets based on the recycled Nd-Fe-B and Sm-Co systems. Rare earths such as Nd and Sm, as well as the transition metal Co, are at the top of the global scale for critical raw materials. With the implementation of a novel sintering technique (Spark Plasma Sintering - SPS), we produced **Nd-Fe-B permanent magnets** from recycled powders obtained after HDDR (hydrogenation-disproportionation-decrepitation-recombination) processing. A 30% increase of the initial coercivity (H_c =1190 kA/m), with remanent magnetization B_r = 0.79, and BH_{max} = 110 kJ/m^3 were achieved. The SPS method was also successfully used in the compacting of recycled HD (hydrogenation-decrepitation) powders based on **SmCo$_5$**, where we achieved a coercivity H_c > 1200 kA/m, measured at 180°C, an improvement over the initial powder properties. In the frame of this EU training network, also chemical recycling, i.e., the processing of the rare earth has been investigated. The electrodeposition of Nd and Fe elements from ionic liquids based on 1-ethyl-3-methylimidazole dicyamide was evaluated. We found that Nd can be reduced only in the presence of Fe, which most probably catalyses the further reduction of Nd, and we also proposed an appropriate mechanism.

In 2017, we started with the new **European project AMPHIBIAN** ("AnisoMetric Permanent HybrId magnets Based on Inexpensive And Non-critical materials"). The goal of the project is to achieve an energy product BHmax higher than 50 kJ/m^3. The upper limit so far is 45 kJ/m^3. We are focusing on the preparation of ferrite-based hybrid anisotropic magnets with enhanced magnetic performance, which would be installed in a flywheel (electric energy storage device). Such an achievement would open up an entirely new field of possible applications. The first steps towards achieving this goal were made. We studied systematically the influence of various processing methods on the magnetic properties of Sr-hexaferrite and determined the densification methods. On the basis of the density-functional theory we investigated the stability of magnetic nanostructures by comparing the calculated total energies for various, experimentally possible, configurations. We studied novel Ba-hexaferrite structural variations stabilized on the nanoscale as building blocks for epitaxial bi-magnetic hard/soft sandwiched maghemite/hexaferrite/maghemite nanoplatelets with out-of-plane easy axis and enhanced magnetization.

In collaboration with the Solid State Physics Department we contributed strongly to the prediction of the hyperfine-coupling tensor and quadrupole frequencies for the interpretation of the measured electron-paramagnetic-resonance (EPR) spectra. The results were published in *Nanoscale (IF = 7.4)*.

In the frame of an ARRS post-doc project, we studied the influence of processing parameters on the final magnetic properties of new **permanent magnets based on nanocrystalline YCo$_{4.8}$Fe$_{0.2}$ grains**. Using metallic binders, we made a magnet that is suitable for recycling after the end of the working cycle. Furthermore, such magnets without heavy rare earth represent a huge market potential. Zn and eutectic Zn/Al-alloy effectively

In the European project REProMag, which ended in 2017, we have successfully achieved the goal of developing a resource-efficient manufacturing route for rare-earth magnets out of recycled magnetic material that allows for the economical and efficient production of net-shape magnetic parts with complex structures and geometries. The new Shaping, Debinding and Sintering (SDS) process, which we developed, is an innovative automated manufacturing route to realize complex 3D and multi-layered parts. First, the recycled magnetic powder is mixed with a patented polymer to achieve a suitable feedstock for different Additive Manufacturing processes, like Metal Injection Moulding (MIM) and 3D printing. After the shaping of the material into a specific form, the polymer binder is removed, and the final green compact is sintered. After the process, the magnet is fully dense and has a magnetic coercivity of H_c = 1120 kA/m, which falls in the same range as conventionally sintered recycled magnets. The project received a prestigious German award for the effective use of raw materials in 2017 (Deutscher Rohstoffeffizienz-Preis 2017), and was also awarded the "Ecotech Award" in Germany.

improve the mechanical properties, i.e., the Vickers hardness, which was comparable to the Nd-Fe-B sintered magnets (460 ± 20 Vickers units). The magnetic measurements in vibrating-sample magnetometer have shown a significant improvement in coercivity from 0.75 T to 0.87 T, which was explained after a thorough microstructural analysis using scanning and transmission electron microscopy. Clusters of ~20-nm $YCo_{4.8}Fe_{0.2}$ grains were surrounded by non-magnetic Zn or Zn/Al alloys, which magnetically isolate the $YCo_{4.8}Fe_{0.2}$ nanograins and suppress the propagation of reverse domains.

We also studied the coercivity of ultra-fast hardened Nd-Fe-B ribbons. Different concentrations of TbF_3 powder were applied to the surface of the Nd-Fe-B ribbons by electrophoretic deposition (EPD) followed by a thermal treatment. Magnetic measurements showed a more than 5% improvement in the coercivity. An important factor leading to the improved coercivity is the high-quality coating, which is the key-factor in the diffusion process taking place at 500 °C to 700 °C.

A novel type of magnet was prepared from a spherical magnetic powder, obtained using inert-gas atomization. The material was successfully consolidated to full density with the SPS technique. Good overall magnetic properties, comparable to other types of isotropic Nd-Fe-B magnets (melt-spun and HDDR-processed materials), were achieved with a combination of sieving and post-consolidation heat treatment. A microscopy study of the raw powder and dense samples was performed. The mechanical properties of the bulk magnets were characterized and compared to other types of Nd-Fe-B magnets, prepared by established manufacturing routes. Another set of experiments was designed with the aim being to develop a new generation of Nd-Fe-B magnets with a reduced amount of critical heavy-rare-earth elements. Bulk magnets with regions containing a Dy-based eutectic alloy were prepared from the HDDR powder. The subsequent heat treatment enabling the diffusion of Dy into the other parts of the sample was achieved by the formation of high-anisotropy regions in the matrix phase. Consequently, the intrinsic coercivity was increased.

Complex Intermetallic Alloys

In the frame of the International Associated Laboratory (LIA) PACS2, which connects CNRS and JSI, we have expanded our studies of the **Al-Cr-Sc system**, resulting in the discovery of two (so far unknown) **ternary phases**. One of them is the Al_8Cr_4Sc phase, which shows similarities to other Al_8Cr_4RE compounds with a tetragonal I4/mmm crystal structure (Figure 1). The second ternary phase has been indexed by the hexagonal prototype crystal structure (space group 194) of $Al_{0.2}Hf_{0.8}Mo_2$.

We have continued our studies of the crystallization mechanisms of a glass prepared by melt-spinning in the **Al-Ce-Fe-Cu** alloys system. Namely, the addition of immiscible Fe and Cu in the stoichiometric $Al_{20.5}Ce_{41.5}(Fe_YCu_{1-Y})_{38}$ alloys have been systematically varied, aiming to trace their impact on the structure, microstructure, thermal properties, and magnetism. While Fe-rich alloys do not completely hinder crystallization and yield nanocrystalline precipitates, Cu-rich alloys are found to be better glass formers. Magnetic measurements show that Fe-rich alloys (y=1, 0.87) are ferromagnetic, while alloys with a lower y value (0 ≤y ≤0.74) exhibit paramagnetic behaviour.

In collaboration with the research team from the Jean Lamour Institute, Nancy, France, we conducted investigations on the Al-Fe-Ir system, where we have successfully identified a new ternary phase with an average composition of $Al_{50}Fe_{32}Ir_{18}$. The crystal structure deduced by XRD corresponds to a face-centred cubic phase, prototype to the $FeRu_2Si$ crystal structure.

Figure 1: Al-Cr-Sc ternary system: a) High-angle annular dark-field scanning TEM (HAADF-STEM) image of newly discovered hexagonal ternary phase enriched with Al-Cr precipitates. The spatially resolved composition was determined from the elemental energy-dispersive x-ray spectroscopy (EDXS) maps using the following elements: b) Al, c) Cr and d) Sc.

In collaboration with the group from the Faculty of Natural Sciences and Engineering (Department of Materials and Metallurgy), we have intensified studies on a potential new family of light alloys based on quasicrystals (QCs) embedded in Al-based alloys. Within this frame we initiated detailed TEM studies of interfacial properties between QCs and the matrix, which control the overall strength, and thus can strongly affect the further development of these high-strength Al-based alloys reinforced with Qc phase appropriate for the automotive and aerospace industries.

Structural Materials

Large efforts are related to the selection and optimization of suitable structural materials capable of withstanding extreme conditions to achieve high efficiency and safe operation of the **future fusion power plants**. One of the key problems is the selection of materials for the **divertor**, which is subjected to very high heat fluxes. The main task of the High-Heat-Flux Materials (HHFM) division within the **EUROfusion program**, in which we are a partner, is thus the development of the components for the DEMO divertor. Tungsten, W, is considered as a primary candidate for high-heat-loaded structural parts in DEMO, mainly due to its very high melting point, good
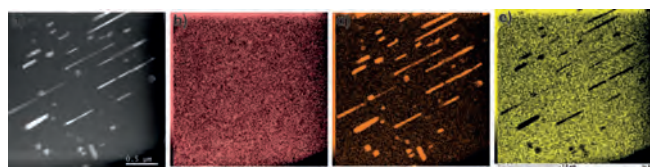
thermal conductivity and relatively low activation regarding long-term waste management. Unfortunately, these advantages are accompanied by a low fracture toughness in lower temperature regimes and the onset of recrystallization resulting in the loss of strength at high temperatures. We are trying to overcome the disadvantages of pure W by the incorporation of SiC fibres (to increase the fracture toughness) and W2C nanoparticles (to prevent the recrystallization and grain growth of W) into the W matrix. The synthesis and consolidation of W-W2C composites were optimized, and our samples were sent to partner institutions for the measurements of thermal conductivity and mechanical properties at temperatures up to 1000 °C. Additionally, high-heat-flux tests and a determination of the recrystallization temperature are in progress. In 2017 we also started a new Enabling project (part of EUROfusion) in which we want to prepare cemented carbides (WC) with or without a low-activation binder phase. The first part was successfully implemented using SPS as a consolidation method, and in the second we are collaborating with the Institute of Metals and Technology.

Materials for Health and a Clean Environment

In the frame of the national project "Bio-responsive **magneto-optically coupled nanomaterial-based systems** for innovative skin cancer treatments", an innovative theranostic material based on FePt/SiO$_2$/Au hybrid nanoparticles was developed and its high potential for both, **photo-thermal therapy and magnetic resonance imaging (MRI)** was demonstrated (Figure 2). The cytotoxicity together with the internalization mechanism and the intracellular fate of the hybrid NPs were evaluated in vitro on normal (NPU) and a half-differentiated cancerous cell line (RT4). The control samples, as well as the normal cell line incubated with the nanoparticles, showed no significant temperature increase during the in-vitro photo-thermal treatment ($\Delta T < 0.8\,°C$) and thus the cell viability remained high ($\sim$90%). In contrast, due to the high nanoparticles uptake by the cancerous RT4 cell line, significant heating of the sample was observed ($\Delta T = 4\,°C$) and, consequently, after laser irradiation, cell viability dropped significantly to $\sim$60%. These results further confirm that the hybrid FePt/SiO$_2$/Au nanoparticles were not only efficient but also highly selective photo-thermal agents. Furthermore, the improvement in the contrast and the easier distinction between the healthy and the cancerous tissues were demonstrated with the in-vitro MRI experiments, proving that hybrid nanoparticles have an excellent potential to be used as a contrast agent.

Within the project "Evaluation of possible harmful effects of nanoparticles and underlying mechanisms – from physical-chemical and in vitro toxicity characterization to innate immune system activation" in cooperation with the Faculty of Electrical Engineering, we performed the *characterization* of industrial nanoparticles and their effect on cells.

Research in the field of **biomaterials and three-dimensional (3D)** scaffolds continued with the development of fibroin material and structures for advanced applications in tissue engineering, regenerative medicine, pharmacy, and the preparation of bio-ink for 3D printers. One of the applications is the development of fibroids with enhanced mechanical properties suitable for bone cell growth. We connected more closely with the Slovenian researcher at the Ludwig Boltzmann Institute for Experimental and Clinical Traumatology (LBIT).

With the company Animacel Ltd, we upgraded the cooperation with the successful development of three-dimensional fibroin silk scaffolds, which without the necessary functionalization of the surface of the material caused the osteogenic differentiation of animal stem cells from the fat tissue. Using a scanning electron microscope (SEM), we monitored the behaviour of cells depending on the method of planting (Figure3). Experimental treatments on animals are in progress.

In cooperation with the National Institute for Biology, three-dimensional carriers of natural materials (silk, gel gum, methyl cellulose) were developed, which was the basis for toxicological tests on liver cells. By optimizing the form of the carriers, we achieved improved results in
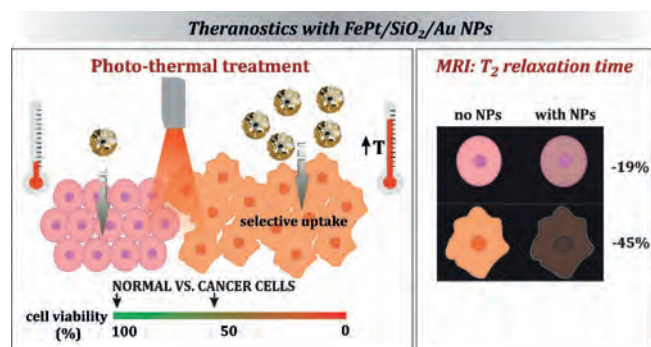
Figure 2: Innovative hybrid FePt/SiO$_2$/Au NPs as both a highly efficient and selective photo-thermal therapy agent and an MRI contrast agent.

We pushed the silk fibroin development in the field of pharmacy, more specifically in the field of advanced delivery systems with the controlled release of active substances (estradiol). We studied the interaction of the active substance with the delivery system, the design of the 3D delivery system and the release profile of estradiol in vitro. The project involves the cooperation of the Department for Nanostructured Materials with the Faculty of Pharmacy and the Faculty of Veterinary Medicine.
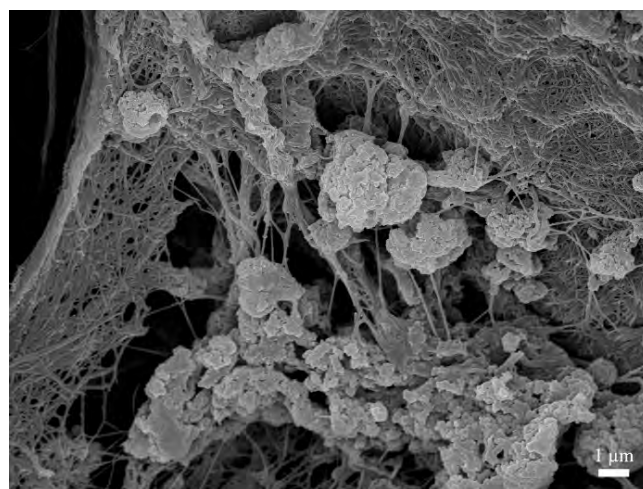
Figure 3: SEM image showing the behaviour of cells depending on the method of planting.
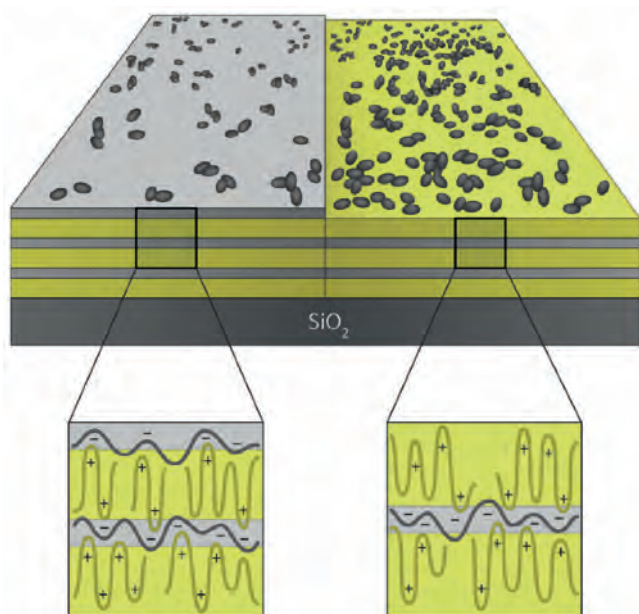
Figure 4: Schematic presentation of PAH/PSS polyelectrolyte multilayers terminating with PSS (6 layers) and PAH (5 layers). 50% less bacteria adhere to a negatively charged surface compared to a positive one.
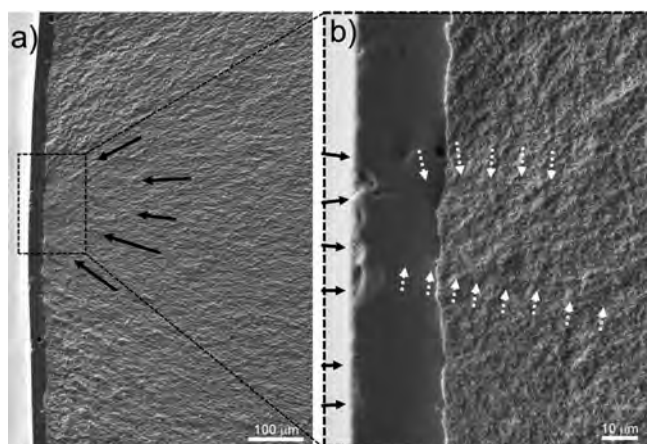
Figure 5: a) Fractographic study of a new generation 3Y-TZP; b) a self-glazed zirconia.

determining the toxicity of substances, as we simulated an appropriate 3D environment, mimicking living tissues.

We continued with the **3D printing of scaffolds for cells** and the development of innovative biological inks. Based on rheological research and the research of mechanical properties, we have developed an improved composite Bio-ink based on silk fibroin and gellan gum. As part of this project, a diploma paper was prepared in cooperation with the Faculty of Natural Sciences and Engineering. In cooperation with the Institute for the Development of Advanced Application Systems, we are developing innovative bio-ink, based on silk fibroin and gelatin, wherein the gelatin represents a carrier phase and support for the silk fibroin during printing.

In collaboration with the Faculty of Health Sciences of the University of Ljubljana, we carried out a series of studies to describe the link between bacterial adhesion *(E. coli, P. aeruginosa, S. aureus and others)* and the surface properties of materials. The influence of the roughness and wetting angle on the adhesion of bacteria was studied on variously treated stainless-steel substrates. It turns out that adhesion is better on surfaces with higher roughness, but the final surface morphology after surface treatment (textured cracks against an electropolished pits with the same roughness) also has a great impact. In the second set of studies, the bacteria adhesion was studied on samples coated with polyelectrolytic layers (poly(allylamine hydrochloride)/sodium poly(4-styrenesulfonate) - PAH/PSS). Samples were prepared with layer-by-layer deposition and terminated with either a positively or negatively charged final layer. It turns out that 50% less bacteria adhere to a negatively charged surface compared to a positive one (Figure 4). Our work was published in *Polymers (IF= 3.34)*.

In the field of **dental ceramics**, we were involved in the research on zirconia (3Y-TZP) as well as other dental materials. We have published several studies in the leading journals for ceramics, dental- and bio-materials; *Journal of the European Ceramic Society, Journal of Prosthodontic Research, Dental Materials*, and *Acta Biomaterialia*. We were reporting on the influence of yttrium-segregation-dependent phase partitioning, residual stresses and airborne-particle abrasion on the aging and fracture behaviour of 3Y-TZP. We have investigated the effect of mechanical fatigue and accelerated aging on the fracture resistance of glazed monolithic 3Y-TZP dental bridges and were involved in a fractographic study of a new generation 3Y-TZP, self-glazed zirconia with improved reliability (Figure 5). A study of the effect of thermo-mechanical cycling on porcelain bonding to Co-Cr and Ti alloys fabricated by casting, milling, and selective laser melting was also performed.

Formaldehyde (HCHO) is one the initial products of the oxidation of methanol, which has technological significance in industrial catalytic processes. However, it has a detrimental impact on human health. We are developing modified printed electrodes via nanostructuring of **the receptor elements based on transition-metal material oxides** that serve as the base for an autonomic sensor platform suitable for in-situ HCHO analytical studies. With applying a novel oxalate-based method, the specific electrochemical surface of the nanostructured Ni was determined for the first time, which represents the basis for investigating the kinetics of the electron-transfer processes. The developed nanostructured NiOOH electrode displays a remarkable electro-catalytic activity for the oxidation of HCHO with 1 μmol/l, which is comparable to the precious metal-based receptor elements, which have until now shown the lowest LODs for formaldehyde detection, but exhibit high prices. The proposed **sensor platform** makes it easy and inexpensive to detect pollution such as formaldehyde in realistic environments.

We continued with the development of innovative reactors for water purification that are based on the process of the **photoelectrocatalysis**. The devices allow for the degradation of organic substances that are potentially present in various wastewaters. Their main part is a photocatalytically active film of titanium oxide nanotubes, which is firmly bound to the titanium metal. The active material is synthesized by the anodic oxidation process. We developed both water-purification and air-purification systems. In the area of water purification, we cooperated with Gorenje d.d. and developed a device that is suitable for photoelectrocatalytic purification of waste water from washing machines. In the field of air purification, we developed photocatalytic devices within the framework of

Climate-KIC accelerator. We were members of the EIT (**European Institute of Technology**) program for the second year for which we were awarded financial support. We presented our air-purification devices at the 10th International Conference on Technology Transfer and won the **award for the best invention for the economy**.

Engineering and Functional Ceramics

The naturally self-driven AlN powder hydrolysis was exploited as an easy and extremely pure synthesis for the preparation of hierarchically assembled, nanocrystalline alumina powder in the form of micron-sized bundles of agglomerated 2D nanosheets, forming flower-like structures. The as-prepared powder was subsequently consoli-

dated to form high-performance hierarchical mesoporous–macroporous alumina monoliths exhibiting exceptionally high flexural strength for an unsintered, porous green body obtained via homogenous, dense packing of the primary crystallites. The work was published in the *Journal of Materials Science*.

We showed how primary crystallites could be used as the building blocks for homogenous packing and rapid sintering. Namely, the ordered agglomeration of zirconia primary crystallites into secondary particle assemblies ensured their homogeneous packing, while also preserving the high surface energy to higher temperatures, increasing the sintering activity.

In the field of n-type **oxide thermoelectric materials**, we continued with the development of **ZnO-based ceramics**. In the $ZnO-In_2O_3$ system, we determined the formation mechanism of $Zn_kIn_2O_{k+3}$-type homologous phases (k = 5, 11, 18) and showed how it affects grain growth, microstructure development, structural and chemical homogeneity, and consequently thermoelectric properties. In the case of **doping with Al**, we found that Al substitutes for In on both primary sites of the $Zn_5(In_{1-x}Al_x)_2O_8$ phase, the octahedral sites in basal-plane inversion boundaries and the trigonal bi-pyramidal sites in zig-zag inversion boundaries. We explained how substitution affects the thermoelectric characteristics.

In the field of **thermoelectrics**, we continued with studies of nanostructure and thermoelectric properties of n-type thermoelectric materials based on **Sr(Ti,Nb)O3**. The addition of various oxides to this structure caused the formation of a three-dimensional network of Rudlesden-Popper-type planar faults. The random stacking of planar faults increased the phonon scattering and lowered the thermal conductivity. Consequently, the material exhibited **an increased figure of merit ZT**.

In ZnO doped with low amounts of Ga, we found that non-periodic planar (2D) defects are formed already in amounts up to 1 at. %. They cause a strong phonon scattering and hence reduced thermal conductivity, while the electrical conductivity is preserved (article in ***Inorganic Chemistry, IF = 4.85***). We also studied the influence of selected dopants and sintering conditions on the **equilibria of defects and the thermoelectric properties of ZnO-based ceramics.** We found that under reductive sintering atmosphere and with SPS processing, the solid solubility of the donor dopant (Al^{3+}, Ti^{4+}) in ZnO grains is increased, while the presence of acceptor defects and hence Schottky barriers at the grain boundaries is eliminated, resulting in an increase of the electrical conductivity by several orders of magnitude. Furthermore, the increased concentration of point defects in ZnO grains results in reduced thermal conductivity. In the article *(Materials & Design, IF = 4.364)*, we explained the possibilities to enhance the thermoelectric properties of ZnO-based ceramics using the engineering of point defects.

In the nano area of ZnO, we exploited a cost-efficient hydrothermal synthesis to produce arrays of ZnO nanowires (NWs) with a high surface area. We showed, for the first time, that a thin carbon nitride (CN) layer can efficiently extract holes from ZnO, which leads to enhanced performance and stability in an alkaline solution. Detailed photoelectrochemical (PEC) characterization reveals that the CN acts as a protective shell and at the same time facilitates a hole transfer from ZnO-NWs to the electrolyte. We managed to increase the current densities by several times as compared to the pristine ZnO-NWs.

Within the frame of the collaboration with the research group from Vinča Institute of Nuclear Sciences, Belgrade, Serbia, we have studied the connection between the absorption kinetics and the structural and chemical **properties of the MgH2 thin films, as a potential hydrogen-storage material.** Processes taking place during hydrogen desorption from MgH_2 thin films were investigated in as-prepared samples and samples modified by argon-ion irradiation. Irradiation was used to produce well-defined defects with an in-depth distribution (Figure 6). It was shown that the size, shape,

> When exposed to intense electromagnetic radiation activated by the SPS set-up providing rapid heating, the assembled crystallites were subjected to further agglomeration, coalescence, and sliding. All these effects lead to rapid densification in the absence of extensive diffusional processes, cancelling out the grain growth during the initial sintering stages and providing a zirconia nanoceramic in only 2 minutes at 1300 °C. The work was published in Scientific Reports and announced in the renowned Ceramic Tech Today portal of the American Ceramic Society.
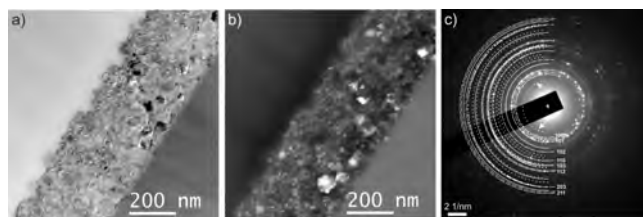

Figure 6: Magnesium hydride thin films: a) Bright-field and b) the corresponding dark-field transmission electron microscopy (TEM) image of the irradiated film. c) The selected-area electron diffraction (SAED) pattern acquired from the irradiated film, showing the presence of MgH_2 (short dashed line), MgO (full line) and Mg (long dashed line) phases.

and concentration of Mg nuclei formed during the hydrogen desorption from the MgH_2 thin films depend on the characteristics and distribution of the induced defects. Variations in sample colour were observed during hydrogen desorption and before the creation of the Mg nuclei. In relation to this, the DFT calculations showed that the observed variations in the optical properties of the samples can be explained by changes in the MgH_2 electronic structure.

Minerals

Within the basic research project "Initial stages of phase transformations in minerals" and different bilateral projects, we continued our investigations of growth-type planar defects in minerals. We studied the mechanisms of their formation, their atomic-scale structure and chemical composition and effects on crystal growth and microstructure development in different minerals and functional ceramic materials. The main topics of our research were: (1) twinning in cassiterite and the synthesis of SnO_2-based ceramics for varistor applications, (2) growth and twinning of rutile TiO_2 according to the principles of mesocrystals self-assembly, (3) growth defects in hydrothermally prepared crystals and (4) characterization of nanomaterials for different applications.

Cassiterite (SnO_2) is a technologically important material, which occurs in nature in the form of (101) twins. We have successfully synthesized SnO_2-based varistor ceramics with excellent nonlinearity and a low leakage current by the optimization of CoO and Nb_2O_5 additions and the sintering conditions. The addition of both aliovalent dopants in a suitable ratio results in their synergistic effect on densification and SnO_2 grain growth, leading to ceramics with almost theoretical density (>99%). The addition of Nb_2O_5, on the other hand, triggers the formation of numerous (101) twins within the SnO_2 grains, which have an effect on the microstructure development in SbO_2-based ceramics and hence electrical properties. The formation of twin boundaries was explained by a series of topotaxial reactions in the initial growth stages due to the addition of Nb_2O_5. The local structure and chemical composition of the twin boundaries was analysed by different methods of electron microscopy. The results of this work are published in *Ceramics International (IF=2.986)*.

In collaboration with our colleagues from the Sobolev Institute for Geology and Mineralogy, we analysed the growth defects in hydrothermally prepared crystals of beryl and sapphire. The preparation of gem-quality crystals is by epitaxial growth on an oriented crystal seed. During the initial stages of crystal growth (close to the seed), defects are observed in the newly formed crystal. These defects were analysed by transmission electron microscopy and the results were published in *Crystal Growth and Design (IF= 4.055) and CrystEngComm (IF=3.474)*.

Analytical Electron Microscopy

For the microstructural characterization of modern materials, we have applied advanced high-resolution scanning electron microscopy (FEGSEM) and analytical methods of energy-dispersive and wavelength-dispersive spectroscopy (EDS, WDS) for qualitative and quantitative elemental analysis. With the implementation of the method of electron backscatter diffraction (EBSD), we have investigated the crystallographic characteristics of the materials: crystallinity, orientation of phases and texture.

The FEGSEM, EDS, WDS and EBSD methods were modified and optimized taking into account the specificity of the individual materials, with the aim being to achieve the most precise and accurate analytical results. By implementing correlative microscopy, i.e., by using an optimum combination of FEGSEM, AFM, EDS, WDS and EBSD methods and taking into account the characteristics of the individual materials, we achieved reliable, precise and accurate analytical results. We studied various materials such as ceramic thermoelectrics, complex metallic and quasicrystalline alloys, magnetic materials based on Nd-Fe-B, abrasives, piezoelectric perovskite ceramics. Among other things, we examined the influence of heat treatment on the microstructure and phase composition in alloys based on Al-Fe-Cu-Ce/Gd and Al-Cr-Sc. Using the microcrystallographic EBSD analysis, we directly confirmed the presence of icosahedral and decagonal quasicrystals in complex alloys based on Al-Mn-Cu-Mg/Si.

The ESTEEM (Enabling Science and Technology through European Electron Microscopy) consortium continued its activities in the field of materials characterization using state-of-the-art techniques of transmission electron microscopy, such as electron energy-loss spectroscopy (EELS), high-resolution scanning transmission electron microscopy (STEM, HAADF-STEM) and mechanical preparation of the TEM samples. The ESTEEM consortium has a status of EU Advanced Community, and a lot of effort was focused on the preparation of a new project proposal for ESTEEM3. The implementation of various electron microscopy analytical techniques and the possibility for the researchers to access research infrastructure for electron microscopy within the **Center for Electron Microscopy and Microanalysis (CEMM)** is of utmost importance for the research group. A member of our department is the scientific coordinator of the consortium.

Industrial partners

We have conducted analyses of innovative composite abrasives for industrial partner SwatyComet within the project "Microstructural investigations of abrasive materials", which are intended to develop and manufacture improved cutting and grinding tools with a prolonged lifetime.

Education and outreach activities

For the fifth year, the members of the department participated in science promotion activities within the framework of the Science on the Street project, which was held under the auspices of the SATENA Society. There were two cycles of popular science lectures, two science slams, and a round table.

Awards and appointments

1. Luka Suhadolnik and Miran Čeh, Best Innovation Award at the 10th International Conference on Technology Transfer, IJS, Ljubljana, Slovenia, 9–13 October 2017

2. Matej Kocen, Best Oral Presentation Award at the 25th International Conference on Materials and Technology, 25 ICM&T, Portorož, Slovenia, 16–19 October 2017 for the contribution "Inhibition of W grain growth in W-based material for fusion application (CM)" (co-authors: Petra Jenuš, Saša Novak, Andreja Šestan).

3. Rok Kocen, Best Scientific Presentation Award at the Joint Students' Conference of the Jožef Stefan International Postgraduate School and Young Researchers Day in the field of Chemistry, Materials, Biochemistry and Environment at the Jožef Stefan Institute for the contribution »3D printing biomaterials for regenerative medicine«, Ljubljana, 19–20 April 2017

4. Rok Kocen, "Science in front of the Microphone" Award given by SATENA - Slovenian Academic Society for Science and Engineering for the Best short presentation of PhD Thesis at the Joint Students' Conference of the Jožef Stefan International Postgraduate School and Jožef Stefan Institute, Ljubljana, 19 April 2017

5. Kristina Žužek Rožman, Finalist for the Best Mentor 2016 Award, given by Young Academy Association in cooperation with the Slovenian Research Agency (ARRS), Ljubljana, Slovenia, 22 March 2017

Organization of conferences, congresses and meetings

1. Project Meeting H2020 REProMag; Resource Efficient Production Route for Rare Earth Magnets, Ljubljana, Slovenia, 10 January 2017

2. The 2nd Slovene Microscopy Symposium, 11–12 May 2017, Piran, Slovenia (co-organisers)

3. The 13th Multinational Congress on Microscopy; MCM 2017, Rovinj, Croatia, 24–26 September 2017 (members of the International Advisory Board)

4. The 25th International conference on Materials and Technology – 25. ICM&T, 16–19 October 2017, Portorož, Slovenia (co-organisers)

5. Annual meeting within of LIA PACS2: International Associated Laboratory; Push-Pull AlloyS and Complex Compounds: from bulk properties to surface functions, 11–13 December 2017, Goriška Brda, Slovenia

6. Annual Meeting of Slovenian Fusion Association - SFA, Podgorica, Slovenia, 13 December 2017 (co-organisers)

INTERNATIONAL PROJECTS

1. Selective Laser Melting (SLM) and Spark Plasma Sintering (SPS) of Cost Effective Rare-earth based Permanent Magnets for Electrical Machines
Prof. Spomenka Kobe
ABB Switzerland Ltd

2. Spark Plasma Sintering (SPS) of Cost Effective and High Performance Rare-Earth Based Permanent Magnets for Electrical Machines
Prof. Spomenka Kobe
ABB Switzerland Ltd

3. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
Prof. Saša Novak Krmpotič
European Commission

4. COST MP1301 - NEWGEN; New Generation Biomimetic and Customized Implants for Bone Engineering
Prof. Saša Novak Krmpotič
Cost Office

5. COST ES1205; The Transfer of Engineered Nanomaterials from Wastewater Treatment & Stormwater to Rivers
Prof. Saša Novak Krmpotič
Cost Office

6. COST MP1407 - e-MINDS; Electrochemical Processing Methodologies and Corrosion Protection for Device and Systems Miniaturization
Asst. Prof. Kristina Žužek Rožman
Cost Office

7. H2020 - REProMag; Resource Efficient Production Route for Rare Earth Magnets
Dr. Benjamin Podmiljšak
European Commission

8. H2020 - DEMETER; Training Network for the Design and Recycling of Rare-Earth Permanent Magnet Motors and Generators in Hybrid and Full Electric Vehicles
Asst. Prof. Kristina Žužek Rožman
European Commission

9. H2020 - STEM4youth; Promotion of STEM Education by Key Scientific Challenges and their Impact on Our Life and Career Perspectives
Dr. Kristina Žagar Soderžnik
European Commission

10. H2020 - AMPHIBIAN; Antisometric Permanent Hybrid Magnets based on Inexpensive and Non-Critical Materials
Dr. Petra Jenuš Brdnik
European Commission

11. H2020 EUROfusion - Materials-PPPT-FU: WC and SiC reinforced tungsten
Prof. Saša Novak Krmpotič
European Commission

12. H2020 EUROfusion - Education-ED-FU
Prof. Saša Novak Krmpotič
European Commission

13. H2020 EUROfusion - ER-4-FU; Enabling Research: Low-activation cemented carbides for high heat flux applications
Prof. Saša Novak Krmpotič
European Commission

14. Advanced Methods and Technologies for Processing of a New Generation of ZnO-based Varistor Ceramics
Prof. Slavko Bernik
Chinese Academy of Sciences

15. Electron Microscopy Study of the Degradation Kinetics of Porous Bioactive Glass based Novel Drug Eluting Implants (Coating/3D Scaffolds) as a Function of Hard Tissue Regeneration for Treatment of Osteoporotic Fractures in Elderly Patients
Asst. Prof. Nina Daneu
Slovenian Research Agency

16. Nucleation and Photocatalytic Activity of Nanoparticles Studied in Actual Liquid Environment under Transmission Electron Microscope
Prof. Sašo Šturm
Slovenian Research Agency

17. 0D to 3D ZnO Nanostructures for Optical, Electonic and Energy Applications
Dr. Matejka Podlogar
Slovenian Research Agency
18. Synthesis of Core/Shell MgAl2O4 Spinel Powders for Transparent Armor and IR Applications – CSMASP
Prof. Slavko Bernik
Slovenian Research Agency
19. Processing of High-performance Zirconia Bioceramics for Dental Application
Asst. Prof. Andraž Kocjan
Slovenian Research Agency
20. Investigations of Twinning and Topotaxial Reactions in Sulphide Minerals
Prof. Aleksander Rečnik
Slovenian Research Agency
21. Crystal and Electronic Structure of NbS3 Phases
Prof. Sašo Šturm
Slovenian Research Agency
22. Crystallography, Twinning and Phase Transformations in Minerals with Aragonite-Type Structure (CaCO3, SrCO3, BaCO3, PbCO3)
Prof. Aleksander Rečnik
Slovenian Research Agency
23. Characterization of Structural Defects in Semiconductor ZnO Films Grown by Atomic Layer Deposition (ALD)
Prof. Aleksander Rečnik
Slovenian Research Agency
24. Advanced Electronic Ceramics for the Sustainable, Efficient and Safe Use of Energy
Prof. Slavko Bernik
Slovenian Research Agency
25. Hydrous Defects and Twinning in Silicates
Asst. Prof. Nina Daneu
Slovenian Research Agency
26. Tungsten-Based Composite for Fusion Applications
Prof. Saša Novak Krmpotič
Slovenian Research Agency
27. Atomic-Scale Investigations of Twinning and Polytypism in Natural Diamonds
Prof. Aleksander Rečnik
Slovenian Research Agency

RESEARCH PROGRAMS

1. Nanostructured Materials
Prof. Spomenka Kobe
2. Engineering and bio-ceramics
Asst. Prof. Andraž Kocjan

R & D GRANTS AND CONTRACTS

1. Structure and Chemical Composition Study of Surfaces and Interfaces with Highresolution Scanning Transmission Electron Microscopy at Atomic Level
Prof. Aleksander Rečnik
2. High-Performance Nanostructured Coatings - breakthrough in concentrated solar power
Asst. Prof. Andraž Kocjan
3. Evaluation of possible harmful effects of nanoparticles and underlying mechanisms – from physico-chemical and in vitro toxicity characterisation to innate immune system activation
Prof. Saša Novak Krmpotič
4. Atomic-scale studies of initial stages of phase transformations in minerals
Asst. Prof. Nina Daneu
5. Bio-responsive magneto-optically coupled nanomaterial-based systems for innovative skin cancer treatments
Prof. Sašo Šturm
6. W- and WC-based composites for high thermally loaded parts in the fusion demonstration power plant DEMO
Prof. Saša Novak Krmpotič
7. Catalytically-assisted high efficiency and low-cost nanostructured sensors based on modified screen printed electrodes for analytical chemistry
Asst. Prof. Kristina Žužek Rožman
8. UV sensors nanoparticles embedded into PA fibres
Prof. Spomenka Kobe
9. From the synthesis of metal oxides to the humidity and oxygen prototype nanosensors
Dr. Kristina Žagar Soderžnik
10. High-coercivity Nd-Fe-B permanent magnets with minimum amount of heavy rare earths
Dr. Marko Soderžnik
11. Microscopy and microanalyses
Dr. Zoran Samardžija
12. Technical ceramics
Asst. Prof. Andraž Kocjan

NEW CONTRACTS

1. Research and development of dental materials
Dr. Nataša Drnovšek, Asst. Prof. Andraž Kocjan
Ustna Medicina d. o. o.
2. Microstructural investigations of abrasive materials
Dr. Zoran Samardžija
Swatycomet d. o. o.
3. Preparation of microvaristor powder for composites with nonlinear resistivity
Prof. Slavko Bernik
Razvojni Center Enem Novi Materiali d. o. o.
4. Photo(electro)catalytic cleaning of washing machine waste water
Prof. Miran Čeh
Gorenje gospodinjski aparati,d.d.
5. Analysing the effect of mechanical fatigue of ZrO2 dental root posts
Asst. Prof. Andraž Kocjan
Vall-cer d. o. o.
6. Preliminary study of processing the varistor ceramics using tape casting
Prof. Slavko Bernik
Keko - Oprema d. o. o. Žužemberk
7. TiO2 pigment
Prof. Saša Novak Krmpotič
Cinkarna Celje

VISITORS FROM ABROAD

1. Prof. Andrzej Dziedzic, Wrocław University of Science and Technology, Wrocław, Poland, 5–7 January 2017
2. Dr. Pavel Gavryushkin, Sobolev Institute of Geology and Mineralogy, Novosibirsk, Russia, 24–31 January 2017
3. Dr. Taisia Aleksandrovna Alifirova, Novosibirsk State University, Novosibirsk, Rusija, 7 February – 3 March 2017
4. Dr. Richard Wheeler, Edinburgh Scientific, Edinburgh, Scotland, 26 February–8 March 2017
5. Dr. Anouk Galtayries, Institut de Recherche de Chimie Paris, Paris, France, 3 March 2017
6. Dr. Matic Krivec, CTR Carinthian Tech Research AG, Villach, Austria, 21 March 2017
7. Dr. Tassilo Moritz, Fraunhofer-Institut für Keramische Technologien und Systeme IKTS, Dresden, Germany, 3 April 2017
8. Vesna Ribić, Institute for Mutidisciplinary Research, Belgrade, Serbia, 10 March – 13 April 2017
9. Martina Orefice, Katholieke Universiteit Leuven, Leuven, Belgium, 9 February – 12 April 2017
10. Juliane Moritz, University of Dresden, Dresden, Germany, 1 April - 30 September 2017
11. Dr. Ulrike Wolf, Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, Dresden, Germany, 5–14 April 2017
12. Dr. José Alberto Padrón, Geosciences Montpellier, Université de Montpellier, Montpellier, France, 1– 14 April 2017
13. Dr. Julian Ledieu, Institut Jean Lamour, Nancy, France, 24–28 April 2017
14. André Baldissera, Universidade Federal de Santa Catarina - UFSC, Florianópolis, Brazil, 3–5 May 2017
15. Dr. Michael Ortner, Georg Franz, CTR Carinthian Tech Research in Technical Innovation Physical Solutions, Villach, Austria, 5 May 2017
16. Vesna Ribić, Institute for Mutidisciplinary Research, Belgrade, Serbia, 10–12 May 2017
17. Dr. Victor Gabrielevich Thomas, Sobolev Institute of Geology and Mineralogy, Novosibirsk, Russia, 13–28 May 2017
18. Dr. Richard Wheeler, Edinburgh Scientific, Edinburgh, Scotland, 2–15 June 2017
19. Laura Treccani in Paolo Vavassori, Petroceramics S.p.A, Bergamo, Italy, 9 June 2017
20. Prof. Guorong Li, Shanghai Institute of Ceramics, Shanghai, China, 9–13 June 2017
21. Dr. Goran Štefanić and Valentina Borko, Rudjer Bošković Institute, Zagreb, Croatia, 14–18 June 2017
22. Prof. Emmanuel Guilmeau, Laboratorie CRISMAT, Caen, France, 18–20 July 2017
23. Fabian Burkhardt, University of Applied Sciences Aalen, Aalen, Germany, 30 July – 30 September 2017
24. Pierre-Louis Julliard, École nationale supérieure des mines de Nancy, Nancy, France, 1–31 August 2017
25. Prof. Carlo Burkhardt, OBE Ohnmacht & Baumgartner GmbH & Co. KG, Ispringen, Germany, 30 August– 2 September 2017
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27. Dr. Goran Branković, Dr. Danijela Luković Golić, Jelena Vukašinović and Vesna Ribič, Institute for Mutidisciplinary Research, Belgrade, Serbia, 18–22 September 2017
28. Prof. Zhijian Shen, University of Stockholm, Department of Materials and Environmental Chemistry, Stockholm, Sweden, 2–3 October 2017
29. Robert Ireson, GTS Glass Tehnologies Services Ltd., and Sarrawat Rehman, JRI Orthopaedics Ltd., Sheffield, United Kingdom, 4– 5 October 2017
30. Dr. Ildikó Cora and Dr. Zsolt Fogarassy, Hungarian Academy of Sciences, Institute of Technical Physics and Materials Science, Budapest, Hungary, 2–9 October 2017

31. Dr. Ulrike Wolf, Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, Dresden, Germany, 3 October – 3 November 2017
32. Jelena Vukašinović, Institute for Multidisciplinary Research, Belgrade, Serbia, 9–12 October 2017
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34. Prof. Mehmet Ali Gülgün, FENS, Sabanci University, Istanbul, Turkey, 4–11 November 2017
35. Dr. José Alberto Padrón-Navarta, Géosciences Montpellier, Université de Montpellier, Montpellier, France, 11–18 November 2017
36. Prof. Michael Gasik, Aalto University, Espoo, Finland, 26–28 November 2017
37. Fabian Burkhardt, University of Applied Sciences Aalen, Germany, 10–12 December 2017

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Original Article

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PUBLISHED CONFERENCE CONTRIBUTION

1. Muhammad Shahid Arshad, Špela Trafela, Kristina Žužek Rožman, Petar Djinović, Albin Pintar, "Multisegmented Au/TiO2 nanowires for plasmon-enhanced photocatalytic applications under visible light: theoretical and experimental aspects", In: *The Fifth International Conference on Water, Energy and Environment (ICWEE/5), February 28-March 2, 2017, American University of Sharjah, United Arab Emirates*, Sharjah, [s. n.], 2017, [1-3].

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5. Iva Kaplanec, Aleksander Rečnik, Gregor Mali, Nevenka Rajić, "Mechanism and kinetics of phosphate removal from water media using iron(III)-modified clinoptilolite", In: *Proceedings of the 7th Slovenian-Serbian-Croatian Sympozium on Zeolites, May 25-27, 2017, Ljubljana, Slovenia*, Nataša Zabukovec Logar, ed., Zagreb, Croatian Zeolite Association (CROZA), 2017, 99-102.

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Mentoring

1. Anže Abram, *Synthesis and characterization of hydrothermally treated and functionalised zinc and aluminium surfaces:* doctoral dissertation, Ljubljana, 2017 (mentor Goran Dražić).

2. Jasna Cotič, *The influence of sintering protocol and airborne-particle abrasion on ageing of zirconia ceramics in vitro and in vivo:* doctoral dissertation, Ljubljana, 2017 (mentor Peter Jevnikar; co-mentor Andraž Kocjan).

3. Sandra Drev, *Twinning and polytypism in the spinel-chrysoberyl system:* doctoral dissertation, Ljubljana, 2017 (mentor Nina Daneu; co-mentor Aleksander Rečnik).

4. Viviana Golja, *Migration of nanoparticles from food contact materials:* doctoral dissertation, Ljubljana, 2017 (mentor Saša Novak Krmpotič; co-mentor Goran Dražić).

5. Rok Kocen, *Viscoelastic properties of hydrogel-based materials for tissue engineering scaffolds:* doctoral dissertation, Ljubljana, 2017 (mentor Saša Novak Krmpotič).

6. Mateja Košir, *Thermoelectric materials based on ZnO:* doctoral dissertation, Ljubljana, 2017 (mentor Slavko Bernik).

DEPARTMENT FOR MATERIALS SYNTHESIS K-8

The research of the Department for Materials Synthesis is mainly related to the synthesis of various advanced materials, especially magnetic materials, semiconducting oxides and optical materials. Special attention is given to nanostructured materials, such as ferrofluids, functionalized nanoparticles for use in biomedicine, multifunctional nanocomposites, magnetic coatings and fluorescent nanoparticles.

In 2017 our investigations focused on several important materials, i.e., materials containing magnetic nanoparticles, multifunctional nanocomposites, fluorescent nanoparticles and semiconducting materials for the preparation of thermistors.

New methods for the synthesis of nanoparticles are continuously being developed. Apart from magnetic nanoparticles of spinel ferrites, hexaferrites and metals (e.g., Fe^0), nanoparticles of noble metals (e.g., Au, Ru, Pt), ferroelectric nanoparticles (e.g., $Bi_4Ti_3O_{12}$), and fluorescent nanoparticles (e.g., rare-earth-doped $NaYF_4$) have been synthesized in 2017. For applications of the nanoparticles, as well as for their assembly into composite materials, engineering of their surface properties is of key importance. The surface properties are usually engineered by bonding different functionalization molecules onto the nanoparticles' surfaces. The functionalization molecules provide specific functional groups for the further (bio)conjugation of the different molecules needed for a specific application. The layer of organic molecules also defines the electric charge at the surfaces and the interactions between the nanoparticles in a liquid medium. For *in-vivo* medical applications the nanoparticles should not display a large surface charge. Therefore, the suspensions have to be stabilized sterically, with the bonding of large hydrophilic molecules, e.g., polyethylene glycol (PEG), polysaccharides, or polypeptides, onto the nanoparticle surfaces. The layer of molecules has to be bonded by forming stable covalent bonds, not to be desorbed or exchanged with other ligands from the medium. The surfaces of oxide materials are chemically relatively inert and in general they do not allow the covalent bonding of organic molecules. To enable covalent bonding the nanoparticles are usually coated with a thin silica layer. The silica provides surface silanol -Si-OH functional groups, which enable the covalent bonding of molecules, for example, different silanes. For biomedical testing we developed a procedure for bonding dextran and its derivatives onto the surfaces of different nanoparticles using the bonding of its hydroxyl groups with epoxy groups of the glycidoxypropyl silane (GLYMO) grafted at the silica-coated nanoplatelets' surfaces. In 2017 the research was focused on a modification of this process to enable the control of an electrical charge on the nanoparticles' surfaces. Namely, the cells internalize the nanoparticles with a positive surface charge to a larger extent. The positive surface charge was controlled with simultaneous bonding of dextran and diethylaminoethyl (DEAE)-dextran in different ratios. The final suspensions of nanoparticles were exceptionally colloidally stable in various biological media.

As an alternative to well-developed silica coatings, dopamine-based coatings, i.e., mussel-inspired polymers in the form of functional coatings, were developed on a variety of substrates by oxidative self-polymerization. Polydopamine (PDA), a major component of the pigment melanin, possesses excellent biocompatibility, biodegradability, universal adhesion, and post-functionalization accessibility. Since the PDA coating contains a variety of functional groups such, as quinone, aldehyde, catechol, hydroxyl, carbonyl, etc., chemicals with thiol or amine groups can feasibly be conjugated on the PDA surface. This approach enables the easy modification of the surfaces and control of their properties. Furthermore, other advantages such as the preparation simplicity, largely explain the growing interest in this material. However, a fundamental understanding regarding the

Head:
Prof. Darko Makovec

Immobilization of catalytic nanoparticles onto magnetic nanoclusters for their magnetic separation.
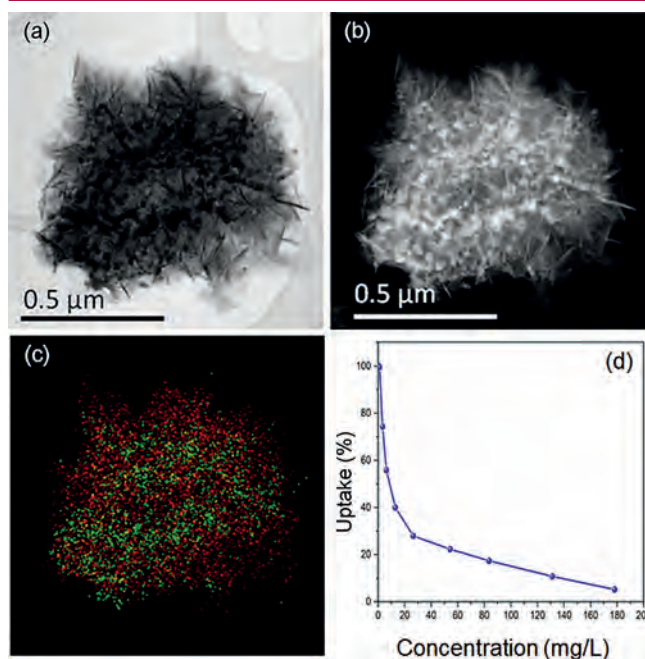

Figure 1: BF (a) and HAADF (b) STEM images with the corresponding EDXS elemental map (c) which shows distribution of Al (red) and Fe (green) in a magnetically retractable adsorbent used for water remediation. The adsorbent is composed of iron-oxide magnetic nanoparticles covered with γ-Al_2O_3 shell with a high surface area. Figure (d) illustrates adsorption of Cd on the adsorbent.

mechanisms of the PDA formation is still lacking. We have developed the PDA coatings on both as-synthesized iron-oxide nanoparticles and on the silica-coated nanoparticles, thus confirming the possibility to effectively coat nanoparticles with different surface properties. The process is based on the simple incubation of the nanoparticles in a dopamine hydrochloride solution at pH 8.5 in the presence of oxygen from the air at room temperature. The thickness of the coatings can simply be tuned by adjusting the concentration of the dopamine in the solution. The functionality of such coatings can beneficially be used to prevent the dissolution of (iron-oxide) nanoparticles in acids. They found applications in biomedicine, as well as in technology, for example, for the preparation of catalyst supports. Our PDA-coated materials are being further studied as catalyst supports in the frame of a collaboration with researchers from the University of Trieste, Italy.

The development of chain-like magnetic particles with hollow compartments for drug delivery.

Figure 2: Magnetic chain-like particle with hollow compartments used for the development of advanced drug delivery systems.

An important part of the research at the department remains devoted to clusters of magnetic iron-oxide nanoparticles (nanoclusters). These nanoclusters are developed for applications based on magnetic separation, such as the separation of poisonous heavy metals from water and their use as magnetically-recoverable supports for (bio)catalysts. When dispersing magnetic particles in a liquid medium it is beneficial if they are small enough to be in the superparamagnetic state. Superparamagnetism is a phenomenon related to ferro/ferrimagnetic particles when their size is reduced below a certain limit and thermal excitation induces rapid fluctuations of the nanoparticles' magnetic moments. The superparamagnetic limit is at approximately 20 nm for soft-magnetic materials. At this point these superparamagnetic nanoparticles no longer exhibit any spontaneous magnetic moments and, in contrast to larger ferromagnetic particles, they do not agglomerate in suspensions due to magnetic dipole-dipole interactions. However, the force acting on the magnetic particle in a magnetic field gradient, which is needed for the particle's separation from the suspension, is proportional to the particle's volume. It appears in practice, therefore, that individual superparamagnetic nanoparticles are just too small to be effectively separated. This magnetic separation is much more effective if the superparamagnetic nanoparticles are assembled into nanoclusters, containing several superparamagnetic nanoparticles in a single nano-unit, but still retaining the relatively large surface area.

For laboratory-scale research the commercially available superparamagnetic nanoclusters produced by Nanos Sci. (http://nanos-sci.com/), a spin-out company of the JSI, are normally used. The spherical nanoclusters display a narrow size distribution around 80 nm. They are coated with a thin silica shell, which enabled the effective covalent bonding of different functionalization molecules onto their surfaces. The fluorescent molecules are incorporated into the silica shell for the tracking of the nanoclusters with methods based on fluorescence microscopy. However, for the use in industrial-scale processes magnetic nanoclusters have to be produced using simple, inexpensive, and scalable methods. New methods have been developed for assembling magnetic nanoparticles into the clusters during their coating with carbon or $AlOOH/Al_2O_3$ coatings.

A precursor material for the preparation of carbon-coated magnetic nanoclusters was synthesized by the hydrothermal carbonization of carbohydrate in the colloidal suspension of superparamagnetic iron-oxide nanoparticles. The carbon layer was formed by the pyrolysis of carbohydrate in an inert atmosphere. The temperature and time of pyrolysis have a major impact on the composition and the surface properties of the carbon-coated magnetic nanoclusters, such as the amount of oxygen surface groups, the content and size of graphite nanocrystals, specific surface area, pore volume and pore size distribution.

Magnetic nanochains were functionalized with dipeptides and co-assembled with soluble dipeptides into magnetic superstructures.

The carbon-coated magnetic nanoclusters were used as supports for catalysts, such as ruthenium. In collaboration with the National Institute of Chemistry we tested magnetically-separable ruthenium nanocatalysts for chemical reactions of hydrogenation and deoxygenation. The Ru nanoparticles were deposited onto the carbon-coated nanoclusters using reduction of a Ru precursor by isopropanol at an elevated temperature. The influence of the pyrolysis temperature on the catalytic performance was systematically studied. The nanocatalysts exhibited catalytic activity that increased with the pyrolysis temperature, reaching a maximum at 600 ºC and decreased above this point. The nanocatalyst that showed the best catalytic performance was significantly better than the commercial one, while others were comparable in performance to the commercial one. They can be magnetically separated from the reaction mixture after completion of the reaction and even heated by exposure to an alternating magnetic field.

We also deposited catalytic Pt nanoparticles on the carbon-coated magnetic clusters. The Pt nanocatalysts were tested in cooperation with Southern Denmark University in an oxygen-evolution reaction, the critical reaction that occurs in fuel cells. Such a catalyst could be magnetically separated from a complex mixture of materials when the electrode is decomposed and can therefore reduce the cost of the Pt recycling from the worn-out fuel cells. The performance tests of our nanocatalysts showed comparable performance to a commercial benchmark.

Besides the carbon-coated nanoclusters, alumina-coated magnetic nanoclusters are desirable. In collaboration with the Department for Nanostructured Materials, JSI, we developed a scalable and simple method for the preparation of the AlOOH-coated magnetic nanoclusters by hydrolysis of an Al precursor in the presence of the magnetic nanoparticles. The nanoclusters are composed of sheets of AlOOH nanocrystals attached to the magnetic iron-oxide nanoparticles (Figure 1). They exhibit an exceptionally large surface area and pore volume. This large surface area was also retained during the transformation of the AlOOH surface coating to alumina (Al_2O_3) at elevated temperatures. The alumina-coated nanoclusters were tested in cooperation with the Faculty of Chemistry and Chemical Technology, University of Ljubljana, for the adsorption of heavy metals from water. Cd adsorption from water was extensively studied. The nanoclusters showed a relatively large capacity for Cd removal, even at high concentrations of the pollutant (Figure 1).

Superparamagnetic nanoclusters could also be used in many biomedical applications where a large magnetic force acting on an individual particle is needed. Magnetic drug delivery and cell-transfection (magnetofection) using magnetic nanoclusters are the most promising applications in those terms. In our joint project with researchers from the Faculty of Pharmacy, University of Ljubljana, magnetic drug-delivery systems have

Figure 3: HAADF STEM image with corresponding EELS elemental maps showing the distribution of Ba, Sc, and Fe in a Sc-substituted Ba-hexaferrite nanoplatelet. The nanoplatelet was annealed for 3 days at 700 °C. A projected hexaferrite structure along <11-20>$_{HF}$ is superimposed over the image. Different Fe lattice sites in the hexaferrite structure (trigonal 2b, tetrahedral 4f1, octahedral 12k, 2a, and 4f2) are marked.

been developed based on the superparamagnetic nanoclusters. The spherical nanoclusters containing around 100 superparamagnetic iron-oxide nanoparticles were coated with a specially designed porous silica layer, which enables the controlled dissolution of one part of iron-oxide nanoparticles from the nanocluster in a strong acid. The resulting voids in the nanocluster's interior enable loading of an active pharmaceutical substance, while the remaining nanoparticles provide magnetic guiding during its application. In 2017 the research was focused on control of the pore size of the silica shell. It appeared that the pores in the silica shell formed by our usual procedure were not large enough for efficient drug loading into preformed, partially hollow, silica-coated nanoclusters in a sufficient amount. As an alternative, a new type of composite nanoclusters were developed based on co-loading the drug orlistat and 1-tetradecanol into magnetic nanoclusters during their assembly. Orlistat is highly hydrophobic and due to its physico-chemical properties very challenging for the preparation of polymeric and lipid-based drug-delivery systems and other pharmaceutical formulations. Our research efforts were focused on the preparation of a delivery system with heat-controlled drug release. The active substance orlistat is incorporated into the voids of th enanocluster interior dissolved in the solid 1-tetradecanol. The 1-tetradecanol displays a solid-to-liquid transformation at temperatures between 38 and 40 °C. We expect that the orlistat will be released once the temperature increases above this value. This thermo-responsive release of the drug at a desired place in the human body can be triggered with heat released with the exposure of the magnetic nanoparticles to an alternating magnetic field during magnetic hyperthermia treatment.

New drug-delivery systems have also been developed based on the magnetic assembly of the superparamagnetic nanoclusters into one-dimensional magnetic nanostructures, i.e., nanochains. To be used in drug delivery the nanochains are magnetically assembled from the nanoclusters coated with silica shells of various thicknesses. First, the nanoclusters with a thin silica shell were assembled into short nanochains. Subsequently, the nanoclusters with a thick silica shell were magnetically assembled to one or both ends of the initial short nanochains. The "mixed" nanochains were then fixed with an additional thin silica layer. When the mixed nanochains were subsequently exposed to acid, the magnetic nanoparticles inside the nanoclusters with the thin silica shell were dissolved while they remained intact in the nanoclusters coated

The lattice site of Sc incorporation into the structure of barium-hexaferrite nanoplatelets was determined using an atomic resolution scanning-transmission microscope.

with the thick, non-permeable silica. Thus, we synthesized the nanochains composed of the short chain of hollow silica shells terminated with the intact superparamagnetic nanoclusters (Figure 2). The hollow silica shells can be loaded with the drug while the intact nanoclusters provide the magnetic responsiveness of the nanostructure.

In the research led by Institute of Cell Biology, University of Ljubljana, magnetic nanoclusters labelled with two fluorescent dyes, fluorescein and rhodamine B were applied for the correlative microscopy (optical and electron
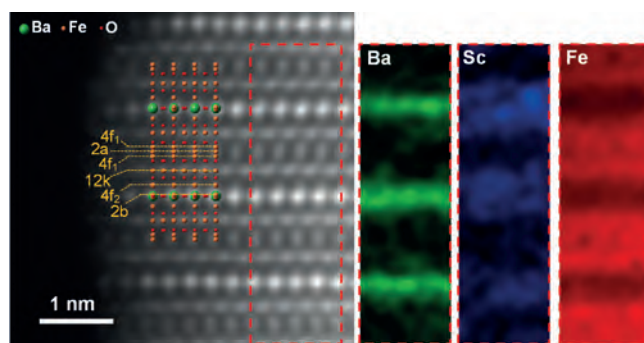
microscopy) of urothelial tunnelling nanotubes. The nanoclusters were used as a contrast agent for TEM microscopy, while molecular dyes are needed for the fluorescent microscopy labelling. The tunnelling membrane nanotubes are spontaneously formed between urothelial cancer cells to transfer information in the form of genetic material and other cellular building blocks between the cells. An important part of the project was aimed at investigating synthetic approaches for the preparation of small nanoclusters with a size of around 70–80 nm, which is the upper limit for urothelial nanotubes' labelling. Additionally, the nanoclusters conjugated with targeting ligands for the recognition of urothelial cancer cells and drug-loaded carriers were developed in the frame of the project.
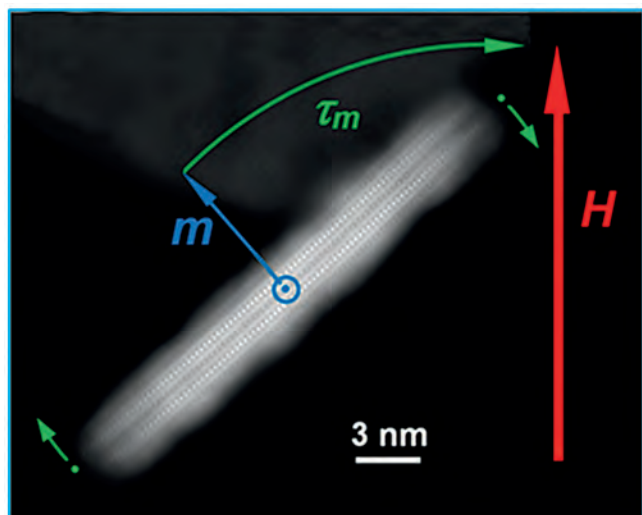

Figure 4: On the image of the nanoplatelet oriented edge-on the direction of its magnetization m is shown schematically. In a magnetic field H the m tends to align with the H resulting in rotation of the nanoplatelet producing a torque τ_m.

We have recently established a collaboration with a research team from the CNRS-IPBS, Toulouse, France, dedicated to the biological evaluation of carboxyl-functionalized magnetic nanoclusters and nanochains focused on the preparation of magnetically-responsive spheroids of the HCT-166 cell line (human colon carcinoma).

We continued our research of barium hexaferrite (BHF) nanoplatelets. The hexagonal nanoplatelets, only a few nm thick and approximately 50 nm wide, can be synthesized using an appropriate hydrothermal method. They display unique magnetic properties, defined by their very large, uniaxial magnetic anisotropy with the easy axis pointing perpendicular to the platelet. This property enables very effective aligning of the nanoplatelets with an applied magnetic field, which has been the key to the development of new materials, e.g., ferromagnetic fluids, soft magneto-electrics, or magneto-optic composites, and new applications, especially in medicine.

An important part of the research of the hexaferrite nanoplatelets was devoted to a determination of their crystal structure. Based on direct atomic-resolution scanning-transmission electron-microscopy (ARM) observations we showed that the nanoplatelets display a distinct structure. The structure can be presented in terms of two alternating structural blocks stacked across the nanoplatelet: a hexagonal $(BaFe_6O_{11})^{2-}$ R block and a cubic $(Fe_6O_8)^{2+}$ spinel S block. The structure of the BHF nanoplatelets comprises only two, or rarely three, R blocks and always terminates at the basal surfaces with the full S blocks. The structure of a vast majority of the nanoplatelets can be described with a SR*S*RS stacking order, corresponding to a $BaFe_{15}O_{23}$ composition. The nanoplatelets therefore display a different structure and composition to the corresponding bulk $BaFe_{12}O_{19}$ hexaferrite and can be considered as a novel structural variation of the hexaferrites stabilized on the nanoscale.

Undoped BHF nanoplatelets exhibit a modest saturation magnetization, M_S, approximately 15 emu/g. The M_S of the undoped BHF nanoplatelets increases when they grow during annealing at high temperature of 700 °C. A breakthrough in applications of the BHF nanoplatelets was enabled with our discovery that their M_S can be increased already during the hydrothermal synthesis with the addition of Sc. With substitution of a part of Fe^{3+} ions with Sc^{3+} the nanoplatelets with applicable M_S of over 30 emu/g were obtained. This increase in the M_S of BHF nanoplatelets is very interesting, since the substitution of the nonmagnetic Sc^{3+} ions in the bulk hexaferrite significantly decreases the M_S. Also, when the Sc-substituted BHF nanoplatelets were annealed at 700 °C their M_S decreased. To reveal the mechanisms behind this unusual magnetic behaviour, the site of the Sc^{3+} incorporation into the hexaferrite structure has been studied using ARM. In the hexaferrite structure the Fe^{3+} ions occupy five different crystallographic sites, i.e., tetrahedral $(4f_1)$, octahedral (12k, 2a, $4f_2$), and trigonal (2b) (Figure 3). The combination of HAADF STEM imaging and elemental EDXS and EELS mappings revealed that the Sc^{3+} ions occupy preferentially bi-pyramidal 2b and octahedral $4f_2$ sites in both the as-synthesized nanoplatelets and in the nanoplatelets annealed at 700 °C (Figure 3). The reason for the increase in M_S of the nanoplatelets with the Sc substitution can therefore not be ascribed to different site of Sc incorporation in the nanoplatelets, compared to that in the bulk.

> **Magneto-mechanical effect of hexaferrite nanoplatelets exposed to a low-frequency magnetic field was tested on giant unilamellar vesicles and cancer cells *in vitro*.**

In 2017 we started a new project devoted to the application of the hexaferrite nanoplatelets and other magnetically-anisotropic nanoparticles in magneto-mechanical cancer treatment. We proposed an entirely new concept of a cancer treatment based on transformation of low-frequency magnetic-field energy (1 Hz to 10 kHz) to mechanical energy mediated with anisotropic magnetic nanoparticles. When an anisotropic magnetic nanoparticle is placed into a magnetic field it directs according to the applied field. The nanoparticle's rotation under the influence of the magnetic field results in the transfer of the force on the environment (Figure 4). The force is applied to damage the cancer cells. In collaboration with the Faculty for Electrical Engineering (Laboratory for Biophysics, Laboratory for

Bioelectromagnetics) and Faculty of Health Sciences (Laboratory for Clinical Biophysics), University of Ljubljana, we tested the magneto-mechanical effect of the BHF nanoplatelets on giant unilamellar vesicles (GUVs). The GUVs represent the simplest model of cell membrane, which comes into a contact with nanoparticles first. With proper surface functionalization of the nanoplatelets we enabled adsorption of the nanoplatelets onto the GUVs by weak electrostatic interactions. Exposure of the GUVs with nanoplatelets to the low-frequency magnetic field resulted in cyclic fluctuations of the GUVs shape, corresponding to the field frequency. By following permeation of stain molecules through the GUV's phospholipid bilayer we studied the permeability of the membrane during the agitation. In collaboration with the Department of Molecular and Biomedical Sciences (JSI) the magneto-mechanical effect of the nanoplatelets was also tested on different cancer cells *in vitro*. For tracking

Fluorescent fluoride nanoparticles, alternative biomarkers in biomedicine, dissolve substantially and relatively quickly in aqueous media. The dissolution and consequent modification of their surface chemistry significantly affect their optical properties.

of the nanoplatelets with fluorescence microscopy a fluorescent dye was incorporated into the nanoplatelets' silica shells. The cytotoxic potential of the nanoparticles without and under the magnetic field was assessed using flow cytometry. The first experiments showed no significant effect of the nanoplatelets or the field on the cells. The research is still in progress.

We also cooperated in nanotoxicology research with the Biotechnical Faculty, University of Ljubljana, where we provided our expertise in the synthesis, functionalization and characterization of nanoparticles.

We continued the research related to the incorporation of hexaferrite nanoplatelets into various types of liquid crystals (in cooperation with the Department of Complex Matter, JSI). Our studies were focused on the modification of the nanoplatelets' surface chemistry. The aim was to increase the concentration of the nanoplatelets dispersed in liquid crystals by hydrophobization of their surfaces or using classic amphiphilic surfactants. This should intensify the magnetic response of the suspensions, i.e., ferromagnetic liquid crystals. In another study (also including Department of Condensed Matter Physics, JSI) the ferromagnetic liquid crystals were used in the development of whispering-gallery-mode lasers. In parallel we were involved (with the Department of Complex Matter, Faculty of Mathematics and Physics of University of Ljubljana, University of Bayreuth, and Max Planck Institute for Polymer Research) in theoretical studies of dynamic magneto-optic coupling of the ferromagnetic liquid crystals.

We also participated in the development of novel magnetic-field sensors (in cooperation with Faculty of Electrical Engineering and Computer Science, University of Maribor) through the optimization of magnetic nanoplatelet suspensions, in particular, with the homogenization of the platelets size.

The synthesis of complex materials combining magnetic nanoparticles with organic soft matter is also a topic of our joint research with researchers from the University of Trieste. A set of short peptides has been synthesized and evaluated to find optimal peptide sequence for the conjugation with magnetic nanochains, i.e., the one-dimensional nanostructures formed by magnetic assembly of the superparamagnetic nanoclusters. A solid-phase

Figure 5: Temperature dependence of electrical resistivity for metal-BaTiO$_3$ composite measured during heating and cooling

peptide synthesis (SPPS) method was applied for the synthesis of the short peptides. The synthesized peptides were purified using high-pressure liquid chromatography (HPLC) and characterized with nuclear magnetic resonance (NMR) spectroscopy and mass spectroscopy (MS). Short peptides such as ^{L}Phe-^{L}Phe, ^{L}Leu-^{L}Phe, ^{L}Trp-^{L}Phe, ^{D}Phe-^{L}Phe, ^{D}Leu-^{L}Phe, and ^{D}Trp-^{L}Phe were bonded to amino-functionalized magnetic nanochains by the sequential attachment of Fmoc-protected amino acids. Binding of the Fmoc-protected amino acids to the nanochains surface was quantified by UV-VIS spectroscopy. Furthermore, the methods for co-assembly of functionalized nanochains and short, self-assembling peptides have been successfully developed, although we have faced many challenges with the stability of the colloidal suspension. The methods based on non-covalent interactions between the dipeptide molecules in the solution and the dipeptide-functionalized nanochains. The formed nanocomposites can magnetically assemble in long-range ordered structures. Moreover, gelation properties of the forming nanocomposite can be controlled by exposing the mixture of magnetic nanochains and dipeptides to a circular magnetic field during their co-assembly. An analysis of the gelation process using complex rheometry confirmed that the gelation can be controlled remotely by the magnetic field.

We continued with the research of fluorescent optical materials. Fluorescent nanoparticles with up-conversion emission can be applied in various optical elements and are also proposed as alternative bio-markers in imaging diagnostic techniques for medicine. We continued with the studies of the chemical stability of fluoride nanoparticles doped with lanthanides in correlation with their optical properties. Namely, the nanoparticles for bio-medicine
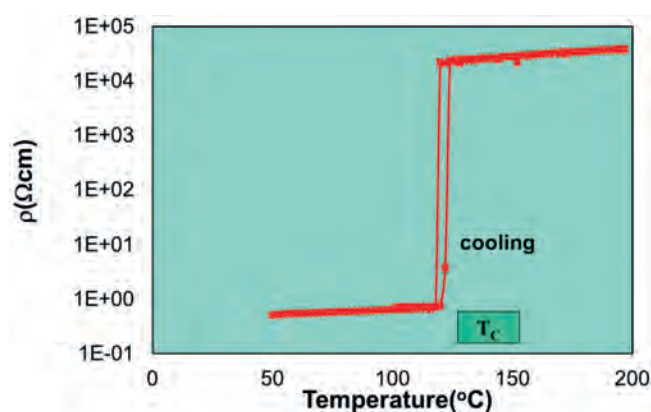
should be chemically and colloidally stable in aqueous media. We showed that fluoride nanoparticles with different compositions (binary and ternary) partly dissolve in water, which limits their applicability in biomedicine. A study of the effect of the dissolution of fluoride fluorescent up-converting nanoparticles on their optical properties was accomplished in cooperation with Bundesanstalt für Materialforschung und prüfung (BAM), Berlin, Germany, and with the Department for Surface Engineering and Optoelectronics, JSI. We showed that changes in the nanoparticles' surface chemistry induced by their partial dissolution significantly reduced the fluorescence lifetime of Tm_{3+} dopants, which limits the applicability of these materials. Our results represent a basis for a new, non-destructive analytical method for screening the changes of the surface composition of up-converting fluorescent nanoparticles, which is being developed in cooperation with BAM. Namely, surface chemistry has a significant effect on the optical properties of the up-converting nanoparticles due to their large surface-to-volume ratio. In parallel, we continued with the studies of protective coatings, which would improve the chemical stability of the up-converting nanoparticles in aqueous media.

> **Thermistors based on a metal–BaTiO$_3$ ceramic composite display extremely steep temperature dependence of resistivity.**

In the last year we started with a new study of magneto-fluorescent nanocomposites. First, we focused on their synthesis based on assembling two kinds of nanoparticles, the magnetic $BaFe_{12}O_{19}$ nanoplatelets and the up-converting $NaYF_4$ nanoparticles, via covalent bonding between molecules grafted on their surfaces. For this purpose we studied two approaches: 1) reaction between amino groups at the one type of nanoparticles with carboxyl groups on the other using carbodiimide (EDC) chemistry, and 2) reaction between azide groups and alkyne groups, i.e., click chemistry (in cooperation with Faculty of Pharmacy, University of Ljubljana). The first approach is suitable for aqueous systems and the second is also applicable in nonpolar organic media. Our preliminary studies were mostly focused on the colloidal stability of reaction systems throughout all coupling steps, which is crucial for the efficient coupling between the two kinds of nanoparticles.

Our research on the positive temperature coefficient of resistivity (PTCR) showed that it is possible to prepare the PTC resistors on the basis of $BaTiO_3$ ceramics without donor-doping when a composite of conducting and non-conducting phase is formed. Due to dimensional changes in the non-conducting phase in $BaTiO_3$ ceramics at the Curie temperature disconnections occur in the conductive phase that leads to the PTCR anomaly. In this way, based on the composite of a conducting and non-conducting phase, we also succeeded to prepare PTC thermistors with a Curie temperature of 180 °C and a low room-temperature resistivity in the $BaTiO_3–Na_{0.5}Bi_{0.5}TiO_3$ system. The newly developed material, unlike the materials available in the market, contains no toxic lead. Moreover, extremely steep temperature dependence of the electrical resistivity of a jump-like form (Figure 5) was obtained in the composite prepared by co-sintering of metal (conducting phase) and ferroelectric $BaTiO_3$ ceramics (non-conducting phase) at the temperature below 1000 °C. To the best of our knowledge such a steep thermistor temperature-resistivity characteristic has not been reported yet.

Some outstanding publications in the past year

1. Belec, Blaž, Dražić, Goran, Gyergyek, Sašo, Podmiljšak, Benjamin, Goršak, Tanja, Komelj, Matej, Nogués, Joseph, Makovec, Darko. Novel Ba-hexaferrite structural variations stabilized on the nanoscale as building blocks for epitaxial bi-magnetic hard/soft sandwiched maghemite/hexaferrite/maghemite nanoplatelets with out-of-plane easy axis and enhanced magnetization. Nanoscale, ISSN 2040-3372, [in press] 2017, 10 str., doi: 10.1039/C7NR05894B.
2. Plohl, Olivija, Kralj, Slavko, Majaron, Boris, Fröhlich, Eleonor, Ponikvar-Svet, Maja, Makovec, Darko, Lisjak, Darja. Amphiphilic coatings for the protection of upconverting nanoparticles against dissolution in aqueous media. Dalton transactions, ISSN 1477-9226, 2017, vol. 46, no. 21, str. 6975-6984, doi: 10.1039/c7dt00529f.
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INTERNATIONAL PROJECTS

1. COST TD1402 - RADIOMAG; Multifunctional Nanoparticles for Magnetic Hyperthermia and Indirect Radiation Therapy
   Prof. Darko Makovec
   Cost Office
2. COST Action CM1403; The European Upconversion Network - From the Design of Photon-Upconverting Nanomaterials to Biomedical Applications
   Prof. Darja Lisjak
   Cost Office
3. The Development of a Nondestructive Analytical Method for the Screening of Upconverting Nanoparticles Surface Properties Based on Optical Characterization
   Prof. Darja Lisjak
   Slovenian Research Agency

RESEARCH PROGRAM

1. Advanced inorganic magnetic and semiconducting materials
   Prof. Darko Makovec

R&D GRANTS AND CONTRACTS

1. Nanotheranostics based on magneto-responsive materials
   Dr. Slavko Kralj
2. Tunneling nanotubes for innovative urinary bladder cancer treatments
   Dr. Slavko Kralj
3. Anisotropic magnetic nanoparticles for the magneto-mechanical therapy of cancer
   Prof. Darko Makovec
4. Electrically tunable ferromagnetic liquids
   Prof. Darja Lisjak

NEW CONTRACTS

1. Development and validation of the TEM method for analysis of an inorganic-core size in final ferric carboxymaltose product
   Prof. Darko Makovec
   Lek d. d.
2. Research of hydrothermal synthesis for pharmacy
   Prof. Darko Makovec
   Lek d. d.

VISITOR FROM ABROAD

1. Nathan Champion, University of Burgundy, Engineer School of Materials Research, Dijon, France, 10. 4.-2. 7. 2017
2. Prof. Joseph Nogues Sanmiquel, Universitat Autonoma de Barcelona, Barcelona, Spain. 25. 7.-26. 7. 2017
3. Katalin Boor, Uppsala University, Uppsala, Sweden, 2. 10. 2017 to 2. 2. 2018
4. Borbála Tegze, Budapest University of Technology and Economics, Budapest, Hungary, 10. 12. 17 to 22. 12. 2017
5. Morten Gildsig Poulsen, University of Southern Denmark, Odense, Denmark, 20. 11.17 to 11. 12. 2017

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8. **Technical and administrative staff**
9. Bernarda Anželak, B. Sc.

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14. Olivija Plohl, Marco Kraft, Janez Kovač, Blaž Belec, Maja Ponikvar-Svet, Christian Würth, Darja Lisjak, Ute Resch-Genger, "Optically detected degradation of $NaYF_4$: Yb, Tm-based upconversion nanoparticles in phosphate buffered saline solution", *Langmuir*, **33**, 2, 553-560, 2017.
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16. Tilen Potisk, Daniel Svenšek, Helmut R. Brand, Harald Pleiner, Darja Lisjak, Natan Osterman, Alenka Mertelj, "Dynamic magneto-optic coupling in a ferromagnetic nematic liquid crystal", *Phys. rev. lett.*, **119**, 9, 097802, 2017.
17. Marin Tadić, Lazar Kopanja, Matjaž Panjan, Slavko Kralj, Jasmina Nikodinović-Runić, Zoran Stojanović, "Synthesis of core-shell hematite ($\alpha - Fe_2O_3$) nanoplates: quantitative analysis of the particle structure and shape, high coercivity and low cytotoxicity", *Appl. surf. sci.*, 628-634, 2017.
18. Marin Tadić, Irena Milošević, Slavko Kralj, Miodrag Mitrić, Darko Makovec, Marie-Louise Saboungi, Laurence Motte, "Synthesis of metastable hard-magnetic $\varepsilon - Fe_2O_3$ nanoparticles from silica-coated akaganeite nanorods", *Nanoscale*, **9**, 30, 10579-10584, 2017.

REVIEW ARTICLE

1. Slavko Kralj, Tanja Potrč, Petra Kocbek, Silvia Marchesan, Darko Makovec, "Design and fabrication of magnetically responsive nanocarriers for drug delivery", *Curr. med. chem.*, **24**, 5, 454-469, 2017.
2. Alenka Mertelj, Darja Lisjak, "Ferromagnetic nematic liquid crystals", *Liq. cryst. rev.*, **5**, 1, 1-33, 2017.

MENTORING

1. Blaž Belec, *Synthesis of composite nanoparticles with different core nanoparticles coated with a magnetic ferrite shell:* doctoral dissertation, Ljubljana, 2017 (mentor Darko Makovec).

DEPARTMENT FOR ADVANCED MATERIALS

K-9

At the Advanced Materials Department we investigate novel materials through an understanding of the mutual dependence of their structural, microstructural and functional characteristics. Modern technologies that enable the synthesis of materials with atomic- and microscale precision are used to prepare pre-designed structural 3D materials, thin films, and nanoparticles with the desired crystal structure, chemical composition, microstructure and morphology. Among our important objectives is the development of: i) novel functional oxide materials for various electronic applications, ii) new materials with improved anti-bacterial and biocompatible properties, and iii) heat-insulation materials with improved properties and sustainability.
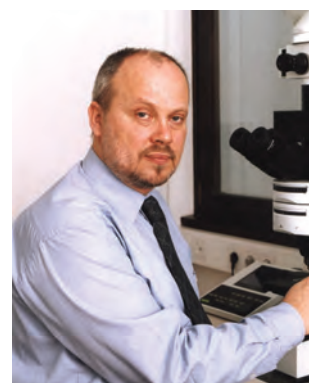
Head:
Prof. Danilo Suvorov

Functionalized oxides for electronic applications

In the research on the topochemical conversion of μm-sized $Bi_4Ti_3O_{12}$ plates into $MTiO_3$ (M=Ba, Ca, Sr) plates we followed two main directions. In the first direction we studied the formation of A-site-substituted, complex perovskite, $Ba_{1-x}Sr_xTiO_3$ plate-like particles in molten salt (NaCl/KCl), while in the second direction we were mainly interested in the mechanism of the topochemical conversion from $Bi_4Ti_3O_{12}$ into $MTiO_3$ perovskites under hydrothermal conditions.

The study of $Ba_{1-x}Sr_xTiO_3$ formation in the molten salt revealed that the Ba/Sr ratio in the formed perovskite plates was smaller than that in initial reaction mixture, which proved that the Sr incorporate more than the Ba. Taking into account the nearly linear relationship ($x \approx 2.7 \cdot x'$) between the Sr content (x) in $Ba_{1-x}Sr_xTiO_3$ and that in the reaction mixture (x′), an arbitrary $Ba_{1-x}Sr_xTiO_3$ composition could be prepared by this method. X-ray diffraction (XRD), piezoresponse force microscope (PFM) and dynamic scanning calorimetry (DSC) were used for an examination of the tetragonality and with this crystal structure related ferroelectric and piezoelectric characteristics. The c/a ratio was found to decrease linearly from 1.0092 (x=0) to 1.0037 (x=0.23), while the compositions with higher x (0.23<x≤1) were cubic (c/a=1). According to the PFM examinations $Ba_{1-x}Sr_xTiO_3$ plates with 0≤x≤0.175 showed ferroelectric and piezoelectric characteristics, whereas by DSC measurements the ferroelectric to paraelectric phase transition was detected only for compositions with 0≤x≤0.11. The peak of the phase transition linearly decreased from 124°C (x=0) to 88°C (x=0.11). XRD examinations revealed the strong *(001)* preferential orientation of the plates (0≤x≤0.11) and the typical *(001)/(100)* peak splitting indicated the presence of **c**- and **a**-domains. In the $BaTiO_3$ plates the **c**-domains dominated over **a**-domains; however, with an increase of the Sr content the amount of **a**-domains increased on account of diminishing of **c**-domains.

In the study of the topochemical conversion from $Bi_4Ti_3O_{12}$ template plates into $SrTiO_3$ under hydrothermal conditions it was found that the concentrations of reactants in addition to template quality to a great extent determined the final shape of the $SrTiO_3$ particles, which changed from cubes, frames and plates. The formation of the last $SrTiO_3$ morphology, which maintained the shape of the initial template, occurred when the $Bi_4Ti_3O_{12}$ was firstly dispersed in the concentrated water solution of $SrCl_2$ and then the NaOH solution was added before the hydrothermal heat treatment at 200°C (Figure 1). We assumed that the Sr^{2+} ions, which were in the first step attached to the negatively charged $Bi_4Ti_3O_{12}$ plates, protect the template plates against their dissolution in a highly concentrated NaOH solution. Additionally, this also meant that the Frank-van der Merve and Stranski-Krastanov growth dominated over the Volmer-Weber growth of the $SrTiO_3$ on the $Bi_4Ti_3O_{12}$. In the course of this topochemical conversion *(00l)*-oriented $Bi_4Ti_3O_{12}$ plates transformed into *(l00)*-oriented $SrTiO_3$ plates. $BaTiO_3$ and $CaTiO_3$ plates were prepared using a similar approach to the topochemical conversion.

Figure 1: Hydrothermal topochemical conversion from (00l)-oriented $Bi_4Ti_3O_{12}$ into (l00)-oriented $SrTiO_3$ plates.

The creation of $SrTiO_3$ (STO)/Si pseudo-templates for the overgrowth of other complex oxides represents one of the most important routes towards the integration of functional oxides with silicon. In order to promote the epitaxial growth, the highly reactive Si surface first needs to be successfully passivated by adding 1/2 monolayer (ML) of metallic Sr forming a Sr/Si(001)(1×2) surface reconstruction. Using Scanning Tunnelling Microscopy (STM) we studied the unique structural features of such surfaces grown by the Pulsed-Laser Deposition (PLD) technique. Large-scale STM images exhibit a smooth surface with terraces composed of one-dimensional (1D) chains, running
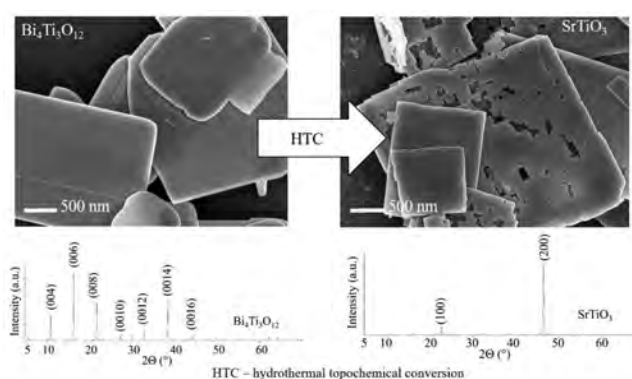
Figure 2: Filled state STM image of the Sr/Si(001)(2×1) surface with 1D chains of Sr atoms running along perpendicular directions on neighbouring terraces. Two types of surface defects are marked by dashed lines: A – arrays of Sr vacancies, B – arrays of Sr adatoms.

along perpendicular directions on neighbouring terraces. We found that the 1D chains display a low-amplitude corrugation exhibiting a period of 0.39 nm, while the chains themselves are separated by 0.78 nm. The measured values agree well with the size of the 2×1 surface unit cell, also observed in surfaces prepared by alternative techniques. Apart from the periodically ordered structures, we observed the two types of surface defects shown in **Figure 2**. We identified the depressions along the 1D chains as arrays of Sr vacancies, while the bright protrusions along the 1D chains were identified as arrays of Sr adatoms. Our observations were confirmed by a comparison with simulated STM images based on Density Functional Theory (DFT) calculations. We demonstrated that PLD can offer precise control for the growth of high-quality Sr-buffer layers with a low defect concentration. These results provide an important insight into the growth procedures needed for the controlled epitaxial growth of $SrTiO_3$ and other complex oxides on Si surfaces.

We designed and optimized a procedure for the growth of 3–4-nm STO pseudo-templates on Si(001) surfaces, which uses only the PLD technique for the whole growth. The impact and optimal values for some of the critical growth parameters were determined previously by means of in-situ Reflection High-Energy Electron Diffraction (RHEED), X-Ray Photoelectron Spectroscopy (XPS), Atomic Force Microscopy (AFM) and X-Ray Reflectivity (XRR). In 2017, the study was completed, delivering a complete, PLD-only route for the growth of STO/Si substrates with optimal interface layers (as low as 1 nm), Sr/Ti ratios and surface crystallinity. This procedure is composed of the following steps. Initially, a 1/2 ML of Sr is deposited on the bare Si (001) surface to form the Sr-buffer layer. After this, STO is grown in a multi-staged way: first, 2 MLs of STO are deposited in an Ar atmosphere of 5×10^{-2} mbar, then this material is exposed to 9×10^{-7} mbar of O_2 in order to oxygenize it, and finally it is annealed at 515 °C in order to crystallize it. This sequence is repeated until the total thickness of the STO pseudo-substrate is around 10 MLs (3 nm). These values ensure the best balance between the minimization of the thermal budget and the STO/Sr/Si interface reactions, STO density and stoichiometry, as well as the surface smoothness and crystallinity. The usefulness of these templates for the overgrowth of other complex oxides was tested by the overgrowth with STO: samples with thicknesses of up to 50 nm were successfully grown on top of these pseudo-substrates, producing (001)-oriented, single-phase samples with crystallinity and STO/Sr/Si interfaces comparable to those of the pseudo-substrates (**Figure 3**).

Figure 3: Left: RHEED patterns (001 azimuth) of the 1/2 ML Sr buffer layer, STO pseudo-substrate and STO overgrowth. Right: TEM (001 azimuth), AFM and XRD data of a 50 nm STO sample grown on top of the STO pseudo-substrate, showing its crystalline quality, surface smoothness and interface thinness.

In order to further improve the functional properties of $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) thin films, we studied their growth mechanism. Using high-resolution transmission electron microscopy, we found that the layers contain structural domains, which are separated by out-of-phase boundaries (OPBs). The formation of OPBs is associated to poor wettability of the $SrTiO_3$ surface and the dynamics of the laser plasma. Poor wetting leads to a 3D growth mechanism, i.e. the formation of islands, on top of which local excess of PbO is accumulated, thereby forming Ruddlesden-Popper (RP)-type defects. The chemical composition of the films was probed using wavelength-dispersive X-ray spectroscopy, which confirmed a slightly excess concentration of Pb and a deficit in Mg content, while the ratio of the remaining elements was stoichiometric. The Mg deficit could be a consequence of the formation of Mg vacancies as a mechanism of Pb-excess compensation. The Mg content was improved by adding excess MgO into the ceramic target. Furthermore, we found that the concentration of RP-type defects and other stacking faults is much higher in films, prepared at a lower process pressure. Although the use of a lower process pressure was demonstrated to be successful at preventing the growth of undesired pyrochlore inclusions, we found that under these processing conditions the plasma is separated into a faster and slower part, which strongly affects the thin-film growth kinetics. The large concentration of structural defects is also reflected in the splitting of the spots in reciprocal space (**Figure 4**), and this leads to a significantly lowered dielectric and piezoelectric response.

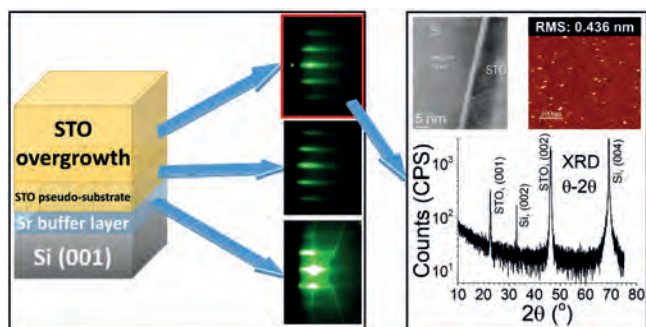High-temperature reactions during the solid-state synthesis of samples from the $(1-x)Na_{0.5}Bi_{0.5}TiO_3-xSrTiO_3$ system were investigated. Due to the number of chemically different elements, the processing of these ceramics is delicate and requires several firing steps under specific conditions to obtain phase-pure samples. Sintering in an air atmosphere resulted in a macroscopically inhomogeneous microstructure, which is a consequence of an incomplete reaction between the different secondary phases. However, prolongation of the sintering time aggregated the pores in the sample, while at a higher firing temperature the sample's secondary phase melted. As a result, the nominal composition was altered, leading to the formation of the $Na_2Ti_6O_{13}$ secondary phase. Sintering under an increased oxygen pressure of 1 MPa limited the evaporation of the secondary phase. This allowed the completion of the reaction, forming a homogeneous and dense sample. The study provides a set of experimental conditions for the successful preparation of ceramics from the investigated system. Based on X-ray powder diffraction analysis we also concluded that the cations (especially on the A site of the perovskite structure) are more and more displaced from their average positions with decreasing x towards 0.3. These cation displacements are large enough (more than 0.1 Å) to explain the electrical properties of the sample with intermediate values of x. However, the displacements are not ordered to a long enough distance to cause any peak splitting or the emergence of the super-structural peaks. Presumably, they are related to the polar nano-regions, typical for relaxor-like materials.

In the scope of the investigation of phase relations in ternary oxide systems, where new compounds and solid solutions form and exhibit interesting electrical properties, we determined high-temperature phase equilibria in the $Bi_2O_3-Mn_2O_3-M_2O_3$, where M=Fe, Ga and Al at 775–790 °C. The samples were prepared by a wet precipitation method from soluble precursors in order to achieve good homogenization of the starting compositions. We identified the formation of several solid solutions and determined their extension ranges based on the microstructural and XRD analyses. In the investigated systems no ternary compounds were observed.

Figure 4: Reciprocal space mapping in the vicinity of the (a) $\bar{1}\bar{1}3$ and (b) $\bar{1}03$ asymmetrical spots of the PMN-PT thin film using high-resolution X-ray diffraction. The violet line represents the anticipated QZ value, assuming a pseudo-cubic crystal structure.

Antibacterial biocompatible materials

The research work on biomaterials included several topics: development of antimicrobial nanomaterials from functionalized gold, development of MgO-based anti-microbial materials, development of new magnetic antimicrobial biomaterials, piezoelectric biomaterials and innovative techniques of cryopreservation.

In the development of antimicrobial materials gold nanoparticles were functionalized with nisin. Nisin is an anti-microbial peptide that has been used for conservation in the food industry for years and has been approved for bio-use in more than 50 countries (by the EU and the FDA) and is thus promising for the development of new anti-microbials. One of the problems is its anti-microbial activity, which prevents growth only in Gram positive bacteria. We have developed a new process that makes it possible to functionalize nisin on the surface of nanoparticles of gold adhering to the surface of carbon spheres (**Figure 5**). We found that the so-formed material provides very strong antimicrobial activity in a variety of different bacteria: Gram + (*Staphylococcus epidermidis*), Gram - (*Salmonella enteritidis*, *Bacteroides fragilis*, *E. coli* and *P. aeruginosa*), Gram +, resistant to various antibiotics (methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus faecium* (VRE)) and Gram –, resistant to antibiotics (Amp-C *Enterobacter cloacae*). Nanomaterial showed very low cytotoxicity in human cells (L929 fibroblasts).

In MgO-based anti-microbial materials formation of reactive oxygen species (ROS) and their effect on anti-microbial properties were investigated. Using different methods of detection (EPR and fluorescence labelling), we found that the formation of reactive oxygen species is not the main reason for anti-microbial activity, which is the consequence of material-cell interactions or the consequence of stress caused by the interaction between cells and material. We found an interesting structure of MgO material and specific defects that influence the solubility of the material and contribute to its anti-microbial activity. The described effects we demonstrated in both Gram positive (*S. epidermidis*) and Gram negative (*P. aeruginosa* and *E. coli*) bacteria.
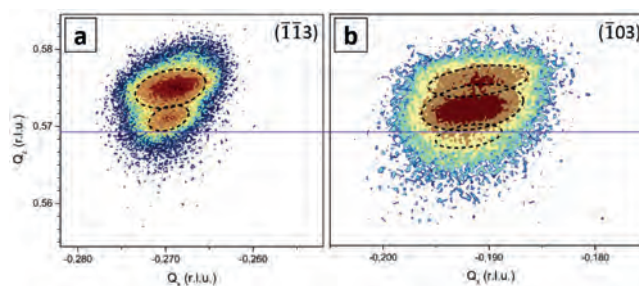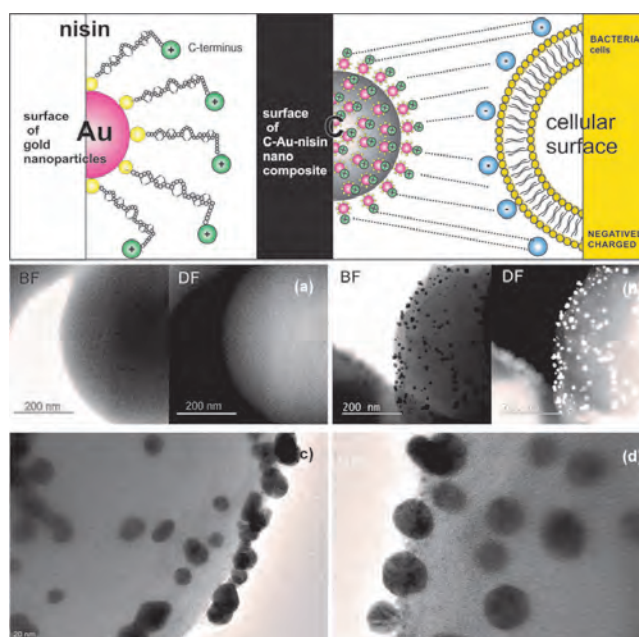
Figure 5: Illustration of the functionalization of Au nanoparticles and their selective interaction with cells and the morphology of functionalized Au nanoparticles on the surface of carbon spheres.

We initiated research on the development of biocompatible piezoelectric materials for the electro-stimulation of cells and tissues in regenerative medicine. The goal is to develop piezoelectric materials that will be used as body implants that will generate electricity as a response to the mechanical deformation that occurs in the body as a consequence of the natural contractile and relaxation motions. In the scope of these studies we are developing degradable composites, which are composed of barium titanate and calcium hydroxyapatite as the inorganic component and poly-L-lactic acid (PLLA) and polyvinylidene fluoride (PVDF) as the organic component. For this topic we were granted a new project by the Slovenian research agency "Piezoelectric biomaterials for electro-stimulated regeneration".

The development of innovative cryopreservation techniques proposed as a Marie Curie research project was awarded with the "Seal of Excellence" from the European Commission and was approved for funding by Slovenian Ministry of Education, Science and Sport in 2017. The project is focused on the development of biocompatible nanotechnology for the cryo-preservation of human cells for medical applications. We have successfully developed biomimetic inorganic calcium hydroxyapatite nanoparticles for delivery of natural cryo-protectant trehalose in erythocytes. The developed process (**Figure 6**) provided successful cryo-protection to cells and enabled high survival rates after freeze-thawing.

Materials for heat-insulation applications

Our research focused on the development of insulation materials with improved insulation capability, temperature stability, and/or improved sustainability. We continued with the investigation of foaming mechanisms of glasses using various standard and custom techniques. The identification of specific additives that enable tuning of the foaming process allowed us to prepare high-quality foam glasses from cullets with different composition.

Figure 6: Use of biomimetic calcium hydroxyapatite nanoparticles for delivery of trehalose in red blood cells.

The demonstrated decreased dependence of the foaming process on the composition of the glass is an important scientific and industrial contribution. The understanding of the puzzling foaming mechanism warrants the control of the pore size, closed- or open-porosity, density and composition of the entrapped gases. These characteristics determine the mechanical and thermal properties of the product. The thermal conductivity of the foams with a CRT panel glass is lower than that of the foams with a container or bottle glass. The thermal conductivity, measured according to a standardized method using a heat-flow meter, was as low as 37 mW/(m·K) for a panel glass sample and 45 mW/(m·K) for a flat glass sample. These low values and the simple preparation method reveal great potential for industrial production. Quantification of the different contributions to the effective thermal conductivity of the foam glass will uncover possibilities to further decrease the thermal conductivity.

HarvEnPiez

In the scope of the M-ERA.NET project HarvEnPiez we deal with the synthesis of various defined-shape ferroelectric perovskite particles with anisotropic shape (plates, rods) that have controlled preferential orientation. Their self-assembled structures are meant for energy harvesting applications. Since the $MTiO_3$-type perovskite particles do not show the tendency for anisotropic growth in the shape of plates and rods, we use the topochemical approach for their preparation. The main focus is on the study of topochemical conversion mechanisms from $Bi_4Ti_3O_{12}$ to $MTiO_3$ (M=Ba, Ca, Sr) and their solid solutions under molten salt and hydrothermal synthesis conditions. The HarvEnPiez project is a cooperation between three European partners from Slovenia, Latvia and Romania. Latvian group is involved in ab-initio calculations and modelling of piezoelectric properties of perovskite, whereas the role of the Romanian partner is designing and fabrication of a piezoelectric device.

CleanTechBlock II

Project CleanTechBlock II – Energy Saving Facade Building Component develops and demonstrates a new building block with an improved foam-glass insulation core and clay brick shells. Preparation of the foam glass according to a new process on a 1:1 scale was demonstrated. The thermal insulation property testing of a wall segment from the new building blocks is ongoing.

CleanTechBlock–Basics

Project CleanTechBlock Basics – Sustainable Multi-functional Building Block Basics was launched to address the heat transfer in the foam glass and demonstrate the adaptability of the CTB wall solution to different climates. The quantification of the contributions to the effective thermal conductivity will enable the identification of new strategies for decreasing the thermal conductivity further. The optimization of the CTB solution and its life-cycle assessment will reveal the great adaptability to various climates and sustainability with environmental as well as economic benefits for the owner.

SIOX

SIOX aims to exploit the rich functionalities of oxides and their heterostructures, which show great promise within the emerging field of oxide electronics. For their implementation, the epitaxial integration of oxides with silicon platforms using industrially appropriate technology is urgently needed, and its development represents the main goal of SIOX. However, such a successful integration is extremely delicate due to materials` intrinsic incompatibility. This challenge will be addressed by a collaboration between three research groups, with expertise in theoretical modelling, atomically-controlled growth and materials` applications. The project has two objectives: to prepare high-quality oxides on silicon by understanding the corresponding interface phenomena, and to functionalize as-prepared layers with functional heterostructures. The protocol for successful integration represents the main result of the project, which is heralded as the next step in the development of forthcoming electronics.

Scopes

In 2017 we completed the work for the SCOPES project, which was a trilateral cooperation between Serbia, Slovenia and Switzerland. Within the project we developed new procedures for the formation of porous structures, which can act as stem-cell carriers and are useful in tissue engineering. These structures include a polymer matrix (made from different, new biodegradable and biocompatible polymers developed together with a TMF partner from Serbia) and inorganic nanoparticles based on doped apatite, which includes ions such as Mg^{2+}, Zn^{2+}, Ga^{3+} and Sr^{2+}. We showed that the materials that were developed are biodegradable, we confirmed their biocompatibility and the ability to release embedded ions that affect different stages of the cell life cycle of stem cells and promote their differentiation and growth.

Some outstanding publications in the past year

1. Marjeta Maček, Boštjan Jančar, Hana Uršič, Melita Tramšek, Danilo Suvorov, "Tailoring the shape, size, crystal structure, and preferential growth orientation of $BaTiO_3$ plates synthesized through a topochemical conversion process", Cryst. growth des., vol. 17, no. 16, str. 3210-3220, 2017, doi: 10.1021/acs.cgd.7b00164.
2. Matjaž Spreitzer, Anton Meden, Danilo Suvorov, "High-temperature solid-state reactions in the $(1-x)$ $Na_{0.5}Bi_{0.5}TiO_3-xSrTiO_3$ system", J. Eur. Ceram. Soc., 8 str., [in press] 2017, doi: 10.1016/j.jeurceramsoc.2017.09.043.
3. Nemanja Aničić, Marija Vukomanović, Danilo Suvorov, "Design of a multifunctional vanadium pentoxide/polymer biocomposite for implant-coating applications", RSC advances, vol. 7, no. 61, str. 38647-38658, 2017, doi: 10.1039/c7ra06471c.
4. Marija Vukomanović, Vojka Žunič, Špela Kunej, Boštjan Jančar, Samo Jeverica, Rok Podlipec, Danilo Suvorov, "Nano-engineering the antimicrobial spectrum of lantibiotics : activity of nisin against gram negative bacteria", Scientific reports, vol. 7, iss. 1, str. 4324-1-4324-13, 2017, doi: 10.1038/s41598-017-04670-0.
5. Martin Štefanič, Kevin Ward, Harvey Tawtik, Robert A. Seemann, Vladimir Baulin, Yachong Guo, Jean-Baptiste Fleury, Christophe Drouet, "Apatite nanoparticles strongly improve red blood cell cryopreservation by mediating trehalose delivery via enhanced membrane permeation", Biomaterials, 140, 138-149, 2017.
6. Jakob König, Rasmus R. Petersen, Yuanzheng Yue, Danilo Suvorov, "Gas-releasing reactions in foam-glass formation using carbon and Mn_xO_y as the foaming agent", Ceram. int., vol. 43, no. 5, str- 4638-4646, 2017, doi: 10.1016/j.ceramint.2016.12.133.

Awards and Appointments

1. Urška Gabor: Award for best oral presentation in young researchers section at the 15th Conference & Exhibition of the European Ceramic Society (ECerS 2017), Budapest, Hungary, European Ceramic Society, "Mechanism of the formation of Pb (Mg1/3Nb2/3) O3-PbTiO3 thin layers using the PLD technique".
2. Tjaša Parkelj: 2nd place Award for oral presentation in young researchers section at the 25th International Conference on Materials and Technology, Portorož, Metals and Technology (IMT): "Different approaches to the preparation of Sr buffered Si (001) surfaces using pulsed laser deposition".

Organization of conferences, congresses and meetings

1. Workshop on international project M.ERA-NET "ENPIEZO – Enabling technology for high-quality piezoMEMS", Kranjska gora, 15.- 18. 2. 2017
2. Workshop on international project M.ERA-NET "ENPIEZO – Enabling technology for high-quality piezoMEMS", Ljubljana, 7.- 8. 8. 2017
3. Workshop on international project M.ERA-NET "CTB Basics - CleanTechBlock - Sustainable Multi-functional Building Block Basics", Ljubljana, 3.- 4. 10.2017
4. 25. International Conference on Materials and Technology, Portorož, 16. - 19. 10. 2017 (co-organizers)

INTERNATIONAL PROJECTS

1. Investigation of Rare Earth Alloys and Related Compounds
   Prof. Danilo Suvorov
   Urban Mining Company
2. RIRAWMAT - Recovery of Calcium Oxide from Electric Arc Furnace Slag
   Prof. Danilo Suvorov
   Gamma Meccanica S.p.a.
3. COST MP1308; Towards Oxide Based Electronics (TO-BE)
   Asst. Prof. Matjaž Spreitzer
   Cost Office
4. Gold/Ferrite Nanocomposites: Antimicrobial and Magnetic Properties for Biomedical Applications
   Marija Vukomanović
   Slovenian Research Agency
5. Thermoelectric Materials based on Layered Crystal Structures
   Asst. Prof. Boštjan Jančar
   Slovenian Research Agency
6. Characterization of Structural Defects in Semiconductor ZnO Films Grown by Atomic Layer Deposition (ALD)
   Prof. Danilo Suvorov
   Slovenian Research Agency

RESEARCH PROGRAM

1. Contemporary Inorganic Materials and Nanotechnologies
   Prof. Danilo Suvorov

R & D GRANTS AND CONTRACTS

1. Development of heterogeneous catalysts for oxidative dehydrogenation of propane with CO
   Asst. Prof. Matjaž Spreitzer
2. Engineering of structural and microstructural characteristics in contemporary dielectrics and ferroelectrics with perovskite and perovskite-like crystal structures
   Prof. Danilo Suvorov

3. Growth of high quality piezoelectric thin films on silicon using pulsed laser deposition
   Asst. Prof. Matjaž Spreitzer
4. Piezoelectric Biomaterials for Electro-stimulated Regeneration
   Marija Vukomanović
5. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
   Prof. Danilo Suvorov
   Ministry of Education, Science and Sport
6. SCOPES; Intelligent Scaffolds as a Tool for Advanced Tissue Regeneration
   Marija Vukomanović
   Snf- Swiss National Science Foundation
7. Cleantech Block II - Energy Saving Cladding
   Dr. Jakob König
   Eddp (eudp) Energy Technology Development
8. Enabling technology for high-quality piezoMEMS
   Asst. Prof. Matjaž Spreitzer
   Ministry of Education, Science and Sport
9. „HarvEnPiez: Innovative nano-materials and architectures for integratedpiezoelectric energy harvesting applications"
   Dr. Marjeta Maček Kržmanc
   Ministry of Education, Science and Sport
10. CTB Basics: CleanTechBlock-Sustainable Multi-functional Building Block Basics
    Dr. Jakob König
    Ministry of Education, Science and Sport
11. SIOX: Engineering of silicon-oxide interface using the pulsed-laser deposition technique
    Asst. Prof. Matjaž Spreitzer
    Ministry of Education, Science and Sport
12. Investigation of NdDyCoCuFe Rare Earth Alloys Alloys and Related Compounds
    Prof. Danilo Suvorov
    Urban Mining Company

NEW CONTRACTS

1. PBE Silent and PBE Varioface
   Prof. Danilo Suvorov
   Knauf Insulation, d. o. o., Škofja Loka
2. Development and characterisation of mineral wool fibers
   Prof. Danilo Suvorov
   Knauf Insulation, d. o. o., Škofja Loka

VISITORS FROM ABROAD

1. Dr. Smilja Marković, Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, Belgrade, 11.-15. 12. 2017
2. Dr. Sonja Jovanović, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 27. 11.- 5. 12. 2017
3. Dr. Zoran Jovanović, Dr. Sonja Jovanović, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 10. 7.-11. 8. 2017
4. Martyna Maya Durko, Wrocław University of Science and Technology, Poland, 10. 7. - 25. 9. 2017
5. Prof. Dragoljub Uskoković, Institut tehničkih nauka, Belgrade, Serbia, 9. - 12. 7. 2017
6. Dr. Jyoti Prosad Guha, Missouri University of Science and Technology, Rolla, USA 2. 7.-13. 9. 2017
7. Dr. Jae-Ho Jeon, Korea Institute of Materials Science (KIMS), Korea, 4. - 6. 6. 2017
8. Dr. Christian Hoffmann, Qualcomm Technologies, Inc., USA, 7. 6. 2017

9. Dr. Bratislav Antić, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 21.-24. 3. 2017
10. Dr. Biljana Dojčinović, Institute of Chemistry, Technology and Metallurgy, University of Belgrade, Belgrade, Serbia, 21.-24. 3. 2017
11. Dr. Ioana Dorina Vlaicu, National Institute of Materials Physics, Romania, 3. - 13. 6.2017
12. Prof. Simonida Tomić, Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia, 6.-9.3.2017
13. Ting-Kai Lin, National Taiwan University, Taipei City, Taiwan, 19.- 24.2.2017

Visiting Researchers

1. Dr. Jyoti Prosad Guha, Missouri University of Science and Technology, Rolla, USA, 2. 7.-13. 9. 2017
2. Dr. Daniel Diaz Fernandez, Universidad Autónoma de Madrid, Spain, 1. 10. 2015 – 31. 12. 2017

STAFF

Researchers
1. *Asst. Prof. Boštjan Jančar, left 30.08.17*
2. Dr. Jakob König
3. Dr. Špela Kunej

4. Dr. Marjeta Maček Kržmanc
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6. **Prof. Danilo Suvorov**, Head
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12. Urška Gabor, B. Sc.
13. Tjaša Parkelj, B. Sc.

14. *Tilen Sever, B. Sc., left 01.04.17*
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18. Vesna Butinar, B. Sc.
19. Silvo Zupančič

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Nemanja Aničić, Marija Vukomanović, Danilo Suvorov, "Design of a multifunctional vanadium pentoxide/ polymer biocomposite for implant-coating applications", *RSC advances*, **7**, 61, 38647-38658, 2017.
2. Vida Čadež, Srečo D. Škapin, Adrijana Leonardi, Igor Križaj, Saša Kazazić, Branka Salopek-Sondi, Ivan Sondi, "Formation and morphogenesis of a cuttlebone's aragonite biomineral structures for the common cuttlefish (Sepia officinalis) on the nanoscale: revisited", *J. colloid interface sci.*, **508**, 95-104, 2017.
3. Daniel Diaz-Fernandez, Matjaž Spreitzer, Tjaša Parkelj, Janez Kovač, Danilo Suvorov, "The importance of annealing and stages coverage on the epitaxial growth of complex oxides on silicon by pulsed laser deposition", *RSC advances*, **7**, issue 40, 24709-24717, 2017.
4. Anderson A. Felix, Vinícius Bezzon, Marcelo O. Orlandi, Damjan Vengust, Matjaž Spreitzer, Elson Longo, Danilo Suvorov, José A. Varela, "Role of oxygen on the phase stability and microstructure evolution of $CaCu_3Ti_4O_{12}$ ceramics", *J. Eur. Ceram. Soc.*, **37**, 1, 129-136, 2017.
5. Omodara Gbotemi, Sami Myllymäki, Jari Juuti, Merja Teirikangas, Heli Jantunen, Marjeta Maček, Danilo Suvorov, Marcin Sloma, Małgorzata Jakubowska, "Microwave characterization of printed inductors with ferrimagnetic BaFe[sub](12)O [sub](19) composite layers", *IEEE trans. magn.*, **53**, 2, 2800206, 2017.
6. Jakob Koenig, Rasmus R. Petersen, Yuanzheng Yue, Danilo Suvorov, "Gas-releasing reactions in foam-glass formation using carbon and Mn_xO_y as the foaming agent", *Ceram. int.*, **43**, 5, str- 4638-4646, 2017.
7. Mario Kurtjak, Marija Vukomanović, Danilo Suvorov, "Antibacterial nanocomposite of functionalized nanogold and gallium-doped hydroxyapatite", *Mater. lett.*, **193**, 126-129, 2017.
8. Marjeta Maček, Boštjan Jančar, Hana Uršič, Melita Tramšek, Danilo Suvorov, "Tailoring the shape, size, crystal structure, and preferential growth orientation of BaTiO[sub]3 plates synthesized through a topochemical conversion process", *Cryst. growth des.*, **17**, 16, 3210-3220, 2017.
9. Smilja Marković, Ana Stanković, Jasmina Dostanić, Ljiljana Veselinović, Lidija T. Mančić, Srečo D. Škapin, Goran Dražić, Ivona Janković - Častvan, Dragan Uskoković, "Simultaneous enhancement of natural sunlight- and artificial UV-driven photocatalytic activity of a mechanically activated ZnO/SnO_2 composite", *RSC advances*, **7**, 68, 42725-42737, 2017.
10. Martin B. Østergaard, Rasmus R. Petersen, Jakob Koenig, Hicham Johra, Yuanzheng Yue, "Influence of foaming agents on solid thermal conductivity of foam glasses prepared from CRT panel glass", *J. non-cryst. solids*, **465**, 59-64, 2017.
11. Mojca Otoničar, Joonsuk Park, Manca Logar, Giovanni Esteves, Jacob L. Jones, Boštjan Jančar, "External-field-induced crystal structure and domain texture in $(1 − x)Na_{0.5}Bi_{0.5}TiO_3 − xK_{0.5}Bi_{0.5}TiO_3$ piezoceramic", *Acta mater.*, **127**, 319-331, 2017.
12. Rasmus R. Petersen, Jakob Koenig, Yuanzheng Yue, "The viscosity window of the silicate glass foam production", *J. non-cryst. solids*, **456**, 49-54, 2017.
13. Tadej Rojac, Andreja Benčan, Goran Dražić, Naonori Sakamoto, Hana Uršič, Boštjan Jančar, Gašper Tavčar, Maja Makarovič, Julian Walker, Barbara Malič, Dragan Damjanovič, "Domain-wall conduction in ferroelectric $BiFeO_3$ controlled by accumulation of charged defects", *Nature materials*, **16**, 3, 322-327, 2017.
14. Tilen Sever, Marjeta Maček, Slavko Bernik, Danilo Suvorov, Boštjan Jančar, "Influence of pulsed-electric-current sintering conditions on the non-stoichiometry and thermoelectric properties of $Ti_{1+x}S_2$", *Mater. des.*, **114**, 642-651, 2017.
15. Martin Štefanič, Kevin Ward, Harvey Tawtik, Robert A. Seemann, Vladimir Baulin, Yachong Guo, Jean-Baptiste Fleury, Christophe Drouet, "Apatite nanoparticles strongly improve red blood cell cryopreservation by mediating trehalose delivery via enhanced membrane permeation", *Biomaterials*, **140**, 138-149, 2017.
16. Marija Vukomanović, Vojka Žunič, Špela Kunej, Boštjan Jančar, Samo Jeverica, Rok Podlipec, Danilo Suvorov, "Nano-engineering the antimicrobial spectrum of lantibiotics: activity of nisin against gram negative bacteria", *Sci. rep.*, **7**, 4324, 2017.

PUBLISHED CONFERENCE CONTRIBUTION

1. Marjeta Maček, Hana Uršič, Danilo Suvorov, Romeo Ciobanu, "Size- and shape-controlled synthesis of ferroelectric plate-like particles and their piezoelectric characteristics", In: *Proceedings of the 22nd IMEKOTC-4 International Symposium "Supporting World Development through Electrical & Electronic Measurements" and 20th International Workshop on ADC Modelling and Testing Congres Hall Palas, September 14-16, 2017 Iasi, Romania*, Budapest, IMEKO, 2017, 439-445.

INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

1. Mario Kurtjak, Nemanja Aničić, Marija Vukomanović, "Inorganic nanoparticles: innovative tools for antimicrobial agents", In: *Antibacterial agents*, Ranjith Kumavath, ed., Rijeka, InTech, 2017, 40-60.
2. Marija Vukomanović, "Advanced nanocomposites with noble metal antimicrobial nanoparticles: how to design a balance among antimicrobial activity, bioactivity, and safe delivery to the place of infection", In: *Nanostructures for antimicrobial therapy*, (Nanostructures in therapeutic medicne series), Anton Ficai, ed., Alexandru Mihai Grumezescu, ed., Amsterdam, Elsevier, 2017, 623-651.

MENTORING

1. Nemanja Aničić, *The innovative oxide-based coatings for the application in medicine coatings:* utilization of the V_2O_5 and MgO multifunctionality: doctoral dissertation, Ljubljana, 2017 (mentors Danilo Suvorov, Marija Vukomanović).
2. Mario Kurtjak, *New antibacterial nanomaterials based on gallium gold and hydroxypatite:* doctoral dissertation, Ljubljana, 2017 (mentors Danilo Suvorov, Marija Vukomanović).

DEPARTMENT OF BIOCHEMISTRY, MOLECULAR AND STRUCTURAL BIOLOGY B-1

The research activities of the members of the department are largely focused on studies of the physiological role of proteases in normal and pathological conditions, the mechanism of their action and regulation, as well as their properties and structure. A part of the activities is devoted to the development of tools that allow us to understand the properties of proteases and other enzymes, as well as to enable their monitoring and manipulation in in-vivo conditions.

Protease research has undergone a major expansion in the past decade, largely due to the extremely rapid development of new technologies, such as quantitative proteomics and *in-vivo* imaging, as well as an extensive use of *in-vivo* models. These have led to the identification of physiological substrates and resulted in a paradigm shift from the concept of proteases as protein-degrading enzymes to proteases as key signaling molecules. Their catalytic activities are precisely regulated, the most important ways being zymogen activation and inhibition by their endogenous protein inhibitors. Any imbalance in this regulation can lead to pathologies such as autoimmune, neurological and cardiovascular disorders, cancer and osteoporosis. However, protease signaling pathways are only partially understood. Currently, only a minor subset of physiological substrates for a limited number of proteases has been identified, and their physiological regulation is still not well understood.

As one of the leaders in the field, we were invited to write a review paper in one of the most important journals in the field, Trends in Pharmacological Sciences. In this feature article we overviewed the progress and current trends in the area of cysteine cathepsins in disease management, including as drug targets, targets for noninvasive diagnostic imaging and for targeted drug delivery and as prodrug activators.

We have continued with proteomic approaches devoted to the identification of protease specificities and the identification of physiological protease substrates. We have thus developed a novel, first, gel-based, label-free, proteomic approach (DIPPS-direct in-gel profiling of protease specificity) that enables the quick and reliable determination of protease-cleavage specificities under a large variety of experimental conditions. The methodology is based on the in-gel digestion of the gel-separated proteome with the studied protease, the enrichment of cleaved peptides by gel extraction, and a subsequent mass-spectrometry analysis combined with a length-limited unspecific database search. We applied the methodology to profile ten proteases ranging from highly specific (trypsin, endoproteinase GluC, caspase-7, and legumain) to broadly specific (matrix-metalloproteinase-3, thermolysin, and cathepsins K, L, S, and V). Using DIPPS, we were able to perform specificity profiling of thermolysin at its optimal temperature of 75°C, which confirmed the applicability of the method for extreme experimental conditions. Additionally, DIPPS enabled the first global specificity profiling of legumain at an acidic pH, which revealed a pH-dependent change in the specificity of this protease, further supporting its broad applicability.

In addition to proteomic approaches, we also worked on small molecule substrates and probes. In collaboration with dr. M. Drag (University of Wroclaw), we used a hybrid combinatorial substrate library (HyCoSuL) approach to obtain specific fluorogenic substrates and biotin-labelled inhibitors that targeted proteases. We developed a highly sensitive and adaptable donor/acceptor pair that can be used to investigate the substrate specificity of cysteine proteases, serine proteases and metalloproteinases. This novel pair comprises 7-amino-4-carbamoylmethylcoumarin (ACC) as the fluorophore and 2,4-dinitrophenyl-lysine (Lys(DNP)) as the quencher. Using caspase-3, caspase-7, caspase-8, neutrophil elastase, legumain, and two matrix metalloproteinases (MMP2 and MMP9), we demonstrated that substrates containing ACC/Lys(DNP) exhibit 7 to 10 times higher sensitivity than conventional 7-methoxy-coumarin-4-yl acetic acid (MCA)/Lys(DNP) substrates; thus, substantially lower amounts of substrate and enzyme can be used for each assay. Therefore, the ACC/Lys(DNP) pair can be considered a novel and sensitive scaffold for designing the substrates for any group of endopeptidases. We further demonstrated that IQF substrates containing unnatural amino acids can be used to investigate protease activities/specificities for peptides containing post-translationally modified amino acids. Finally, we used IQF substrates to re-investigate the P1-Asp characteristic of caspases, thus demonstrating that some human caspases can also hydrolyze substrates after glutamic acid.

We also continued to work on targeted drug-delivery systems based on designed Ankyrin repeat proteins (DARPins). The development of highly selective and versatile small-molecule probes for cathepsins has been challenging; however, we were able to develop several cathepsin B-specific DARPins that have the potential for non-invasive diagnostic imaging and theranostic applications for cancer and inflammation.

Head:
Prof. Boris Turk

The most potent was selective DARPin *8h6*, which inhibited cathepsin B in the picomolar range by binding to a site with low structural conservation in cathepsins, as revealed by the X-ray structure of the complex. DARPin *8h6* blocked cathepsin B activity in tumours *ex vivo* and was successfully applied in *in-vivo* optical imaging in two mouse breast-cancer models, in which cathepsin B was bound to the cell membrane or secreted to the extracellular milieu by tumour and stromal cells. Our approach validates cathepsin B as a promising diagnostic and theranostic target in cancer and other inflammation-associated diseases.

Besides drug-delivery systems for active targeting, we also worked on drug-delivery systems for oral application. As part of the FP7 Alexander project in collaboration with A. Azqueta (University of Navarra), we used an in-vivo imaging system, IVIS Spectrum, to validate the biodistribution of poly(anhydride) Gantrez® AN 119 (GN-MA-NP) nanoparticles in the gastro intestinal tract. We were able to determine the retention times for each segment of gastro intestinal tract and also confirmed the excretion of nanoparticles, therefore making GN-MA-NP a promising nanocarrier for oral drug-delivery systems.

Part of the work was also devoted to inhibitors. Since cysteine cathepsins, in addition to their important physiological functions, have been associated with multiple pathologies, including cancer. Therefore, we investigated their major and most potent inhibitor cystatin C that regulates the extracellular activity of cysteine cathepsins. We investigated the role of cystatin C in mammary cancer using CstC knockout mice and a mouse model of breast cancer induced by the expression of the polyoma middle T oncoprotein (PyMT) in the mammary epithelium. We showed that the ablation of CstC reduced the rate of mammary tumor growth. Notably, a decrease in the proliferation of CstC knockout PyMT tumor cells was demonstrated *ex vivo* and *in vitro*, indicating a role for this protease inhibitor in signaling pathways that control cell proliferation. An increase in phosphorylated p-38 was observed in CstC knockout tumors, suggesting a novel function for cystatin C in cancer development, independent of the TGF-β pathway. Moreover, a proteomic analysis of the CstC wild-type and knockout PyMT primary cell secretomes revealed a decrease in the levels of 14-3-3 proteins in the secretome of knock-out cells, suggesting a novel link between cysteine cathepsins, cystatin C and 14-3-3 proteins in tumorigenesis.

Additionally, some animals such as the tick, in order to ensure successful feeding, their saliva contains a number of inhibitory proteins, among which is also cystatin OmC2, that interfere with the host immune response and help to create a permissive environment for pathogen transmission. The potential targets of the salivary cystatins are two host cysteine proteases, cathepsin S, which is essential for antigen- and invariant chain-processing, and cathepsin C (dipeptidyl peptidase 1, DPP1), which plays a critical role in processing and activation of the granule serine proteases. To study salivary cystatin OmC2 from *Ornithodoros moubat*, we used differentiated MUTZ-3 cells as a model of immature dendritic cells of the host skin. Following internalization, cystatin OmC2 was initially found to inhibit the activity of several cysteine cathepsins, as indicated by the decreased rates of degradation of fluorogenic peptide substrates. To identify the targets, affinity chromatography was used to isolate His-tagged cystatin OmC2 together with the bound proteins from MUTZ-3 cells. Cathepsins S and C were identified in these complexes by mass spectrometry and confirmed by immunoblotting. We also observed a reduced increase in the surface expression of MHC II and CD86, which are associated with the maturation of dendritic cells. In contrast, human inhibitor cystatin C, which is normally expressed and secreted by dendritic cells, did not affect the expression of CD86.

Besides proteases we also investigated the conformational plasticity of myotilin, which is important in the organization and maintenance of Z-disk integrity. This involves direct binding to F-actin and filamin C, a function mediated by its Ig domain pair. While the structures of these two individual domains are known, information about their relative orientation and flexibility remains limited. We set out to characterize the Ig domain pair of myotilin with an emphasis on its molecular structure, dynamics and phylogeny.

It is worth mentioning that our department has, partially through the help of the Center of Excellence Center for Integrative approaches for Chemistry and Biology of Proteins (CIPKEBIP), established several technological platforms that are all unique in Slovenia and include a structural biology platform, a proteomics platform and a whole-body imaging platform, based on an IVIS Spectrum imaging system and a Quantum FX micro CT. All three platforms are open for external collaborations and several works resulting from these collaborations have already been published.

We were involved in the Slovenian Center of Excellence CIPKEBIP that we coordinate. In addition, there are numerous other international collaborations with excellent research teams from different countries, including Belgium (a joint project through FWO), Spain, France, Germany, Sweden, Switzerland, UK, USA, Australia, Hungary and Japan, which resulted in joint publications.

In addition, B. Turk organized an EMBO Workshop Mitochondria, Apoptosis, Cancer (MAC17) in Bled, and several members of the department were invited to give lectures at international symposia and foreign universities.

Some outstanding publications in the past year

1. Završnik J, Butinar M, Prebanda Trstenjak M, Krajnc A, Vidmar R, Fonovic M, Grubb A, Turk V, Turk B, Vasiljeva O (2017) Cystatin C deficiency suppresses tumor growth in a breast cancer model through decreased proliferation of tumor cells. Oncotarget 8, 73793-73809 doi: 10.18632/oncotarget.17379.
2. Zavašnik-Bergant T, Vidmar R, Sekirnik A, Fonovic M, Salát J, Grunclová L, Kopáček P, Turk B. (2017) Salivary Tick Cystatin OmC2 Targets Lysosomal Cathepsins S and C in Human Dendritic Cells. Front Cell Infect Microbiol. 7:288. doi: 10.3389/fcimb.2017.00288. eCollection 2017
3. Kramer L, Turk D, Turk B (2017) The future of cysteine cathepsins in disease management. Trends Pharmacol Sci, 38:873-898.
4. Kramer L, Renko M, Završnik J, Turk D, Seeger MA, Vasiljeva O, Grütter GG, Turk V, Turk B (2017) Non-invasive in vivo imaging of tumour-associated cathepsin B by a highly selective inhibitory DARPin. Theranostics, 7: 2806-2821.
5. Vidmar R, Vizovišek M, Turk D, Turk B, Fonović M (2017) Protease cleavage site fingerprinting by label-free in-gel degradomics reveals pH-dependent specificity switch of legumain. EMBO J. 36: 2455-2465.

Awards and Appointments

1. Vito Turk: Honorary Member of the Jožef Stefan Institute, Ljubljana, Slovenia, 26. 10. 2017
2. Eva Vidak: Prešeren Award at the University of Ljubljana, Ljubljana, Slovenia, 6 December 2017, Preparation of recombinant human caspase-1 and identification of its extracellular substrates

Organisation of conferences, congresses and meetings

1. 34th Winter School on Proteinases and Inhibitors 2017, Tiers, Italy, 8–12 March 2017, co-organisers
2. Mitochondria, Apoptosis and Cancer (MAC 2017), Bled, Slovenia, 15–18 September 2017

Patents granted

1. Henry Berbard Lowman, Luc R. Desnoyers, Shouchun Liu, James William West, Jason Sagert, Olga Vasiljeva, Elizabeth Menendez, Activatable antibodies that bind epidermal growth factor receptor and methods of use thereof, US9545442 (B2), US Patent Office, 17. 01. 2017.
2. Olga Vasiljeva, Georgy Mikhaylov, Boris Turk, Norbert Schaschke, Cathepsin-binding compounds bound to a carrier and their diagnostic use, US9827337 (B2), US Patent Office, 28. 11. 2017.

INTERNATIONAL PROJECTS

1. COST BM1307; European Network to integrate Research on Intracellular Proteolysis Pathways in Health and Disease (PROTEOSTASIS)
   Prof. Boris Turk
   Cost Office
2. COST OC-2015; TRANSAUTOPHAGY: European Network of Multidisciplinary Research and Translation of Autophagy Knowledge
   Prof. Eva Žerovnik
   Cost Office
3. COST CA 15203; Mitochondrial Mapping: Evolution-Age-Gender-Lifestyle-Environment
   Asst. Prof. Nataša Kopitar – Jerala
   Cost Office
4. COST CA15124; NEUBIAS - A New Network of European Bioimage Analysts to Advance Life Science Imaging
   Asst. Prof. Tina Zavašnik Bergant
   Cost Office
5. COST CA15214; An Integrative Action for Multidisciplinary Studies on Cellular Structural Networks
   Asst. Prof. Nataša Kopitar – Jerala
   Cost Office
6. Building Interface between Crystallographic Software MAIN and Integrative Modeling Platform IMP
   Prof. Dušan Turk
   Slovenian Research Agency
7. Effect of Anti-oxidants on Protein Aggregation; In Vitro Study of Amyloid Fibrillation on the Model of Stefin B and Beta2-microglobulin
   Prof. Eva Žerovnik
   Slovenian Research Agency
8. Cancer management with cathepsin-targeting protein-drug conjugates: application to brain tumor therapies
   Prof. Boris Turk
   Slovenian Research Agency

RESEARCH PROGRAMS

1. Structural biology
   Prof. Dušan Turk
2. Proteolysis and its regulation
   Prof. Boris Turk

R & D GRANTS AND CONTRACTS

1. Structural insight into iodine metabolism
   Dr. Ajda Taler-Verčič
2. „Insights into the protein interactions involved in the Potato virus Y potatorelation"
   Prof. Dušan Turk
3. Cathepsin X inhibitors impair the resistence of tumor cells to antiprotease therapy
   Prof. Boris Turk
4. Proteases in inflammation and cell death
   Prof. Boris Turk
5. Role of cysteine cathepsins in inflammation-associated diseases
   Prof. Boris Turk
6. The role of micro RNA-21 and cathepsins in delayed preconditioning to acute kidney injury
   Prof. Boris Turk

7. Inhibition of Staphylococcus aureus cell wall remodeling
   Prof. Dušan Turk
8. Enabling technology for high-quality piezoMEMS
   Prof. Boris Turk
   Ministry of Education, Science and Sport
9. Lyposomal Proteases in Semaphorin Signaling and Cell Polarity
   Prof. Boris Turk
   Icgeb - International Centre For Genetic

10. Proteomic analysis
    Prof. Marko Fonović

NEW CONTRACT

1. Mass spectromety analysis
   Prof. Boris Turk
   Krka, Tovarna Zdravil, d. d.

VISITORS FROM ABROAD

1. Samra Hasanbašić, Univerzitet Tuzla,Tuzla, Bosnia and Herzegovina, 18. 9.– 17. 11. 2017

2. Alma Jahić, Univerzitet Tuzla, Tuzla, Bosnia and Herzegovina, 20. 3.– 28. 5. 2017

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22. Dr. Ajda Taler-Verčič
23. Dr. Aleksandra Usenik
24. Dr. Robert Vidmar
25. Dr. Matej Vizovišek

26. Dr. Janja Završnik

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28. Janja Božič, B. Sc.
29. Andreja Bratovš, B. Sc.
30. Marija Grozdanić, B. Sc.
31. *Katarina Hočevar, B. Sc., left 01.05.17*
32. Urban Javoršek, B. Sc.
33. Aleksander Krajnc, B. Sc.
34. Jure Loboda, B. Sc.
35. Sara Pintar, B. Sc.
36. Mojca Trstenjak Prebanda, B. Sc.
37. Eva Vidak, B. Sc.

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38. *Marjeta Arnolj, B. Sc., left 01.08.17*
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45. *Barbara Vrtačnik, left 31.12.17*

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BIBLIOGRAPHY

Original Article

1. Yael Ben-Nun, Gait Fichman, Lihi Adler-Abramovich, Boris Turk, Ehud Gazit, Galia Blum, "Cathepsin nanofiber substrates as potential agents for targeted drug delivery", *J. control. release*, **257**, 60-67, 2017.
2. Katja Bidovec, Janja Božič, Iztok Dolenc, Boris Turk, Vito Turk, Veronika Stoka, "Tumor necrosis factor-α induced apoptosis in U937 cells promotes cathepsin D-independent stefin B degradation", *J Cell Biochem*, **118**, 12, 4813-4820, 2017.
3. Vashendriya V. V. Hira, Urška Verbovšek, Barbara Breznik, Matic Srdič, Marko Novinec, Hala Kakar, Jill Wormer, Britt van der Swaan, Brigita Lenarčič, Luiz Juliano, Shwetal Mehta, Cornelis J. F. van Noorden, Tamara Lah Turnšek, "Cathepsin K cleavage of SDF-1[alpha] inhibits its chemotactic activity towards glioblastoma stem-like cells", *Biochim. biophys. acta, Mol. cell res.*, **1864**, 3, 594-603, 2017.
4. T. Iglesias, J. M. Irache, Miha Butinar, Boris Turk, A. López de Cerain, A. Azqueta, "Genotoxic evaluation of poly(anhydride) nanoparticles in the gastrointestinal tract of mice", *Int. j. pharm.*, issues. 1-2, **530**, 187-194, 2017.
5. Lovro Kramer, Miha Renko, Janja Završnik, Dušan Turk, Markus A. Seeger, Olga Vasiljeva, Markus G. Grütter, Vito Turk, Boris Turk, "Non-invasive in vivo imaging of tumour-associated cathepsin B by a highly selective inhibitory DARPin", *Theranostics*, **7**, 11, 2806-2821, 2017.
6. Marko Mihelič, Kristina Vlahoviček-Kahlina, Miha Renko, Stephan Mesnage, Andreja Doberšek, Ajda Taler-Verčič, Andreja Jakas, Dušan Turk, "The mechanism behind the selection of two different cleavage sites in NAG-NAM polymers", *IUCrJ*, **4**, part 2, 185-198, 2017.
7. Marcin Poreba *et al.* (13 authors), "Highly sensitive and adaptable fluorescence-quenched pair discloses the substrate specificity profiles in diverse protease families", *Sci. rep.*, **7**, 43135, 2017.
8. Jure Pražnikar, "Particulate matter time-series and Köppen-Geiger climate classes in North America and Europe", *Atmos. environ.*, **150**, 136-145, 2017.
9. Vid Puž, Miha Pavšič, Brigita Lenarčič, Kristina Djinović Carugo, "Conformational plasticity and evolutionary analysis of the myotilin tandem Ig domains", *Sci. rep.*, **7**, 3993, 2017.
10. Clifford Taggart *et al.* (12 authors), "Protean proteases: at the cutting edge of lung diseases", *Eur Respir J*, **49**, 2, 1501200, 2107.
11. Ajda Taler-Verčič, Samra Hasanbašić, Selma Berbić, Veronika Stoka, Dušan Turk, Eva Žerovnik, "Proline residues as switches in conformational changes leading to amyloid fibril formation", *Int. j. mol. sci.*, **18**, 3, 549, 2017.
12. Aleksandra Usenik, Miha Renko, Marko Mihelič, Nataša Lindič, Jure Borišek, Andrej Perdih, Gregor Pretnar, Uwe Müller, Dušan Turk, "The CWB2 cell wall-anchoring module is revealed by the crystal structures

of the Clostridium difficile cell wall proteins Cwp8 and Cwp6", *Structure (Lond.)*, **25**, 3, 514-521, 7 Mar. 2017.

13. Robert Vidmar, Matej Vizovišek, Dušan Turk, Boris Turk, Marko Fonović, "Protease cleavage site fingerprinting by label-free in-gel degradomics reveals pH-dependent specificity switch of legumain", *EMBO j.*, **36**, 16, 2455-2465, 2017.

14. Danijela Vujošević, Uroš Cvelbar, Urška Repnik, Martina Modic, Saša Lazović, Tina Zavašnik-Bergant, Nevena Puač, Boban Mugoša, Evangelos Gogolides, Zoran Lj. Petrović, Miran Mozetič, "Plasma effects on the bacteria Escherichia coli via two evaluation methods", *Plasma Sci. Tech.*, **19**, 7, 075504, 2017.

15. Tina Zavašnik-Bergant, Robert Vidmar, Andreja Sekirnik, Marko Fonović, Jiří Salát, Lenka Grunclová, Petr Kopáček, Boris Turk, "Salivary tick cystatin OmC2 targets lysosomal cathepsins S and C in human dendritic cells", *Front. cell. infect. microbiol.*, **7**, 288, 2017.

16. Janja Završnik, Miha Butinar, Mojca Trstenjak-Prebanda, Aleksander Krajnc, Robert Vidmar, Marko Fonović, Anders Grubb, Vito Turk, Boris Turk, Olga Vasiljeva, "Cystatin C deficiency suppresses tumor growth in a breast cancer model through decreased proliferation of tumor cells", *Oncotarget*, **8**, 73793-73809, 2017.

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2. Nataša Kopitar-Jerala, "The role of interferons in inflammation and inflammasome activation", *Front. immunol.*, **8**, 1-9, 2017.

3. Lovro Kramer, Dušan Turk, Boris Turk, "The future of cysteine cathepsins in disease management", *Trends pharmacol. sci. (Regul. ed.)*, **38**, 10, 873-898, 2017.

Independent Component Part or a Chapter in a Monograph

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Patent

1. Henry Berbard Lowman, Luc R. Desnoyers, Shouchun Liu, James William West, Jason Sagert, Olga Vasiljeva, Elizabeth Menendez, *Activatable antibodies that bind epidermal growth factor receptor and methods of use thereof,* US9545442 (B2), US Patent Office, 17. 01. 2017.

2. Olga Vasiljeva, Georgy Mikhaylov, Boris Turk, Norbert Schaschke, *Cathepsin-binding compounds bound to a carrier and their diagnostic use,* US9827337 (B2), US Patent Office, 28. 11. 2017.

Mentoring

1. Lovro Kramer, *Targeting cysteine cathepsins in inflammatory diseases:* doctoral dissertation, Ljubljana, 2017 (mentor Boris Turk).

2. Janja Završnik, *The role of stefin B and cystatin C knockout on cancer progression and metastasis in mouse model:* doctoral dissertation, Ljubljana, 2017 (mentor Vito Turk; co-mentor Olga Vasiljeva).

DEPARTMENT OF MOLECULAR AND BIOMEDICAL SCIENCES   B-2

The research program of the Department of Molecular and Biomedical Sciences is focused mainly on basic research in protein biochemistry, molecular and cellular biology, and genetics. The primary goal of our investigations is to gain a new understanding of mammalian pathophysiology with the aim of improving human and animal health.

Toxinology

One of our most important research topics in the field of toxinology is the study of molecular mechanisms of toxic action of secreted phospholipases A_2 ($sPLA_2$s) from animal venoms. In particular, we are interested in their presynaptic neurotoxicity. The knowledge that we gather from studying toxic $sPLA_2$s represents valuable assistance in understanding the pathophysiological roles of orthologous mammalian $sPLA_2$s, for example, their role in the development of neurodegenerative diseases such as Alzheimer's disease.

Ammodytoxin A (AtxA) is a neurotoxic $sPLA_2$ from the venom of the nose-horned viper (*Vipera a. ammodytes*). The result of the action of this toxin on the motor neuron is the inhibition of secretion of the neurotransmitter acetylcholine into the synaptic cleft and the flaccid paralysis of muscle. Among characteristic effects of AtxA on nerve cells are damaged mitochondria. That the toxin possesses a specific protein receptor in the mitochondria we reported in 1998, but until recently its nature has been eluding identification. In 2017 we finally succeeded in obtaining the results that without doubt confirmed the identity of this protein. It is known that endogenous GIIA $sPLA_2$, very similar in structure to Atx, is localized in the mitochondria of mammalian cells. Besides the confirmed involvement of this enzyme in neuritogenesis, its role in this orgalelle is still hypothetical and unknown. Based on its similarity to AtxA we suggest the involvement of this enzyme in the regulation of cellular respiration. Deregulation of its function, induced by the increase of its concentration and, concomitantly, the activity is likely associated with the etiology of some neurodegenerative diseases, such as Alzheimer's, at which the mitochondrial dysfunctions are very similar to those inflicted by AtxA at its poisoning of the nerve cell. We initiated the preparation of a paper describing the first intracellular membrane $sPLA_2$ receptor and we expect an attention-grabbing publication.

In 2017 we continued with the systematic analysis of the components of the nose-horned viper venom. We deepened the proteomic analysis of the venom and expanded it with a comprehensive study of the viper venom gland transcriptome. The transcriptomic survey of *Vipera a. ammodytes* venom glands has shown that the most abundant venom transcripts (more than a quarter of all) are those encoding precursors of multiple bioactive peptides, i.e., tripeptide metalloproteinase inhibitors, bradykinin-potentiating peptides and natriuretic peptide. They are followed by those of snake C-type lectin-like proteins (Snaclecs), serine proteinases, metalloproteinases of P-II and P-III classes, toxic and nontoxic $sPLA_2$s, and disintegrins. Almost nine-tenths of the entire viper transcriptome thus contain the information for these major seven protein groups. The remaining portion of transcripts is that encoding two serine proteinase inhibitors, vascular endothelial growth factor, cysteine-rich protein (Crisp), *L*-aminoacid oxidase and venom nerve growth factor. We also found a few identical transcripts of a novel, so far unidentified protein, rich in leucine residues, whose function remains unknown. A publication with the most complete description of the composition of *Vipera a. ammodytes* venom glands is in preparation. It should significantly improve the planning of therapeutic strategies.

Animal venoms are a rich source of new substances and molecular tools to improve human and animal health.

In the scope of systematic analysis of the *Vipera a. ammodytes* venom also goes the identification of a cardiotoxic component of this venom. In collaboration with colleagues from the Clinical Department of Infectious Diseases, University Hospital Centre Split, Croatia, and the Department of Pharmacology, Mostar University School of Medicine, Bosnia and Herzegovina, we identified the venom component with the strongest effect on the heart. In a publication we described in detail its effects on an isolated rat heart (S. Karabuva et al., *Toxicon*, 139 (2017), 94–100).

We intensively studied the nose-horned viper venom proteins that affect the blood coagulation process–haemostasis, in particular two such proteins, a homologue of serine protease with anticoagulant activity (VaaSPH-1) and a serine protease with procoagulant, FVIIa-like activity (SP-10). In collaboration with the group of Dr. Manjunatha R. Kini, the renowned expert for haemostasis from the National University of Singapore, we concluded in the past year a detailed characterization of the molecular mechanism of action for both proteins. We also developed a procedure to produce the recombinant form of VaaSPH-1 in mammalian cells. We prepared a publication describing

Head:
Prof. Igor Križaj

the characteristics of the mode of anticoagulant action of VaaSPH-1, the protein very interesting for the development of a new inhibitor for blood coagulation that specifically affects the intrinsic coagulation pathway. The presentation of this work in the form of a poster presentation at the 12th Meeting of the Slovenian Biochemical Society with International Participation in September 2017 on Bled was awarded with 1st prize by the Scientific Committee (Figure 1, Z. Latinović).

We wrote the first article about disintegrins from the nose-horned viper (Z. Latinović et al., *Acta Chim. Slov.*, 64 (2017), 555–559). Disintegrins are polypeptides that bind to integrin molecules and impair in this way their function. The nose-horned viper disintegrins efficiently prevent migration and thus the spreading of cancer cells. They thus express an anti-metastatic potential, which gives a good prospective for their development in the direction of a new anti-cancer drug.

In 2017 we continued and concluded the Slovenian-Croatian bilateral research project. The result of a common work with colleague immunologists from the University of Zagreb and medical doctors from the Centre for Clinical Toxicology and Pharmacology, University Medical Centre Ljubljana is publication of the paper (M. Brvar et al., *Clin. Toxicol.*, 55 (2017), 241–248), in which we described the treatment of patients, envenomed by the nose-horned viper venom, using antivenom directed towards the common adder venom (ViperaTAb®). We found that the treatment using paraspecific antivenom alleviated swelling and temporarily improved the systemic effects of envenomation, by lowering the concentration of toxic components in the patients' blood, but did not abolish neurotoxic effects.

On the specific area of toxinology, we collaborated with our colleagues from the Department of Surface Engineering and Optoelectronics (F4) at the Jožef Stefan Institute. Together, we prepared a review paper on the mycotoxin decontamination of food and feed comparing new approaches using cold atmospheric pressure plasma decontamination with the "classic" decontamination methods (N. Hojnik et al., Toxins, 9 (2017), 151).

In the past year we put a lot of energy into the popularization of our scientific activity by presenting our work to the broader community. We presented our activities in an interview dedicated to animal venoms for the Italian RAI, Radio Trieste A, in the broadcast called Hevreka and in the interview for Ognjišče magazine (I. Križaj, *Ognjišče*, 53 (2017), 102–103).

The Springer publishing company invited us to prepare a chapter for their monograph Snake Venoms. The book was issued in 2017 (D. Kordiš and I. Križaj, Handbook on Toxinology, Springer (2015), ISBN: 78-94-007-6648-8). Among other things, we presented in the article a critical overview of all the important results on the action of presynaptically neurotoxic sPLA$_2$s, and based on them proposed a hypothesis about the mechanism of action of these toxins and suggested experimental approaches to test it.

As experts from the field of toxinology we have been invited as lecturers on expert meetings and scientific conferences. Most worth mentioning is the invitation to deliver the keynote lecture at the 19th World Congress of the International Society on Toxinology in Haikou, China, to I. Križaj.

Figure 1: *Young researchers from our department were awarded for their work. Our young researchers, Zorica Latinović (left) and Eva Jarc (right), received 1st and 2nd prize for their poster presentations at the 12th Meeting of the Slovenian Biochemical Society with International Participation that took place in Bled between 20th and 23rd September 2017. The Scientific Committee of the conference awarded Zorica with the 1st prize for the work entitled "Serine protease homologue from the venom of the nose-horned viper is a promising new anticoagulant lead molecule" and Eva with the 2nd prize for the work entitled "Lipid droplets are involved in eicosanoid generation and protection against nutrient stress in breast-cancer cells".*

Figure 2: *Sequestration of polyunsaturated fatty acids (PUFAs) in lipid droplets protects cancer cells from lipotoxicity. Exposing breast-cancer cells to high concentrations of PUFAs leads to the biogenesis of lipid droplets that contain highly unsaturated PUFA-TAG species. The breakdown of lipid droplets by the lipase ATGL leads to the production of reactive oxygen species (ROS) and oxidative stress-dependent apoptotic cell death (A). We found that PUFA lipotoxicity may be reduced by two complementary mechanisms that sequester PUFAs in lipid droplets (B): (I) Cell membrane hydrolysis by the sPLA$_2$ enzyme leading to lipid droplet biogenesis and TAG remodelling (including the incorporation of the monounsaturated oleic acid (OA)) thereby reducing the fraction of highly unsaturated PUFA-TAGs, or (II) inhibition of ATGL-mediated lipolysis leading to retention of PUFAs within lipid droplets. Figure adapted from E. Jarc et al., Biochim. Biophys. Acta (in press).*

Lipid metabolism and signalization

Lipid droplets are newly recognized organelles composed of a core of neutral lipids, mainly triacylglycerol and cholesterol esters, and covered with a phospholipid monolayer and lipid droplet-associated proteins. They are present in all cells and act as platforms integrating the cellular lipid metabolism and signalling, protein management and quality control, viral replication and immunity. Their biogenesis is generally induced when cells are exposed to a surplus of lipids in the environment (E. Guštin et al., *Acta Chim. Slov.*, 64 (2017), 549–554), but, intriguingly, they are also formed in different stressful conditions for the cell, including nutrient deprivation, hypoxia and oxidative stress. Recent studies have revealed that they also accumulate in cancer cells. Given that the ability of cancer cells to survive stress is indispensable for tumour growth and metastasis, lipid droplets might be important for their resistance to various stresses and thus promote tumourigenesis. In our study (E. Jarc et al., *Biochim. Biophys. Acta*, in press), we examined the role of lipid droplets in the protection of aggressive breast-cancer cells from lipotoxic and nutrient deprivation-induced stress. We found that cancer cells sequester unsaturated fatty acids from their environment and store them in the form of triglycerides in lipid droplets, which in turn provide fuel for

mitochondrial energy production during nutrient deprivation. However, exposing cells to high concentrations of polyunsaturated fatty acids (PUFAs) is toxic to the cells (lipotoxicity), because surplus PUFAs are released from lipid droplets and cause oxidative damage (Figure 2). By silencing the crucial enzyme in lipid droplet breakdown,

adipose triglyceride lipase (ATGL), by inhibiting lipid droplet biogenesis and by modulating the unsaturation levels of triglycerides stored in lipid droplets, we show that these organelles protect sensitive PUFAs from oxidation by storing them in the form of inert triglycerides, while concurrently providing

Lipid droplets protect cancer cells from nutrient and oxidative stress.

fatty acids for mitochondrial energy production, redox homeostasis and cell survival. Lipid droplets thus balance unsaturated fatty-acid trafficking with cell-survival mechanisms and protect cancer cells from nutrient and oxidative stress. Our study reveals that targeting lipid droplet metabolism could be exploited to significantly reduce the resilience of cancer cells to oxidative and metabolic stress and thus impair tumour progression. Presentation of this work in the form of poster presentation at the 12th Meeting of the Slovenian Biochemical Society with International Participation in September 2017 on Bled was awarded the 2nd prize by the Scientific Committee (Figure 1, E. Jarc).

High-throughput genetics and functional genomics in yeast *Saccharomyces cerevisiae*

Polygenic trait analysis is one of the fastest-developing fields in genetics. It will fundamentally influence our understanding of processes in biotechnology and biomedicine. Using the approaches that we developed ourselves, in which the CRISPR/Cas9 method is used to edit the yeast genome at will, we further elucidated the genetic architecture of traits connected to neutral lipid content in yeast (Figure 3). The same approaches were used in the studies on the *MKT1* gene, a model gene for several polygenic traits in yeast.

Also, obesity in humans and in mice is a polygenic trait. Using yeast as a model organism we studied the molecular function of the *TUM1* gene, the homologue of the mammalian gene *TST* which has been shown to be involved in the onset of obesity in humans and mice. We showed that the TUM1 protein is involved in the sterol ester metabolism, but that its function is not identical to the one of the TST protein (K. Uršič et al., *BMC Microbiol.*, 17 (2017), 181).

Polygenic trait analysis in yeast for the development of biomedicine and biotechnology.

reference yeast strain with low neutral lipid content
~ 50.000 SNV
yeast strain with high neutral lipid content

Figure 3: Fluorescent microscopy of strains with low and high neutral lipid content that differ in approximately 50,000 nucleotides over the genome. Polygenic trait analysis methods enable us to find from this set the few that are causal for a given trait.

Analysis of genomes

In a book chapter we have presented the most exciting insights obtained from our study about the origin, distribution, diversity, and evolution of retro-element-derived domesticated genes in mammals (D. Kordiš, Evolutionary Biology: Self/Nonself Evolution, Species and Complex Traits Evolution, Methods and Concepts, Springer (2017), ISBN: 978-3-319-61569-1). We have mapped the life history of domesticated genes, from birth, their fixation in the genome, gain of regulatory elements and structural complexity to complete integration into the functional network of the cell. We have demonstrated that domesticated genes originated from retro-element remains and that they acquired regulatory regions *de novo*. Newly emerged domesticated genes may evolve new functional roles through the adaptive evolution of encoded proteins and/or by developing new spatial or temporal expression patterns. The regulatory wiring of domesticated genes and their rapid fixation in the ancestor of placental mammals have played an important role in the origin of their innovations and adaptations, such as placenta and newly evolved brain functions. We have demonstrated the utility of molecular domestication as a good model for understanding the origination and functional evolution of novel genes.

Early evolutionary analyses of sPLA$_2$ toxins in venomous animals took place in the "pre-genomic era", and were based on a small sample of taxonomic diversity and diversity within the sPLA$_2$ toxins. Since then, the number of representatives has increased significantly, largely due to the accumulation of the venom transcriptomic resources since the large genomic data regarding sPLA$_2$ toxins in venomous animals are still very sparse. In the book chapter (D. Kordiš and I. Križaj, Handbook on Toxinology, Springer (2017), ISBN: 978-94-007-6409-5) we highlighted how the progress in the last decade has increased our understanding of the evolution of sPLA$_2$ toxins in venomous animals.
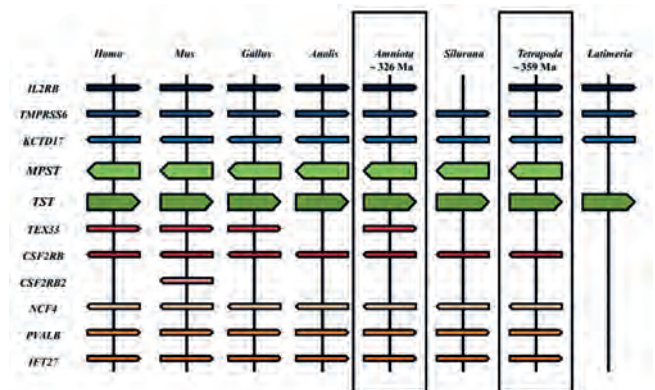
Figure 4: Conserved synteny of the rhodanese superfamily in vertebrates. Chromosomal regions carrying TST and MPST genes in the species considered in this analysis were compared, and neighbouring genes with conserved synteny were identified. Horizontal lines denote the orthologous relationships. Each gene is represented by a horizontal line on the chromosome. Neighbouring genes that are in synteny are shown with a schematic indication of their orientation and distance (not to scale). Ancestral states of the TST and MPST chromosomal positions in Amniota and Tetrapoda were reconstructed from comparisons of syntenic positions between multiple vertebrate lineages. Analysis of conserved synteny demonstrated that the gene duplication of rhodanese gene superfamily occurred in the ancestor of land vertebrates (~ 359 Mya). The figure is reproduced from K. Uršič et al., BMC Microbiology, 17 (2017), 181.

TUM1 is the yeast *Saccharomyces cerevisiae* ortholog of the human *TST* gene. TUM1 and TST/MPST (mercaptopyruvate sulphurtransferase) proteins belong to the rhodanese protein superfamily. Our analysis has demonstrated that rhodanese superfamily is widespread in archaea, bacteria and in all major eukaryotic groups (K. Uršič et al., *BMC Microbiology*, 17 (2017), 181). The prokaryotic proteins are scattered among the eukaryotic representatives, indicating the possibility of horizontal gene transfer, which is further supported by relatively high levels of sequence identity between some prokaryotic and eukaryotic rhodanese representatives (Figure 4). Ancestral states of the *TST* and *MPST* chromosomal positions were reconstructed from comparisons of syntenic positions between the diverse vertebrate lineages. Analysis of conserved synteny has demonstrated that the gene duplication of rhodanese gene superfamily occurred in the ancestor of land vertebrates (~ 359 Mya), producing *TST* and *MPST* genes.

Analysis of rich genome data provide new insights into the origin, diversity and evolution of genes.

Other subjects

In 2017 we also participated at several research projects out of the thematic scope of our department.

As partners in a project led by colleagues from the Faculty of Electrical Engineering of the University of Ljubljana (UL) we accomplished structural identification analysis of protein corona composition of nanoparticles prepared in different dispersion media. As protein corona of nanoparticles primarily determines the pathophysiological characteristics of nanoparticles in biological systems, the knowledge about its controlled formation is vitally important for the safe use of nanoparticles in medicine. Our results and conclusions we published in 2017 (K. Strojan et al., *PLoS One*, 12 (2017), e0169552).

Also in the field of nanoparticles research, we were partners in a collaboration coordinated by our colleagues from the Biotechnical Faculty UL. We participated with the cell-culture studies, determining the influence of non-cytotoxic concentrations of silica-coated superparamagnetic iron oxide nanoparticles (SiO_2-SPIONs) on human alveolar epithelial A549 cells, a model of alveolar type-II cells. The pulmonary delivery of nanoparticles is namely a promising approach in nanomedicine. We succeeded in publishing our results in the prestigious journal Nanotoxicology (V. Kononenko et al., *Nanotoxicol.*, 11 (2017), 419–429).

On the project led by the partners from the Ruđer Bošković Institute in Zagreb we participated at establishing the mechanism of formation and morphogenesis of the aragonite nanostructure of the common cuttlefish (*Sepia officinalis*) cuttlebone. We accomplished the mass-spectrometric identification of protein components of the cuttlebone, potentially involved in the process of biomineralization, i.e., initiation of the extracellular nucleation of aragonite nanocrystals. The work has already been published (V. Čadež et al., *J. Coll. Interf. Sci.*, 508 (2017), 95–104).

We collaborated also with our colleagues from the NMR Centre of the Utrecht University, the Netherlands, at establishing the mechanism of binding of structure-specific endonuclease ERCC1/XPF on DNA in the process of its repair (D. Das et al., *J. Biol. Chem.*, 292 (2017), 2842–2853).

Some outstanding publications in the past year

1. Karabuva, S., Lukšić, B., Brizić, I., Latinović, Z., Leonardi, A. and Križaj, I.: Ammodytin L is the main cardiotoxic component of the *Vipera ammodytes ammodytes* venom. Toxicon, 139 (2017), 94–100

2. Kordiš, D. and Križaj, I.: Secreted phospholipases A$_2$ with β-neurotoxic activity. In: Handbook on Toxinology (Gopalakrishnakone, P., Inagaki, H., Mukherjee, A.K., Rahmy, T.R. and Vogel C.-W.; Eds.), Volume: Snake Venoms. ISBN: 978-94-007-6409-5 (2017), Springer; pp. 67–86

3. Uršič, K., Ogrizović, M., Kordiš, D., Natter, K. and Petrovič, U.: TUM1 is involved in the metabolism of sterol esters in *Saccharomyces cerevisiae*. BMC Microbiol., 17 (2017), 181

4. Kononenko, V., Erman, A., Petan, T., Križaj, I., Kralj, S., Makovec, D. and Drobne, D.: Harmful at non-cytotoxic concentrations: SiO$_2$-SPIONs affect surfactant metabolism and lamellar body biogenesis in A549 human alveolar epithelial cells. Nanotoxicology, 11 (2017), 419–429

5. Strojan, K., Leonardi, A., Bregar, V.B., Križaj, I., Svete, J. and Pavlin, M.: Dispersion of nanoparticles in different media importantly determines the composition of their protein corona. PLoS One, 12 (2017), e0169552

Awards and Appointments

1. Eva Jarc: Best poster Award – Second place, 12th Meeting of the Slovenian Biochemical Society, Bled, 23 September 2017

2. Zorica Latinović: Best poster Award – First place, 12th Meeting of the Slovenian Biochemical Society, Bled, 23 September 2017

Organization of conferences and meetings

1. Annual meeting of co-workers of the research programme "Toxins and Biomembranes" from the Department of Molecular and Biomedical Sciences at the Jožef Stefan Institute and the Department of Biology, Biotechnical Faculty, University of Ljubljana, Ljubljana, 21 November and 23 November 2017

2. 12th Meeting of the Slovenian Biochemical Society, Bled, 20 September - 23 September 2017 (co-organizers)

3. 19th World Congress of the International Society on Toxinology, Haikou, China, 24 October – 31 October 2017 (co-organizers)

INTERNATIONAL PROJECTS

1. 7FP - YeSVitE; Yeasts for the Sustainability in Viticulture and Oneology
   Prof. Uroš Petrovič
   European Commission

2. Antivenomics as a Tool to increase Efficacy of Specific and Paraspecific Serotherapy against Envenomation with Viperidae Venoms
   Prof. Igor Križaj
   Slovenian Research Agency

RESEARCH PROGRAM

1. Toxins and biomembranes
   Prof. Igor Križaj

R&D GRANTS AND CONTRACTS

1. Applications of aegerolysin-like proteins for detection and eradication of pests
   Prof. Igor Križaj

2. Genetic background of mastitis resistance
   Prof. Igor Križaj

3. Evaluation of possible harmful effects of nanoparticles and underlying mechanisms – from physico-chemical and in vitro toxicity characterisation to innate immune system activation
   Prof. Igor Križaj

4. DNA sampling II: a method for identification of directly or indirectly bound proteins at specific loci on bacterial chromosomes
   Prof. Igor Križaj

5. Thermophoretic guidance, accumulation and sorting of biomolecules in microfluidic devices
   Prof. Igor Križaj

6. Crosstalk betwen lipid and central carbon metabolism
   Prof. Uroš Petrovič

7. Bisphenol A alternatives: transfer from food contact material, fate and human exposure
   Asst. Prof. Toni Petan

8. Anisotropic magnetic nanoparticles for the magneto-mechanical therapy of cancer
   Prof. Igor Križaj

9. Improved treatment and monitoring of Water Framework Directive priority pollutants
   Prof. Igor Križaj

10. Definition of molecular parameters for protection of Carniolan honeybee
    Prof. Igor Križaj

VISITORS FROM ABROAD

1. Merve Yilmazer, Istanbul University, Istanbul, Turkey, 19 October 2016 – 17 February 2017
2. Dr. Maja Lang Balija, Centre for Research and Knowledge Transfer in Biotechnology, University of Zagreb, Zagreb, Croatia, 25 January 2017
3. Dr. Julija Erhardt, Faculty of Science, University of Zagreb, Zagreb, Croatia, 25 January 2017
4. Blanka Smolić, dr. vet. med., Centre for Research and Knowledge Transfer in Biotechnology, University of Zagreb, Zagreb, Croatia, 25 January 2017
5. Dubravka Švob Štrac, Institut Rudjer Bošković, Zagreb, Croatia, 25 January 2017
6. Monika Tunjić, Faculty of Science, University of Zagreb, Zagreb, Croatia, 20 March – 14 April 2017
7. Dr. Svjetlana Karabuva, Clinical Hospital Center Split, Split, Croatia, 4 April 2017
8. Alenka Hafner, University of Cambridge, Cambridge, Great Britain, 26 August – 15 September 2017
9. Prof. Juan José Calvete, Biomedicine Institute of Valencia, Valencia, Spain, 19 September – 24 September 2017

STAFF

Researchers
1. Prof. Dušan Kordiš
2. **Prof. Igor Križaj, Head**
3. Asst. Prof. Adrijana Leonardi
4. Asst. Prof. Toni Petan
5. Prof. Uroš Petrovič*
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8. Adrijan Ivanušec, B. Sc.
9. Eva Jarc, B. Sc.

10. Mojca Ogrizović, B. Sc.
11. Sabina Ott, B. Sc.
Technical officers
12. Beti Kužnik, B. Sc.
Technical and administrative staff
13. Igor Koprivec
14. Maja Šimaga, M. Sc.

Note:

* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Miran Brvar, Tihana Kurtović, Damjan Grenc, Maja Lang Balija, Igor Križaj, Beata Halassy, "*Vipera ammodytes* bites treated with antivenom ViperaTAb: a case series with pharmacokinetic evaluation", *Clin. toxicol.*, **55**, 4, 241-248, 2017.

2. Vida Čadež, Srečo D. Škapin, Adrijana Leonardi, Igor Križaj, Saša Kazazić, Branka Salopek-Sondi, Ivan Sondi, "Formation and morphogenesis of a cuttlebone's aragonite biomineral structures for the common cuttlefish *(Sepia officinalis)* on the nanoscale: revisited", *J. colloid interface sci.*, **508**, 95-104, 2017.

3. Das Devashish, Maryam Faridounnia, Lidija Kovačič, Robert Kaptein, Rolf Boelens, Gerd E. Folkers, "Single-stranded DNA binding by the helix-hairpin-helix domain of XPF protein contributes to the substrate specificity of the ERCC1-XPF protein complex", *J Biol Chem*, **292**, 7, 2842-2854, 2017.

4. Ema Guštin, Eva Jarc, Ana Kump, Toni Petan, "Lipid droplet formation in HeLa cervical cancer cells depends on cell density and the concentration of exogenous unsaturated fatty acids", *Acta chim. slov. (Print ed.)*, **64**, 3, 549-554, 2017.

5. Eva Jarc, Irena Preložnik-Zupan, Jadranka Buturović-Ponikvar, Nada Snoj, Helena Podgornik, "Comparison of erythrocyte and reticulocyte

indices for the diagnosis of iron deficiency", *Zdravniški vestnik*, **86**, no. 1/2, 19-27, 2017.

6. Svjetlana Karabuva, Boris Lukšić, Ivica Brizić, Zorica Latinović, Adrijana Leonardi, Igor Križaj, "Ammodytin L is the main cardiotoxic component of the *Vipera ammodytes ammodytes* venom", *Toxicon (Oxford)*, **139**, 94-100, 2017.

7. Veno Kononenko, Andreja Erman, Toni Petan, Igor Križaj, Slavko Kralj, Darko Makovec, Damjana Drobne, "Harmful at non-cytotoxic concentrations: SiO_2-SPIONs affect surfactant metabolism and lamellar body biogenesis in A549 human alveolar epithelial cells", *Nanotoxicology*, **11**, 3, 419-429, 2017.

8. Zorica Latinović, Adrijana Leonardi, Toni Petan, Margareta Žlajpah, Igor Križaj, "Disintegrins from the venom of *Vipera ammodytes ammodytes* efficiently inhibit migration of breast cancer cells", *Acta chim. slov. (Print ed.)*, **64**, 3, 555-559, 2017.

9. Klemen Strojan, Adrijana Leonardi, Vladimir Boštjan Bregar, Igor Križaj, Jurij Svete, Mojca Pavlin, "Dispersion of nanoparticles in different media importantly determines the composition of their protein corona", *PloS one*, **12**, 1, 1-21, Jan. 4, 2017.

10. Katja Uršič, Mojca Brložnik, Dušan Kordiš, Klaus Natter, Uroš Petrovič, "Tum1 is involved in the metabolism of sterol esters in *Saccharomyces cerevisiae*", *BMC Microbiol*, **17**, 181, 2017.

REVIEW ARTICLE

1. Nataša Hojnik, Uroš Cvelbar, Gabrijela Tavčar-Kalcher, James L. Walsh, Igor Križaj, "Mycotoxin decontamination of food: cold atmospheric pressure plasma versus "classic" decontamination", *Toxins*, **9**, 5, 151, 2017.

INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

1. Dušan Kordiš, "The life history of domesticated genes illuminates the evolution of novel mammalian genes", In: *Evolutionary biology: self/nonself evolution, species and complex traits evolution, methods and concepts*, Pierre Pontarotti, ed., Cham, Springer, 2017, 147-162.

2. Dušan Kordiš, Igor Križaj, "Secreted phospholipases A_2 with β-neurotoxic activity", In: *Snake venoms*, (Toxinology, **7**), (Springer reference), P. Gopalakrishnakone, ed., Hidetoshi Inagaki, ed., 2017, 67-86.

DEPARTMENT OF BIOTECHNOLOGY
B-3

At the Department of Biotechnology we investigate biological molecules of microbiological, fungal, plant and animal origin using modern biotechnological methods. We would like to apply them for diagnostic and therapeutic purposes in human and veterinary medicine, for plant protection, preparation of quality and safe food and for the protection of the environment, contributing to an improvement in peoples' health and the environment in which we live. Our research work is focused on the processes of cancer progression and immune response, neurodegenerative processes, the biology of fungi, plant stress response and in the search for new biotechnological approaches and products.

Head:
Prof. Janko Kos

Mushrooms represent a promising source of bioactive proteins and biopesticides based on their own arsenal of various compounds used against pests, parasites and pathogens. Among them the defence proteins are very important and include lectins and protease inhibitors with strong and specific insecticidal and/or nematicidal activity. Phylogenetic analyses have revealed that these proteins are widely present among higher fungi, ascomycetes and basidiomycetes, which means that these protein toxins have potential applications in veterinary and human medicine, biotechnology and in crop protection.

For lectin MpL we demonstrated that it represents an effective tool to deliver therapeutic and other proteins to the tumour cells. Proteins, which by themselves are not able to enter the cells, can reach their intracellular targets by support of this lectin. The results have been published in the prestigious journal Oncotarget. Additionally, we confirmed the exclusive cytotoxicity of CNL lectin from clouded funnel against leukemic T cells Jurkat causing programmed cell death through binding a receptor in a plasma membrane. In several other papers we published the properties of other compounds of mushroom origin and their applicability in crop protection or their cytotoxic activity.

Cystatin F regulates the cytotoxicity of natural killer cells.

Investigating the role of proteolytic enzymes in the regulation of cell cytotoxicity we focused our research work on cathepsins C and H, two main convertases of progranzyme B, the molecule that triggers the processes of cell death. The activity of cathepsins C and H in secretory granules is controlled by the endogenous inhibitor cystatin F.

Secretory-granule-dependent cytotoxicity is typical for natural killer (NK) cells and cytotoxic T lymphocytes, and consequently we focused our studies on these cell types. Using different cystatin F mutants we have shown that the internalization of both the dimeric and monomeric forms of cystatin F leads to a reduction in the activity of cathepsins C and H in recipient cells. The internalization rate of both dimeric and monomeric cystatin F was shown to be governed by their glycosylation pattern. Finally, we have shown that both dimeric and monomeric cystatin F can be transported to endosomes/lysosomes of NK cells resulting in the decreased activity of the effector granzymes A and B as well as lower cytotoxicity towards target cells.

Figure 1: Schematic representation of the effects of increased extracellular concentration of cystatin F on natural killer (NK) cells.

The source of extracellular cystatin F could be tumour cells, which by secreting of this inhibitor inactivate an anti-tumour immune response. These findings identify cystatin F as one of the possible mediators of tumour-induced immunosuppression and a possible therapeutic target. By lowering the uptake of extracellular cystatin F and/or its activation the efficacy of NK cell cytotoxicity could be increased in order to improve the immunotherapy of cancer patients. These results were published in Frontiers in Immunology.

We have also examined the regulation of cystatin F expression in immune cells and identified the transcription factor CEBP alpha as one of the regulators of cystatin F expression.

CRISPR/Cas9 system for gene editing was adopted for use in lactic acid bacterium *Lactococcus lactis*.

In the field of neurobiology we continued investigations of molecular mechanisms of frontotemporal dementia (FTD) and amyotrophic lateral sclerosis (ALS). We published an article on the use of neuromuscular co-culture in the investigation of intracellular localization of FUS and TDP-43 proteins (Journal of Molecular Neuroscience). We also reported the effect of nanoparticles on the intracellular localization of these two proteins (Neurotoxicity Research). In collaboration with the group at King's College London, we published
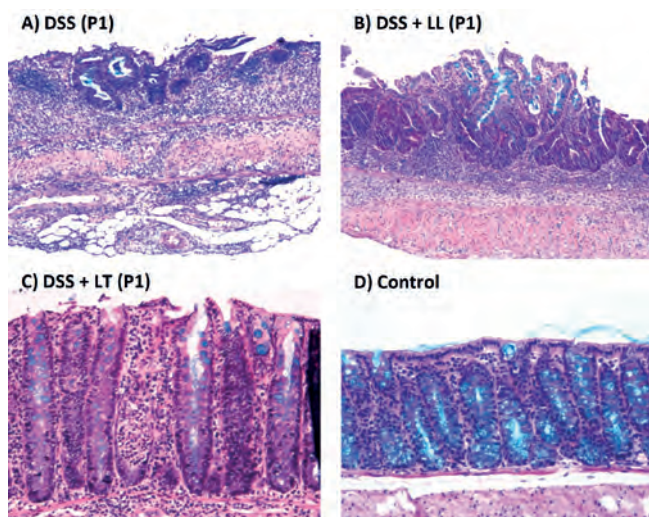
Figure 2: Representative micrographs of mice colonic mucosa from each group using Kreyberg-Jareg staining. A) Transmural inflammation accompanied by small and shallow erosion one week after DSS-induced colitis. B) Moderate inflammation limited to mucosa and submucosa one week after DSS induced colitis treated with control L. lactis. C) Moderate inflammation limited to mucosa and submucosa one week after DSS induced colitis treated with control TNFα-binding L. lactis. Note increased height of crypts and crypt abscess. D) Healthy colon mucosa. Magnifications: A – 100x; B – 100x; C – 200x; D – 200x.

The toxic effect of dipeptide repeats resulting from the mutation of hexanucleotide repeats in the C9orf72 gene is associated with amyotrophic lateral sclerosis.

A member of the department, Dr. Boris Rogelj, received a Lapanje award, the highest acknowledgement from the Slovenian Biochemical Society for excellent research achievements.
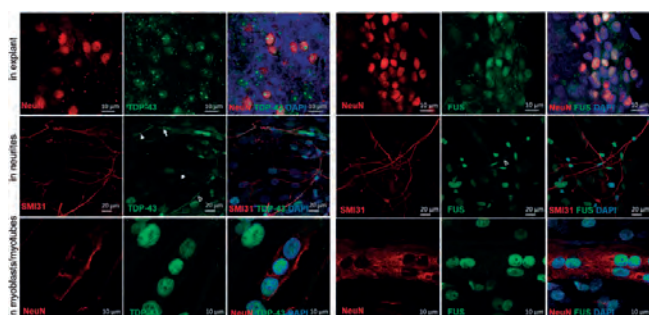
Figure 3: Representative images of endogenous expression and cellular localisation of TDP-43 and FUS in an in vitro model of innervated human muscle. Occasional cytoplasmic TDP-43 aggregates were seen in neuronal somas (arrow) and in neurites (filled arrow heads). In neurites, uneven cytoplasmic TDP-43 and FUS expression was also noted (empty arrow heads). In the muscle cells, TDP-43 and FUS were localised in the nuclei of the myoblasts and myotubes. NeuN labelled the neuronal nuclei, and SMI31 labelled the neurons. Scale bars, as given for individual panels. The nuclei were stained by DAPI (blue) (Prpar Mihevc et al., Journal of Molecular Neuroscience 2017).

a study on the toxic effect of dipeptide repeats resulting from the mutation of hexanucleotide repeats in the C9orf72 gene (Human Molecular Genetics). We have established that the toxic effect of dipeptide repetition of GA can be reduced by dipeptide repetition of PA. We also published two review articles in prestigious journals (Brain, Progress in Neurobiology).

Inflammatory bowel disease is a chronic inflammation of the gastrointestinal tract that can manifest itself as Crohn's disease or ulcerative colitis. Neutralization of pro-inflammatory cytokines with monoclonal antibodies represents an established treatment approach; however, it is associated with high costs and side effects. At the department we have developed lactic acid bacteria that are capable of neutralizing pro-inflammatory cytokines and chemokines and enable local delivery to mucosal surfaces.

We have displayed on the surface of lactic acid bacterium *Lactococcus lactis* tick proteins evasins that are capable of binding different chemokines. By using recombinant bacteria we were able to remove 15–90 % of eleven chemokines. The ability to remove chemokine CXCL-8 and decrease its secretion was confirmed in a Caco-2 cellular model of the epithelium. We have also coated the lactic acid bacterium *Lactobacillus salivarius* with binders of cytokines IL-17, IL-23 in TNFα by using a previously developed approach of non-GMO surface display. We were the first to prepare the bacteria with the ability to concomitantly bind three different cytokines. The bacteria were assessed by using different concentrations of bacteria and different concentrations of cytokines. Their stability in simulated gastric juice was confirmed. Bacterium *Lactococcus lactis* with TNFα-binding ability was evaluated in a mouse model of colitis, induced with sodium dextran sulphate. The decrease of the symptoms of colitis and improvement of histological picture of inflammation was effectively achieved with wild-type *Lactococcus lactis* bacteria, especially when they were administered in a preventive manner. Surprisingly, the TNFα-binding bacteria were shown to be less efficient. This is probably due to the properties of a specific animal model, for which it was previously shown that the neutralization of TNFα is not necessarily beneficial. This finding was additionally confirmed by administering a specific monoclonal antibody that has worsened the symptoms of colitis. TNFα-binding bacteria and monoclonal antibody have also increased the tissue concentration of TNFα in healthy mice to a similar level, serving as additional proof of similar activity, as well as the efficacy of developed bacteria.

The results of the research work at the Department of Biotechnology in 2017 were published in 26 scientific papers in journals with an impact factor. Also, one national and one international patent were granted and one patent application was filed. We received two research grants from the Slovenian Research Agency, one bilateral international grant and international research grant WADA. Dr. Boris Rogelj received the Lapanje award, the highest acknowledgement from the Slovenian Biochemical Society for excellent research achievements. Dr. Ana Mitrović received a Krka award for her research work. The members of the department were also very active in pedagogical work as lecturers and mentors to students preparing diploma and doctoral thesis at universities in Slovenia and abroad.

Some outstanding publications in the past year

1. Perišić, Milica, Sabotič, Jerica, Švajger, Urban, Jewett, Anahid, Kos, Janko. Cystatin F affects natural killer cell cytotoxicity. Frontiers in immunology, ISSN 1664-3224, 2017, vol. 8, pages 1459-1-1459-14, doi: 10.3389/fimmu.2017.01459. [COBISS.SI-ID 30930471].

2. Prpar Mihevc, Sonja, Darovic, Simona, Kovanda, Anja, Bajc Česnik, Ana, Župunski, Vera, Rogelj, Boris. Nuclear trafficking in amyotrophic lateral sclerosis and frontotemporal lobar degenera-

tion. Brain : journal of neurology, ISSN 0006-8950, 2017, vol. 140, issue 1, doi: 10.1093/brain/aww197, [COBISS.SI-ID 29663527] .

3. Žurga, Simon, Perišić, Milica, Kos, Janko, Sabotič, Jerica. Fungal lectin MpL enables entry of protein drugs into cancer cells and their subcellular targeting. Oncotarget, ISSN 1949-2553, 2017, doi: 10.18632/oncotarget.15849, [COBISS.SI-ID 30318887].

Awards and Appointments

1. Polona Megušar: Biotechnical Faculty Prešeren Prize 2017, Biotechnical Faculty, University of Ljubljana, Ljubljana, Characterisation of antimicrobial and antiadhesive activity of mushrooms aqueous extracts, 21 December 2017

2. Ana Mitrović: Krka Prize, Novo mesto, Slovenia, Krka, Role of cysteine cathepsins B and X and their inhibitors in epithelial-mesenchymal transition of tumour cells, 13 October 2017

3. Boris Rogelj: Lapanje Award, Bled, Slovenian Biochemical Society, for exceptional achievements in biochemical science, 21 September 2017

Organization of conferences and meetings

1. Annual meeting of co-workers of the research programme Pharmaceutical Biotechnology: Knowledge for Health, from the Department of Biotechnology at the Jožef Stefan Institute and the Chair of Pharmaceutical Biology, Faculty of Pharmacy, University of Ljubljana, Ljubljana, 23 November 2017

2. 8th Conference on Experimental and Translational Oncology, Association of Radiology and Oncology, Portorož, 19 April – 23 April 2017 (co-organizers)

Patents granted

1. Mojca Lunder, Matjaž Ravnikar, Borut Štrukelj, Aleš Berlec, Boris Čeh, Modified food grade microorganism for treatment of inflammatory bowel disease, EP2521737 (B1), European Patent Office, 30. 08. 2017.

2. Katja Žmitek, Nataša Tavčar, Tina Pogačnik, Janko Žmitek, Petra Keršmanc, Tadej Rejc, Uroš Petrič, Borut Štrukelj, Samo Kreft, Extract from the wood of trees of the genus fir to prevent, alleviate or treat unwanted skin changes and preparations, SI25053 (A), Urad RS za intelektualno lastnino, 31. 03. 2017.

INTERNATIONAL PROJECTS

1. Functional and Structural Studies of Lectins from Mushrooms
Dr. Jerica Sabotič
Slovenian Research Agency
2. The Role of C/EBP Alpha in Regulation of Cystatin F Expression
Prof. Janko Kos
Slovenian Research Agency
3. Pathological Mechanisms of TDP-43 in Amyotrophic Lateral Sclerosis and Frontotemporal Dementia
Prof. Boris Rogelj
Slovenian Research Agency

RESEARCH PROGRAM

1. Pharmaceutical Biotechnology: Knowledge for Health
Prof. Janko Kos

R & D GRANTS AND CONTRACTS

1. Genetics and pharmacogenomics of inflammatory bowel diseases and genetically related chronic immune diseases
Prof. Boris Rogelj
2. Pathogenic mechanism of the C9orf72 expanded hexanucleotide repeat mutation in neurodegeneration
Prof. Boris Rogelj
3. Evaluation of possible harmful effects of nanoparticles and underlying mechanisms – from physico-chemical and in vitro toxicity characterisation to innate immune system activation
Prof. Boris Rogelj
4. Nucleart transport defect in neurodegenerative diseases
Prof. Boris Rogelj
5. Cathepsin X inhibitors impair the resistence of tumor cells to antiprotease therapy
Prof. Janko Kos
6. The role of cysteine protease inhibitors in NK cell mediated lysis of tumour cells
Prof. Janko Kos

VISITORS FROM ABROAD

1. Esmeralda Dautović, M. Sc., Faculty of Pharmacy, University of Tuzla, Tuzla, Bosnia and Herzegovina, 27 February– 22 April 2017
2. Prof. Anahid Jewett, University of California, Los Angeles, USA, 10 April 2017
3. Dr. Annabelle Varrot, Centre de Recherches sur les Macromolécules Végétales, CERMAV, Grenoble, France, 9 May – 24 May 2017
4. Aurore Cabanettes, Centre de Recherches sur les Macromolécules Végétales, CERMAV, Grenoble, France, 9 May – 24 May 2017
5. Katarzyna Walkiewicz, Nanotemper Technologies GmbH, München, Germany, 24 May 2017
6. Maria Hlavnickova, Institute of Biotechnology, The Czech Academy of Sciences, Prague, Czech Republic, 28 May – 9 June 2017
7. Dr. Peter Malý, Institute of Biotechnology, The Czech Academy of Sciences, Prague, Czech Republic, 6 July 2017
8. Esmeralda Dautović, M. Sc., Faculty of Pharmacy, University of Tuzla, Tuzla, Bosnia and Herzegovina, 6 August – 26 August 2017
9. Prof. dr. Serge Pérez, Université Grenoble Alpes, Grenoble, France, 17 October – 18 October 2017
10. Dr. Annabelle Varrot, Centre de Recherches sur les Macromolécules Végétales, CERMAV, Grenoble, France, 17 October – 18 October 2017

Jožef Stefan Institute

STAFF

Researchers
1. Asst. Prof. Aleš Berlec
2. Prof. Janko Kos*, Head
3. Asst. Prof. Helena Motaln
4. Prof. Boris Rogelj
5. Dr. Jerica Sabotič
6. Prof. Borut Štrukelj*

Postdoctoral associates
7. *Dr. Vida Kocbek, left 16.01.17*
8. *Dr. Anja Kovanda, left 01.07.17*
9. Dr. Ana Mitrović
10. Dr. Milica Perišić Nanut

11. *Dr. Sonja Prpar Mihevc, left 01.05.17*
12. Dr. Anja Pucer Janež

Postgraduates
13. Ana Bajc Česnik, B. Sc.
14. Mirjana Malnar, B. Sc.
15. Mateja Prunk, B. Sc.
16. Katja Škrlec, B. Sc.

Technical and administrative staff
17. Maja Šimaga, M. Sc.

Note:

* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Aleš Berlec, Martina Perše, Matjaž Ravnikar, Mojca Lunder, Andreja Erman, Anton Cerar, Borut Štrukelj, "Dextran sulphate sodium colitis in C57BL/6J mice is alleviated by Lactococcus lactis and worsened by the neutralization of tumor necrosis Factor α", *International immunopharmacology*, **43**, 219-226, 2017.
2. Barbara Breznik, Helena Motaln, Miloš Vittori, Ana Rotter, Tamara Lah Turnšek, "Mesenchymal stem cells differentially affect the invasion of distinct glioblastoma cell lines", *Oncotarget*, **8**, 15, 25482-25499, 2017.
3. Anja Klančnik, Polona Megušar, Meta Sterniša, Barbara Jeršek, Franz Bucar, Sonja Smole Možina, Janko Kos, Jerica Sabotič, "Aqueous extracts of wild mushrooms show antimicrobial and antiadhesion activities against bacteria and fungi", *PTR, Phytother. res.*, **31**, 1971-1976, 2017.
4. Staša Kosler, Borut Štrukelj, Aleš Berlec, "Lactic acid bacteria with concomitant IL-17, IL-23 and TNF[alpha]- binding ability for the treatment of inflammatory bowel disease", *Current pharmaceutical biotechnology*, **18**, 4, 318-326, 2017.
5. Urban Košak, Damijan Knez, Nicolas Coquelle, Boris Brus, Anja Pišlar, Florian Nachon, Xavier Brazzolotto, Janko Kos, Jacques-Philippe Colletier, Stanislav Gobec, "N-propargylpiperidines with naphthalene-2-carboxamide or naphthalene-2- sulfonamide moieties", *Bioorg. med. chem.*, **25**, 2, 633-645, 2017.
6. Youn-Bok Lee *et al.* (15 authors), "C9orf72 poly GA RAN-translated protein plays a key role in amyotrophic lateral sclerosis via aggregation and toxicity", *Hum Mol Genet*, **26**, 24, 4765-4777, 2017.
7. Jasna Lojk, Sonja Prpar Mihevc, Vladimir Boštjan Bregar, Mojca Pavlin, Boris Rogelj, "The effect of different types of nanoparticles on FUS and TDP-43 solubility and subcellular localization", *Neurotox. res.*, **32**, 3, 325-339, Oct. 2017.
8. Tjaša Lukanc, Jože Brzin, Janko Kos, Jerica Sabotič, "Trypsin-specific inhibitors from the Macrolepiota procera, Armillaria mellea and Amanita phalloides wild mushrooms", *Acta Biochim. Pol.*, **64**, 1, 21-24, 2017.
9. Ana Mitrović, Urša Pečar Fonović, Janko Kos, "Cysteine cathepsins B and X promote epithelial-mesenchymal transition of tumor cells", *Eur. j. cell biol.*, **96**, 6, 622-631, 2017.
10. Ana Mitrović, Izidor Sosič, Špela Kos, Urša Lampreht Tratar, Barbara Breznik, Simona Kranjc, Bojana Mirković, Stanislav Gobec, Tamara Lah Turnšek, Maja Čemažar, Gregor Serša, Janko Kos, "Addition of 2-(ethylamino)acetonitrile group to nitroxoline results in significantly improved anti-tumor activity in vitro and in vivo", *Oncotarget*, **8**, 35, 59316-59147, 2017.
11. Urša Pečar Fonović, Ana Mitrović, Damijan Knez, Tanja Jakoš, Anja Pišlar, Boris Brus, Bojan Doljak, Jure Stojan, Simon Žakelj, Jurij Trontelj, Stanislav Gobec, Janko Kos, "Identification and characterization of the novel reversible and selective cathepsin X inhibitors", *Sci. rep.*, **7**, 11459, 2017.
12. Milica Perišić, Jerica Sabotič, Urban Švajger, Anahid Jewett, Janko Kos, "Cystatin F affects natural killer cell cytotoxicity", *Front. immunol.*, **8**, 1459, 2017.
13. Anja Pišlar, Biljana Božić, Nace Zidar, Janko Kos, "Inhibition of cathepsin X reduces the strength of microglial-mediated neuroinflammation", *Neuropharmacology*, **114**, 88-100, 2017.
14. Monika Primon, Peter C. Huszthy, Helena Motaln, Krishna M. Talasila, Hrvoje Miletic, Nadia A. Atai, Rolf Bjerkvig, Tamara Lah Turnšek, "Cathepsin L silencing increases As2O3 toxicity in malignantly transformed pilocytic astrocytoma MPA58 cells by activating caspases 3/7", *Exp. cell res.*, **356**, 1, 64-73, 2017.
15. Sonja Prpar Mihevc, Mojca Pavlin, Simona Darovic, Marko Živin, Matej Podbregar, Boris Rogelj, Tomaž Marš, "Modelling FUS mislocalisation in an in vitro model of innervated human muscle", *J. mol. neurosci.*, **62**, 3/4, 318-328, Aug. 2017.
16. Mateja Prunk, Janko Kos, "Nanoparticle based delivery of protease inhibitors to cancer cells", *Curr. med. chem.*, **24**, 42, 4816-4837, 2017, .
17. Nina Recek, Matic Resnik, Rok Zaplotnik, Miran Mozetič, Helena Motaln, Tamara Lah Turnšek, Alenka Vesel, "Cell proliferation on polyethylene terephthalate treated in plasma created in SO_2/O_2 mixtures", *Polymers (Basel)*, **9**, 3, 82, 2017.
18. Katja Škrlec, Anja Pucer Janež, Boris Rogelj, Borut Štrukelj, Aleš Berlec, "Evasin-displaying lactic acid bacteria bind different chemokines and neutralize CXCL8 production in Caco-2 cells", *Microb. biotechnol.*, **10**, 6, 1732-1743, 2017.
19. Maja Zakošek, Janko Mrkun, Breda Jakovac-Strajn, Katarina Pavšič Vrtač, Janko Kos, Anja Pišlar, Petra Zrimšek, "The influence of macro- and microelements in seminal plasma on diluted boar sperm quality", *Acta vet. Scand.*, 11, **59**, 1-9, 2017.
20. Gašper Žun, Janko Kos, Jerica Sabotič, "Higher fungi are a rich source of L-amino acid oxidases", *3 biotech*, **7**, no 3, 230, 2017.
21. Simon Žurga, Milica Perišić, Janko Kos, Jerica Sabotič, "Fungal lectin MpL enables entry of protein drugs into cancer cells and their subcellular targeting", *Oncotarget*, **8**, 26896-26910, 2017.

REVIEW ARTICLE

1. Barbara Breznik, Helena Motaln, Tamara Lah Turnšek, "Proteases and cytokines as mediators of interactions between cancer and stromal cells in tumours", *Biol Chem*, **398**, 7, 709-719, 2017.
2. Andrea Markovinovic, Raffaello Cimbro, Tereza Ljutic, Jasna Kriz, Boris Rogelj, Ivana Munitic, "Optineurin in amyotrophic lateral sclerosis: multifunctional adaptor protein at the crossroads of different neuroprotective mechanisms", *Prog. neurobiol.*, **154**, 1-20, 2017.
3. Sonja Prpar Mihevc, Simona Darovic, Anja Kovanda, Ana Bajc Česnik, Vera Županski, Boris Rogelj, "Nuclear trafficking in amyotrophic lateral sclerosis and frontotemporal lobar degeneration", *Brain*, **140**, issue 1, 13-26, 2017.

PATENT

1. Mojca Lunder, Matjaž Ravnikar, Borut Štrukelj, Aleš Berlec, Boris Čeh, *Modified food grade microorganism for treatment of inflammatory bowel disease,* EP2521737 (B1), European Patent Office, 30. 08. 2017.
2. Katja Žmitek, Nataša Tavčar, Tina Pogačnik, Janko Žmitek, Petra Keršmanc, Tadej Rejc, Uroš Petrič, Borut Štrukelj, Samo Kreft, *Extract from the wood of trees of the genus fir to prevent, alleviate or treat unwanted skin changes and preparations,* SI25053 (A), Urad RS za intelektualno lastnino, 31. 03. 2017.

MENTORING

1. Ana Mitrović, *Role of cysteine cathepsins B and X and their inhibitors in epithelial-mesenchymal transition of tumor cells:* doctoral dissertation, Ljubljana, 2017 (mentor Janko Kos).

DEPARTMENT OF ENVIRONMENTAL SCIENCES

The Department of Environmental Sciences focuses on the interweaving of the physical, chemical and biological processes that shape our environment, humans and their activities. Our research is interdisciplinary and multidisciplinary and takes place in several areas, such as Environmental analytical chemistry, Biogeochemical cycles, Microbial ecology, Environment and health, Environmental technologies, Risk and environmental assessment, and Environmental monitoring. We also work on the development of technical solutions for environmental problems and environmental management. The department hosts the "ISO-FOOD" ERA Chair for isotope techniques in food safety, quality and traceability, the infrastructure Centre of Mass Spectrometry (CMS) and the Mobile Ecological Laboratory Unit (ELMU).

Head:
Prof. Milena Horvat

Environmental analytical chemistry

The role of trace elements and their impact on the environment and living organisms depend not only on their total concentration but also on the chemical forms in which they are present. Our research is oriented to the development of new analytical procedures for the speciation of elements like Al, As, Cr, Se, Sn, Br, Pt, Ru, Ni, V, Zn, etc. in environmental, food and biological samples.

In the field of elemental speciation, the high-performance liquid chromatography - inductively coupled plasma mass spectrometry (HPLC-ICP-MS) procedure was developed for the simultaneous speciation of chromate, arsenate, molybdate and vanadate at alkaline pH. In the investigations of titanium dioxide nanoparticles (TiO_2NPs) in the environment, an analytical procedure was developed for the quantitative determination of the concentration and the size distribution of TiO_2NPs as anatase and rutile with the use of a single particle (SP)-ICP-MS.

A long-lived ($t_{1/2}=2.14 \times 10^6$ y) alpha-emitting radionuclide ^{237}Np is one of the most important alpha-emitting radionuclides contributing to the collective dose commitment delivery in the long-term. Determination of a low level ^{237}Np in environmental samples was performed by various techniques: i) direct gamma-ray spectrometry, ii) alpha-particle spectrometry that followed pre-separation of neptunium radioisotope(s) by ion-exchange or extraction chromatography and iii) pre-separation radiochemical neutron activation analysis (RNAA). The RNAA for the determination of ultra-trace levels of uranium and thorium in electrolytic copper, which is used as a shielding material in gamma-ray spectrometry, via their induced nuclides Np-239 and Pa-233, respectively, were developed.

In the area of organic analysis, we continued our research into the occurrence and cycling of Compounds of Emerging Concern residues (CECs; representatives of pharmaceutical and personal care products and industrial compounds with endocrine disrupting effect) in environmental samples, biological materials and food/feed. To improve the performance of sertraline analysis, we developed and tested molecularly imprinted polymers (MIPs) with sertraline (an antidepressant) as the target compound.

We also developed an analytical method for the simultaneous determination of 48 various CECs (pharmaceuticals, UV filters, preservatives, industrial chemicals and their metabolites/transformation products: TPs) in aqueous samples. We found that two UV-filters, one estrogen and one antimicrobial agent, despite their low abundance, posed a medium-to-high environmental risk.

Being the first, and still the only, research group in the world to have implemented an analytical method for bleomycin determination in biological samples, we have continued with its analyses in the serum and tumours of test mice and oncological patients (Oncological Institute, Ljubljana). We also extended this research and together with the Faculty of Veterinary Medicine, University of Ljubljana, took part in a study dealing with the efficiency of bleomycin pharmacotherapy in cats, dogs and pigs. As the analytical partner, we also participated in an EU-wide clinical study on bleomycin pharmacotherapy.
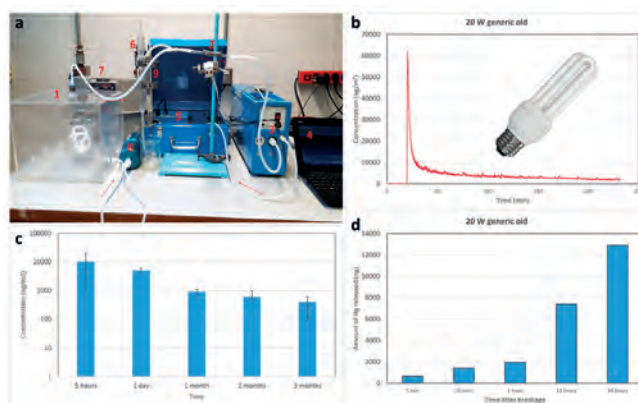
Figure 1. In the EMPIR project MeTra we developed a method for measuring mercury emissions after the breakdown of a compact fluorescent lamp (CFL). Particular attention was paid to the calibration and traceability of measurements. a) Hg emissions measurement system after the breakdown of the lamp; b) Hg emissions after the breakdown of the lamp within the first few minutes; c) days and months; and d) the amount of released Hg within the first 24 hours after the breakdown.

Within the EMPIR MeTra project we developed a traceable method for the measurement of Hg emissions after compact fluorescent lamp (CFL) breakage and measured the emissions from the most common types of CFLs on the market.

Within the PRO-METROFOOD_RI project, a pilot service for the Physical Infrastructure was organized with the aim being to demonstrate the actual capability of METROFOOD-RI to supply services and test its inter-operability. The pilot consisted of developing, preparing and characterising three new multipurpose Reference Materials (oyster tissue, rice grains and rice flour). We also participated in the interlaboratory comparison FIT-PTS, which is organized tree times per year by EUROFINS. We have also started implementing the EMIRS SIRS project Metrology for Stable Isotope Reference Standards, where a new reference CO_2 gas for determining the isotopic composition of carbon and oxygen will be produced.

In the framework of GEOTRACES, we participated in a interlaboratory comparison for the determination of Hg species in seawater organized by MIO-CNRS (Marseilles, France).

In collaboration with CENAM from Mexico, a key intercomparison CCQM-K127 Contaminant and other elements in soil, which will enable the sign up of a new CMC in BIPM KCDB base, was successfully completed. We also participated in several interlaboratory comparisons organised by WEPAL, IAEA, IPEN-CNEN/SP, NPL, BfS and MRI; among others, we contributed the k_0-INAA characterization of a new reference material ERM-EB090b Titanium, prepared by Joint Research Centre, Geel, Belgium.

Biogeochemical cycles

Our research focuses on the study of biological, geological and chemical factors that are involved in the cycling of chemical elements (light elements: C, N, S, O, H; metals and metalloids: Hg, Cd, Pb, As, Se) in various environmental compartments on the scales of molecules to watersheds. We develop and employ chemical and biological techniques to follow elements' speciation, transformation and isotopic fractionation, including the use of stable and radioactive isotopes as tracers. Our goal is, in cooperation with the wider medical and public health research, to provide an insight into the source-pathway-receptor-consequences relationships.

We also studied the adaptation of cultured mussels *Mytilus galloprovincialis* from the Northern Adriatic Sea to translocation to nearby aquaculture sites. Factors that contributed to the recent eutrophication of two Slovenian mountain lakes (Fifth and Sixth Triglav Lakes) were determined by a detailed analysis of phosphorous pools in the lake and potential external P sources.

In addition to the target analysis of organic compounds, we have also dedicated studies to the identification of transformation products of bisphenol (BP) formed during laboratory-scale direct (UV) and indirect (Photo Fenton) photolysis and biodegradation. We have shown that mainly hydroxylated isomers and cleavage products are being formed. This part of our research we performed in collaboration with the University of Antwerp, Belgium. In the area of suspect screening, we continued with the identification of the transformation producrts of cytostatic vincristine in collaboration with CSIC, Barcelona, Spain. In the field of non-target analysis, we are working closely with the JSI's Department E8 to develop a machine-learning tool for identifying silyl derivatives of semi-polar organic compounds using GC-MS analysis.

Figure 2: Analyzed tufa barriers on Krka. Within several national and international projects, we continued the hydrogeochemical and isotopic research of aquatic environments in Slovenia, especially rivers and groundwater in fractured karst aquifers in central Slovenia. We analyzed CO_2 binding in 16 tufa barrages on a 13-km section of the Krka River. On the basis of the hydrochemical and hydrological data we calculated the rate of precipitation of carbonate, and with the help of stable isotopes of oxygen and carbon, we identified the main factors that influence the binding of CO_2 and the distribution of elements between the water and the sediment.

The research performed within the GLOBAQUA project includes integrated approaches - geochemical and multivariate statistical methods for studying surface-groundwater interactions in Ljubljansko polje aquifer system. In order to provide a reliable simulation of the complex interactions between groundwater and surface water, multiple models were combined (FEFLOW coupled with MIKE 11) for a simulation of the Sava River's dynamics, as well as leaching river water into the aquifer and vice versa. Percolation was simulated in WaSiM, and for this reason we also established a link between FEFLOW and WaSiM. The results obtained with the model match the measured distribution of the isotopic composition of oxygen in groundwater (i.e., the contribution of individual sources) and the determination of the retention time, which was estimated using of the $^3H/^3He$ method. The influence of variable river-flow conditions on the mobilization of potentially toxic elements (PTE) from sediments into the overlaying waters of the Sava River was investigated. Due to the sediment perturbation, the concentrations of PTE in the water were in general higher at high water discharges, while the soluble concentrations were higher during low-water-level conditions. In collaboration with

the Institute for Biological Research Siniša Stanković from Belgrade, correlations between diatoms growth and selected environmental factors were investigated. The results showed that arsenic, silicon and iron have a negative influence on the growth of diatoms, although their concentrations in water were relatively low. The data suggest that in moderately polluted large rivers, benthic diatoms are good bioindicators of multiple pressures, could serve as indicators of the level of overall degradation of an ecosystem. The occurrence of halogenated and organophosphate flame retardants in sediment and fish samples from the Sava, Evrotas and Adige European river basins was also investigated in collaboration with researchers from Spanish National Research Council from Barcelona, Spain.

The use of stable isotopes has also an applied value in other fields of research, for example, for detecting CO_2 leakage from proposed carbon capture and storage (CCS) sites, i.e., depleted gas and oil reservoirs or saline formations, which lie below the seabed. In collaboration with "Istituto Nazionale di Oceanografia e di Geofisica Sperimentale" (OGS) and within ECCSEL (European Carbon Dioxide Capture and Storage Laboratory Infrastructure) project, we tested the usefulness of stable isotopes as a tool to assess the impact of additional anthropogenic CO_2 sources on the dissolved inorganic carbon and marine phytoplankton communities in a microcosm experiment. The method was successfully applied in the field at the natural gas seep at the Natural Laboratory of Panarea (Italy).

In this year, our research on radon (as a useful scientific tool and main source of population radiation dose) and nano-aerosol (as a harmful agent and carrier of radioactive radon products into lungs) has been continued. In cooperation with the Slovenian Environment Agency, radon (^{222}Rn) has been continuously monitored in air (1.5 m above ground, once per hour) at meteorological stations in Ljubljana and Ajdovščina, two sites with different geologies and climates. The time series of Rn activity concentration and meteorological data, were analysed in order to identify the geophysical parameters causing deviations of radon levels from their seasonal averages, and to use radon as a tracer of vertical air mixing and estimating the mixing height. Rn in air has also been measured monthly at various sites along the tourist path in the Anthony's Shaft – Tourist Mine in Idrija (Slovenia). Analysis of the data time series and the differences between discrete values and seasonal averages is expected to provide additional knowledge on the airflow underground.

^{210}Po, one of the most radiotoxic elements, was investigated in seawater, suspended matter, plankton and in different fish organs from the Gulf of Trieste. The results showed a several orders of magnitude of increase in the concentration of ^{210}Po from seawater to plankton, while the ^{210}Po distribution in fish tissues was as follows: liver > stomach with intestine > kidney > spleen > gonads > gills > muscle.

For the first time, mercury isotope fractionation was studied in the Idrija mercury mining region, in particular in the different ores and environmental samples. In collaboration with the Institute of Oceanography and Fisheries (Split, Croatia), we studied relations between mercury fractions and microbial community structure in the Central Adriatic Sea. In the framework of MEDOCEANOR project, we took part in the research campaign EFESTO 2017, organized by National Research Council (CNR, Rome, Italy) in August–September 2017. That research campaign on board the research vessel Minerva Uno had the purpose of improving our knowledge of the complexity of the Hg cycling in the Mediterranean.

Figure 3: Further investigatiosn of the CO_2 fluxes above the subterranean cave and the identification of sources of CO_2 in cave air in Pisani rov in Postojna cave were carried out. We used stable isotopic techniques in combination with radon (^{222}Rn) and ^{14}C activity measurements and hydrological modelling. The main findings of our investigation do not match with the conclusions of other researchers. We found that outside-air temperature is the major parameter influencing cave ventilation. The study indicated that the major source of cave CO_2 is the CO_2 originating from soil respiration, transported directly into the cave and that CO_2 transported into the cave by the degassing of dripwater has a minor influence on the cave CO_2 concentration levels. It was also found that the cave air is not homogeneously mixed and therefore simplified models of the cave-air movement cannot be used in Pisani rov.
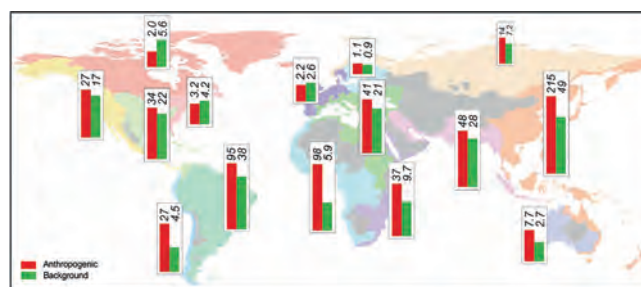
Figure 4: Based on a long-term cooperation in the preparation of the UN Environment Global Mercury Assessment report, which is a technical report on mercury sources, releases and cycling on a global level, a publication on the global Hg releases into aquatic environments due to anthropogenic and natural sources was prepared. (Kocman et el., Int. J. Environ. Res. Pub. Health 14 (2017) 1-16.)

Microbial system ecology

The microbial system ecology is focused on the interaction of microbes with surfaces, particularly the colonisation and tripartite bio-physico-chemical processes occurring on surfaces. We use molecular biology, chemical analytics, microscopy, nanotechnology as well as colloid physics-based methods.

Our activities were focused on the entrapment of single bacterial cells in polyelectrolyte layers, where we investigated the mechanical effects of the entrapment of bacterial cells on growth and division, as well as colony establishment using microscopy techniques (fluorescence, electron scanning microscopy and time-lapse confocal microscopy). Since bacteria in close contact with each other exchange very frequently their DNA, we successfully
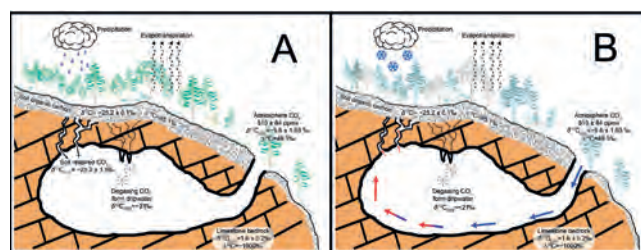
developed new bioinformatic tools for studying DNA structures involved in the horizontal gene transfer of plasmids (in cooperation with the University of Primorska).

In cooperation with FP and the University Clinical Centre from Ljubljana we isolated a new strain from human oral microbiome that is able to fight against pathogenic bacteria involved in periodontal disease. The isolated bacteria were incorporated into the delivery system based on gel, electrostatic matrix and introduced in electrospun fibres.

Environment and health

Our main task is to support and interlink environment, health, and food-related studies at all steps from planning to data interpretation. Food is the source of energy, but also the main transport route of contaminants and pathogens and as such an obvious way to prevent diseases.

In the framework of the European Human Biomonitoring project (HBM4EU, H2020) that started on 1.1.2017 we coordinated activities related to one of the nine priority chemical groups (Cd and the Cr(VI) group), which interacts horizontally with most of work packages within the project. We have prepared a scoping document for the selected elements, which includes, together with the basic information, the key research and policy-relevant questions that need to be addressed by the project. Apart from this, we have participated in the acquisition of existing data for priority substances, collecting toxicodynamic data from '*in vivo*' studies, the preparation of protocols for sample exchange, the preparation of practical and theoretical HBM trainings, etc.

Figure 5: The relationship between the environment and health is studied with the "Exposome" approach, which combines various techniques. One of the components of such studies is the preparation of biological samples for laboratory analysis. In the photograph, participants at the UNEP training prepare hair samples for mercury analysis.

In the frame of the national CRP project *Exposure of children and adolescents to selected chemicals through their habitat environment*, coordinated by our department, we prepared a study protocol, obtained ethics permission and set the sampling campaigns in Prekmurje region.

We prepared and conducted a training course addressing mercury speciation in human and environmental specimens and HBM study conduct under the umbrella of the United Nations Environmental Programme (UNEP) and World Health Organization (WHO) in November 2017. Trainees from Kyrgyzstan, Argentina, Chile, Ecuador, Paraguay, Peru and Uruguay attended the course.

Based on indoor-air radon levels, measured in the 1990–2017 period for 2650 buildings in Slovenia, a map of radon risk areas at the community level was elaborated, with respect to the lithological units. Low risk appears in 76 %, medium in 13 %, and high in 11 % of communities. The study was carried out for the Slovenian Nuclear Safety Administration. Nanoparticles are the main Rn decay product carriers in the atmosphere; their characteristics, in particular those of the smallest ones, thus play a key role in Rn dosimetry. The number concentration and number size distribution of particles in the 10–1100 nm size range formed during tea candles and incense sticks burning were measured in the laboratory. Candles and sticks emitted <30 nm particles and 20–300 nm particles, respectively, whereas in the same time interval, the number of emitted particles from incense stick was more than double than that from the tea candle.

In collaboration with the Department of Hematology (University Medical Centre, Ljubljana) we are studying the metabolism and interactions of arsenic (As) in patients treated with As trioxide used as a target drug for acute promielocytic leukemia and a testing drug for multiple myeloma. During 2017 we studied the inter-patients variability of As methylation rates by following individual levels and shares of As metabolites in combination with gene polymorphisms of As methyl-transferase (enzyme responsible for As biotransformation). Next to that, we studied arsenic-selenium interactions by following the excretion of both by faeces and by measuring the gene expression of As methyl-transferase and selected selenoproteins for patients with an adequate number of samples during the treatment phase. Besides, in a patient group some of the measured parameters like As metabolites shares in combination with gene polymorphisms have also been followed at a general population (participants of past and current human biomonitoring projects – PHIME, CROME, HEALS; children, pregnant and non-pregnant mothers). Comparison of therapeutic data with results obtained for low environmental As exposure (seafood, rice, rice milk, etc.) is important for a better interpretation of the data for a general population.

In biomedical research, analytical data was provided to other departments from the JSI, which produced an innovative, theranostic material based on $FePt/SiO_2/Au$ hybrid nanoparticles (NPs) for photo-thermal therapy and magnetic resonance imaging. Data revealed that hybrid NPs have an excellent potential to be used as contrast agents. In cooperation with the Oncology Institute from Ljubljana, electrochemotherapy with trans-$[PtCl_2(3\text{-Hmpy})_2]$ was investigated *in vitro* and *in vivo*.
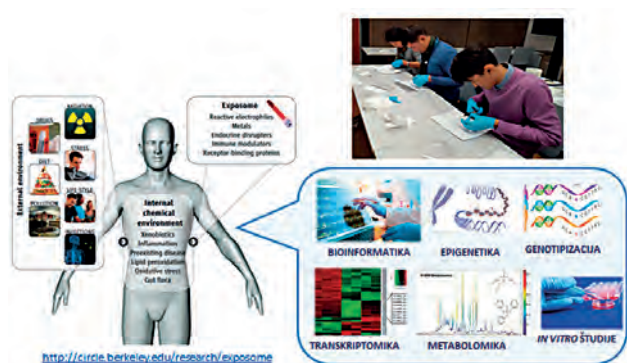
In collaboration with the National Institute of Biology, we have continued to explore the ecotoxicity (algae, *Daphnia magna*) and estrogenicity (JSI-Department B2: BCC line MCF7-ER) of bisphenols and their mixtures in influents and effluents from pilot-scale bioreactors and photoreactors. The results indicate that the parent compounds vary greatly in their ecotoxic and estrogenic potential. In the area of ecotoxicity, we have, in collaboration with University of Campania, Naples, Italy, evaluated the acute and chronic ecotoxicity of parent cytostatics cyclophosphamide and ifosfamide and their mixtures including metabolites/TPs in UV treated samples. Finally, the cytotoxicity and genotoxicity of anti-cancer drug residues and their mixtures in an experimental model with zebrafish liver cells were studied (National Institute of Biology). It is apparent from our results that it is not always possible to predict the adverse effects of complex mixtures based on the toxicological data for individual compounds and that the toxic effects found in aquatic organisms are due to the interactions between the parent compounds and their metabolites/TPs. With these findings, we concluded our 8-year intense research on the occurrence and cycling of cytostatic compounds and their effects in the aqueous environmental that began with the EU FP7 CytoThreat in 2011.

Food research and activities of the ERA Chair ISO-FOOD

The ISO-FOOD - ERA Chair for isotope techniques in food safety, quality and traceability was established in 2014.

An analytical procedure was developed for the speciation of nickel in cocoa infusions. Ni species were separated on a specific monolithic chromatographic column and quantified by the post-column isotope dilution inductively coupled plasma mass spectrometry (ID-ICP-MS). The nickel-binding ligands in the separated fractions were identified "off line" by quadrupole time-of-flight mass spectrometry (Q-TOF MS). Nickel was found to be present in the cocoa infusions as Ni^{2+} and Ni-gluconate and Ni-citrate complexes, of which Ni-gluconate prevailed.

A method of iodine (I) determination in various plant samples by ICP-MS was optimized and used for the determination of I in pea seeds, pumpkin seeds and buckwheat achenes, from plants foliar sprayed with iodide or iodate solutions at the time of blooming. A > 8-fold higher iodine content was found in enriched buckwheat achenes, regardless of the iodine form in the spraying solution, showing potential to be used as alternative source of iodine in the diet.

The data on particular radionuclide contents in infant formula are scarce, therefore we determined ^{238}U, ^{234}U, ^{230}Th and ^{210}Po activity concentrations in infant formulas available on the Slovenian market. A dose assessment was carried out as well. The results obtained show that the main contributor to the estimated cumulative radiation dose (230 to 350 μSv y−1) is ^{210}Po.

The suitability of isotopic compositions of light elements ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$, $\delta^{34}S$) in combination with multi-elemental fingerprinting (P, S, Cl, K, Ca, Si, Mn, Fe, Zn, Br, Rb, Sr) to provide rapid, robust and inexpensive screening methods for distinguishing the geographical origin of vegetables was studied. Multivariate disc Slovenian organic farms (*Allium sativum L.*), although the overall success rate of correctly classified samples was on average 77 %. An analysis of commercially available lettuce, sweet pepper and tomato bought on the Slovenian market, originating in Slovenia, Austria, Spain, Morocco, Italy and Greece was performed. The predictions of the suggested discriminant analysis models per kind using cross-validation leave-one-out were 86.2%, 71.1% and 74.4% for lettuce, sweet pepper and tomato, respectively. The research in relation to the authenticity and geographical origin determination in milk and dairy products was further conducted covering three main topics: 1) development of the method for determining milk dilution with water using stable isotope composition of oxygen in lactose and milk water; 2) developing the stable isotope composition of Sr for geographical origin discrimination; 3) the use of composition and stable isotopes to discriminate between the year and season of production, type of diet and geographical origin. Furthermore, several new avenues of research including the study of retention-sweetness relationships of artificial sweeteners and variations in phytoestrogen content between organically and conventionally produced beer and hops were initiated.

In the smart specialization program "Food for Future", we studied the authenticity of raw materials such as natural flavourings in collaboration with Frutarom Etol. A dynamic headspace solid-phase microextraction

Figure 6: Statistical analysis of fatty acids in Slovenian milk shows high variability. The samples were well differentiated between the season (winter, summer), as well as the year of production. We were also able to monitor eating habits, but we did not manage to differentiate milk regarding the geographical area.

(HS-SPME) methodology used with gas chromatography-mass spectrometry (GC-MS) and gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS) analysis was developed for compound identification and stable-isotope analysis. The optimised methodology was then used to differentiate between natural and synthetic
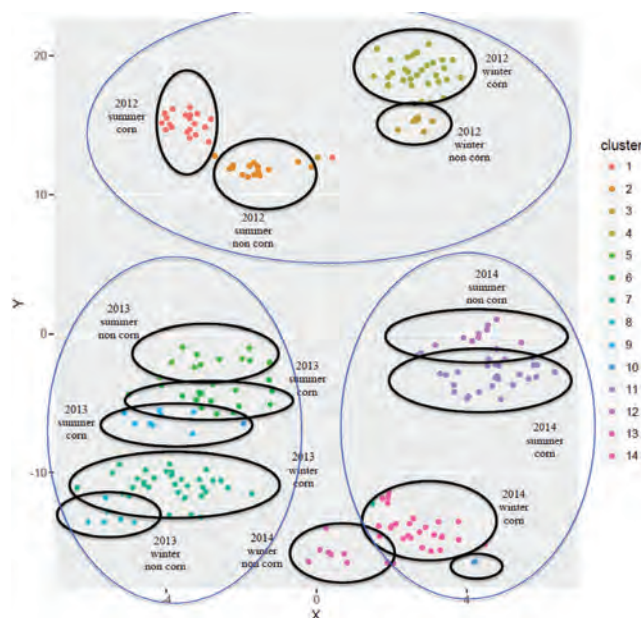
aroma compounds in self-produce and commercial apple and strawberry distillates. We also started with the implementation of the new REALMed project (Pursuing authenticity and valorisation of Mediterranean traditional products) financed within ArimNet EU scheme. Research will be conducted on Slovenian truffles as a selected Mediterranean commodity.

An interlaboratory study for the determination of stable isotope ratios of carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$) and sulphur ($^{34}S/^{32}S$) in rice flour was also performed. The performance of ten participants was very good, illustrating their ability to obtain accurate results for carbon, nitrogen and sulphur isotope ratios within the calibration range afforded by internationally agreed reference materials. This was despite the fact that no two participants used exactly the same approach in terms of instrumentation or data treatment.

Environmental technologies

In the area of industrial chemicals, we developed and validated analytical methods for determining bisphenol A (BPA) and its alternatives in wastewater and applied them to a series of samples from a pilot (suspended and attached growth biomass) and five most important Slovenian operating wastewater treatment plants with different configurations and sizes. To the best of our knowledge, this is the first study of its kind in Europe, significantly contributing to the knowledge on presence of BPs in European aqueous environment. We have also begun researching the treatment of wastewater containing bisphenol residues in photoptrophic ponds. For this purpose, we set up a series of lab-scale reactors and are developing methods for the extraction and chemical analysis of wastewater and algae. Within the EU project RusaLCA in collaboration with researchers from the Slovenian National Building Institute, the use of different nanoscale zero-valent iron particles (nZVI) was critically evaluated for the treatment of effluent water from a small biological wastewater treatment plant. The results demonstrated that in-house nZVI, which was the most reactive of the nanoparticles tested, most effectively removed the metals and inactivated the pathogenic bacteria. However, the application of in-house nZVI is restricted, as it contaminates the remediated water with boron, which originated from the reagents used in its synthesis. To a certain extent, all of the investigated types of nZVI reduced nitrates and nitrites to ammonium cations. It was demonstrated that the most efficient removal of elements and disinfection of pathogens was achieved when a commercially available Nanofer25 slurry was applied for the remediation.

In the field natural-resources management, concentrations of coal-bed gases (CO_2, CH_4,) and CDMI (Carbon Dioxide Index) in a combination of isotopic composition of coal-bed gases were collected from a 500-m-deep borehole for tracing the coal-bed gas composition and gas origin in collaboration with Velenje Coalmine d.o.o. In collaboration with the University of Wroclaw (Poland), stable isotopes of methane in natural gas were also used as tracers to elaborate a new tool with great potential for application in assessment of gas migration and carbon capture and storage technologies. Furthermore, isotopic analyses of water from deep geothermal resources in the Mura–Zala basin (north-eastern Slovenia) provided a new insight into the mixing of deep groundwater and surface water due to the overexploitation of aquifers without reinjection.

Environmental management, environmental impact assessment and risk assessment

In the framework of the 4-year H2020 ICARUS project (ICARUS stands for Integrated Climate forcing and Air Pollution Reduction in Urban Systems) large-scale air-pollution monitoring was implemented in Ljubljana. The national research project "Potential substances of very high concern in the context of REACH regulation" in the framework of the Targeted Research Programme 2016 was successfully completed. Activities have started on two new international projects: the EU H2020 project SciShops - Enhancing the Responsible and Sustainable Expansion of the Science Shops Ecosystem in Europe and MODARIA II – Modelling and Data for Radiological Impact Assessments coordinated by the IAEA. The department is also engaged in the new ERA-PLANET network (*The European network for observing our changing planet*) in two sub-projects – iGOSP (*Integrated Global Observing Systems for Persistent Pollutants*) and SMURBS (*SMart URBan Solutions for air quality, disasters and city growth*).

A scheme on the inclusion of risk assessment results into the spatial planning process (Matko et al., 2017)

Shematski prikaz vključevanja ocen ogroženosti in ocen tveganja v prostorsko načrtovanje (Matko in sod., 2017)
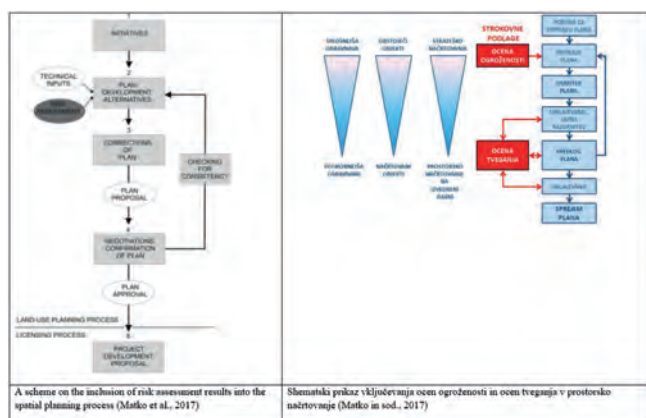
Figure 7: A scheme of the inclusion of risk-assessment results into the spatial planning process

Environmental monitoring

Monitoring of organotin compounds in sea and surface waters was performed in collaboration with the Slovenian Environmental Agency (ARSO), while in collaboration with the Environmental Agency from Croatia, monitoring of organotin compounds and polybrominated diphenyl ethers in surface and sea water continued in 2017. In collaboration with ARSO, we performed the monitoring of Hg in precipitation and in air at Iskrba meteorological station.

The monitoring of natural radionuclides within the influential area of the former uranium mine and mill at Žirovski vrh was performed. We also participated in off-site monitoring of the Krško Nuclear Power Plant (NPP) with a determination of strontium and tritium in environmental samples, as well as tritium and radiocarbon in gas effluents from the NPP. With analyses of strontium and tritium, we also participated in the monitoring of radioactivity in drinking water in Slovenia, as well as in the monitoring of the living environment in Slovenia. Methods used for the determination of strontium, tritium and radiocarbon for the monitoring purposes are accredited by the Slovenian accreditation body (SA LP-090).

Infrastructural Centre for Mass Spectrometry (CMC)

The Infrastructural Centre for Mass Spectrometry is involved in research and analytical measurements within various research programs and projects in the fields of environmental chemistry, chemistry for sustainable development, organic synthetic and pharmaceutical chemistry, biochemistry, medicine and other natural sciences fields, whose holders are research groups at the JSI, the National Institute of Chemistry, the National Institute of Biology, the Universities of Ljubljana, Maribor and Nova Gorica, Centres of Excellence, and partners from Slovenian industry, etc.

With the high-resolution tandem mass spectrometer Qtof, coupled to chromatographic methods LC-MS and GC-MS, the structure of various organic compounds, organometallic complexes, biopolymers, pollutants and similar compounds were identified. We studied new synthetized organic compounds, active substances, proteins, lipids and similar organic and biomolecules, ceramic materials, food supplements and food additives, monitoring pollutants in the environment, food and other matrices.

In cooperation with the Faculty of Pharmacy of the University of Ljubljana, by using high-resolution tandem mass spectrometer, we identified some lignans in the silver fir wood extract and determined the anti-oxidant activity and gastro-intestinal stability of these natural compounds. In *Environmental Science and pollution research international*, we published a study on the rate of degradation of antibiotic enrofloxacin, which is widely used in chicken farms and is through wastewater and sludge persistent for several months and is gradually decomposed in the environment through ciprofloxacin and other degradation products.

LC-MS was used for the characterization of organic acids in the specification of nickel in cocoa and tea and zinc in breast milk, for the determination of biodegradable products of benzotriazoles in Ljubljana groundwater, for the study of the effectiveness of aflatoxin degradation on the surface with plasma, laser and UV light, for the analysis of the efficiency of waste-water treatment with a photoelectric and electrocatalytic process in a pilot reactor where hexane diol and adipic acid were used as model compounds, to determine the anti-diabetic effect of fomentariol isolated from the mushroom *Fomes fomentarius*. In all of these studies, a mass spectrometric measurement was used to identify non-target compounds or chemicals, which allowed the characterization of compounds and the determination of their impact on human health and the environment. Similar conclusions were also obtained from the LC-MS analysis of the composition of cannabinoids, with an emphasis on the determination of the ratio of CBD to harmful THC in medicinal hemp extracts prepared to treat children with epilepsy at the University Children's Hospital in Ljubljana.

Ecological Laboratory with a Mobile Unit

The unit – a mobile chemical laboratory – operates within the Department of Environmental Science and is organized as a special unit of Slovenian Civil Protection and Rescue System for intervention on ecological accidents involving hazardous substances and materials. The chemical mobile unit had eight interventions in 2017, mainly due to pollution of air with dangerous substances emitted from big fires in facilities for the storage and processing of waste materials and on other air pollution in Slovenia last year.

Some outstanding achievements in the past year

1. Being the first, and still the only, research group in the world to have implemented an analytical method for bleomycin determination in biological samples
2. For the first time we showed that bacteria from the genus *Bacillus* are an important group of probiotic agents in human mouth microbiome
3. We received a prize for our contribution to the FEMS congress for research of structural interactions of DNA in the horizontal transmission of genes between bacteria.
4. We developed a non-stationary hydrological model for the determination of interactions between the surface and groundwater in Ljubljansko polje
5. Development of the method to determine the authenticity of aroma using a stable isotope approach
6. We have successfully completed the key study CCQM-K127 Contaminant and other elements in soil, which will enable the entry of new calibration and measuring capacities (CMC) in the BIPM KCDB database.
7. In collaboration with researchers from the Slovenian National Building Institute, we have developed a procedure and constructed a remediation device, which by the use of nanoparticles of zerovalent iron in

combination with other cleaning procedures enables the production of purified water that fulfils, regarding its physicochemical and microbiological characteristics, the criteria for drinking water.

Some outstanding publications in the past year

1. J. Snoj Tratnik, Janja, I. Falnoga, A. Trdin, D. Mazej, Darja, M. Horvat Horvat et al. Prenatal mercury exposure, neurodevelopment and apolipoprotein E genetic polymorphism. *Environmental research 152(*2017) 375-385,

2. K. Peeters, T. Zuliani, D. Žigon, R. Milačič, J. Ščančar. Nickel speciation in cocoa infusions using monolithic chromatography: post-column ID-ICP-MS and Q-TOF-MS. *Food Chemistry* 230 (2017) 327-335.

3. S. Zavadlav, B. Rožič, M. Dolenec, S. Lojen. Stable isotopic and elemental characteristics of recent tufa from a karstic Krka River (south-east Slovenia): useful evironmental proxies? *Sedimentology* 64 (2017) 808-831.

4. M. Trdin, M., Nečemer, L. Benedik. Fast decomposition procedure of solid samples by lithium borates fusion employing salicylic acid. *Analytical chemistry* 89 (2017) 3169-3176.

5. C. Russo, M. Lavorgna, M. Česen, T. Kosjek, E. Heath, M. Isidori. Evaluation of acute and chronic ecotoxicity of cyclophosphamide, ifosfamide, their metabolites/ transformation products and UV treated samples. *Environmental pollution* 233 (2018) 356-363.

6. B. Horemans, A. Lapanje, et al. Biocarriers improve bioaugmentation efficiency of a rapid sand filter for the treatment of 2, 6-dichlorobenzamide (BAM)-contaminated drinking water. *Environmental science & technology* 51 (2017) 1616-1625.

7. M. Gerbec, B. Kontić. Safety related key performance indicators for securing long-term business development – A case study. *Safety Science* 98 (2017) 77-88.

Awards and Appointments

1. Matic Bergant: Krka Prize, Novo mesto, Slovenia, 47th Krka Prizes, "Determination of meglumine by derivatization with sodium naphthoquinone sulfonate and high performance liquid chromatography"

2. Lojze Gačnik: Best Student Presentation Award, Montreal, Canada, 7th International k0-Users' Workshop, "Effect of control rod insertion on the TRIGA neutron spectrum and the determination of elemental concentrations with k0-INAA".

3. Aleš Lapanje and Jaz Zrimec: Best Poster Award in the Early Stage Scientist Category, Valencia, Spain, Federation of European Microbiological Societies FEMS 2017, "DNA Structural Alignement Algorithm Can Predict Plasmid Mobility and Host Range by Locating DNA Substrates for Plasmid Transfer".

4. Anja Mahne Opatič: Best Poster Award, Bologna, Italy, 5th MS Food Day, "A preliminary traceability model for tomato using analysis of stable isotopes, elemental content and chemical markers".

5. Nives Ogrinc, guest editor, Special issue on the 22nd International Symposium on Environmental Biogeochemistry, Geomicrobiol. j., vol. 34, no. 7.

6. Nives Ogrinc, guest editor, Special issue on ISEB 2015: Biogeochemical Dynamics of Sediment-Water Systems: Processes and Modelling, Journal of soils and sediments, vol. 17, no. 7.

7. Milena Horvat, guest editor, Special issue on the role of oceans in the global mercury observing systems, Mar. Chem., vol. 193, 2017.

Organization of conferences, congresses and meetings

1. MASSTWIN Group Training (GT2): Validation of Analytical Methods Using ID ICP-MS, Reactor Centre Podgorica, Ljubljana, Slovenia, 15–16 May 2017

2. ISO-FOOD Summer School on Trace Element Speciation in Food, Reactor Centre Podgorica, Ljubljana, Slovenia, 25–27 September 2017

3. Kick-off Meeting of the EMPIR Project "Metrology of Oxidized Mercury" - MercOx, Reactor Centre Podgorica, Ljubljana, Slovenia, 8–11 October 2017

4. PRO-METROFOOD Meeting: Overview and Characterization of Reference Materials of Rice Grains, Rice Flour and Oysters, Reactor Centre Podgorica, Ljubljana, Slovenia, 26–27 October 2017

5. IAEA Training Workshop on Intercomparison Feedback of Neutron Activation Analysis Proficiency Tests Performed in 2017, Reactor Centre Podgorica, Ljubljana, Slovenia, 6–10 November 2017

6. Hg Analysis and Speciation Training Course, Reactor Centre Podgorica, Ljubljana, Slovenia, 8–18 November 2017

7. Global Mercury Assessment Expert Group Meeting, Reactor Centre Podgorica, Ljubljana, Slovenia, 21–22 November 2017

Patent granted

1. Milena Horvat, Ermira Begu, Yaroslav Shlyapnikov, Andrej Stergaršek, Peter Frkal, Jože Kotnik, Flow device, SI25182 (A), Urad RS za intelektualno lastnino, 30. 10. 2017.

INTERNATIONAL PROJECTS

1. Analyses of Metals, TBT and DBT in Sediments, Mussels and Fish
   Prof. Janez Ščančar
2. Analyses of the Swiss Moss Samples in the Framework of the UNECE ICP Vegetation Programme
   Asst. Prof. Zvonka Jeran
   Fub Ag
3. Global Mercury Assessment - Releases to Aquatic Environments
   Prof. Milena Horvat
   Ivl Svenska Miljöinstitutet Ab
4. 7FP - HEALS; Health and Environment-wide Associations Based on Large Population Surveys
   Prof. Milena Horvat
   European Commission
5. 7FP - GLOBAQUA; Managing the Effects of Multiple Stressors on Aquatic Ecosystems Under Water Scarcity
   Prof. Radmila Milačič
   European Commission
6. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Prof. Milena Horvat
   European Commission
7. LIFE RusaLCA; Nanoremediation of Water from Small Waste Water Tretment Plants and Reuse of Water and Solid Remains for Local Needs
   Prof. Janez Ščančar
   European Commission
8. LIFE12 ENV/ - CROME-LIFE; Cross-Mediterranean Environment and Health Network
   Prof. Milena Horvat
   European Commission
9. MeTra; EMRP - Traceability for Mercury Measurements
   Prof. Milena Horvat
   Euramet E.v.
10. EMPIR; ENVCRM - Matrix Reference Materialls for Environmental Analysis
    Prof. Milena Horvat
    Euramet E.v.
11. COST ES1403 - New and Emerging Challenges and Opportunities in Wastewater Reuse (NEREUS)
    Prof. Ester Heath
    Cost Office
12. EMPIR; SIRS - Metrology for Stable Isotope Reference Standards
    Prof. Nives Ogrinc
    Euramet E.v.
13. The Use of Stable Isotopes and Elemental Composition for Determination of Authenticity and Geographical Origin of Milk and Dairy Products; Accessible Technologies for the Verification of Origin of Dairy Products as an Example Control System
    Prof. Nives Ogrinc
    IAEA - International Atomic Energy Agency
14. Training Fees for Mrs Delali Tulasi (Ghana), 17.9.2016 - 16.1.2017, 31.8.-31.12.2018
    Prof. Milena Horvat
    Ictp - Centro Internazionale Di Fisica Teorica
15. IAEA Fellowship for Ms Nthabiseng Sylvia Mohlala SAF (16002), 26.2.2017-8.4.2017; Training on the Radioanalytical Method for the Measurement of Radium in Drinking Water
    Prof. Ljudmila Benedik
    IAEA - International Atomic Energy Agency
16. IAEA Fellowship for Ms Najmah H M H Kamal (KUW/16015), 11.-25.02.2017; Training on the Radioanalytical Method for the Measurement of Radium in Drinking Water
    Prof. Ljudmila Benedik
    IAEA - International Atomic Energy Agency
17. Stability Monitoring of Certified Reference Material ERM-CE477
    Asst. Prof. Tea Zuliani
    European Commission
18. COST ES1307; Sewage Analysis CORe Group Europe
    Prof. Ester Heath
    Cost Office
19. Stability Monitoring of Certified Reference Materials BCR-462, BCR-646
    Asst. Prof. Tea Zuliani
    European Commission
20. Characterization of Minor and Trace Elements in Ti (ERM-EB090)
    Dr. Radojko Jaćimović
    European Commission
21. Training Fees for Mr Kyrylo Korychenskyi (Ukraine), 30.7.2017 - 29.10.2017
    Prof. Borut Smodiš
    Ictp - Centro Internazionale Di Fisica Teorica
22. Enhancing Nuclear Analytical Techniques to Meet the Needs of Forensic Sciences; Forensics with Nuclear Methods: Art and Food Forgery, Drugs in Hair
    Dr. Radojko Jaćimović
    IAEA - International Atomic Energy Agency
23. EMPIR - MercOx; Metrology for oxidised mercury
    Prof. Milena Horvat
    Euramet E.v.
24. Training Fee for IAEA"s Fellow Mr. Ahmed Boukadi (TUN/16018), 15.10.2017-16.12.2017
    Prof. Ljudmila Benedik
    IAEA - International Atomic Energy Agency
25. IAEA Training Workshop on Intercomparison Feedback of Neutron Activation Analysis Proficiency Tests Performed in 2017, Ljubljana, Slovenia, 6-10 November 2017, Ref. No: T3-TR-55250
    Dr. Radojko Jaćimović
    IAEA - International Atomic Energy Agency
26. Characterization Study of Certified Reference Material of ERM-BB185 by k0-INAA and ICP-MS Methods
    Asst. Prof. Tea Zuliani
    European Commission
27. Training Fees for Mr Dalerjon Hojiboev
    Asst. Prof. Zdenka Šlejkovec
    Ictp - Centro Internazionale Di Fisica Teorica
28. ERDF - UIA; APPLAUSE - Alien Plant Species - From Harmful to Useful with Citizens Let Activities
    Asst. Prof. Aleš Lapanje
    European Regional Development Fund (erdf)
29. Characterisation of ERM-CE101 by k0-INAA, CVAAS in ICP-MS
    Dr. Radojko Jaćimović
    European Commission
30. H2020 -IGOSP; Integrated Global Observing Systems for Persistent Pollutants
    Prof. Milena Horvat
    European Commission
31. H2020 - ICARUS; Integrated Climate Forcing and Air Pollution Reduction in Urban Systems
    Prof. Milena Horvat
    European Commission
32. H2020 - HBM4EU; European Human Biomonitoring Initiative
    Prof. Milena Horvat
    European Commission
33. H2020 - PRO-METROFOOD; Progressing Towards the Construction of METROFOOD-RI
    Prof. Nives Ogrinc
    European Commission
34. H2020 - SciShops.eu; Enhancing Responsible and Sustainable Expansion of the Science Shops Ecosystem in Europe
    Prof. Milena Horvat
    European Commission
35. H2020 - MEET-CINCH; A Modular European Education and Training Concept in Nuclear and RadioChemistry
    Asst. Prof. Marko Štrok
    European Commission
36. H2020 - NEUROSOME; Exploring the Neurological Exposome
    Prof. Milena Horvat
    European Commission
37. H2020 - MASSTWIN; Spreading Excellence and Widening Participation in Support of Mass Spectrometry and Related Techniques in Health, Environment, and Food Analysis
    Prof. Milena Horvat
    European Commission
38. Exposure-response Asessment of Ambient Air Pollution (AAP) and Hg Contamination in Affected Cities of India and Slovenia: A Comparative Study
    Prof. Milena Horvat
    Slovenian Research Agency
39. Screening of Organic Pollutants and their Effects in Water
    Prof. Ester Heath
    Slovenian Research Agency
40. Anthropogenic Radionuclides in the Sava River and their Transboundary Effects
    Asst. Prof. Marko Štrok
    Slovenian Research Agency
41. Air Pollution Monitoring, Maps and Tools for Assessment of Exposure to Selected Pollutants in Slovenia and Serbia
    Dr. David Kocman
    Slovenian Research Agency
42. Trace Metals Partitioning between Water Column, Suspended Particulate Matter and Sediments of the Sava River
    Prof. Janez Ščančar
    Slovenian Research Agency
43. Assessment of Emerging Contaminants in the Sava River
    Prof. Ester Heath
    Slovenian Research Agency
44. Effects of Electrostatic Modifications of Bacterial Cells on their Physiology: Growth, Division, Expression
    Asst. Prof. Aleš Lapanje
    Slovenian Research Agency

45. Formation and Growing Process of the Radioactive Aersosols including Radon and Thoron Decay Products under Different Climate Conditions in Hungary and Slovenia
Prof. Janja Vaupotič
Slovenian Research Agency

46. Geographic Sourcing of Milk and Milk Powder using Elemental and Stable Isotope Composition
Prof. Nives Ogrinc
Slovenian Research Agency

47. Methods for Trace Elements Preseparation and Determination in Some Minerals and Other Inorganic Substances
Dr. Radojko Jaćimović
Slovenian Research Agency

48. Dynamics of Soil Air Components (Radon, Carbon Dioxide, and its Carbon Isotopes) under Semi-Natural Forest Sites
Prof. Nives Ogrinc
Slovenian Research Agency

49. Vice-President and a Board Member of International Association for Sediment Water Science (IASWS)
Prof. Nives Ogrinc
Slovenian Research Agency

RESEARCH PROGRAMS

1. Modelling and environmental impact assessment of processes and energy technologies
Prof. Borut Smodiš
2. Cycling of substances in the environment, mass balances, modelling of environmental processes and risk assessment
Prof. Milena Horvat

R&D GRANTS AND CONTRACTS

1. Vegetation and hydrology of Ljubljansko barje in the past, present and future a consequence of succession, human impact or climatic fluctuations?
Prof. Nives Ogrinc
2. Modelling hydrologic response of nonhomogeneous catchments
Prof. Sonja Lojen
3. Electrostatic immobilisation of bacterial cells and effects on their physiology
Prof. Milena Horvat
4. Ligands bearing tzNHCs in Organometallic Chemistry and Homoheneous Catalysis: c-C and C-N Bond Formation in Water
Prof. Ester Heath
5. Closing material flows by wastewater treatment with green technologies
Prof. Ester Heath
6. Mortality of lowland oak forests - consequence of lowering underground water or climate change?
Dr. Polona Vreča
7. Development of Molecularly Imprinted Polymers and their application in environmental and bio-analysis
Asst. Prof. Tina Kosjek
8. Bisphenol A alternatives: transfer from food contact material, fate and human exposure
Prof. Ester Heath
9. Spatial distribution of water isotopes in precipitation in Europe with special fokus on the transect from the Adriatic Coast to the Pannonian Plain
Dr. Polona Vreča
10. Stable isotopes in the study of the impact of increasing CO2 levels on C and Hg cycling in coastal waters
Prof. Nives Ogrinc
11. In-situ remediacija onesnažene zemljine na področju stare Cinkarne In-situ remediation of polluted grouns in the area of the Zink-works at Celje
Prof. Janez Ščančar
12. Comparative study of ecosystem management and services in contrasting Slovenian freshwater systems
Dr. David Kocman
13. Improved treatment and monitoring of Water Framework Directive priority pollutants
Prof. Ester Heath
14. Potential substances of very high concern in the context of REACH regulation
Dr. Davor Kontić
15. In situ immobilization of contaminated soil using innovative nanotechnology, for processingand use as urban soils
Prof. Radmila Milačič
16. Exposure of children and adolescents to selected chemicals through their habitat environment
Prof. Milena Horvat
17. Slovenian National Implementation Plan for the Minamata Convention on Mercury
Dr. David Kocman
18. Food for future - F4F

Prof. Nives Ogrinc
Ministry of Education, Science and Sport

19. Potential substances of very high concern in the context of REACH regulation
Dr. Davor Kontić
Slovenian Research Agency

20. In situ immobilization of contaminated soil using innovative nanotechnology, for processingand use as urban soils
Prof. Radmila Milačič
Ministry of the Environment and Spatial Planning

21. EMRP; MeTRA - Traceability for Mercury Measurements
Prof. Milena Horvat
Ministry of Education, Science and Sport

22. Exposure of children and adolescents to selected chemicals through their habitat environment
Prof. Milena Horvat
Slovenian Research Agency

23. Slovenian National Implementation Plan for the Minamata Convention on Mercury
Dr. David Kocman
Slovenian Research Agency

24. Determination of Elemental Content in Reference Materials from Saudi Arabia
Dr. Radojko Jaćimović
King Khalid University, College Of Science,

25. Determination of Isotope Composition of Oxygen and Hydrogen in Water
Dr. Polona Vreča
Pe „water Supply And Sewage" Podgorica

26. Enhancing Capacity on Mercury Monitoring and Contaminated Sites Assessment and Remediation in Kyrgyzstan
Prof. Milena Horvat
United Nations Environment Programme

27. Determination of 87Sr/86Sr Isotopic Ratio of Olive Oils and Soil Samples
Asst. Prof. Tea Zuliani
Institute For Adriatic Crops And

28. Mercury Analysis and Speciation Training Course
Prof. Milena Horvat
Bccc-scrc, Technological Laboratory Of

29. Isotope analysis of coal gas samples and analysis of gas concentrations
Dr. Tjaša Kanduč

30. Annual order for the analysis of metals
Prof. Janez Ščančar

31. Thermal water analysis
Asst. Prof. Marko Štrok

32. LC-MS measurements of samples E-5
Dr. Dušan Žigon

33. Determination of elemental composition in samples of gypsum and titanium dioxide
Dr. Radojko Jaćimović

34. Analysis of the isotopic composition of oxygen and hydrogen
Prof. Sonja Lojen

35. Determination of the isotopic composition of oxygen and hydrogen in water
Dr. Polona Vreča

36. Estimated location for the production of asphalt mixtures in Celje
Dr. Davor Kontić
Voc Celje, d. d.

37. Determination of the dissolved Ra-226 content - I. quartal
Asst. Prof. Zvonka Jeran

38. Analysis of flavor samples
Prof. Nives Ogrinc

39. Measurements of radon concentrations
Prof. Janja Vaupotič

40. Analysis of mercury
Prof. Milena Horvat

41. Environmental impact assessments
Asst. Prof. Branko Kontić

42. Measurements of H-3 on VOP-1/06, V-12/77 and V-7/77 wells
Asst. Prof. Marko Štrok
Nuklearna Elektrarna Krško d. o. o.

43. APPENDIX NO.14 Co-financing the activities of the national standard holder for 2017 - the quantity of substance / chemical trace element / in organic and inorganic materials
Dr. Polona Vreča
Ministry of Education, Science and Sport

44. Measurements of total Hg in precipitation at the Iskrba measuring station near the Kočevska River in monthly rainfall patterns
Asst. Prof. Jože Kotnik
Ministry of the Environment and Spatial Planning

45. Off-site radiological monitoring of the Krško Nuclear Power Plant in2016 and 2017
Asst. Prof. Marko Štrok
Nuklearna Elektrarna Krško d. o. o.

46. Determination of the total arsenic and its speciation in the urine of children involved in the study. An in-depth assessment of the risks to children's health due to arsenic exposure in the Zagorje ob Savi municipality

Prof. Milena Horvat
Občina Zagorje ob Savi

47. Monitoring of radioactivity in drinking water - conducting additional analyzes
Asst. Prof. Marko Štrok
Ministry of Health

48. Preparation of a radon map at settlement level
Prof. Janja Vaupotič
Ministry of Health

49. Measurement of total mercury in precipitations and instrument for measurement of total gaseous mercury in air
Asst. Prof. Jože Kotnik
Ministry of the Environment and Spatial Planning

50. Independent monitoring of operational monitoring of the Krsko NPP for 2017
Asst. Prof. Marko Štrok
Nuklearna Elektrarna Krško d. o. o.

51. Sampling and fodder testing for gamma and beta emission activities for 2017
Asst. Prof. Marko Štrok
Ministry of Agriculture, Forestry and Food

52. Contract for the preparation of analyzes for the isotopic ratio of oxygen (18O) to wine and olive (13C) in ethanol number 08-6-98 / 2017
Prof. Nives Ogrinc
Kmetijski Inštitut Slovenije

53. Independent control over regular radiological monitoring of NPP Krško 2016

Asst. Prof. Marko Štrok
Ministry of the Environment and Spatial Planning

NEW CONTRACTS

1. Operational monitoring of radioactivity in the surrounding of NEK in RS in 2017
Asst. Prof. Marko Štrok
Ministry of the Environment and Spatial Planning

2. Ecology laboratory with mobile unit
Dr. Dušan Žigon
Ministry of Defence

3. Mass spectrometric measurements of samples from Krka, pharmaceutical company
Dr. Dušan Žigon
Krka, Tovarna Zdravil, d. d.

4. Aanalyses of atmospheric releases in 2015, 2016 and 2017
Asst. Prof. Marko Štrok
Nuklearna Elektrarna Krško

5. Analysis of di- and tributyltin compounds
Asst. Prof. Tea Zuliani
Ministry of the Environment and Spatial Planning

6. MOdels and DAta for Radiological Impact Assessment – MODARIA
Asst. Prof. Branko Kontić
Gen Energija, d. o. o.

VISITORS FROM ABROAD

1. Delali Tulasi, University of Ghana, School of Nuclear and Allied Sciences, Legon, Accra, Ghana, 1–15 January 2017 and 31 August 2017 to 31 December 2017
2. Agneta Annika Runkel, Universität Bayreuth, Bayreuth, Germany, 16 January to 16 April 2017
3. Prof. Dr Ivana lvančev Tumbas, Univerza v Novem Sadu, Novi Sad, Serbia, 10–16 February 2017 and 22– 26 November 2017
4. Najmah Hmh Kamal, Radiation Protection Department, Ministry of Health, Qadeseyah,
5. Kuwait, 11–25 February 2017
6. Nthabiseng Sylvia Mohalala, National Nuclear Regulator (NNR), Centurion, South Africa, 26 February to 8 April 2017
7. Celine Gys, University of Antwerp, Antwerp, Belgium, 27 February to 31 March 2017
8. Yekaterina Chudinova, Department of Experimental Physics, National Research Tomsk Polytechnic University, Tomsk, Russia, 2–25 March 2017
9. Marijan Ahel, Petra Kostanjevečki, Ivona Krizman, Ruđer Bošković Institute, Zagreb, Croatia, 7 March 2017
10. Prof. Dr Adrian Covaci, University of Antwerp, Antwerp, Belgium, 14–18 March 2017
11. Elisa Petranich, University of Trieste, Trieste, Italy, 3–10 April 2017
12. Dr Patrick Pang, Dr Lian Liang, CEBAM Analytical, Inc., Washington, USA, 14–18 April 2017
13. Iaroslav Rybkin, Saratov State University, Saratov, Russia, 18 April to 18 June 2017 and 23 September to 19 December 2017
14. Amalia Säynäjäkangas, Mika Saari, Raahe Municipal Education and Training Consortium, Raahe, Finland, 18 April to 26 May 2017
15. Stefan Anđus, Milica Marković, Jelena Čanak Atlagić, Jelena Đuknić, Institute for Biological Research "Siniša Stanković", Belgrade, Serbia, 18–21 April 2017
16. Dr Arijit Chowdhuri, Acharya Narendra Dev College, Univeristy of Delhi, Kalkaji, New Delhi, India, 3–12 May 2017
17. Tricia Marie Hoffman, University of Miami, Miami, Florida, USA, 7 May to 7 June 2017
18. Robin Fouquer, University of Tours, Tours, France, 8 May to 4 August 2017
19. Aleksandra Tubić, University of Novi Sad, Novi Sad, Serbia, 13–20 May 2017
20. Minja Bogunović, University of Novi Sad, Novi Sad, Serbia, 15–21 May 2017
21. Dr Dolores Hernando, National Institute for Agricultural Research and Experimentation (INIEAF), Madrid, Spain, 29 May to 6 June 2017
22. Federica Relitti, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale – OGS, Sezione Oceanografia, Trieste, Italy, 10–14 July 2017
23. Macarena Ferriz Nunes, National Institute for Agricultural Research and Experimentation (INIEAF), Madrid, Spain, 29 May to 22 July 2017
24. Dr Hana Cho, Dr Kishore Babu Dasari, Korea Research Institute of Standards and Science, Yuseong-Gu, South Korea, 11 July to 31 August 2017
25. Daniyar Khussainov, Fatima Meiirman, Gulsana Amanova, Viktoriya Kim, Faculty of Chemistry and Chemical Technology, Kazakhstan, 21–31 August 2017
26. Prof. Ilona Matveyeva, Faculty of Chemistry and Chemical Technology, al-Farabi Kazakh National University, Almaty, Kazakhstan, 21 August to 3 September 2017
27. Kyrylo Korychenskyi, Ukrainian Hydrometeorological Institute (UHMI), Kiev, Ukraine, 30 July to 27 October 2017
28. Dr Milena Taseska-Gjorgjijevski, Institute of Chemistry, Faculty of Natural Science and Mathematics, Ss Cyril and Methodius University, Skopje, Macedonia, 1–30 June 2017
29. Jovica Todorov, Vasil Makrievski, Institute of Chemistry, Faculty of Natural Science and Mathematics, Ss Cyril and Methodius University, Skopje, Macedonia, 19–30 June 2017

30. Gordana Šelo, Josip Juraj Strossmayer, University of Osijek, Faculty of Food Technology Osijek, Osijek, Croatia, 1 September to 13 October 2017
31. Dr Ryoko Fujiyoshi, Faculty of Engineering, Hokkaido University, Sapporo, Japan, 3–17 September 2017
32. Dr Andrius Garbaras, Center for Physical Sciences and Technology, Vilnius, Lithuania, 3–17 September 2017
33. Iker Marcaida, University of the Basque Country, Faculty of Science and Technology, Leioa, Spain, 4 September to 22 December 2017
34. Prof. Dr Savithri Singh, Acharya Narendra Dev College, University of Delhi, Kalkaji, India, 8–17 September 2017
35. Dr Naveen Chand Varanahally Puttaswamy, Faculty of Public Health, Sri Ramachandra Medical University, Porur, Chennai, India, 10–24 September 2017
36. Zhoroev Choenbai, The Aydarken Centre for General Medicine Practice (ACGMP), Aydarken, Kyrgyzstan, Ormanova Nurkamal, Aydarken Mercury Plant, Aydarken, Kyrgyzstan, 30 September to 8 October 2017
37. David Douglas, John Entwisle, LGC Standards, Teddington, Great Britain, Panayot Petrov, Süleyman Z. Can, TÜBİTAK, Ankara, Turkey, Ina Fettig, Jan Koschorreck, UBA, Berlin, Germany, Hugo Ent, Iris de Krom, VSL Dutch Metrology Institute, Delft, Holland, Timo Ramajaki, VTT Technical Research Centre of Finland Ltd, Oulu, Finland, Ian Hedgecock, Attilio Naccarato, The National Research Council, Rome, Italy, Moeseler Reinhold, Sergej Sholupov, Lumex Analytics GmbH, Germany, Toni Laurila, Optoseven, Espoo, Finland, Warren Corns, P S Analytical, Kent, Great Britain, Oliver Donard, UPPA, Pau, France, Maria Rocio Torres Arvizu, National Metrology Center (CENAM), Municipio El Marqués, Mexico, Eric Prestbo, Tekran®, Instruments Corporation, Toronto, Canada, Mae Gustin, University of Nevada, Reno, USA, Parisa Ariya, McGill University, Montreal, Canada, 9-11 October 2017
38. Ahmed Boukadi, National Center for Nuclear Sciences and Technologies, Sidi Thabet, Tunisia, 15 October to 16 December 2017
39. Asel Ablesova, Osh Interregional Joint Clinical Hospital, Maternity Department, Osh, Kyrgyzstan, 5 November to 2 December 2017
40. Mamataliev Nurlan, Anushova Gulkhan, Kadamzhai District Centre for Disease Prevention and Sanitary-Epidemiologic Surveillance (KCDPSSES), Kadamzhai, Kyrgyzstan, Salymbekova Kasiet, Scientific and Production Centre for Preventive Medicine (SPCPM) of the Ministry of Health, Bishkek, Kyrgyzstan, Zhuravleva Elena, Chui Ecology Laboratory, Kara-Balta, Kyrgyzstan, 5–17 November 2017
41. Nazarov Melis, State Regulation Center in the Sphere of Environmental Protection and Ecological Safety of the State Agency for Environmental Protection and Forestry under the Government of the Kyrgyz Republic, Bishkek, Kyrgyzstan, 5–23 November 2017
42. Bakai Zhumakadyr, State Regulation Center in the Sphere of Environmental Protection and Ecological Safety of the State Agency for Environmental Protection and Forestry under the Government of the Kyrgyz Republic, Bishkek, Kyrgyzstan, 5–25 November 2017
43. Agostino Tonon, Edmund Mach Foundation, San Michele all'Adige, Italy, 6–10 November 2017
44. Nataša Sarap, Vinča Institute of Nuclear Science, Belgrade, Serbia, 26 November to 15-December 2017
45. Dr Martina Furdek Turk, Ruđer Bošković Institute, Zagreb, Croatia, 27 November to 1 December 2017
46. Miloš Davidović, Dušan Topalović, Maja Jovanović in Milena Jovašević-Stojanović, Vinča Institute of Nuclear Science, Belgrade, Serbia, 27 November to 1 December 2017

47. Marija Janković, Vinča Institute of Nuclear Science, Belgrade, Serbia, 29 November to 1 December 2017
48. Li Yuan, Bai Baozhu, Dong Mingli, Shao Dingding, Wang Zuguang, Foreign Economic Cooperation Office, Ministry of Environmental Protection of China, Beijing, China, 26–28 November 2017
49. Dr Sarata Kumar Sahoo, Tokyo Metropolitan University, Tokyo, Japan, 3–13 December 2017

STAFF

Researchers
1. Prof. Ljudmila Benedik
2. Asst. Prof. Ingrid Falnoga
3. Dr. David John Heath
4. Prof. Ester Heath
5. Prof. Milena Horvat, Head
6. Dr. Radojko Jaćimović
7. *Asst. Prof. Zvonka Jeran, retired 04.07.17*
8. Dr. David Kocman
9. Asst. Prof. Branko Kontić
10. Asst. Prof. Tina Kosjek
11. Asst. Prof. Jože Kotnik
12. Asst. Prof. Aleš Lapanje
13. Prof. Sonja Lojen
14. Dr. Darja Mazej
15. Prof. Radmila Milačič
16. Prof. Nives Ogrinc
17. Prof. Borut Smodiš
18. Prof. Janez Ščančar
19. Asst. Prof. Zdenka Šlejkovec
20. Asst. Prof. Marko Štrok
21. Prof. Janja Vaupotič
22. Dr. Polona Vreča
23. Asst. Prof. Tea Zuliani
24. Dr. Dušan Žigon

Postdoctoral associates
25. Dr. Raghuraj Singh Chouhan
26. Dr. Marjeta Česen
27. Dr. Andrija Ćirić
28. Dr. Jelena Golubović
29. Dr. Tjaša Kanduč
30. Dr. Davor Kontić
31. *Dr. Kelly Peeters, left 01.06.17*
32. Dr. Tomaž Rijavec
33. *Dr. Miha Trdin, left 23.12.17*
34. Dr. Janja Vidmar

Postgraduates
35. Lojze Gačnik, B. Sc.
36. *Dr. Ana Jerše, left 01.04.17*
37. Ana Kovačič, B. Sc.
38. Dr. Bor Krajnc
39. *Ana Kroflič, B. Sc., left 01.05.17*
40. Jasmina Masten, B. Sc.
41. *Dr. Petra Novak, left 18.04.17*
42. Majda Pavlin, B. Sc.
43. Doris Potočnik, B. Sc.
44. Johanna Amalia Robinson, B. Sc.
45. Leja Rovan, B. Sc.
46. Janja Snoj Tratnik, B. Sc.
47. Anja Stajnko, B. Sc.
48. Žiga Tkalec, B. Sc.
49. Vanja Usenik, B. Sc.
50. *Igor Živković, B. Sc., left 01.05.17*

Technical officer
51. Vesna Fajon, B. Sc.

Technical and administrative staff
52. Maša Bonča, B. Sc.
53. Alja Kump, B. Sc.
54. *Damjana Nikovski, B. Sc., 01.04.17, transferred to Department U3*
55. Barbara Svetek, B. Sc.
56. Zdenka Trkov, B. Sc.
57. Stojan Žigon

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Khaled Abass, Markku Koiranen, Darja Mazej, Janja Snoj Tratnik, Milena Horvat, Jukka Hakkola, Marjo-Riitta Järvelin, Arja Rautio, "Arsenic, cadmium, lead and mercury levels in blood of Finnish adults and their relation to diet, lifestyle habits and sociodemographic variables", *Environ. sci. pollut. res. int.*, **24**, 2, 1347-1362, 2017.
2. M. Rocio Arvizio Torres *et al.* (33 authors), "Contaminant and other elements in soil (CCQM-K127)", *Metrologia*, **54**, tech. suppl., 08010, 2017.
3. Marija Baković, Polona Vreča, Davor Mayer, "Case of fatal starvation: can stable isotope analysis serve to support morphological diagnosis and approximate the length of starvation?", *Forensic sci. int.*, **62**, 1, 258-264, 2017.
4. Ljudmila Benedik, Miha Trdin, "Determination of low level Np-237 by various techniques", *Appl. radiat. isotopes*, **126**, 208-213, 2017.
5. S. Berisha, Mitja Skudnik, Urša Vilhar, M. Saboljević, Saša Zavadlav, Zvonka Jeran, "Trace elements and nitrogen content in naturally growing moss Hypnum cupressiforme in urban and peri-urban forests of the Municipality of Ljubljana (Slovenia)", *Environ. sci. pollut. res. int.*, **24**, 5, 4517-4527, 2017, .
6. M. Blaauw, D. Ridikas, S. Baytelesov, P. S. Bedregal Salas, Y. Chakrova, Cho Eun-Ha, R. Dahalan, A. H. Fortunato, Radojko Jaćimović, A. Kling, Luis Muñoz, N. M. A. Mohamed, D. Párkányi, T. Singh, V. Dong Duong, "Estimation of ^{99}Mo production rates from natural molybdenum in research reactors", *J. radioanal. nucl. chem.*, **311**, 409-418, 2017.
7. Marko Bohanec, Nejc Trdin, Branko Kontić, "A qualitative multi-criteria modelling approach to the assessment of electric energy production technologies in Slovenia", *Cent. Eur. j. oper. res.*, **25**, 3, 611-625, 2017.
8. Bojana Božiček, Sonja Lojen, Matej Dolenec, Goran Vižintin, "Impacts of deep groundwater monitoring wells on the management of deep geothermal Pre-Neogene aquifers in the Mura-Zala Basin, Northeastern Slovenia", *Groundwater for sustainable development*, **5**, 193-205.
9. Arne Bratkič, Neža Koron, Sergio Ribeiro Guevara, Jadran Faganeli, Milena Horvat, "Seasonal variation of mercury methylation potential in pristine coastal marine sediment from the Gulf of Trieste (Northern Adriatic Sea)", *Geomicrobiol. j.*, **34**, 7, 587-595, 2017.
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10. Nataša B. Sarap, Marijana Nodilo, Marko Štrok, Marija M. Janković, Željko Grahek, "Intercomparison of different methodologies for determination of radiostrontium in soil samples", In: *Zbornik radova jedanaestog simpozija Hrvatskog društva za zaščitu od zračenja, Osijek, Hrvatska 5. - 7. travnja 2017: HDZZ - CRPA: Zagreb, 2017*, (Zbornik radova ... simpozija hrvatskog društva za zaščitu od zračenja), Vanja Radolić, ed., Maja Sovilj Poje, ed., Ines Krajcar Bronić, ed., Zagreb, Hrvatsko društvo za zaščitu od zračenja, 2017, 255-260.

11. Mateja Štefančič, Radmila Milačič, Ana Mladenovič, Ksenija Janković, Janez Turk, Marko Stojanović, Aljoša Šajna, Alenka Mauko Pranjić, "Leaching tests of lead and zinc from mine tailings of the Mežica, Slovenia and Rudnik, Serbia mining areas", In: *Zbornik radova*, Međunarodni simpozijum o istraživanjima i primeni savremenih dostignuća u građevinarstvu u oblasti materijala i konstrukcija, [u okviru] XXVII Kongresa Društva za ispitivanje i istraživanje materijala i konstrukcija (DIMK) Srbije - Vršac, 18.-20. oktobar 2017 = International Symposium on Researching and Application of Contemporary Achievements in Civil Engineering in the Field of Materials and Structures, [within] XXVII Congress of Society for Materials and Structures Testing of Serbia - Vrsac, October 18-20, 2017, Dragica Jevtić, ed., Radomir Folić, ed., Beograd, Društvo za ispitivanje i istraživanje materijala i konstrukcija Srbije, 2017, 97-106.

12. Anja Torkar, Mihael Brenčič, Polona Vreča, "Analiza dinamike izvira reke Radovne z uporabo stabilnih izotopov", In: *Razprave, poročila*, 23rd Meeting of Slovenian Geologists, Ljubljana, marec 2017, Boštjan Rožič, ed., Ljubljana, Univerza v Ljubljani, Naravoslovnotehniška fakulteta, Oddelek za geologijo, *Geol. zbor.*, **24**, 171-173, 2017.

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14. Polona Vreča, Tjaša Kanduč, David Kocman, Sonja Lojen, Johanna A. Robinson, Marko Štrok, "Slovenska mreža opazovanj izotopske sestave padavin (SLONIP): pregled in možnost uporabe pri upravljanju z vodnimi viri", In: *Zbornik*, Drugi slovenski kongres o vodah 2017, [19. in 20. april 2017, Podčetrtek], Lidija Globevnik, ed., Andrej Širca, ed., Ljubljana, SLOCOLD - Slovenski nacionalni komite za velike pregrade, DVS - Društvo vodarjev Slovenije, 2017, 225-234.

INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

1. Mihael Budja, Nives Ogrinc, "Arheologija lipidov - odkrivanje organskih ostankov hrane v prazgodovinskih posodah", In: *Preteklost pod mikroskopom: naravoslovne raziskave v muzeju*, Mateja Kos, et al, Ljubljana, Narodni muzej Slovenije, 2017, 145-153.

2. Tome Eftimov, Peter Korošec, Doris Potočnik, Nives Ogrinc, David John Heath, Barbara Koroušić-Seljak, "How to perform properly statistical analysis on food data?: an e-learning tool: advanced stati stics in natural sciences and technologies", In: *Science within food: up-to-date advances on research and educational ideas*, (Formatex food science series, **1**), A. Méndez-Vilas, ed., Badajoz, Formatex Research Center, 2017, 144-151.

3. Radojko Jaćimović, "Determination of minor and trace elements in the wepal ipe/ise proficiency tests in the years 2011, 2012 and 2013 using k0-INAA", In: *Proficiency testing by interlaboratory comparison performed in 2010-2015 for neutron activation analysis and other analytical techniques*, (IAEA TECDOC series, 1831), L. Hamidatou, Vienna, IAEA, 2017, 148-162.

SCIENTIFIC MONOGRAPH

1. Mateja Kos, Alenka Miškec, Tomaž Lazar, Nataša Nemeček, Saša Rudolf, Žiga Šmit, Zora Žbontar, Mihael Budja, Tomislav Kajfež, Katja Mahnič, Eva Menart, Nives Ogrinc, Urša Pajk, Daša Pavlovič, Miran Pflaum, Tjaša Tolar, Matija Turk, Peter Turk, Anton Velušček, *Preteklost pod mikroskopom: naravoslovne raziskave v muzeju*, Ljubljana, Narodni muzej Slovenije, 2017.

PROFESSIONAL MONOGRAPH

1. Lucija Perharič, Maja Martinčič, Simona Uršič, Andreja Kukec, Vesna Zadnik, Darja Mazej, Zdenka Šlejkovec, Mateja Šter, Alenka France Štiglic, Ivan Eržen, *Poglobljena ocena tveganja za zdravje otrok zaradi izpostavljenosti arzenu v občini Zagorje ob Savi*, Ljubljana, Nacionalni inštitut za javno zdravje, 2017.

PATENT

1. Milena Horvat, Ermira Begu, Yaroslav Shlyapnikov, Andrej Stergaršek, Peter Frkal, Jože Kotnik, *Flow device,* SI25182 (A), Urad RS za intelektualno lastnino, 30. 10. 2017.

MENTORING

1. Ana Jerše, *Determination of iodine and its compounds in iodine enriched plants:* doctoral dissertation, Ljubljana, 2017 (mentor Vekoslava Stibilj).

2. Bor Krajnc, *CO_2 fluxes from soil and karst caves edetermination of sources, pathways and interactions using a stable isotope approach:* doctoral dissertation, Ljubljana, 2017 (mentor Nives Ogrinc).

3. Petra Novak, *Determination of polybrominated diphenyl ethers in environmental samples by gas chromatography coupled with inductively coupled plasma mass spectrometry:* doctoral dissertation, Ljubljana, 2017 (mentor Janez Ščančar; co-mentor Tea Zuliani).

4. Janja Vidmar, *Quantification and sizing of metal-based nanoparticles in the environmental and biological samples:* doctoral dissertation, Ljubljana, 2017 (mentor Radmila Milačič; co-mentor Janez Ščančar).

DEPARTMENT OF AUTOMATION, BIOCYBERNETICS AND ROBOTICS   E-1

The research strategy within our department is unique, as it supports a variety of multi- and interdisciplinary research projects. Specifically, our research combines the fields of robotics (including intelligent control, humanoids, cognitive robotics, robot learning and robot vision), automation, biomechanics, biocybernetics, ergonomics and environmental physiology. The common theme of our research endeavours to date has been optimising "the behaviour of man and machine", accounting for interactions with the environment. By combining engineering and life sciences we have been able to make significant contributions to the development of humanoid robotic systems, a planetary habitat simulation facility, new methods for robot learning based on imitation, manikins enabling the evaluation of protective garments for industry and recreation, kinematic models of the human body that serve as a basis for the design of anthropomorphic systems, and a medical treatment for frostbite.

Head:
Prof. Aleš Ude

The department maintains the programme group "Automation, robotics and biocybernetics" in the field of Production Technologies (leader prof. dr. Igor B. Mekjavic). Members of the department participate in numerous EU projects in the area of robotics and artificial intelligence, factories of the future, health, and space technologies. In 2017 we coordinated two Horizon 2020 projects: ReconCell and SPEXOR. We are also active in transferring our research results to various applications through direct collaborations with industry. By maintaining a critical mass of researchers in all areas within one programme group, we have managed to foster exciting multidisciplinary projects.

Research in the area of humanoid and cognitive robotics as well as robot learning is primarily conducted within the Humanoid and Cognitive Robotics Lab (leader dr. Bojan Nemec), which operates within the department. The aim of this laboratory is to create robots that are capable of acquiring new knowledge through learning and to collaborate with people in their natural environments. In 2017 we established a new Laboratory for Neuromechanics and Biorobotics, which is led by prof. dr. Jan Babič. The main focus of this lab is to integrate the results of biomechaniscs, neurophysiology and robotics to study human motor control and develop new robot systems that can effectively assist people in their daily activities.

The main focus of the newly established Laboratory for Neuromechanics and Biorobotics is to apply the results of biomechanics, neurophysiology and robotics to study human motor control and develop new robot systems that can effectively assist people.

During the past year our research focused on the development of cognitive robotic systems, new robot-learning methodologies, including learning for dual-arm systems and deep learning, contact modelling, robotic assistive devices, reconfigurable robotic workcells, the automation and digitalization of industrial manufacturing, studies of human physiology in extreme environments, the evaluation of protective equipment, and the development of biomedical methods.

Robotics

In 2017 we continued our work in the Horizon 2020 project **Recon-Cell** (A **Recon**figurable robot work**Cell** for the fast set-up of automated assembly processes in SMEs, http://www.reconcell.eu/) where we have been developing new reconfiguration technologies that enable the rapid setup of robotic workcells in industrial production. The proposed workcell is based on a number of novel technologies including 1. robot programming by kinesthetic teaching, 2. sensor-based feedback control, 3. robot-aided reconfiguration, 4. object localization using 3D vision, 5. visual quality control, 6. robot simulation, and 7. integration with business intelligence. Our software implementation is based on ROS (Robot Operating System), which provides tools for effective communication between all workcell elements. In the past year we successfully applied the developed approaches to

Reconfigurable robotic workcell and EU Commissioner G. Öttinger at Hanover fair 2017

real industrial production tasks including the assembly of a gripper for a wall-mounting robot, the final assembly & customization of drive systems and control boxes, and the assembly of automotive lights. The results of the ReconCell project were demonstrated at the Hannover Fair 2017, which is the largest industrial fair in the world.

In the EU project ReconCell we developed new methodologies for the reconfiguration of robotic workcells. We applied these techniques to real industrial production tasks.

Another important research topic in the past year was the development of new methodologies for **learning and the autonomous adaptation of dual-arm assembly and service tasks**. Our research in this area addresses the following issues: 1. development of new efficient methods for the learning and demonstration of bi-manual tasks, 2. development of new algorithms for the efficient and autonomous adaptation of bimanual coordinated tasks to deviations, which arise in industrial tasks, and 3. verification of the developed methods and algorithms on some typical industrial and domestic tasks.

A focal point of our work in 2017 was the Horizon 2020 project AUTOWARE (http://www.autoware-eu.org). This project focuses on the development of new **digital technologies** including reliable wireless networking, fog computing, reconfigurable and collaborative robotics, modular production lines, augmented virtuality, machine learning, cognitive autonomous systems, etc. These technologies are being made ready for their application in smart factories. Special attention is paid to the interoperability between them and also with legacy devices and information systems on the factory floor. Our main contribution in the project was the integration of robotics with these new digital technologies. To this end we focused on open platforms, protocols and interfaces.

In 2017 we initiated a new research topic in our department – **deep learning in robotics**. Deep learning is a rapidly growing research area in robotics. Research has shown that it is suitable for learning end-to-end visuomotor policies that require close coordination between vision and control. We proposed a new approach for learning perception-action couplings and showed that by collecting a large dataset of raw images and the associated movement trajectories, a deep encoder-decoder network can be trained that takes raw images as input and outputs the corresponding dynamic movement primitives.

In the scope of the Horizon 2020 project SPEXOR (http://www.spexor.eu/) we developed and evaluated several different **algorithms for the online classification of movements**, which will be used for engaging or disengaging the actuators of the back exoskeleton, and for controlling the state of the viscoelastic elements to smooth the motion of the uncontrolled trunk movements. To allow future control of the active spinal exoskeleton we formulated a framework for assistive, training and diagnostic modes. The framework is used to further develop different high-level control concepts. The developed control algorithms were evaluated on currently available exoskeleton robots and haptic devices that simulate the behaviour of the exoskeleton devices.

Finally, in the scope of the Horizon 2020 project AnDy we developed a novel method for the control **of human-robot co-manipulation** that takes into account the **ergonomic requirements** for the human co-worker. The robot uses a whole-body dynamic model of the human to optimise for the position of the co-manipulation task in the workspace. In this configuration the overloading joint torques due to the effects of an external load in human-body joints are minimised. The main advantage of this approach is that the robot can potentially help to reduce the work-related strain and increase the productivity of the human co-worker. In addition, the on-line estimation of the overloading joint torques does not require an external force plate or sensor insoles. We validated the proposed method with experiments in two co-manipulation tasks: human using a device to polish an object that is delivered by the robot and a human-robot object handover. The results show that the proposed method is successful in achieving the ergonomic conditions for the human during the collaboration.

Figure 2: Reconfigurable fixture

In the Horizon 2020 project AnDy we developed a novel control approach that allows robots to take into account the ergonomic parameters of humans during the human-robot collaboration.

Figure 3: Cooperation task with a heavy tool

Automation and industrial robotics

A vital mission of our department is the transfer of our research results to industrial applications. In the past year we focused on a new smart specialisation program GOSTOP: Building blocks, tools and systems for factories of the future, which is coordinated by members of our department. The aim of the GOSTOP program is to accelerate the development of the factories-of-the-future concept in Slovenia and to provide solutions to the current needs of

Slovenian industry, where some companies have already started to introduce this concept into their production facilities. In GOSTOP, 13 companies and 6 research organizations with compatible research and development programs joined forces to advance the concept of smart factories. We identified four areas in which decisive breakthroughs can be achieved in Slovenia in the near future: **control technologies, tooling, robotics, and photonics**. In the area of robotics we collaborate with companies such as Kolektor, Domel, Yaskawa, and Podkrižnik.

Our main topics in the GOSTOP program are: 1. **intelligent sensors and actuators**, 2. **adaptive robotic workcell for visual quality control**, and 3. **platform of the virtual factory**. Research in the area of intelligent sensors and actuators is directed towards the development of intelligent drive systems with torque-control algorithms and a built-in monitoring system and the possibility for predictive maintenance of each drive system. In the second research theme, which is adaptive robotic workcell, we develop new flexible grasping and manipulation processes, machine vision, and machine-learning solutions. A specific objective of this activity is to develop an adaptive robotic workcell for visual quality control of industrial parts. The main goal of the development of the virtual factory platform is to design and produce an intelligent, competitive, and sustainable information system in a smart factory that includes the elements of robotics. This combines research in the field of intelligent control algorithms, discrete event simulation in real time, and Plug & Produce interfaces with the principles of IoT.

Environmental physiology and ergonomics

The **Biocybernetics group** in our department conducts research into the influence of extreme environmental factors on humans as well as on the development and evaluation of technologies and strategies to maintain safety and unhindered performance in such environments.

We are coordinating a new program in the scope of Slovenia's smart specialization strategy GOSTOP: Building blocks, tools and systems for factories of the future.

Figure 4: Weight manipulation supported by an exoskeleton

We maintain a research facility at the Nordic Centre Planica, where we conduct studies investigating the **effect of inactivity and unloading of the weight-bearing limbs** on physiological function. This facility was established with the support of the European Space Agency and the European Commission (Framework 7 Programme; PlanHab project). The effects of inactivity/unloading, as experienced by astronauts during microgravity exposure in space, is simulated with the bed rest experimental model. Prolonged exposure to microgravity results in musculoskeletal atrophy and deconditioning of the cardiovascular system, which constitute a threat to the health and well-being of astronauts. Given that various space agencies are aiming to pursue a long-term space mission in the near future, novel issues connected to space habitation are very important. In particular, for technical reasons, the environment within future Lunar and Mars habitats will be **hypobaric and hypoxic**. The continued aim of our research programme in space life sciences is to assess the effect of hypoxia on the processes of adaptation to microgravity, which have been observed in a normoxic environment. We achieve this by comparing the adaptation of physiological systems to inactivity/unloading in a normoxic environment, with the changes observed in a hypoxic environment.

We have initiated a research programme investigating the concept of physiological cross-tolerance. Specifically, we are investigating how prolonged exposure to one environmental stressor will influence the same responses to another stressor. We are currently most interested in the

Figure 5: Investigating the effect of hypoxic acclimation on exercise performance in a hot enviroment

interactions between heat, hypoxia and metabolic stress (exercise), and their respective effects on human performance, and on the characteristics of autonomic temperature regulation. To this effect we have compared exercise performance in normal temperature normoxic environments, with performance in hypoxic and hot environments, after altitude (4000 m) and heat (35°C) acclimation.

Our hypoxic exercise and confinement studies investigate the potential additive effects of exercise training during intermittent or continuous exposure to hypoxia on appetite regulation, oxidative stress and sleep modulation.

Figure 6: Sweating thermal head manikin

The impetus for these studies is recent evidence that **hypoxia** *per se* **can modify appetite** and thereby modulate body mass and could thus provide a strategy for inducing weight loss and treating metabolic syndrome. This is one of the key priorities of modern research in the field of non-communicable disease prevention, given the fact that the prevalence of obesity is escalating in Europe, particularly among children and adolescents.

Hypoxia associated with high-altitude exposure triggers numerous **cardiovascular adjustments** and can lead to life-threatening conditions. Nowadays, a vast number of high-altitude visitors are potentially more susceptible to the detrimental effects of **hypobaric hypoxia**. In particular, individuals born prematurely might be especially vulnerable due to prematurity induced cardiorespiratory control alternations resulting in **blunted ventilator and cerebrovascular responses to hypoxia**. Within the ARRS-funded project we compared the effect of normobaric and hypobaric hypoxic exercise-induced cardiorespiratory responses in adults that had been born prematurely with results observed in normal-birth individuals. Preliminary data indicates that individuals born prematurely might exhibit reduced ventilatory response at rest, but not during physical activity.

Climate change is the biggest global health threat of the 21st century with enormous consequences for humanity. Rising temperatures have been observed in Europe considerably more than in other areas, and have become a growing challenge for our community. Problems are already experienced by millions of Europeans during summer months, particularly in occupational settings. In addition to the well-known effects of heat exposure, a number of studies have confirmed a 2% reduction in productivity for each degree centigrade above 25°C. Given this productivity loss, **reducing the impacts of rising workplace temperatures** will produce two strategic benefits for EU: i) it will ensure the well-being of EU's workforce, and ii) it will improve the EU's competitiveness and secure its future economy. In the framework of the Horizon 2020 project "Heat Shield" (www.heat-shield.eu) we are collaborating with the industrial partner odelo d.o.o. to mitigate the detrimental effects of heat waves on the workforce in their manufacturing plant. Within the framework of this project we have installed sensors throughout the manufacturing plant at Odelo d.o.o., and provide continuous monitoring of the conditions within the factory, particularly during heat waves. In addition, the workers provide ratings of thermal comfort, temperature sensation and fatigue at regular intervals. Preliminary analyses of the data suggest that the conditions within the factory are constant throughout the year, and that the decrease in productivity observed as a consequence

Figure 7: Compression socks undergoing testing

of heat waves, occurs after the heat wave. This is suggestive of a cumulative effect of heat, more related to an inability to properly recover during the workers' time off work. This is one aim of our investigations in the following year. Within the framework of the Heat Shield project we are also investigating the effect of ambient temperature and humidity on thermal balance, physical performance and cognitive function, particularly with reference to the effect on the productivity of workers in the manufacturing industry. In this regard, we continue to assess the available technologies and various strategies in mitigating heat stress in industrial settings, thus maintaining unhindered performance in hot environments.

With our industrial partner Kimberly-Clark (USA) we continue to investigate novel strategies in the development of **optimal personal protective garments**. A significant step in our human-manikin programme was the development of a **sweating thermal head manikin**, with both visual and breathing functionality. Visual images obtained from cameras situated in the eye sockets of the manikin can be analysed with dedicated software to provide an index of the magnitude of fogging in goggles and/or face masks/visors. Furthermore, the mouth of the manikin is connected to a breathing simulator that monitors the pressure and volume during inspiration and expiration, and calculates the work of breathing imposed by a breathing apparatus. The sweating thermal head manikin is currently being used for evaluating helmets, hoods and breathing apparatus. Additionally, utilising our **sweating thermal hand manikin** we evaluated the thermal and evaporative resistances of new concepts in hand protection for the industrial partner W. L. Gore and Associates (USA & Germany). We are currently developing a new generation of hand manikins for our industrial partner W.L. Gore & Associates.

Some outstanding publications in the past year

1. Z. Potočanac, R. Goljat, and J. Babič (2017) A robotic system for delivering novel real-time, movement dependent perturbations. *Gait & posture*, vol. 58, pp. 386-389.

2.   A. Kramberger, A. Gams, B. Nemec, D. Chrysostomou, O. Madsen, and Ude, A. (2017) Generalization of orientation trajectories and force-torque profiles for robotic assembly. *Robotics and Autonomous Systems*, vol. 98, pp. 333-346.

3.   T. Petrič, C. S. Simpson, A. Ude, and A. J. Ijspeert (2017) Hammering does not fit Fitts' law. *Frontiers in Computational Neuroscience*, vol. 11, pp. 45-1-45-12.

4.   L. Peternel, O. Sigaud, and J. Babič (2017) Unifying speed-accuracy trade-off and cost-benefit trade-off in human reaching movements. *Frontiers in Human Neuroscience*, vol. 11, pp. 615-1-615-14.

5.   I. B. Mekjavić, U. Ciuha, M Grönkvist, and O. Eiken (2017) The effect of low ambient relative humidity on physical performance and perceptual responses during load carriage. *Frontiers in Physiology*, vol. 8, pp. 451-1-451-9

6.   U. Ciuha and I. B. Mekjavić (2017) Thermal comfort zone of the hands, feet and head in males and females. *Physiology & Behavior*, vol. 179, pp. 427-433.

Awards and Appointments

1.   Mišel Cevzar: The Satena award for the best presentation selected by a committee of journalists, Ljubljana, Slovenia, Fitts' Law for Human-Human Collaborative Reaching Task

2.   Mišel Cevzar: Best presentation award chosen by the scientific committee, Ljubljana, Fitts' Law for Human-Human Collaborative Reaching Task

3.   Mišel Cevzar: Award for the best poster selected by audience, Ljubljana, Fitts' Law for Human-Human Collaborative Reaching Task

4.   Bojan Nemec, Leon Žlajpah, Aleš Ude: Best paper in Intelligent Robotics, Hong Kong, China, International Conference on Advanced Robotics (ICAR), Door Opening by Joining Reinforcement Learning and Intelligent Control

Organization of conferences, congresses and meetings

1.   Review meeting of Horizon 2020 project ReconCell, Ljubljana, 5. – 6. 7. 2017.

2.   Workshop at a major robotics conference IROS 2017: Learning for Collaborative Robotics: Enabling Flexible, Redeployable and Agile Industrial Application, Vancouver, Canada, 24. 9. 2017.

3.   Workshop at Humanoids 2017: Exoskeleton design through optimization and adaptive control, Birmingham, UK, 15. 11. 2017.

INTERNATIONAL PROJECTS

1.   Stimulators and Parts
     Prof. Aleš Ude

2.   Kimberly Clark: Stetson and Pillars of Comfort
     Prof. Igor Mekjavić
     Kimberly-Clark

3.   Kimberly-Clark - Development of LCD Shutter in the Year 2017
     Asst. Prof. Leon Žlajpah
     Kimberly-clark

4.   7FP - CoDyCo; Whole-body Compliant Dynamical Contacts in Cognitive Humanoids
     Prof. Jan Babič
     European Commission

5.   COST CA16116 - 20786; Wearable Robots for Augmentation, Assistance or Substitution of Human Motor Functions
     Prof. Jan Babič
     Cost Office

6.   H2020 - HEAT-SHIELD; Integrated Inter-Sector Framework to increase the Thermal Resilience of European Workers in the Context of Global Warming
     Prof. Igor Mekjavić
     European Commission

7.   H2020 - AUTOWARE; Wireless Autonomous, Reliable and Resilient Production Operation Architecture for Cognitive Manufacturing
     Prof. Aleš Ude
     European Commission

8.   H2020 - An.Dy; Advancing Anticipatory Behaviors in Dyadic Human-Robot Collaboration
     Prof. Jan Babič
     European Commission

9.   H2020 - ReconCell; A Reconfigurable Robot Workcell for Fast Set-up of Automated Assembly Processes in SME-s
     Prof. Aleš Ude
     European Commission

10. H2020 - SPEXOR; Spinal Exoskeletal Robot for Low Back Pain Prevention and Vocational Reintegration
     Prof. Jan Babič
     European Commission

11. Control of Bimanual Physical Human-Robot Interaction for Rehabilitation and Industrial Services
     Asst. Prof. Andrej Gams
     Slovenian Research Agency

12. Improving Prediction of Optimization Based Model-Predictive Control for High-Performance Bipedal Robotic Plaforms with Learning of Initial Approximations
     Asst. Prof. Andrej Gams
     Slovenian Research Agency

13. Discovery of the Optimality Criteria for Full Body Human Movements Using Inverse Reinforcement Learning
     Prof. Jan Babič
     Slovenian Research Agency

RESEARCH PROGRAM

1.   Avtomation, robotics and biocybernetics
     Prof. Igor Mekjavić

R & D GRANTS AND CONTRACTS

1.   Cardiorespiratory responses during hypoxic exercise in individuals born prematurely
     Asst. Prof. Tadej Debevec

2.   Learning and autonomous adaptation of dual arm assembly and service tasks
     Prof. Aleš Ude

3.   Methods of algebra and functional analysis in theory and practice of financial mathematics
     Prof. Igor Klep

4.   Building blocks, tools and systems for the Factories of the Future – GOSTOP

Asst. Prof. Igor Kovač
Ministry of Education, Science and Sport
5. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
Asst. Prof. Igor Kovač
Ministry of Education, Science and Sport
6. Testing of Thermal Resistance of Mittens
Prof. Igor Mekjavić
Ministry Of Defence
7. ALT-2 Stimulator Service
Prof. Aleš Ude
8. Stimulators and Parts
Prof. Aleš Ude
9. Customer Service
Prof. Aleš Ude

NEW CONTRACTS

1. Building Blocks, Tools and Systems for Factories of the Future – GOSTOP
Prof. Aleš Ude
NELA razvojni center d.o.o.
2. Building Blocks, Tools and Systems for Factories of the Future – GOSTOP
Prof. Aleš Ude
Podkrižnik d.o.o.
3. Building Blocks, Tools and Systems for Factories of the Future – GOSTOP
Prof. Aleš Ude
Kolektor Group d.o.o.
4. Building Blocks, Tools and Systems for Factories of the Future – GOSTOP
Asst. Prof. Igor Kovač

VISITORS FROM ABROAD

1. dr. Minija Tamosiunate, University of Göttingen, Germany, 12.3.-17.3.2017
2. dr. Mirko Raković, University of Novi Sad, Serbia, 13.3-15.3.2017
3. Jovica Tasevski, University of Novi Sad, Serbia, 13.3-15.3.2017
4. doc. dr. Milutin Nikolić, University of Novi Sad, Serbia, 13.3-15.3.2017
5. dr. Elmar Rueckert, Technische Universität Darmstadt, Germany, 10.4.-12.4.2017
6. prof. Mikael Grönkvist, Royal Institute of Technology, Sweden, 22.5.-24.5.2017
7. Eddie Bergsten, Royal Institute of Technology, Sweden, 22.5.-24.5.2017
8. dr. Kosta Jovanović, University of Belgrade, Serbia, 31.5.–2.6.2017
9. Marija Tomić University of Belgrade, Serbia, 31.5.–2.6.2017
10. Branko Lukić, University of Belgrade, Serbia, 31.5.–2.6.2017
11. Zaviša Gordić, University of Belgrade, Serbia, 31.5.–2.6.2017
12. prof. dr. Balint Farkas, University of Wuppertal, Germany, 11.6.-17.6.2017
13. Elmar Rueckert, Technische Universität Darmstadt, Germany, 11.6.-13.6.2017
14. Cian Mulrooney, Athlone Institute of Technology, Ireland, 12.6.-18.8.2017
15. Frederik Hagelskjær, Mærsk Mc-Kinney Møller Instituttet, Syddansk Universitet, Denmark, 26.6.-7.7.2017
16. dr. Tetyana Ivanovska, University of Göettingen, Germany, 3.7.-6.7.2017
17. James E. Pascoe, Washington University in St. Louis, USA, 7.8.-20.8.2017
18. Luca Marchionni, PAL Robotics, Spain, 22.8.-25.5.2017
19. Jordan Augusto Palacios, PAL Robotics, Spain, 22.8.-25.5.2017
20. Tom Lukas Kriel, Universität Konstanz, Germany, 26.8.-2.9.2017
21. dr. Kunihito Tobita, Osaka Prefecture University, Japan, 1.9.-31.12.2017
22. prof. dr. Gordon Cheng, Technische Universität München – TUM, Germany, 12.10.-13.10.2017
23. Florian Berger, Technische Universität München – TUM, Germany, 12.10.-13.10.2017
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28. Vladimir Šimović, Zagreb University of Applied Sciences, Croatia, 19.10.-20.10.2017
29. Vladimir Šimović, Zagreb University of Applied Sciences, Croatia, 26.10.-27.10.2017
30. Vladimir Šimović, Zagreb University of Applied Sciences, Croatia, 9.11.-10.11.2017
31. Vladimir Šimović, Zagreb University of Applied Sciences, Croatia, 16.11.-17.11.2017
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33. prof. dr. Tamim Asouf, Karlsruhe Institute of Technology, Germany, 22.12.2017

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28. Elias Molina *et al.* (11 authors), "The AUTOWARE framework and requirements for the cognitive digital automation", In: *Collaboration in a data-rich world: 18th IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2017, Vicenza, Italy, September 18-20, 2017: proceedings*, (IFIP advances in information and communication technology, **506**), Luis Camarinha-Matos, ed., Hamideh Afsarmanesh, ed., Rossana Fornasiero, ed., 2017, 107-117.

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32. Luka Peternel, Wansoo Kim, Jan Babič, Arash Ajoudani, "Towards ergonomic control of human-robot co-manipulation and handover", In: *HUMANOIDS 2017*, IEEE-RAS 17th International Conference on Humanoid Robots, November 15-17, 2017, Birmingham, UK, Danvers, IEEE, 2017, 55-60.

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INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

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PATENT APPLICATION

1. Igor Kovač, *Cardan joint,* GB 1706520.2, Intellectual Property Office, 25. 04. 2017.

MENTORING

1. Miha Deniša, *Discovery and synthesis of new robot control policies through search in a hierarchical database of example movements:* doctoral dissertation, Ljubljana, 2017 (mentor Aleš Ude).

2. Aljaž Zalar, *Contributions to a noncommutative real algebraic geometry:* doctoral dissertation, Ljubljana, 2017 (mentor Jaka Cimprič; co-mentor Igor Klep).

The department is engaged in the analysis, control and optimization of systems and processes. The activities of the department are focused on the research of new methods and algorithms for automatic control, the development of procedures and tools to support the design of control systems, the development of specific measurement and control modules, and the development and construction of complete systems for the control and supervision of machines, devices and industrial processes.

Basic and applied research in 2017 was devoted to three sub-areas: methodologies for analysis and control systems design; tools and building blocks for implementation; and applied research in the priority problem domains.

The first topic addressed the *modelling and identification of nonlinear and complex dynamical systems*. The research on methods for the dynamical systems' modelling was pursued in the direction of the development of Gaussian-process models and their use in environmental systems. Online as well as offline methods for system identification based on Gaussian processes were investigated.

The second topic was *advanced control.* We have continued the research and development of model predictive control (MPC) methods by using fast online first-order quadratic programming optimization techniques. We have been developing fast implementations of the advanced MPC controller for the outer loop of plasma current and shape control for the Iter tokamak plasma magnetic control, based on the dual fast-gradient method. These methods would allow the use of such control also on dynamically faster medium-sized tokamaks and for other fast processes, where advanced handling of the constraints on process signals is important. We have also developed an MPC controller for the stabilization of the unstable resistive wall modes in Iter, which appear in certain advanced tokamak operation modes. In this case, the primal fast-gradient method was used due to the much faster system dynamics.

Within the framework of *prognostics and health management*, a novel algorithm for state-of-health estimation and remaining useful life (RUL) prediction, dedicated to solid-oxide fuel cells (SOFCs), was developed. Combining the 1st principle models and measurements on a SOFC system, the algorithm is capable of reconstructing the area-specific resistance (ASR) of the stack, which proves to be an efficient indicator of the system's health, regardless of the operating conditions. Later on, a degradation model, identified from semi-past data, serves for RUL predictions. The estimation of corresponding variables is achieved via non-linear filtering techniques (Figure 1).

In the area **tools and building blocks for implementation** we continued the design of a tool for the analysis and optimization of production performance. We have realized and laboratory tested the architectural design of a system for an on-line analysis of the discrete event data flow. Together with that, an environment for the analysis of the production data through web-services was designed. It integrates various analytical tools like big data platforms, Python libraries, Matlab algorithms, etc.

In collaboration with the University of Arkansas, Fayetteville, the modelling of landscape evolution was conducted. The modelling showed that steady-state topography cannot exist when rock layers are close to the horizontal. The resulting landscape may differ strongly from expectations coming from a landscape equilibrium perspective. For example, stream channels can be steeper in weaker rock layers than in harder rock layers. The finding has been presented in an article in *Earth surface dynamics* and at the GSA Annual Meeting.

In the course of a 3-year programme "Gostop-Building Blocks, tools and systems for factories of the future" we performed activities both on programme management as well as within the framework of R&D projects. We participated in three areas of R&D content. The first area relates to the development of a module to provide 100% quality in a series of finished products using the example of an electric-motors production line. In this regard, trends within the Industry 4.0 concept were taken into account as an important guideline. The second area represents the
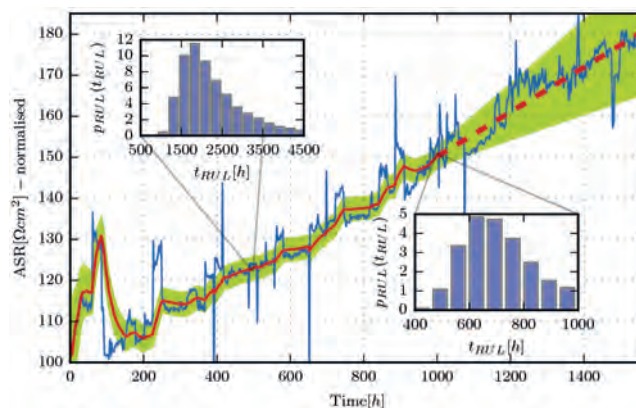

Figure 1: The estimated ASR (blue), its filtered value (red), and a prediction of the future evolution of ASR (dashed red). Due to the stochastic setup, the RUL predictions (purple) come in the form of probability density functions.

Head:
Dr. Vladimir Jovan

development of a system for adaptive production control, also on an example of an electric-motors production line. In this context, the definition of the infrastructure for capturing and storing data from different production steps was performed. The third area covers the development of agents for the synthesis of models from production data and for supporting decision-making based on these models. This activity will be carried out on a sample line for the production of plastomagnetic rotors. A study of current trends and guidelines in the field of technologies relevant to this field was performed. Furthermore, a structural analysis of the production process and the associated information ecosystem was carried out. Two agents are being developed, i.e., a prototype agent for monitoring the state of production equipment, where the functional design of the sensor for the jet tool was performed, and the prototype agent for the real-time monitoring, prediction and improvement of production processes. In the past year, the functions of the MES/MOM system were defined and its architectural design was defined. For this purpose, a platform for production data analysis through pre-prepared web services and a system for online data analysis are under development and laboratory testing.

Applied research in the priority problem domains was the third sub-area of our interest. For the Slovenian Research Agency project Method for the forecasting of local radiological pollution of atmosphere using Gaussian process models we have started with the evaluation of meteorological forecasts and the identification of key deficiencies in pollution dispersion modelling and with the evaluation of different Gaussian-process-based modelling methods for the identification of models useful for forecasting the variables under consideration.

Figure 2: Project DIAMOND - Experimental validation of the supervisory optimizer

Figure 3: Diagnostic system on ML-14 assembly line at Domel d.o.o.

In the area of *condition monitoring, prognostics and health management* (CM&PHM) of the rotational machines the foundations of an embedded system for on-line monitoring of the vital components of mechanical drives have been laid down. The concept builds on local signal processing for feature extraction and then fusion of the features for the sake of final diagnosis and prognosis of the remaining useful life. Together with the team from the company Domel, the partner in this development project, we completed a novel test rig for bearings lifelong tests and executed a series of experiments on 12 bearings.

Within the "State-of-health estimation of electrochemical energy systems", funded by the Slovenian Research Agency, activities can be divided into two segments: performing long-term experiments and the development of models for an estimation of the remaining useful life. In 2017 we successfully performed initial experiments on the test bed developed within the project. Additionally, in cooperation with the Technical University of Graz, we have performed experiments on SOFCs too. Activities on the segment of model development were focused on the implementation of numerical tools for the simulation and parameter identification of fractional order models. These models are applicable for describing diffusion processes that are the governing processes for fuel cells. For that purpose we have started an active collaboration with a research group from Johannes Kepler University from Linz, Austria.

International R&D projects

In 2017 we successfully concluded the development within the 3-year EU FW7 project "Diamond - Diagnosis-aided control for SOFC power systems". The supervisory optimizer was implemented on a programmable logic controller and tested on a 5-kW SOFC power system. The optimizer was in charge of solving a constrained optimisation problem where various instances of the criterion function included electrical efficiency and/or degradation rate. In the experiment carried out on site, the objective of the optimizer was to minimise the degradation rate of the cells by manipulating the stack temperature. In spite of the short duration of the experiment, caused by a too rapid deterioration of the stack, the proposed optimizer returned promising initial results (Figure 2).

In the framework of the 3-year project "Fast Model Predictive Control for Magnetic Plasma Control - FMPCFMPC", "Enabling Research" activity of the EUROfusion Work Programme 2015 (part of Horizon 2020 / Euratom), we have been collaborating with the consortium ENEA/CREATE from Naples, Italy. The aim of the project is to apply novel,

fast MPC approaches to plasma magnetic control for the Iter tokamak, where MPC is currently not applicable due to the large-scale multivariable nature of the problem and a sub-second sampling rates. In the final project year, the emphasis was on the stabilization of resistive wall modes.

The scope of an international project H2020 "Memphys - MEMbrane based Purification of HYdrogen System" is the development of an electro-chemical system for hydrogen compression and cleaning using membranes, similar to the ones, used in PEM fuel cells. The electrochemical compression has no moving parts, it is driven by electricity and it has higher energy efficiency than mechanical compressors. The task of the Department of Systems and Control is the design of the hardware and the software for the control and diagnostic system, which will estimate the process condition by the system identification methods. The activities of the last year were focused on the preparation of the experimental setup.

A new H2020 project INSIGHT has been started in cooperation with the leading academic and industrial players in the domain of SOFCs. The project is aimed to develop the efficient tools for on-line health monitoring of a SOFC stack, detection and isolation of the evolving degradation mechanisms and design of the accommodation actions. The IJS team contributes an innovative approach to the characterisation of SOFCs based on dynamic response to the persistently excited stack and the identified mathematical model in terms of the lumped fractional order differential equations.

Research in the domain of degradation monitoring of solid-oxide electrolysis cells is conducted in cooperation with CEA, Grenoble. To better understand anode delamination, numerical modelling of a single, electrolyte supported, solid oxide electrolysis cell (SOEC) was performed in the COMSOL Multiphysics environment. The proposed model is an efficient tool to analyse the hot spots of current density, where a high pressure of oxygen possibly appears and hence accelerates the degradation rate. The simulation results show that increasing the area of the delaminated anode increases the operating voltage and decreases the conversion efficiency of the SOEC.

Based on the existing references, a contract for the development of the control system for the 100-kW natural-gas fuel-cell cogeneration unit (CHP) was signed with the *Institute Fraunhofer ICT IMM* (Institut Mikromechanic Mainz). Our task is the definition of the control system specification, the development of the control system software and the support during commissioning and optimization of the system. The project will result in fully functional demonstration system with an emphasis on the high efficiency, which will be achieved by thermal integration and optimal control.

Figure 4: Matching of the SBR model with the measurements

Applied work

In the course of our long-term partnership with Danfoss Trata d.o.o in 2017 we continued to develop hardware and software for three families of valve drives. The smart drives will be able to reduce the oscillations in the system by reducing the operating pressure. They will also have other functionalities, including a communication interface that will be used in both HVAC systems and in district heating systems.

A diagnostic system for the assembly line ML13 of the DOMEL Company was upgraded with new functionalities, dedicated to new types of motors. Namely, the production range of the line was upgraded by small suction units, used by the Wagner GmBH for paint sprayers. The upgrade required the design of smaller velocity sensors, adaptation of the velocity controllers, addition of special supervision algorithm and expansion of diagnostic features. The second functionality – classification of the produced units into quality classes required development of new modules for information-communications system.

A fully automatic diagnostic system for electronically commutated (EC) motors was designed and put into operation on the assembly line ML14. The main customers of this production line are the VTS Group and Gorenje. The main R&D efforts were dedicated to a diagnosis of the interplay between the electromechanical part and the electronic part of the product under test. The diagnostic system (Figure 3) together with other manipulation systems that were appointed to us to develop are tightly coupled with many of the Domel's ICT systems. As such this work is seen as the corner stone of the future Domel's smart factory.

A new diagnostic system on the assembly line ML15 was designed and put into the operation. It supports the quality assessment of high-performance and low-power suction units for vacuum cleaners of the Kaercher Company. Our R&D work supports the pioneering role of DOMEL in the manufacturing of highly efficient electronically com-
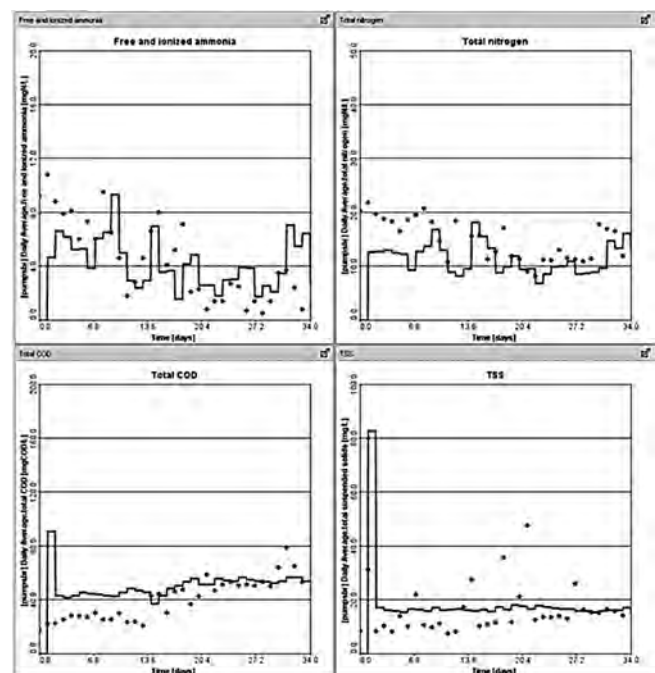
Figure 5: Ceremony of awarding Puh's acknowledgments for the most important development achievements in 2017

mutated motors in this field of application. Here, basic R&D efforts were given into the diagnostics of the interplay of the electromechanical and the electronic part of the product.

Another project in Domel d.o.o was installed in their unit PE ECS. During 2017 we have performed a major upgrade on the line for end-quality control. The line was upgraded from the initial hand manipulated one into a semi-automatic version. Additionally, we have upgraded the measurement loops as well as the algorithms for fault detection. Furthermore, we performed upgrades on the system for production tracking. The upgraded version of the system allows the aggregation of quality data from various measurement points along the production line into one overall assessment of the products quality. For the complete systems we were awarded the Puch Award for 2017.

The mathematical model of the sequential batch reactor (SBR) technology of the Domžale-Kamnik wastewater treatment plant (WWTP) was developed in GPS-X software. It is a technology with four batch reactors that alternately operate in 3-hour cycles. The model shows a relatively good agreement with the measurements (Figure xxxx). Simulation analyses indicate that the SBR is very sensitive to aeration of the reactors and waste sludge removal, low organic carbon load deteriorates denitrification process and operation with only three reactors deteriorates nitrification process.

Educational and training activities

Some members of the department are giving lectures and practical courses at different faculties and universities: the Faculty of Electrical Engineering, University of Ljubljana, the Faculty of Logistics, University of Maribor, the University of Nova Gorica and the "Jožef Stefan" International Postgraduate School. They also act as the supervisors of four Ph.D. students.

Some outstanding publications in the past year

1. Pregelj, Boštjan, Debenjak, Andrej, Dolanc, Gregor, Petrovčič, Janko. A diesel-powered fuel cell APU: reliability issues and mitigation approaches. *IEEE transactions on industrial electronics*, ISSN 0278-0046. [Print ed.], 2017, vol. 64, no. 8, pp. 6660-6670
2. Dolanc, Gregor, Pregelj, Boštjan, Petrovčič, Janko, Samsun, Remzi Can. Control of an afterburner in a diesel fuel cell power unit under variable load. *Journal of power sources*, ISSN 0378-7753, 2017, vol. 338, pp. 117-128
3. Dolenc, Boštjan, Vrečko, Darko, Juričić, Đani, Pohjoranta, Antti, Pianese, Cesare. Online gas composition estimation in solid oxide fuel cell systems with anode off-gas recycle configuration. *Journal of power sources*, ISSN 0378-7753, 2017, vol. 343, pp. 246-253
4. Dolenc, Boštjan, Boškoski, Pavle, Stepančič, Martin, Pohjoranta, Antti, Juričić, Đani. State of health estimation and remaining useful life prediction of solid oxide fuel cell stack. *Energy conversion and management*, ISSN 0196-8904. [Print ed.], 2017, vol. 148, pp. 993-1002
5. Boškoski, Pavle, Debenjak, Andrej, Mileva-Boshkoska, Biljana. Rayleigh copula for describing impedance data - with application to condition monitoring of proton exchange membrane fuel cells. *European journal of operational research*, ISSN 0377-2217

Some outstanding achievements in the past year

1. The Puh award 2017 for development achievements was awarded to our Department members Dr. Pavle Boškoski, Dr. Bojan Musizza and Dr. Andrej Debenjak, and our partners from Domel company (Figure 5)
2. The book entitled "*Fast electrochemical impedance spectroscopy as a statistical condition monitoring tool*", authored by Pavle Boškoski and Andrej Debenjak (our Department members) and Biljana Mileva Boshkovska, has appeared in the Springer series „ Springer Briefs in Applied Sciences and Technology „
3. The department member Tomaž Kos was awarded with the PCT technology network award (Process Control Technology) for his Master's thesis entitled „Measurement system for automated low-frequency and high-temperature characterization of dielectric materials"
4. Two new projects in the field of the development of hydrogen technologies (Memphys, Insight) have started in 2017 within the scope of Horizon 2020 programme (Fuel Cells and Hydrogen Joint Undertaking)

Awards and appointments

1. Pavle Boškoski, Bojan Musizza, Andrej Debenjak and DOMEL company (Damjan Demšar, Jernej Tomažin, Janez Urh, Miha Kržišnik in Marjan Kavčič): received the Puh award for 2017. This is the highest state award for development achievements issued by the Ministry of Education, Science and Sport within the Zois awards - the state highest awards for scientific and research achievements. The award was bestowed for an adaptive system for the quality control of blowers and production tracking.
2. Tomaž Kos: was awarded with the PCT technology network award (Process Control Technology) for his Master's thesis entitled "Measurement system for automated low-frequency and high-temperature characterization of dielectric materials".

INTERNATIONAL PROJECTS

1. 7FP - FLUMABACK; Fluid Management Component Improvement for Back up Fuel Cell Systems
   Dr. Pavle Boškoski
   European Commission
2. 7FP - DIAMOND; Diagnosis-aided Control for SOFC Power System
   Prof. Đani Juričić
   European Commission
3. 7FP - FCGEN; Fuel Cell Based On-board Power Generation
   Dr. Boštjan Pregelj
   European Commission
4. H2020 - MEMPHYS; Membrane based Purification of Hydrogen System
   Dr. Gregor Dolanc
   European Commission
5. H2020 - INSIGHT; Implementation in Real SOFC Systems of Monitoring and Diagnostic Tools Using Signal Analysis to Increase their Lifetime
   Prof. Đani Juričić
   European Commission
6. H2020 EUROfusion - Fast Model Predictive Control for Magnetic Plasma Control - FMPCFMPC, ER-3-FU
   Dr. Samo Gerkšič
   European Commission
7. Non-invasive Condition Monitoring of High Temperature Steam Electrolyser
   Prof. Đani Juričić
   Slovenian Research Agency

RESEARCH PROGRAM

1. Program systems and control
   Prof. Đani Juričić

R & D GRANTS AND CONTRACTS

1. State-of-health prognostics of electrochemical energy systems
   Dr. Pavle Boškoski
2. E-maintenance of electro-mechanical drives: prognostics and health management solutions under non-stationary operating conditions
   Prof. Đani Juričić
3. Method for the forecasting of local radiological pollution of atmosphere using Gaussian process models
   Prof. Juš Kocijan
4. Building blocks, tools and systems for the Factories of the Future – GOSTOP
   Dr. Vladimir Jovan
   Ministry of Education, Science and Sport
5. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
   Dr. Vladimir Jovan
   Ministry of Education, Science and Sport
6. Development of the Control System for the Gas Fuel Processor / Fuel Cell System (Phase 1)
   Dr. Gregor Dolanc
   Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung

NEW CONTRACTS

1. Design and assembly of diagnostic system for quality assessment of the 771 family of brushless motors
   Dr. Janko Petrovčič
   Domel, d. o. o.
2. Upgrade of DSML13 Diagnostic System
   Dr. Andrej Debenjak
   Domel, d. o. o.
3. Diagnostic line for the end-quality control of electronically commutated blowers
   Dr. Pavle Boškoski
   Domel, d. o. o.
4. Simulation study of the operation of the sequencing batch reactors at the Domžale-Kamnik wastewater treatment plant
   Dr. Darko Vrečko
   JP Cčn Domžale-Kamnik d. o. o.
5. Upgrade of Communication Capabilities on the Assembly Line Ml-13
   Dr. Andrej Debenjak
   Domel, d. o. o.
6. Modification of the iSET Functionality
   Asst. Prof. Damir Vrančić
   Danfoss Trata, d. o. o.
7. Design and Assembly of the Electrical and Control Cabinet for the Diagnostic System on line ML-15
   Dr. Janko Petrovčič
   Domel, d. o. o.
8. Upgrade of Diagnostic System on the Assembly line ML-13 - Electrical and Control Part
   Dr. Janko Petrovčič
   Domel, d. o. o.
9. Upgrade of Diagnostic System on the Assembly line ML-14 - Electrical and Control Part
   Dr. Janko Petrovčič
   Domel, d. o. o.
10. Development and Manufacture of the USB-AKO Communication Converter
    Dr. Andrej Debenjak
    Domel , d. o. o.
11. Functional upgrades on existing diagnostics systems for on-line analysis of operating characteristics and vibration measurement of motors
    Dr. Janko Petrovčič
    Domel, d. o. o.
12. Development of the new family of dpMA and MD valve actuators
    Asst. Prof. Damir Vrančić
    Danfoss Trata, d. o. o.
13. Co-financing project: Method for the forecasting of local radiological pollution of atmosphere using Gaussian process models
    Prof. Juš Kocijan
    Reodom d. o. o.
14. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"
    Dr. Dejan Gradišar
    TECOS
15. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"
    Dr. Pavle Boškoski
    LPKF Laser & Electronics d.o.o.
16. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"
    Dr. Pavle Boškoski
    Špica International d.o.o.
17. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"
    Dr. Giovanni Godena
    Yaskawa Slovenija d.o.o.
18. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"
    Dr. Bojan Musizza
    Optotek d.o.o.
19. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"
    Dr. Bojan Musizza
    L-TEK d.o.o.
20. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"

Dr. Vladimir Jovan
Fotona d.o.o.

21. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"
Prof. Đani Juričić
University of Maribor

22. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"
Dr. Pavle Boškoski
Kolektor Group d.o.o.

23. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"
Prof. Đani Juričić
Inea d.o.o.

24. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories

of the Future"
Dr. Pavle Boškoski
Cosylab, d.d.

25. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"
Dr. Pavle Boškoski
NELA razvojni center d.o.o.

26. Contract for the program „GOSTOP: Building Blocks, Tools and Systems for Factories of the Future"
Dr. Bojan Musizza
Podkrižnik d.o.o.

27. Development of Programme Modules for „Podkrižnik" Company
Dr. Bojan Musizza
Podkrižnik d.o.o.

VISITOR FROM ABROAD

1. Armando Salvati, University of Salerno, Fisciano (SA), Italy, 1 January to 28 February 2017
2. Ilaria La Rocca, University of Salerno, Fisciano (SA), Italy, 6 February to 6 June 2017
3. Ornella Cannavacciuolo, University of Salerno, Fisciano (SA), Italy, 6 February to 6 June 2017
4. Vanja Subotić, Technische Universität Graz, Graz, Austria, 18 October 2017
5. Dr Nicole Gehring, Johannes Kepler University, Linz, Austria, 21–30 October 2017

STAFF

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1. Dr. Pavle Boškoski
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4. Dr. Giovanni Godena
5. Dr. Dejan Gradišar
6. Dr. Nadja Hvala
7. **Dr. Vladimir Jovan, Head**
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9. Prof. Juš Kocijan
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12. Dr. Matija Perne
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27. Miroslav Štrubelj

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Darko Belavič, Andraž Bradeško, Tomaž Kos, Tadej Rojac, "Design and integration of a piezoelectric vibrating device in an LTCC structure", *Microelectron. int.*, **34**, 3, 121-126, 2017.
2. Marija Božnar, Boštjan Grašič, Primož Mlakar, Dejan Gradišar, Juš Kocijan, "Nonlinear data assimilation for the regional modeling of maximum ozone values", *Environ. sci. pollut. res. int.*, **24**, 31, 24666-24680, 2017.
3. Marija Božnar, Boštjan Grašič, Primož Mlakar, Dejan Gradišar, Juš Kocijan, "The use of a new diagram for the analysis of the daily cycles in the air-pollution data", *Int. j. environ. pollut.*, **62**, 2/4, 385-394, 2017.
4. Gregor Dolanc, Boštjan Pregelj, Janko Petrovčič, Remzi Can Samsun, "Control of an afterburner in a diesel fuel cell power unit under variable load", *J. power sources*, **338**, 117-128, 2017.
5. Boštjan Dolenc, Pavle Boškoski, Martin Stepančič, Antti Pohjoranta, Đani Juričić, "State of health estimation and remaining useful life prediction of solid oxide fuel cell stack", *Energy convers. manage.*, **148**, 993-1002, 2017.
6. Boštjan Dolenc, Darko Vrečko, Đani Juričić, Antti Pohjoranta, Cesare Pianese, "Online gas composition estimation in solid oxide fuel cell systems with anode off-gas recycle configuration", *J. power sources*, **343**, 246-253, 2017.
7. Nadja Hvala, Darko Vrečko, Meta Levstek, Cirila Bordon, "The use of dynamic mathematical models for improving the designs of upgraded wastewater treatment plants", *J. sustain. dev. energy water environ. syst.*, **5**, 1, 15-31, 2017.
8. Danjela Kuščer, Tadej Rojac, Darko Belavič, Marina Santo-Zarnik, Andraž Bradeško, Tomaž Kos, Barbara Malič, Marcel Boerrigter, Diego Morrilo Martin, Mirko Faccini, "Integrated piezoelectric vibration system for fouling mitigation in ceramic filtration membranes", *J. membr. sci.*, **540**, 277-284, 2017.
9. Primož Mlakar, Dragana Kokal, Boštjan Grašič, Marija Božnar, Dejan Gradišar, Juš Kocijan, "Validation of meteorological forecasts in fine spatial and temporal resolution produced as an input for dispersion models", *Int. j. environ. pollut.*, **62**, 2/4, 236-246, 2017.
10. Marko Nerat, "Modeling and analysis of short-period transient response of a single, planar, anode supported, solid oxide fuel cell during load variations", *Energy (Oxford)*, **138**, 728-738, 2017.
11. Matija Perne, Matt Covington, Evan Thaler, Joseph M. Myre, "Steady state, erosional continuity, and the topography of landscapes developed in layered rocks", *Earth surface dynamics*, **5**, 85-100, 2017.
12. Boštjan Pregelj, Andrej Debenjak, Gregor Dolanc, Janko Petrovčič, "A diesel-powered fuel cell APU: reliability issues and mitigation approaches", *IEEE trans. ind. electron.*, **64**, 8, 6660-6670, 2017.
13. Gregor Primc, Alenka Vesel, Gregor Dolanc, Damir Vrančić, Miran Mozetič, "Recombination of oxygen atoms along a glass tube loaded with a copper sample", *Vacuum*, **138**, 224-229, 2017.

PUBLISHED CONFERENCE CONTRIBUTION

1. Darko Belavič, Katarina Vojisavljević, Danjela Kuščer, Tanja Pečnik, Jerzy Zając, Adrian Anghelescu, George Muscalu, Marjan Hodnik, Tomaž Kos, Silvo Drnovšek, Barbara Malič, "Ceramic packaging of PiezoMEMS

devices", In: *European Microelectronics Packaging Conference, EMPC 2017, 10-13 September 2017, Warsaw, Poland.*

2. Pavle Boškoski, Boštjan Dolenc, Bojan Musizza, Đani Juričić, "Model-based prediction of the remaining useful life of the machines", In: *Proceedings of the 20th IFAC World Congress, 9-14 July 2017, Toulouse, France*, (IFAC papersOnline, **50**), New York, International Federation of Automatic Control = IFAC, 2017, **50**, 1, 12803-12808.

3. Boštjan Dolenc, Pavle Boškoski, Antti Pohjoranta, Matti Noponen, Đani Juričić, "Hybrid approach to remaining useful life prediction of solid oxide fuel cell stack", In: *SOFC-XV, 15th International Symposium on Solid Oxide Fuel Cells, July 23, 2017 - July 28, 2017, Hollywood, FL,* Subhash C.Singhal, ed., T. Kawada, ed., *ECS transactions*, **78**, 1, 2251-2264, 2017.

4. Nadja Hvala, Darko Vrečko, Cirila Bordon, "Assessment of upgraded full-scale wastewater treatment plant performance through a plant-wide modelling approach", In: *Proceedings*, fFrontiers International Conference on Wastewater Treatment (FICWTM), May 21-24, 2017, Palermo, Italy, Giorgio Mannina, ed., [S. l.], IWA = International Water Association, 2017, 896-902.

5. Juš Kocijan, Gorazd Karer, Mojca Žagar Karer, Tadej Bajd, Rihard Karba, "The Slovenian dictionary of automatic control, systems and robotics", In: *Proceedings of the 20th IFAC World Congress, 9-14 July 2017, Toulouse, France*, (IFAC papersOnline, **50**), New York, International Federation of Automatic Control = IFAC, 2017, **50**, 1, 5166-5171.

6. Matija Perne, Samo Gerkšič, Boštjan Pregelj, "Local decay of residuals in dual gradient method applied to MPC studied using active set approach", In: *Proceedings of the 14th International Conference on Informatics in Control, Automation and Robotics, July 26-28, 2017, Madrid, Spain*, ICINCO 2017, Oleg Gusikhin, ed., Kurosh Madani, ed., Setúbal, Science and Technology Publications, 2017, zv. 1, 54-63, 2017.

7. Martin Stepančič, Juš Kocijan, "On-line identification with regularised Evolving Gaussian process", In: *IEEE EAIS 2017: Conference on Evolving and Adaptive Intelligent Systems, May 31 - June 2, 2017, Ljubljana, Slovenia*, Conference on Evolving and Adaptive Intelligent Systems, May 31 - June 2, 2017, Ljubljana, Igor Škrjanc, ed., Sašo Blažič, ed., [Sl. l.], IEEE, 2017.

8. Damir Vrančić, Paulo Moura Oliveira, Jan Cvejn, "The model-based disturbance rejection with MOMI tuning method for PID controllers", In: *CONTROLO 2016: proceedings of the 12th Portuguese Conference on Automatic Control, September 14th to 16th, Guimarães, Portugal*, (Lecture notes in electrical engineering, **402**), Paulo Garrido, ed., Filomena Soares, ed., António Paulo Moreira, ed., 2017, 81-91.

9. Darko Vrečko, Marko Nerat, Damir Vrančić, Gregor Dolanc, Boštjan Dolenc, Boštjan Pregelj, Fabien Meyer, Siu Fai Au, Robert Makkus, Đani Juričić, "Improving operation of a 2.5kW SOFC power system with supervisory control", In: *SOFC-XV, 15th International Symposium on Solid Oxide Fuel Cells, July 23, 2017 - July 28, 2017, Hollywood, FL,* Subhash C.Singhal, ed., T. Kawada, ed., *ECS transactions*, **78**, 1, 2017.

Independent Component Part or a Chapter in a Monograph

1. Tamara Fernández-Arévalo, Xavier Flores-Alsina, Paloma Grau, Ulf Jeppsson, Miguel Mauricio-Iglesias, Darko Vrečko, Eduardo Ayesa, "Model-based comparative assessment of innovative processes", In: *Innovative wastewater treatment & resource recovery technologies: impacts on energy, economy and environment*, Juan M. Lema, ed., Sonja Suarez Martinez, ed., London, IWA Publishing, 2017, 599-621.

Scientific Monograph

1. Pavle Boškoski, Andrej Debenjak, Biljana Mileva-Boshkoska, *Fast electrochemical impedance spectroscopy: as a statistical condition monitoring tool*, (Springer briefs in applied sciences and technology), Cham, Springer, 2017.

Mentoring

1. Boštjan Dolenc, *Condition monitoring, prognosis, and life extending control for solid oxide fuel cells:* doctoral dissertation, Ljubljana, 2017 (mentor Đani Juričić; co-mentor Pavle Boškoski).

ARTIFICIAL INTELLIGENCE LABORATORY

E-3

The Artificial Intelligence Laboratory (http://ailab.ijs.si/) is concerned mainly with the research and development of information technologies, with an emphasis on artificial intelligence. Our main areas of research are: data analysis with an emphasis on text, web and cross-modal data, scalable real-time data analysis, machine learning, analysis and modelling of large networks, visualization of complex data, semantic technologies, language technologies, reasoning methods and knowledge management. The Artificial Intelligence Laboratory has employees and students with an international background and expertise in different areas of artificial intelligence. In addition to publishing their research results in international publications and presenting their work at international events, our researchers have also developed numerous software tools for multimodal data analysis. These tools include: Text-Garden, a suite of text-mining tools; OntoGen (http://ontogen. ijs.si/), a tool for ontology learning; Document-Atlas (http://docatlas.ijs.si/), a tool for complex visualization; Atlas of Slovenian Science (http://scienceatlas.ijs.si/), a web portal for analyzing the scientific community; Enrycher (http://enrycher.ijs.si/), a system for the semantic enrichment of textual data; SearchPoint (http://searchpoint.ijs.si/), a portal for visual and contextualized web browsing; OntoPlus, a methodology for semi-automatic ontology extension; Contextify (http:// contextify.net/), a tool for contextualized e-mail and contact management; Qminer (http:// qminer.ijs.si/), a data-analytics platform for processing large-scale real-time streams containing structured and unstructured data; NewsFeed (http://newsfeed.ijs.si/), a clean, continuous, real-time aggregated stream of semantically enriched news articles from RSS-enabled sites across the world; iDiversiNews (http://aidemo.ijs.si/diversinews/), a system for the processing and visualization of news; EventRegistry (http://eventregistry.org/), a system for identifying world events in news media; Twitter Observatory (http://twitterobservatory.net/), a system for the analysis of selected tweets; Wikifier (http://wikifier.org), a system for annotating documents with links to relevant Wikipedia pages; StreamStory (http://streamstory.ijs.si), an exploratory data-stream-analysis tool offering an alternative type of visualization by representing the multivariate data stream using a Markovian model; Videolectures Explorer (http://explore.videolectures.net/), a tool enabling users to search through the videolectures and find similarities between them; EDSA dashboard (http://jobs. videolectures.net/policymakers), a tool aggregating demand data (job postings around Europe) and supply data (training materials) in data science; nextPin (http://traffic.ijs.si/NextPin/?user=demo), a system for the analysis of time-varying data of geographic locations. The laboratory's strategy is to combine scientific excellence with strong industrial collaboration, enabling the transfer of research results into real-world business environments.

Head:
Prof. Dunja Mladenić

In the past 15 years, members of the Artificial Intelligence Laboratory have successfully participated in 49 EU projects, of which 5 were concluded in 2017 and 12 were still ongoing. In 2017, we were also involved in 11 national projects and 5 industrial project.

Our work in industrial projects has resulted in a successful collaboration with Telekom Slovenia and Petrol in the development of probability models for nonpayment and credit limits using data mining and statistical methods. Experience from the FP6 and FP7 projects NRG4CAST and Sunseed has been successfully upgraded into collaboration with Iskratel, where we have developed an autonomous platform for forecasting energy usage in smartgrids based on heterogeneous streams of data.

In 2017, in the area of **statistical data modelling and machine learning** our work focused on three EU H2020 projects and one national ARRS project. In the H2020 EU project, **OPTIMUM** *(Multi-source Big Data Fusion Driven Pro-activity for Intelligent Mobility)*, our team is building a scalable big-data traffic infrastructure platform that serves more than 40

Jure Leskovec, a member of the AILab and a professor at Stanford University, has published a paper in the journal Nature.

traffic-related APIs with data from Slovenia and the EU, both from the project consortium and the public at large. Part of this data infrastructure is used commercially, running inside the project partner's premises, serving their data. As part of the project, we also continue to build a personal pattern-detection and prediction service, which was extended to provide route analytics for individuals as well as groups of users. In an experimental setting, it already

has approximately 10,000 units sending GPS locations in real-time. This service is becoming the main geo-spatial analytics driver inside OPTIMUM, also in use by other projects. As part of the OPTIMUM project and our ongoing collaboration with the Department for Communication Systems (E6) and Adria Mobil, we are also collaborating on developing custom hardware that will allow the users to control and communicate with motor-homes, which today are becoming smart-connected vehicles. Within the H2020 Marie Skłodowska-Curie ITN project **BigDataFinance** (*Training for Big Data in Financial Research and Risk Management*) two doctoral students continued to work on two projects entitled "Deep Knowledge Extraction from Financial, Business, and Social Text" and "Characterising Financial Markets from Event-driven Perspective". In 2017, BigDataFinance implemented two training events and one conference. The first training event, entitled "Complex Financial Networks", took place at the University of Zurich in Switzerland. The second, entitled "Textual Data in Finance", was organised by our department and took place in Dubrovnik, Croatia.

A paper written by James Hodson, a member of the AILab and a PhD student within the BigDataFinance ITN, received multiple international prizes: Winner of the Jack Treynor Prize from the Institute for Quantitative Research in Finance *and* Second place in the 2017 PanAgora Asset Management Dr. Richard A. Crowell Memorial Prize.

The BigDataFinance conference was organised in London, UK and attracted many renowned speakers. The two doctoral students also completed individual secondments in Zurich, Switzerland with the Swiss Fintech company OLSEN, which is building a global blockchain-powered marketplace, and Aarhus, Denmark with the Centre for Research in Econometric Analysis of Time Series at Aarhus University. Finally, a paper written by one of the students received multiple international prizes (winner of the Jack Treynor Prize from the Institute for Quantitative Research in Finance and second place in the 2017 PanAgora Asset Management Dr. Richard A. Crowell Memorial Prize). In 2017, we have successfully completed the first year of the **PrEstoCloud** (*Proactive Cloud Resources Management at the Edge for Efficient Real-Time Big Data Processing*) project. The goal of the project is to develop a software architecture for the processing of big-data streams with the intelligent allocation of computational resources. We have already started research on the mobility data provided by one of the project use-case partners. In 2017, our Laboratory is also leading the ARRS project **TOPREP** (*Learning Topological Representations*) which is the result of a second-round ERC Starting Grant proposal. The goal of the project is to not only identify clusters based on local structure called strata but also how they fit together using computational topology. This has applications in machine learning and is especially important for time-varying systems, where tipping points can be thought of as the meeting point between two strata. In 2017, the project had several notable research results including "An Approximate Nerve Theorem" published in the Foundations of Computational Mathematics, which relates how local error can affect global error for persistent homology. A new result that proves the Wasserstein stability theorem, a much stronger stability than was previously known was submitted to the Symposium of Computational Geometry. This has important implications for understanding statistical estimators. Finally, work was begun on homological percolation, which looks at higher-dimensional emergent behaviour in random processes.

In the areas of **text and network analysis** and **language technologies**, our department, together with the Department of Knowledge Technologies (E8), continued to lead the Slovenian research infrastructure **CLARIN.SI**, which provides easy publication and sustainable access to digital language data for scholars in the humanities and social sciences. In addition to providing support for the CLARIN.SI repository, we contributed Slovene data for the shared task on automatic identification of verbal Multi-Word Expressions and worked on annotation of Semantic Role Label system for Slovene. We are also leading the ARRS project *New grammar of contemporary standard Slovene: sources and methods,* which began in 2017. The project aims to explore linguistic methodological foundations of a complex analysis of written and spoken Slovene, as found in the new corpora developed in recent projects. The resulting methodology and data will provide a sound foundation for future work on an empirically based description of Slovene. Following from the methodology, we intend to compile and publish extensive collections of extracted material from corpora that will be useful for the development of language technology applications for Slovene. The extracted data will be used for the linguistic analysis of real language, which represents the first step towards the compilation of a new descriptive corpus grammar of Slovene.
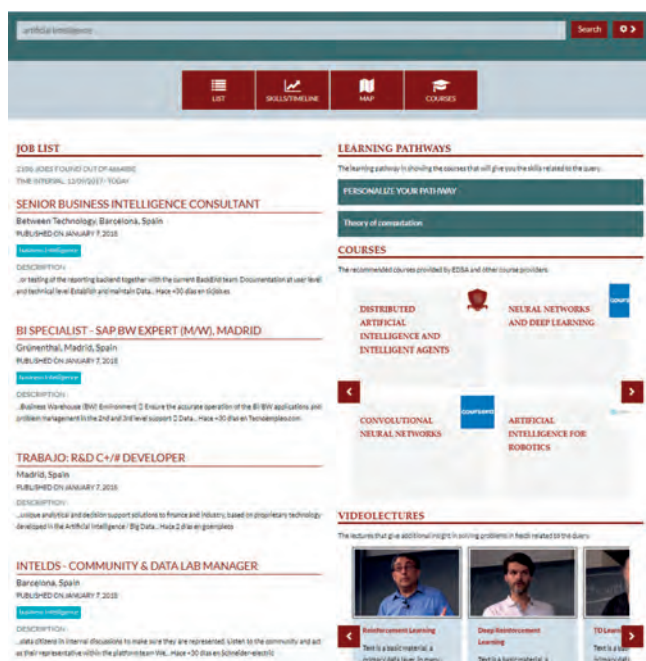

Figure 1: The dashboard aggregating demand and supply data on the topic of data science. The figure shows relevant job positions, courses and learning materials for the query "artificial intelligence".

In the area of **semantic technologies,** the team's work has focused on four European projects. In 2017 the EU FP7 project **ProaSense** (*The Proactive Sensing Enterprise*) successfully concluded. The project demonstrated the application of analytical and decision-making services to optimize the production process in an enterprise environment. Within the project, we developed tools for multivariate data-stream exploration, prediction and anomaly detection. Within the H2020 Marie Skłodowska-Curie RISE project **RENOIR** (*Reverse engineering of social information processing*), we completed 15 secondments to institutions such as Stanford University and Carnegie Mellon in the US as well as Nanyang Technological University in Singapore. Our work in 2017, focused on an analysis of social dynamics from structured and unstructured data. One domain of study is the prediction of future actions of individuals from their past behaviour in a large communication network. We also analysed the differences in sentiment of news coverage of the same events between different news publishers. Finally, we are using data from *Event Registry* to build common chains of related events with the aim of inferring event consequences. The Horizon 2020 project **euBusinessGraph** (*Enabling the European Business Graph for Innovative Data Products and Services*) started in January 2017. The aim of the project is to build a European cross-lingual "business graph" that will aggregate, link and provision high quality company-related data over which the user will be able to perform searches and business analytics with the help of artificial intelligence. In the past year, our work on the project consisted of collecting and preparing the data of companies, which we included in our Wikifier tool. We continued our work with the preparation of algorithms for finding relationships between data, which will enable us to provide complex business analytics over the collected data in the business graph. As members of the H2020 innovation action project **EW-Shopp** (*Supporting Event and Weather-based Data Analytics and Marketing along the Shopper Journey*), we are building a platform for supporting data-driven e-commerce. The platform enables businesses to integrate their data with contextual information about weather and events and use analytics on this data to power their services. Our chief role is to design and implement the machine-learning functionality of the platform. Furthermore, we are contributing the *Event Registry* system, which is used as the source of event data. The project has a large number of international business partners including three Slovenian companies - Ceneje.si, Big Bang and CDE.

> **In collaboration with the Centre for Knowledge Transfer in Information Technologies (CT3), the Laboratory of Artificial Intelligence participated in the organization of the 2nd World Open Educational Resources (OER) Congress, September 2017 in Ljubljana. The Congress closed as experts and national delegates from 111 countries adopted by acclamation the 2017 Ljubljana OER Action Plan.**

In the area of knowledge management, the group's main focus, includes research and development by using methods and tools from a broader Artificial Intelligence area in real business settings. We have successfully concluded the FP7 project **SunSeed** (*Sustainable and robust networking for smart electricity distribution*) whose goal was to improve the observability of the distribution grid, which allows higher penetration of distributed resources into the grid and avoids high investment costs for redesigning the grid. In collaboration with the Department for Communication Systems (E6), we achieved better observability by developing three phase state estimation based on nonlinear Weighted Least Squares (WLS) and advanced streaming short-term load forecasting module, able to process multiple heterogeneous data-sources in real time. Results (forecasts, estimates, profiles, etc.) are visualized in a specifically developed GUI for analytics and general data-visualization system based on GIS software. To ensure the scalability of the system, a prototype also enables simple parallelization due to its decentralized and modular architecture. Our solution was successfully deployed and tested on a real time electric grid of Elektro Primorska on three different test-beds with different characteristics. In 2017, we have successfully completed the H2020 **Aquasmart** project (*Aquaculture Smart and Open Data Analytics as a Service*). Our work

Figure 2: By leveraging Machine Learning to enrich a very large and granular dataset detailing the global employment markets, Hodson's work gives us new insight into the dynamics of industries, skills, and companies over time. In this figure, the flows of skilled labour between industries is shown for the period 2010–2017.

was focused on the preparation of tools, which we developed during the course of the project, for use in a central system accessible online. With these tools, using the methods of machine learning, the web user can model data and assess how the environment, fish feeding and managing a farm affects production. With ready-made models, the user can identify trends, optimize feeding and estimate the fish population in the farm. At the end of the project, a commercial site (http://www.aquaknowhow.com) was set up, which also includes our tools. Within the H2020 Marie Skłodowska-Curie RISE project **Water4Cities** (*Holistic Surface Water and Groundwater Management*

for Sustainable Cities), our work focuses on sensor technologies, data and visual analytics to enable localization, visualization and analysis of urban water (both surface water and groundwater) at a holistic urban setting providing services to multiple water stakeholders. Our aim has been to develop the necessary models and associated platform that will enable water providers and relevant stakeholders to monitor in real-time the urban water resources to support their decisions for optimal urban water management. Use cases will be checked in Ljubljana and on the Greek island Skiathos.

Promotion of science is continually present in the efforts of the Artificial Intelligence Laboratory. In 2017, Marko Grobelnik appeared in two separate interviews on two Slovenian National Radio channels, entitled "Consciousness, feelings and artificial intelligence" (http://radioprvi.rtvslo.si/2017/04/mozgani-na-dlani-nevron-pred-mikrofon-71/) and "Digitization must be understood as part of everyday culture" (http://val202.rtvslo.si/2017/01/odbita-do-bita-37/). Within the H2020 project **EDSA** (*European Data Science Academy*), the Artificial Intelligence Laboratory contributed a dashboard aggregating demand and supply data in data science - demand data of data-science job postings around Europe and supply data of data-science training materials, in particular videolectures from the VideoLectures.NET portal. The department participated in the EDSA curriculum development, developing and maintaining training and learning analytics applications based on Videolectures.NET data, such as *Videolectures Explorer* (enabling users to search through the lectures and find similarities between them) and the *Videolectures Learning Analytics Dashboard* (allowing

> **We have successfully concluded two EU FP7 projects and one EU H2020 project:**
> **ProaSense** (The Proactive Sensing Enterprise) (http://www.proasense.eu/),
> **SunSeed** (Sustainable and robust networking for smart electricity distribution) (https://sunseed-fp7.eu/),
> **AquaSmart** (Aquaculture Smart and Open Data Analytics as a Service) (http://www.aquasmartdata.eu/)

for analysis of viewer behavior). Department representatives delivered presentations on the topic of Data Science at several events, such as the BBC Data Science Research Partnership event (http://www.bbc.co.uk/rd/projects/data-science-research-partnership) and the 2nd World OER Congress (http://www.oercongress.org/). In 2017, the department also acted as a subcontractor in a **EUROSTAT** project dedicated to the topic of utilizing big data for statistical purposes. Our main role was the development of a training strategy to bridge the big-data skills gap in European official statistics. In particular, we performed the following activities:

- Identification of skills required for the use of big-data sources;
- Inventory of existing skills in Eurostat and in the NSIs in Europe;
- Analysis of the big-data training needs;
- Definition of training objectives and content;
- Development of a training provision strategy to bridge the skills gap.

The H2020 project **x5gon** (*Cross Modal, Cross Cultural, Cross Lingual, Cross Domain, and Cross Site Global OER Network*) had its kick-off meeting in September 2017. The goal of the project is to implement innovative technology elements for connecting scattered Open Educational Resources (OER) available across Europe and the globe. Our department, in collaboration with the Centre for Knowledge Transfer in Information Technologies (CT3), is leading work focused on the development of a platform for connecting different components of the system, services, products and API access points as well as developing rich models for the recommendation and personalization of learning materials. In collaboration with the Centre for Knowledge Transfer in Information Technologies (CT3), we have continued work on the H2020 project *MOVING (TraininG towards a society of data-saVvy inforMation prOfessionals to enable open leadership INnovation)*. Our main work was the provision of digital video contents through VideoLectures.NET, in particular large-scale data sets for the two project use cases (20,000 videos and transcripts) as well as the production and provision of educational sequences.

Together with the Centre for Knowledge Transfer in Information Technologies (CT3), we continued to use the Videolectures.NET portal to promote Artificial Intelligence, the Jožef Stefan Institute and Slovenian research in general. Our laboratory is also among the main organizers and supporters of the annual national ACM Computer Science Competition for secondary-school students; in 2017, 225 students participated in the competition. We have been organizing a touring exhibition about female PhD holders from the area of computer science in Slovenia since 2006, thereby promoting the role of women in science (http://ScienceWithArt.ijs.si/).

In 2017, we were very actively involved in submitting new project proposals, particularly within the H2020 Programme. Once again, we were very successful, obtaining funding for six new projects in H2020: *x5Gon*, *SILKNOW*, *ELEXIS, TheyBuyForYou, DataBench* and *PerspectiveSentinel*. We continue with our successful efforts to include Slovenian industry in the European research area, where over the last 12, years we have produced a list of numerous companies participating in EU projects.

Some outstanding publications in the past year

1. Kažič, Blaž, Rupnik, Jan, Škraba, Primož, Bradeško, Luka, Mladenić, Dunja. Predicting users' mobility using Monte Carlo simulations. *IEEE access*, ISSN 2169-3536, [in press] 2017, 20 pages,

2. Starc, Janez, Mladenić, Dunja. Joint learning of ontology and semantic parser from text. *Intelligent data analysis*, ISSN 1088-467X. [Print ed.], 2017, vol. 21, no. 1, pp. 19-38,

3. Bradeško, Luka, Witbrock, Michael J., Starc, Janez, Herga, Zala, Grobelnik, Marko, Mladenić, Dunja. Curious cat–mobile, context-aware conversational crowdsourcing knowledge acquisition. V: RIJKE, Maarten de (ur.). *ACM Transactions on Information Systems (TOIS) : special issue Search, Mining and their Applications on Mobile Devices,* 2017, vol. 35, no. 4, pp. 33-1-33-46,

4. Kuntarič, Sašo, Krek, Simon, Robnik Šikonja, Marko. Primerjava običajnih in faktorskih modelov pri statističnem strojnem prevajanju iz angleščine v slovenščino z orodjem Moses. *Slovenščina 2.0 : empirične, aplikativne in interdisciplinarne raziskave*, ISSN 2335-2736, 2017, letn. 5, št. 1, pp. 1-25,

5. Bobrowski, Omer, Kahle, Matthew, Škraba, Primož. Maximally persistent cycles in random geometric complexes. *Annals of applied probability*, ISSN 1050-5164, 2017, vol. 27, no. 4, pp. 2032-2060,

6. Govc, Dejan, Škraba, Primož. An approximate nerve theorem. *Foundations of computational mathematics*, ISSN 1615-3375, 2017, vol. , iss. , 53 pages.

7. Mole, Maruška, Wang, Longlong, Stanič, Samo, Bergant, Klemen, Eichinger, William, Oca a, Francisco, Strajnar, Benedikt, Škraba, Primož, Vučković, Marko, Willis, William B. Lidar measurements of Bora wind effects on aerosol loading. *Journal of quantitative spectroscopy & radiative transfer : JQSRT*, ISSN 0022-4073. [Print ed.], Feb. 2017, vol. 188, pp. 39-45,

8. Kudryavtseva, Ganna, Škraba, Primož. The principal bundles over an inverse semigroup. *Semigroup forum*, ISSN 0037-1912, 2017, vol. 94, iss. 3, pp. 674-695.

9. Representation Learning on Graphs: Methods and Applications. W. Hamilton, R. Ying, J. Leskovec. *IEEE Data Engineering Bulletin*, 2017.

10. Human Decisions and Machine Predictions. J. Kleinberg, H. Lakkaraju, J. Leskovec, J. Ludwig, S. Mullainathan. *Quarterly Journal of Economics*, 2017.

11. Large-scale physical activity data reveal worldwide activity inequality. T. Althoff, R. Sosic, J. L. Hicks, A. C. King, S. L. Delp, J. Leskovec. *Nature*, 547.7663, 2017.

12. Predicting multicellular function through multi-layer tissue networks. M. Zitnik, J. Leskovec. *Bioinformatics*, 33 (14): i190-i198, 2017.12. SnapVX: A Network-Based Convex Optimization Solver. D. Hallac, C. Wong, S. Diamond, A. Sharang, R. Sosič, S. Boyd, J. Leskovec. *Journal of Machine Learning Research (JMLR)*, 18(4):1–5, 2017.

13. Network Analysis: A novel Method for Mapping Neonatal Acute Transport Patterns in California. S.N. Kunz, J.A.F. Zupancic, J. Rigdon, C.S. Phibbs, H.C. Lee, J.B. Gould, J. Leskovec, J. Profit. J*ournal of Perinatology*, 2017.

Awards and Appointments

1. James Alexander Hodson: Jack Treynor Prize from the Institute for Quantitative Research in Finance, New York, USA, Q Group, Trading on Talent: Human Capital and Firm Performance

2. James Alexander Hodson: Second place in the 2017 PanAgora Asset Management, Boston, USa, PanAgora Asset Management, Trading on Talent: Human Capital and Firm Performance

3. Dr. Jure Leskovec: Best paper award, Portland, USA, CSCW 2017, Anyone Can Become a Troll: Causes of Trolling Behavior in Online Discussions

4. Dr. Jure Leskovec: Best paper award honorable mention, Perth, Australia, WWW 2017, An Army of Me: Sockpuppets in Online Discussion Communities

5. Dr. Jure Leskovec: Best paper runner-up, Portland, USA, CSCW 2017, Toeplitz Inverse Covariance-Based Clustering of Multivariate Time Series Data

Organization of Conferences, Congresses and Meetings

1. H2020 EDSA, Ljubljana, 18 - 19 May 2017
2. 14th ESWC conference, Portorož, 28 May - 1 June 2017
3. H2020 BigDataFinances, Dubrovnik, Croatia, 4 - 8 September 2017
4. 2nd World OER Congress, Ljubljana, 18 - 20 September 2017

INTERNATIONAL PROJECTS

1. ELRC - European Language Resource Coordination
   Dr. Simon Krek
   Dfki Gmbh - Deutsches Forschungszentrum Fuer
2. Services Concerning Ethnical, Communication, Legal, Skills Issues and Methodological

Cooperation related to the Use of Big Data in European Statistics
Marko Grobelnik
Sogeti Luxembourg S.a.
3. 7FP - ProaSense; The Proactive Sensing Enterprise
Marko Grobelnik
European Commission
4. 7FP - SUNSEED; Sustainable and Robust Networking for Smart Electricity Distribution

Prof. Dunja Mladenić
European Commission

5. INEA/CEF - eTranslation TermBank
Dr. Simon Krek
Innovation And Networks Executive Agency (inea)

6. PARSEME: PARSing and Multi-Word Expressions. Towards Linguistic Precision and Computational Efficiency in Natural Language Processing
Dr. Simon Krek
Cost Office

7. IS1305, European Network of E-Lexicography (ENeL)
Dr. Simon Krek
Cost Office

8. COST CA16105; European Network for Combining Language Learning with Crowdsourcing Techniques
Dr. Simon Krek
Cost Office

9. H2020 - AquaSmart; Aquaculture Smart and Open Data Analytics as a Service
Prof. Dunja Mladenić
European Commission

10. H2020 - EDSA; European Data Science Academy
Marko Grobelnik
European Commission

11. H2020 - OPTIMUM; Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility
Marko Grobelnik
European Commission

12. H2020 - BigDataFinance; Training for Big Data in Financial Research and Risk Management
Marko Grobelnik
European Commission

13. H2020 - RENOIR; Reverse Engineering of Social Information Processing
Marko Grobelnik
European Commission

14. H2020 - MOVING; Training Towards a Society of Data-Savvy Information Professionals to enable Open Leadership Innovation
Marko Grobelnik
European Commission

15. H2020 - PrEstoCloud; Proactiive Cloud Resources Management at the Edge for Efficient Real-Time
Marko Grobelnik
European Commission

16. H2020 - euBusinessGraph; Enabling the European Business Graph for Innovative Data Products and Services
Prof. Dunja Mladenić
European Commission

17. H2020 - EW-Shopp; Supporting Event and Weather-based Data Analytics and Marketing along the Shopper Journey
Marko Grobelnik
European Commission

18. H2020 - Water4Cities; Holistic Surface Water and Groundwater Management for Sustainable Cities
Marko Grobelnik
European Commission

19. H2020 - X5gon; Cross Modal, Cross Cultural, Cross Lingual, Cross Domain, and Cross Site Global OER Network
Marko Grobelnik
European Commission

20. H2020 - TheyBuyForYou; Enabling Procurement Data Value Chains for Economic Development, Demand Management, Competitive Markets and Vendor Intelligence
Marko Grobelnik
European Commission

21. H2020 - GlobalDNA; Dynamic Network of Global News Events
Prof. Dunja Mladenić
European Commission

22. Representation of Big Data
Prof. Dunja Mladenić
Slovenian Research Agency

23. Semantic Role Labeling in Slovene and Croatian
Dr. Simon Krek
Slovenian Research Agency

RESEARCH PROGRAM

1. Knowledge Technologies
Prof. Dunja Mladenić

R&D GRANTS AND CONTRACTS

1. Integration of mobile devicas into survey research in social sciences: Development of a comprehensive methodological approach
Marko Grobelnik
Collocation as a basis for language description: semantic and temporal perspectives
Dr. Simon Krek
Slovene scientific texts: resources and description
Dr. Simon Krek

2. Learning Topological Representations
Asst. Prof. Primož Škraba

3. New grammar of modern standard Slovene: resources and methods
Dr. Simon Krek

4. Forbidden Books in the Slovenian Lands in the Early Modern Period
Dr. Simon Krek

5. For the Quality of Slovene Textbooks
Dr. Simon Krek

6. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
Prof. Dunja Mladenić

7. The establishment and up-keeping of a language source and language technologies web portal
Prof. Dunja Mladenić

8. Summer School within the Project H2020 - BigDataFinance, Dubrovnik, Croatia, 4. - 8. 9. 2017
Marko Grobelnik

NEW CONTRACTS

1. Modeling probability of default and credit limits
Prof. Dunja Mladenić
Telekom Slovenije, d. d.

2. Data Analytics (Module) for Iskratel IoT platform for Energetics
Marko Grobelnik
Iskratel, d. o. o., Kranj

3. Intelligent railway infrastructure - energy data analytics
Marko Grobelnik
Iskratel, d. o. o., Kranj

VISITORS FROM ABROAD

1. Dr. Jeff Thompson, UCLA, Los Angeles, USA, 16 January 2017
2. Anna Grzywacz, Warsaw University of Technology, Warsaw, Poland, 3 - 17 February 2017
3. Piotr Szymański, Univerza Politechnika Wroclawska, Wroclaw, Poland, 3 February - 2 March 2017
4. Łukasz Augustyniak, Univerza Politechnika Wroclawska, Wroclaw, Poland, 3 February - 2 March 2017
5. Dr. Estevam Hruschka, Federal University of Sao Carlos, Sao Carlos, Brazil, 24 May - 1 June 2017
6. Diego Collarana, Fraunhofer, München, Germany, 18 - 19 May 2017
7. Simon Scerri, Fraunhofer, München, Germany, 18 - 19 May 2017
8. Camilo Jose Morales Rodriguez, Fraunhofer, München, Germany, 18 - 19 May 2017
9. Dr. John Davies, British Telecom, London, United Kingdom, 28 May - 1 June 2017
10. Dr. Rudi Studer, Institute AIFB, Karlsruhe, Germany, 26 May 2017
11. Dr. Jasminka Dobša, Fakultet Organizacije i Informatike, Univerza Zagreb, Varaždin, Croatia, 11 - 15 June 2017
12. Dr. Danijel Radošević, Fakultet Organizacije i Informatike, Univerza Zagreb, Varaždin, Croatia, 11 - 15 June 2017
13. Dr. Tina Eliassi-Rad , Northeastern University, Boston, USA, 9 June 2017
14. Dr. Branden Fitelson, Northeastern University, Boston, USA, 9 June 2017
15. Dr. Julian Sienkiewicz, Warsaw University of Technology, Warsaw, Poland, 19 June - 3 July 2017
16. Piotr Szymański, Univerza Politechnika Wroclawska, Wroclaw, Poland, 26 June - 17 July 2017
17. Dr. Krzysztof Suchecki, Warsaw University of Technology, Wroclaw, Poland, 3 - 31 July 2017
18. Piotr Szymański, Univerza Politechnika Wroclawska, Wroclaw, Poland, 28 August - 17 September 2017
19. Abraham Hsuan, Irwin & Hsuan LLC, New York, USA, 3 - 6 September 2017
20. Dr. Jasminka Dobša, Fakultet Organizacije i Informatike, Univerza Zagreb, Varaždin, Croatia, 21 - 22 September 2017
21. Dr. Omer Bobrowski, Technion – Israel institute of technology, Haifa, Israel, 2 - 9 October 2017
22. Dr. Goran Matošević , Fakultete za ekonomijo, Univerza v Puli, Pula, Croatia, 22 September 2017
23. Jan Chołoniewski, Warsaw University of Technology, Warsaw, Poland, 2 November 2017 - 7 February 2018
24. Abraham Hsuan, Irwin & Hsuan LLC, New York, USA, 23 - 26 November 2017
25. Pat Moore, Bloomberg, New York,USA, 3 - 6 December 2017

STAFF

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3. Dr. Simon Krek
4. Dr. Gregor Leban
5. Dr. Jurij Leskovec
6. **Prof. Dunja Mladenić, Head**
7. Prof. John Stewart Shawe-Taylor
8. Asst. Prof. Primož Škraba

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10. Dr. Mario Karlovčec
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13. Dr. Jan Rupnik
14. Dr. Polona Škraba Stanič

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17. Rayid Ghani, M. Sc.
18. James Alexander Hodson, B. Sc.

19. Mitja Jermol, M. Sc.
20. Blaž Kažič, B. Sc.
21. Klemen Kenda, B. Sc.
22. Blaž Novak, B. Sc.
23. Luka Stopar, B. Sc.
24. Miha Torkar, B. Sc.

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26. Zala Herga, B. Sc.
27. Dr. Matej Kovačič
28. Mojca Kregar Zavrl, B. Sc.
29. Matjaž Rihtar, B. Sc.
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31. Maja Škrjanc*, B. Sc.

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32. Aleš Buh
33. Marko Grobelnik
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Note:
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2. Branko Kavšek, "Using words from daily news headlines to predict the movement of stock market indices", *Managing global transitions*, **15**, 2, 109-121, 2017.
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8. Klemen Kenda, Dunja Mladenić, "Usage of SVM for a triggering mechanism for higgs boson detection", In: *Slovenska konferenca o umetni inteligenci: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9. - 13. oktober 2017, Ljubljana, Slovenia: zvezek C: proceedings of the 20th International Multiconference Information Society - IS 2017, 9-13 October, 2017, Ljubljana, Slovenia: volume C*, Dunja Mladenić, ed., Marko Grobelnik, ed., Ljubljana, Institut Jožef Stefan, 2017, 39-42.
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INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

1. Kaja Dobrovoljc, Simon Krek, Tomaž Erjavec, "The Sloleks morphological lexicon and its future development", In: *Dictionary of modern Slovene: problems and solutions*, (Book series Prevodoslovje in uporabno jezikoslovje), Vojko Gorjanc, ed., et al, 1st ed., e-ed., Ljubljana, Ljubljana University Press, Faculty of Arts, 2017, 42-63.

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MENTORING

1. Luka Bradeško, *Knowledge Acquisition through Natural Language Conversation and Crowdsourcing:* doctoral dissertation, Ljubljana, 2017 (mentor Dunja Mladenić).

2. Dejan Govc, *Unimodal category:* doctoral dissertation, Ljubljana, 2017 (mentor Dušan Repovš; co-mentor Primož Škraba).

3. Janez Starc, *Machine learning of semantics for text understanding:* doctoral dissertation, Ljubljana, 2017 (mentor Dunja Mladenić).

LABORATORY FOR OPEN SYSTEMS AND NETWORKS E-5

The main activities of the laboratory are R&D in the area of next-generation networks, telecommunications technologies, components and integrated systems, information-society services and applications, especially those that ensure an efficient and pervasive life-long learning concept.

The research in 2017 was performed within the research programme "Future Internet Technologies: concepts, architectures, services and socio-economic issues" and the "Content and data communication interoperability of first responders' networks" project, funded by the Slovenian Research Agency. In addition, research was carried out in the EU Horizon 2020 projects "Flex4Grid", "Defender" and "Compact", the 7FP project "EmployID", the "eSENS" project from the CIP (Competitiveness and innovation) programme, the "SENTER" project from the ISFP programme, the EU DG Justice "LIVE_FOR" project, the "GIRDA" project from the Erasmus*plus* programme, the "EkoSmart" project from the European regional development fund, and the national "Technological and business aspects of future ecosystem for e-health" project. The focus was on the development of technologies and services in advanced, next-generation networks, security and privacy in information systems, and technology-enhanced learning.

Members of the laboratory are teaching at the undergraduate and graduate levels at the University of Ljubljana, the Jožef Stefan International Postgraduate School, the DOBA Faculty, and the Faculty of Commercial and Business Sciences. In 2017 they were mentoring up to graduation three Ph.D. theses, two Master theses, and one diploma thesis.

Head:
Prof. Borka Jerman Blažič

Concepts and architectures of the secure future internet

The first area of research and development was focused on security infrastructures and secure services based on a partnership in the large-scale eSENS pilot project from the EU Competitiveness and Innovation (CIP) programme. The staff of the laboratory is involved in the creation of a Pan-European infrastructure that will offer secure cross-border services based on national eID credentials, such as digital identity cards.

The building blocks, such as eID, eDocuments, e-Delivery, and e-Signatures, developed within several large-scale pilots were consolidated. The developed architecture was adopted as a part of the European Interoperability Architecture (EIA) for the efficient and effective delivery of cross-border and cross-sector electronic public services. The contributions from the laboratory staff were the trust model implementation in the piloting domains, such as e-procurement, e-health, e-justice, and business lifecycle, and the assessment of the cyber-security principles integrated in the European interoperability reference architecture (EIRA).

The experience in creating building blocks will be used in two new projects from the EU CEF (Connecting Europe Facility) programme: SI-PASS and eID4U. The SI-PASS project, which is coordinated by the laboratory, will build a production-ready Slovenian eIDAS node that is compliant with the latest version of the eIDAS technical specifications, and integrate four existing public and one private cross-border e-services with the eIDAS node. The services belong to the eHealth, intellectual property systems, e-pension, public legal records, and business transactions domains. The eID4U project is dealing with the use of notified national eIDs in academia and the creation of a virtual Erasmus student card based on the standard eIDAS attributes.

In 2017, the work in the project "Prosumer Flexibility Services for Smart Grid management (**Flex4Grid**)" from the Horizon 2020 EU programme was focused on the improvement of smart-grid operation by utilizing the prosumers' flexibility. The project has a strong Slovenian contribution with Elektro Celje and Smart Com as partners in the project, besides the Jožef Stefan Institute. In 2017, the Flex4Grid project extended collaboration with Elektro Celje in the national Critical Peak Tariff project (CPTP), initiated by Public Agency of the Republic of Slovenia for Energy and financed by SODO. The project synergy resulted in large-scale piloting in the Celje region with more than 750 test users in a population of 14,000 end users. The laboratory members have developed a dynamic energy-consumption forecasting model together with a data analytic tool for peak-events evaluation. The new "Defending the European Energy Infrastructures (**Defender**)" project is aimed to ensure the European critical energy infrastructures with security solutions. The goal is ensuring the protection of all energy-domain segments, from generation, transmission to distribution. The Laboratory for Open Systems and Networks leads the work on cyber-physical threats' assessment and analysis. The solutions will be evaluated in the ELES pilot environment.

The laboratory members are also involved in a 3-year national programme "Ecosystem of a smart city (**Eko-Smart**)" with the main focus on citizen health, mobility, active lifestyle, and well-being. The laboratory is acting in

> **We have created building blocks for security infrastructures and secure internet services.**

the segment named Electronic Mobile Health (EMZ), where operative directions include information technologies for whole health care, home support, mobile monitoring of vital and environmental data, method and algorithms development, and the development of corresponding ICT platforms. The main contribution is in the development of methods and algorithms for securing the privacy of personal health data for all users of EMZ services. Security solutions are providing k-anonymity, l-diversity, and LKC-privacy. The research project titled "**Technological and business aspects of future ecosystem for e-health**" is focused on implementing the work within the priority area of the European cohesion policy "Smart cities and communities". Its fundamental goal is the creation of a functional model to ensure the sustainable technological and business development of an ecosystem for e-health. Several research questions will be resolved that arise when medical applications that are based on common e-health ecosystem are used in real environment, for example, how to ensure the integration of new IoT devices in a way that the safety and privacy of patients is guaranteed. The project supports Slovenian vendors of medical applications and other IT solutions, such as Marand Inženiring, to take the lead with their solution on the global market.

Under the Infrastructure program in research organizations we keep providing support services that enable better communication among members of the various research programs, as well as students and their mentors from geographically distributed institutions.

Security and privacy in information systems

The provision of security and privacy services is crucial for the modern information society and for the emerging digital market. In 2017 the R&D activities in this field were focused on the research of novel security mechanisms and methods that enable an efficient fight against cybercrime.

The fight against cybercrime is the main focus of the "Strengthening European Network Centres of Excellence in Cybercrime (**SENTER**)" project. SENTER created a single point of reference for EU national cybercrime centres of excellence (CoE) and developed further national CoE into a well-defined and well-functioning community. The Laboratory for Open Systems and Networks is acting in the project as the Slovenian CoE. The main activities carried in 2017 included the preparation of guidelines on the establishment and management of cybercrime centres of excellence, and the organisation of the SENTER conference on open-source intelligence (OSINT) and the fight against cybercrime and cyber terrorism. Recent OSINT R&D results were presented as well as some leading industrial solutions. The fight against cybercrime, especially when crypto currencies are concerned, was the hottest topic that triggered a wide-ranging discussion. The conference was attended by representatives of law-enforcement agencies, judicial authorities, industry, and academia from 22 countries. The SENTER research activities were also carried out within the three special interest groups formed by the project, i.e., Education and training, Digital forensics, and OSINT.

Figure 1: The SENTER Conference

The Laboratory for Open Systems and Networks is coordinating the "Criminal Justice Access to Digital Evidences in the Cloud - LIVE_FORensics (**LIVE_FOR**)" project from the EU DG Justice programme. The partners in this 2-year project are universities from Belgium (Vrije Universiteit Brussel), Spain (Polytechnic University of Catalonia and Autonomous University of Madrid), Germany (Fachhochschule Albstadt - Sigmaringen), and Czech Republic (Masaryk University). The LIVE_FOR project is one of the vehicles that bring knowledge and understanding of the new modern technologies being developed for carrying out digital investigation in the cloud-computing environment. In addition, the LIVE_FOR project investigates the implementation of Directive 2014/41/EU, raises the awareness of the prosecutors and investigators of the new European tool for collecting cross-border evidence in the connected European digital world, establishes a collection of best practices, and develops standard educational content for training and education in the area of digital forensics.

Our research and development results enable a more secure information society and the establishment of the single European market.

In 2017, the laboratory members focused their work in LIVE_FOR on identifying the status of the implementation of Directive/2014/41 in the EU Members States and the obstacles that hinder the use of efficient methods for the seizure and preservation of cross-border digital evidences.

The educational and training needs of the judicial authorities were covered by a workshop in Ljubljana. The workshop attracted 25 participants from 11 countries (Bulgaria, Croatia, Czech Republic, Hungary, Ireland, Italy, Latvia, Netherlands, Romania, Slovakia, and Slovenia). The results of the workshop and carried out web surveys are used as input for defining best practices for cross-border digital evidence seizure and preservation, especially in the cloud environment.

Mathematical models for the construction of symmetric cryptographic algorithms were also the subject of research. The developed methods enable infinite construction of quadratic vectorial bent functions, which can be used as combinatorial objects with several areas of application. The results were published in the IEEE Transaction on Information Technology journal.

Technology-enhanced learning

The main focus of the research and development activities in the area of technology-enhanced learning was on serious games and new e-learning services and platforms for public employment services.

The main goal of the "Scalable cost-effective facilitation of professional identity transformation in public employment services (**EmployID**)" project is to support and facilitate the learning process of PES (Public Employment Services) practitioners in their professional identity development. The project partners are developing a set of services combining and linking eCoaching, reflection, MOOCs, networking, analytical and learning support tools, leading

Figure 2: Transfer of knowledge on cross-border digital evidence to judicial authorities

to improved individual and organisational performance in the delivery of employment services. Privacy issues are also being tackled in the project through the development of a concept for handling privacy and ethical aspects at different levels, ranging from organisational policies, via creating awareness, up to technical measures regarding the ownership and stewardship of data. The activities of the laboratory members ensure that the tools developed are privacy aware, abide privacy principles, and are compliant with the newest EU privacy and data-protection regulation. Among other main results of the laboratory research and development activities in 2017, evaluation of a community of practice platform for public employment services and evaluation of platforms for MOOC (Massive Open Online Course) provision need to be mentioned.

The overall goal of the "Gameplay for Inspiring Digital Adoption (**GIRDA**)" project that started in 2016 is to address the problem of the digital divide and the barriers to learning and adoption faced by older citizens who often have no digital skills. Seven partners from Slovenia, UK, Austria, and Macedonia investigate with field experiments the efficacy of an alternative approach to facilitating digital literacy and digital adoption based on digital games designed on touch-table technology devices.

Internet services and applications

The objective of the 3-year H2020 project "From Research to Policy through Raising Awareness of the State of the Art on Social Media and Convergence (**COMPACT**)" (October 2017-2020) is to increase awareness (including scientific, political, cultural, legal, economic and technical areas) of the latest technological discoveries among key stakeholders in the context of social media and convergence. The project is performing extensive research on policies and regulatory frameworks, as well as pre-standardization efforts in social media for preventing fake news and hate speech.

Part of the study that addressed the phenomena of internet addiction and abuse among the Slovenia population was finished and the work was published in the leading journal in its group. This was the first scientific study that explored the trigger of addiction among the employed Slovenian population, but the focus in the study was given to abuse at the work place and the disciplinary measures like e-monitoring applied by employers.

Borut Pahor, President of Republic of Slovenia, awarded prof. Borka Jerman Blažič with the Medal for Services for her contribution to the development of the internet and computer communications.

Awards

In August 2017, Borut Pahor, President of the Republic of Slovenia, awarded the Head of the Laboratory, prof. Borka Jerman Blažič with the Medal for Services for her contribution to the development of the internet, computer communications and internet services. In the 1980s, in the key period of the internet's development, prof. Jerman Blažič was a member of an international academic community that shaped the internet into a global computer network. With equipment obtained through the Eureka project, she established the first international internet connection in Slovenia, connecting the Jozef Stefan Institute with the international internet. At that time, Slovenia was one of only 16 countries in the world with such a connection.

Figure 3: Prof. Borka Jerman Blažič is awarded with the Medal for Services by Borut Pahor, President of Republic of Slovenia

Some outstanding publications in the past three years

1. Callanan, Cormac, Jerman-Blažič, Borka, Jerman Blažič, Andrej. User awareness and tolerance of privacy abuse on mobile internet: an exploratory study. Telematics and informatics, ISSN 0736-5853, 2016, vol. 33, iss. 1, pp. 109-128.
2. Pavleska, Tanja, Jerman-Blažič, Borka. User bias in online trust systems: aligning the system designers' intentions with the users' expectations. Behaviour & information technology, ISSN 0144-929X. [Print ed.], 2017, vol. 26, iss. 4, pp. 404-421.
3. Jerman-Blažič, Borka, Gorenc, Mateja. Deviance in the internet use in working environment: key factors and remedies based on an exploratory study. Review of European studies, ISSN 1918-7173, 2017, vol. 9, no. 4, pp. 52-71.

Organization of conferences, congresses and meetings

1. Organization of the EmployID (Scalable & Cost-effective Facilitation of Professional Identity Transformation in Public Employment Services) project meeting, Bled, May 8-10, 2017
2. Organisation of the LIVE_FOR (Criminal Justice Access to Digital Evidences in the Cloud – LIVE_FORensics) workshop on Directive 2014/41/EU and the European Investigation Order, Ljubljana, May 30, 2017
3. Organization of the DEFENDER (Defending the European Energy Infrastructures) kick-off meeting, Ljubljana, July 17–18, 2017
4. Organization of the SENTER (The European Network of Centres of Excellence in Cybercrime – SENTER) conference, Bled, November 7–9, 2017
5. Organization of the Flex4Grid (Prosumer Flexibility Services for Smart Grid Management) project meeting, Ljubljana, December 11–14, 2017

Awards and Appointments

1. Borut Pahor, President of the Republic of Slovenia, awarded prof. dr. Borka Jerman Blažič with the Medal for Services for her contribution to the development of Internet and computer communications.

INTERNATIONAL PROJECTS

1. 7FP - EmployID; Scalable Cost-effective Facilitation of Professional Identity Transformation in Public Employment Services
Asst. Prof. Tomaž Klobučar
European Commission
2. CIP-e-SENS; Electronic Simple European Networked Services
Prof. Borka Džonova Jerman Blažič
European Commission
3. SENTER - Strengthening European Network Centres of Excellence in Cybercrime
Prof. Borka Džonova Jerman Blažič
European Commission
4. ERASMUS+; GIRDA - Gameplay for Inspiring Digital Adoption
Prof. Borka Džonova Jerman Blažič
European Commission
5. LIVE_FOR; Criminal Justice Access to Digital Evidences in the Cloud - LIVE_FORensics
Prof. Borka Džonova Jerman Blažič
European Commission
6. H2020 - Flex4Grid; Prosumer Flexibility Services for Smart Grid Management
Dr. Dušan Gabrijelčič
European Commission
7. H2020 - DEFENDER; Defending the European Energy Infrastructures
Dr. Dušan Gabrijelčič
European Commission
8. H2020 - COMPACT; From Research to Policy through raising Awareness of the State of the Art on Social Media and Convergence
Dr. Tanja Pavleska
European Commission

RESEARCH PROGRAM

1. Future Internet Technologies: concepts, architectures, services and socio-economic issues
Prof. Borka Džonova Jerman Blažič

R&D GRANTS AND CONTRACTS

1. Content and data communication interoperability of first responders networks
Prof. Borka Džonova Jerman Blažič
2. Smart City Ecosystem – EkoSmart
Dr. Živa Stepančič
Ministry of Education, Science and Sport
3. Strategic Research & Innovation Partnership (SRIP) Smart Cities and Communities
Dr. Dušan Gabrijelčič
Ministry of Education, Science and Sport
4. Technological and business aspects of future ecosystem for e-health
Dr. Marina Trkman
Ministry of Education, Science and Sport

NEW CONTRACT

1. Preparation of guidelines for connecting service providers with SI-PASS
Asst. Prof. Tomaž Klobučar
Ministry of Public Administration

STAFF

Researchers
1. *Asst. Prof. Tanja Arh*, left 01.06.17*
2. Asst. Prof. Rok Bojanc*
3. **Prof. Borka Džonova Jerman Blažič, Head**
4. Dr. Dušan Gabrijelčič

5. Asst. Prof. Tomaž Klobučar

Postdoctoral associates
6. *Dr. Matej Babič, left 13.07.17*
7. Dr. Samed Bajrić
8. Dr. Tanja Pavleska

9. Dr. Živa Stepančič
10. Dr. Marina Trkman
Postgraduates
11. Primož Cigoj, B. Sc.
12. *Blaž Ivanc, B. Sc., left 01.03.17*
13. Andrej Jerman Blažič, B. Sc.
Technical officers

14. *David Djurić, B. Sc., left 19.06.17*
Technical and administrative staff
15. Tatjana Martun, B. Sc.

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Matej Babič, "Comparision of different methods for fractal estimating dimension with the method of statistics", *Acad. J. Manuf. Eng.*, **15**, 4, 20-25, 2017.
2. Matej Babič, "New hybrid method of intelligent systems using to predict porosity of heat treatment materials with network and fractal geometry", *Acad. J. Manuf. Eng.*, **15**, 1, 29-34, 2017.
3. Matej Babič, "A new method for complexity determination to be used in new hyper-hybrid AD HOC cloud computing", *Elektrotehniški vestnik*, **84**, 1/2, 24-29, 2017.
4. Matej Babič, "New method for determination complexity of network using in image processing", *Geo-Sci. Educ. J.*, **4**, 1, 1-6, 2017.
5. Matej Babič, "New method for image analysis using method of estimating fractal dimension of 3D space", *Journal of production engineering*, **20**, nr. 1, 117-121, 2017.
6. Matej Babič, "New method for image analysis using new algorithm for constructing visibility network in 3D space", *Journal of production engineering*, **20**, 2, 54-58, 2017.
7. Matej Babič, Ladislav Hluchý, Peter Krammer, Branko Matović, Ravi Kumar, Pavel Kovač, "New method for constructing a visibility graph-network in 3D space and a new hybrid system of modeling", *Comput. inform.*, **36**, 5, 1108-1126, 2017.
8. Borka Jerman-Blažič, Mateja Gorenc, "Deviance in the internet use in working environment: key factors and remedies based on an exploratory study", *Review of European studies*, **9**, 4, 52-71, 2017.
9. Tanja Pavleska, Borka Jerman-Blažič, "User bias in online trust systems: aligning the system designers' intentions with the users' expectations", *Behav. inf. technol.*, **26**, 4, 404-421, 2017.

PUBLISHED CONFERENCE CONTRIBUTION

1. Matej Babič, Borka Jerman-Blažič, "New method for determination complexity using in AD HOC cloud computing", In: *MIPRO 2017: 40th Jubilee International Convention, May 22-26, 2017, Opatija, Croatia: proceedings*, (MIPRO ... (Tisak)), Petar Biljanović, ed., Rijeka, Croatian Society for Information and Communication Technology, Electronics and Microelectronics - MIPRO, cop. 2017, 205-213.
2. Andrej Jerman Blažič, Primož Cigoj, Tanja Arh, Borka Jerman-Blažič, "Applicability of the learnability attributes in serious game design: the case of digital forensic game design", In: *INTED 2017: conference proceedings*, (INTED proceedings (Internet)), 11th International Technology, Education and Development Conference Valencia, Spain. 6-8 March, 2017, Louis Gómez Chova, ed., A. López Martínez, ed., I. Candel Torres, ed., Valencia, IATED Academy, 2017, 8425-8434.
3. Vladimir Jovanovikj, Dušan Gabrijelčič, Tomaž Klobučar, "Security policy model for ubiquitous social systems", In: *Modeling and using context: 10th International and Interdisciplinary Conference, CONTEXT 2017, Paris, France, June 20-23, 2017: proceedings*, (Lecture notes in artificial intelligence, **10257**), Patrick Brézillon, ed., Roy Turner, ed., Carlo Penco, ed., 2017, 302-314.
4. Giovanni Paolo Sellitto, Tanja Pavleska, "IoT, big data, machine learning and Business 4.0: is real time economy a viable model of business?", In: *Marketing and Innovation Strategies for Small and Mediumsized Enterprises (SMEs): book of abstracts: Business Systems Laboratory International Workshop, September 11-12, 2017, Roma, Italy*, Davide Di Fatta, [S. l.], Business Systems Laboratory, 2017, 49-53.

INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

1. Borka Jerman-Blažič, Andrej Jerman Blažič, Tanja Arh, "Applying the user experience Study of a Virtual Multi-Cultural community in a service re-design", In: *Handbook of research on technology adoption, social policy, and global integration*, Mehdi Khosrowpour, ed., Hershey, IGI Global, 2017, 109-134.

MENTORING

1. Cormac Callanan, *Evaluation of user data protection and privacy provision in mobile networks with case studies:* doctoral dissertation, Ljubljana, 2017 (mentor Borka Jerman Blažič).
2. Andrej Jerman Blažič, *Extending taxonomy of serious computer games with emphasis on learnability and its application:* doctoral dissertation, Ljubljana, 2017 (mentor Tanja Arh).
3. Vladimir Jovanovikj, *Context-aware security for protection of ubiquitous social systems:* doctoral dissertation, Ljubljana, 2017 (mentor Tomaž Klobučar).

DEPARTMENT OF COMMUNICATION SYSTEMS

E-6

The core activities of the Department of Communication Systems comprise the research, development and design of next-generation telecommunication networks, technologies and services; wireless communications, embedded and sensor systems; and new procedures and algorithms for parallel and distributed computing. Within these activities our research work includes the development of the methods and software tools for the modelling, simulation, analysis and synthesis of communication systems, computer simulations supporting biomedical procedures and specialised equipment and procedures for advanced bio-signal processing and interpretation.

The research and development activities at the department are carried out in three laboratories: the *Communication Technology Laboratory (CTL),* the *Parallel and Distributed Systems Laboratory (PDSL)* and the *Networked Embedded Systems Laboratory (NESL).* The research work of the three laboratories is complementary, which is reflected in the joint applied projects.

In 2017 the research activities within the **Communication Technology Laboratory** were concentrated on different challenges associated with access-segment technologies, enabling end-users to access new multimedia services and applications. As part of the research program on Communication Networks and Services (P2-0016), the emphasis was on research in the areas of: radio propagation, access architectures for heterogeneous wireless networks, management of radio and network resources and cognitive communications.

Head:
Prof. Mihael Mohorčič

The investigation of the radio-signal propagation was focused on two main topics. The first topic concerns the research on high-speed train (HST) communications in the millimetre-wave (mmWave) frequency band. A geometry-based multipath model is established for the dominant multipath behaviour in delay and Doppler domains to depict rapidly time-varying features of the mmWave HST channels. Due to insufficient mmWave HST channel measurements at high train mobility, the model is developed by a measurement-validated ray tracing (RT) simulator. The influence of typical objects to the mmWave propagation channels are analysed for different scenarios based on propagation measurements. In addition, we analysed the impact of traffic on mmWave propagation in tunnels for 5G communications. We studied the radio propagation in sub-6GHz frequency bands in natural caves. The qualitative analysis and corresponding findings are useful for realizing intelligent transportation systems in railway and subway systems, as well as the provision of wireless communications in caves in the case of an emergency.

The second topic concerns the development, implementation and testing of software tool for radiowave propagation modelling in mobile communication systems and wireless communication systems optimization. The tool is integrated into an open-source geographical information system (GIS) and incorporates statistical models, channel models based on ray tracing and optimization procedures. We studied computationally efficient radio ray-tracing techniques in the context of physical channel models. The developed procedures were evaluated in the design and management of telecommunications networks.

Development of a framework for the design and evaluation of the non-cooperative and cooperative localization algorithms.

Ray-tracing algorithms based on a brute-force approach have been studied extensively in the context of ray-tracing pipelines on the latest many-core computing architectures. The far superior modelling of electromagnetic propagation effects than any other stochastic modelling is computationally demanding and requires extensive algorithmic optimization. In particular, detecting unique wavefronts at the observation point proves to be resource consuming because the geometry of the ray distribution in space does not allow a perfect detection of exactly one ray per wavefront. We proposed the optimal double counting avoidance of wavefronts by Bloom filtering, which made possible simultaneous channel evaluations at a number of observation points.

In 2017 we continued joint efforts with Xlab and Alanta to develop and launch the first cloud-based radio frequency ray-tracing engine. The service will allow the wider incorporation of deterministic channel characterization in emerging communication systems, even when dedicated computing resources at the required scale cannot be provided on site. The activities have a supporting role for the improvement of indoor localization techniques, which is also one of the research areas within the Communications Technology Laboratory.

The wireless network optimization using multi-objective evolutionary algorithm, which determines for a given set of criteria functions the optimal network parameters, was upgraded with additional criteria functions to also take into account the quality of the user experience. The basic criteria functions applied in the past, such as the network

efficiency, reduce the needed resources and consequently reduce the operational costs. Based on the terrain-profile maps and construction locations, the tool calculates the path loss by applying state-of-the-art statistical models and determines the optimal allocation of users to the base-stations or base-station locations and their parameters by maximizing defined criteria functions. The implemented solution is generic and it could be used for planning any heterogeneous wireless network using appropriately adjusted criteria functions. The optimization algorithms have been included in the GRASS RaPlaT framework and applied for the optimization of frequency channel allocation in the digital wireless system for the Public protection and relief forces of the Republic of Slovenia that is operating in the VHF frequency band.

In collaboration with European partners within the H2020 project eWine "elastic WIreless Networking Experimentation" we continued the investigation of the wireless elastic networks that can scale to the needs of users and services through the use of intelligent software and flexible hardware. Within the project, the Communication Technology Laboratory is focused on problems related to retrieving and processing the location of a user as a context of communications applicable for the optimization of wireless communication systems. In an outdoors environment, we succeeded to bring the location error close to one meter by using radio environment properties and measured the received signal level. In the indoors environment, we increased the localization precision by using an ultra-wide band (UWB) radio signal by not considering the non-line-of-sight (NLOS) connections in triangulation of the user. Standard localization methods were complemented by cooperative localization methods, which in addition to the estimated distances between the anchor (i.e., node with perfectly known location) to agent (node which location is unkonwn) distance, apply also to the agent-to-agent distance.

Figure 1: Vehicle to X millimetre wave channel modelling in tunnels.

In the field of wireless mesh networks, we continued to investigate network coding techniques and network coding aware routing procedures in order to increase the network capacity. We have designed novel opportunistic network-coding procedure, which significantly improves the performance of different networks and supported applications in terms of throughput, delay and jitter. The proposed procedure was upgraded with a self-adaptive algorithm, which gives even better results. We have shown that opportunistic network coding can significantly improve the performance of different wireless networks and applications, in particular, if the usage of opportunistic network coding is considered upfront in the wireless network's design phase.

Based on the incentive of the European Space Agency (ESA), the project SatProSi-Alpha was prolonged in 2017. The intention is to continue the measurement collection of the Ka-band (19.7 GHz) and Q-band (39.4 GHz) beacon signals from the Alphasat satellite. Besides the European group of ASAPE, within which we have already collaborated, we have also joined a smaller network of ASALASCA, where collaboration in data collection and processing is taking place. The motivation behind the international activities is to collect as much of the propagation data and their mutual analyses as possible, and thus enable an in-depth research of the atmosphere impacts on the satellite radio waves propagation. The obtained results will enable engineers to develop efficient telecommunications technology for high satellite communication throughputs, achieving speeds of the order of up to terabit/s.

In 2017 we continued with active participation in the COST Action 15104 IRACON "Inclusive radio communication networks for 5G and beyond", where we are contributing to disciplinary working groups concerned with the radio channel, physical layer and network layer, as well as to experimental working groups on the localization and tracking and on the Internet of Things.

Research activities in the field of network optimization and management have also been applied to the field of smart grids. Their complexity is constantly increasing with the introduction of distributed electric generators, such as wind turbines, solar power, cogeneration, etc., and the introduction of electric cars on the other side, which in the near future will represent large consumption. Therefore, the precise monitoring of the distribution network status is the first prerequisite for the quality management of the grid. Thus, we focused on the development of a three-phase distribution system state estimation, for the needs of which we developed a unified three-phase network model, and defined measurement configurations that can reduce the impact of the uncertainty of the model and the measurements in the three-phase state estimator for the distribution networks. The work in this area has led to the very successful conclusion of the FP7 SUNSEED project "Sustainable and robust networking for smart electricity distribution", where we served as technical/scientific coordinator.

In the **Parallel and Distributed Systems Laboratory**, we successfully continued interdisciplinary research work in the framework of the research programme that also includes the Machine Vision Laboratory from the Faculty of Electrical Engineering and the Laboratory for Algorithms and Data Structures from the Faculty of Computer and Information Science, both from the University of Ljubljana. We also cooperated with researchers from industry and medicine on research projects and with joint papers.

The basic tasks of the laboratory are the investigation of computer algorithms that are efficiently implementable on parallel and distributed computers, and their testing on a 152-core research computer cluster with a flexible interconnection network. The cluster is a part of a cloud established in cooperation with research and industrial partners. Research results are usefully employed in the field of demanding computer simulations and for the processing of massive data flows that strongly exceed the performances of personal computers and require high-performance computing and communication resources. The international exchange of results is conducted within the COST Action IC1305 „Network for Sustainable Ultrascale Computing (NESUS)" and the project „European Network on High Performance and Embedded Architecture and Compilation (HiPEAC)".

In 2017 we successfully continued our work on the FWO project "Multi-Analysis of Fretting Fatigue Using Physical and Virtual Experiments". In the project consortium we cooperate with researchers from the University of Gent and the University of Luxembourg. Our task is to design and implement parallel programs for the accurate simulation of fretting-cracks propagation. We developed a program for the simulation of contact and conceived its parallelization. We published our second FWO paper in a prominent scientific journal and some conference papers.

In cooperation with the Milan Vidmar Electric Power Research Institute, for our client ELES we started the project "Cooling of Overhead Lines at Horizontal Speeds below 0.6 m/s". For such wind speeds it is supposed to enable more accurate forecasting of the thermal load of high-voltage power transmission lines and of the current where overheating starts. To this end we are developing a physical model of lines cooling due to natural convection, an environment for numerical simulation and an experimental polygon.

For important achievements in medical equipment, we received the Puh Certificate of Recognition.

Figure 2: Among the recipients of the Zois Awards and Certificates of Recognition and the Puh Certificates of Recognition for the year 2017, as many as seven members of the department, together with four external collaborators, received one of the three Puh Certificates. The photograph is from the ceremony on 23.11.2017 in Ljubljana (photo: Marjan Verč).

Together with an industrial partner, we completed the transfer of knowledge to carry out long-term ECG measurements, to the extent that our Savvy system is produced and successfully marketed. Our ECG measuring device is a small and autonomous device for the unobtrusive long-term (weekly, monthly and longer) recording of the ECG activity. Measurements are wirelessly transmitted to a personal terminal, e.g., a phone, and, if necessary, a computer cloud. Devices such as this will form the basis of future tele-health services, which are essential for reducing the costs of general health care. The cooperation is continued under a contract on the maintenance and further development of software and hardware. The transfer of knowledge to industry was also presented to the general public, as we received a prestigious national prize, the Puh Certificate of Recognition for the year 2017.

We continued the project EkoSmart ("Ecosystem of a Smart City") of the Ministry of Education, Science and Sport, in the framework of the call for "RDI in chains and networks of values". Within the project we support the implementation of pilot studies of the use of a mobile ECG measurer in a medical environment. We are exploring effective ways of analyzing data and integrating them into existing medical databases. In 2017 we started implementing the related H2020 project "Supporting Active Ageing through Multimodal Coaching (SAAM)", in which we will upgrade our research for practical use.

In the framework of the bilateral OTKA project "Graph Optimization and Big Data", financed by the Slovenian and Hungarian Research Agencies, we addressed the Big Data challenge interpreted in terms of graph models and their processing. The project goals are to prove theorems about model parameters, to design efficient parallel algorithms for model analysis and to implement these algorithms on next-generation supercomputers. The research will contribute results relevant to graph theory and broader to discrete mathematics, as well as algorithms and methods useful for the more efficient processing of big data. The partnership on the project spurred an idea for further work, which culminated in a joint proposal for a H2020 project.

In the field of formal methods for distributed systems, we discovered a weaker sufficient condition for choreography realizability. Within the COST Action IC1405 "Reversible Computation - Extending Horizons of Computing", we continued to investigate methods for finer specification of reversibility.

In the **Networked Embedded Systems Laboratory** we continued in 2017 the research and development in the fields of the Internet of Things and cognitive communications. The emphasis was placed on the vertical integration of different wireless sensor and communication-network technologies in support of development and introduction of new applications. As the core building block we were using and upgrading the modular platform VESNA used for the development of wireless-sensor networks, in particular a new hardware module and corresponding software to support edge computing, remote reconfiguration and remote debugging on devices with restricted capabilities. The new VESNA module forms a baseline for the upgrade of the LOG-a-TEC wireless sensor network testbed at the

![Jožef Stefan Institute logo] Jožef Stefan Institute

premises of Jožef Stefan Institute, which is through the Fed4FIRE federation and the H2020 Fed4FIRE+ (Federation for FIRE plus) project made available also to the community of external experimenters.

The LOG-a-TEC testbed was used and validated in the eWINE project for the performance evaluation of localization algorithms and for the investigation of radio-spectrum occupancy in various frequency bands. The emphasis was on the investigation of ultra-narrowband (UNB) radio-signal detection in order to support the performance optimization and the increase of the density of low-power wide-area (LPWA) devices, and on novel approaches for signal detection and technology classification using a machine-vision algorithm that is able to observe streams of spectrum data and identify and label transmissions in that stream. Besides sensing of the spectrum occupancy at particular frequency bands, the classification of wireless technologies is essential for efficient radio resource management in heterogeneous radio networks.

As part of the work in eWINE we continued the work on a UWB radio channel classifier based on a convolutional neuron network approach, and used it as a support in increasing the indoor localization algorithm accuracy. The machine learning approaches were used also in the design of a new link quality predictor for the wireless link quality estimation (LQE) based on measured signal strength (RSSI, received signal strength indicator) and the sequence of received data packets.

In the field of 5G networks, we addressed the problem of efficient integration between heterogeneous machine-type communication (MTCs) devices, based on existing and upcoming wireless technologies that are connected through advanced Internet of Things gateways or 5G base stations. Particular emphasis was given to software interfaces that enable network monitoring, as well as to the methodology for experimental evaluation of the connectivity solutions between devices in 5G networks.

Within the SUNSEED project that has been concluded in 2017, we developed in collaboration with a company ComSensus two types of wide area measurement system (WAMS) devices for the use in smart grids; one for the measurement of voltage and current phasors in real time (CP-SPM) and the other for the measurement of power quality and for the control of end devices (CP-PMC). We also actively participated in the deployment of these devices in the distribution network pilot of the project partner Elektro Primorska, where we were primarily responsible for secure collection and transmission of measurement data to the remote data and application server.

Successful conclusion of the FP7 SUNSEED project and the start of the new H2020 projects DEFENDER, NRG-5, SAAM and WiSHFUL.

In 2017 we also started the work on three new H2020 projects, in particular DEFENDER, NRG-5 and SAAM, as well as an open-call 9-months extension to H2020 project WiSHFUL.

In DEFENDER we started with participation in defining a dynamic security service level agreement (DS-SLA) concept to mitigate threats and to optimize protection, service restoration and costs as well as with the design and implementation of advanced data-processing algorithms for detection, identification and localization of cyber-physical threats based on data from synchrophasor measurement (SPM) units deployed in the energy grid. After thorough testing and validation in laboratory environment these units will be used in a pilot demonstration of SPM based threat detection in a real operating environment at Italian Distribution System Operator ASM Terni.

In NRG-5 we initiated the investigation of the suitability of the 5G communication network to serve the energy vertical sector, in particular to provide optimal communications of the energy grid services in terms of supporting massive smart metering and very low latency for control and fault localization.

In SAAM we started with the design of the system architecture for unobtrusive sensing support for monitoring and identifying the activity of the elderly population in their home environment. This will be followed by the development of new and the adaptation of existing sensing and communication devices and algorithms to enable multimodal coaching of the aging population and their caregivers, also planned for testing and validation in real home environments.

Figure 3: Synchro-phasor measurement unit (red circle) deployed in a real environment on a transformer mast. Developed within FP7 SUNSEED project.

Finally, in WiSHFUL we extended the original capabilities of the project with addition of LOG-a-TEC testbed 5G capillary capabilities and the adaptation of WiSHFUL universal programming interfaces for the use in the LOG-a-TEC testbed.

As an important recognition of our research in the area we were also selected for the organization of EuCNC 2018 conference, to be held 18-21 June 2018 in Ljubljana. EuCNC is one of the biggest annual European events focusing on 5G and the Next Generation Internet technologies, services and applications, and is supported financially and in content also by the European Commission.

Some outstanding publications in the past year

1. Nielsen, Jimmy, Jorgušeski, Ljupčo, Alič, Kemal, Smolnikar, Miha, Kuhar, Urban, Švigelj, Aleš, et al. Secure real-time monitoring and management of smart distribution grid using shared cellular networks.

IEEE wireless communications, ISSN 1536-1284. [Print ed.], 2017, vol. 24, no. 2, str. 10-17, doi: 10.1109/MWC.2017.1600252.

2. Kelmendi, Arsim, Kandus, Gorazd, Hrovat, Andrej, Kourogiorgas, Chariaos, Panagopoulos, Athanasios, Schönhuber, Michael, Mohorčič, Mihael, Vilhar, Andrej. Rain attenuation prediction model based on hyperbolic cosecant Copula for multiple site diversity systems in satellite communications. IEEE transactions on antennas and propagation, ISSN 0018-926X. [Print ed.], 2017, vol. 65, no. 9, str. 4768-4779, doi: 10.1109/TAP.2017.2726679.

3. He, Danping, Ai, Bo, Guan, Ke, García-Loygorri, Juan Moreno, Tian, Li, Zhong, Zhangdui, Hrovat, Andrej. Influence of typical railway objects in mmWave propagation channel. IEEE transactions on vehicular technology, ISSN 0018-9545. [Print ed.], [in press] 2017, 12 str., doi: 10.1109/TVT.2017.2782268.

4. Trobec, Roman, Stamatović, Biljana. Analysis and classification of flow-carrying backbones in two-dimensional lattices. Advances in engineering software, ISSN 0965-9978. [Print ed.], 2017, vol. 103, pp. 38-45.

5. Depolli, Matjaž, Kosec, Gregor. Assessment of differential evolution for multi-objective optimization in a natural convection problem solved by a local meshless method. Engineering optimization, ISSN 0305-215X, 2017, vol. 49, no. 4, pp. 675-692.

6. Kosec, Gregor, Maksić, Miloš, Djurica, Vladimir. Dynamic thermal rating of power lines : model and measurements in rainy conditions. International journal of electrical power & energy systems, ISSN 0142-0615. [Print ed.], 2017, vol. 91, pp. 222-229.

7. Fortuna, Carolina, Bekan, Adnan, Javornik, Tomaž, Cerar, Gregor, Mohorčič, Mihael. Software interfaces for control, optimization and update of 5G machine type communication networks. Computer networks : the international journal of computer and telecommunications networking, ISSN 1389-1286. [Print ed.], 2017, vol. 129, part 2, str. 373-383, doi: 10.1016/j.comnet.2017.06.015.

8. Sociu, Mihai, Šolc, Tomaž, Cremene, Ligia, Mohorčič, Mihael, Fortuna, Carolina. Discrete transmit power devices in dense wireless networks : methodology and case study. IEEE access, ISSN 2169-3536, 2017, vol. 5, str. 1762-1778, doi: 10.1109/ACCESS.2017.2669403.

Awards and appointments

1. Dr. Viktor Avbelj, co-mentor with Prešeren Award for students awarded Ada Lazar and **Špela** Likar, Ljubljana, University of Ljubljana; FOR: research work Application of wireless electrocardiogram in hospitalised patients

2. Prof. Dr. Roman Trobec, Dr. Viktor Avbelj, Dr. Matjaž Depolli, Dr. Aleksandra Rashkovska Koceva, Dr. Gregor Kosec, Tomaž Krištofelc, Klemen Bregar, Dr. Ivan Tomašić: The Puh Certificate of Recognition, Ljubljana, The Board of the Republic of Slovenia for the Zois Award, the Zois Certificate of Recognition, the Ambassador of Science of the Republic of Slovenia Certificate of Recognition and the Puh Certificate of Recognition; FOR: a miniature personal device with an on-board ECG sensor for long-term measurement of heart rhythm Savvy ECG - an important achievement in the field of mobile health

3. Prof. Dr. Roman Trobec, Dr. Viktor Avbelj, Dr. Matjaž Depolli, Dr. Aleksandra Rashkovska Koceva, Dr. Gregor Kosec, Tomaž Krištofelc, Klemen Bregar, Dr. Ivan Tomašić: A golden award of Celjski sejem, Celje, Celjski sejem; FOR: a miniature personal device with an on-board ECG sensor for long-term measurement of heart rhythm Savvy ECG - an important achievement in the field of mobile health

Organization of Conferences, Congresses and Meetings

1. 5G PPP Phase 3 Information day and Stakeholders event, Ljubljana, Slovenia, 17th October 2017
2. FWO project meeting »Multi-analysis of fretting fatigue using physical and virtual experiments«, Jožef Stefan Institute, Ljubljana, 9 February 2017
3. H2020 project "eWine" Plenary and Review Meeting, Jožef Stefan Institute, Ljubljana, 6–9 March 2017
4. FWO project meeting »Multi-analysis of fretting fatigue using physical and virtual experiments«, Jožef Stefan Institute, Ljubljana, 2–6 October 2017

INTERNATIONAL PROJECTS

1. 7FP - CITI-SENSE; Development of Sensor-based Citizens' Observatory Community for Improving Quality of Life in Cities
Prof. Mihael Mohorčič
European Commission

2. 7FP - ProaSense; The Proactive Sensing Enterprise
Prof. Mihael Mohorčič
European Commission

3. 7FP - SUNSEED; Sustainable and Robust Networking for Smart Electricity Distribution

Prof. Mihael Mohorčič
European Commission
4. COST IC1405; Reversible Computation - Extending Horizons of Computing
Prof. Monika Kapus Kolar
Cost Office
5. COST IC1305; Network for Sustainable Ultrascale Computing (NESUS)
Prof. Roman Trobec
Cost Office
6. COST CA15104; Inclusive Radio Communication Networks for 5G and Beyond (IRACON)
Prof. Tomaž Javornik
Cost Office
7. ESA - SatProSi-Alpha; Ka/Q-band Propagation Measurements and Modelling - Slovenian Contribution to the Alphasat TDP#5 Scientific Mission
Dr. Andrej Vilhar
Esa/estec.
8. H2020 - eWINE; Elastic Wireless Networking Experimentation
Prof. Mihael Mohorčič
European Commission
9. H2020 - Fed4FIREplus; Federation for FIRE Plus
Prof. Mihael Mohorčič
European Commission
10. H2020 - WISHFUL; Wireless Software and Hardware platforms for Flexible and Unified radio and network control
Prof. Mihael Mohorčič
European Commission
11. H2020 - DEFENDER; Defending the European Energy Infrastructures
Prof. Mihael Mohorčič
European Commission
12. H2020 - EuConNeCts3; European Conferences on Networks and Communications (EuCNC)
Prof. Mihael Mohorčič
European Commission
13. H2020 - NRG-5; Enabling Smart Energy as a Service via 5G Mobile Network Advances
Dr. Carolina Fortuna
European Commission
14. H2020 - SAAM; Supporting Active Ageing through Multimodal Coaching
Prof. Mihael Mohorčič
European Commission

RESEARCH PROGRAMS

1. Telecommunication Systems
Prof. Mihael Mohorčič

2. Parallel and Distributed Systems
Prof. Roman Trobec

R&D GRANTS AND CONTRACTS

1. Graph Optimisation and Big Data
Dr. Matjaž Depolli
2. Multi-analysis of fretting fatigue using physical and virtual experiments
Prof. Roman Trobec
3. Advanced Ray-Tracing Techniques in Radio Environment Characterization and Radio Localization
Prof. Mihael Mohorčič
4. Smart City Ecosystem – EkoSmart
Prof. Roman Trobec
Ministry of Education, Science and Sport
5. Strategic Research & Innovation Partnership (SRIP) Smart Cities and Communities
Prof. Mihael Mohorčič
Ministry of Education, Science and Sport
6. Antenna Tracking System Simulator Verification
Dr. Andrej Vilhar
Hitec Luxembourg S.a.
7. The European conference on Networks and Communications 2018 (EuCNC 2018)
Prof. Mihael Mohorčič
Cankarjev dom

NEW CONTRACTS

1. Advanced Ray-Tracing Techniques in Radio Environment Characterization and Radio Localization
Prof. Mihael Mohorčič
Xlab d. o. o.
2. MobECG module for exporting PDF reports
Dr. Matjaž Depolli
Saving trgovina in storitve d. o. o.
3. Cooling of overhead power lines in wind regimes below 0.6 m/s
Dr. Gregor Kosec
Eles, d. o. o.

VISITORS FROM ABROAD

1. Prof. Dr Stephane Bordas, University of Luxembourg, Luxemburg, 9. 2. 2017
2. Prof. Dr Magd Abdel Wahab, Ghent University, Ghent, Belgium, 9. 2. 2017
3. Prof. Dr Ingrid Moerman, IMEC, Leuven, Belgium, 6–7 March 2017
4. Prof. Dr Luiz DaSilva, Trinity College Dublin, Dublin, Ireland, 6–7 March 2017
5. Dr Jorge Pereira, European Commission - DG CONNECT, Brussels, Belgium, 6–7 March 2017
6. Jean-Pierre Bienaimé, Secretary General, 5G Infrastructure Association, (5G-IA), Brussels, Belgium, 17. 10. 2017
7. Pavlos Fournogerakis, European Commission - DG CONNECT, Brussels, Belgium, 17. 10. 2017
8. Dr Didier Bourse, Senior Director, European R&I Programs, Nokia, Paris, France, 17. 10. 2017
9. Pravir Chawdhry, Joint Research Centre, European Commission, Brussels, Belgium, 17. 10. 2017
10. Ao.Univ.-Prof. Dipl.-Ing. Dr. Erich Leitgeb, Institut für Hochfrequenztechnik / Institute of Microwave and Photonic Engineering Graz University of Technology, Graz, Austria, 30 November 2017

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COMPUTER SYSTEMS DEPARTMENT
E-7

The Computer Systems Department is concerned primarily with the development of advanced computing structures and efficient algorithms for massive-data processing, and systems for effective human-computer interaction. Within this broad area, we are concentrating on self-reparable and self-adapting systems, modelling and optimizing of complex, dynamic and nondeterministic systems. Our research results are implemented within applications for production, transport, energy, environmental sustainability, bioinformatics, health, and medicine. As an integral part of our research activities, members of the department have close contacts and collaborations with scientists world-wide, through academic links and industrial contacts, thus enabling us to keep at the forefront of rapidly developing fields.

Head:
Asst. Prof. Gregor Papa

Our research work in 2017 in the fields of efficient algorithms for massive-data processing, computing structures for faster and more reliable execution of algorithms, and interactive interfaces for efficient acquisition and handling of data was complemented by the design and development of various solutions within 12 European projects in *Horizon 2020, ECSEL/ARTEMIS, FP7* and *EFSA* programs, as well as in five national projects.

Algorithms for Data Processing

Our research in the field of efficient algorithms for computer data processing was focused on the development of multi-objective optimization approaches, new statistical approaches, the study of the optimal information transfer in networks, new approaches to statistical comparison and knowledge extraction, neural networks and pattern recognition. Several solutions were used on the application level within computer support for diet planning and our *Open platform for clinical nutrition - OPEN* (http://www.opkp.si). Here, we can highlight the algorithms for food matching, and for the automatic recognition and detection of food and drinks from images using deep learning.

Optimization algorithms

In the field of **multi-objective optimization, supported by parallelization and surrogate modelling**, we continued with a Twinning project Horizon 2020 *SYNERGY - Synergy for smart multi-objective optimisation* (http://synergy-twinning.eu/). Within the coordination of the project we established a connection with the *Chamber of Commerce and Industry of Slovenia*, where future collaboration in the form of workshops is planned to transfer our solutions to Slovenian industry, in line with the *Slovenian smart specialisation strategy*. As a part of enhancing networking, we at-

Novel approach to statistical comparison of optimization algorithms.

tended the most prominent conferences in the field of evolutionary computation, *IEEE Congress on Evolutionary Computation* and *The Genetic and Evolutionary Computation Conference*. We had several visits of researchers from partner institutions, where they give various trainings to JSI members and invited lectures at the *Jožef Stefan Institute* and the *University of Primorska.*

We started with Horizon 2020 Marie Skłodowska-Curie Actions project *UTOPIAE - Uncertainty Treatment and OPtimisation In Aerospace Engineering* (http://utopiae.eu/). The main aim is in bridging **optimization and uncertainty quantification** in aerospace systems applications. The network consists of 15 partners across 6 European countries, collecting mathematicians, engineers and computer scientists from academia, industry, public and private sectors. Developing fundamental mathematical methods and algorithms to bridge the gap between uncertainty quantification and optimization and between probability theory and imprecise probability theory for uncertainty quantification will lead to efficient solutions of high-dimensional, expensive and complex engineering problems. The task of our PhD student (Early Stage Researcher) within the network is to develop efficient computational methods for worst-case and multi-level optimization. The series of network-wide training events started with the Opening Training School (OTS) at *University of Strathclyde*, where our ESR and our two supervisors participated in the common programme.

We continued with studies on **mathematical formalization of artificial genetic representations with neutrality** within the COST Action *ImAppNIO – Improving Applicability of Nature-Inspired Optimisation by Joining Theory and Practice* (http://imappnio.dcs.aber.ac.uk/). The potential that neutral networks have to establish alternative paths for the evolution of the population, and to lead to improved search quality, is the main motiva-
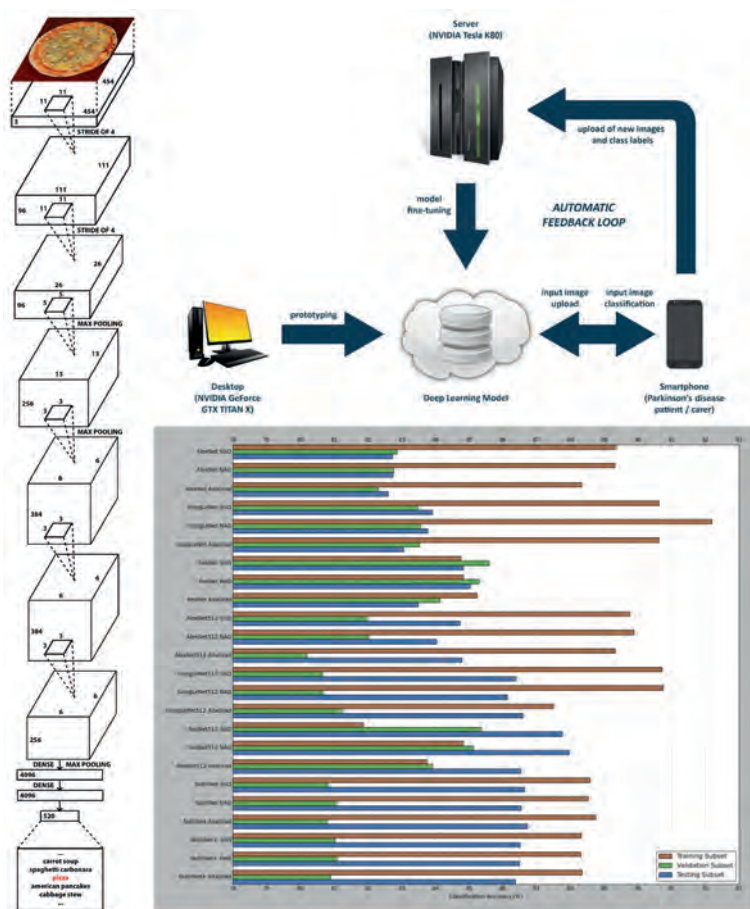
Figure 1: The NutriNet architecture for food recognition from images.

tion for the use of redundant representations in evolutionary computation. The role of neutrality in evolutionary search has been widely considered in the literature, but it remains unclear as to what extent it might contribute to search performance. In studies, a promising class of representations based on error-control codes was proposed, leading to families of representations with various degrees of neutrality, synonymity, connectivity and locality.

In the scope of the ARRS research project *Biomedical data fusion by nonnegative matrix tri-factorization*, in collaboration with the *University of Ljubljana*, the central research objective of the project is the development of new, efficient and accurate **methods for non-negative matrix factorization** problems applied to real-world, complex biomedical data. The goal is to help answer the foremost biomedical questions of precision medicine: patient stratification, biomarker discovery and drug repurposing. The central mathematical optimization problem that we study is penalized non-negative matrix tri-factorization, which is a non-convex high-dimensional optimization problem, hence there is no general efficient algorithm to solve it to optimality. Therefore, we focus on developing state-of-the-art approximate algorithms using fixed-point and coordinate descent methods combined with variants of first- and second-order methods. We implemented an evolutionary multi-objective algorithm and tested it for a non-negative matrix tri-factorization problem. Due to insufficient and slow convergence, we indicated local search approaches that will replace the existing mutation operator in tested evolutionary algorithms. Further, these local search approaches will also be used for the development of a memetic algorithm that we believe will be able to obtain better solutions for the non-negative matrix tri-factorization problem than the existing evolutionary algorithms.

We continued research on the **optimal broadcasting of multiple messages** – in terms of time and the number of messages – in a model, where every vertex of a synchronous network can receive at each time unit at most one message. We considered the simultaneous broadcasting of multiple messages from the same source in such networks with an additional restriction that every received message can be sent out to neighbours only in the next time unit and never to an already informed vertex. We used a general concept of level-disjoint partitions developed for this scenario. We provided a necessary condition in terms of the girth and eccentricity of the root for the existence of more same-rooted level-disjoint partitions of optimal height and provided a structural characterization of graphs that admit simultaneous broadcasting of two messages from a given vertex. We introduced a subgraph extension technique for an efficient information spread within the concept of level-disjoint partition. This approach, with so called bi-wheels, leads to simultaneous broadcasting of the optimal number of messages on a wide class of graphs in optimal time. In particular, we provided tight results for bipartite tori, meshes, hypercubes. We published the paper in *Journal of Combinatorial Optimization*.

We extended the research on the **simultaneous broadcasting of multiple messages** from the same source vertex in synchronous networks. This is considered under restrictions that each vertex receives at most one message in a unit time step, every received message can be sent out only in the next time step, no message is sent to already informed vertices. The number of outgoing messages is unrestricted, messages have unit length, and we assume full-duplex mode. We developed a concept of level-disjoint partitions to study simultaneous broadcasting under this model. In this work we consider the optimal number of level-disjoint partitions. We also provide a necessary condition in terms of eccentricity and girth on the existence of more v-rooted level-disjoint partitions of optimal height. In particular, we provide a structural characterization of the graphs admitting two level-disjoint partitions with the same root.

In cooperation with the *Department of Intelligent Systems* at the JSI and the *Faculty of Electrical Engineering and Computer Science, University of Maribor*, we organized, for the fourteen consecutive year, the **Nature-inspired algorithms workshop** dealing with stochastic optimization techniques.

Statistical approaches

We proposed a **novel approach to the statistical comparison** of meta-heuristic stochastic optimization algorithms, known as Deep Statistical Comparison (DSC). The main contribution of the approach is the novel ranking scheme that is based on comparing distributions instead of using only one statistic, such as the average or median. Experimental results shown that our approach gives more robust results compared to the standard approach for making a statistical comparison in cases when the results are affected by outliers or statistically insignificant differences that exist between data values. The approach is published in the *Information Sciences* journal. The DSC web-based tool is available at http://ws.ijs.si/dsc/. The DSC was also evaluated for different criteria of comparing distribution and presented at the *International Joint Conference on Computational Intelligence*. Studies of how DSC works in the case of multi-objective optimization and quality indicators to access their performances were further presented at the *Third International Conference on Machine Learning, Optimizaiton and Big Data*, and at *IEEE Symposium Series on Computation Intelligence*.

We introduced an in-house developed and freely available **e-learning tool for advanced statistics** in natural sciences and technologies that has the benefit of checking the required conditions of each statistical method and offering only those methods that are appropriate for analysing the

> **Recognising food and drinks from images using deep-learning techniques.**

experimental data (http://ws.ijs.si/statTool/). A tutorial on the e-learning tool and the usage of statistical analysis on food data is presented by a research group of the *Era-Chair ISO-FOOD* project, and as a part of the book "*Science within Food: Up-to-date Advances on research and Educational Ideas*".

As a part of the *Era-Chair ISO-FOOD* project, we also provided results analysing data for the differentiation of Slovenian milk based on the content and carbon isotope composition of fatty acids. The work was presented at the *5th MS Food day*. We are also working on a methodology that can be used for borrowing missing values in food composition databases. The methodology we are working on is based on a statistical comparison, which is done for a specific nutrient in a selected food group. The purpose of the work is not to fill a concrete food composition database, but to provide a methodology to work with missing values, which can then be used for each country. In the analysis only analytical values will be involved.

Within the ARRS applied project *Trans fatty acids* we were also developing statistical methods for data mapping. Our department contributed to an estimation of the intake of trans fatty acids by the use of the *Open platform for clinical nutrition*.

Knowledge extraction

Within the work in Horizon 2020 project *RICHFIELDS – Research Infrastructure on Consumer Health and Food Intake for Escience with Linked Data Sharing* (http://www.richfields.eu/) and in collaboration with EFSA *EU Menu Slovenija*, we developed a **methodology for a string similarity of domain-specific short text segments** that combine morphological information with probability theory. To help the automatic transformation from food intake to nutrient intake, the problem that appears is that the name of the same food (food concept) can be different regarding different ways of how people express themselves. The **StandFood method** consists of two steps. The first step is to use POS tagging to obtain the morphological information presented in the text. The second step is to define which of the extracted morphological information is relevant for the domain of interest and then to use probability theory to model the domain using the relevant morphological information. The method is published in the *Nutrients* journal, and was presented at several international conferences.

As a part of *Era-Chair ISO-FOOD* and Horizon 2020 *RICHFIELDS* projects, we developed a **rule-based named-entity recognition method for knowledge extraction**, drNER, that does not use an annotated corpus and the rules are not associated with the characteristics of the entities of interest. drNER works with text that is composed of sentences and paragraphs. The difference with the other rule-based NERs is that we do not use rules associated with the characteristics of the entities of interest but we use a small number of Boolean algebra rules that help us define the phrases that are entities mentions. Experiments have shown that the presented method provides good results when an annotated corpus is missing and there are no rules created by human experts. This work was presented in *PloS One* journal.

Neural networks

In the area of **pattern recognition** we continued our previous work on evaluating different sources of heart arrhythmias and establishing the influence that each such source has on the electrocardiographic indices. We focused our study on the anti-arrhythmic agents that block the rapidly activating component of the ionic current. The aim of our ongoing work is twofold. First, to quantify the effects of the anti-arrhythmic drug sotalol in the heart muscle repolarization using advanced signal processing and classification techniques. Second, to analyse patients with a history of a drug-induced abnormal heart rhythm with machine-learning approaches to their ECG signal recordings.

We developed several **models for forecasting the natural-gas consumption** of an urban area using machine-learning and data-mining methods. The paper was presented at *Smart Systems and Technologies* conference. The extended work was also submitted to the *Energy* journal. Further, we developed a **methodology for using a deep neural network** as an extremely fast heuristic for optimization problems. This methodology was applied to the production scheduling optimization problem and protein structure optimization problem.

We improved the application based on the automatic recognition of food and drinks from images taken by patients or their caregivers using a smartphone. The **recognition algorithm is implemented by deep-learning techniques**. The method of automatic food recognition was published in the *Nutrients* journal. This work was a part of the Horizon 2020 projects *RICHFIELDS*, that is focused on food- and nutrition-related data, and *PD_manager – mhealth platform for Parkinson's disease management* (http://www.parkinson-manager.eu/) that develops a set of unobtrusive and co-operative mobile devices, to be used by Parkinson's disease patients for symptoms monitoring and the collection of adherence data.

Computing Structures

To support and accelerate our algorithms several approaches were studied and developed at the level of hardware and computing structures; the use and **online reconfiguration of FPGAs**, customized embedded systems and sensors.

In the field of advanced computer structures we developed a **reconfigurable FPGA based hardware acceleration platform**. In order to achieve high data throughput a high-speed PCI Express bus (PCI-E) was chosen. The FPGA configuration is typically made using on-board flash memory or using a programming interface. Both methods have limitations: the first method limits the FPGA device to a few configurations, while the latter allows the reconfiguration but it is slow and requires FPGA programming device. To overcome these drawbacks, we developed a dynamically reconfigurable platform using an internal configuration port. The platform consists of the static part and the dynamic part. The static part is responsible for the PCI-E data transfer and dynamic partial reconfiguration, and it also defines the reconfiguration and data-exchange protocols of the hardware accelerator. The dynamic part can be used for hardware accelerators and is loaded or modified during runtime. The developed reconfigurable platform supports Xilinx Virtex 5 family and later Xilinx FPGA families with a PCI-E interface. It includes the device driver and some example applications for the Linux operating system. It was tested with the AES encryption algorithm. The platform is documented in a master thesis.

We started with studies on the **hardware acceleration of learning of a Deep Neural Network** (DNN) using FPGA devices. The most time-consuming operation in DNN learning is dense matrix multiplication, which can be accelerated by exploiting the parallelism in matrix multiplication. While the basic arithmetic units in the CPU and GPUs have predetermined precision the precision of the arithmetic units in FPGA devices can be reduced in order to increase the number of arithmetic units. Several trade-offs between multiplication time and arithmetic implementations can be studied like floating-point vs. fixed-point arithmetic and/or different arithmetic precision. The FPGA hardware accelerator will be implemented on a reconfigurable FPGA-based hardware platform, which provides fast data transfer via PCI-E bus and allows runtime algorithm modifications.

In the field of **embedded systems** the Libra kitchen scale with Bluetooth interface was finalized. They were assembled and calibrated, and a new, more reliable firmware for the scale micro-controller was developed. The scale consists of a communication module built of the BLE113 interface that connects other parts of the scale, allowing also power-save mode, and a measurement module that is built around a measurement bridge and an accurate AD converter. The basic smartphone applications for the iOS and Android platforms were developed.

In the frame of Horizon 2020 *TETRAMAX - Technology Transfer via Multinational Application Experiments* (https://www.tetramax.eu/) project we made initial steps towards the implementation of the local competence centre offering technology brokerage via an EU-wide Competence Centres Network and assistance to the SMEs in the activities supporting the European "*Smart Anything Everywhere*" initiative in the domain of **customized low-energy computing** for cyber-physical systems and internet of things.

A **multi-hop data-transfer mechanism for Bluetooth Low Energy** (BLE) 4.0 ad-hoc sensor network was developed. The BLE 4.0 protocol supports only the piconet topology and does not support data transfer over multiple nodes. To overcome this limitation a mechanism to relay sensor data over multiple BLE 4.0 nodes using Master/Slave switching was developed. The mechanism dynamically creates communication paths within the BLE ad-hoc sensor network where all the BLE nodes are identical. The sensor data query is initiated from a designated node and forwarded through the dynamically built network. The sensor data are collected over the same path, back to the designated node. The mechanism does not perform route discovery; therefore, no routing tables are needed. Using this mechanism, the range of the sensor data acquisition can be extended from the BLE range to the whole BLE sensor network.

Multi-hop data transfer mechanism for Bluetooth.

In the scope of **sensors research** we studied the effect of condensing environments on the characteristics of piezoresistive LTCC-based pressure sensors. The achieved results indicate that the sensors' short-term reactions on the extremely humid atmosphere and/or occasional presence of water are non-negligible and should be considered throughout the entire span of the sensor lifecycle. Knowledge of these mechanisms can help in the selection of appropriate sensors in target system applications and their maintenance. The work was published in *Sensors and Actuators* journal.

Human-Computer Interaction

In the area of efficient interaction systems, we focused on the study of **usage scenarios** within a human-machine interaction, computer vision approaches in sport training, as well as development of **serious games** for tele-rehabilitation, and web tools for nutrition and food informatics.

We contributed to the **HMI framework for system maintenance** in the frame of the ECSEL project *MANTIS – Cyber Physical System based Proactive Collaborative Maintenance* (http://www.mantis-project.eu/), where we used a scenario-based approach to collect essential information regarding the HMI requirements of individual use cases, to identify the related content elements, as well as to design and implement usability tests of the HMI prototype. The developed HMI model allows us to conceive the HMI framework of a given use case and to define its particular content elements, their functionalities and input/output data at the desired level of detail, both at the early design phase and at implementation. The framework can also serve other purposes, like for example, to identify content elements involved in context-awareness issues and provide the basis for analysing developed solutions.

In the area of **computer vision** we developed a measuring protocol and we performed preliminary measurements of the ball height over the net in games of table tennis. The goal of the work was to establish the influence of the net height on the table-tennis game characterised by several attributes such as the ball-to-net distance, net errors, net balls, net serve errors, set duration and lets. The measurements were performed by using a calibrated high-speed camera positioned near the table with the optical axis aligned to the net top line. In the post-processing phase of the high-speed camera recordings the net-to-ball distances were determined with the in-house-developed image-processing algorithm. The protocol and the procedure were successfully tested for the three net heights with a limited number of male and female players playing a small number of games.

Figure 2: The HMI model for proactive maintenance systems.

We developed several **web tools for nutrition and food informatics**. Within the *FOOD LABELS* project, we collaborate with *Administration of the Republic of Slovenia for Food Safety, Veterinary Sector and Plant Protection* to develop a web tool for calculating and checking the food label with respect to the Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers. The tool enables an easy calculation of the food label using national food composition data. Within the *FOOD DA BEST - FOOD Supplement DAtaBasE STandardization* project we contributed to the standardization of the dietary supplement data, while in the project Innovative solutions for informed decisions in collaboration with *NUTRIS - Inštitut za nutricionistiko*, *Zveza potrošnikov Slovenije* and *GS1 Slovenia* we are preparing a national database of branded foods and a **mobile application Veš, kaj ješ**.

We started with the Horizon 2020 project *SAAM – Supporting Active Ageing through Multimodal coaching* (http://bilsp.org/saam-active-ageing/) where we will focus upon innovative, technology-enabled approaches to support the aging population living at home, with a novel and practical emphasis on ambient sensing and learning user needs and preferences, and effective coaching by leveraging the user's social support networks. We will develop and upgrade **web tools and services to support the elderly population**.

In frame of the Horizon 2020 project *REFRESH – Resource Efficient Food and dRink for the Entire Supply cHain* (http://eu-refresh.org/) we developed **web tool for gathering and handling of data of food waste** and developed web services to connect the web tool with other information systems. The application is available at https://ws.eurofir.org/FoodWasteExplorer/login.htm. Within the *REFRESH* project we will contribute towards the
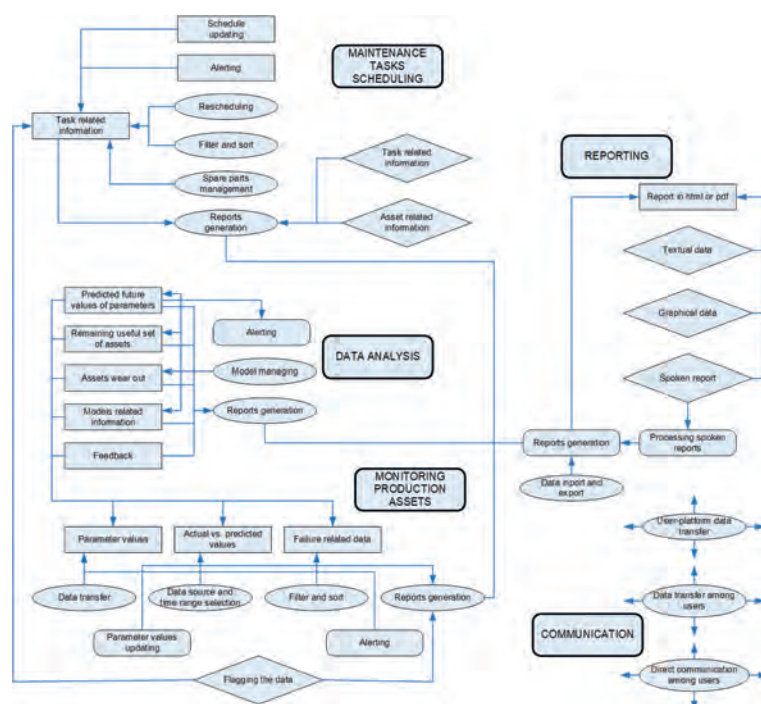
Figure 3: Influence of ball height over the net in table tennis.

objectives of reducing food waste across Europe by 30 % by 2025, reducing waste-management costs, and maximizing the value from unavoidable food waste and packaging materials.

Some outstanding publications in the past year

1. T. Eftimov, P. Korošec, B. Koroušić Seljak, "A novel approach to statistical comparison of meta-heuristic stochastic optimization algorithms using deep statistics" Information sciences, 417: 186-215, 2017, doi: 10.1016/j.ins.2017.07.015.

2. T. Eftimov, B. Koroušić Seljak, P. Korošec, "A rule-based named-entity recognition method for knowledge extraction of evidence-based dietary recommendations", PloS One, 12 (6): 0179488-1-0179488-32, 2017, doi: 10.1371/journal.pone.0179488.

3. M. Santo Zarnik, F. Novak, "Effect of condensing environments on characteristics of piezoresistive ceramic pressure sensors", Sensors and actuators A: Physical, 267: 385-392, 2017, doi: 10.1016/j.sna.2017.10.038.

4. T. Eftimov, P. Korošec, B. Koroušić Seljak, "StandFood: standardization of foods using a semi-automatic system for classifying and describing foods according to FoodEx2", Nutrients, 9 (6): 542-1-541-16, 2017, doi: 10.3390/nu9060542.

5. S. Mezgec, B. Koroušić Seljak, "NutriNet: a deep learning food and drink image recognition system for dietary assessment", Nutrients, 9 (7): 657-1- 657-19, 2017, doi: 10.3390/nu9070657.

Organization of conferences, congresses and meetings

1. 30th Slovenian Workshop Algorithms by Nature Models, 9. 5. 2017
2. 31st Slovenian Workshop Algorithms by Nature Models, IJS, 8. 12. 2017
3. Working Group Meeting, COST Action CA15140 Improving Applicability of Nature-Inspired Optimisation by Joining Theory and Practice (ImAppNIO) 21.9.2017 Bernardin, Slovenia
4. Management Committee Meeting, COST Action CA15140 Improving Applicability of Nature-Inspired Optimisation by Joining Theory and Practice (ImAppNIO) 22.9.2017 Bernardin, Slovenia

INTERNATIONAL PROJECTS

1. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Asst. Prof. Barbara Koroušić Seljak
   European Commission
2. EU MENU Slovenija; LOT 1; Support to National Dietary Survey in Compliance with the EU MENU Methodology - Fourth Support
   Asst. Prof. Barbara Koroušić Seljak
   European Food Safety Authority - Efsa
3. EU MENU Slovenija; LOT 2; Support to National Dietary Survey in Compliance with the EU MENU Methodology - Fourth Support
   Asst. Prof. Barbara Koroušić Seljak
   European Food Safety Authority - Efsa
4. COST CA15140 - ImAppNIO; Improving Applicability of Nature-Inspired Optimisation by Joing Theory and Practise
   Dr. Vida Vukašinović
   Cost Office
5. H2020 - MANTIS; Cyber Physical System based Proactive Collaborative Maintenance
   Prof. Gregor Papa
   European Commission
6. H2020 - REFRESH; Resource Efficient Food and Drink for the Entire Supply Chain
   Asst. Prof. Barbara Koroušić Seljak
   European Commission
7. H2020 - RICHFIELDS; Research Infrastructure on Consumer Health and Food Intake using E-science with Linked Dara Sharing
   Asst. Prof. Barbara Koroušić Seljak
   European Commission
8. H2020 - UTOPIAE; Uncertainty Treatment and OPtimization in Aerospace Engineering
   Prof. Gregor Papa
   European Commission
9. H2020 - TETRAMAX; TEchnology TRAnsfer via Multinational Application eXperiments
   Dr. Marina Santo Zarnik
   European Commission
10. H2020 - SAAM; Supporting Active Ageing through Multimodal Coaching
    Asst. Prof. Barbara Koroušić Seljak
    European Commission
11. H2020 - PD_manager; Mhealth Platform for Parkinson's Disease Management
    Asst. Prof. Barbara Koroušić Seljak
    European Commission
12. H2020 - SYNERGY; Synergy for Smart Multi-Objective Optimisation
    Prof. Peter Korošec
    European Commission

RESEARCH PROGRAM

1. Computer Structures and Systems
   Prof. Gregor Papa

R & D GRANTS AND CONTRACTS

1. Biomedical data fusion by nonnegative matrix tri-factorization
   Prof. Gregor Papa
2. Advanced electrocaloric energy Conversion
   Asst. Prof. Barbara Koroušić Seljak
3. Upgrade of the web portal for school nutrition "Šolski lonec" with respect to the national dietary guidelines
   Asst. Prof. Barbara Koroušić Seljak
4. Innovative solutions for informed food choices for healthier consumers
   Asst. Prof. Barbara Koroušić Seljak
5. Internationally comparable database standardization of dietary supplements FOOD'S DA BEST
   Asst. Prof. Barbara Koroušić Seljak
6. Strategic Research & Innovation Partnership (SRIP) Smart Cities and Communities
   Prof. Gregor Papa
7. Upgrade of the Open Platform for Clinical Nutrition to suit the needs of the Federation of EU member National Associations of Dietitians EFAD
   Asst. Prof. Barbara Koroušić Seljak
8. iNet - The Impact of Net Height in Table Tennis
   Dr. Drago Torkar

NEW CONTRACTS

1. Application development (web, mobile) „Food Labeling" and annual maintenance (12 months)
   Asst. Prof. Barbara Koroušić Seljak
   Ministry of Agriculture, Forestry and Food

VISITORS FROM ABROAD

1. Prof. El-Ghazali Talbi, University Lille 1, Lille, France, 08. 01. – 10. 01. 2017
2. Prof. Nouredine Melab, University Lille 1, Lille, France, 08. 01. – 10. 01. 2017
3. Prof. Veljko M. Milutinović, assistant Zoran Babović and assistant Blažo Burić, University of Belgrade Faculty of Electrical Engineering, Belgrade, Serbia, 20. 03 – 23. 03. 2017
4. Prof. Boris Naujoks, Tehnische Hohschule, Koeln, Germany, 08. 05. 2017
5. Prof. Vanessa Volz, Tehnische Hohschule, Koeln, Germany, 08. 05. 2017
6. Dr. Katarína Hriňáková, Slovak University of Technology in Bratislava, Bratislava, Slovakia, 03. 07. – 07. 07. 2017
7. Prof. El-Ghazali Talbi, University Lille 1, Lille, France, 02. 10. – 03. 10. 2017

STAFF

Researchers
1. Asst. Prof. Anton Biasizzo
2. Prof. Peter Korošec
3. Prof. Barbara Koroušić Seljak
4. *Prof. Stanislav Kovačič*, left 01.10.17*
5. *Prof. Franc Novak, left 30.12.17*
6. **Prof. Gregor Papa**, Head
7. Asst. Prof. Jurij Šilc

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9. Dr. Marko Pavlin*
10. Dr. Drago Torkar
11. Dr. Vida Vukašinović

Postgraduates
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13. Tome Eftimov, B. Sc.
14. Rok Hribar, B. Sc.

Technical officers
15. Peter Novak, B. Sc.
16. Špela Poklukar, B. Sc.
17. Urban Škvorc, B. Sc.

Technical and administrative staff
18. Jolanda Jakofčič

Note:
* part-time JSI member

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ORIGINAL ARTICLE

1. Klemen Bohinc, Nejc Vantur, Drago Torkar, Tomaž Lampe, Marija Hribernik, Miroljub Jakovljević, "Knee stiffness and viscosity: new implementation and perspectives in prosthesis development", *Bosn. j. basic med. sci.*, **17**, 2, 164-171, 2017.

2. Tome Eftimov, Peter Korošec, Barbara Koroušić-Seljak, "A novel approach to statistical comparison of meta-heuristic stochastic optimization algorithms using deep statistics", *Inf. sci.*, **417**, 186-215, 2017.

3. Tome Eftimov, Peter Korošec, Barbara Koroušić-Seljak, "StandFood: standardization of foods using a semi-automatic system for classifying and describing foods according to FoodEx2", *Nutrients*, **9**, 6, 542, 2017.

4. Tome Eftimov, Barbara Koroušić-Seljak, Peter Korošec, "A rule-based named-entity recognition method for knowledge extraction of evidence-based dietary recommendations", *PloS one*, **12**, 6, 0179488, 2017.

5. Simon Mezgec, Barbara Koroušić-Seljak, "NutriNet: a deep learning food and drink image recognition system for dietary assessment", *Nutrients*, **9**, 7, 657, 2017.

6. Marina Santo-Zarnik, Franc Novak, "Effect of condensing environments on characteristics of piezoresistive ceramic pressure sensors", *Sens. actuators, A, Phys.*, **267**, 385-392, 2017.

7. Kostas M. Tsiouris *et al.* (11 authors), "PD_Manager: a mHealth platform for Parkinson's disease patient management", *Healthc. technol. lett.*, **4**, 3, 102-108, 2017.

PUBLISHED CONFERENCE CONTRIBUTION

1. Pedro David Arini, Drago Torkar, "Optimal lead selection for evaluation ventricular premature beats using machine learning approach", In: *Biomedical engineering system and technologies: 9th International Joint Conference, BIOSTEC 2016 Rome, Italy, February 21 - 23, 2016: revised selected papers*, (Communications in computer and information science, **690**), Ana Fred, Hugo Gamboa, ed., 2017, 419-204.

2. Imre Cikajlo, Alma Hukić, Irena Dolinšek, Dejana Zajc, Mateja Vesel, Tatjana Krizmanič, Karmen Peterlin-Potisk, Bojan Blažica, Anton Biasizzo, Franc Novak, "Telerehabilitation of upper extremities with target based games for persons with Parkinson's disease", In: *2017 International Conference on Virtual Rehabilitation (ICVR), 19-22 June 2017, [Montreal, Canada]*, [S. l.], Institute of Electrical and Electronics Engineers, cop. 2017.

3. Tome Eftimov, Gordana Ispirova, Barbara Koroušić-Seljak, Peter Korošec, "A semi-automatic system for classifying and describing foods accordings to FoDEx2", In: *Book proceedings*, 3rd IMEKOFOODS, Metrology Promoting Harmonization & Standardization in Food & Nutrition, 1st - 4th October, Thessaloniki, Greece, [S. l., s. n.], 2017, 56-59.

4. Tome Eftimov, Peter Korošec, Barbara Koroušić-Seljak, "The behavior of deep statistical comparison approach for different criteria of comparing distributions", In: *IJCCI 2017: proceedings of the 9th International Joint Conference on Computational Intelligence, November 1-3, 2017, Funchal, Madeira, Portugal*, Christophe Sabourin, ed., [S. l.], SCITEPRESS, = Science and Technology Publications, cop. 2017, 73-82.

5. Tome Eftimov, Peter Korošec, Barbara Koroušić-Seljak, "Comparing multi-objective optimization algorithms using an ensemble of quality indicators with deep statistical comparison approach", In: *2017 IEEE Symposium Series on Computational Intelligence, November 27 to December 1, 2017, (SSCI), Honolulu, Hawai*, Danvers, IEEE = Institute of Electrical and Electronics Engineers, 2017, 2801-2809.

6. Rok Hribar, Gregor Papa, Jurij Šilc, "Prediction of natural gas consumption using empirical models", In: *Proceedings of 2017 International Conference on Smart Systems and Technologies, (SST), Osijek, Croatia, October 18-20, 2017*, Drago Žagar, ed., Danvers, Institute of Electrical and Electronics Engineers = IEEE, 2017, 31-36.

7. Gordana Ispirova, Tome Eftimov, Barbara Koroušić-Seljak, Peter Korošec, "Mapping food composition data from various data sources to a domain-specific ontology", In: *IC3K 2017: proceedings of the 9th International joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management, November 1-3, 2017, Lisbon, Portugal. Volume 2, KEOD*, David Aveiro, ed., Jan L. G. Dietz, ed., Joaquim

Filipe, ed., Lisbon, SCITEPRESS = Science and Technology Publications, 2017, 203-210.

8. Tamara Jakovljević, Gregor Papa, "The role of physiological sensors in dyslexia treatment", In: *Zbornik šestindvajsete mednarodne Elektrotehniške in računalniške konference ERK 2017*, (Zbornik ... Elektrotehniške in računalniške konference ERK ..., 26), ERK 2017, Portorož, Slovenija, 25. - 26. september 2017, Andrej Žemva, ed., Andrej Trost, ed., Ljubljana, IEEE, Slovenska sekcija IEEE, 2017, 325-328.

9. Martin Pečar, Gregor Papa, "Transportation problems and their potential solutions in smart cities", In: *Proceedings of 2017 International Conference on Smart Systems and Technologies, (SST), Osijek, Croatia, October 18-20, 2017*, Drago Žagar, ed., Danvers, Institute of Electrical and Electronics Engineers = IEEE, 2017, 195-199.

INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

1. Tome Eftimov, Peter Korošec, Doris Potočnik, Nives Ogrinc, David John Heath, Barbara Koroušić-Seljak, "How to perform properly statistical analysis on food data?: an e-learning tool: advanced stati stics in natural sciences and technologies", In: *Science within food: up-to-date advances on research and educational ideas*, (Formatex food science series, **1**), A. Méndez-Vilas, ed., Badajoz, Formatex Research Center, 2017, 144-151.

DEPARTMENT OF KNOWLEDGE TECHNOLOGIES E-8

The Department of Knowledge Technologies performs research in advanced information technologies aimed at acquiring, storing and managing knowledge to be used in the development of an information- and knowledge-based society. Established areas of our work include intelligent data analysis (machine learning, data mining, and knowledge discovery in databases), language technologies and computational linguistics, computational creativity, decision support and knowledge management. In addition to research in knowledge technologies, we are also developing applications in environmental sciences and management, agronomy, medicine, biomedicine and bioinformatics, economics, finance and marketing. The department is also a recognised centre of linguistic research and digital humanities.

Head:
Prof. Nada Lavrač

In 2017 we were involved in fourteen national projects, two EU FP7 and ten Horizon 2020 projects, one COST action, one INTERREG V-A Slovenia-Italy project, one infrastructure project, one smart-specialization project, two bilateral projects, and five industry projects. The department hosted eight junior researchers working towards their PhDs.

In the area of **intelligent data analysis and data mining** we have developed several new methods and used them in a number of application domains. In the area of heterogeneous network analysis we developed new search heuristics based on text mining. In the area of semantic data mining we achieved a one-hundred-times efficiency improvement by network-ranking-assisted data preprocessing and filtering. In redescription mining we developed a new method for redescription construction using predictive clustering trees as well as a new framework and method for redescription set construction. We published methods that enable big-data analysis within the ClowdFlows platform, which is continually developed and whose commercialization potential is being funded within the FET Innovation Launchpad project CF-Web. Within the PD_manager project, which we coordinate at JSI, we developed a method that combines multi-target learning with short-time-series analysis for the identification of groups of similar patients with Parkinson's disease. We started to work on a new H2020 project SAAM (Supporting Active Ageing through Multimodal coaching), where we are developing a Virtual Assistant-Coach that supports the aging population living at home.

In the context of developing methods for the automated modelling of dynamic systems, using both data and domain knowledge, we have proposed a meta-model framework for surrogate-based numerical optimization. The use of surrogate models allows for more efficient parameter optimization in the differential equations used to model dynamic systems.

Nada Lavrač had an invited lecture "From Relational to Semantic Data Mining" at the 16th International Semantic Web Conference ISWC-2017 in Vienna. The conference is the main world-wide Semantic Web event, with over 600 participants.

We successfully completed the coordination of the MAESTRA project (Learning from Massive, Incompletely Annotated, and Structured Data), which received the highest evaluations by the EU's reviewers. The project focused on analysing data that can be complex in several ways, including the semi-supervised setting with partially annotated data. Within the project, we developed many new methods for predicting different types of structured outputs in both a batch and a streaming setting. These include batch methods for semi-supervised classification and multi-target regression, online tree-based methods for multi-target regression, option trees for hierarchical multi-label classification, as well as trees for hierarchical multi-target regression and tree ensembles for multi-label classification using random label subset selections. We have also developed methods for the feature ranking for different types of structured outputs, such as multi-target regression and hierarchical multi-label classification.

We have used the developed methods for image analysis and modelling forest growing stock data. In the area of medicine, we have used them for modelling time-series of glucose measurements from diabetes patients and analysing the influence of pathogens on the composition of human gut microbiota. Finally, we have used them in the ESA Mars Express Power Challenge, where the task was to predict the power consumption of 33 different lines of the thermal subsystem of the Mars Express orbiter.

In the context of the FET Flagship HBP (Human Brain Project) project, we are developing new data-mining methods and applying them to discover the biological signatures of neurodegenerative diseases, such as Alzheimer's. Two novel methods for mining redescription sets were developed based on predictive clustering, and applied to relate the clinical and biological characteristics of cognitively impaired and Alzheimer's disease patients.

In the LANDMARK project we continued with the development of models for the prediction of soil functions. Most of the research activities were focused on data pre-processing, which was a very complex task. Models for the prediction of primary productivity from long-term experimental studies in Austria were developed. The results of this study were submitted to a special issue of the Regional Environmental Change Journal. In addition, more prediction models were developed for other soil functions as well and are in the process of validation with the domain experts. An important part of our research activities in the LANDMARK project was the development of multiple-attribute decision models using the DEX methodology for an assessment of five soil functions. Each of the models was verified by experts and calibrated to three prevailing pedoclimatic European zones. Data from various national and EU databases were extracted and pre-processed. This required a lot of coordination efforts in order to collect the data and to perform the discretisation of their values, which was done after a long process of determining threshold values.

A large part of the activities in the BioDiv project were connected to data pre-processing. The completed database consists of three large sets of attributes describing: i) taxonomic and functional traits of Syrphide auxiliary species, ii) landscape properties, describing the fields and semi-natural habitats, and iii) environmental conditions during the sampling periods. The abundance of the prevailing Syrphide species and selected functional traits were modelled using model and regression trees.

Figure 1: Concordance of verb "gledati" ("to look") in the Janes Forum corpus. The KonText concordancer of the CLARIN.SI research infrastructure offers over 40 corpora, among them several new corpora of user-generated Slovene. Note that the query also returns results with non-standard forms of the verb, such as "gledo".

Two H2020 projects started in 2017: TRUE (TRansition paths to sUstainable legume based systems in Europe), and TomRes (A novel and integrated approach to increase multiple and combined stress tolerance in plants using tomato as a model). Since the majority of our activities are planned for 2018 and 2019, we were mainly focused on initial research activities such as an intensive literature search. Within TRUE we developed the first drafts of the conceptual model for the assessment of the sustainability of legume quality chains. Our activities in the TomRes project were focused on a study of the research domain and on the structuring of the existing knowledge about the prediction models of tomato responses to nutrient and water stress on the eco-physiology level.

In the area of **text and web mining**, **and heterogeneous information network analysis** we successfully completed the SIMPOL project (Financial Systems Simulation and Policy Modelling). We continued work on an existing H2020 FET project DOLFINS (Distributed Global Financial Systems for Society). We also continued to work on the new national project FORMICA (Influence of formal and informal corporate communications on capital markets). The main emphasis of the research in this area is combining text mining, network analysis and sentiment analysis to reveal and highlight the underlying properties in different domains. The main sources of data that we analyse are social media (Twitter, Facebook), online news, annual reports, and other relevant data (e.g., voting on the Brexit referendum, stock prices, register of lobby organizations, etc.).

We proposed a methodology to properly evaluate Twitter sentiment (or stance) classification models for Twitter-specific time-ordered data. The classification models are language and topic dependent. They are constructed using text-mining methods, from a large set of manually annotated tweets by domain experts, and result in high-quality domain- and language-specific models. We showed that the standard cross-validation approach is appropriate to evaluate such models only if one applies blocked cross-validation, and does not randomly shuffle the examples. We applied the above methodology to a highly relevant European use case: the UK referendum on Brexit. We developed a Brexit-specific Twitter stance classification model and used it to monitor public mood before and during the referendum. We also identified the most influential Twitter users and noted that the proponents of Brexit were considerably more active than the remain camp. We also provided an in-depth analysis of the Twitter volume and stance about the 30 companies in the Dow Jones Industrial Average index (DJIA), over a period of three years. We focused on Earnings Announcements and showed that there is a considerable difference with respect to when the announcements are made: before the market opens or after the market closes. We analysed the differences in terms of the Twitter volumes, cumulative abnormal returns, trade returns, and earnings surprises. We also collected a dataset of annual reports from the DJIA and studied the correlations between the linguistic and financial indicators.

Martin Breskvar, Matej Petkovič and Blaž Škrlj were part of the winning team at the HackElect 2017 hackathon. Using methods such as predictive classification trees and deep neural networks, they were the only ones who successfully predicted the consumption of electricity at the level of individual household appliances for different time scales.

In the area of **decision support** our long-term goal is to develop methods and techniques of decision modelling, support them with software and integrate them with data-mining systems. In 2017, we published a methodological
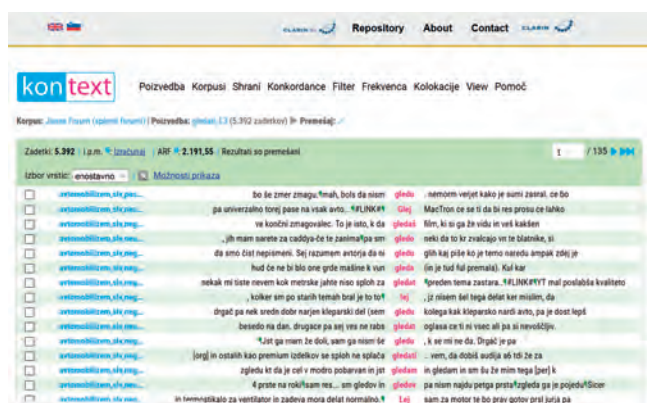
paper in which – in addition to a formal description of our most commonly used decision-modelling method DEX – we proposed a number of methodological extensions of the approach in terms of using numeric attributes, value distributions and a relational evaluation of alternatives. We also published the results of applying these approaches in the assessment of the long-term sustainability of electric energy production in Slovenia. We continued working on two EU H2020 projects aimed at the development of computer platforms and decision-support systems for the management of severe chronic diseases: the Parkinson's disease (project PD_manager) and congestive heart failure (HeartMan). We also investigated the performance of three methods for the approximation of utility functions in the DEX method, analysed statistical properties of DEX models and carried out preliminary studies for introducing feedback loops (cycles) in DEX models.

In the area of **language technologies and digital humanities** we work on producing language resources and methods to annotate text with linguistic information, with a focus on Slovene. In 2017 we helped in producing the digital text-critical edition of the 700-page Poljane Manuscript from 1800, developing a universal dependencies treebank for Serbian, organising the evaluation campaign of VarDial, the Fourth Workshop on NLP for Similar Languages, Varieties and Dialects, and in expanding the Slovene Gigafida reference corpus with internet content. We described the processes and tools necessary for annotation creation, the multilingual MULTEXT-East resources, and the Slovene reference morphological lexicon Sloleks and made a roadmap for its development.

In 2017 we were concluding our work in the scope of the national research project JANES "Resources, Tools and Methods for Research of Non-standard Internet Slovene", where we contributed to an overview of best practices from projects on computer-mediated communication, analysed non-standard language as found in tweets, and developed a system for part-of-speech tagging of non-standard Slovene, Croatian and Serbian. We developed several approaches for gender prediction on social media, including a language-independent system using non-textual information, gender and language variety prediction from text (2nd place in shared task PAN), and a focused study on gender prediction for Slovene. We produced two manually annotated training corpora for non-standard Slovene, the syntactically annotated Janes-Syn and the second version of the Janes-Tag dataset, which adds named entity annotations to the existing normalised words, part-of-speech tags and lemmas. We also produced datasets for Croatian and Serbian non-standard language, which cover the same levels of annotation as Janes-Tag. We compiled manually annotated datasets for linguistic investigations of non-standard language, in particular Janes-Vejica, which annotates (in)correctly placed commas, Janes-Kratko, which annotates shortened words, and Janes-Preklop, which is annotated for code-switching. Finally, we produced the main deliverable of the project, i.e., version 1.0 of the JANES corpus, which contains 250 million tokens or 13 million texts of user-generated internet Slovene, with rich metadata and automatically standardised, part-of-speech tagged and lemmatised words. The complete corpus is available on-line for searching through the CLARIN.SI concordancers, while its constituent parts are also available for download from the CLARIN.SI repository, in particular: Janes-Tweet, Janes-Blog, Janes-Forum, Janes-News, and Janes-Wiki.

We continued work on our national research project KAS "Slovene scientific texts: resources and description", where we analysed the lexis of the previously produced KAS corpus, containing almost one billion words of scientific texts gathered from the digital libraries of Slovene universities. We started work on a new national research project FRENK "Resources, methods, and tools for the understanding, identification, and classification of various forms of socially unacceptable discourse in the information society", where we developed an annotation schema for socially unacceptable online discourse practices.

In the scope of the industrial project TermIolar for the Slovene language service provider Iolar, we developed a system for semi-automated
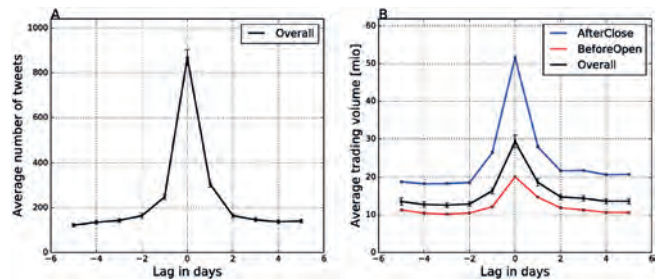
Figure 2: Daily number of tweets (A) and trading volume (B) around the Earnings Announcements. The overall average number of tweets per trading day is 200. The trading volume (B) shows the overall average across all EAs (black line), the average trading for the AfterClose (blue line), and for the BeforeOpen (red line) announcements. Error bars around the black lines denote one standard error.

Nikola Ljubešić and Yves Scherrer (University of Geneva) won the CLIN2017 shared task on normalising historical text with their CSMtiser tool, which had been developed within the national basic research project JANES and the national research infrastructure CLARIN.SI.
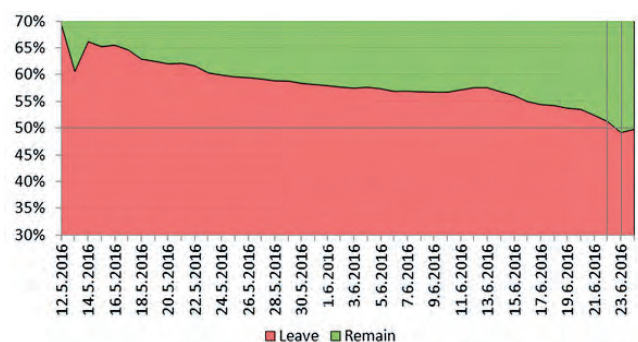
Figure 3: Cumulative stance of Twitter users regarding Brexit. Red color represents the Leave users, and green color represents the Remain users (Neutral users are not included). Remain users were gradually joining as opposed to the Leave users that were present and dominating in the number of tweets most of the time. It was only 2 days before the referendum that the number of Remain users exceeded the number of Leave users.

terminology management. We studied machine-learning approaches to good example extraction and ontology-based translation memory maintenance.

We lead the Slovene research infrastructure CLARIN.SI, which provides easy publication and sustainable access to digital language data for scholars in the humanities and social sciences. In 2017 the number of deposited resources in the CLARIN.SI repository almost doubled, reaching 79 at the end of the year. Here, we participated in the creation of the second version of the Gos VideoLectures spoken corpus, the manually annotated training corpus ssj500k, and the Slovenian parliamentary corpus SlovParl. We installed two concordancers under CLARIN.SI, i.e., KonText and noSketch Engine, and made available over 40 corpora for on-line searching and analysis through these concordancers. We also continued work on integrating tools for the annotation of Slovene into the on-line workflow design and execution platform WebLicht. CLARIN.SI supported the organisation of "TransTech17: 3rd Summer School in Translation Technologies" (September 4–8, 2017) and "ReLDI Seminar: Empirical data in linguistics: From research design to data analysis" (June 21-23, 2017).

We collaborated in the work of the Slovene Institute for Standardization as the Slovene representatives in ISO/TC37/SC4 (Terminology and Other Language and Content Resources / Language Resources Management) by reviewing, translating and approving Slovene standards from this field. We also continue to serve as technical editors for the on-line Slovene Biographical Lexicon.

Some outstanding publications in the past year

1. Pavle Boškoski, Andrej Debenjak, Biljana Mileva-Boshkoska. Rayleigh copula for describing impedance data - with application to condition monitoring of proton exchange membrane fuel cells. *European journal of operational research*, ISSN 0377-2217. [in press] 2017, 21 pp., doi: 10.1016/j.ejor.2017.08.058.

2. Jurica Levatić, Michelangelo Ceci, Dragi Kocev, Sašo Džeroski. Self-training for multi-target regression with tree ensembles. *Knowledge-based systems*, ISSN 0950-7051. 2017, vol. 123, pp. 41-60, doi: 10.1016/j.knosys.2017.02.014.

3. Manja Klemenčič, Martin Žnidaršič, Anže Vavpetič, Matej Martinc. Erasmus students' involvement in quality enhancement of Erasmus+ mobility through digital ethnography and ErasmusShouts. *Studies in higher education*, ISSN 0307-5079, 2017, vol. 42, no. 5, pp. 925-932, doi: 10.1080/03075079.2017.1293879.

4. Tomaž Erjavec. MULTEXT-East. In: Nancy M. Ide, James Pustejovsky (eds.). Handbook of linguistic annotation. Amsterdam: Springer. 2017, pp. 441-462.

5. Grčar, Miha, Čerepnalkoski, Darko, Mozetič, Igor, Kralj Novak, Petra. Stance and influence of Twitter users regarding the Brexit referendum. *Computational social networks*, ISSN 2197-4314, 2017, vol. 4, pp. 6-1-6-25, doi: 10.1186/s40649-017-0042-6.

6. Peter Gabrovšek, Darko Aleksovski, Igor Mozetič, Miha Grčar. Twitter sentiment around the earnings announcement events. *PloS one*, ISSN 1932-6203, 2017, vol. 12, no. 2, pp. e0173151-1-e0173151-21, doi: 10.1371/journal.pone.0173151.

7. Marko Bohanec, Nejc Trdin, Branko Kontić. A qualitative multi-criteria modelling approach to the assessment of electric energy production technologies in Slovenia. *Central European Journal of Operations Research*, ISSN 1435-246X, 2017, vol. 25, no. 3, pp. 611-625, doi: 10.1007/s10100-016-0457-4.

8. Matej Mihelčić, Marko Bohanec. Approximating incompletely defined utility functions of qualitative multi-criteria modeling method DEX. *Central European Journal of Operations Research*, ISSN 1435-246X, 2017, vol. 25, no. 3, pp. 627-649, doi: 10.1007/s10100-016-0451-x.

9. Janez Kranjc, Roman Orač, Vid Podpečan, Nada Lavrač, Marko Robnik Šikonja. ClowdFlows : online workflows for distributed big data mining. *FGCS*, ISSN 0167-739X. 2017, vol. 68, pp. 38-58, doi: 10.1016/j.future.2016.07.018.

10. Matej Mihelčić, Sašo Džeroski, Nada Lavrač, Tomislav Šmuc. A framework for redescription set construction. *Expert systems with applications*, ISSN 0957-4174. 2017, vol. 68, pp. 196-215, doi: 10.1016/j.eswa.2016.10.012.

11. Sabina Horvat, Aleksander Mahnič, Martin Breskvar, Sašo Džeroski, Maja Rupnik. Evaluating the effect of Clostridium difficile conditioned medium on fecal microbiota community structure. *Scientific reports*, ISSN 2045-2322, 2017, vol. 7, 11 pp., doi: 10.1038/s41598-017-15434-1.

12. Dragan Gamberger, Nada Lavrač, et al. Identification of clusters of rapid and slow decliners among subjects at risk for Alzheimer's disease. *Scientific reports*, ISSN 2045-2322, 2017, vol. 7, pp. 1-12, doi: 10.1038/s41598-017-06624-y.

Awards and appointments

1. Marko Bohanec was awarded the "*Fellow and Distinguished Schola*r" by the *International Institute for Applied Knowledge Management*.
2. Martin Breskvar, Matej Petkovič and Blaž Škrlj were in the winning team of the HackElect 2017 hackathon. With methods such as predictive classification trees and deep neural networks they, as the only team, managed to predict electricity consumption for each household appliance in various time frames.
3. Nikola Ljubešić and Yves Scherrer (University of Geneva) won the *CLIN2017 Shared Task on Normalising Historical Text* with their CSMtiser tool, which was developed within the national basic research project JANES and the national research infrastructure CLARIN.SI.
4. The approach developed by Matej Martinc, Iza Škrjanec, Katja Zupan, and Senja Pollak for author profiling has been ranked second among 22 groups in the PAN2017 competition, which this year focused on *Gender and Language Variety Identification on Twitter*.

Organization of conferences, congresses and meetings

1. The European Conference on Machine Learning and Principles and Practice of Knowledge Discovery – ECML PKDD 2017, Skopje, Macedonia, 18.–22. 9. 2017
2. Final meeting of EU project MAESTRA, Ljubljana, 3.–7. 4. 2017
3. Organization of project "Medical Informatics Platform (SP8)", part of EU project HBP, Ljubljana, 25.–27. 1. 2018
4. "The Tenth International Ljubljana-Zagreb Workshop on Knowledge Technologies", Fiesa, Slovenia, 15.–16. 6. 2017

INTERNATIONAL PROJECTS

1. BIODIV - Understanding and Managing Biodiversity in Agricultural Ecosystems by Data Mining and Decision Support; Structured Output Prediction with Applications in Sustainable Agricultural Production
   Prof. Sašo Džeroski
   Arvalis - Institut Du Végétal
2. 7FP - SIMPOL; Financial Systems Simulation and Policy Modelling
   Prof. Igor Mozetič
   European Commission
3. 7FP - MAESTRA; Learning from Massive, Incompletely Annotated, and Structured Data
   Prof. Sašo Džeroski
   European Commission
4. PARSEME: PARSing and Multi-Word Expressions. Towards Linguistic Precision and Computational Efficiency in Natural Language Processing.
   Prof. Tomaž Erjavec
   Cost Office
5. H2020 - DOLFINS; Distributed Global FInancial Systems for Society
   Prof. Igor Mozetič
   European Commission
6. H2020 - HBP SGA1; Human Brain Project Specific Grant Agreement 1 within HBP FPA; Human Brain Framework Partnership Agreement
   Prof. Sašo Džeroski
   European Commission
7. H2020 - TRUE; Transition Paths to Sustainable Legume based Systems in Europe
   Prof. Marko Debeljak
   European Commission
8. H2020 - TomRes; A Novel and Integrated Approach to increase Multiple and Combined Stress Tolerance in Plants Using Tomato as a Model
   Prof. Marko Debeljak
   European Commission
9. H2020 - LANDMARK; LAND Management: Assessment, Research, Knowledge Base
   Prof. Marko Debeljak
   European Commission
10. H2020 - NARSIS; New Approach to Reactor Safety Improvements
    Prof. Marko Bohanec
    European Commission
11. H2020 - SAAM; Supporting Active Ageing through Multimodal Coaching
    Asst. Prof. Bernard Ženko
    European Commission
12. H2020 - PD_manager; Mhealth Platform for Parkinson's Disease Management
    Dr. Dragana Miljković
    European Commission
13. H2020 - HeartMan; Personal Decison Support System for Heart Failure Management
    Prof. Marko Bohanec
    European Commission
14. H2020 - CF-Web; ClowdFlows Data and Text Analytics Marketplace on the Web

Asst. Prof. Martin Žnidaršič
European Commission
15. Mining Complex Data in Environmental and Life Sciences
    Prof. Sašo Džeroski
    Slovenian Research Agency
16. Mining Heterogeneous Linked Biomedical Data
    Prof. Nada Lavrač
    Slovenian Research Agency
17. Semantic Role Labeling in Slovene and Croatian
    Prof. Tomaž Erjavec
    Slovenian Research Agency

RESEARCH PROGRAM

1. Knowledge Technologies
   Prof. Nada Lavrač

R & D GRANTS AND CONTRACTS

1. Integrative research of sexual dimorphism evolution
   Prof. Sašo Džeroski
2. Resources, Tools and Methods for the Research of Nonstandard Internet Slovene
   Prof. Tomaž Erjavec
3. Molecular bases of interactions among the grapevine and phytoplasmal causing agents of the grapevine yellows diseases
   Prof. Nada Lavrač
4. Development of a multimethod approach to study wildlife behavior: investigating humanbear conflicts in contrasting landscapes of Europe
   Prof. Sašo Džeroski
5. Influence of formal and informal corporate communications on capital markets
   Dr. Senja Pollak
6. Collocation as a basis for language description: semantic and temporal perspectives
   Dr. Nikola Ljubešić
7. Slovene scientific texts: resources and description
   Prof. Tomaž Erjavec
8. Analysis of heterogeneous information networks for knowledge discovery in life-sciences
   Prof. Nada Lavrač
9. Machine Learning for Systems Sciences
   Prof. Sašo Džeroski
10. Resources, methods and tools for the understanding, identification and classification of various forms of socially unacceptable discourse in the information society
    Prof. Tomaž Erjavec
11. Fellowship to visit ERC Grantee
    Dr. Vedrana Vidulin

12. Forbidden Books in the Slovenian Lands in the Early Modern Period
Prof. Tomaž Erjavec
13. Structured output prediction with applications in sustainable agricultural production
Prof. Sašo Džeroski
14. Food for future - F4F
Asst. Prof. Bernard Ženko
Ministry of Education, Science and Sport
15. TRAIN: Big Data and Disease Models: A Cross-border Platform for Validated Biotech Industry Kits
Prof. Sašo Džeroski
Regione Autonoma Friuli Venezia Giulia
16. Data Mining and Decision support in Sustainable Food Production
Dr. Vladimir Kuzmanovski
Ministry of Education, Science and Sport
17. Learning models of diseases and treatments for systems and personalized medicine
Dr. Jovan Tanevski
Ministry of Education, Science and Sport
18. ReLDI - Regional Linguistic Data Initiative
Dr. Nikola Ljubešić
University Of Zurich, Urpp Language and Space
19. ECML PKDD 2017 - The 28th European Conference on Machine Learning and The 21st European Conference on Principles and Practice of Knowledge Discovery in Databases; Skopje, Macedonia, 18.-22.09.2017
Prof. Sašo Džeroski
20. CLARIN Project: Multilingual Corpus Annotation Tools: Development and Integration
Prof. Tomaž Erjavec
Clarin Eric

NEW CONTRACTS

1. Conducting a seminar „Data Mining in ClowdFlows and TextFlows"
Prof. Nada Lavrač
Comtrade d. o. o.
2. TermIolar: Development of a Prototype program solution for support of semi-automatic extraction and management of monolingual and multilingual corpora
Dr. Senja Pollak
Iolar d. o. o.
3. TermIOLAR2: Prototype program solution for extraction and alignment of terminology from parallel corpora of translation memories
Dr. Senja Pollak
Iolar d. o. o.

VISITORS FROM ABROAD

1. prof. dr. Donato Malerba, University of Bari "Aldo Moro", Bari, Italy, 13.–15. 3. 2017.
2. prof. dr. Michelangelo Ceci, University of Bari "Aldo Moro", Bari, Italy 2.–8. 4. 2017 and 1.–2. 6. 2017
3. dr. Ivica Dimitrovski, Ss. Cyril and Methodius, Faculty of Computer Science and Engineering, University of Skopje, Skopje, Macedonia, 2.–8. 4. 2017
4. dr. Tomislav Šmuc, Institut Ruđer Bošković, Zagreb, Croatia, 3.–5. 4. 2017
5. prof. dr. Hendrik Blockeel, KU Leuven, Department of Computer Science, Heverlee, Belgium, 31. 5.–3. 6. 2017
6. Franziska Schütze, Global Climate Forum, Berlin, Germany, 16.–21. 5. 2017
7. Dan Davis, SHARK company, Boston, USA, 5. 6. 2017
8. dr. Vesna Andova, Faculty of Electrical Engineering and Information Technologies, Skopje, Macedonia, 17.–25. 6. 2017
9. Ilin Tolovski, Faculty of Electrical Engineering and Information Technologies, Skopje, Macedonia, 17.–25. 6. 2017
10. Ana Kostovska, Faculty of Electrical Engineering and Information Technologies, Skopje, Macedonia, 17.–25. 6. 2017
11. dr. Maja Miličević, University of Belgrade, Faculty of Philology, Department of General Linguistics, Belgrade, Serbia, 20.–25. 6. 2017
12. dr. Tanja Samardić, University of Zurich, URPP Language and Space, Zurich, Switzerland, 20.–25. 6. 2017
13. dr. Saturnino Luz, Usher Institute of Population Health Sciences and Informatics, Edinburgh Medical School: Molecular, Genetic and Population Health Sciences, Edinburgh, Great Britain, 25.–27. 6. 2018 and 21.–22. 9. 2017
14. Franklin Parrales Bravo, Complutense University of Madrid, Madrid, Spain, 24. 9.-6. 12. 2017
15. prof. dr. Geoff Squire, James Hutton Institute, Dundee, Scotland, 4.–6. 9. 2017
16. Nataša Terzić, Centre for Health System Development, Institute of Public Health, Podgorica, Montenegro, 16.–19. 10. 2017
17. Jihed Khiari, NEC Europe Ltd, Heidelberg, Germany, 22.–27. 10. 2017
18. Jozef Misutka, Charles University in Prague, Czech Republic, 26.–27. 10. 2017
19. Frank van der Velde, University of Twente, Enschede, Centre for Telematics and Information Technology (CTIT), Enschede, The Netherlands, 8.–10. 11. 2017
20. prof. dr. Geraint Wiggins, Queen Mary University of London, London Great Britain, 15.–26. 11. 2017
21. dr. Maximilian Moser, Medical University of Graz, Austria, 20. 11. 2017
22. mag. Thomas Hassler, Human Research Institute, Graz, Austria, 20. 11. 2017
23. prof. dr. Henrik Bostrom, KTH Royal Institute of Technology, Stockholm, Sweden, 23.–26. 11. 2017
24. dr. Luca Leonardo Bologna, Italian National Research Council (CNR), University of Palermo, Italy, 26.–30. 11. 2017
25. Luke Lucas, European Space Agency (ESA), Darmstadt, Germany, 10.– 14. 12. 2017
26. Redouane Boumghar, European Space Agency (ESA), Darmstadt, Germany 10.–14. 12. 2017

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18. *Dr. Miha Grčar, left 01.12.17*
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22. *Dr. Jurica Levatić, left 01.08.17*
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BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Kristina Ban, Matjaž Perc, Zoran Levnajić, "Robust clustering of languages across Wikipedia growth", *Royal Society Open Science*, **4**, 10, 1-12, 2017.
2. Marko Bohanec, Nejc Trdin, Branko Kontić, "A qualitative multi-criteria modelling approach to the assessment of electric energy production technologies in Slovenia", *Cent. Eur. j. oper. res.*, **25**, 3, 611-625, 2017.
3. Bojan Cestnik, Elsa Fabbretti, Donatella Gubiani, Tanja Urbančič, Nada Lavrač, "Reducing the search space in literature-based discovery by exploring outlier documents: a case study in finding links between gut microbiome and Alzheimer's disease", *Genomics and computational biology*, **3**, 3, e58, 2017.
4. Dagmar Divjak, Serge Sharoff, Tomaž Erjavec, "Slavic corpus and computational linguistics", *J. Slav. linguist.*, **25**, 2, 171-198, 2017.
5. Peter Gabrovšek, Darko Aleksovski, Igor Mozetič, Miha Grčar, "Twitter sentiment around the earnings announcement events", *PloS one*, **12**, 2, e0173151, 2017.
6. Dragan Gamberger *et al.* (5 authors), "Identification of clusters of rapid and slow decliners among subjects at risk for Alzheimer's disease", *Sci. rep.*, **7**, 6763, 2017.
7. Miha Grčar, Darko Čerepnalkoski, Igor Mozetič, Petra Kralj Novak, "Stance and influence of Twitter users regarding the Brexit referendum", *Comput. soc. networks*, **4**, 6, 2017.
8. Donatella Gubiani, Elsa Fabbretti, Bojan Cestnik, Nada Lavrač, Tanja Urbančič, "Outlier based literature exploration for cross-domain linking of Alzheimer's disease and gut microbiota", *Expert syst. appl.*, **85**, 386-396, 2017.
9. Sabina Horvat, Aleksander Mahnič, Martin Breskvar, Sašo Džeroski, Maja Rupnik, "Evaluating the effect of Clostridium difficile conditioned medium on fecal microbiota community structure", *Sci. rep.*, **7**, 16448, 2017.
10. Jernej Jevšenak, Sašo Džeroski, Tom Levanič, "Uporaba metod strojnega učenja za preučevanje odnosov med značilnostmi branik in okoljem", *Acta silvae et ligni*, [Št.] 114, 21-29, dec. 2017.
11. Manja Klemenčič, Martin Žnidaršič, Anže Vavpetič, Matej Martinc, "Erasmus students' involvement in quality enhancement of Erasmus+ mobility through digital ethnography and ErasmusShouts", *Stud. high. educ. (Dorchester-on-Thames)*, **42**, 5, 925-932, 2017.
12. Janez Kranjc, Roman Orač, Vid Podpečan, Nada Lavrač, Marko Robnik Šikonja, "ClowdFlows: online workflows for distributed big data mining", *FGCS, Future gener. comput. syst.*, **68**, 38-58, 2017.
13. Marc Grau Leguia, Ralph G Andrzejak, Zoran Levnajić, "Evolutionary optimization of network reconstruction from derivative-variable correlations", *J. phys., A, Math. theor.*, **50**, 33, 334001, 2017.
14. Jurica Levatić, Michelangelo Ceci, Dragi Kocev, Sašo Džeroski, "Self-training for multi-target regression with tree ensembles", *Knowl.-based syst.*, **123**, 41-60, 2017.
15. Jurica Levatić, Michelangelo Ceci, Dragi Kocev, Sašo Džeroski, "Semi-supervised classification trees", *Journal of intelligent information systems*, **49**, 3, 461-486, 2017.
16. Matej Mihelčič, Goran Šimić, Mirjana Babić Leko, Nada Lavrač, Sašo Džeroski, Tomislav Šmuc, "Using redescription mining to relate clinical and biological characteristics of cognitively impaired and Alzheimer's disease patients", *PloS one*, **12**, 10, 0187364, 2017.
17. Matej Mihelčič, Marko Bohanec, "Approximating incompletely defined utility functions of qualitative multi-criteria modeling method DEX", *Cent. Eur. j. oper. res.*, **25**, 3, 627-649, 2017.
18. Matej Mihelčič, Sašo Džeroski, Nada Lavrač, Tomislav Šmuc, "A framework for redescription set construction", *Expert syst. appl.*, **68**, 196-215, 2017.
19. Dragana Miljković, Nada Lavrač, Marko Bohanec, Biljana Mileva-Boshkoska, "Discovering dependencies between domains of redox potential and plant defence through triplet extraction and copulas", *Int. j. intell. eng. inform.*, 1-17, 2017.
20. Jasmina Smailović, Martin Žnidaršič, Aljoša Valentinčič, Igor Lončarski, Marko Pahor, Pedro Martins, Senja Pollak, "Automatic analysis of annual financial reports: a case study", *Computación y sistemas*, **21**, 4, 809-818, 2017.
21. Erik Tjong Kim Sang *et al.* (19 authors), "The CLIN27 shared Task: Translating historical text to contemporary language for improving automatic linguistic annotation", *Computational linguistics in the Netherlands journal*, **7**, 53-64, 2017.
22. Antonio Toral, Miquel Esplá-Gomis, Filip Klubička, Nikola Ljubešić, Vassilis Papavassiliou, Prokopis Prokopidis, Raphael Rubino, Andy Way, "Crawl and crowd to bring machine translation to under-resourced languages", *Language resources and evaluation*, **51**, 4, 1019-1051, 2017.
23. Kostas M. Tsiouris *et al.* (11 authors), "PD_Manager: a mHealth platform for Parkinson's disease patient management", *Healthc. technol. lett.*, **4**, 3, 102-108, 2017.
24. Tea Tušar, Klemen Gantar, Valentin Koblar, Bernard Ženko, Bogdan Filipič, "A study of overfitting in optimization of a manufacturing quality control procedure", *Applied soft computing*, **59**, 77-87, 2017.
25. Anita Valmarska, Nada Lavrač, Johannes Fürnkranz, Marko Robnik Šikonja, "Refinement and selection heuristics in subgroup discovery and classification rule learning", *Expert syst. appl.*, **81**, 147-162, 2017.

PUBLISHED CONFERENCE CONTRIBUTION

1. Michael Beißwenger *et al.* (11 authors), "Closing a gap in the language resources landscape: groundwork and best practices from projects on computer-mediated communication in four European countries", In: *Selected papers from the CLARIN Annual Conference 2016*, (Linköping Electronic Conference Proceedings, **136**), 2017, 1-18.
2. Michael Beißwenger *et al.* (19 authors), "Connecting resources: which issues have to be solved to integrate CMC corpora from heterogeneous sources and for different languages?", In: *Proceedings of the 5th Conference on CMC and Social Media Corpora for the Humanities (cmccorpora17)*, Egon W. Stemle, ed., Ciara R. Wigham, ed., Bolzano, [S. n.], 2017, 10-13.
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MENTORING

1. Jože Bučar, *Sentiment based classification of the web texts:* doctoral dissertation, Novo Mesto, 2017 (mentor Janez Povh; co-mentor Martin Žnidaršič).

2. Jan Kralj, *Heterogeneous information network analysis for semantic data mining:* doctoral dissertation, Ljubljana, 2017 (mentor Nada Lavrač; co-mentor Marko Robnik Šikonja).

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DEPARTMENT OF INTELLIGENT SYSTEMS

E-9

The Department of Intelligent Systems develops new methods and techniques for intelligent computer systems, with applications in the areas of the information society, computer science and informatics, and network communication systems. The main research areas are ambient intelligence, computational intelligence, agent and multi-agent systems, language and speech technologies, electronic and mobile health, and smart cities. The department closely collaborates with the Faculty of Computer and Information Science of the University of Ljubljana on the joint research program "Artificial Intelligence and Intelligent Systems", led by Prof. Dr. Ivan Bratko. The department also continuously collaborates with industry and contributes significantly to the inclusion of intelligent systems in products and services.

Head:
Prof. Matjaž Gams

Intelligent systems simulate intelligence so that a typical user perceives them as truly intelligent. In reality, these systems use complex mechanisms and implement them on digital platforms to imitate human behaviour by exploiting raw, exponentially growing computer power. This field is somewhat broader than artificial intelligence, both are rapidly growing worldwide and enabling the development of the information society.

Ambient intelligence is a research area aiming to introduce technology into our everyday environment in a friendly way that is undemanding for the user. The main topic of ambient intelligence tackled by the department in 2017 was health. We coordinate the H2020 project **HeartMan**, which is developing an application to help congestive-heart-failure patients manage their condition: it monitors them with a sensing wristband, and provides advice on exercise, nutrition, etc. Most of the technical work is complete: we developed methods for activity monitoring and estimating blood pressure from a PPG sensor in the wristband, as well as a decision-support system that utilises expert knowledge and predictive models. In the H2020 project **IN LIFE**, we are translating solutions intended to prolong the independence of the elderly into real life. We developed a smart-watch application that detects falls and similar events, which is connected to a web application for carers. This solution was piloted with 150 users in cooperation with the Slovenian company Doktor 24, and we are now attempting to commercialise it. The AAL project **Fit4Work** is aiming to help older workers do their job more easily by providing advice on relaxation, exercise and work environment (temperature, CO_2 in the air, etc.). In 2017 we focused on methods for improving the work environment: we developed predictive models and a simulator to evaluate the actions that can improve the environment and recommend the best one. The project was successfully concluded with a pilot. We started the H2020 project **CrowdHealth**, whose objective is to mine health data to help craft better public-health policies. We started developing methods that can forecast time-series data and assess health risk based on such forecasts. One of the use cases is the SloFit data describing the fitness of Slovenian primary- and high-school students, on which we cooperate with the Faculty of Sports of the University of Ljubljana. We also recently started the H2020 project **WellCo**, where we will develop a virtual coach advising older users on wellbeing and health. Our ambient-intelligence projects use wearable sensing devices, whose use is limited by their typically small batteries. As a **doctoral research project** we thus developed a general method that can intelligently turn sensors on and off in such a way that the energy consumption is as small as possible without sacrificing a lot of quality of the results obtained with these sensors. We also work on merging different sensor datasets for the purpose of machine learning.

Computational intelligence is the study of stochastic search, optimization and learning methods, inspired by biological and physical systems. Research in this area at the Department of Intelligent Systems focuses on the evolutionary computation methods. We study evolutionary algorithms for multi-objective optimization, their acceleration through parallel com-

> In the H2020 project HeartMan, which we coordinate, we are finalizing an application that provides comprehensive personalized support for the self-management of congestive heart failure.

Figure 1: The Department Head, Prof. Matjaž Gams, was elected national councillor for research activities in December 2017.

> We started two new H2020 projects on ambient intelligence and health, which have joined three on-going European projects on these topics. Our department is thus becoming a leading research group in this area.

Figure 2: We are developing a computer system for the multi-objective optimization of process parameters in the continuous casting of steel. The system evaluates parameter settings with a numerical simulation of the casting process and supports the visualization of results.

puting and surrogate models, visualization of their results, and applications in engineering design and optimization problems. In the H2020 Twinning project **SYNERGY** we are strengthening our research and innovation potential in parallelization, surrogate modelling and combining the two techniques in multi-objective optimization. The project is carried out by three partners with complementary expertise: the Jožef Stefan Institute, the University of Lille, and Cologne University of Applied Sciences. The expertise and solutions gained in this cooperation are targeted at both academic and industrial organizations, particularly those participating in the Slovenian Smart Specialisation Strategy. Together with the Chamber of Commerce and Industry of Slovenia we are preparing educational activities for these companies. The goal of the **bilateral Slovenian-Japanese research project** is to enhance the methodology of evolutionary multi-objective optimization for real-world applications. We cooperate with Shinshu University, Nagano, on developing optimization algorithms and visualizing their results. The methodology is evaluated on the design of the JAXA (Japan Aerospace Exploration Agency) Destiny mission. The postdoctoral basic research project **Incorporating real-world problems into the benchmarking of multi-objective optimizers** builds on the state-of-the-art open-source COCO (Comparing Continuous Optimizers) platform for optimization-algorithm benchmarking and extends it by incorporating real-world problems and their properties in order to bridge the gap between research and application in multi-objective optimization. The transfer of our knowledge and methods to industrial practice takes place in the project **Upgrade of the optimization system for steel continuous casting (KN3)** for the Štore Steel company. We are developing a computer system to search for the optimal setting of process parameters with respect to criteria for process output variables. The system is based on the numerical simulation of steel casting and supports the visualization of results.

In the field of **agent and multi-agent systems** the key research areas are focused on the development of smart autonomous systems for the control of smart cities, smart homes and the preservation of cultural heritage. In the Slovenian Smart Specialisation program **EkoSMART** we continue with research activities in the field of smart cities and communities. The purpose of the program is to develop a smart-city ecosystem with all the support mechanisms that are necessary for the efficient, optimized and gradual integration of different smart-city areas into a unified and well-connected system. Within the program we are involved in activities linked to the research and development projects "*Zasnova ekosistema pametnega mesta*" and "*Elektronsko in mobilno zdravstvo*" (**EMZ**), where we are the leading partner. The main goal is to develop new and innovative devices and solutions to support the elderly and chronic patients at home. We are also involved in the Smart Specialisation program **IQDOM** in the field of smart buildings and homes, coordinated by Gorenje. Our focus is on the development of smart-home automation services. The aim is to apply advanced machine-learning and optimization methods to build user models and consumption profiles for housing units in order to generate control strategies that increase user comfort and, at the same time, decrease the operational costs of a smart home. Similar approaches are also applied to heat pumps. The controller learns the behaviour of the user and formulates a strategy for water heating during periods of cheaper electricity and, at the same time, lowers the temperature of the stored water during days of lower consumption. In the Interreg **AS-IT-IC** project we will develop an integrated tourist platform for cross-border tourist exchange, tour planning and effective communications between tourists and tourist offices. The platform will support natural language communication between the users and the system and the automatic creation of personalized itineraries based on the search concepts and preferences of users. In the Horizon 2020 Twinning project **eHeritage** we continue to provide support to increase the capacity and quality of the research and innovation excellence of the Romanian partner in the area of cultural heritage preservation using intelligent methods and 3D modelling, and employing augmented and virtual reality. To this end we are developing innovative applications that enable efficient search and richer visualisations of digital content related to cultural heritage from various internet sources and dedicated databases. As part of the project activities, the "Advanced Study Institute" event was organized in Padova, Italy, where we delivered lectures and a hands-on workshop regarding the use of systems for natural language processing and communication, information extraction from textual data, and data fusion from various sources. The goal of the **bilateral Slovenian-Macedonian research project** is to study
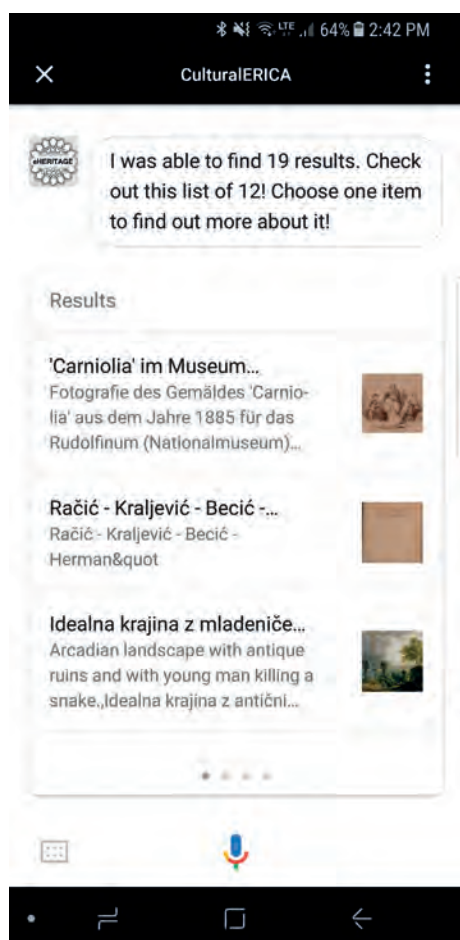

Figure 3: A mobile application, where the user can interact in natural language and visualize content related to cultural heritage from Europeana.

and advance wearable and non-wearable sensors for detecting the user's physical and mental state.

In the field of **speech and language technologies** we work on speech synthesis, the semantic analysis of text and question answering. Together with the companies Alpineon and Amebis we developed a new, high-quality speech synthesizer eBralec (http://ebralec.si/). The synthesizer is improved in terms of both comprehensibility and natural perception of the speech. The software package has more than a thousand subscribers and is an indispensable tool for blind and visually-impaired users (it is the "official" speech synthesizer of the Slovenian Association for the Blind and Visually Impaired) and people with reading impairments (the Bravo association). For these users, eBralec is free of charge and can be ordered at the Library for the Blind and Visually Impaired (http://www.kss-ess.si/ebralec-sintetizator-govora-slovenskega-jezika/). eBralec is also an integral part of the DarsTraffic+ application, which provides traffic information, while its server version has been used by the National and University Library since 2017. We have also developed a service of speech synthesis for mobile devices (http://dis.ijs.si/dyslex/), which is free for anyone to use.

We have developed **two plugins for Orange**, an open-source machine-learning, data-mining and data-visualization toolkit. **Audio-IJS** makes it easy to build and test models for the classification of different kinds of audio recordings. The plugin is intended primarily for users without extensive prior knowledge of machine learning. By means of a graphical interface, the user determines the filtering and segmentation parameters of the sound recordings and then tests various classification models. **Hybrid Trees** provides users with three widgets that have a user-friendly interface for learning, validating, evaluating and using classifiers built with the MOLHC algorithm for the multi-objective learning of comprehensible and accurate hybrid trees.

The **20th International Multiconference Information Society – IS 2017** (https://is.ijs.si) took place at the Jožef Stefan Institute from 9 to 13 October 2017. It consisted of 11 independent conferences with 200 presentations. Four conference awards were presented: for lifetime achievements ("Donald Michie and Alan Turing" award) to Prof. Marjan Krisper, for current achievements in the field of information society to Prof. Andrej Brodnik, and the information strawberry and lemon for the best and worst public information-society services.

Some outstanding publications in the past year

1. Gjoreski, M., Luštrek, M., Gams, M., Gjoreski, H. Monitoring stress with a wrist device using context. Journal of Biomedical Informatics, 73 (2017), 159–170
2. Kužnar, D., Piltaver, R., Gradišek, A., Gams, M., Luštrek, M. An intelligent system to monitor refrigeration devices. Expert systems, 34 (2017), e12199-1-e12199-13
3. Tavčar, A., Kužnar, D., Gams, M. Hybrid Multi-Agent Strategy Discovering Algorithm for human behavior. Expert Systems with Applications, 71 (2017), 370–382
4. Tušar T., Gantar, K., Koblar, V., **Ženko**, B., Filipič, B. A study of overfitting in optimization of a manufacturing quality control procedure. Applied Soft Computing, 59 (2017), 77–87

Awards and appointments

1. Tomaž Šef: Gold recognition for product innovation, Slovenia, Chamber of Crafts Gorenjska, "Text-to-Speech Synthesizer eBralec", 14 June, 2017

Organization of conferences, congresses and meetings

1. AS-IT-IC project meeting, Ljubljana, 28 February–1 March 2017
2. IN LIFE project review meeting, Ljubljana, 2–3 March 2017

Figure 4: HeartMan mobile application, which helps patients with heart failure manage their disease, and the sensing wristband that collects the patients' physiological signals for the application.

In cooperation with Shinshu University in Nagano, Japan, we utilize methods of visualization in multi-objective optimization to analyse alternative trajectories for the JAXA (Japan Aerospace Exploration Agency) Destiny mission.
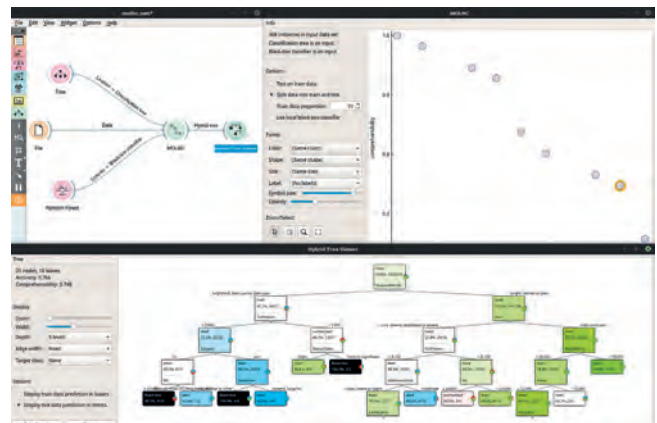

Figure 5: The Hybrid Trees plugin for the Orange toolkit supports learning, validating, evaluating and using hybrid trees, which offer different trade-offs between comprehensibility and the accuracy of the predictions.

3. 30th Slovene Workshop on Nature-Inspired Algorithms, AVN, Šmarna gora, 9 May 2017
4. Presentation of the Internet application for tourism, Nazarje, 30 June 2017
5. Genetic and Evolutionary Computation Conference, GECCO 2017, Berlin, Germany, 15–19 July 2017 and the co-located events:
   - VizGEC (Visualisation Methods in Genetic and Evolutionary Computation) workshop
   - BBOB (Bi-Objective Blackbox Optimization Benchmarking) workshop
   - Women@GECCO workshop
   - GECCO Job Market
6. 20th International Multiconference Information Society, IS 2017, Ljubljana, Slovenia, 9–13 October 2017; independent conferences:
   - Slovenian Conference on Artificial Intelligence
   - Facing demographic challenges
   - Cognitive science
   - Collaboration, software and services in information society
   - Data mining and data warehouses – SiKDD
   - Education in Information Society
   - Cognitonics
   - 10th International technology transfer conference – 10ITTC
   - AS-IT-IC Workshop
   - Robotics
   - Workshop Electronic and Mobile Health and Smart Cities
7. Site visit and AS-IT-IC project presentation, Ljubljana, 30 November 2017
8. 31st Slovene Workshop on Nature-Inspired Algorithms, AVN, Ljubljana, 8 December 2017

INTERNATIONAL PROJECTS

1. COST TD1405; ENJECT, European Network for the Joint Evaluation of Connected Health Technologies
   Božidara Cvetković, B. Sc.
   Cost Office
2. H2020 - IN LIFE; INdependent Living support Functions for the Elderly
   Prof. Matjaž Gams
   European Commission
3. H2020 - eHERITAGE; Expanding the Research and Innovation Capacity in Cultural Heritage Virtual Reality Applications
   Prof. Matjaž Gams
   European Commission
4. H2020 - CrowdHEALTH; Collective Wisdom Driving Public Health Policies
   Dr. Mitja Luštrek
   European Commission
5. H2020 - WellCo; Wellbeing and Health Virtual Coach
   Dr. Mitja Luštrek
   European Commission
6. H2020 - HeartMan; Personal Decison Support System for Heart Failure Management
   Dr. Mitja Luštrek
   European Commission
7. H2020 - SYNERGY; Synergy for Smart Multi-Objective Optimisation
   Prof. Bogdan Filipič
   European Commission
8. Advanced Methodology of Evolutionary Multi- and Many-Objective Optimization for Real-World Applications
   Prof. Bogdan Filipič
   Slovenian Research Agency
9. Patient Health Prediction and Diagnostics based on Sensor Data and Machine Learning
   Prof. Matjaž Gams
   Slovenian Research Agency

RESEARCH PROGRAM

1. Artificial Intelligence and Intelligent Systems
   Prof. Matjaž Gams

R & D GRANTS AND CONTRACTS

1. Intelligent home of the new generation designed on smart appliances and wood
   Prof. Matjaž Gams
   Ministry of Education, Science and Sport
2. Smart City Ecosystem – EkoSmart

Prof. Matjaž Gams
Ministry of Education, Science and Sport
3. Food for future - F4F
   Dr. Mitja Luštrek
   Ministry of Education, Science and Sport
4. HEP-Y: Application for raising awareness about viral hepatitis infections
   Prof. Matjaž Gams
   Javni štipendijski, razvojni, invalidski in preživninski sklad Republike Slovenije
5. Innovative student project to benefit society
   Prof. Matjaž Gams
   Javni štipendijski, razvojni, invalidski in preživninski sklad Republike Slovenije
6. Austrian-Slovenian Intelligent Tourist Information Center (AS-IT-IC)
   Prof. Matjaž Gams
   Government Office for Development and European Cohesion Policy
7. Strategic Research & Innovation Partnership (SRIP) Smart Cities and Communities
   Prof. Matjaž Gams
   Ministry of Education, Science and Sport
8. Self-management of physical and mental fitness of older workers
   Dr. Mitja Luštrek
   Ministry of Education, Science and Sport
9. 20th International Multiconference Information Society 2017 (IS 2017), Ljubljana, Slovenia, 9.10.2017-13.10.2017
   Prof. Matjaž Gams
10. Young Ph.D. - Mlakar Miha
    Dr. Miha Mlakar
    Andra - The French National Radioactive Waste
11. IN LIFE Smartwatch – advanced solutions for safety of elderly
    Prof. Matjaž Gams
12. eBralec Project
    Dr. Tomaž Šef
    Amebis, d. o. o., Kamnik
13. Information Society IS 2017 – Multiconference
    Prof. Matjaž Gams

NEW CONTRACTS

1. Upgrade of the optimization system for steel continuous casting (KN3)
   Prof. Bogdan Filipič
   Štore Steel d. o. o.
2. The development of text-to-speech system for Slovenian language
   Dr. Tomaž Šef
   Alpineon d. o. o.
3. System for analysing and managing bank customers
   Dr. Miha Mlakar
   Unicredit Banka Slovenija d. d.

VISITORS FROM ABROAD

1. Prof. El-Ghazali Talbi, Prof. Nouredine Melab, University Lille 1, Lille, France, 9–10 January 2017
2. Prof. Hernán Aguirre, Shinshu University, Nagano, Japan, 8–10 March 2017
3. Vadim Ielkin, IUT de Cachan, Paris, France, 10 April–11 July 2017
4. Redione Reddad, IUT de Cachan, Paris, France, 10 April–11 July 2017
5. Antoine Voreux, IUT de Cachan, Paris, France, 10 April–11 July 2017
6. Monika Simjanoska, Ss. Cyril and Methodius University in Skopje, Skopje, Republic of Macedonia, 24 April–24 June 2017
7. Prof. Boris Naujoks, Cologne University of Applied Sciences (TH Köln), Gummersbach, Germany, 8–11 May 2017
8. Vanessa Volz, Technical University Dortmund, Dortmund, Germany, 8–11 May 2017
9. Dr. Hristijan Gjoreski, University of Sussex, Brighton, Great Britain, 15 June 2017
10. Andreas Røyset Stensbye, Norwegian University of Science and Technology, Trondheim, Norway, 16 June–25 August 2017
11. Stephane Gu, Polytech Paris UPMC, Robotics Engineering school, Paris, France, 19 June–18 August 2017
12. Mathieu Russo Polytech Paris UPMC, Robotics Engineering school, Paris, France, 19 June–18 August 2017
13. Prof. Juan Antonio Alvarez-Garcia, University of Seville, Seville, Spain, 1 July–31 September 2017
14. Blagoj Mitrevski, Ss. Cyril and Methodius University in Skopje, Skopje, Republic of Macedonia, 3 July–3 September 2017
15. Prof. El-Ghazali Talbi, University Lille 1, Lille, France, 2–3 October 2017
16. Prof. Gerhard Widmer, Johannes Kepler University Linz and Austrian Research Institute for Artificial Intelligence Vienna, Vienna, Austria, 12–13 October 2017
17. Prof. Vladimir Trajkovikj, Ss. Cyril and Methodius University, Skopje, Republic of Macedonia, 23 November 2017
18. Prof. Sašo Koceski, Univerza Goce Delcev, Štip, Republic of Macedonia, 23 November 2017
19. Prof. Franz Wotawa, Oliver Tazl, Institute for Software Technology, Graz, Austria, 30 November 2018
20. Prof. El-Ghazali Talbi, Jan Gmys, Univeristy Lille 1, Lille, France, 11–13 December 2017
21. Prof. Boris Naujoks, Beate Breiderhoff, Cologne University of Applied Sciences (TH Köln), Gummersbach, Germany, 11–13 December 2017

STAFF

Researchers
1. Prof. Ivan Bratko*
2. Dr. Erik Dovgan*
3. Prof. Bogdan Filipič
4. **Prof. Matjaž Gams, Head**
5. Dr. Anton Gradišek
6. Dr. Mitja Luštrek
7. Dr. Tomaž Šef

Postdoctoral associates
8. *Dr. Hristijan Gjoreski, on leave 01.12.16*
9. Dr. Matej Guid
10. *Dr. Boštjan Kaluža, left 01.04.17*
11. Dr. Miha Mlakar
12. Dr. Rok Piltaver*
13. Dr. Aleksander Pivk*
14. Dr. Tea Tušar

Postgraduates
15. *Jani Bizjak, B. Sc., left 30.10.17*
16. *Robert Blatnik, M. Sc., 01.12.17, transferred to Department CTT*
17. Božidara Cvetković, B. Sc.
18. Martin Gjoreski, B. Sc.
19. Vito Janko, B. Sc.
20. Tomaž Kompara*, B. Sc.
21. Dr. Jana Krivec*

22. Damjan Kužnar, B. Sc.
23. Aleš Tavčar, B. Sc.
24. Aljoša Vodopija, B. Sc.
25. Jernej Zupančič, B. Sc.

Technical officers
26. Luka Colarič, B. Sc.
27. Gregor Grasselli, B. Sc.
28. Gašper Slapničar, B. Sc.
29. Sebastijan Stanivuk, B. Sc.
30. Jure Šorn*, B. Sc.
31. *Jure Šorn, B. Sc., left 01.09.17*

Technical and administrative staff
32. Grigory Evseev, B. Sc.
33. Vesna Koricki, B. Sc.
34. Mitja Lasič
35. Liljana Lasič
36. Blaž Mahnič, B. Sc.
37. Pavel Maslov, B. Sc.
38. Nina Reščič, B. Sc.
39. Luka Stepančič, B. Sc.
40. Lana Zemljak

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Alen Ajanović, Jaka Konda, Gašper Fele-Žorž, Anton Gradišek, Matjaž Gams, Ana Peterlin, Karolina Počivavšek, Mojca Matičic, "Application for sexually transmitted infection risk assessment", *Informatica (Ljublj., Tisk. izd.)*, **41**, 2, 253-254, 2017.
2. Jani Bizjak, Anton Gradišek, Luka Stepančič, Hristijan Gjoreski, Matjaž Gams, "Intelligent assistant carer for active aging", *EURASIP J. Adv. Signal Process.*, **2017**, 76, 2017.
3. Martin Gjoreski, Mitja Luštrek, Matjaž Gams, Hristijan Gjoreski, "Monitoring stress with a wrist device using context", *J Biomed Inform*, **73**, 159-170, 2017.
4. Anton Gradišek, Gašper Slapničar, Jure Šorn, Mitja Luštrek, Matjaž Gams, Janez Grad, "Predicting species identity of bumblebees through analysis of flight buzzing sounds", *Bioacoustics (Berkhamsted)*, **26**, 1, 63-76, 2017.
5. Vito Janko, Božidara Cvetković, Anton Gradišek, Mitja Luštrek, Boro Štrumbelj, Tanja Kajtna, "e-Gibalec: mobile application to monitor and encourage physical activity in schoolchildren", *Journal of ambient intelligence and smart environments*, **9**, 5, 595-609, 2017.
6. Andraž Kocjan, Luka Kelhar, Anton Gradišek, Blaž Likozar, Kristina Žagar, Jaafar Ghanbaja, Spomenka Kobe, Jean-Marie Dubois, "Solid solubility in $Cu_5Gd_{1-x}Ca_x$ system: structure, stability, and hydrogenation", *Adv. Mater. Sci. Eng.*, **2017**, 9203623, 2017.
7. Jana Krivec, Tea Golob, "Psychosocial approach to migrants: current state, issues and improvement possibilities", *Innovative issues and approaches in social sciences*, **10**, 2, 42-61, May 2017.
8. Damjan Kužnar, Rok Piltaver, Anton Gradišek, Matjaž Gams, Mitja Luštrek, "An intelligent system to monitor refrigeration devices", *Expert syst.*, **34**, 5, e12199, 2017.
9. Aleš Tavčar, Damjan Kužnar, Matjaž Gams, "Hybrid multi-agent strategy discovering algorithm for human behavior", *Expert syst. appl.*, **71**, 370-382, 2017.
10. Tea Tušar, Klemen Gantar, Valentin Koblar, Bernard Ženko, Bogdan Filipič, "A study of overfitting in optimization of a manufacturing quality control procedure", *Applied soft computing*, **59**, 77-87, 2017.
11. Hongyang Zou, Anton Gradišek, Samuel B. Emery, John J. Vajo, Mark S. Conradi, "$LiBH_4$ in aerogel: ionic motions by NMR", *The journal of physical chemistry. C, Nanomaterials and interfaces*, **121**, 28, 15114-15119, 2017.
12. Jernej Zupančič, Matjaž Gams, "Dynamic protocol for demand management of heterogeneous resources with convex cost functions", *Informatica (Ljublj., Tisk. izd.)*, **41**, 1, 121-128, 2017.

PUBLISHED CONFERENCE CONTRIBUTION

1. Alen Ajanović, Karolina Počivavšek, Matic Podpadec, Andrej Ulčar, Ana Marija Peterlin, Ana Prodan, Saša Rink, Anton Gradišek, Matjaž Gams, Gašper Fele-Žorž, Mojca Matičič, "Application for viral hepatitis infection risk assessment", In: *Delavnica za elektronsko in mobilno zdravje ter pametna mesta: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9.-13. oktober 2017, [Ljubljana, Slovenia]: zvezek I: proceedings of the 20th International Multiconference Information Society - IS 2017, 9th-13th October, 2017, Ljubljana, Slovenia: volume I*, Matjaž Gams, ed., Aleš Tavčar, ed., Ljubljana, Institut Jožef Stefan, 2017, 46-48.

2. Jani Bizjak, Anton Gradišek, Luka Stepančič, Hristijan Gjoreski, Matjaž Gams, Karmen Goljuf, "Intelligent system to assist the independent living of the elderly", In: *IE' 2017*, The 13th International Conference on Intelligent Environments, 23-25 August 2017, Seoul, Korea, Jason J. Jung, ed., Danvers, IEEE = Institute of Electrical and Electronics Engineers, 2017, 180-183.

3. Jani Bizjak, Anton Gradišek, Luka Stepančič, Primož Presetnik, "Bat classification using deep neural network", In: *Slovenska konferenca o umetni inteligenci: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9.-13. oktober 2017, [Ljubljana, Slovenia]: zvezek A: proceedings of the 20th International Multiconference Information Society - IS 2017, 9th-13th October, 2017, Ljubljana, Slovenia: volume A*, Mitja Luštrek, ed., Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2017, 27-30.

4. Marko Bohanec, Erik Dovgan, Pavel Maslov, Aljoša Vodopija, Mitja Luštrek, Paolo Emilio Puddu, Michele Schiariti, Maria Constanza Ciancarelli, Anneleen Baert, Sofie Pardaens, Els Clays, "Designing a personal decision support system for congestive heart failure management", In: *Slovenska konferenca o umetni inteligenci: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9.-13. oktober 2017, [Ljubljana, Slovenia]: zvezek A: proceedings of the 20th International Multiconference Information Society - IS 2017, 9th-13th October, 2017, Ljubljana, Slovenia: volume A*, Mitja Luštrek, ed., Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2017, 67-70.

5. Dimo Brockhoff, Anne Auger, Nikolaus Hansen, Tea Tušar, "Quantitative performance assessment of multiobjective optimizers: the average runtime attainment function", In: *Evolutionary multi-criterion optimization: 9th International Conference, EMO 2017, Münster, Germany, March 19-22, 2017: proceedings*, (Lecture notes in computer science, **10173**), Heike Trautmann, ed., 103-119, 2017.

6. Borut Budna, Martin Gjoreski, Anton Gradišek, Matjaž Gams, "JSI Sound - platforma za enostavno klasifikacijo zvočnih posnetkov: demonstracija na zvokih živali", In: *Slovenska konferenca o umetni inteligenci: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9.-13. oktober 2017, [Ljubljana, Slovenia]: zvezek A: proceedings of the 20th International Multiconference Information Society - IS 2017, 9th-13th October, 2017, Ljubljana, Slovenia: volume A*, Mitja Luštrek, ed., Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2017, 23-25.

7. Božidara Cvetković, Vid Drobnič, Mitja Luštrek, "Recognizing hand-specific activities with a smartwatch placed on dominant or non-dominant wrist", In: *Slovenska konferenca o umetni inteligenci: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9.-13. oktober 2017, [Ljubljana, Slovenia]: zvezek A: proceedings of the 20th International Multiconference Information Society - IS 2017, 9th-13th October, 2017, Ljubljana, Slovenia: volume A*, Mitja Luštrek, ed., Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2017, 75-78.

8. Božidara Cvetković, Martin Gjoreski, Jure Šorn, Martin Frešer, Mitja Luštrek, Maciej Bogdański, Katarzyna Jackowska, Michał Kosiedowski, Aleksander Stroiński, "Management of physical, mental and environmental stress at the workplace", In: *IE' 2017*, The 13th International Conference on Intelligent Environments, 23-25 August 2017, Seoul, Korea, Jason J. Jung, ed., Danvers, IEEE = Institute of Electrical and Electronics Engineers, 2017, 76-83.

9. Božidara Cvetković, Martin Gjoreski, Jure Šorn, Pavel Maslov, Michał Kosiedowski, Maciej Bogdański, Aleksander Stroiński, Mitja Luštrek, "Real-time physical activity and mental stress management with a wristband and a smartphone", In: *UbiComp'17: proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and proceedings of the 2017 ACM International Symposium on Wearable Computers, September 11-15, 2017, Maui, Hawaii*, New York, ACM = Association for Computing Machinery, cop. 2017, 225-228.

10. Božidara Cvetković, Martin Gjoreski, Jure Šorn, Pavel Maslov, Mitja Luštrek, "Monitoring physical activity and mental stress using wrist-worn device and a smartphone", In: *Machine learning and knowledge discovery in databases: European Conference, ECML PKDD 2017, Skopje, Macedonia, September 18-22, 2017. Part I: proceedings*, (Lecture notes in computer science, **10534**), Michelangelo Ceci, ed., Ljupčo Todorovski, ed., Sašo Džeroski, ed., 2017, 414-418.

11. Tomaž Čegovnik, Klemen Trontelj, Erik Dovgan, Jaka Sodnik, "Ocenjevanje voznikovega vedenja in varnosti v prometu na simulatorju vožnje", In: *Zbornik šestindvajsete mednarodne Elektrotehniške in računalniške konference ERK 2017*, (Zbornik ... Elektrotehniške in računalniške konference ERK ..., 26), ERK 2017, Portorož, Slovenija, 25. - 26. september 2017, Andrej Žemva, ed., Andrej Trost, ed., Ljubljana, IEEE, Slovenska sekcija IEEE, 2017, 264-267.

12. Erik Dovgan, Jaka Sodnik, Ivan Bratko, Bogdan Filipič, "Multiobjective discovery of human-like driving strategies", In: *GECCO'17 companion: proceeding of the 2017 on Genetic and Evolutionary Computation Conference Companion, July 15-19, 2017 Berlin, Germany*, New York, ACM = Association for Computing Machinery, 2017, 1319-1323.

13. Erik Dovgan, Jaka Sodnik, Ivan Bratko, Bogdan Filipič, "Optimiranje časa in porabe goriva v modelih človeške vožnje", In: *Slovenska konferenca o umetni inteligenci: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9.-13. oktober 2017, [Ljubljana, Slovenia]: zvezek A: proceedings of the 20th International Multiconference Information Society - IS 2017, 9th-13th October, 2017, Ljubljana, Slovenia: volume A*, Mitja Luštrek, ed., Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2017, 35-38.

14. Greg Evseev, Jani Bizjak, Gregor Grasselli, Aleš Tavčar, Blaž Mahnič, Matjaž Gams, "Intelligent society", In: *Delavnica AS-IT-IC: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9. in 13. oktober 2017, [Ljubljana, Slovenia]: zvezek E: proceedings of the 20th International Multiconference Information Society - IS 2017, October 9th and 13th, 2017, Ljubljana, Slovenia: volume E*, Matjaž Gams, ed., Jernej Zupančič, ed., Ljubljana, Institut Jožef Stefan, 2017, 7-10.

15. Matjaž Gams, "Artificial intelligence in 2017", In: *Slovenska konferenca o umetni inteligenci: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9.-13. oktober 2017, [Ljubljana, Slovenia]: zvezek A: proceedings of the 20th International Multiconference Information Society - IS 2017, 9th-13th October, 2017, Ljubljana, Slovenia: volume A*, Mitja Luštrek, ed., Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2017, 7-10.

16. Matjaž Gams, "Asilomar AI principles", In: *Kognitivna znanost: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9-13. oktober 2017, [Ljubljana, Slovenia]: zvezek B: proceedings of the 20th International Multiconference Information Society - IS 2017, 9th-13th October 2017, Ljubljana, Slovenia: volume B*, Olga Markič, ed., et al, Ljubljana, Institut Jožef Stefan, 2017, 10-13.

17. Matjaž Gams, "Globalizem in prednosti superinteligence za RS Slovenijo", In: *Prenova Evrope*, Matej Avbelj, et al, Ljubljana, Slovenska akademija znanosti in umetnosti, = Academia scientiarum et artium Slovenica, 2017, 118-128.

18. Matjaž Gams, "Umetna inteligenca in izbrane demografske-ekonomske analize", In: *Soočanje z demografskimi izzivi: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9.-13. oktober 2017, [Ljubljana, Slovenia]: zvezek F: proceedings of the 20th International Multiconference Information Society - IS 2017, 9th-13th October, 2017, Ljubljana, Slovenia: volume F*, Janez Malačič, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2017, 33-37.

19. Matjaž Gams, Aleš Tavčar, "Integracija v EMZ EkoSMART", In: *Delavnica za elektronsko in mobilno zdravje ter pametna mesta: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9.-13. oktober 2017, [Ljubljana, Slovenia]: zvezek I: proceedings of the 20th International Multiconference Information Society - IS 2017, 9th-13th October, 2017, Ljubljana, Slovenia: volume I*, Matjaž Gams, ed., Aleš Tavčar, ed., Ljubljana, Institut Jožef Stefan, 2017, 7-9.

20. Hristijan Gjoreski, Daniel Roggen, "Unsupervised online activity discovery using temporal behaviour assumption", In: *Proceedings of the 2017 ACM International Symposium on Wearable Computers, ISCW 2017, September 11 - 15, 2017, Maui, Hawai*, New York, ACM = Association for Computing Machinery, 2017, 42-49.

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INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

1. Jana Krivec, "Cognitive processes and information technology in education", In: *Information society and its manifestations: economy, politics, culture*, Borut Rončević, ed., Matevž Tomšič, ed., Frankfurt am Main [etc.], Peter Lang, cop. 2017.

SCIENTIFIC MONOGRAPH

1. Yusuke Sugomori, Boštjan Kaluža, Fábio Soares, Alan M. F. Souza, *Deep learning: practical neural networks with Java: build and run intelligent applications by leveraging key Java machine learning libraries*, Birmingham, Packt Publishing, 2017.

PROFESSIONAL MONOGRAPH

1. Matej Guid*, Learn and master Progressive Chess*, 1st ed., Ljubljana, Založba UL FRI, 2017.

DEPARTMENT OF REACTOR ENGINEERING

R-4

The Department of Reactor Engineering is involved in basic and applied research in the fields of nuclear engineering and safety. Topics include the modelling of basic thermal-hydrodynamic phenomena, thermal-hydraulic safety analyses of design-basis and severe accidents, structural safety analyses and probabilistic safety assessment. Most research activities are part of international cooperation programs. The research results are incorporated into projects for industry and for the regulatory authorities, as well as in under-graduate and doctoral studies programmes.

Head:
Prof. Leon Cizelj

Modelling of basic thermal-hydrodynamic phenomena

Turbulent heat transfer was investigated by performing Direct Numerical Simulations, using the spectral element method and the computer code nek5000, within the European Commission (EC) project SESAME that is dedicated to the thermal hydraulics of liquid metals. Simulations are being performed in the geometry of a backward-facing step, with a heater attached below the floor after the step. Results obtained at low Reynolds numbers will be used for the validation of various turbulent heat-transfer models by other partners.

As part of the study of jet-impingement flows, the uncertainty of statistically averaged Large Eddy Simulation (LES) results was analyzed, which is particularly important for the validation purposes of statistical RANS (Reynolds Averaged Navier-Stokes) turbulence models. These results were used in assessment studies of predictive abilities of computationally less demanding URANS (Unsteady RANS) simulation methods, where an incomplete description of unsteady phenomena in impinging jets was observed.

Conjugate heat-transfer simulations were performed with a wall-resolved LES model, using the open-source code Code_Saturne and in collaboration with Electricité de France (EDF). We have validated the capabilities of the LES models for detailed simulations of the turbulent heat transfer in geometries, where the penetration of turbulent fluctuations into solid walls must be predicted.

The flow in a fuel bundle with a mixing grid spacer was simulated using the hybrid SAS (Scale Adaptive Simulation) turbulence model and compared with the URANS turbulence model results. On the same numerical mesh, the SAS model describes the unsteady nature of the vortices separation behind the mixing vanes much better. The results of both simulations were validated on the MATiS-H experiment (Measurement and analysis of turbulent mixing in sub-channels – horizontal) performed at the Korea Atomic Energy Research Institute.

Analyses and simulations of separated upward air-water flow in a vertical pipe were continued. The influence of the initial liquid film's wave shape on the wave propagation was investigated. The wave shape was modelled using analytical models and compared with the numerical simulations that use interface-capturing methods.

The basic phenomena of vapour explosion and debris bed coolability, which might occur during a hypothetical severe accident in a nuclear power plant (NPP) if the hot reactor-core melt comes into contact with the coolant, were investigated. Analyses of the metal corium oxidation on the ex-vessel vapour explosion in the cavity of a pressurized water reactor have shown a significant influence of the oxidation on the simulation results. We also continued the study of vapour explosions in stratified melt-coolant configurations. The recently performed experiments in the PULiMS/SES facility (Royal Institute of Technology, Sweden) have revealed that strong, stratified explosions can develop spontaneously. In order to investigate the premixed layer formation mechanisms in stratified conditions, the SES-S1 test, which was performed in the SES facility in the frame of the EC SAFEST project, was analysed using the MC3D code (Institut de Radioprotection et de Sûreté Nucléaire - IRSN, France). The test was proposed by an international user group led by the JSI and EDF. Based on the performed analysis, the fraction of the melt, which participated in the explosion, was estimated. In addition, we have introduced a newly developed model for the premixture layer formation and presented the first numerical tests. Apart from that, the potential of vapour explosions during melt-sodium interaction was also investigated. Different pressurization process modelling approaches were analysed and the needs for future experimental and numerical investigations were identified. The MC3D code was
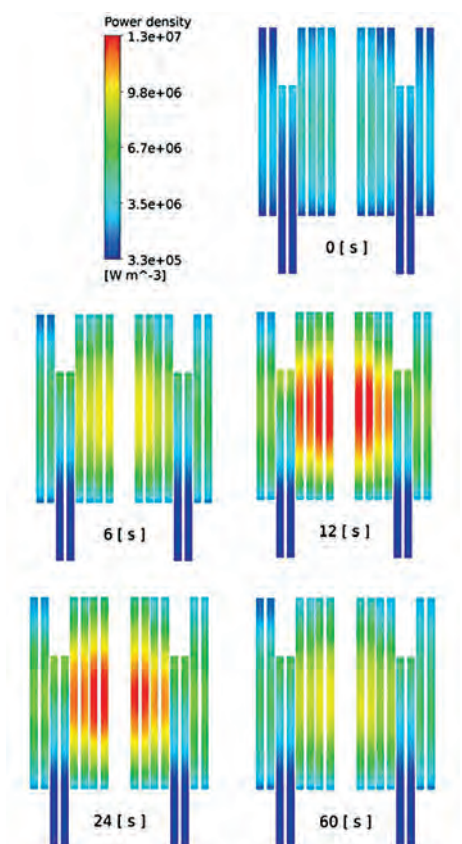

Figure 1: Time evolution of the power density distribution in TRIGA reactor predicted with coupled neutronic - thermalhydraulic model.
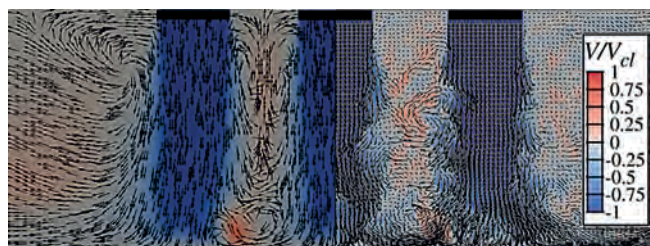
Figure 2: Flow fields of turbulent cooling impinging jets: URANS (left) and LES (right) simulations.

also used to provide additional insights into the debris bed reflooding in recently performed PEARL experiments (IRSN).

In the research field of hydrogen distribution in NPP containment, a series of experiments on containment atmosphere mixing, performed in the PANDA experimental facility (Paul Scherrer Institute, Switzerland) was simulated with the open-source Computational Fluid Dynamics (CFD) code OpenFOAM. In the research field of hydrogen combustion, we participated in the MITHYGENE benchmark, where we simulated experiments, performed in the ENACCEF-2 experimental facility, located at the Institut de Combustion Aérothermique Réactivité et Environnement (ICARE, France), using the Fluent CFD code and the ASTEC system code. Apart from that, we continued simulations of the experiment on hydrogen combustion, which was performed with our participation in 2016 on the HYMIT facility at Shanghai Jiao Tong University, China.

Regarding the construction of the experimental laboratory for fluid mechanics and heat-transfer research, we focused on the installation of instruments and on the construction of the test section. Furthermore, the test facility was equipped with a dual-cavity laser and a high-speed camera, which will allow instantaneous measurements of the velocity field in the test section annulus where local heat-transfer coefficients will be measured and the governing physical mechanisms will be studied.

A coupled neutronic-thermalhydraulic model of the TRIGA research nuclear reactor was developed.

A coupled neutronic-thermalhydraulic model of the TRIGA research nuclear reactor was developed in collaboration with the JSI Reactor Physics Department. The neutronic model is based on the Monte-Carlo method and the thermalhydraulic modelling is based on CFD. The model was validated using additional measurements of the coolant temperature distributions in the cooling channels of the TRIGA reactor.

Thermal-hydraulic safety analyses

The SB-HL-02 experiment, performed on the ROSA Large Scale Test Facility, Japan, represents a large break loss-of-coolant accident with a break size equivalent to 10% cross section in the cold leg. The total loss of high-pressure safety injection and auxiliary feedwater were assumed, simultaneously with loss of external power supply. Such a scenario extends beyond a design-basis accident. The simulation results of the experiment with the RELAP5 and TRACE system codes are comparable and agree well with the experimental data.

A loss-of-coolant accident in the spent-fuel pool of the Krško nuclear power plant was simulated.

The development of the thermal shielding concept for the demonstration fusion power plant DEMO was continued within the frame of the EUROfusion project. The predicted total power required for cryogenic cooling of the magnets and thermal shields was further reduced by the modifications of the cryostat thermal shield supports and by additional passive shielding of the vacuum vessel.

In the frame of the fusion project WP-MST2, we have been involved in the development of a Langmuir probe used for plasma diagnostics in small fusion tokamak devices. By using numerical simulation methods, we predicted that the support structures of the probe are able to withstand the expected thermal loads during operation.

A research project, co-financed by the Krško NPP, was dedicated in 2017 to the simulation of a hypothetical prolonged loss-of-coolant accident in the Krško NPP spent fuel pool. Independent simulations were performed with the ASTEC system code and our own code, developed within the MATLAB programming environment.

Structural safety analyses

In cooperation with the Commissariat à l'Energie Atomique (CEA, France), grain-boundary stress distributions were investigated systematically in various polycrystalline materials with the goal being to identify the most relevant material and structural parameters contributing to intergranular stress corrosion cracking. The stress distributions were calculated using crystal plasticity finite-element simulations accounting for various elastic and plastic grain properties as well as different macroscopic loading conditions. A simple but accurate phenomenological law was identified that relates the first two distribution moments with commonly known material variables and properties.

A simple phenomenological law was introduced for the identification of the most relevant material and structural parameters contributing to intergranular stress corrosion cracking in polycrystalline materials.

Within the EC project SOTERIA and in collaboration with IRSN and the Centre National de la Recherche Scientifique (CNRS, France), a comparison between Finite Element Method simulations and Fast Fourier Transforms based simulations was performed on polycrystalline simulations of irradiated austenitic stainless steel. The accuracy of the cohesive zone approach was also tested in a finite-element framework for the calculation of intergranular stresses in a polycrystal.

In cooperation with VTT, Finland, synthetic fluid temperature histories generated with an improved spectral method developed at the JSI were compared with those obtained in a validated CFD LES of turbulently mixing fluids at different temperatures. The aim of this study was to evaluate the applicability of the more affordable synthetic temperatures in the thermal fatigue assessment of the pipes.

We also participated in two EC projects in the field of nuclear fusion. Within the WPDC project (diagnostic and control), a finite-element analysis on electromagnetic disruption forces was carried out for the divertor thermo-current measurement diagnostics for the DEMO fusion reactor. A limiting electrical current was calculated through the water-cooling pipes.

Within the PMI-PPPT-FU project (plant level system engineering), the initial concept design for the Cryostat Bellows, i.e., the expansion joints between the vacuum vessel port and cryostat in DEMO, was further studied. The tool for Cryostat Bellows design was improved to integrate trapezoidal bellows shape and multi-ply analysis. The validation of the tool's new features was performed through a parametric finite-element analysis.

Probabilistic safety assessment

An analysis of the electrical power system generating adequacy, considering the introduction of wind power generating units, was performed. The implication of the substitution of NPPs with wind power generating units on the risk of the remaining operational NPPs within the analysed power system was evaluated. The change of generating adequacy, resulting from the introduction of wind power generating units, depends on load uncertainty and wind-speed shape parameters. The substitution of nuclear power with wind power causes a small risk reduction.

An independent water-storage system for water injection in the primary and secondary loops was proposed for an improvement of the pressurized water reactor's safety. The system is used for the mitigation of station blackout and large loss-of-coolant accidents. The assessment of the effectiveness of the proposed system, performed with a probabilistic safety assessment (PSA), indicates an improvement of NPP safety.

An analysis of the electrical power system generating adequacy, considering the introduction of wind-power generating units, was performed.

We joined the EC NARSIS project, which aims to extend the present PSA methodologies to extreme events with very low frequencies. Our contribution to the project will be a better characterization of natural external hazards and their combinations, as well as their appropriate consideration in PSA and supporting deterministic analyses.

Technical cooperation, consulting services and education

In 2017, the Reactor Engineering Division cooperated in projects for industry and the state administration as well. As an authorized institution for radiation and nuclear safety, we prepared several independent evaluations on the alternative spent-fuel pool cooling and implementation of the emergency control room in the Krško NPP. The instalation of new instruments, systems and components leads to changes in the Krško NPP Updated Safety Analysis Report.

For the Slovenian nuclear safety administration, we analysed the influence of the Krško NPP safety-upgrade program on the severe-accident management guidelines and prepared an overview of core melt cooling strategies after reactor-vessel failure. For the utility company GEN energija, we have been describing the safety characteristics of seven candidate reactors for the potential second unit of the Krško NPP.

Researchers of the department represent the core staff of the Chair for Nuclear Engineering, and are involved in nuclear engineering undergraduate, master and doctoral studies at the Faculty of Mathematics and Physics at the University of Ljubljana. The programmes are associated with the European Nuclear Education Network (ENEN).

Some outstanding publications in the past year

1. R. Henry, I. Tiselj, M. Matkovič, Natural and mixed convection in the cylindrical pool of TRIGA reactor, Heat and Mass Transfer, 53 (2017), 537-551
2. M. Draksler, B. Končar, L. Cizelj, B. Ničeno, Large Eddy Simulation of multiple impinging jets in hexagonal configuration : flow dynamics and heat transfer characteristics, International Journal of Heat and Mass Transfer, 109 (2017), 16-27
3. M. Tekavčič, B. Končar, I. Kljenak, The concept of liquid inlet model and its effect on the flooding wave frequency in vertical air-water churn flow, Chemical Engineering Science, 175 (2017), 231-242
4. M. Uršič, R. Meignen, M. Leskovar, Analysis of film boiling heat transfer during fuel-coolant interaction, International Journal of Heat and Mass Transfer, 107 (2017), 622-630
5. O. Costa Garrido, S. El Shawish, L. Cizelj, Assessment of thermal fatigue predictions of pipes with spectral methods, Journal of Nuclear Engineering and Radiation Science, 3 (2017), 041001-1-041001-8

Awards and appointments

1. Matej Tekavčič, Boštjan Končar, Ivo Kljenak: Best poster award (ICONE25 conference, Shanghai, China), American Society of Mechanical Engineers, Liquid inlet boundary effect on the simulation of liquid waves in vertical air-water churn flow
2. Rok Krpan: Best young author paper award (NENE2017 conference, Bled, Slovenia), Nuclear Society of Slovenia, Simulation of a low-momentum steam jet interaction with a light gas layer in a containment facility

Organization of conferences, congresses and meetings

1. Training course on "Lessons learned from the Fukushima Daiichi incident and EU stress tests", Jožef Stefan Institute Reactor Center, 13.-17. 3. 2017
2. Training course on "Thermo-hydraulic analysis from regulatory prespective for NPP accident analysis", Jožef Stefan Institute Reactor Center, 10.-14. 4. 2017
3. Summer workshop ETSON Junior Staff Programme "Uncertainly and sensitivity in safety analysis", Jožef Stefan Institute Reactor Center, 10.-14. 7. 2017
4. 26th International conference "Nuclear Energy for New Europe NENE 2017", Bled, Slovenia, 11.-14. 9. 2017
5. Short course on severe accident phenomenology, Jožef Stefan Institute, 23.-27. 10. 2017
6. Training course on "Requirements and safety evaluation for NPP Safety Analysis Report", Jožef Stefan Institute Reactor Center, 13.-18. 11. 2017

INTERNATIONAL PROJECTS

1. 7FP - CESAM; Code for European Severe Accident Management
   Asst. Prof. Ivo Kljenak
   European Commission
2. Analysis to support Implementation in Practise of Articles 8a-8c of Directive 2014/87/Euratom
   Prof. Leon Cizelj
   European Commission, Directorate-general
3. Training and Tutoring for Experts of the National Regulatory Authorities and their Technical Support Organisations for Developing or Strengthening their Regulatory and Technical Capabilities - MC3.01/13
   Prof. Leon Cizelj
   Iter-consult Srl - Independent
4. H2020 - SESAME; thermal hydraulics Simulations and Experiments for the Safety Assessment of MEtal cooled reactors
   Prof. Iztok Tiselj
   European Commission
5. H2020 - SOTERIA; Safe Long Term Operation of Light Water Reactors based on Improved Understanding of Radiation Effects in Nuclear Structural Materials
   Prof. Leon Cizelj
   European Commission
6. H2020 - ANNETTE; Advanced Networking for Nuclear Education and Training and Transfer of Expertise
   Prof. Leon Cizelj
   European Commission
7. H2020 - ATLASplus; Advanced Structural Integrity Assessment Tools for Safe Long Term Operation
   Prof. Leon Cizelj
   European Commission
8. H2020 - NARSIS; New Approach to Reactor Safety Improvements
   Dr. Andrej Prošek
   European Commission
9. H2020 - ENENplus; Attract, Retain and Develop New Nuclear Talents Beyond Academic Curricula
   Asst. Prof. Ivo Kljenak
   European Commission
10. H2020 EUROfusion - Research Unit - Administration and Services RU – FU
    Dr. Boštjan Končar
    European Commission
11. H2020 EUROfusion - Education-ED-FU
    Dr. Boštjan Končar
    European Commission
12. H2020 EUROfusion - Plant Level System Engineering-PMI-PPPT-FU
    Dr. Boštjan Končar
    European Commission
13. H2020 EUROfusion - JET Enhancements-JET4-FU, EUROFUSION
    Dr. Boštjan Končar
    European Commission
14. H2020 EUROfusion - Diagnostic and Control-WPDC-PPPT-FU
    Dr. Samir El Shawish
    European Commission

15. Experimental and Numerical Studies of High Temperature Gas-Cooled Reactors
    Prof. Leon Cizelj
    Slovenian Research Agency
16. General Assembly of the ETSON Association, Member of the Governing Board
    Prof. Leon Cizelj
    Slovenian Research Agency
17. Investigation of stratified steam explosions
    Dr. Matjaž Leskovar
    Slovenian Research Agency
18. Towards quantitative prediction of stress corrosion cracking initiation stress threshold for PWR's internals
    Dr. Samir El Shawish
    Slovenian Research Agency

RESEARCH PROGRAM

1. Reactor engineering
   Prof. Leon Cizelj

R&D GRANTS AND CONTRACTS

1. Pressurization process during vapour explosion in sodium cooled fast reactors
   Dr. Mitja Uršič
2. JOPRAD; Joint Programming on Radioactive Waste Disposal
   Prof. Leon Cizelj
   Andra - The French National Radioactive Waste
3. Financing of project visits at the Slovenian higher education institutions - pilot project
   Dr. Andrija Volkanovski
   Javni štipendijski, razvojni, invalidski in preživninski sklad Republike Slovenije
4. Research of Conjugate Heat Transfer in Turbulent Pipe Flow
   Prof. Iztok Tiselj
   Electricite De France S.a.
5. Feasibility of the Modelling of Interaction between Molten Corium and Sodium in the MC3D Software for SFR Applications
   Dr. Mitja Uršič
6. Short Course on Severe Accident Phenomenology, IJS, Ljubljana, Slovenia, 23.-27.10.2017
   Prof. Leon Cizelj
7. Exisiting Training Course on „Severe Accident Phenomenology", JSI, Ljubljana, Slovenia, from 23 October 2017 to 27 October 2017
   Asst. Prof. Ivo Kljenak
   Iter-consult Srl - Independent
8. International Conference Nuclear Energy for New Europe
   Prof. Leon Cizelj
9. Short Course on Severe Accident Phenomenology
   Asst. Prof. Ivo Kljenak

NEW CONTRACTS

1. Expert Opinion on Mod. 1028SF-L Alternative Cooling of SFP
   Asst. Prof. Ivo Kljenak
   Nuklearna Elektrarna Krško d. o. o.
2. Cooperation in an international CAMP program
   Dr. Andrej Prošek
   Nuklearna Elektrarna Krško
3. Joint Expert Assessment of the Outage Activities, Interventions and Tests during a shutdown and refueling outage 2016
   Dr. Mitja Uršič
   Elektroinštitut Milan Vidmar
4. Understanding and managing the processes related to SFP under loss of cooling and loss of coolant accident scenario

   Asst. Prof. Marko Matkovič
   Nuklearna Elektrarna Krško d. o. o.
5. Independent expert opinion of modification 1007-XI-L
   Dr. Mitja Uršič
   Nuklearna Elektrarna Krško d. o. o.
6. Analysis of Krško NPP Safety Upgrade Program Influence on Severe Accident Management Guidelines
   Dr. Matjaž Leskovar
   Ministry of the Environment and Spatial Planning
7. Safety characteristics and severe accident management in selected nuclear power plants
   Dr. Matjaž Leskovar
   Gen Energija, d. o. o.
8. Overview of core melt cooling strategies after reactor vessel failure
   Dr. Matjaž Leskovar
   Ministry of the Environment and Spatial Planning

VISITORS FROM ABROAD

1. H.E. Brent R. Hartley, M. Kavčič, S. Reisinger, Embassy of the United States of America in Ljubljana (Ljubljana, Slovenia), 19.01.2017
2. Prof. Hiroshige Kikura, Tokyo Institute of Technology (Tokyo, Japan), 12.02.2017
3. Azwidovhiwi Emmanuel Nengudza, National Nuclear Regulator (NNR) (Centurion, South African Republic), 17.4.-9.6.2017
4. Catur Febriyanto Sutopo, Nuclear Energy Regulatory Agency of Indonesia (BAPETEN) (Jakarta Pusat, Indonesia), 17.4.-9.6.2018

5. Prof. dr. József Györkös, prof. dr. Marko Topič, Slovenian Research Agency (Ljubljana, Slovenia), 16.06.2017
6. Dr. Sofiane Benhamadouche, dr. Martin Ferrand, Electricité de France (EDF) Research and Development (Chatou, France), 18.-19.11.2017
7. Amir Hossein Vosoughi, Iran Nuclear Regulatory Authority/ Atomic Energy Organisation (Iran), 18. - 22. 12. 2017
8. Daniel Omar Torres Anaya, Comisión nacional de seguridad nuclear y salvaguardias (CNSNS) (Mexico), 18. - 22. 12. 2017

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2. Dr. Samir El Shawish
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5. Dr. Matjaž Leskovar
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7. Dr. Andrej Prošek
8. Prof. Iztok Tiselj
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10. Dr. Andrija Volkanovski

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12. Dr. Martin Draksler
13. Dr. Cedric Cyril Henri Flageul
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Postgraduates
15. Romain Claude Francis Henry, B. Sc.
16. Tadej Holler, B. Sc.
17. Janez Kokalj, B. Sc.
18. Rok Krpan, B. Sc.
19. Matic Kunšek, B. Sc.
20. Jure Oder, B. Sc.
21. Matej Tekavčič, B. Sc.
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26. Zoran Petrič, B. Sc.
27. Nina Rehar, B. Sc.

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5. Cedric Flageul, Iztok Tiselj, "Impact of unresolved smaller scales on the scalar dissipation rate in direct numerical simulations of wall bounded flows", *Int. j. heat fluid flow*, **68**, 173-179, 2017.
6. Oriol Costa Garrido, Samir El Shawish, Leon Cizelj, "Assessment of thermal fatigue predictions of pipes with spectral methods", *Journal of nuclear engineering and radiation science*, **3**, 4, 041001, 2017.

7. Blaže Gjorgiev, Andrija Volkanovski, Giovanni Sansavini, "Improving nuclear power plant safety through independent water storage systems", *Nucl. Eng. Des.*, **232**, 8-15, 2017.
8. Romain Henry, Iztok Tiselj, Marko Matkovič, "Natural and mixed convection in the cylindrical pool of TRIGA reactor", *Heat mass transf.*, **53**, 2, 537-551, 2017.
9. Romain Henry, Iztok Tiselj, Luka Snoj, "CFD/Monte-Carlo neutron transport coupling scheme, application to TRIGA reactor", *Ann. nucl. energy*, **110**, 36-47, 2017.
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11. Blaž Mikuž, Iztok Tiselj, "URANS prediction of flow fluctuations in rod bundle with split-type spacer grid", *Int. j. heat fluid flow*, **64**, 10-22, 2017.
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13. Mitja Uršič, Renaud Meignen, Matjaž Leskovar, "Analysis of film boiling heat transfer during fuel-coolant interaction", *Int. j. heat mass transfer*, **107**, 622-630, 2017.
14. Jean-Pierre Van Dorsselaere, François Bréchignac, Felice De Rosa, Luis Enrique Herranz, Ivo Kljenak, Alexei Miassoedov, Sandro Paci, Pascal

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15. Andrija Volkanovski, "Wind generation impact on electricity generation adequacy and nuclear safety", *Reliab. eng. syst. saf.*, **158**, 85-92, 2017.

SHORT ARTICLE

1. Oriol Costa Garrido, Samir El Shawish, Leon Cizelj, "Comments on "Study of the quantitative assessment method for high-cycle thermal fatigue of a T-pipe under turbulent fluid mixing based on the coupled CFD-FEM method and the rainflow counting method" [Y. Zhang, T. Lu, Nucl. Eng. Des. 309 (2016) 175-196.]", *Nucl. Eng. Des.*, **318**, 274-275, 2017.

PUBLISHED CONFERENCE CONTRIBUTION

1. Vasilij Centrih, Matjaž Leskovar, Mitja Uršič, "Analysis of stratified steam explosion duration consideration considering recent SES-S1 test", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 412.

2. Olivia Coindreau *et al.* (31 authors), "Severe accident code-to-code comparison for two accident scenarios in a Spent Fuel Pool", In: *ERMSAR 2017*, 8th European Review Meeting on Severe Accident Research, May 16-18, 2017, Warsaw, Poland, [S. l.], SARNET, 2017.

3. E. De Malmazet *et al.* (18 authors), "Stratified steam explosion phenomena: SAFEST SES-S1 test results and preliminary analysis", In: *ERMSAR 2017*, 8th European Review Meeting on Severe Accident Research, May 16-18, 2017, Warsaw, Poland, [S. l.], SARNET, 2017.

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5. Samir El Shawish, Leon Cizelj, "Predicting neutron irradiation effects on intergranular stresses in austenitic stainless steel", In: *Multiscale computational methods for solids and fluids: proceedings: september 20-22, 2017, Ljubljana, Slovenia*, Third International Conference on Multiscale Computational Methods for Solids and Fluids, September 20-22, 2017, Ljubljana, Slovenia, Adnan Ibrahimbegović, ed., Boštjan Brank, ed., Ivica Kožar, ed., Ljubljana, Faculty of Civil and Geodetic Engineering, 2017, 31-33.

6. Samir El Shawish, Leon Cizelj, Pierre-Guy Vincent, Hervé Moulinec, "Polycrystalline simulations of an irradiated stainless steel: a comparison between Finite Element and Fast fourier transforms based simulations", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 309.

7. Cedric Flageul, Sofiane Benhamadouche, Iztok Tiselj, Martin Ferrand, "Quantification of the discontinuity of the temperature variance dissipation rate at a fluid-solid interface: wall-resolved Large Eddy Simulation of turbulent channel flow with conjugate heat transfer", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 212.

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9. M. Freitag *et al.* (15 authors), "Benchmark exercise TH27 on natural convection with steam injection and condensation inside the extended THAI facility", In: *ERMSAR 2017*, 8th European Review Meeting on Severe Accident Research, May 16-18, 2017, Warsaw, Poland, [S. l.], SARNET, 2017.

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12. Oriol Costa Garrido, Boštjan Končar, Richard J. C. Brown, Christian Bachmann, "Effect of DEMO load cases on rectangular bellows design", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 718.

13. Oriol Costa Garrido, Antti Timperi, Samir El Shawish, Leon Cizelj, "Comparison of spectral methods with CFD simulation of turbulent fluid mixing", In: *SMiRT 24*, 24th International Conference on Structural Mechanics in Reactor Technology, August 20-25, 2017, Busan, Korea, [S. l.], AASMiRT = American Association for Structural Mechanics in Reactor Technology, 2017.

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15. Tadej Holler, P. B. Ghionzoli, Ed. M. J. Komen, "CFD-based validation of different combustion models for slow hydrogen deflagration", In: *NURETH-17*, 17th International Meeting on Nuclear Reactor Thermal Hydraulics, Sept. 3-8, 2017, X'ian, China, [S. l.], American Nuclear Society, 2017.

16. Tadej Holler, Po Hu, Shuwei Zhai, Ed. M. J. Komen, Mikhail Kuznetsov, Ivo Kljenak, "CFD and lumped-parameter simulations of medium-scale hydrogen deflagration experiment in the hymit experimental facility", In: *NURETH-17*, 17th International Meeting on Nuclear Reactor Thermal Hydraulics, Sept. 3-8, 2017, X'ian, China, [S. l.], American Nuclear Society, 2017.

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23. Janez Kokalj, Matjaž Leskovar, Mitja Uršič, "Modelling of premixed layer formation in stratified melt-coolant configuration", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 409.

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28. Matjaž Leskovar, Vasilij Centrih, Mitja Uršič, N. Cassiaut Louis, Claude Brayer, Pascal Piluso, "MC3D premixing analysis using x-ray radioscopy experimental data of KROTOS-SERENA tests", In: *ERMSAR 2017*, 8th European Review Meeting on Severe Accident Research, May 16-18, 2017, Warsaw, Poland, [S. l.], SARNET, 2017.

29. Marko Matkovič, Leon Cizelj, Ivo Kljenak, Boštjan Končar, Blaž Mikuž, Andrej Sušnik, Iztok Tiselj, Boštjan Zajec, "Building a unique test section for local critical heat flux studies in light water reactor: like accident conditions", In: *HEFAT2017*, 13th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics, Portorož, Slovenia, 17-19 July, 2017, [S. l.], International Centre for Heat and Mass Transfer (ICHMT), American Society of Thermal and Fluids Engineers (ASTFE), 2017.

30. Marko Matkovič, Martin Draksler, "Building an experimental apparatus for advanced heat transfer and fluid flow studies during convective single-phase and two-phase flows", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 222.

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32. Pedro Porras Dieguez, Csilla Pesznyák, S. Bazargan Sabet, Abdesselam Abdelouas, Filip Toumisto, Leon Cizelj, "An approach to attract, retain and develop new nuclear talents beyond academic curricula: the ENEN+ Project", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 1106.

33. Andrej Prošek, "RELAP5 and TRACE simulation of hot leg break LOCA experiment on LSTF", In: *Spring 2017 CAMP meeting: May 22-24, 2017, Warsaw, Poland*, [S. l., s. n.], 2017.

34. Andrej Prošek, "Simulation of ROSA/LSTF test SB-HL-02 using RELAP5 and TRACE", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 203.

35. Andrej Prošek, "Status of CAMP activities in Slovenia", In: *Fall 2017 CAMP meeting: November 28-30, 2017, Ann Arbour, USA*, [S. l., s. n.], 2017.

36. Andrej Prošek, Catur Febriyanto Sutopo, Azwidovhivi Emmanuel Nengudza, "Semiscale natural circulation S-NC-2 and S-NC-3 tests simulations", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 219.

37. Andrej Prošek, A. Wielenberg, H. Löffler, Emmanuel Raimond, "Methodology for selecting initiating events and hazards for consideration in an extended PSA", In: *Safety & reliability: theory and applications: proceedings of the 27th European Safety and Reliability*

Conference, ESREL 2017, Portorož, Slovenia, 18-22 June 2017, Marko Čepin, ed., Radim Briš, ed., Boca Raton, CRC Press, London, Taylor & Francis, 2017, 3337-3345.

38. Tomaž Skobe, Matjaž Leskovar, Leon Cizelj, "Influence of metal corium oxidation on ex-vessel steam explosion", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 421.

39. Boris Sučić, Sandi Cimerman, Marko Pečkaj, Fouad Al-Mansour, "Practical approach for energy consumption optimisation in educational and research buildings - case study cluster computers and data room", In: *Energy efficiency: (conference proceedings)*, Jurij Krope, ed., et al, Maribor, University of Maribor Press, Faculty of Chemistry and Chemical Engineering, 2017, 165-174.

40. Matej Tekavčič, Boštjan Končar, Ivo Kljenak, "Liquid inlet boundary effect on the simulation of liquid waves in vertical air-water churn flow", In: *ICONE25*, The 24th International Conference on Nuclear Engineering, June 2-6, 2017, Shanghai, China, [S. l.], ASME = American Society of Mechanical Engineers, 2017.

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42. Mitja Uršič, Matjaž Leskovar, "Pressurization process modelling in sodium during fuel-coolant interaction", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 419.

43. Andrija Volkanovski, V. Matuzas, "A new method for evaluation of the qualitative importance measures", In: *Safety & reliability: theory and applications: proceedings of the 27th European Safety and Reliability Conference, ESREL 2017, Portorož, Slovenia, 18-22 June 2017*, Marko Čepin, ed., Radim Briš, ed., Boca Raton, CRC Press, London, Taylor & Francis, 2017, 2829-2834.

44. Andrija Volkanovski, Miguel Peinador, "Loss of essential power system", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 1006.

INDEPENDENT COMPONENT PART OR A CHAPTER IN A MONOGRAPH

1. Emmanuel Raimond, Gryffroy Dries, Andrej Prošek, "Technological risk: nuclear accidents", In: *Science for disaster risk management 2017: knowing better and losing less*, (EUR, 28034 EN), Karmen Poljanšek, ed., [S. l.], European Commission, cop. 2017, 356-366.

PROFESSIONAL MONOGRAPH

1. Andrej Prošek, *RELAP5 and TRACE calculations of LOCA in PWR*, (International agreement report, NUREG/IA-0479), Washington, U.S. Nuclear Regulatory Commission, 2017.

MENTORING

1. Romain Henry, *Neutronic and thermal-hydraulics coupling for simulations of the TRIGA Mark II reactor:* doctoral dissertation, Ljubljana, 2017 (mentor Iztok Tiselj; co-mentor Luka Snoj).

REACTOR INFRASTRUCTURE CENTRE   RIC

The Reactor Infrastructure Centre (RIC) incorporates a TRIGA Mark II research reactor and a Hot Cells Facility. The reactor, operating since 1966, is used for neutron research, training and for radioactive isotope production. A detailed technical description of the reactor is available at http://www.rcp.ijs.si/~ric/. The Hot Cells Facility is used for the treatment and handling of radioactive materials and radioactive waste within research and applicative projects. In addition, it is used for performing regular radiological measurements of radioactive waste and irradiated samples.

Besides operating and maintaining the reactor, the members of the reactor staff participate in other activities requiring specialists skilled in work with sources of radiation and in reactor technology, such as the servicing of industrial radioactive sources and surveillance of the fuel management in NPP Krško.

Head:
Prof. Borut Smodiš

The reactor operated in accordance with a program approved by the Heads of the RIC and the Radiation Protection Unit – RPU (SVPIS in Slovenian language) for each week. In 2017 the reactor operated for 151 days and produced 109.5 MWh of heat. Altogether, forty-six pulses were carried out. A total of 1121 samples were irradiated in the rotary specimen rack, irradiation channels and in the pneumatic transfer system.

The reactor operators supported researchers by performing the operations and services for which the researchers are not qualified and authorized, such as operating the reactor, performing irradiations and manipulating radioactive samples.

In 2017 the reactor was mainly used as a neutron source for neutron-activation analysis, irradiation of electronic components and education. For educational purposes, it was mostly used for the needs of the Jožef Stefan Institute's Nuclear Training Centre. For the irradiation of samples, it was mostly used by the Department of Environmental Sciences O2 and the Department of Experimental Particle Physics F9. The Reactor Physics Department F8 used the reactor for experiments in reactor physics.

The shutdown reactor, being a powerful source of gamma radiation, was repeatedly used for testing the resistance of electronic components to radiation, irradiation of ceramic samples for the Department of Electronic Ceramics K5 and sterilization of samples from the Department for Nanostructured Materials K7.

In the Hot Cells Facility the activities were mostly performed by the Department of Environmental Sciences O2, the Radiation Protection Unit and the Slovenian Agency for Radioactive waste Management (ARAO) – processing and preparation of radioactive waste for storage needs.

The reactor was used for the following research activities:
–   Reactor physics and neutronics;
–   Activation analysis;
–   Research on radiation damage of semiconductors;
–   Neutron dosimetry and spectrometry;
–   Activation of materials, nuclear waste and decommissioning;
–   Radiation hardness studies;
–   Irradiation of materials for fusion reactors;
–   Irradiation of electronic and medical components;
–   Development and testing of new detectors;
–   Development of new methods for measuring power profiles, neutron spectra, etc.;
–   Verification and validation of methods for calculating the transport of neutrons, photons and electrons;
–   Development of educational tools in reactor physics.

Figure 1: Spent-fuel handling training

In the framework of a collaboration between the Reactor Physics Department F8 and the French Alternative Energies and Atomic Energy Commission (CEA), Cadarache, the following activities were carried out:
–   irradiation of TLD (thermoluminescent detectors) in the TRIGA Reactor,
–   measurements of neutron flux with bare 3-mm fission cells and additionaly with Cd and Gd filters, and
–   20-hour irradiation of FT-TIMS.

Since 2011, the TRIGA Reactor participates in the FP7 AIDA (*Advanced Infrastructures for Detectors and Accelerators*), in the framework of project "*Horizon 2020 - the AIDA-2020 GA No. 654168, Task 15.5 - Irradiation Facilities*" (*http://aida.web.cern.ch/aida/index.html*), project that brings together advanced European infrastructures for future particle physics experiments, we have completed the production of an experimental device in the channel number 6. Now, we are already irradiating larger samples with a maximum diameter of 14 cm.

In the scope of the NATO SPS project E-SiCure (http://e-sicure.web.ua.pt/) aimed at engineering silicon carbide material for detectors of special nuclear material for border and port security, in which also the Reactor Physics Department F8 is involved, the reactor was used to perform test irradiations of silicon carbide samples to study the neutron-induced defects in the material.

In February we have introduced an invention entitled "Method for determining the resistance of objects against radiation of neutrons and gamma radiation" at the Jožef Stefan Institute. The authors of the invention are: doc. dr. Luka Snoj (head of F8 and reactor leader), Darko Kavšek inž. el., Marko Rosman, Anže Jazbec, B.Sc. and Sebastjan Rupnik, B. Eng..

Figure 2: Technical tour of operators to Cadarache, France

Among others, technology is used by Slovenian companies for the development of radiation-resistant LED lights, DITO d.o.o. and Nanocut d.o.o..

From 16 October 2017 to 3 November 2017 we hosted a researcher from the National Institute of Nuclear Research Centre (NNRC), Azerbaijan, for the fifth time. In collaboration with the Department of Low and Medium Energy Physics F2 and the Department of Condensed Matter Physics F5 samples of silicon carbide powder (SiC) were irradiated at the TRIGA Reactor.

In cooperation with the Institute of Metals and Technology, Ljubljana (IMT), we have started with the irradiation of material, which is intended for the medical production of artificial hips.

In November we hosted an international inspection "Mission EPREV", which examines preparedness for extraordinary events. The situation on the TRIGA reactor is appropriate and we have not received any comments.

Cable samples were irradiated for the Krško Nuclear Power Plant (NPP). Samples were irradiated: firstly, only with gamma radiation, and secondly, together with neutrons. The analysis of the irradiated cables was carried out by the Krško NPP staff at the Reactor Infrastructure Centre (RIC) premises. Based on the promising preliminary results of the radiation we have applied for a research project at Slovenian Research Agency / Javna agencija za raziskovalno dejavnost Republike Slovenije (ARRS).

In the field of training, different lectures and practical exercises were conducted at the reactor. The participants were students from the Slovenian Universitiy – Faculty of Mathematics and Physics (Programme: Master of Science in Nuclear Engineering Course: Experimental reactor physics). To carry out the exercises, the reactor was used for about three months, the average number of participants per experiment was 13. All the exercises were performed by our personnel in collaboration with the Reactor Physics Department F8.

The reactor was also used for practical exercises within the training program of the NPP Krško reactor operators (practical training in the area of secure and efficient operation of nuclear reactors), lasting from 14 November 2016 to 11 April 2017, and attended by four participants.

In 2017 there were more than 50 group visits to the reactor. The visitors were mainly foreign scientists, students and 41 groups of schoolchildren. Their total number was more than 1500. In March the *Jožef Stefan Institute's Open Days* were organized, during which the reactor was visited by around 200 people.

R & D GRANTS AND CONTRACTS

1. Irradiation for FT-TIMS Method at the JSI TRIGA Mark II Reactor
   Asst. Prof. Luka Snoj
2. Irradiations in TRIGA Nuclear Reactor
   Prof. Borut Smodiš
3. Experimental Testing of Self-Powered Neutron Detector Assembly for CEA DISCOMS Project
   Prof. Borut Smodiš
   Cea List Institute, Dept. Of Metrology,
4. Irradiation and Analysis of Nano SiC Samples in the Year 2017
   Anže Jazbec, B. Sc.
   National Nuclear Research Center
5. Small Services
   Prof. Borut Smodiš

NEW CONTRACTS

1. Processing and preparation of radioactive waste for the purpose of storage
   Prof. Borut Smodiš
   Arao
2. Technology for the development of radiation resistant lights
   Prof. Borut Smodiš
   Dito, d. o. o.
3. Application of technology and organising mutual relations
   Prof. Borut Smodiš
   Nanocut d. o. o.

VISITORS FROM ABROAD

1. Brent Hartley, U.S. Ambassador to the Republic of Slovenia, with his colleagues, 19 January 2017.
2. Ryan Olivares, ITER Consult, Manila, Philippines, 6 February 2017 – 31 March 2017.
3. Gerard Ratoka Lekhema, ITER Consult, Mapoteng, Kingdom of Lesotho, 6 February 2017 – 31 March 2017.
4. Vangeline Kinilitan Parami and Teresita De Jesus, Philippine Nuclear Research Institute (PNRI), Manila, Philippines, 18 and 19 May 2017.
5. Prof. dr. József Györkös, the director of the Slovenian Research Agency (ARRS) and prof. dr. Marko Topič, president of the Scientific Council of the Slovenian Research Agency (ARRS), 16. June 2017.
6. Dr. Elchin Huseynov and Ms. Aydan Garibli, PhD student, National Nuclear Research Centre (NNRC), Baku, Azerbaijan, 16 October 2017 – 3 November 2017.
7. Carl M. Nohay, Philippine Nuclear Research Institute (PNRI), Manila, Philippines, 13 – 17 November 2017.

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3. Dr. Tinkara Bučar

Technical and administrative staff
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5. Darko Kavšek, B. Sc.
6. Marko Rosman
7. Sebastjan Rupnik, B. Sc.
8. Nina Udir, B. Sc.

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ORIGINAL ARTICLE

1. Elchin Huseynov, Anže Jazbec, "Trace elements investigation of high purity nanocrystalline silicon carbide (3C-SiC) using k_0-INAA method", *Phys., B Condens. matter*, **517**, 30-34, 2017.
2. Andreja Peršič, Tomaž Žagar, Matjaž Ravnik, Slavko Slavič, Bojan Žefran, Dušan Ćalić, Andrej Trkov, Gašper Žerovnik, Anže Jazbec, Luka Snoj, "TRIGLAV: A program package for TRIGA reactor calculations", *Nucl. Eng. Des.*, **318**, 24-34, 2017.
3. Petra Planinšek, Borut Smodiš, Ljudmila Benedik, "Vpliv radiološko onesnaženega okolja na rastline", *Ujma (Ljublj.)*, no. 31, 114-123, 2017.

PUBLISHED CONFERENCE CONTRIBUTION

1. Klemen Ambrožič, Bor Kos, Anže Jazbec, Vladimir Radulović, Luka Snoj, "Characterization of neutron fields in the TRIGA irradiation facilities inside and outside the biological shield", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 511.
2. Romain Henry, Anže Jazbec, "Experimental determination and calculation of the temperature reactivity coefficients for TRIGA MARK II reactor", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 506.
3. Ivan Aleksander Kodeli, Vladimir Radulović, Gregor Veniger, Darko Kavšek, T. Kuc, M. Ciechanowski, W. Pohorecki, "Irradiations of Mn, Au, Li_2O foils and TLDs in the JSI TRIGA reactor for potential use as Tritium production monitors in fusion", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 704.
4. Vladimir Radulović, Matjaž Stepišnik, Tanja Goričanec, Darko Kavšek, Vladimir Cindro, Marko Mikuž, Luka Snoj, "Large object irradiation facility in the tangential channel of the JSI TRIGA reactor", In: *Proceedings*, European Research Reactor Conference, RRFM, 14 - 18 May 2017, Rotterdam, Rotterdam, Dutch Research Reactor Community, 2017.
5. Luka Snoj, Dan Toškan, J. Malec, Jure Beričič, Anže Jazbec, Sebastjan Rupnik, Lucijan Plevnik, Bor Kos, Gašper Žerovnik, "Advances in teaching and training reactor physics", In: *ANS 2017 Winter Meeting, Oct. 29-Nov. 2, 2017, Washington DC*, (Transactions of American Nuclear Society, Vol. 117), ANS 2017 Winter Meeting, Oct. 29-Nov. 2, 2017, Washington DC, New York, Academic Press, 2017, 177-182.

PROFESSIONAL MONOGRAPH

1. Tinkara Bučar *et al.* (13 authors), *Operational intervention levels for reactor emergencies and methodology for their derivation*, (Emergency preparedness and response, EPR-NPP-OILs), Vienna, IAEA = International Atomic Energy Agency, mar. 2017.

NETWORKING INFRASTRUCTURE CENTRE   NIC

The Networking Infrastructure Centre (NIC) is responsible for the administration, development, management and expansion of the core network, ICT services and infrastructure for the Jožef Stefan Institute. It also supports the development of the computational, communication, data and security infrastructure for our research departments, centres and services.

The NIC's main mission is to maintain the computing networks, services and hardware necessary to support the operation of the research departments, programmes, groups and projects at the Jožef Stefan Institute. We provide a high level of connectivity to and integration with local and international communication networks and infrastructures, but we also deliver ICT support for research activities at the Jožef Stefan Institute, including the development, management and administration of the ICT infrastructure, computing facilities and services at the Institute. We work in four main domains: networking infrastructure, network security, network services and distributed network computing/supercomputing.

Networking Infrastructure. The Networking Infrastructure Centre is responsible for the development, management, administration and support of the physical networking infrastructure of the Institute. It delivers support for local networks so as to ensure local and internet connectivity for users and services at the Institute. This task includes the management of wireless networks at the Institute locations and also a number of dedicated networks for specific services, projects and activities (i.e., dedicated links to other institutions, secure links to the Reactor Infrastructure Centre Podgorica, etc.).

Physical Network: In 2017 we continued our on-going extension and optimisation of the physical network, cabling installations, active equipment and wireless access point installations and equipment upgrades (specifically core backbone network routers). We expanded the network and its support for virtual network links that are increasingly used for dispersed internal networks, (super)computing clusters, virtual machine farms, remote access and device support access by outside contractors. We continued our work on expanded IPv6 protocol stack feature support and optimizations to the Institute's backbone network. Massively upgraded external connections have been maintained and optimised to support high network throughput work and the experiments needed for collaboration within WLCG (Worldwide Large Hadron Collider Computing Grid) for ATLAS, but also Belle2 and other EGI or ???

Monitoring: Besides the continued maintenance and integration of the existing traffic, event and status-monitoring infrastructure, implemented on the basis of software packages Nagios, Ganglia, Cacati, Observium and a customised dynamic analytical visualisation package build with Kibana and ElasticSearch as a backend, we have extended our internally developed solutions for environmental monitoring with Grafana-based monitoring that allows us a straightforward way to display and us to react to usage fluctuations and unexpected events in the domain of web services, security policies, firewalls, authentication and authorization, network time systems e-mail delivery, analysis, processing and security systems, physical machine sensory status, environmental data, power line data, etc.

Wireless network: We have introduced cheaper components to be able to continue to improve the wireless coverage and density of our wireless networks to alleviate the effect of increasing numbers of users and devices and their more frequent and more critical usage patterns.

IPv6 support: Support for the IPv6 protocol stack across all the network segments is crucial in our long-term strategy for alleviating the load on the already mostly spent IPv4 address pool. Continuous upgrading and improvements to the network router protocol stack provides flexible support for new protocols, where IPv6 support and expanded use is our core strategy.

Network Security. The NIC is responsible for implementing security measures and policies in three domains: external network connectivity security, security of the network itself and security of the services and software deployments. External network security is implemented with dynamic management and configuration of active deep packet inspection firewall systems and routing configurations, with the exception of dedicated links where passive measures (configuration, filtering and supervision) are used. Constant dynamic supervision, traffic monitoring and event analysis is needed to ensure suitable security in the complex constraints and requirements of an open academic network that collide with current security considerations due to the increased detection of threats from

Head (until 1. 8. 2017):
Vladimir Alkalaj, M. Sc. *

> **Modern, up-to-date, multiple 10 Gbit/s network backbone, IPv6 protocol and dedicated external links are the basis of a flexible modern network at the Jožef Stefan Institute that needs to support high availability and advanced services with many fixed and wireless clients.**

Photo by Sašo Radelj

the outside network. Therefore, ensuring the secure and open environment requires disproportionate increases in equipment capabilities and efforts in the dynamic security policy configuration, event monitoring and analytics. Due to the general worsening of security conditions in the global network, we have introduced more restrictive security measures at the network perimeter. We have completed a survey and security audit of all existing e-mail and eduGAIN/AAI or Eduroam accounts.

Internal development of e-mail security and dynamic network firewalling, encrypted connections, virtual networks, and advanced analysis and monitoring ensure the security of an open academic network in the age of a hostile Internet.

Since the NIC is responsible for the security of the ICT infrastructure of the Institute, we are active members of relevant institutions and groups, notably the national security response centre SICERT, FIRST (Forum of Incident Response and Security Teams) and EGI CSIRT (European Grid Initiative distributed computing security incident response team). We also take part in the response team of the national distributed computing network SLING (Slovenian Initiative for National grid). The national science certificate agency SiGNET CA (Slovenian Grid Network Certification Authority), managed by the NIC, is a full member of EU Grid PMA (EU Grid Policy Management Authority) and IGTF (Interoperable Global Trust Federation). We participate in the work of Slovenian network technology and security association SINOG (Slovenian Network Operators Group) and supported the organization by hosting two of the technical workshops at the Institute this year.

E-Mail: In the area of e-mail security and protection against undesired or malignant messages we have continued with our in-house software development, notably of the SpamAssassin package, and with continuous improvements in the support for international character sets in domain-name handling and e-mail message protocol stacks.

Cryptography and certification: We have continued with the gradual integration of DNSSEC-signed internet domain names using automated mechanisms for the verification of the signatures and with gradual introduction of the DANE system (integration of TLS certificates with the DNS system) in e-mail transfers and publishing SSHFP records via DNS servers. The number of issued digital certificates based on the SiGNET CA scientific certificate PKI system has increased, but also many free DigiCert server certificates, courtesy of Arnes support, have been issued for services that are offered to the general public, since DigiCert certificates are recognised by the major operating systems and browsers. We have also continued widening the use of TLS encryption by widely introducing "Let's Encrypt" certificates to many services. The number of users of our VPN infrastructure has been steadily increasing, in particular also for connections to the user network at the Reactor Infrastructure Centre, Podgorica. The system is not used only by researchers at foreign conferences and exchanges who have to deal with foreign networks that block certain types of connections, but is also more frequently used by users who are working from their homes and users that need it for access to on-line resources, such as scientific publication repositories. To alleviate the need for a VPN for this common use case, we have worked with the Science Information Centre in an on-going effort to ensure accessibility of scientific publications using the eduGAIN single-sign-on federation credentials.

ICT services. The NIC provisions, develops and maintains a number of core and some secondary ICT services. The most important among these are e-mail (e-mail routing and delivery, in-box management, directory management, web mail services etc.) and world-wide-web support (main Institute web server, web hosting for users, departments and projects, a web directory). Secondary ICT services are provided in support of certain core or specific activities at the Institute, such as web presentations, a conference system, supervision and monitoring etc. In some of these services the NIC is directly invested in the software or infrastructure development, such as the network time services and e-mail filtering and security, while others are simply administered and maintained. The third NIC service category is comprised of services supporting our users (calendaring, event management, directories) and software/system developers (code repositories, integration and verification, licence management, mobile platform software development, integration and shipping for Apple Appstore, Google Play and Microsoft Store). The software-development repository has stood out by attracting a large number of new users in the last year. In addition, we provide physical server hosting and management, aimed primarily at larger projects and systems, the administration of directories for personal computing and user management (such as departmental single sign-on or directory services) and the administration of mission-critical workstations and components.

In 2017, we have continued expanding the computationally-intensive infrastructure in the new computing centre at Teslova that we established in 2015 and 2016, while at the NIC computing centre, on the other hand, we have continued to accept new less computationally intensive servers from several departments, where we can provide cooling, network facilities and a high-performance uninterrupted power supply for critical services. We have also expanded our web-hosting activity (over 75 distinct virtual servers) and started deploying a test bed for virtualised hosting.

We have continued the updating of our user-facing documentation and our user interfaces. A Single-Sign-On (SSO) service, integrated with the national AAI federation at Arnes and the European eduGAIN federation is gaining popularity since it gives our users easier access to numerous national and international services using their

institute credentials. At the same time, the new feature is meant to simplify user and authentication management to software developers who work on internal projects and services.

Network computing. In the field of network computing technology and infrastructure, including high-throughput computing, high-performance computing, network supercomputing, grids and HPC clouds (ICT as a service), the NIC is collaborating with individual computing clusters at the Institute and contributing directly to the Slovenian National Supercomputing Network SLING as a founding member and core partner and has taken part in the process of restructuring the network to form a national consortium with Arnes as the official representative. The NIC maintains the Slovenian certification agency SLING CA for science, research and grid computing, takes part in the maintenance and support of the core national supercomputing grid network services and coordinates work with international infrastructure projects and collaborations.

In 2017, the New System Cluster (NSC), the common computing cluster in the new facilities of the Jožef Stefan Institute's Computing Centre Teslova, has continued to see an increase in system usage and the number of users. The cluster with 1984 64-bit computing cores, 16 GPGPU accelerators (NVidia Kepler 40), almost 9 TB RAM and 90 TB disk storage is far from the biggest cluster at the Institute, but it is an important step in the evolving traditions of supercomputing at the Jožef Stefan Institute, since it is available to all researchers at the Institute and is thus provides an important modern computing platform to all of our departments. As a common infrastructure, it is instrumental in forwarding collaborations among departments with their own computing facilities and among researchers and groups with similar software requirements or computational problems that can be solved in an environment that can support supercomputing and high-throughput computing. In the context of this work, we have continued with the support for users of JSI clusters and with work on the integration of the clusters with the national supercomputing network SLING using the NorduGrid ARC Grid Middleware to enable users to use all the resources in the network with the same interfaces and in the same way and we have been involved with the software development and maintenance also at the national level.

> **The constant growth of network services and network computing provides better support for collaboration and teamwork, software development, data protection and access to large computing and data resources for scientific research. A new common facility is an important step further for collaboration in the field of high-performance and network supercomputing at the JSI, promoting collaboration at the national level.**

In the domain of network computing we have been most involved with Slovenian National Supercomputing Network (SLING), but we also worked with in the European Grid Initiative EGI (with the development of the EGI Federated Cloud pilot – federated infrastructure as a service), the NorduGrid ARC collaboration and a number of international projects (ATLAS – dedicated link, Belle2 – computing grid network support planning, CLARIN – support for different services of Slovenian national node, ELIXIR – collaboration with the national node and the European collaboration). SLING has supported a number of research projects and applications in 2016, among others in high-energy physics, medical sensor and image analysis, theoretical physics, astrophysics, biochemistry, protein-folding simulations, crystal analysis, knowledge technologies, statistical analysis and fluid dynamics, computational linguistics, etc. In a number of cases we have been involved as part of the SLING support group in the parallelization and preparation of computing tasks and administration of the required run-time environments.

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4. Mark Martinec, B. Sc.

Technical and administrative staff
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6. Janez Jezeršek
7. Matjaž Levstek
8. Janez Srakar
9. Matej Wedam

SCIENCE INFORMATION CENTRE

SIC

The Jožef Stefan Institute Science Information Centre is the central Slovenian physics research library and the largest research library in Slovenia. Our main tasks are the acquisition, archiving, and loan of books and periodicals, and the input, update and control of bibliographic data of the Institute's staff, as requested by the funding ministry.

Our collection of over 100,000 publications covers the fields of physics, chemistry, biochemistry, electronics, information science, artificial intelligence, nuclear technology, energy management and environmental science. We provide access to over 4000 electronic journals. We are a founding member of the ScienceDirect, SpringerLink, Wiley online library, IEEExplore and ACS consortia. We subscribe to the SCOPUS, INSPEC and Web of Science databases, and to the SciVal research evaluation and management tool.

We manage bibliographic data for approximately 700 researchers. Our bibliographic database, which is a part of the COBISS system, contains about 80,000 records, going back to the Institute's inception in 1949. Last year's data is included as part of this report.

Head:
Dr. Luka Šušteršič

R&D GRANTS AND CONTRACTS

1. OPENACCESS.SI+; Upgrading the Slovenian National Open Access Web Site
   Dr. Luka Šušteršič
   Stichting Eifl.net

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11. Saša Žnidar, B. Sc.

ENERGY EFFICIENCY CENTRE

EEC

The basic activities of the Energy Efficiency Centre relate to efficient energy use, long-term planning in energy and the reduction of greenhouse-gas emissions. The centre is a focal point for the collection and transfer of energy-efficiency technologies to energy users, the state, energy service and equipment providers, and other interested agencies. At the same time it covers the environmental effects of energy use and conversion. The most significant part of the EEC's activities is thus cooperation with state institutions in the preparation of strategic documents and legislation in the field of efficient energy use, energy planning, distributed electricity production and emissions trading. Nevertheless, it remains strongly connected, by its consulting and training role in energy, with industrial companies and other institutions as well as also being more and more involved in European research projects.

Head:
Stane Merše, M. Sc.

Energy and the environment

In 2017 the EEC with its professional work ensured high-quality support to ministries in the preparation of the strategic development documents and transfer of EU legislation. Energy efficiency is a priority field to achieve global climate and energy goals and in accordance with the directive on energy efficiency (2012/27/EU) the EEC prepared an update of the Action plan for energy efficiency for the period 2014–2020, a report on its implementation and an update of the national long-term strategy for the promotion of investments in the energy renovation of buildings. The EEC also cooperated in the updating of the Action plan for renewable energy sources for the period 2010–2020 and inclusion in the procedure of the integrated assessment of impacts on the environment.

Within the expert support of the Ministry of Environment and Spatial Planning the EEC activities focused on the preparation of the Second annual report on carrying out the Operative programme of measures for GHG emission reduction until 2020, updating of GHG emissions projections by the year 2035 and the preparation of analytical bases for international reporting in the framework of the MMR mechanism. The EEC continued its professional support for the design of goals and national policy concerning pollutants from the NEC directive.

On June 2017 the EEC started the implementation of the LIFE ClimatPath2050 project with the goal being to contribute to better climate governance through enhanced monitoring and planning of the GHG mitigation measures in buildings, transport, industry, agriculture, forestry and waste. Developments and improvements to the existing system for long-term GH projections and the monitoring of measures implementation are key for annual project pillars to enable better decision support in Slovenia to set its own goals for GHG mitigation until 2050 and contribute to the global goal to limit global warming.

The EEC cooperates with the Statistical Office of the Republic of Slovenia, where it annually prepares a model calculation for fuels and energy use in households for the national energy statistics. In 2017 the EEC prepared a detailed analysis of kilometres of all registered road vehicles in Slovenia and a proposal for improving national renewable energy statistics.

Also in 2017, the EEC continued with activities of the state referential centre for energy with the preparation of an expanded set of indicators for energy and the environment.

For the Energy Agency the EEC prepared a Report on the fulfilment of national goals in the area of renewable energy and cogeneration in the period 2015-2016 and set new reference electricity generation costs for RES and cogeneration electricity production units for the support scheme.

For the natural-gas transmission system operator the EEC prepared the study Long term strategic of natural gas in Slovenia (Figure 2),

Research and development work of the Energy Efficiency Centre is an important contribution to the preparation of key documents in Slovenia in the field of energy development, energy efficiency, renewables exploitation and the transition of Slovenia to a low-carbon society, with training activities and support to industry it significantly contributes to an increase in competitiveness and development restructuring.
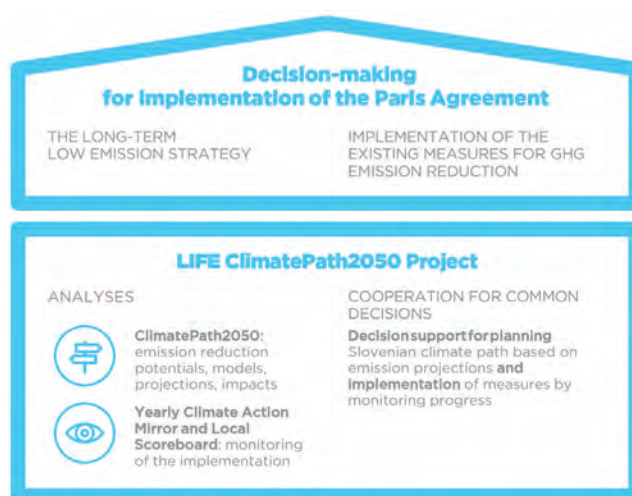

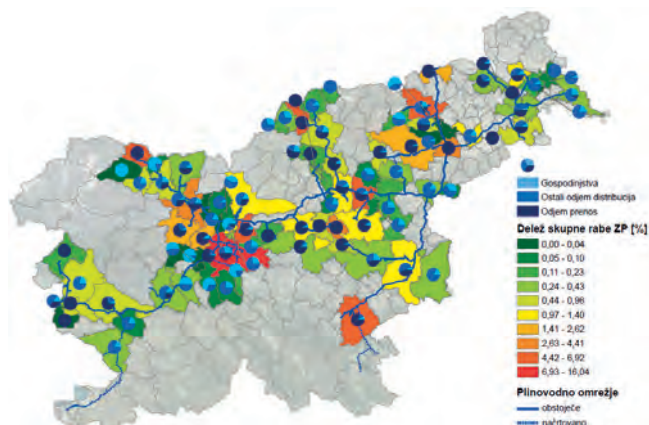*Figure 1: Objectives and key actions of LIFE ClimatPath2050 project.*

Figure 2: Shares and structure of the total natural gas consumption in Slovenia by municipalities

Figure 3: Anton Končar from Koto d.o.o. received the EUREM award in the small companies category on the 8th International conference of energy managers in Ljubljana.
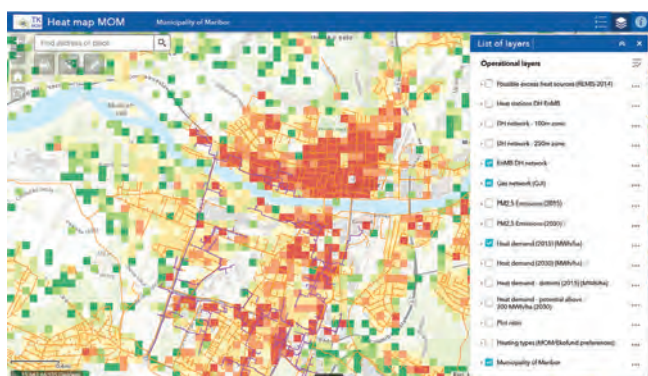

Figure 4: Web application Heat map of City of Maribor

Promotion of efficient energy use and energy consulting

In 2017 the EEC continued with its training activities where already the tenth cycle of energy managers training was successfully concluded within the European programme EUREM and successfully organised the Eighth international conference EUREM in Ljubljana. Due to the very positive reaction of participants and their interest (in Slovenia there are already more than 200 energy managers with the EUREM licence), it is clear that there is a great need for such training. High-quality knowledge in this field is of key importance for the execution of efficient solutions in practice.

An intensive development of the GIS tool for the spatial analysis of heat consumption in buildings ("heatmap") has continued and with the elaboration of spatial analysis of heat use and production for the preparation of the local energy concept it has been tested as a pilot project in the City of Maribor (Figure 4).

In 2017 the EEC carried out deep energy audits in the companies KOTO, Ljubljanske mlekarne, BTC and Sberbank. The professional cooperation with Luka Koper continued with energy audits of port terminals, a study of electric vehicle logistics and a study of the technical potential for powering ships during berth in the port. For the company Petrol Energetika Ravne an elaboration of a study for the introduction of advanced energy services for industry and the local community, which are based on smart energy networks, was prepared.

The EEC prepared the programme for the ninth conference "Energy Managers Days", the annual meeting of energy managers with more than 200 participants confirms the quality and public profile of the EEC's professional work.

International cooperation

In 2016 the EEC carried out as many as 9 international projects, financed from the European Union resources in the framework of LIFE and HORIZON 2020. Projects cover activities in the fields of:
- Slovenian mid-century climate path (LIFE ClimatePath2050)
- Heat pipe technology for waste heat recovery in industry (ETEKINA),
- Driving investment in energy-efficiency services through quality assurance (QualitEE),
- Promotion of the introduction of energy contracting in the public and private sectors in the EU (guarantEE),
- Energy contracting Plus Plus (EPC Plus),
- Tool for the evaluation of the suitability of integrated energy retrofit - (Enerfund),
- Monitoring of indicators for energy use and energy efficiency in the EU – (ODYSSEE MURE),
- carrying out the EU directive on energy efficiency (CA – EED),
- carrying out the EU directive on renewable energy sources (CA – RES).

Projects include cooperations with research and development organisations from Europe with a strong emphasis on concrete applications and the promotion of energy efficiency. In the framework of each project the EEC staff took part in numerous foreign professional meetings and visits.

Some outstanding achievements in the past year

1. **Preparation of several key support documents for the government of the Republic of Slovenia** in the field of energy policy (Green paper and strategic studies for the National Energy Programme), energy efficiency (First and Second National Action Plan for Energy Efficiency), renewable energy sources (Action Plan for Renewable energy sources for the period 2010–2020) and climate policy (Operative programme of GHG emissions reduction up to 2020).
2. **Establishment of energy managers training** in the framework of the European project EUREM and **professional support to industry and other institutions** by carrying out energy audits, feasibility studies and other consulting (Goodyear, TE-TOL, Luka Koper, Salonit Anhovo, Telekom Slovenije, Letrika–Mahle, BTC, KOTO, etc.).

3. In the framework of the European project **Transparense** the EEC led, very successfully, the preparation of the **European code of Conduct for energy contracting**. The Code identifies the basic values and principles, which are of key importance for the successful preparation and carrying out of projects with third-party financing. The Code was very successfully accepted at the European level and currently already has 171 signatories, among them also the European association of companies for energy services (eu.ESCO) and the European federation for intelligent services of energy efficiency (EFIEES), supported also by the European Commission. In Slovenia the code was already tested in practice in a project for integrated energy renovation of the municipal building of the municipality Brda.

Awards and appointments

1. Marko Kovač: Competition FLL-First Lego League Slovenia - 2nd award for the project of Growing Engineers (coach of the team Marko Kovač); overall 4th place in the competition.

Organization of conferences, congresses and meetings

1. European Energy Managers, Brinje, 18 January - 20 June 2017,
2. Energy Managers Days 2017 – 19th Meeting of Slovenian Energy Managers, Portorož, 11-12 April 2017,
3. First project meeting of LIFE project ClimatePath 2050, Brinje, 19 June 2017,
4. Second project meeting of LIFE project ClimatePath 2050, Brinje, 21 September 2017,
5. Workshop on LIFE project ClimatePath 2050, Brinje, 27 September 2017,
6. 8th International Conference for European Energy Managers – EUREM 2017, Ljubljana, 29-30 November 2017,
7. EUREM Consortium Meeting, Brinje, 30 November 2017.

Figure 5: Installation of measuring equipment on the chimney of steel company Metal Ravne for assessment of waste heat recovery potential within ETEKINA project.

INTERNATIONAL PROJECTS

1. „LIFE ClimatePath 2050" Slovenian Path towards the Mid-Century Climate Target
   Andreja Urbančič, M. Sc.
   Borzen, d. o. o.
2. H2020 - EPC_PLUS; Energy Performance Contracting Plus
   Damir Staničić, M. Sc.
   European Commission
3. H2020 - ENERFUND; An ENErgy Retroit FUNding rating tool
   Jure Čižman, M. Sc.
   European Commission
4. H2020 - ODYSSEE-MURE; ODYSSEE-MURE, A Decision Support Tool for Energy Efficiency Policy Evaluation
   Dr. Fouad Al-Mansour
   European Commission
5. H2020 - guarantEE; Energy Efficiency with Performance Guarantees in Private and Public Sector
   Damir Staničić, M. Sc.
   European Commission
6. H2020 - QualitEE; Quality Certification Frameworks for Energy Efficiency Services to scale up Responsible Investment in the Building Sector
   Damir Staničić, M. Sc.
   European Commission

RESEARCH PROGRAM

1. Modelling and environmental impact assessment of processes and energy technologies
   Dr. Fouad Al-mansour

R&D GRANTS AND CONTRACTS

1. Organisation of 8th International Conference for European Energy Managers, Ljubljana, Slovenia, 29. - 30. November 2017
   Dr. Boris Sučić

NEW CONTRACTS

1. Energy audit PC TST and PC TA in the port Luka Koper d.d.
   Dr. Boris Sučić
   Luka Koper d. d.

2. Detailed energy audit of company KOTO d.o.o.
   Marko Pečkaj, B. Sc.
   Koto d. o. o.
3. Professional audit and supplement of the concept of the report for Act. 4 (EU project CarEsmatic)
   Dr. Boris Sučić
   Luka Koper d. d.
4. Report on the achievement of the national RES and CHP targets for the period 2015-2016
   Marko Đorić, B. Sc.
   Energy Agency, Ljubljana
5. Energy audit of bank Sberbarnk Slovenia
   Dr. Boris Sučić
   Sberbank Banka d. d.
6. Setting of reference electricity generation cost from RES and CHP units for the year 2018
   Stane Merše, M. Sc.
   Energy Agency, Ljubljana
7. Detailed Energy audit of two locations of a company Telekom Slovenije
   Dr. Boris Sučić
   Telekom Slovenije, d. d.
8. Inclusion in the procedure of integrated assessment of impacts on the environment for an updated Action plan for RES for the period 2010 – 2020
   Andreja Urbančič, M. Sc.
   Ministry of Infrastructure
9. Preparation of strategic studies for elaboration of strategic documents, action plans and measures from the field of energy
   Stane Merše, M. Sc.
   Ministry of Infrastructure
10. Spatial analysis of heating needs and supply in the framework of local energy concept – City of Maribor case study
    Damir Staničić, M. Sc.
    Energetika Maribor d. o. o.
11. Strategic studies for elaboration of a report on measures for the reduction of greenhouse gases emissions and projections of GHG emissions, Second annual report on carrying out of the Operative programme of emissions reduction measures
    Andreja Urbančič, M. Sc.
    Ministry of the Environment and Spatial Planning
12. Elaboration of a concept of introduction of advanced energy services and solutions for industry and local communities based on smart energy grids
    Aleš Podgornik, M. Sc.
    Petrol Energetika
13. 19th meeting of energy managers of Slovenia - Energy managers days 2017
    Stane Merše, M. Sc.
    Časnik Finance, d. o. o.

14. Refreshment, of indicators from the field of Environment and Energy for the needs of the report on Environment for 2017
Matjaž Česen, B. Sc.
Ministry of the Environment and Spatial Planning
15. Model calculation of driving kilometers
Matjaž Česen, B. Sc.
Statistical Office of the Republic of Slovenia
16. Study on needed additional measures to increase share of vehicles on alternative fuels in Slovenia and preparation of a draft of a Strategy for the deployment of alternative fuels in transport in Slovenia
Matjaž Česen, B. Sc.
National Institute of Chemistry, Ljubljana
17. Strategic long term role of natural gas in Slovenia
Stane Merše, M. Sc.
Plinovodi d. o. o.
18. Energy audit of BTC d.d. in Ljubljana
Dr. Boris Sučić
BTC d. d.
19. Energy audit of company Ljubljanske mlekarne
Dr. Boris Sučić
Ljubljanske mlekarne, d. d.

20. Analyisis of impact of adding bioethanol to gasoline because of increase in vapour pressure on air quality in Slovenia
Matjaž Česen, B. Sc.
Petrol d. d., Ljubljana
21. Strategic studies for the preparation of a proposal of Integral project for drawing funds from LIFE programme for carrying out the Operation programme of measures for the greenhouse gases emissions reduction by 2020
Jure Čižman, M. Sc.
Ministry of the Environment and Spatial Planning
22. Energy Consumption of Slovenian Households Based on Model Calculation for 2016
Matjaž Česen, B. Sc.
Statistical Office of the Republic of Slovenia
23. Study on possibilities for the use of shore-side electricity for ships
Dr. Boris Sučić
Luka Koper d. d.
24. Concerted actions in the field of the directive on renewable energy (CA RES)
Stane Merše, M. Sc.
Ministry of Infrastructure
25. Concerted Action 2 – Energy Efficiency Directive: National experts participation
Damir Staničić, M. Sc.
Ministry of Infrastructure

VISITORS FROM ABROAD

1. Andreas Horneber, Dr Robert Schmidt and Stefan Schmidt, IHK – Industrie- und Handelskammer Nürnberg für Mittelfranken Nuremberg Chamber of Commerce and Industry, Nürnberg, Germany; Dr Stephan Schwarzer, Wirtschaftskammer Österreich, Wienna, Austria and MSc Hermine Dimitroff-Regatschnig, Dimitroff-Unternehmensberatung, Graz, Austria, 1 December 2017

STAFF

Researchers
1. Dr. Fouad Al-Mansour
2. **Stane Merše, M. Sc., Head**
3. Damir Staničić, M. Sc.
4. Andreja Urbančič, M. Sc.
Postdoctoral associates
5. Dr. Matevž Pušnik
6. **Technical officers**
7. Matjaž Česen, B. Sc.
8. Jure Čižman, M. Sc.
9. Marija Kavčič, B. Sc.
10. Dr. Marko Kovač

11. *Polona Lah, B. Sc., left 13.11.17*
12. Marko Pečkaj, B. Sc.
13. Barbara Petelin Visočnik, M. Sc.
14. *Aleš Podgornik, M. Sc., left 01.04.17*
15. Dr. Boris Sučić
Technical and administrative staff
16. *Peter Bevk, B. Sc., left 01.03.17*
17. Marko Đorić, B. Sc.
18. *Roza Pergarec, B. Sc., retired 01.09.17*
19. Igor Ribič
20. Gašper Stegnar, B. Sc.
21. Katarina Trstenjak, B. Sc.

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Original Article

1. Fouad Al-Mansour, Viktor Jejčič, "A model calculation of the carbon footprint of agricultural products:: The case of Slovenia", *Energy (Oxford)*, **136**, 7-15, 2017.
2. Blaž Luin, Stojan Petelin, Fouad Al-Mansour, "Modeling the impact of road network configuration on vehicle energy consumption", *Energy (Oxford)*, **137**, 260-271, 2017.
3. Jurgita Malinauskaite, H. Jouhara, D. Czajczynska, P. Stanchev, Evangelia Katsou, P. Rostkowski, R. J. Thorne, J. Colón, S. Ponsa, Fouad Al-Mansour, L. Anguilano, R. Krzyzynska, L. C. Lopez, A. Vlasopoulos, N. Spencer, "Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe", *Energy (Oxford)*, **141**, 2013-2044, 2017.
4. Matevž Pušnik, Fouad Al-Mansour, Boris Sučić, Matjaž Česen, "Trends and prospects of energy efficiency development in Slovenian industry", *Energy (Oxford)*, **136**, 52-62, 2017.
5. Boris Sučić, Polona Lah, Barbara Petelin-Visočnik, "An education and training program for energy managers in Slovenia: Current status, lessons learned and future challenges", *J. clean. prod.*, **142**, 3360-3369, 2017.
6. Marjana Šijanec-Zavrl, Gašper Stegnar, "Comparison of simulated and monitored energy performance indicators on NZEB case study Eco Silver House", *Procedia environmental sciences*, **38**, 52-59, 2017.

Published Conference Contribution

1. Fouad Al-Mansour, Viktor Jejčič, Igor Škrjanec, "Possibilities for micro biogas plants in Slovenian agriculture", In: *Renewable energy sources: (conference proceedings)*, Jurij Krope, ed., et al, Maribor, University of Maribor Press, Faculty of Chemistry and Chemical Engineering, 2017, [137]-146.
2. Jure Čižman, Damir Staničić, Matjaž Česen, "Prostorska analiza dolgoročne rabe toplote v lokalni skupnosti in vloga sistema daljinskega ogrevanja pri oskrbi s toploto - primer Mestne občine Maribor", In: *Mednarodna konferenca daljinske energetike 2017, Portorož, 19.-21. marec 2017*, Ljubljana, Slovenian District Energy Association, 2017.
3. Jure Čižman, Damir Staničić, Matjaž Česen, "Use of thermal atlas and heating model for strategic municipal energy planning", In: *Digital proceedings*, 12th Conference on Sustainable Development of Energy, Water and Environment Systems, October 4-8, 2017, Dubrovnik, Croatia, Marko Ban, ed., [Zagreb], SDEWES, 2017.
4. Jure Čižman, Damir Staničić, Matjaž Česen, Miran Rožman, Ljubo Germič, Filip Kokalj, "Koncept prostorske analize rabe in proizvodnje toplote v Mestni občini Maribor", In: *26. mednarodno posvetovanje Komunalna energetika, 9. do 11. maj 2017, Maribor, Slovenija: (konferenčni zbornik)*, Jože Pihler, ed., Maribor, Univerzitetna založba Univerze, 2017, 9-17.
5. Viktor Jejčič, Fouad Al-Mansour, Tomaž Poje, "Carbon footprint of final food products", In: *Environmental management and impact assessment: (conference proceedings)*, 10th International Conference on Sustainable Energy and Environmental Protection, (June 27th-30th, 2017, Bled, Slovenia), Jurij Krope, ed., et al, Maribor, University of Maribor Press, Faculty of Chemistry and Chemical Engineering, 2017, [211]-218.
6. Boris Sučić, Sandi Cimerman, Marko Pečkaj, Fouad Al-Mansour, "Practical approach for energy consumption optimisation in educational and research buildings - case study cluster computers and data room", In: *Energy efficiency: (conference proceedings)*, Jurij Krope, ed., et al Maribor, University of Maribor Press, Faculty of Chemistry and Chemical Engineering, 2017, 165-174.

CENTRE FOR ELECTRON MICROSCOPY AND MICROANALYSIS CEMM

The Centre for Electron Microscopy and Microanalysis (CEMM) is an instrumental centre at the JSI that combines analytical equipment in the field of electron microscopy and microanalysis. Access to the research equipment of CEMM is provided to other JSI departments as well as other research institutions, universities and industrial partners. The equipment at the CEMM is used by researchers interested in the morphology and structural and chemical characterization of materials between the micrometre and the atomic levels. At the CEMM there are three scanning electron microscopes (JSM-5800, JXA-840A, JSM-7600F), two transmission electron microscopes (JEM-2100 (CO NIN), JEM-2010F) and the equipment for sample preparation. CO NAMASTE contributed to the equipment for electron microscopy with a CCD camera and an ADF detector for the JEM-2010F microscope and an EBSD system for the JSM-7600F. Additionally, the JSI is a co-owner of a Jeol ARM 200F (scanning transmission electron microscope).

Head:
Prof. Miran Čeh

The research involving the staff and equipment at the CEMM is diverse regarding the investigated materials and the methods used. Scanning electron microscopy (SEM) is employed to observe the morphology and structure of the surfaces and for the microstructural investigation and determination of the chemical composition of polycrystalline oxide and non-oxide ceramic materials, nanostructures, metallic magnetic materials, metals, alloys glass, etc. All of the scanning electron microscopes in the CEMM are equipped with an energy-dispersion (EDXS) and/or wavelength dispersion (WDXS) spectrometer for X-rays, allowing non-destructive determination of the chemical composition of the investigated materials. The scanning electron microscope JSM-7600F is additionally equipped with an electron back-scattered diffraction (EBSD) detector and an electron lithography system.

Transmission electron microscopy (TEM) provides an insight into the structure of the material on the nano-scale. Transmission electron microscopy enables structural and chemical analyses of the grain boundaries, planar defects, dislocations and precipitates. The transmission electron microscope JEM-2100 is equipped with an EDXS spectrometer and a CCD camera, and the JEM-2010F is additionally equipped with a STEM unit, EDXS and EELS spectrometers, and a CCD camera. The CEMM also manages the necessary equipment for the SEM and TEM sample preparation.

The operation of the Centre is managed by properly trained employees. Besides maintenance of the equipment, among other CEMM activities are the training of new operators, organization of workshops and conferences on the topic of electron microscopy, providing services for industrial partners and the introduction of new analytical techniques. CEMM personnel are also responsible for the demonstration of electron microscopy to the general public in the scope of organized visits to the JSI, as well through publications in traditional and digital media. For users of microscopes the CEMM organized

Figure 1: 5th Workshop, CEMM (Koblar M)

the 5th workshop (vacuum in electron microscopy, sample preparation for SEM, scanning electron microscope). The aim of the workshops was to present the operation of the equipment and preparation techniques for SEM samples.

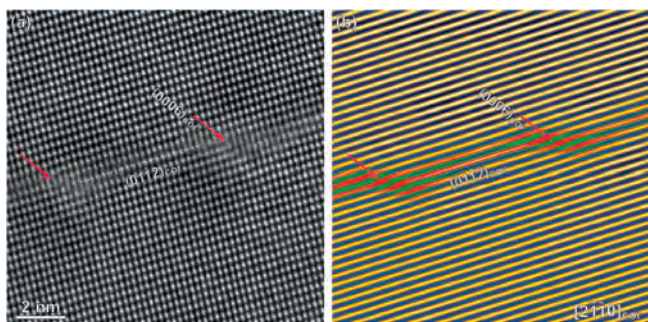Individual research works and analysis using CEMM equipment:

Figure 2: (a) HRTEM image of an interface in hydrothermally grown ruby with characteristic dilatation at the contact area of the two corundum domains and (b) geometric phase analysis of the interface. The dilatation is caused by trapped OH-groups at the contact (Daneu N, Rečnik A, JEM 2010F).
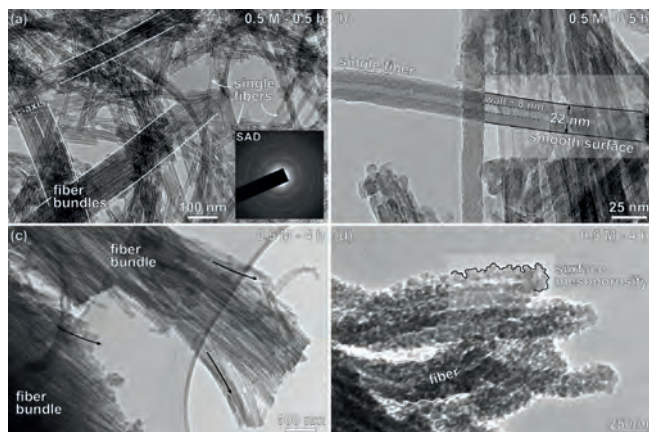
Figure 3: (a,b) Chrysotile fibres before and (c,d) after treatment with 0.5-M HCl showing the development of surface mesoporosity on the surface of the fibres (Daneu N, JEM 2100).
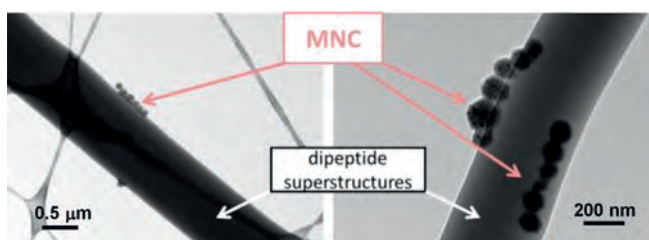

Figure 5: Transmission electron microscopy (TEM) images of silica-coated chains of superparamagnetic nanoparticle clusters (nanochains MNC) attached at the s the nanocomposites composed of self-assembled dipeptide (Phe-Phe) fibres (Kralj S, JSM 2100).
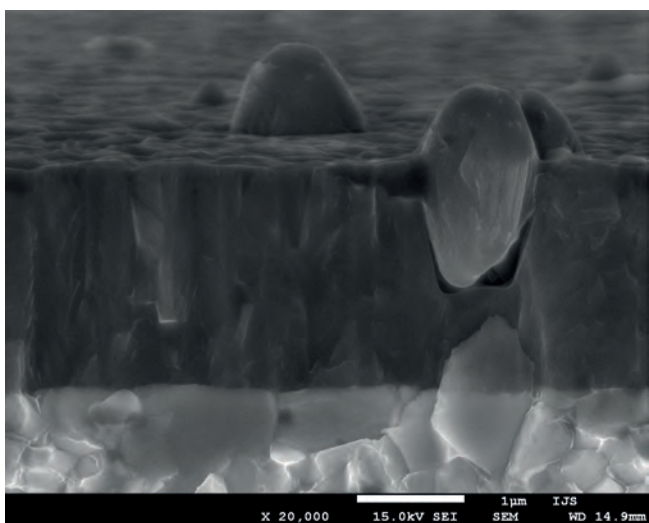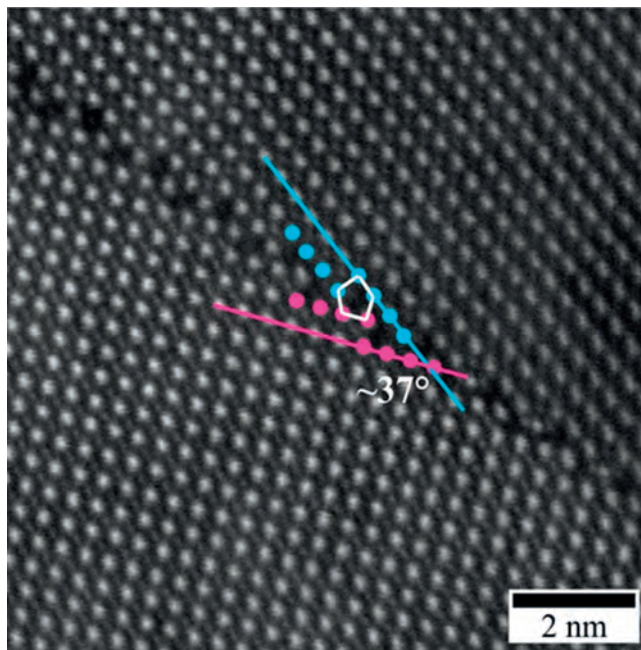

Figure 4: Atomic-scale micrograph of a clean, high-angle grain boundary in potassium sodium niobate doped with strontium. The micrograph was made with a scanning transmission electron microscope (Dražić G., Hreščak J., Jeol ARM 200F).
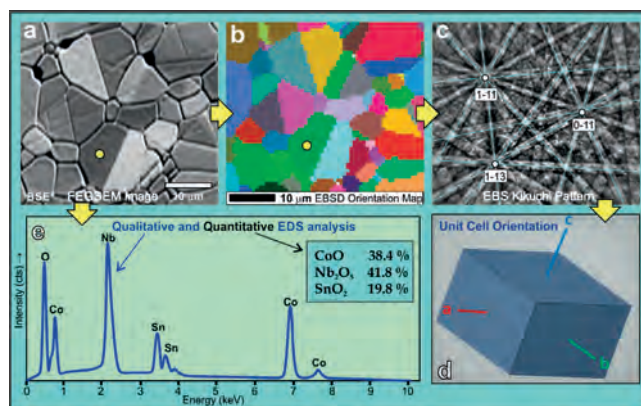

Figure 6: Growth defects embedded in a TiN coating, deposited by cathodic arc evaporation (Čekada M, JSM 7600F).

Figure 7: Correlative microscopy and microanalysis of SnO2-CoO-Nb2O5 ceramics: (a) FEGSEM BSE micrograph in compositional contrast mode showing the microstructure of ceramics, (b) corresponding EBSD orientation map reveals random crystallographic orientations of the grains, (c) individual EBSP Kikuchi pattern from selected grain (o), (d) reconstruction of orientation of tetragonal unit cell in selected grain, (e) EDS qualitative and quantitative analysis of chemical composition of the material (Samardžija Z, JSM 7600F).

INTERNATIONAL PROJECT

1. H2020 EUROfusion - Education-ED-FU
   Andreja Šestan Zavašnik, B. Sc.
   European Commission

R&D GRANTS AND CONTRACTS

1. Plasma-assisted wound treatment and topical introduction of molecules
   Dr. Janez Zavašnik

2. Advanced hydrodesulphurisation with catalyst nanomaterials
   Dr. Janez Zavašnik

NEW CONTRACT

1. Compatibility assessment between chosen primary wrapper and biological drug
   Prof. Miran Čeh
   Lek d. d.

2. Determination of correlation between physicochemical properties of various biological medications formulations (LI and LYO) and delamination of vial's surface
   Prof. Miran Čeh
   Lek d. d.

STAFF

Researcher
1. Prof. Miran Čeh, Head

Postdoctoral associates
2. Dr. Sandra Drev
3. Dr. Jitka Hreščak
4. Dr. Janez Zavašnik

Postgraduates
5. Goran Miličić, B. Sc.
6. Andreja Šestan Zavašnik, B. Sc.

Technical officer
7. Maja Koblar, B. Sc.

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ORIGINAL ARTICLE

1. A. A. Esin, Denis Alikin, A. P. Turygin, Sergei A. Abramov, Jitka Hreščak, Julian Walker, Tadej Rojac, Andreja Benčan, Barbara Malič, Andrei L. Kholkin, Vladimir Shur, "Dielectric relaxation and charged domain walls in $(K, Na)NbO_3$-based ferroelectric ceramics", *J. appl. phys.*, **121**, no 7, 074101, 2017.

2. Jitka Hreščak, Goran Dražić, Marco Deluca, Iztok Arčon, Alojz Kodre, Monica Dapiaggi, Tadej Rojac, Barbara Malič, Andreja Benčan, "Donor doping of $K_{0.5}Na_{0.5}NbO_3$ ceramics with strontium and its implications to grain size, phase composition and crystal structure", *J. Eur. Ceram. Soc.*, **37**, 5, 2073-2082, 2017.

3. Jitka Hreščak, Barbara Malič, Jena Cilenšek, Andreja Benčan, "Solid-state synthesis of undoped and Sr-doped $K_{0.5}Na_{0.5}NbO_3$, Study by thermal analysis and in situ high-temperature X-ray diffraction", *J. therm. anal. calorim.*, **127**, 1, 129-136, 2017.

4. Eda Mehmeti, Dalibor M. Stanković, Sudkate Chaiyo, Janez Zavašnik, Kristina Žagar, Kurt Kalcher, "Wiring of glucose oxidase with graphene nanoribbons: an electrochemical third generation glucose biosensor", *Mikrochim. acta*, **184**, 4, 1127-1134, 2017.

5. Eda Mehmeti, Dalibor M. Stanković, Astrid Ortner, Janez Zavašnik, Kurt Kalcher, "Highly selective electrochemical determination of phlorizin using square wave voltammetry at a boron-doped diamond electrode", *Food anal. methods*, **10**, 11, 3747-3752, 2017.

6. Hugo Mercier, Barbara Malič, Hana Uršič, Jitka Hreščak, Franck Levassort, Danjela Kuščer, "Electrophoretic deposition and properties of strontium-doped sodiumpotassium niobate thick films", *J. Eur. Ceram. Soc.*, **37**, 16, 5305-5313, 2017.

7. Jasminka Popović, Marijana Jurić, Damir Pajić, Martina Vrankić, Janez Zavašnik, Jelena Habjanić, "Effect of the cation distribution and microstructure on the magnetic behavior of the $CoMn_2O_4$ oxide", *Inorg. chem.*, **56**, 7, 3983-3989, 2017.

8. Aleš Šoster, Janez Zavašnik, Mihael Ravnjak, Uroš Herlec, "REE-bearing minerals in Drava river sediments, Slovenia, and their potential origin", *Geologija*, let. 60, no. 2, 257-266, 2017.

9. Victor G. Thomas, Nina Daneu, Aleksander Rečnik, Rudolf I. Mashkovtsev, Goran Dražić, Sandra Drev, Sergey P. Demin, Pavel N. Gavryushkin, Dmitry A. Fursenko, "Micro-sectoriality in hydrothermally grown ruby crystals: the internal structure of the boundaries of the growth sectors", *CrystEngComm*, **19**, 44, 6594-6601, 2017.

10. E. Venkata Ramana, Majeti Narasimha Vara Prasad, David Maria Tobaldi, Janez Zavašnik, M. K. Singh, María Jésus Hortigüela, M. P. Seabra, G. Prasad, M. A. Valente, "Effect of samarium and vanadium co-doping on structure, ferroelectric and photocatalytic properties of bismuth titanat", *RSC advances*, **7**, 16, 9680-9692, 2017.

11. Gregor Žerjav, Muhammad Shahid Arshad, Petar Djinović, Ita Junkar, Janez Kovač, Janez Zavašnik, Albin Pintar, "Improved electron-hole separation and migration in anatase TiO_2 nanorod/reduced graphene oxide composites and their influence on photocatalytic performance", *Nanoscale*, **9**, 13, 4578-4592, 07 Apr. 2017.

12. Gregor Žerjav, Muhammad Shahid Arshad, Petar Djinović, Janez Zavašnik, Albin Pintar, "Electron trapping energy states of $TiO_2 - WO_3$ composites and their influence on photocatalytic degradation of bisphenol", *Appl. catal., B Environ.*, **209**, 273-284, 2017.

PUBLISHED CONFERENCE CONTRIBUTION

1. A. P. Turygin, Denis Alikin, A. S. Abramov, Jitka Hreščak, Julian Walker, Andreja Benčan, Tadej Rojac, Barbara Malič, Andrei L. Kholkin, Vladimir Shur, "Characterization of domain structure and domain wall kinetics in lead-free Sr^{2+} doped $K_{0.5}Na_{0.5}NbO_3$ piezoelectric ceramics by piezoresponse force microscopy", In: *Proceedings of Second International Workshop Modern Nanotechnologies (IWMN-2016)*, August 27-29, 2016, Ekaterinburg, Russia, *Ferroelectrics*, vol.508, 1, 77-86, 2017.

2. Janez Zavašnik, "Electron crystallography in mineralogy and materials science", In: *Razprave, poročila*, (Geološki zbornik, **24**), 23. posvetovanje slovenskih geologov = 23rd Meeting of Slovenian Geologists, Ljubljana, marec 2017, Boštjan Rožič, ed., Ljubljana, Univerza v Ljubljani, Naravoslovnotehniška fakulteta, Oddelek za geologijo, 2017, **24**, 191-197.

MENTORING

1. Sandra Drev, *Twinning and polytypism in the spinel-chrysoberyl system:* doctoral dissertation, Ljubljana, 2017 (mentor Nina Daneu; co-mentor Aleksander Rečnik).

CENTRE FOR KNOWLEDGE TRANSFER IN INFORMATION TECHNOLOGIES CT-3

The Centre for Knowledge Transfer in Information Technologies performs educational, promotional and infrastructural activities and provides for the direct exchange of information and experience between researchers and the users of their research results.

The centre has thirteen researchers and technical staff working in the areas of research results dissemination and eLearning. In particular, the centre is well known by the portals: VideoLectures.NET with multimedia materials of numerous scientific events, on-line training materials, and collection of tutorials on different scientific fields; ScienceAtlas.ijs.si and IST-World.Org for analysis and visualization of large bibliographic and project databases. The centre is covering management, training and dissemination activities of several EU projects. In 2017 we were active in the following projects from the H2020 program: EDSA (European Data Science Academ), AQUASMART (Aquaculture Smart and Open Data Analytics as a Service), OPTIMUM (Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility), MOVING (TraininG towards a society of data-saVvy inforMation prOfessionals to enable open leadership Innovation), EW-SHOPP (Supporting Event and Weather-Based Data Analytics and Marketing along the Shopper Journey), EUBUSINESSGRAPH (Enabling the European Business Graph for Innovative Data Products and Services), PRESTOCLOUD (Proactive Cloud Resources Management at the Edge for Efficient Real-Time Big Data Processing), WATER4CITIES (Holistic Surface Water and Groundwater Management for Sustainable Cities), MEET CINCH (A Modular European Education and Training Concept In Nuclear and RadioCHemistry), X5GONE (Cross Modal, Cross Cultural, Cross Lingual, Cross Domain, and Cross Site Global OER Network), THEYBUYFORYOU (Enabling procurement data value chains for economic development, demand management, competitive markets and vendor intelligence) and ERASMUS+: Micro HE - Support Future Learning Excellence through Micro-Credentialing in Higher Education.

Head:
Mitja Jermol, M. Sc.

The centre prepares and organizes educational events such as conferences, seminars, workshops, and summer schools. They are targeted at experts who would like to apply the latest knowledge and achievements from intelligent data analysis, knowledge technologies, data mining, text mining and decision support to the areas of network organizations,

In 2017 the Centre for Knowledge Transfer in IT was actively involved in 12 European projects.

business decisions, finance, and marketing. A special consideration is put on the managers and decision makers who are aware of the strengths and benefits to the success of their business. All educational events are designed to transfer basic, additional and latest expert knowledge to the companies, research and educational organizations.

In order to make the knowledge transfer efficient we are combining traditional and ICT-supported training methods. For this purpose we are operating a number of training web portals. The most popular one is http://videolectures.net/. It now offers 24,381 recorded tutorials from different scientific events and it was visited by 628,415 different visitors from around the world. The main purpose of the portal is to provide free and open access to high-quality video lectures presented by distinguished scholars and scientists at the most important and prominent events. In today's world VideoLectures.NET presents a free knowledge hub, a way of opening up education to everyone for everyone and as there is a great need to share educational content on all levels in order to benefit society and foster economy. It also gives a learning opportunity to audiences of all social levels.

VideoLectures.Net has strong connections in Open Cast Foundation, Open Course Ware Consortium and Knowledge 4 All Foundation Ltd.

In collaboration with the Artificial Intelligence Laboratory (E3), we have continued work on the EU H2020 project MOVING (TraininG towards a society of data-saVvy inforMation prOfessionals to enable open leadership INnovation). Our main work was the provision of digital video content through VideoLectures.NET, in particular large-scale data sets for the two project use cases (20,000 videos and transcripts). Moreover, we were working on the production and provision of educational video sequences for the MOVING platform to train data-savvy information professionals. The focus is on the production of so-called "micro content" that means small learning units also called media fragments that can be used by the platform users accompanying their working process. Another task was filming important MOVING events and hosting the materials at the VideoLectures.NET portal. Last but not least, we were active in project promotion, dissemination and exploitation activities.

In 2017 we started with a project within the H2020 Marie Skłodowska-Curie RISE project Water4Cities (Holistic Surface Water and Groundwater Management for Sustainable Cities), our work focuses on sensor technologies,

data and visual analytics to enable the localization, visualization and analysis of urban water (both surface water and groundwater) in a holistic urban setting providing services to multiple water stakeholders. Our aim has been to develop the necessary models and associated platform that will enable water providers and relevant stakeholders to monitor in real-time the urban water resources to support their decisions for optimal urban water management. Use cases will be checked in Ljubljana and on the Greek island Skiathos.

In the same year the ProaSense (The Proactive Sensing Enterprise) and AquaSmart (Aquaculture Smart and Open Data Analytics as Service) projects were successfully concluded and started to participate in the project entitled "3Smart - Smart Building, Smart Network, Smart City" as an associate partner under the European Territorial Cooperation Program for the Danube Region. The vision of the project is to enable the economically optimal connectivity of renewable energy sources and measures for energy efficiency and contributing to energy security in the Danube area. The aim of the project is to provide technological and legislative bases and conditions for the cross-energy management of buildings, energy networks and major municipal infrastructures in the Danube Region, and to pilot the system at five locations in the Danube region, i.e., Slovenia, Austria, Bosnia & Herzegovina, Croatia and Hungary. One of the objectives of the project is the development of a modular platform for the coordinated construction and management of the distribution network. The leading partner is the University of Zagreb, and various partners from five countries from the Danube region are involved; from Slovenia this includes the Municipality of Idrija, Elektro Primorska, the Goriška Local Energy Agency and the Jožef Stefan Institute.

During the year we submitted many project proposal in the fields of education, open education, knowledge transfer, artificial intelligence, security, decarbonisation, energy efficiency, analysis of big data and open data, automatic translation, robotics, internet of things, information-communication technologies, smart cities, digitalisation of cultural heritage.

In March 2017 we organized the 12th Student Competition in Computer Science, attended by 225 students from Slovenian secondary schools. We have also organized project meetings for different EU projects (Prestocloud, euBusinessGraph, BigData Finance, EWShopp and X5gone), co-organized ESWC - Extended Semantic Web Conference, held in Portorož in Slovenia.

Within the UNESCO Chair (http://unesco.ijs.si/), we have successfully co-organized the 2nd World Open Educational Resources Congress, titled "OER for Inclusive and Equitable Quality Education: from Commitment to Action". There were more than 400 delegates from 96 Member States attended the event, among which 14 ministers for science and education.

Within the UNESCO Chair (http://unesco.ijs.si/), we attended Annual OER Meeting in Canada and 2d OER Policy Forum, held in Poland.

In September 2017 our UNESCO Chair organized in collaboration with Ministry of Education, Science and Sport and UNESCO Paris the 2nd World Open Educational Resources Congress, titled "OER for Inclusive and Equitable Quality Education: from Commitment to Action". The congress was held in Ljubljana, September 18–20, 2017. More than 400 delegates from 96 Member States attended the event, among which 14 ministers for science and education. Parallel to the congress 21 satellite events on Open Education and Open Technologies were organized, attended by an additional 100 participants. The Ljubljana OER Action Plan 2017 is the outcome document of the 2nd World OER Congress and is based on the outputs of the Regional Consultations, a global online consultation of the document in the months leading up to the Congress, and the deliberations of the 2nd World OER Congress. The Action Plan embodies a collective will to convert OER commitment into concrete actions to help achieve SDG 4 through the key pillars of access, equity and inclusion. It provides recommendations to stakeholders in five strategic areas: building the capacity of users to find, re-use, create and share OER; language and cultural issues; ensuring inclusive and equitable access to quality OER; developing sustainability models; and developing supportive policy environments.

The UNESCO Chair on Open Technologies for OER and Open Learning and University of Nova Gorica launched a new, free international online OPEN EDUCATION FOR A BETTER WORLD mentoring programme. The first round will take place from January to July 2018. In the first year fourteen candidates and forty mentors with concrete ideas for open e-learning courses aligned with sustainable development goals were chosen to be guided online towards the implementation of their course. The goal is the design and implementation of an open e-learning course that will unlock potentials and bring benefits to many at no cost for participants. Next year we expect more applicants from all around the world who will develop their open e-learning courses, which will be free, open and available in various languages.

In June 2017 we completed the third cycle of activities within the MyMachine project, and we completed work on three prototypes. As an example of good practice in the Slovenian educational environment, we were presented at the second World OER Congress.

In October we organized four interesting workshops for children from socially deprived families, together with the organization for the promotion of programming among the young, CodeWeek. At workshops, children from primary and high schools learned how to assemble and program Arduino micro controllers. We connected Arduino with sensors, lights, speakers and switches, and created various interesting and useful devices. We made a

simple electrocardiograph (ECG), a temperature, humidity and hazardous gas measuring device, a traffic counter, detector of light source, an electronic display and an ultrasonic distance meter. We did some experiments with a dust detector and performed some simple chemical experiments in which we practically tested the operation of our sensor device. A similar workshop has also been performed during the summer time within the project School of Experimental Chemistry, which is carried out at the JSI. With our sensor device we conducted a series of chemical experiments with children, in cooperation with the Association of Electronics of Slovenia, children have been making etchings and printed-circuit boards.

On November 8th we organized an information security conference "Day Of Information Security«. The conference has been held at the JSI and organized in cooperation with the national computer emergency response center SI-CERT (Arnes). The first part of the conference was intended to public administration and critical infrastructure managers. In this section, the experts presented a review of current information security threats, followed by practically focused lectures on limitations in forensic analysis of digital photos and videos, security of mobile communications, critical infrastructure security and modern cryptographic procedures in protecting information. In the afternoon, the draft of the Information Security Act was presented, followed by a discussion on the solutions proposed by the law and a public-private partnership in the field of information security.

The development of the anonymisation software for court decisions, Tacita, has been this year a little bit slower due to lower customer responsiveness. At the Ministry of Justice is underway a project of publishing judicial decisions on the Internet. Before the published, parts of the court decisions should be anonymised due to privacy protection. That means that from the text need to be removed all references to the information through which persons involved in the procedure could be identified. At the JSI we therefore started development of the system, which will help the judges to anonymise court decisions with machine-learning techniques. Our approach to the problem was the development of the learned statistical model, which is able to predict if a word should be anonymised or not. Prediction is based on the form and context of the word in the text. In this year, the system has been further developed and successfully deployed in a test environment. In addition, we have slightly expanded the approach towards the problem. Our system now includes the analysis of word vectors, so it can also capture the semantic similarities of words. The analysis on the test data showed more than 72% precision of the model and more than 91% of recall. Test data are of a somewhat lower quality (in technical terms and not in terms of content), so we expect that these statistics will improve after the system will be fully operable.

Organization of conferences, congresses and meetings

1. Organization of workshop BIG Data, Ljubljana, 2. 2. 2017
2. 12th Student competition in computer science, Ljubljana, Ljubljana, 25. 3. 2017
3. Coorganization of the ESWC "European Semantic Web Conference", Portorož, 28. 5. - 1. 6. 2017
4. Project meeting of the EU project Prestocloud, Dubrovnik, Croatia, 28. 6. – 29. 6. 2017
5. Project meeting BIG DATA Finance project, Dubrovnik, Croatia, 4. 9. – 8. 9. 2017
6. Project meeting of the EU project euBusiness Graph, Dubrovnik, Croatia, 11. 9. – 13. 9. 2017
7. Project meeting of the EU project EWShopp, Dubrovnik, Croatia, 13. 9. – 15. 9. 2017
8. Coorganization of the 2nd World Open Educational Resources Congress, titled "OER for Inclusive and Equitable Quality Education: from Commitment to Action" Ljubljana, 18. 9. - 20. 9. 2017
9. Organization of conference "Day Of Information Security", Ljubljana, 8. 11. 2017
10. Kick-off project meeting of the EU project X5gone "Cross Modal, Cross Cultural, Cross Lingual, Cross Domain and Cross Site Global OER Network", Ljubljana, 23. 11. – 24. 11. 2017

INTERNATIONAL PROJECTS

1. 7FP - ProaSense; The Proactive Sensing Enterprise
Mitja Jermol, M. Sc.
European Commission
2. 7FP - SUNSEED; Sustainable and Robust Networking for Smart Electricity Distribution
Mitja Jermol, M. Sc.
European Commission
3. ERASMUS+: Micro HE - Support Future Learning Excellence through Micro-Credentialing in Higher Education
Mihajela Črnko
European Commission
4. H2020 - AquaSmart; Aquaculture Smart and Open Data Analytics as a Service
Anja Polajnar, M. Sc.
European Commission
5. H2020 - EDSA; European Data Science Academy
Mitja Jermol, M. Sc.
European Commission

6. H2020 - OPTIMUM; Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility
Dr. Matej Kovačič
European Commission
7. H2020 - MOVING; Training Towards a Society of Data-Savvy Information Professionals to enable Open Leadership Innovation
Tanja Zdolšek Draksler, B. Sc.
European Commission
8. H2020 - STEM4youth; Promotion of STEM Education by Key Scientific Challenges and their Impact on Our Life and Career Perspectives
Dr. Matej Kovačič
European Commission
9. H2020 - PrEstoCloud; Proactiive Cloud Resources Management at the Edge for Efficient Real-Time
Mitja Jermol, M. Sc.
European Commission
10. H2020 - euBusinessGraph; Enabling the European Business Graph for Innovative Data Products and Services

Mitja Jermol, M. Sc.
European Commission

11. H2020 - EW-Shopp; Supporting Event and Weather-based Data Analytics and Marketing along the Shopper Journey
Mitja Jermol, M. Sc.
European Commission

12. H2020 - Water4Cities; Holistic Surface Water and Groundwater Management for Sustainable Cities
Mitja Jermol, M. Sc.
European Commission

13. H2020 - MEET-CINCH; A Modular European Education and Training Concept in Nuclear and RadioChemistry
Mihajela Črnko
European Commission

14. H2020 - X5gon; Cross Modal, Cross Cultural, Cross Lingual, Cross Domain, and Cross Site Global OER Network
Mitja Jermol, M. Sc.
European Commission

15. H2020 - TheyBuyForYou; Enabling Procurement Data Value Chains for Economic Development, Demand Management, Competitive Markets and Vendor Intelligence
Dr. Matej Kovačič
European Commission

R&D GRANTS AND CONTRACTS

1. Videorecording and Post-Processing
Mitja Jermol, M. Sc.

2. CLARIN - European Research Infrastructure for Language Resources and Technology

Mitja Jermol, M. Sc.
Clarin Eric

3. Logistical Support to the Organization of the 2nd World Open Educational Resources (OER) Congress, to be held in Ljubljana, Slovenia, from 18-20 September 2017
Monika Kropej, B. Sc.
The United Nations Educational, Scientific And

4. Supporting of the Project „Conference on Communication Security"
Dr. Matej Kovačič
Embassy of the United States of America

5. Videorecording
Mitja Jermol, M. Sc.

6. 12. ACM Contest in computer science and informatics
Mitja Jermol, M. Sc.

NEW CONTRACTS

1. National Institute of Biology – videolectures
Mitja Jermol, M. Sc.
National institute of biology, Ljubljana

2. 3Smart project travel reimbursement
Mitja Jermol, M. Sc.
Municipality of Idrija

3. 2nd World Open Educational Recources (OER) Congress sponsorship
Mitja Jermol, M. Sc.
Pošta Slovenije d. o. o.

4. 2nd World Open Educational Recources (OER) Congress
Monika Kropej, B. Sc.
Ministry of Education, Science and Sport

STAFF

Postgraduate
1. Anja Polajnar, B. Sc.
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2. **Mitja Jermol, M. Sc., Head**
3. Dr. Matej Kovačič
4. Tanja Zdolšek Draksler, B. Sc.
Technical and administrative staff
5. Aleš Buh

6. *Gaber Cerle, B. Sc., left 16.04.17*
7. Mihajela Črnko
8. Ana Fabjan, B. Sc.
9. Adis Krečo, B. Sc.
10. Monika Kropej, B. Sc.
11. Davor Orlić, B. Sc.
12. Matija Ovsenek
13. Špela Sitar, B. Sc.

MILAN ČOPIČ NUCLEAR TRAINING CENTRE ICJT

The mission of training centre ICJT is training in the field of nuclear technologies and radiation protection. In addition, ICJT is actively informing the public about these technologies. **Training in the area of nuclear technologies is our primary mission.** Due to restrictions in employment at Krško Nuclear Power Plant (NEK) we conducted only one *Nuclear technology* (TJE) course. This course is the first, theoretical phase of training for future control-room operators. It started in the autumn of 2016 and ended in the spring of 2017. In addition, two shorter courses were conducted for NEK: the course *Use of programs LOADF, TRM/PCN and DMR-PIS* was performed in collaboration with Reactor physics division and the course *Nuclear Energy in Short* (JEK), intended for administrative and financial staff of NPP:

There were 25 **radiological protection training** courses for the medical, industrial and research use of radioactive sources.

In collaboration with the Reactor Engineering Division, three **international courses** were organized in the area of nuclear safety.

Public information remains an important part of our activities. Groups of visitors (mainly schoolchildren, students and various societies) were regularly attending lectures and visiting the permanent exhibition on nuclear energy, smaller groups also the TRIGA reactor and/or the accelerator. The lectures were offered on electricity from nuclear energy, fusion, isotopes, and energy in general. Altogether, there were 150 groups or 6236 visitors this year. Since 1993, a total of 174,880 pupils, teachers and others, visited our information centre. We have continued monitoring and analysing media reports on nuclear energy.

Head:
Dr. Igor Jenčič

> In 2017 the 16th course *Nuclear technology* was completed. This course is the first, theoretical phase of training for future NPP control-room operators.

Figure 1: JSI Open Day at the Nuclear Training Centre

Figure 2: US Ambassador to Slovenia Brent R. Hartley visiting the Nuclear Training Centre

Figure 3: Participants of the Nuclear Technology course

Figure 4: Participants of the short course on Nuclear Energy in the control room of the TRIGA reactor

Table of training activities at the Nuclear Training Centre in 2017

Date	Title of the course	Partici-pants	Lecturers	Weeks	Participants × weeks
(14.11.2016) 12.4.	Nuclear technology, theory	4	23	14	56
23.–27.1.	Radiation protection for RP department staff - Refresher course	9	7	1	9
13.–24.2.	Use of programs LOADF, TRM/PCN and DMR-PIS	9	2	0.6	5.4
6.–22.3.	Radiation protection for medical and veterinary workers	1	5	0.6	0.6
6.–9.3.	Radiation protection for industrial and other practices (measurement of road-way density and humidity)	1	4	0.8	0.8
6.–22.3.	Radiation protection for medical and veterinary workers - radiological diagnostic	2	5	0.6	1.2
6.–8.3.	Radiation protection for industrial and other practices (unsealed sources)	2	5	0.6	1.2
6.–9.3.	Radiation protection for Dental Radiography	10	5	0.2	2
6.–8.3.	Radiation protection for industrial and other practices (sealed sources)	11	4	0.6	6.6
13.–17.3.	EU Dedicated Training Course on "Lessons learned from the Fukushima Dai–Ichi incident and EU stress tests"	13	9	1	13
14.3.	Radiation protection for industrial and other practices (measurement of road-way density and humidity) - Refresher Course	4	4	0.2	0.8
14.3.	Radiation protection for industrial and other practices (unsealed sources) - Refresher Course	2	5	0.2	0.4
14.3.	Radiation protection for industrial and other practices (radiography) - Refresher Course	2	4	0.2	0.4
14.3.	Radiation protection for industrial and other practices (sealed sources) - Refresher Course	10	4	0.2	2
17.3.	Training Extension for Dental Radiography - Refresher Course	5	3	0.2	1
17.3.	Radiation protection for exposed workers in medicine and veterinary - Refresher Course	4	3	0.2	0.8
10.– 14.4.	Training course on „T/H analyses from regulatory perspective for NPP accident analysis"	14	8	0.2	2.8
16.5.	Radiation protection for industrial and other practices (min. exposed workers)	11	3	0.2	2.2
4.9. – 22.11.	Radiation protection for industrial and other practices (radiography)	8	7	1	8
9.–11.10.	Radiation protection for industrial and other practices (unsealed sources)	4	5	0.6	2.4
9.–11.10.	Radiation protection for industrial and other practices (measurement of roadway density and humidity)	1	4	0.6	0.6
9.–11.10.	Radiation protection for industrial and other practices (sealed sources)	14	4	0.6	8.4
9.–13.10.	Radiation protection for medical and veterinary workers - Nuclear medicine workers	2	9	1	2
17.10.	Radiation protection for industrial and other practices (radiography) - Refresher Course	1	4	0.2	0.2
17.10.	Radiation protection for industrial and other practices (sealed sources) - Refresher Course	9	4	0.2	1.8
17.10.	Radiation protection for industrial and other practices (unsealed sources) - Refresher Course	3	5	0.2	0.6
17.–24.10.	Radiation protection for industrial and other practices (measurement of road-way density and humidity) - Refresher Course	2	4	0.4	0.8

Table of training activities at the Nuclear Training Centre in 2017

Date	Title of the course	Partici-pants	Lecturers	Weeks	Participants × weeks
9.11.	Radiation protection for Nuclear Medicine Dpt. - Refresher Course	10	4	0.2	2
13.–17.11.	EU Dedicated Training Course "Requirements and Safety evaluation of NPP SAR"	13	15	0.8	10.4
30.11.	Radiation protection for industrial and other practices	2	2	0.2	0.4
6.–7.12.	Nuclear Energy in Short	12	4	0.4	4.8
TOTAL		195	174	28	148.6

INTERNATIONAL PROJECT

1. Training and Tutoring for Experts of the National Regulatory Authorities and their Technical Support Organisations for Developing or Strengthening their Regulatory and Technical Capabilities - MC3.01/13
   Saša Bobič
   Iter-consult Srl - Independent

R & D GRANTS AND CONTRACTS

1. Strengthening the Competence of Entrepreneurship and Promoting Flexible Transition between Education and the Environment in Primary and lower Secondary Schools
   Tomaž Skobe, M. Sc.
2. Trainings of the RZ for Foreign Market
   Matejka Južnik, M. Sc.

NEW CONTRACTS

1. Implementation of activities on modifications and updates of equipment and documentation at the simulator hardware
   Matejka Južnik, M. Sc.
2. Operation of the Nuclear Information Centre in 2017
   Dr. Igor Jenčič
   Arao
3. Basic Training Course on Nuclear Technology and Nuclear Power Plants
   Dr. Igor Jenčič
4. Implementation of public information and awarenes activities about energy and nuclear energy in central Slovenia
   Dr. Igor Jenčič
   GEN d.o.o.
5. ICJT Training Programme implementation in the year 2017
   Dr. Igor Jenčič
   Nuklearna Elektrarna Krško d. o. o.
6. Trainings of the Radiation protection
   Matejka Južnik, M. Sc.

STAFF

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Technical officers
2. Jure Hribar, B. Sc.
3. Matjaž Koželj, M. Sc.
4. Tomaž Skobe, M. Sc.

5. Vesna Slapar Borišek, B. Sc.
6. Luka Tavčar, B. Sc.
Technical and administrative staff
7. Saša Bobič
8. Matejka Južnik, M. Sc.
9. Borut Mavec, B. Sc.

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1. Radko Istenič, Igor Jenčič, "Public opinion about nuclear energy - year 2017 poll", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 1108.
2. Tomaž Skobe, Matjaž Leskovar, Leon Cizelj, "Influence of metal corium oxidation on ex-vessel steam explosion", In: *Proceedings*, 26th International Conference Nuclear Energy for New Europe - NENE 2017, Bled, Slovenia, September 11-14, Leon Cizelj, ed., Tadej Holler, ed., Ljubljana, Nuclear Society of Slovenia, 2017, 421.
3. Matjaž Koželj, Vesna Slapar Borišek, "Spreading knowledge on radiation protection in nuclear technology information centre", V: *Conference proceedings*, ETRAP 2017, 6th International conference on education and training in radiological protection, 30 May - 2 June 2017, Valencia, 2017, 174.

RADIATION PROTECTION UNIT

SVPIS

SVPIS has been involved in ionizing-radiation measurements and radiation protection since the commissioning of the TRIGA MARK II Research reactor in 1966. The responsibility of SVPIS is the radiation control of all the activities at the Institute dealing with ionizing radiation. Our main task is the supervision of work in the reactor with the Hot Cell facility and we are authorised by the regulatory authority to perform environmental monitoring.

SVPIS also controls 17 laboratories that use sources of ionising radiation in their research work. There are different sources of radiation used, such as sealed sources, open sources, X-ray units and the accelerator TANDETRON, which need regulatory control. Furthermore, we are involved in radioactive waste management.

SVPIS is authorized by the Slovenian radiation protection administration to perform control in industrial and research institutions dealing with open or sealed radioactive sources and X-ray units.

The measurements of dose rate, contamination and gamma spectrometry are performed by an accredited method (LP-022, EN ISO/IEC 17025).

Head:
Matjaž Stepišnik, M. Sc.

Personal dosimetry

The personal doses of 109 workers that regularly or occasionally deal with ionizing radiation were monitored with Thermo Luminescent Dosimeters. The maximum individual yearly dose was 0.20 mSv. This is only 1 % of the regulatory limit for occupational exposure (20 mSv per year) and 20 % of the limit for the public (1 mSv per year). The collective dose at JSI in 2017 was 1.67 man-mSv.

Supervision of the Research Reactor and laboratories

The controlled area of the Research Reactor, the Hot Cell Facility and the Department of Environmental Sciences was monitored on a weekly basis. During some activities the constant presence of a radiation-protection worker was needed (i.e., for the opening of activated samples or radioactive-waste management). Measurements of dose rate, surface contamination, contamination of different objects and personal contamination were performed routinely. In most cases, no or very low contamination levels could be measured. Locally elevated radiation levels could be measured mostly in the reactor controlled area.

In 2017 some 20 radiological inspections in other JSI laboratories were performed. An independent inspection by an external authorized institution was performed in the SVPIS laboratory and two additional laboratories at the JSI. There were no deficiencies recognized that could be important for radiation protection.

At present, 110 sources of radiation are in use, which require regulatory control and additionally 430 low-activity sources in different laboratories.

Environmental monitoring of the Reactor Center

The environmental monitoring of the Reactor Center was performed according to the existing programme. The programme consists of effluent measurements and measurements of samples in the environment. The sctivity concentrations of gamma emitters in water samples, filters, noble gases, soil samples and sediment samples were measured periodically. About 370 different samples have been measured with gamma spectrometry. Environmental passive dosimeters have been used to monitor radiation levels in the surroundings of the reactor. Based on the effluent measurements and a conservative environmental transfer model, the effective dose to the reference group of the public was estimated to be less than 1 μSv/year. **The public exposure in 2017 due to activities at the Reactor Center was insignificant**.

Expert assessments and measurements for external customers

The Radiation Protection Unit is authorized for supervision measurements and expert assessments in the field of radiation protection. In the past year several radiological control investigations were carried out in industrial and research institutions. Our group has participated in the evaluation of radiological monitoring of Krško NPP, the research reactor TRIGA and storage for low- and intermediate-level waste in Brinje.

STAFF

Technical officers
1. Dr. Tinkara Bučar
2. Eva Kalšek, B. Sc.
3. Matjaž Stepišnik, M. Sc., Head

Technical and administrative staff
4. Emira Bašić, B. Sc.
5. Thomas Breznik, B. Sc.
6. Nina Udir, B. Sc.

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1. Vladimir Radulović, Matjaž Stepišnik, Tanja Goričanec, Darko Kavšek, Vladimir Cindro, Marko Mikuž, Luka Snoj, "Large object irradiation facility in the tangential channel of the JSI TRIGA reactor", In: *Proceedings*, European Research Reactor Conference, RRFM, 14 - 18 May 2017, Rotterdam, Rotterdam, Dutch Research Reactor Community, 2017.

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1. Matjaž Stepišnik, "Reka Sava", In: *Ovrednotenje izpustov iz NEK in primerjava z meritvami v okolju - stanje pred polnitvijo akumulacijskega jeza za HE Brežice*, Matjaž Stepišnik, et al, 1. izd., Ljubljana, Institut Jožef Stefan, 2017, 108.

PROFESSIONAL MONOGRAPH

1. Tinkara Bučar *et al.* (13 authors)*, Operational intervention levels for reactor emergencies and methodology for their derivation*, (Emergency preparedness and response, EPR-NPP-OILs), Vienna, IAEA = International Atomic Energy Agency, mar. 2017.

CENTER FOR TECHNOLOGY TRANSFER AND INNOVATION   CTT

Established in 1996, the Office of Technology Transfer was transformed in January 2011. Based on its work the independent Center for Technology Transfer and Innovation (CTT) continues its mission at the Jožef Stefan Institute. We assist in the process of technology and knowledge transfer from the JSI to industry, which includes licensing, spin-out creation, associated procedures for the protection of intellectual property and assisting companies with finding suitable local and international research partners for contract and collaborative research. We also transfer knowledge from science to the school system and promote the recognisability of the JSI and science in general among young people and the wider population.

The Center's success is based on the work of 17 professionals, 8 of which are educated in natural sciences and engineering, 6 in economics, 3 in law and 2 in social sciences, while one of the experts is also qualified as a patent attorney. We are members of the ASTP (Association of Science and Technology Professionals), the LES (Licensing Executives Professionals) and three team members hold the U. S. "Certified Licensing Professional" certificate. The head of the group has the titles of Latin Legum Magister (LLM), Master of Business Administration (MBA) and Registered Technology Transfer Professional (RTTP).

Head:
Dr. Špela Stres, MBA, LLM

Our important tool is a created network of contacts with enterprises and other organisations in Slovenia and abroad. **Our services**, fine-tuned towards individual needs, are offered to JSI researchers and external organisations and include first meeting, needs analysis, registration and protection of intellectual property, marketing of intellectual property (including secret know-how), negotiations and the preparation of suitable agreements. Our clients are primarily JSI researchers, although numerous companies and other research organisations have also been known to procure our services in 2017.

We successfully finalized our training within the EU support system for progressive technology transfer offices "Progress-TT".

In 2017 the Center for technology transfer and innovation was partly funded through **five bigger and numerous smaller EU and national projects**. The projects belonged to various funding programmes and schemes: Open-iSME (CIP scheme), Enterprise Europe Network (EEN) Slovenia and EEN Scaleup (COSME scheme), We4SMESLO and INPRO (Horizon 2020), Scale(up) Alps (INTERREG Alpine Space), SYNERGY and KETgate (INTERREG Central Europe), Co-Create (INTERREG MED), and two projects connected to science in the school system: SciChallenge (Horizon 2020) and STEM4YOUTH (Horizon 2020). The project activities were connecting and completing our core TT activities.

In 2017, CTT faced several organisational, structural, and activity-related challenges, the biggest of which were: (i) transformation of individual offices into a common space allowing improved interaction among coworkers; (ii) implementation of eTT, the electronic tool for managing technology transfer; (iii) preparation, negotiation, and successful application for establishing a Consortium of Technology Transfer (KTT), covering all the largest Slovenian PROs, and led by CTT. In addition, an electronic system for reporting KTT results was set up. On the Enterprise Europe Network, the Slovenian branch of which is led by CTT, administrative work was carried out in regards to a partner change. At the 10th International Conference on Technology Transfer, a ceremony for awarding best innovations was carried out along with the ceremony for the Multiconference Informational Society.

Internally, CTT is divided into four groups whose activities mutually interact with, and complement, each other.

Group for protection and marketing of intellectual property deals with cases that were applied through the single entry point (32 cases), gives first advice to researchers (27), prepares assessments of patentability – reviews state of the art (5). The number of these activities has risen considerably in comparison with the previous year. The group also evaluates market potential, helps prepare the invention for disclosure within the research organisation (7), helps draft the patent applications, prepares agreements on the ownership of intellectual property (4), advises on the choice of patent attorney, prepares and files the patent application and gives advice about the strategy of the international (2) and national (2) expansion of patent protection. The group also takes care of the active marketing of JSI technologies (8 technologies promoted to 371 enterprises and other organisations, 24

Marketing of 8 JSI technologies, procedures for creation of a spin-out company, 64 identified RR topics.

technologies promoted through the Enterprise Europe Network). It manages received interests (39) and starts the negotiations (12). It markets technologies through making expressions of interest towards other published profiles (107). Moreover, group members arrange for the signing of non-disclosure agreements (15), manage affairs with partners in different consortia (7), take part in negotiations (16), prepare license agreements (3) and arrange their signing. Experts that belong to this group provide individual consulting regarding all phases of spin-out company formation, help with the preparation of business plans, manage discussions on the arrangement of the relationship between the JSI and the researcher and prepare license agreements for the use of technology within the spin-out company. To encourage the researches in their entrepreneurial

Organisation of 10th International Technology Transfer Conference – more than 100 visitors, competition for the best innovation idea, international visit from Slovenia, EU countries, 60 B2R meetings.

aspirations, this group's experts organize a contest for the selection of innovations with the highest commercial potential and various workshops for young researches. In 2017 one spin-out company was created, and one case was in the final stage.

The above-mentioned group tightly cooperates with the **Group for contractual collaboration with industry,** which visits both large and small companies (68 in 2017), organises their return visits to the JSI (8), organises sector and regional visits of companies to the JSI and collaborates with other support environment entities. This group's members are trying to find new topics for cooperation within the development projects amongst companies and researchers (64), prepare technology offers, arrange for the signing

2000 visitors during the Open Day at the JSI, 60 school visits.

of non-disclosure agreements and acquire written consent for further international cooperation with business or technology-research goals (10). The group also takes part in various events; in the course of the 10th International Technology Transfer Conference it organised individual meetings between companies and researchers (60).

Group for promotion, **education and project management** has prepared and disseminated lists of Slovenian and EU tenders (12) and foreign partner searches, helped prepare project applications, especially in the "Exploitation" and "Dissemination" part, weekly disseminated other information to TT coordinators, which has efficiently contributed to the application of new projects with foreign partners (3). The group has successfully spread various information through the CTT e-newsletter and CTT's Facebook profile, organised an Open Day at the JSI (2000 visitors), organised 60 school visits at the JSI, provided two entrepreneurial education sessions for young researchers (67 participants in total), and organised the 10th International Technology Transfer Conference.

Group for research in the field of technology transfer and innovation has participated in the Europe Commission Advisory Group for "Future and Emerging technologies" and the Europe Commission Advisory group

Inducted by the JRC into the TTO Circle, the group of PROs most active in the field of knowledge and technology transfer (including the institutes Max Planck, Weitzman, Fraunhofer, VITO and VTT). Some of the best rated commercialization experts of European Commission.

for "Science with and for society". We successfully finalized our training within the EU support system for progressive technology transfer offices "Progress-TT". We operate as valuators and external experts in the frame of the European Commission for different respectable international institutions (Academy of Science Finland; Federal Ministry of Science, Research and Economics, Austria; Investment Fund South East Europe, MGRT, ERC). We were recognized by the JRC as one of the most propulsive technology transfer offices in the EU and were included into the TTO Circle, the group of PROs most active in the field of knowledge and technology transfer (including the institutes Max Planck, Weitzman, Fraunhofer, VITO and VTT). As one of the best-rated commercialization external experts in the EU we work for the European Commission and advise different consortia within H2020, with emphasis on the program Industrial Leadership (FoF, NMP, ICT). The Chamber of Craft and Small Business of Slovenia issued a special thanks to CTT for active participation at the "Business to Science" event at the 50th MOS Fair in Celje, Slovenia.

Organization of Conferences, Congresses and Meetings

1. Jožef Stefan Institute Open Day, Ljubljana, 25. 03. 2017
2. Entrepreneurial education for young researchers 2017, JSI, Ljubljana, 20. 05. 2017
3. 10th International technology transfer conference, JSI, Ljubljana, 27. 09. 2017, 09.–13. 10. 2017
4. Entrepreneurial education for young researchers 2017, JSI, Ljubljana, 22. 11. 2017

INTERNATIONAL PROJECTS

1. K7, CTT - ID Creations; Rights and Obligations regarding the Development, Use and Commercialization of Hydrothermally Synthetized TiO2 Coatings in Metal Orthopaedic and Dental Implants
Dr. Špela Stres
Id Creations Oy

2. STPII - Second Science and Technology Project - Preparation of Feasibility Studies with Cost Benefit Analysis for Three RDI Instrastructure Projects
Dr. Špela Stres
Wyg Savjetovanje d. o. o.

3. OPENiSME; Open Platform for Innovative SMEs; EACI, CIP Programme

Figure 1: 10th International Technology Transfer Conference, JSI, Ljubljana, 27 Sept. to 13 Oct. 2017

Figure 2: 10th International Technology Transfer Conference, JSI, Ljubljana, 27 Sept. to 13 Oct. 2017

Figure 3: 10th International Technology Transfer Conference, JSI, Ljubljana, 27 Sept. to 13 Oct. 2017

Slika 4: Entrepreneurial Education for Young Researchers 2017, JSI, Ljubljana, 22 Nov. 2017

Dr. Špela Stres
European Commission
4. COSME; EU-GIVE - Generating Opportunities from Intangible Assets and Value Chains in the Collaborative Economy in Europe
    Dr. Špela Stres
    European Commission
5. COSME - EEN Slovenia; EEN Slovenia Services in Support of Business and Innovation in Slovenia
    Dr. Špela Stres
    European Commission
6. COSME - SGA2; EEN Slovenia 2; EEN Slovenia Services in Support of Business and Innovation in Slovenia
    Dr. Špela Stres
    European Commission
7. H2020 - SCICHALLENGE; Next Generation Science Challenges using Participatory Techniques and Digital Media
    Dr. Špela Stres
    European Commission
8. H2020 - STEM4youth; Promotion of STEM Education by Key Scientific Challenges and their Impact on Our Life and Career Perspectives
    Dr. Špela Stres
    European Commission
9. H2020 - INPRO; Improving IPR Management Service to SMEs Engaging in Peer Learning Activities
    Dr. Špela Stres
    European Commission
10. H2020 - We4SMESLO_3; Enhancing the Innovation Management Capacity of SMEs (by EEN), Slovenia

Dr. Špela Stres
European Commission

R&D GRANTS AND CONTRACTS

1. Accelerate and promote the Alpine Space Start-up Ecosystem
    Dr. Špela Stres
    Joint Secretariat
2. Co-Create: Setting up a network of COmpetitive MED Clusters with the contribution of cREATive Industries
    Dr. Špela Stres
    Joint Technical Secretariat Med Programme
3. Central European SME Gateway zo Key-enabling Technology Infrastructures - Sparking new Transnational KET Innovation Ecosystem
    Dr. Špela Stres
    Interreg Central Europe Programme
4. Synergic Networking for Innovativeness Enhancement of central european actoRs focused on hiGh-tech industry
    Dr. Špela Stres
    Interreg Central Europe Programme
5. Strategic Research & Innovation Partnership (SRIP) Smart Cities and Communities
    Dr. Špela Stres
    Ministry of Education, Science and Sport
6. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
    Dr. Špela Stres
    Ministry of Education, Science and Sport

7. The consortium for technology transfer from the PRO to the economy
Dr. Špela Stres
Ministry of Education, Science and Sport

NEW CONTRACTS

1. Preparation and signature of the NDA, preparation of a patent application draft and communication with a patent attorney until filing the patent application 'Method of hydrophobization of metal surfaces'. Short state of the art analysis
Dr. Špela Stres
Inštitut za kovinske materiale in tehnologije
2. JSI share of license revenues related to exploitation of inventions
Dr. Špela Stres
Lek d. d.

VISITORS FROM ABROAD

1. David Sanz Escribano, AIDIMME, Paterna Valencia, Spain, 23. 01. 2017
2. Claudia Di Benedetto, FINN, Udine, Italy, 23.–24. 01. 2017
3. Elena Piccinato, FINN, Udine, Italy, 23.–24. 01. 2017
4. Tommaso Bernardini, FINN, Udine, Italy, 23.–24. 01. 2017
5. Eva Martinez, AIDIMME, Paterna, Valencia, Spain, 23.–24. 01. 2017
6. Estrella Alcón, EEN, València, Spain, 23.–24. 01. 2017
7. Jon Wulff Petersen, TTO, Plougmann Vingtoft, Copenhagen, Denmark, 23.–24. 01. 2017
8. Tony Raven, Chief Executive, Cambridge Enterprise Limited, University of Cambridge, Cambridge, United kingdom, 08.–12. 05. 2017
9. Richard Ding, EUPIC, Qingdao, China, 03. 10. 2017
10. Peter Kuang, EUPIC, Qingdao, China, 03. 10. 2017
11. Nebojša Mršić, Energy Manager, Prijedorčanka a. d., Prijedor, Bosnia and Herzegovina, 23. 10. 2017
12. Dario Marjanović, Process engineer, Elas d. o. o., Banja Luka, Bosnia and Herzegovina, 23. 10. 2017
13. Amer Alibegović, Manager, Klas d. d., Sarajevo, Bosnia and Herzegovina, 23. 10. 2017
14. Muhidin Mehanović, Officer Safety and Health at work and fire protection, Menprom, d. o. o., Tuzla, Bosnia and Herzegovina, 23. 10. 2017
15. Selma Mašnić, Managing Director, Prevent CEE d. o. o., Sarajevo, Bosnia and Herzegovina, 23. 10. 2017
16. Almir Bajtarević, Quality and Environmental Manager, Tvornica cementa Kakanj, d. d., Kakanj, Bosnia and Herzegovina, 23. 10. 2017
17. Aleksandar Vucanović, Production manager, Colorit d. o. o., Banja Luka, Bosnia and Herzegovina, 23. 10. 2017
18. Samra Pehilj, Environmental Manager, Aerodrom Sarajevo, Sarajevo, Bosnia and Herzegovina, 23. 10. 2017
19. Edina Husaković, Technical Manager, RD Mošćanica, Zenica, Bosnia and Herzegovina, 23. 10. 2017
20. Željka Šobot Pešić, Monitoring officier; licensed chemical advisor, RD DEPOT, Banja Luka, Bosnia and Herzegovina, 23. 10. 2017
21. Lazo Šinik, Secretary of Branch Association, Privredna komora RS, Banja Luka, Bosnia and Herzegovina, 23. 10. 2017
22. Lejla Sadiković, Secretary to Association of renewable energy sources, Federalna privredna komora, Sarajevo, Bosnia and Herzegovina, 23. 10. 2017
23. Azra Rogović, Unido_Focal Point, MOFTER – Ministrstvo vanjske trgovine i ekonomskih odnosa, Sarajevo, Bosnia and Herzegovina, 23. 10. 2017
24. Samra Arnaut, Spremstvo ekipe NCPP, Sarajevo, Bosnia and Herzegovina, 23. 10. 2017
25. Đorđe Vojinović, Spremstvo ekipe NCPP, Sarajevo, Bosnia and Herzegovina, 23. 10. 2017
26. Dimitar Taskovski, Professor, Saints Cyril and Methodius University in Skopje, Faculty of Electrical Engineering and Information Technologies, Skopje, Republic of Macedonia, 08. 11. 2017
27. Vladimir Atanasovski, Professor, Saints Cyril and Methodius University in Skopje, Faculty of Electrical Engineering and Information Technologies, Skopje, Republic of Macedonia, 08. 11. 2017
28. Vladimir Dimchev, Professor, Saints Cyril and Methodius University in Skopje, Faculty of Electrical Engineering and Information Technologies, Skopje, Republic of Macedonia, 08. 11. 2017

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5. Tomaž Lutman, B. Sc.
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7. Dr. Duško Odić
8. Dr. Levin Pal
9. France Podobnik, B. Sc.
10. Marija Šebjan Pušenjak, B. Sc.
11. Marjeta Trobec, M. Sc.
Technical and administrative staff
12. Barbara Bercko, B. Sc.
13. Gašper Juvančič, B. Sc.
14. Špelca Kompara, B. Sc.
15. *Tamara Matevc, B. Sc., 01.08.17, transferred to Department K5*
16. David Mirosavljević, B. Sc.
17. Matej Mrak, B. Sc.
18. Luka Virag, B. Sc.

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Duško Odić, Jana Kemperl, Gorazd Avguštin, "Identification of bacterial contaminants from calcium carbonate filler production lines and an evaluation of biocide based decontamination procedures", *Biofouling (Chur Switz.)*, **33**, 4, 327-335, 2017.

PUBLISHED CONFERENCE CONTRIBUTION

1. Tomaž Šef, Robert Blatnik, "Vpliv različnega prenosnega kanala pri referenčnih in testnih posnetkih na forenzično verifikacijo govorcev", In: *Slovenska konferenca o umetni inteligenci: zbornik 20. mednarodne multikonference Informacijska družba - IS 2017, 9.-13. oktober 2017, [Ljubljana, Slovenia]: zvezek A: proceedings of the 20th International Multiconference Information Society - IS 2017, 9th-13th October, 2017, Ljubljana, Slovenia: volume A*, Mitja Luštrek, ed., Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2017, 19-22.

CENTER FOR SMART CITIES AND COMMUNITIES   CSC&C

The Center for Smart Cities and Communities CSC&C was established at the beginning of 2017. The main task of the newly established center is to coordinate and operate the Strategic Development and Innovation Partnership of Smart Cities and Communities (SRIP SC&C). In addition, the center will also promote cross-sectoral cooperation within the Jožef Stefan Institute, thus supporting the partnership in the field of state-of-the-art technologies and at the same time actively participating in the creation of national R&D policies for the coming years.

Head:
Martin Pečar, B. Sc.

Strategic Development Innovation Partnership Smart Cities and Communities

Strategic Development Innovation Partnership Smart Cities and Communities is a form of partnership in which stakeholders have joined forces in developing and selling solutions to raise the quality of life in the cities of the future.

The purpose of SRIP SC&C is to connect companies and research institutions in a particular field into value chains, to set priorities for development investments and to coordinate R&D activities. We are building a good support environment for sharing knowledge and experiences in the form of workshops, seminars and joint events; we offer access to test environments, laboratories, databases; and we provide assistance in market analysis, human-resources development, intellectual-property protection and internationalization.

We want to approach the smaller towns in Central and Eastern Europe with solutions, as we consider that due to its size and geostrategic position, Slovenia is very suitable as a reference country for various "smart urban" solutions suitable for implementing in other parts of Central and Eastern Europe.

SRIP SC&C was formally constituted at the Assembly on 23 March 2017, and currently involves more than 150 companies and research institutions from all over Slovenia.

Key areas and technologies

Strategic Research and Innovation Partnership Smart Cities and Communities covers several research areas as well as the ICT horizontal key enabling technologies.

The key objectives of SRIP SC&C are:
- Developing globally competitive solutions in the SC&C field
- Establishment of a globally recognized ecosystem of partners that permanently synergistically build and link their competencies in SC&S domains and technologies.
- Providing resources and conditions (an open-platform ecosystem) for as short a time as possible from planning to marketing globally competitive high-tech solutions
- International promotion of the Slovenian "brand" in Smart Town and Community – Smart Towns

SRIP SC&C creates and supports business and research synergies in smart cities for new products, services and technologies, and helps companies enter the global market by focusing on niche areas, with the aim of making Slovenian companies an important European provider of such solutions.

As part of the preparation of the Action Plan and with the aim of promoting networking, information exchange and encouraging organizations to become members of the SRIP SC&C, an event was held on February 2nd, attended by more than 80 participants. At the event the whole idea and purpose of SRIP SC&C was presented in detail. Subsequently, there were another 20 thematic workshops and working meetings within key areas and technologies, where the activities and plans of each area were presented to potential members: Energy and Utilities (14.2., 22.3.), Mobility, transport and logistics (16.2., 28.2, 9.3, 29.8.), Information Communication Technologies (23.2.), Safety (13.3., 12.12.), HPC and Big data (16.3.), Smart City Ecosystem (17.3.), Digital Transformation (21.3), Gis-T (21.3.), IoT (22.3.), IoS (22.3.), Cyber security (22.3., 3.4.), Health (23.3., 18.4., 2.6.); At the announcement of the public
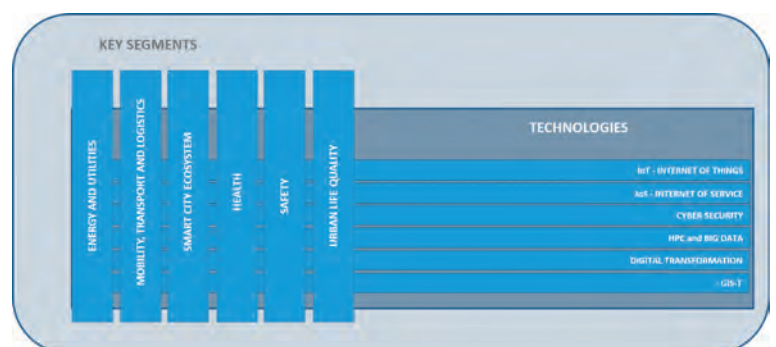

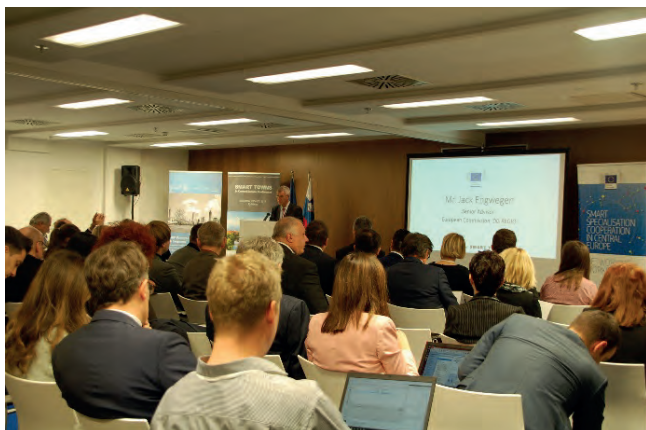*Figure 1: Key areas and technologies*

Figure 2: Participants of the Smart Towns Conference

Figure 3: Participants of the Smart Towns Conference

call for tender RRI2, we organized an educational and consulting workshop for the members in the preparation of tenders (29.8.2017).

The first SRIP SC&C Assembly was held with the leaders and representatives of the members in the Program Council, from the economy and research organizations for individual areas, and members of the Steering Committee were elected.

One of the most important events is certainly the organization of the two-day **International Smart Towns Conference in Central and Eastern Europe**, which took place in Ljubljana from 29th to 30th November 2017 in cooperation with the European Commission and Watify. The conference was opened by the Minister of Public Administration, Boris Koprivnikar, followed by presentations of many foreign and domestic experts. The conference was attended by over 130 people from 12 countries of Central and Eastern Europe. The event was also covered by TV Slovenia in their main news programme Odmevi.

As part of the **promotion and internationalization** of the SRIP SC&C, a number of activities were carried out for members. Together with the representatives of specific key areas and in cooperation with Siemens we visited the smart city Aspern in Vienna (23.5.2017). In June 2017, SRIP SC&C was presented at the Smart Communications 2.0 International Conference in Helsinki, in September at the Smart Cities Live 2017 in London, in October at the 15th European Regional Week and cities in Brussels, and in November at the Smart City Expo 2017 in Barcelona.

SRIP SC&C actively participated and was promoted at some of the most important events in Slovenia: Digital Forum at Bled e-conference (19. 6.2017), SMEs - City Center Management, Slovenian Digital Coalition Forum (4.7.2017), MOS Fair - Meeting of Mayors (13.9.2017), entry of SMEs into the supply chains of companies (14.9.2017), Ljubljana forum 2017 (28.9.2017), round table - New technologies and their impact on the world of work-smart villages and industry 4.0. (29.9.2017), Fair of Innovative Digital Solutions Feel the Future (19.-21.10.2017), Consultation - Connectivity, Personnel Challenges and International Inclusion (October 19, 2017), Ganesha Business Technology Workshop (October 26, 2017), Transport and Research in the Danube region (6-7.11.2017), Public consultation: E-participation of the population in decision making in Slovenian municipalities (10.11.2017).

R&D GRANTS AND CONTRACTS

1. Strategic Research & Innovation Partnership (SRIP) Smart Cities and Communities
   Matjaž Šteblaj, B. Sc.

2. SRIP (Strategic Research & Innovation Partnership) Smart Cities and Communities
   Martin Pečar, B. Sc.

STAFF

Technical and administrative staff
1. Petja Grizilo, B. Sc.

2. Nataša Juvančič, B. Sc.
3. **Martin Pečar, B. Sc., Head**

BIBLIOGRAPHY

PUBLISHED CONFERENCE CONTRIBUTION

1. Martin Pečar, Gregor Papa, "Transportation problems and their potential solutions in smart cities", In: *Proceedings of 2017 International Conference on Smart Systems and Technologies, (SST), Osijek, Croatia, October 18-20, 2017*, Drago Žagar, ed., Danvers, Institute of Electrical and Electronics Engineers = IEEE, 2017, 195-199.

CENTER FACTORY OF THE FUTURE

CFoF

Center Factory of the Future - CFoF, led by Rudi Panjtar, was established at the beginning of 2017. The main task of the newly established center is the coordination and operation of the Strategic Development and Innovation Partnership of the Factory of the Future (SRIP FoF). In addition to this, the Center will also promote cross-sectoral cooperation within the Jožef Stefan Institute, thereby contributing to support for the partnership in the field of the latest technologies, while also actively participating in the development of research and development policies in the coming years.

Head:
Rudi Panjtar , B. Sc.

What does the Strategic Development Innovation Partnership of the Factory of the Future offer?

The SRIP FoF's strategy is to collect and link Slovenian research and innovation know-how and experience from the industrial and academic spheres and to highlight the priority breakthroughs of new products, technologies and services for the Factory of the Future. A supportive environment is needed to build a professional service for industry and research organizations with an emphasis on emerging new, cutting-edge technologies that combine and upgrade to existing Slovenian research and innovation achievements.

The SRIP FoF will create and support business and research synergies in the field of factories of the future for new products, services and technologies, and help companies enter the global market by focusing on niche areas, thus ensuring that Slovenian companies become an important European provider of such solutions.

The SRIP FoF is already supported by more than 80 different companies, associations or institutions in Slovenia. In the next period, the operation will ensure a qualitative shift in the direction of greater linking of knowledge and the joint appearance of stakeholders on domestic and foreign markets. The primary goals are an increase in the share of high-tech industrial products in exports and an increase in the added value of Slovenian industry.

Key areas of action

SRIP FoF includes eight areas (verticals), through which all horizontal areas (KET) are intertwined (Figure 1).

The SRIP FoF will indirectly contribute to accelerating the transition to an energy-efficient economy through the effective direction of research and development and the introduction of knowledge and technologies that will enable the production of better-quality products, with less energy and raw-materials consumption, less pollution of the environment, better inclusion of people, etc. with low greenhouse-gas emissions or to intensively promote the transition to a low-carbon society and a circular economy. The essence of the concept of the factories of the future is mainly reflected in the greater possibilities for the reuse of waste materials, which is made possible by a more flexible and optimally guided production.

As part of the preparation of the Action Plan and with the aim of promoting networking, information exchange and encouraging organizations to become members of the SRIP FoF, in 2017 we held events and thematic workshops around Slovenia, among others: Circular Economy and Innovation, Chamber of Commerce and Industry; Digitalization in a circular economy, Chamber of Commerce and Industry; Digital Transformation as an Opportunity - "What is smart production 4.0 and how to do it".We actively participated in many of the most important events in Slovenia and abroad, to name a few: "Smart regions-smart robots - Winning formula, Brussels", "Strategies to Foster Collaboration Between Science and Industry and Reinforce Private Investment"

Figure 1: SRIP FoF key areas of action

in Vilnius Lithuania, CENTRAL EUROPEAN COOPERATION FOR INDUSTRY 4.0 workshop, Budapest, Hungary, Digital Innovation Hub, Ljubljana.And finally, the process of formal management-structure forming and business-model implementation concluded with the SRIP FoF Founding Assembly.
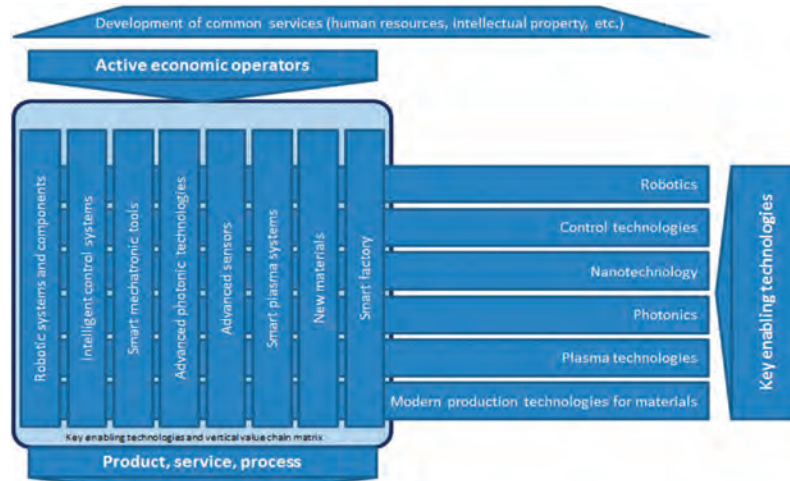
R&D GRANTS AND CONTRACTS

1. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
   Rudi Panjtar, B. Sc.

2. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
   Asst. Prof. Igor Kovač

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1. *Asst. Prof. Igor Kovač, 01.04.17, transferred to Department E1*
Technical and administrative staff

2. Petja Grizilo, B. Sc.
3. **Rudi Panjtar, B. Sc., Head**
4. Jana Stanič