

**INSTITUTE OF PHYSICS
ZAGREB**



**ANNUAL REPORT
2011**

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FOREWORD

Dear readers,

The Institute of Physics in Zagreb is a public institution primarily dedicated to fundamental and applied research in physics and related fields. The Institute also participates in higher education and promotion of physics. Our current research covers the fields of condensed matter, surface, statistical, soft-matter, atomic, molecular, optical and plasma physics. This annual report presents a detailed account of the research activities and other achievements of the Institute's laboratories, groups and services as well as comprehensive lists of projects, publications and scientific visits in 2011. However, there are several particularly important events and achievements that I would like to highlight here.

One of the most important events for the research community in Croatia was the thematic evaluation of public institutes conducted by the Agency of Science and Higher Education (ASHE). On behalf of the ASHE the evaluation was carried out by an international team of experts (Prof. Dr. Peter Samuely, Slovakian Academy of Science and Prof. Dr. Dietrich Wegener, Technical University of Dortmund). The overall conclusion of the Evaluating Committee is that the mission of the Institute of Physics is well defined, and a strong recommendation for a more focused research. The Committee emphasized that some of the Institute's research activities and fields are unique on the national level, that the overall quality of research is at international level, and that a strong orientation to basic research with positive examples of technology transfer is justified. Finally, the Committee has affirmed that the current performance of the Institute justifies its existence as an independent institution.

A significant advance in the upgrade of Institute's research infrastructure was achieved in the past year through the establishment of photo-lithography laboratory with the support of Unity Through Knowledge Fund (UKF) and collaboration with the Brookhaven National Laboratory. We are also indebted to the Max Planck Institute in Stuttgart where several of our young scientist were trained to use such a facility. The long awaited possibility to study the properties of matter under pressure and high magnetic field at the Institute was realized with the support of the UKF, EPFL (Lausanne) and Erstes Physikalisches Institut (Stuttgart).

Collaboration of the Institute with the universities has always been important. The framework for present and future joint activities in research and higher education at the Institute and the University of Zagreb was formalized in 2011 through the Agreement on Collaboration. It already becomes clear that this agreement has opened up new possibilities for stronger and more effective collaboration in many segments pivotal to both institutions.

In 2011 the Institute of Physics made an important step in its continuing effort to support education of physics teachers and pupils in primary and secondary schools. An agreement was signed with the Agency for Education and, equally important, with the XV Gymnasium Zagreb. We are proud of our program which offers the gifted pupils to be actively involved in advance research topics.

An important part of the Institute's activity is education of young scientists. Institute of Physics has admitted three new students to its PhD program in 2011 and meanwhile four of our Ph.D. students have completed their theses by working on the Institute's research projects. This confirms the position of the Institute as a one of the most successful research organizations in Croatia in bringing almost every PhD student to completion of the internationally recognized PhD program.

The scientists of the Institute continue to successfully organize international conferences and workshops. Several events of this kind were organized in 2011 in the fields of solid state- and bio- physics.

Institute of Physics has been organizing the Open Days since 2001. In 2011 the 10th anniversary event attracted again more than one thousand of pupils and their teachers from all parts of Croatia who attended specially designed lectures and toured the laboratories.

Dr. Petar Pervan
Director of the Institute of Physics

STRUCTURE OF THE INSTITUTE

Executive Board

Dr. Hrvoje Meštrić, MSES, President
Prof. dr. Hrvoje Kraljević, Faculty of Sciences, member
Prof. dr. Hrvoje Buljan, Faculty of Sciences, member
Dr. Đuro Drobac, IP, representative of employees
Dr. Čedomil Vadla, IP, representative of Scientific Council

Office of the Director

Dr. Petar Pervan, Director
Dr. Nazif Demoli, Assistant director
Dr. Damir Starešinić, Assistant director

Scientific Council

Dr. Katica Biljaković, chairwoman till 19/05/2011
Dr. Mladen Movre, chairman from 20/05/2011
Dr. Mladen Prester, deputy chairman till 19/05/2011
Dr. Ognjen Milat, deputy chairman from 20/05/2011

Scientists and Researchers, Working Positions

1. Damir Aumiler, dr., senior research associate (from 15/09/2011)
2. Ivica Aviani, dr., research associate
3. Ticijana Ban, dr., senior research associate
4. Osor Slaven Barišić, dr., research associate
5. Robert Beuc, dr., research advisor I
6. Katica Biljaković, dr., research advisor II
7. Nazif Demoli, dr., research advisor I
8. Đuro Drobac, dr., senior research associate
9. Jadranko Gladić, dr., technical advisor
10. Branko Gumhalter, dr., research advisor II
11. Bojana Hamzić, dr., research advisor II
12. Berislav Horvatić, dr., senior research associate
13. Vlasta Horvatić, dr., research advisor I
14. Jovica Ivkov, dr., research advisor I
15. Marko Kralj, dr., senior research associate
16. Davorin Lovrić, dr., technical advisor
17. Željko Marohnić, dr., senior research associate
18. Ognjen Milat, dr., research advisor II
19. Slobodan Milošević, dr., research advisor II
20. Milorad Milun, dr., research advisor II
21. Mladen Movre, dr., research advisor II
22. Miroslav Očko, dr., research advisor I
23. Petar Pervan, dr., research advisor II
24. Goran Pichler, dr., research advisor II
25. Mladen Prester, dr., research advisor I
26. Hrvoje Skenderović, dr., senior research associate
27. Ana Smontara, dr., research advisor I
28. Damir Starešinić, dr., senior research associate
29. Antonio Šiber, dr., research advisor I
30. Silvia Tomić, dr., research advisor II
31. Eduard Tutiš, dr., senior research associate
32. Katarina Uzelac, dr., research advisor II
33. Čedomil Vadla, dr., research advisor II
34. Zlatko Vučić, dr., research advisor II
35. Tomislav Vuletić, dr., senior research associate
37. Ivica Živković, dr., research associate

Students

1. Ivan Balog, dr. (from 17/03/2011)
2. Marijan Bišćan, B.Sc.
3. Matija Čulo, dipl. prof.
4. Ida Delač Marion, M.Sc. (till 10/01/2011)
5. Damir Dominko, B.Sc.
6. Goran Gatalica, B.Sc.
7. Danijel Grgičin, B.Sc.
8. Mirta Herak, dr.
9. Tomislav Ivek, dr. (from 30/06/2011)
10. Ivan Jurić, B.Sc.
11. Gordana Kregar, B.Sc.

12. Zlatko Kregar, B.Sc.
13. Nikša Krstulović, dr. (from 18/06/2010.)
14. Levatić Ivana, mag.phys. (from 01/10/2011)
15. Sanjin Marion, mag.phys. (from 01/10/2011)
16. Marin Petrović, B.Sc.
17. Ivo Pletikosić, B.Sc.
18. Petar Popčević, dr.
19. Mario Rakić, B.Sc.
20. Krešimir Salamon, dr. sc
21. Juraj Szavitz-Nossan, dr.sc (from 20/10/2011)
22. Kristina Šariri, dr. sc
23. Iva Šrut, B.Sc.
24. Kristijan Velebit, B.Sc.
25. Silvije Vdović, dr.
26. Nataša Vujičić, dr.sc (from 15/12/2011)

Technicians

1. Krešimir Drvodelić, technician (retired with 02/02/2011)
2. Ivan Čičko, technician
3. Branko Kiš, senior technician
4. Josip Pogačić, senior technician
5. Franjo Zdravec, technician (from 10/05/2011)
6. Žarko Vidović, technician
7. Alan Vojnović, senior technician

Administrative and Maintenance jobs

1. Ivana Bagarić, technician
2. Mladen Bakale, porter-telephone operator
3. Ivanka Bakmaz, accountancy clerk
4. Berti Erjavec, higher technical associate
5. Marica Fučkar – Marasović, prof., librarian (retired with 31.12/2011)
6. Mario Juričić, chief of the informatics section
7. Željko Kneklin, dipl. oec., higher economic advisor
8. Nevenka Kralj, accountancy clerk
9. Mirjana Ličina, cleaning lady
10. Renata Macešan, cleaning lady
11. Gordana Matić, cleaning lady
12. Snježana Mostečak, cleaning lady
13. Darko Oštarčević, facility maintenance
14. Jadranka Rajić, secretary
15. Marija Sobol, administrative clerk
16. Nataša Šuput, cleaning lady
17. Draženka Zajec, cleaning lady
18. Jozo Zovko, technician

LABORATORY FOR LASER SPECTROSCOPY

HEAD

Dr. Čedomil Vadla

Co-workers

Dr. Vlasta Horvatić

Co-workers from other institutions

Prof. dr. Damir Veža, Faculty of Science, University of Zagreb

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

Laboratory activities in the year 2011 were focused on spectroscopic diagnostics of miniature dielectric barrier discharge plasmas produced in helium and argon, which are of significant interest for analytical applications.

Characterization of Dielectric Barrier Discharge Plasma Jet

In order to perform diagnostics of processes important for generation of protonated water, which enables soft ionization, i.e., ionization without destruction, of organic macromolecules, extensive spatially resolved spectroscopic measurements of emission of dielectric barrier discharge (DBD) burning in helium were carried out. Spatial distributions of He, N_2^+ and N_2 spectral lines relevant for understanding the collision processes in the discharge, which eventually lead to creation of protonated water were measured. The emission intensity distributions were recorded along the discharge axis in the capillary between the electrodes and in the jet outside the capillary. End-on and side-on intensity measurements were done, combination of which enabled determination of the atom number densities in particular metastable states of He. These states are assumed to have crucial role in generation of ionized nitrogen molecules, occurrence of which constitutes the starting point in the process of water protonation. The knowledge about the populations in the metastable states and their spatial behaviour is necessary to enlighten the complex physical processes occurring in DBD, especially bearing in mind that metastable atoms serve as a precursor to the desired final reaction (water protonation) which is of great importance for analytical purposes.

The characteristics DBD in helium were also investigated in dependence on the applied voltage. Three different modes of DBD operation were observed, two filamentary (above 4.2 kV) and one homogeneous (below 4.2 kV). Running the DBD at 4.2 kV has shown to be most efficient for producing plasma with optimum characteristics for applying the jet as soft ionization source. Characterization of DBD was performed by spatially resolved and voltage dependent measurements of N_2^+ 391 nm and N_2 380 nm lines, as well as He emission at 728, 706,667, 587, 501 and 388 nm.

Evaluation of the extensive experimental data, drawing the conclusions and preparation of the corresponding papers are in progress.

Construction of DBD electrodes

Reliable analysis and quantitative comparison of the measured emission intensities require stable operation of DBD lasting at least one day so that all measurements necessary to obtain the complete set of data for one analysis can be performed in the course of single ignition of DBD. The quality of electrode-capillary (metal-quartz) contact turned out to be critical for durability of DBD operation. Therefore, special efforts were made to the end of eliminating micron-thick air gap between the electrode and the capillary wall. If such gap exists, sparking that builds up across it, overheats and melts thin (250 μm) capillary wall very quickly, thus reducing continuous operation of DBD to only couple of hours (less than 4 h). After testing various materials and constructions, the most satisfying configuration turned out to be to one in which the electrodes were made of a bundle of 100 μm thick copper wires sheathed in Sn-Pb alloy, shaped to tightly fit the capillary, and soldered to the quartz wall with the same alloy (Fig. 1).

The DBD with such electrodes exhibited very high stability and could be operated and repeatedly ignited without deterioration in metal-quartz contact for more than one month.

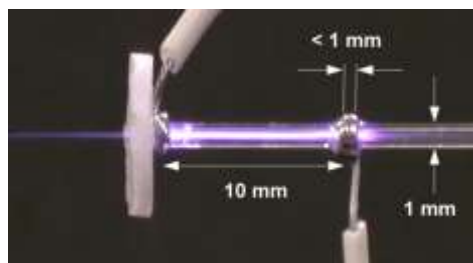


Figure 1

PROJECTS

Title: *Spectroscopy of Rydberg atoms and molecules*

Project type: MZOŠ (035-0352851-2853)

Head researcher(s): Č. Vadla (IF)

Duration: 2007-2011

Title: *Absorptionsspektroskopische Charakterisierung der metastabilen Zustände im Jet einer wichen Ionisierungsquelle fuer organische Molekuele*

Project type: DFG (FR 1192/13-1)

Head researcher(s): Č. Vadla (IF) and J. Franzke (ISAS, Dortmund)

Duration: 2011-2013

PUBLICATIONS

SCIENTIFIC ARTICLES

1) S. B. Olenici-Craciunescu, A. Michels, V. Horvatic, C. Vadla, J. Franzke

Spatially resolved spectroscopic measurements of a dielectric barrier discharge plasma jet applicable for soft ionization
Spectrochimica Acta Part B **66** (2011) 268-273

- 2) S. Müller, S. B. Olenici-Craciunescu, T. Krähling, V. Horvatic, C. Vadla, J. Franzke
Characterization of a DBD plasma jet for soft ionization
Proceedings of the 30th ICPIG, C10, 234, 2011, Belfast, UK

SCIENTIFIC VISITS

- 1) S. Müller
Leibniz-Institut für Analytische Wissenschaften – ISAS – e.V.
(8/9/2011-22/9/2011)
- 2) T. Krähling
Leibniz-Institut für Analytische Wissenschaften – ISAS – e.V.
(8/9/2011-22/9/2011)

ORGANIZATION OF SCIENTIFIC MEETINGS AND BOARD MEMBERSHIPS

- 1) V. Horvatić
• Member of the Organization Board of the 7th Scientific Meeting of the Croatian Physical Society, Primošten (13-16/10/2011)

REVIEWING

- 1) Č. Vadla
• Spectrochimica Acta Part B, Optics Communications, JQSRT
- 2) V. Horvatić
• Spectrochimica Acta Part B, JQSRT

MISCELLANEOUS

- 1) Č. Vadla
• Member of the Executive Board of the Institute of Physics
- 2) V. Horvatić
• Member of the Executive Board of the Croatian Physical Society
• Institute of Physics Seminar leader
• Website administrator for the Croatian Physical Society
• Website administrator for the 7th Scientific Meeting of the Croatian Physical Society

LABORATORY FOR FEMTOSECOND LASER SPECTROSCOPY

HEAD

Dr. Goran Pichler

Co-workers

Dr. Hrvoje Skenderović, Dr. Ticijana Ban, Dr. Damir Aumiler, Dr. Silvije Vdović, Dr. Nataša Vujičić, Gordana Kregar, B.Sc., Mario Rakić, B.Sc.

Co-workers from other institutions

Prof. dr. Z. Tarle, School of Dental Medicine, University of Zagreb

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

Our scientific work was performed within three laboratory units, where in all of them a certain instrumental and device improvement was achieved. Beside a few subjects dealing with fundamental atomic and molecular laser spectroscopy we turned our attention to several applied fields especially dental endeavors. We studied new light sources with high pressure lamps with interesting features and with possible applications to lighting and medical physics. Femtosecond laser frequency comb spectroscopy has been essentially improved and new results have been achieved.

Frequency comb spectroscopy

Femtosecond laser frequency comb spectroscopy has been essentially improved and new results have been achieved using polarization measurements. The experimental study of Zeeman components optical pumping effects, induced by interaction with circularly polarized fs laser pump laser. If such, optically prepared, medium is examined by linearly polarized continuous-wave (cw) probe laser, the effects of rotation of polarization of probe beam can be observed. Such polarizations effects, induced by interaction of atoms with optical frequency comb are, as far as we know, for the first time experimentally studied. The phenomenon of polarization rotation of a weak linearly polarized cw optical field in room-temperature rubidium vapor have been investigated for different polarizations of the fs pump laser, in dependence on fs pump laser power as well as on external magnetic field strength. Semi-classical model of probe beam propagation through anisotropic medium gives good description of system and is in accordance with observed experimental results.

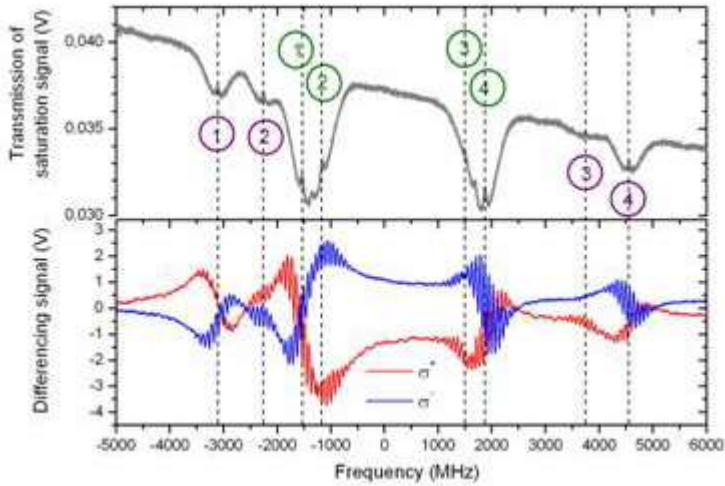


Figure 1. Experimental results of polarization spectroscopy on rubidium vapor. Polarization effects on rubidium resonance lines induced by frequency comb laser can be observed.

Laser cooling and magneto optical trapping

Experiments in the field of laser cooling and trapping of rubidium atoms were revived at the end of the year with the main aim to investigate ultra-cold rubidium atoms in different experimental conditions and to explore new phenomena concerning the physics at ultra-low temperatures. Specifically, we are interested in the understanding of mechanical action force on cold atoms induced by continuous lasers or by femtosecond frequency comb.

Our magneto-optical trap (MOT) for cooling and trapping rubidium atoms operates in classical retro-reflected configuration with the main parts consist of: glass cell equipped with rubidium dispensers, two diode laser systems each locked to the specific hyperfine rubidium transition and magnetic coils in anti-Helmholtz configuration. Parts of the experimental set-up are shown in Fig. 2.

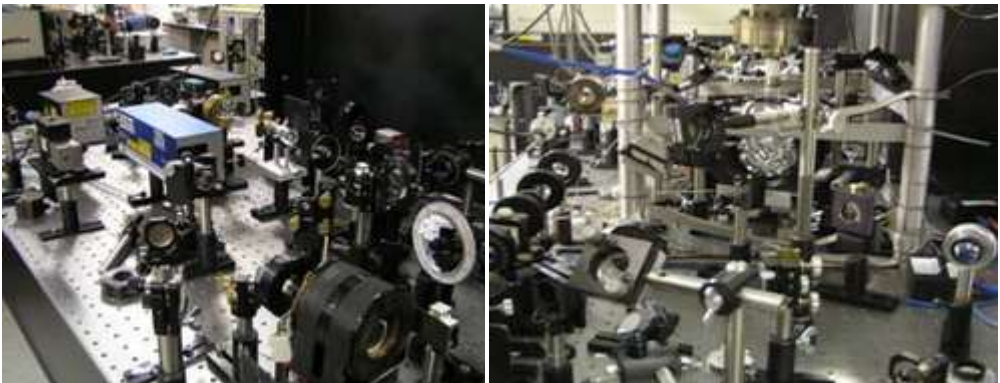
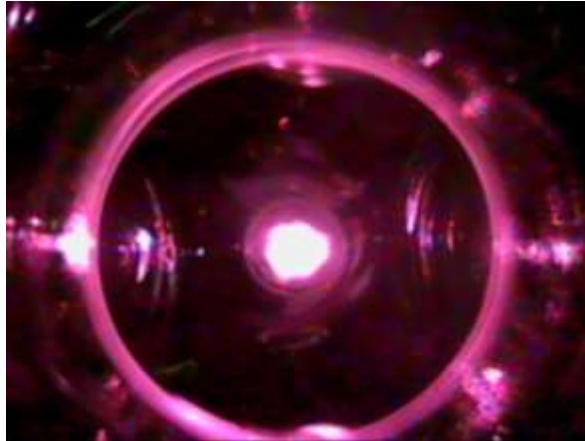


Figure 2. Experimental set-up for cooling and trapping rubidium atoms.

Ultra-cold cloud of rubidium atoms is observed by CCD camera and photodiode. In Figure 2 we show picture of the cold rubidium atoms appearing in the intersection of the six laser beams taken through one small window on the glass cell by camera. The cloud is positioned in the centre of the picture, it has spherical shape with average radius in one dimension of (0.9 ± 0.1) mm and it is very bright due to the fluorescence light



3Figure 3. Ultra-cold rubidium cloud.

In order to measure number of atoms in MOT, loading curves for different experimental conditions were measured. Loading curves were obtained by measuring total fluorescence light coming from the cold atoms. From these measurements we concluded that in our MOT we can trap $3 \cdot 10^9$ rubidium atoms in the time period about 1 hour, which gives as satisfactory starting point for further investigations.

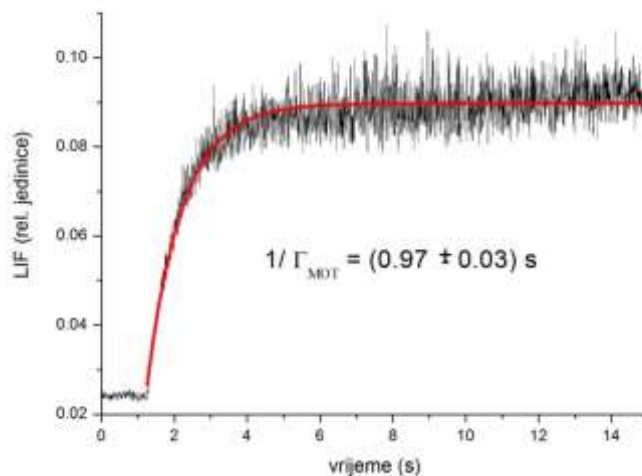


Figure 4. The laser absorption spectroscopy, through the cloud of ultra-cold ^{87}Rb atoms (blue trace) is measured and compared with the results from the vapor at room temperature (red trace). These results demonstrates the power of the ultra-cold atom samples, where no Doppler broadening and absorption line covering is present, thus leading to the understanding the pure nature of different physical phenomena.

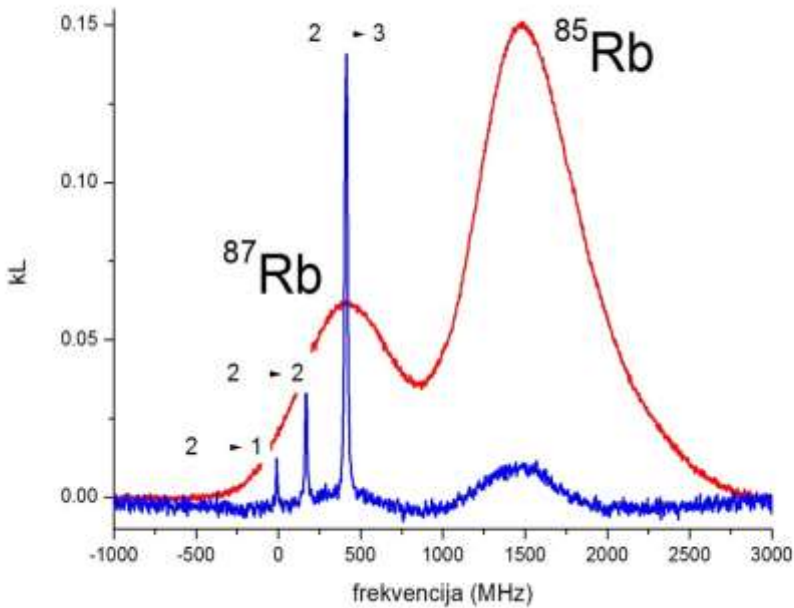


Figure 5. Laser absorption spectroscopy of ultra-cold ^{87}Rb sample (blue trace) and rubidium vapor at room temperature.

Studies of the high pressure metal vapor lamps

We compared the visible and the infrared spectrum of cesium and the sodium high pressure discharge light sources of 70 W power, run at different voltages from 180 to 240 V. Although the cesium discharge lamp exhibits remarkable white light in the visible spectrum, it suffers from the large infrared radiation intensity. The study of the causes of large infrared losses and their possible reduction was the main motivation for the present investigation. Sodium discharge plasma appears to be more efficient light source than the cesium discharge plasma due to the smaller infrared emission, although the latter has much better colour rendering index.

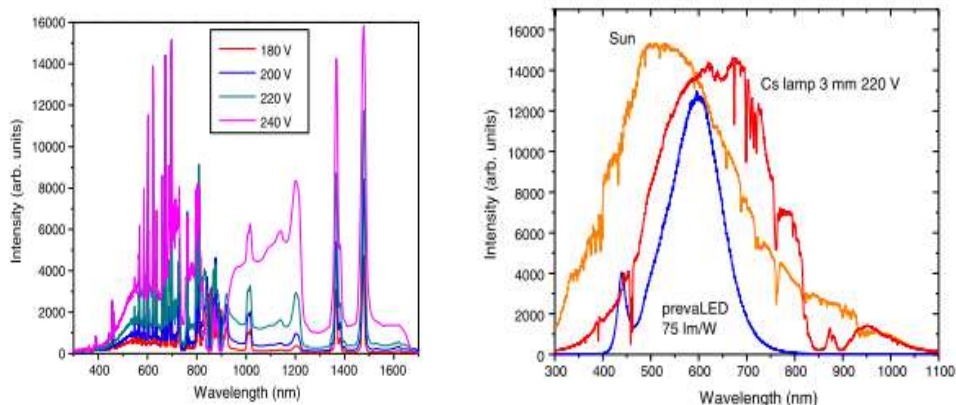


Fig. 6 a) Combined spectrum of the high pressure cesium lamp of 70 W at different voltages. b) Comparison spectrum of 3 mm high pressure cesium lamp, sun and prevaLED.

Ultrafast pump-probe measurements by four-wave mixing

Time-domain spectroscopy using ultra short laser pulses with duration of about 100 fs enabled to directly access molecular and reaction dynamics. Time-delayed Degenerate four-wave mixing spectroscopy (DFWM) is commonly used for observing wave packet motion by impulsive Raman scattering. For the study of alkali dimers and their vibration dynamics a heat-pipe oven is filled with sodium, and when heated sodium vapor emerged with a few percent of sodium dimers. Three input beams intersect in the middle of the oven and generate the DFWM signal in the phase-matched direction, as shown in the figure below:

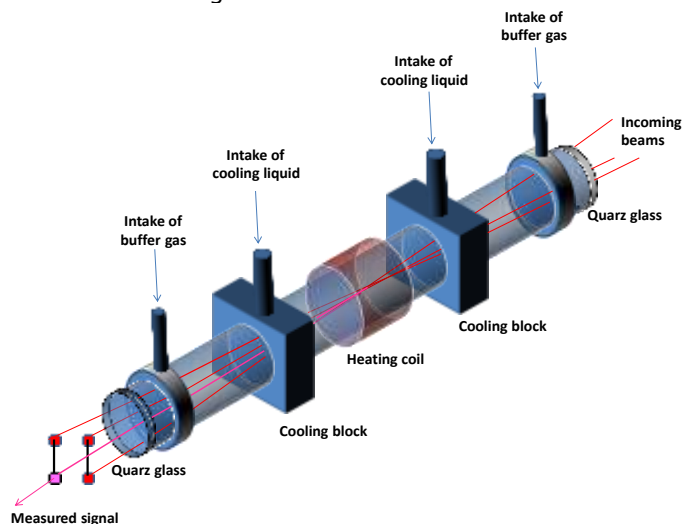


Figure 7 Experimental setup for the BOXCARS DFWM spectroscopy.

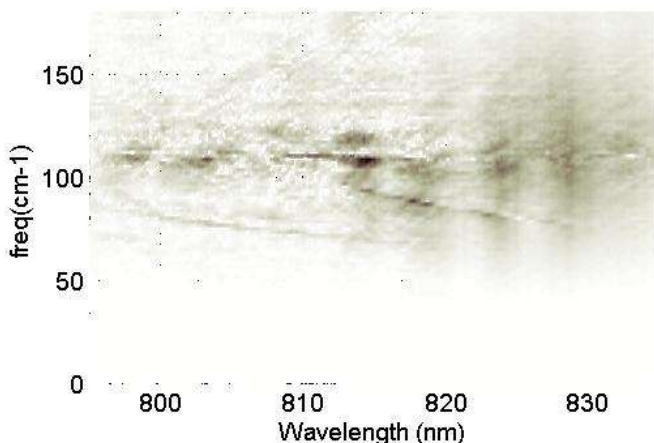


Figure 8 Fourier analysis of the 2D signal gives frequencies of vibronic levels which are excited by DFWM, as shown in the figure below:

Time-resolved laser fluorescence microscopy

Fluorescence correlation spectroscopy (FCS) is essentially correlation analysis of the fluorescence intensity fluctuations in time. FCS is one of many methods to analyze extreme low concentration of biomolecules at high spatial and time resolution. The most important parameter is the spontaneous intensity fluctuations. From these fluctuations the local concentration, diffusion constants, and characteristic features connected with inter- and intramolecular bonding can be determined of fluorescence labeled biomolecules at nanomolar concentrations. We worked on Cyanine-5 (Cy5) biomolecule. The small intensity fluctuations were quantified in their strength and duration by using time autocorrelation procedure. The autocorrelation analysis gives the measure of similarities of time sequences, from which the key informations about the molecular dynamics may be obtained.

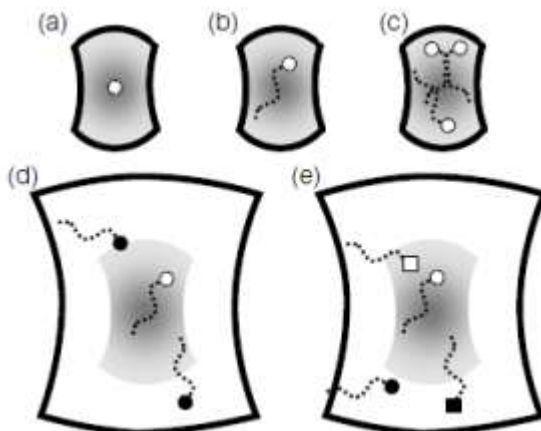


Figure 10 (a) Nonfluctuating fluorescence particle fixed at the center of the closed excitation volume, (b) Fluctuation caused by the diffusion of the molecule with spatial varying excitation-detection efficacy (c) The case of many particles, (d) The particles may leave and enter the observing volume (e) The same as (d) but with molecules of different fluorescence efficacy.

Teeth whitening with different light sources

We studied the efficiency of four different tooth whitening procedures and we examined 30% carbamide peroxide gel alone and compared it with two available in-office whitening methods (Discus Dental, Culver City, CA, USA and Beyond Technology Corp, Santa Clara, CA, USA) and a procedure involving a femtosecond laser which consists of a 6W green laser pump (Millennium, Spectra Physics) and a mode-locked laser (Tsunami, Spectra Physics) which have not been clinically tested so far. 40 pastilles of hydroxylapatite were used and immersed in green tea for 8 hours. After drying, pastilles were randomly divided into 4 groups, each consisting of 10 pastilles and treated with one of the 4 bleaching procedures. The color of pastilles was determined by the colorimeter in the RGB index prior to immersion into the tea, after the immersion and after the whitening treatment. Non-parametric tests were used for the analysis of colorimetric sum values - Kruskal-Wallis and Mann-Whitney test for independent samples and Wilcoxon test for dependent samples. Results: The colorimetric sum value for the pastilles treated with the gel only was 3024.42, for the pastilles treated with ZOOM 2 it was 2999.74, for the pastilles treated with Beyond it was 2944.12 and for the laser-treated pastilles it was 2687.22. The best results were obtained using the 30% carbamide peroxide gel and ZOOM2, followed by Beyond and the femtosecond laser method, which exhibited a whitening effect proportional to treatment duration and gel concentration. Although all four bleaching methods proved effective, the final result of bleaching depends upon the duration of treatment and the type and concentration of the gel applied.

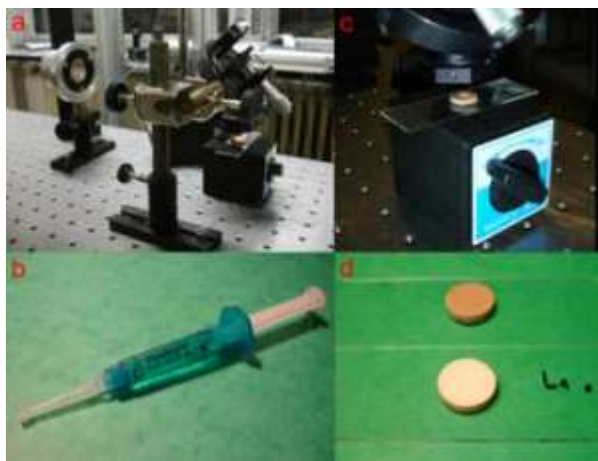


Figure 9 (a) Whitening procedure with femtosecond laser. (b) VivaStyle gel (c) Femtosecond laser application on the pastille; (d) A comparison of pastilles before and after laser treatment.

PROJECTS

Title: Femtosecond laser physics of atoms and molecules
Project type: MZOŠ (035-0352851-2857)
Head researcher(s): G. Pichler (IF)
Duration: 2007-2011

Title: Optical nonlinearities and electronic correlations of nanocrystals by means of the four wave mixing spectroscopy
Project type: Croatian-Austrian bilateral project
Head researcher(s): H. Skenderović
Duration: 2011-2012

Title: Nonadiabatic effects in molecular reaction dynamics studied by femtosecond laser spectroscopy
Project type: Chinese-Croatian bilateral project
Head researcher(s): D. Aumiler
Duration: 2011-2013

SCIENTIFIC COLLABORATION

- 1) Coherent control of molecules by shaped ultrashort pulses in the MID-IR spectral range
H. Skenderović and prof. M. Motzkus (University of Heidelberg)

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) A. Foltynowicz, T. Ban, P. Maslowsky, F. Adler, J. Ye
Quantum-Noise-Limited Optical Frequency Comb Spectroscopy
Phy. Rev. Lett. 107, 233002 (2011).
- 2) J. Paliska, A. Stipetić, Z. Tarle, M. Ristić, T. Ban, N. Vujičić, G. Pichler
Colorimetric Assessment of Different Tooth Whitening Procedures
Acta Stomatol. Croat. 45, 258 (2011).
- 3) T. Vuletić, S. Dolanski Babić, D. Grgičin, D. Aumiler, J. Rädler, F. Livolant, S Tomić
Manning free counterion fraction for a rodlike polyion: Aqueous solutions of short DNA fragments in presence of very low added salt
Phys. Rev. E 83, 041803 (2011).
- 4) M. Rakić, G. Pichler
Comparison of visible and infrared spectrum of light sources
Opt. Comm. 284, 2881 (2011).
- 5) A. Turković, P. Dubček, K. Juraić, M. Rakić, S. Bernstorff
SAXS/DSC/WAXD Study of gamma-irradiated Polymer Electrolyte for Zn Rechargeable Nanostructured Galvanic Cells
J. Inorg. Organomet. P. 21, 3 (2011)
- 6) A. Foltynowicz, P. Maslowski, T. Ban, F. Adler, K. C. Cossel, C. Briles, J. Ye
Optical frequency comb spectroscopy
Faraday Discuss. 150, 1 (2011).

- 7) Y. Wang, X. Ma, S. Vdović, L. Yan, X. Wang, Q. Guo, A. Xia
Photophysical Property of Photoactive Molecules with Multibranched Push-Pull Structures
Chin. J. Chem. Phys. 24, 563 (2011).

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) D. Aumiler
Coherent accumulation effects in alkali metal vapors
Japanese - Croatian workshop on Material Science, Zagreb
(lecture)
- 2) M. Rakić, G. Pichler
Atomic spectrum of high pressure Cs and Na light sources and their energy usage
7. znanstveni sastanak HFD-a, Primošten, 2011
(poster)
- 3) S. Vdović, H. Skenderović, T. Ban, D. Aumiler, G. Pichler
Degenerate four-wave mixing of femtosecond pulses in sodium vapor
'The 12th National Chemical Dynamics Symposium', Chengdu
(poster)
- 4) T. Ban, A. Foltynowicz, P. Maslowski, F. Adler, D. Aumiler, G. Pichler, J. Ye
Direct frequency comb spectroscopy: time and frequency domain approach
43rd EGAS, Fribourg, Switzerland, 2011
(invited lecture)
- 5) G. Pichler, M. Rakić
Atomic spectra of high-pressure Cs and Na light sources and their energy applications
43rd Conference of the European Group for Atomic Systems,
(Fribourg, Switzerland June 28 – July 2, 2011, poster page 83)

TEACHING

COURSES

- 1) N. Vujičić
 - Elektrodinamika
winter semester, undergraduate study, PMF Zagreb
(2011/2012)
- 2) D. Aumiler
 - Osnove atomske i molekulske fizike
summer semester, undergraduate study, PMF Zagreb
(2011/2012)
- 4) G. Pichler

MENTORSHIP

- 1) G. Pichler
 - N. Vujičić, PhD defended on 15.12.2011, Physics Department, Faculty of mathematics and natural sciences, University of Zagreb.

- M. Rakić, PhD student, Physics Department, Faculty of mathematics and natural sciences, University of Zagreb.
- 2) T. Ban
 - Gordana Kregar, Ph.D. student, Physics Department, Faculty of mathematics and natural sciences, University of Zagreb.
 - 3) D. Aumiler
 - M. Šoštar, Diploma work, Physics Department, Faculty of mathematics and natural sciences, University of Zagreb
 - 4) H. Skenderović
 - Z. Pašić, Diploma work:
"Pobuđivanje i opažanje valnih paketa pomoću ultrakratkih laserskih pulseva "
Department of Physics, Faculty of Science, University of Zagreb
(7/10/2011).

SCIENTIFIC VISITS

- 1) T. Ban
 - Joint Institute for Laboratory Astrophysics (JILA), University of Colorado, Boulder, USA.
(01/09/2010-31/05/2011)
- 2) G. Pichler
 - Physics Department, University of Kuwait, Kuwait
(19/11/2011- / /)
- 3) S. Vdović
 - The State Key Laboratory of Molecular Reaction Dynamics, Institute of Chemistry Chinese Academy of Sciences, Beijing, China
(14/02/2011- / /)
- 4) H. Skenderović
 - University of Heidelberg, Physical Chemistry Institute
(01/06/2011-01/09/2011)
 - University of Wien, Wien, Austria
(14/11/2011)

AWARDS

- 1) T. Ban
 - Fulbright grant for academic year 2010/2011

REVIEWING

- 1) G. Pichler
 - Physical Review A B, Physical Review Letters, Optics Communications, Journal of Physics B D, European Physical Journal, MZOŠ projekti,
 - European Physical Journal plus (associate editor)
- 2) D. Aumiler
 - Journal of the Optical Society of America B
- 3) S. Vdović
 - Journal of Physics B: Atomic, Molecular & Optical Physics
 - Journal of Optics

- 4) H. Skenderović
- Journal of Physics B: Atomic, Molecular & Optical Physics
 - Journal of Physics D: Applied Physics

POPULARIZATION OF PHYSICS

- 1) D. Aumiler
- Laser Harp
Science Fair (Zagreb, Split, Sinj)
 - Laser Harp
Open Day of the Institute of Physics
- 2) N. Vujičić
- Lasers in Communications
Science Fair (Zagreb)
 - A miracle of colors
Documentary program, Croatian National Television
 - Laser Harp
Open Day of the Institute of Physics

MISCELLANEOUS

- 1) G. Pichler
- Member of American Physical Society, Optical Society of America, Institute of Physics England, Deutsche Physikalische Gesellschaft
- 2) T. Ban
- Executive secretary of the Independent Union in science and education for the Institute of Physics, Zagreb.
 - Member of the Croatian national Committee for physics competition for high school students (experimental part)

LABORATORY FOR LASER SPECTROSCOPY OF COLD PLASMA

HEAD

Dr. Slobodan Milošević

Co-workers

Dr. Nikša Krstulović, Zlatko Kregar, B.Sc., Marijan Bišćan, B.Sc.

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

We studied several types of plasmas and their combinations: plasmas produced by lasers and/or discharge plasmas using electrodeless RF-IC discharge or single-electrode discharge at atmospheric pressures. We focus our research towards in situ diagnostics of various radicals formed in plasmas. Simultaneous uses of complementary laser techniques such as CRDS, LIBS, LA TOF MS or OES provide advances in plasma characterization. We focus on new optimized plasma sources development for various applications in biomedicine, new food preparation technologies or for advanced materials preparation.

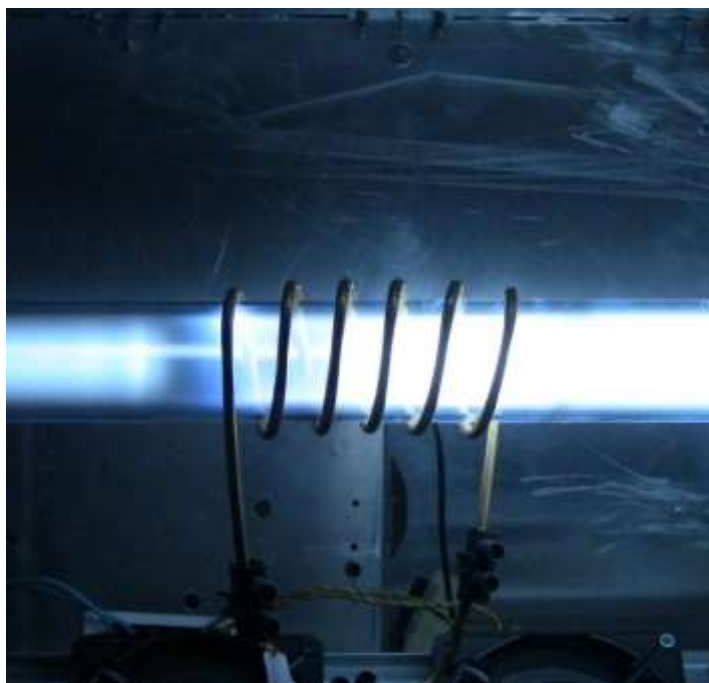


Laser produced plasmas

When an intense focused laser pulse hits a solid or liquid target, dense and hot plasma is produced in early stage followed by rapid expansion into the vacuum or background gas environment. Most of particles move out perpendicularly to the target surface but due to collisions certain number of atoms is reflected back to the target. The backward scattering of ablated species is usually experimentally observed indirectly through deposits on the target. We employed cavity ringdown spectroscopy (CRDS) technique to measure the Fe atom ground state densities through measurements of spectral line shapes in the regions above and below the target. To demonstrate the method properly, care was taken to keep LA parameters fixed. Peculiar line shapes were observed depending on temporal and spatial observation parameters. These lines were then interpreted through modeling which takes into account angular distribution of atoms and their velocity distributions [M. Bišćan and S. Milošević submitted to Spectrochimica Acta B].

Low pressure inductively coupled plasmas

The CO molecule is a common molecular product observed upon reactive oxygen plasmas treatment of various organic materials [IEEE Transactions on Plasma Science, (2011) 39(5) 1239-1246]. As such, its spectral analysis is important for deducing molecular excitation schemes and atomic processes



involved during plasma applications. In most cases, excited CO is a product of dissociation of CO₂, oxidation of various carbon compounds or simply excitation of CO in collisions with electrons. All these processes result in different excited state ro-vibrational population of the CO which give different

emission spectra. In this research we used optical emission spectroscopy to study CO spectra in CO, CO₂ and oxygen plasmas under conditions of low pressure inductively coupled RF discharge. Quantum-mechanical spectral simulation of four CO electronic transitions emitting from 200 nm to 1000 nm have been performed and compared with observations. Different CO excitation mechanisms are discussed [poster presentation Bohinj 2011].

Atmospheric plasmas

We have developed new single-electrode atmospheric plasma source operating at 2kV and 35 kHz. Operating gas is either helium or argon at a flow rate of about 2 l/min. The plasma jet is typically of 1 cm length. Plasma source has been characterised by optical emission spectroscopy. The experimental set-up has been built which allows plasma treatment of various objects, with position control, temperature monitoring (pyrometer) and optical emission spectroscopy monitoring. Other plasma source variants (multi-capillary) are under development.



Laser produced plasma in advanced materials research

In [Applied Surface Science (0169-4332) 257 (2011), 12; 5358-5361] we have investigated the effect of nanosecond laser pulse lengths on the ablation of GaAs in an inert atmosphere. The number of pulses was varied in order to find the optimal condition for nano particles formation in our setup. The deposited structures were studied by grazing incidence small angle X-ray scattering and atomic force microscopy. It is shown that the GaAs nanoparticle sizes and size distributions can be controlled partly by the number of laser pulses applied in their production. In addition GaAs plasma plume has been characterised by time-gated emission spectroscopy. Thin films of titanium on Si substrate were produced by dual pulse PLD technique.

Biomedical applications of plasmas

Two applications were considered. The work on use of low pressure hydrogen plasma for etching of dental posts has been completed as a part of Višnja Negovetić Mandić doctoral thesis (School of Dental Medicine University of Zagreb, 10.06. 2011, 94 str. supervisor, prof. Zrinka Tarle). Particularly, trans-illumination of composite posts after treatment in cold H₂ plasma has been studied. In conclusion, etching of posts in plasma increases trans-illumination of posts up to 10% which may enable better setting of adhesive cements compared to standard treatment with orthophosphoric acid. New application has been initiated on use of atmospheric plasma for treatment of hard dental tissue, which is planned as a part of Vedran Šantak doctoral thesis (co-supervisors S. Milošević and Z. Tarle).

PROJECTS

Title: Laser spectroscopy of cold plasmas for treatment of materials

Project type: MZOŠ (035-0352851-2856)

Head researcher(s): S. Milošević (IF)

Duration: 2007-2011

SCIENTIFIC COLLABORATION

- 1) OES of oxygen plasmas and applications
S. Milošević (IF), M. Mozetič (IJS, Ljubljana)
- 2) OES of argon containing plasmas
S. Milošević (IF), D. Gracin (IRB, Zagreb)
- 3) Laser induced fluorescence of powders
S. Milošević (IF), B. Gržeta (IRB)
- 4) Atmospheric plasmas applications in dentistry
S. Milošević (IF), Z. Tarle (SD, Univ.Zagreb)
- 5) Plasma diagnostics
S. Milošević (IF), J. Dobrinić, N. Glavan-Vukelić (ThRi)

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) Z. Kregar, S. Milošević, A Vesel
Optical emission from oxygen plasma in E and H modes
IEEE Transactions on Plasma Science, (2011) 39(11) 2002-3
- 2) Z. Kregar, M. Bišćan, S. Milošević, A Vesel
Monitoring Oxygen Plasma Treatment of Polypropylene with Optical Emission Spectroscopy
IEEE Transactions on Plasma Science, (2011) 39(5) 1239-1246
- 3) P. Dubček, B. Pivac, S. Milošević, N. Krstulović, Z. Kregar, S. Bernstorff
Pulsed Laser ablation of GaAs using nano pulse length
Applied Surface Science 257 (2011) 5358–5361
- 4) A. Das Arulsamy, Z. Kregar, K. Eleršič, M. Modič, U. Shankar Subramani

Polarization induced water molecule dissociation below the first-order electronic-phase transition temperature
Physical Chemistry Chemical Physics. 13 (2011) , 33; 15175-1

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) M. Bišćan, Z. Kregar, N. Glavan-Vukelić, S. Milošević
Analysis of CO emission spectra observed in plasmas
18th Int.Sci. Meet. on Vacuum Sci. and Tec., Bohinj, 2011
(poster)
- 2) Z. Kregar, M. Bišćan, S. Milošević
Spectroscopy of cold plasmas during treatment of polymers under laser irradiation
20th International Laser Physics Workshop, Sarajevo 2011
(lecture)
- 3) Z. Kregar, M. Bišćan, S. Milošević, K. Eleršić, R. Zaplotnik, G. Primc, A. Vesel, U. Cvelbar, M. Mozetič
Optical Emission Characterization Of Extremely Reactive Oxygen Plasma During Treatment Of Graphite Samples
18th Int.Sci. Meet. on Vacuum Sci. and Tec., Bohinj, 2011
(poster)
- 4) M. Bišćan, S. Milošević
Study of backscattered atoms within laser produced plasma plume
20th International Laser Physics Workshop, Sarajevo 2011
(lecture)
- 5) V. Negovetić Mandić, S. Milošević, B. Janković, I. Ciglar, K. Prskalo, Z. Tarle
Transillumination of composite posts after treatment in cold H₂ plasma
CED- IADR, Budapest, 2011
(poster)
- 6) N. Krstulović, K. Salamon, M. Modič, M. Bišćan, O. Milat, S. Milošević
Morphology of thin Ti-films produced by double-pulse laser deposition
18th Int.Sci. Meet. on Vacuum Sci. and Tec., Bohinj, 2011
(poster)
- 7) R. Stefanuik, N. Krstulovic, B. Ramakrishna, E. Sokell, P. Dunne, F. O'Reilly, G. O'Sullivan
X-ray emission from Indium target produced from a 30 fs 1 TW laser
I-SWAMP, Dublin, Ireland, 21-23 July 2011
(poster)

LECTURES AND SEMINARS

- 1) S. Milošević
 - Laser and plasma applications in industry (in Croatian)
Workshop: Physics applications: Department of Physics, Univ. Zagreb
(22/02/2011, lecture)
 - Light, lasers and plasmas (in Croatian)
Festival Znanosti, Rijeka
(13/04/2011, lecture)
 - MC projects form evaluator perspicitve (in Croatian)
INFO day, FESB, Univ. Split
(26/05/2011, lecture)

- 2) N. Krstulović
 - Presentation of current work on Mid-term-review (FIRE project under EU Marie Curie FP7-PEOPLE-IAPP-2008 programme) (10/11/2011, Dublin)

TEACHING

COURSES

- 1) S. Milošević
 - Molecular beam methods
lecturer, PhD studies, Faculty of Science, University of Zagreb (2010/2011)

MENTORSHIP

- 1) S. Milošević
 - Zlatko Kregar, doctoral study 3rd year
Department of Physics, Faculty of Science, University of Zagreb
 - Marijan Bišćan, doctoral study 2nd year
Department of Physics, Faculty of Science, University of Zagreb
 - Vedran Šantak, doctoral study 2nd year
School of dental medicine, University of Zagreb
co-mentor prof. Zrinka Tarle

SCIENTIFIC VISITS

- 1) N. Krstulović
 - UCD Dublin, Ireland
(01/02/2011-31/12/2011)

ORGANIZATION OF SCIENTIFIC MEETINGS AND BOARD MEMBERSHIPS

- 1) S. Milošević
 - Member of the Program board 18th International Scientific Meeting on Vacuum Science and Technology, Bohinj, 2011

REVIEWING

- 1) Z. Kregar
 - IEEE Transactions of Plasma Science

POPULARIZATION OF PHYSICS

- 1) M. Bišćan
 - Institute of Physics Open day - laboratory presentation
25.03.2011

- Lasers in communications, participation in workshop at Festival znanosti, Zagreb
11.04.2011
- 2) Z. Kregar
 - Institute of Physics Open day - laboratory presentation
25.03.2011
 - Lasers in communications, participation in workshop at Festival znanosti, Zagreb
11.04.2011

MISCELLANEOUS

- 1) S. Milošević
 - President of the Croatian Vacuum Society
 - Member of the "Matični odbor"
 - MC FP7 projects evaluator
 - Croatian representative for the COST project MP1101 BioMedical applications of atmospheric plasmas
 - Councillor of the Croatian Vacuum Society in IUVSTA
- 2) N. Krstulović
 - member of the Croatian Vacuum Society
- 3) Z. Kregar
 - member of the Croatian Vacuum Society
- 4) M. Bišćan
 - member of the Croatian Vacuum Society

GROUP FOR THEORETICAL ATOMIC AND MOLECULAR PHYSICS

HEAD

Dr. Mladen Movre

Co-workers

Dr. Robert Beuc, Dr. Berislav Horvatić, Goran Gatalica, B.Sc.

MAJOR RESULTS

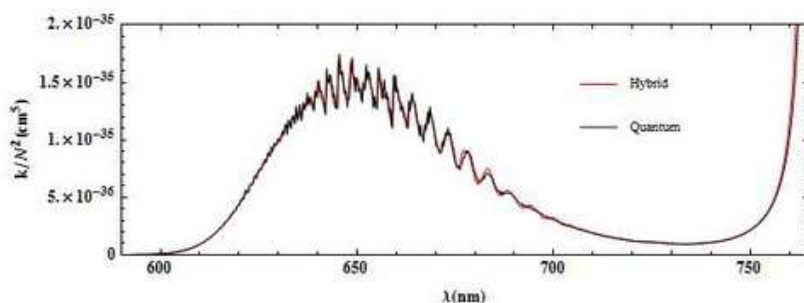
GENERAL OVERVIEW OF ACTIVITIES

The main objective was the construction of a numerically efficient method for calculation of optical spectra of diatomic molecules which unites good properties of the semiclassical and quantum mechanical approach. The method enables the analysis of spectra in ultracold conditions, spectra of molecules adsorbed on cold He droplets, as well as the analysis of spectra of hot gases, either in laboratory conditions or in the atmospheres of cold stars. Fundamental studies mentioned above could be used in applied research as well (e.g. design and optimization of efficient light sources).

Towards the efficient numerical methods

We developed a full quantum mechanical procedure for calculating the emission and absorption spectra of diatomic molecules in dense weakly ionized plasma at high temperatures. Discrete and continuous spectrum contributions, which are the result of transitions between bound, free, and quasi-bound states of diatomic molecules were treated on the same footing. The relevant rovibrational energies and wave functions were determined using the Fourier grid Hamiltonian method. Using the stationary-phase approximation and the classical Franck-Condon principle, we developed a "quasiquantum" simulation method of the spectrum, which allows a time-efficient algorithm, suitable for use in the spectroscopic data analysis. Theoretical results we obtained were tested by comparison with experimental absorption spectra of potassium molecules at different temperatures. Vibration band continuum approximation of Lam, Gallagher, and Hessel described extremely well the discrete spectrum structure due to the transitions from deeply bound rovibrational states, but less correctly the one due to transitions from weakly bound and free states. The semiclassical approximation does not give the rovibrational molecular structure of the spectrum bands, but agrees perfectly with the averaged out quantum mechanical spectra. The quasiquantum approximation is in very good agreement with full quantum calculations, while its consumption of computer time is lower by three orders of magnitude. A disadvantage of this method is a not sufficiently good description of the discrete structure of molecular bands. For the calculation of the absorption spectrum of the B-X transition at the temperature of 985 K, the computer time required (quad-core 3 GHz

processor, 8 GB RAM) amounts to 2675 s for the full quantum calculations, 59 s for the LGH approximation, 0.17 s for the semiclassical, and 0.16 s for the quasiquantum approximation. It was found that our theoretical approach gives much better results than recent studies by other authors [F. Talbi et al, Eur. Phys. J. D 50,141–151(2008)]. If accurate molecular electronic potential curves and corresponding electronic transition dipole moments are known, it is possible, by using the fast quasiquantum approach and comparing the obtained theoretical spectra with experimental data, to determine the temperature and number density of molecules in real time.



Nonadiabatic mixing

Nonadiabatic mixing of molecular electronic dimer states in the region of avoided crossing of molecular potential curves of the same symmetry leads to nonradiative transitions among them. We analyzed the influence of the nonadiabatic mixing on the optical spectra using the full quantum and “quasiquantum” approach, as well as a simple semiclassical Landau-Zenner model. The quantum and quasiquantum calculations were applied for the case of absorption to the (1) 1-Sigma-u and (1) 3-Pi-u states exhibiting the nonadiabatic mixing. Absorption spectra calculated for K2 and Rb2 molecules in both adiabatic and diabatic electronic state representations were compared to the coupled-channels calculations.

PROJECTS

Title: Physics of atoms and molecules under extreme conditions
 Project type: MZOŠ (035-0352851-3213)
 Head researcher(s): R. Beuc (IF)
 Duration: 2007-2011

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) M. Movre
 Notes on Light - Concepts and Models (in Croatian)
 X. Croatian Symposium on Physics Education, Zadar, 2011
 (invited lecture)
- 2) R. Beuc, G. Gatalica, M. Movre
 New contributions to the theory of optical spectra of diatomic molecules
 (in Croatian)

TEACHING

COURSES

- 1) M. Movre
 - Quantum theory of atoms and molecules (in Croatian)
lecturer, doctoral studies in physics, Faculty of Science, University of Zagreb
(2011/2012)
 - Physics of cold collisions (in Croatian)
lecturer, doctoral studies in physics, Faculty of Science, University of Zagreb
(2010/2011)
- 2) R. Beuc
 - Theory of optical spectra of diatomic molecules (in Croatian)
lecturer, doctoral studies in physics, Faculty of Science, University of Zagreb
(2010/2011)
 - Physics
lecturer, undergraduate studies, University of Applied Health Studies, Zagreb
(2010/2011)
- 3) G. Gatalica
 - Physics 1
assistant, undergraduate studies, Faculty of Chemical Engineering and Technology, Univ. of Zagreb
(2010/2011)
 - Physics 2
assistant, undergraduate studies, Faculty of Chemical Engineering and Technology, Univ. of Zagreb
(2010/2011)

MENTORSHIP

- 1) R. Beuc
 - G. Gatalica, doctoral thesis
Department of Physics, Faculty of Science, University of Zagreb

REVIEWING

- 1) M. Movre
 - The European Physical Journal Plus
 - Manualia universitatis studiorum Zagrabiensis, Faculty of Graphic Arts

MISCELLANEOUS

- 1) M. Movre
 - Chairman of the Scientific Council
 - Member of the Council for Cooperation (IRB, IF, Univ. Zagreb)

COHERENT OPTICS LABORATORY

HEAD

Dr. Nazif Demoli

Co-workers

Dr. Kristina Šariri

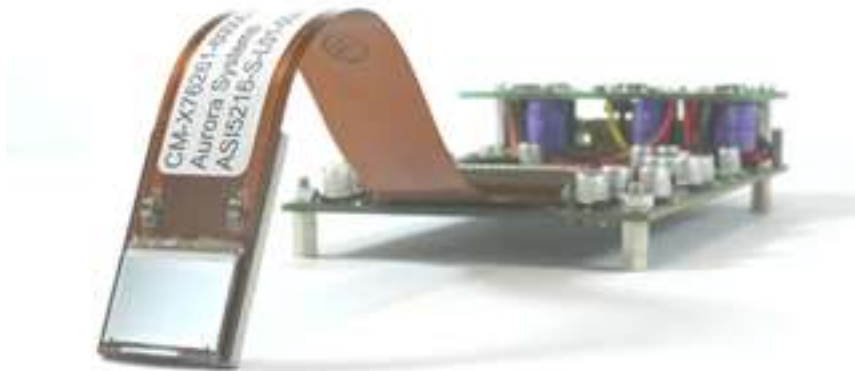
MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

Research activities were focused on optimizing the experimental procedures used in digital holography, and laser and holographic interferometry. This primarily refers to the utilization of a liquid crystal on silicon (LCoS) spatial light modulator, which is a reflective microdisplay based on a silicon backplane technology. Due to its modulation characteristics, the LCoS is used to provide high-quality optical reconstruction of digital holograms in real-time. Many of our activities are organized in collaboration with the research groups inside and outside of the Institute.

Optical reconstruction of digital holograms

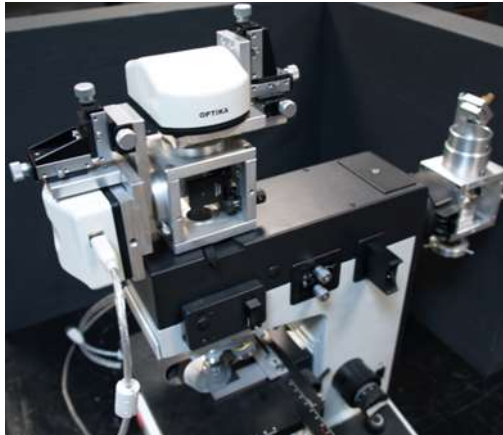
Basic laboratory device for the optical reconstruction of digital holograms is LCoS (resolution: 1920 x 1080, diagonal: 0.55", pixel pitch: 6.4 μm , frame rate: 60 Hz), see Fig. 1. Its uses cover different areas of laboratory work, from optimizing setup parameters to monitoring the vibration modes obtained by the time-averaged digital holographic interferometry measurements.



Digital-optical holographic microscope (DOHM)

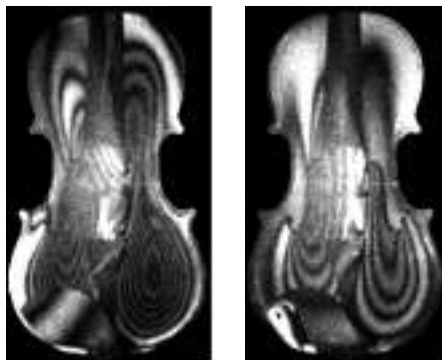
The DOHM is a holographic microscope with optical recording of digital holograms of microscopic samples and digital or optical reconstructing of the

recorded holograms. Use of the LCoS allows instantaneous observing of the phase changes. In collaboration with the SAXS laboratory (dr. O. Milat), the DOHM development is based on upgrading a commercial optical microscope (Leitz), see Fig. 2. At the end of the year the DOHM was completed by two identical digital cameras for performing various algebraic operations with holograms.



Time averaged digital holographic interferometry (TADHI)

Time averaged digital holographic interferometry (TADHI) commonly used for analyzing vibration properties of objects, combined with the LCoS microdisplay allows monitoring of vibration modes in real-time. The system was applied for investigating the influence of different chin rest mountings on the vibrational properties of the violin body in its whole interval of frequencies (from 196 Hz to 3520 Hz). The vibration fringe patterns at frequency 659 Hz are illustrated in Figs. 3(a) without load and 3(b) with 8 kg load applied perpendicularly to the chin rest surface.



Characterization of dental materials by digital laser interferometry

Characterization of dental materials by digital laser interferometry
In collaboration with the School of Dental Medicine, University of Zagreb (prof. Z. Tarle), we have investigated the dimension variations of dental materials during polymerization applying digital laser interferometry. The goals were to determine the dimensional changes as well as the temperature

distribution and the hardness of the variety of commercially available materials, composite resins and glass ionomers, under different curing protocols.

Image recognition by moment analysis

Image moment analysis is applied to the pattern recognition problems. We investigate the sensitivity of moments to noise with the corresponding coefficient corrections. The method is applied to the comparative analysis of characters from two Glagolitic tablets. Another application was to compare the similarity of spectra of a microseismic sample recorded in the time interval immediately before and after the earthquake.

PROJECTS

Title: Development of digital procedures in holography and interferometry
Project type: MZOŠ (035-0352851-2854)
Head researcher(s): N. Demoli (IF)
Duration: 2007-2011

SCIENTIFIC COLLABORATION

- 1) Polymerization shrinkage measurements of dental materials using laser interferometry
N. Demoli (IF) and Z. Tarle (School of Dental Medicine, University of Zagreb)
- 2) Digital holography
N. Demoli (IF) and D. Vukičević (University of Strasbourg, France)

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) D. Đurek, N. Demoli
Vibrations in the loudspeaker enclosure evaluated by hot wire anemometry and laser interferometry
Proc. 130th Audio Engineering Society Convention 2011, (Curran Associates, Inc., New York), 68(2011)

EXPERT ARTICLES

- 1) N. Demoli
Chin rest influence on the vibrational properties of the violin resonator by time-averaged digital holography (in Croatian)
Institute of Physics, expertise (19 pages)

BOOKS / CHAPTERS IN BOOKS

- 1) N. Demoli
3D visual information and holography: scientific foundations of media attractiveness (in Croatian)

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) N. Demoli
Holographic concept - interpretation and applications (in Croatian)
7th scientific meeting of Croatian Physical Society, Primošt
(plenary lecture)
- 2) V. Pandurić, M. Mrakužić, K. Šariri, I. Sović, N. Demoli, Z. Tarle
Does "soft-start" curing mode really makes a difference
CED IADR, Budapest, 2011
(poster)
- 3) D. Matošević, Z. Tarle, K. Šariri, I. Sović, N. Demoli, D. Škrtić, G. Schmalz
Evaluation of polymerization contraction of experimental composites
using laser interferometry
CED IADR, Budapest, 2011
(poster)
- 4) I. Sović, K. Šariri
Comparing microseismic noise spectra by the image moments
Geofizički izazovi 21. stoljeća, Zagreb, 2011
(poster)

LECTURES AND SEMINARS

- 1) N. Demoli
 - Hologram - caught light (in Croatian)
Festival of Science, Rijeka
(13/4/2011, lecture)
 - Holography (in Croatian)
Festival of Science, Split
(14/4/2011, lecture)

TEACHING

COURSES

- 1) N. Demoli
 - Optics and Holography (in Croatian)
lecturer, postgraduate study, Faculty of Science, University of Zagreb
(2010/2011)

MENTORSHIP

- 1) N. Demoli
 - J. Spajić, doctoral study
Comparison of dimensional changes and mechanical properties of
biactive restorative materials
School of Dental Medicine, University of Zagreb
 - M. Mrakužić, doctoral study
Analysis of physical properties of photopolimerization composite
materials with various organic matr
School of Dental Medicine, University of Zagreb

REVIEWING

- 1) N. Demoli
 - Opt. Express, J. Opt. Soc. Am. A and B, Opt. Eng., Opt. Lett., Chinese Opt. Lett., Appl. Opt.

POPULARIZATION OF PHYSICS

- 1) N. Demoli, K. Šariri
 - Holograms - Institute's logo
 - Open day of the Institute of Physics, Zagreb (25/3/2011)

MISCELLANEOUS

- 1) N. Demoli
 - E-school project leader "Coherent Optics"
 - memberships: OSA, SPIE, Croatian Physical Society, Croatian Microscopy Society
 - assistant director

LABORATORY FOR LASER INTERFEROMETRIC MEASUREMENTS OF CRYSTAL GROWTH

HEAD

Dr. Zlatko Vučić

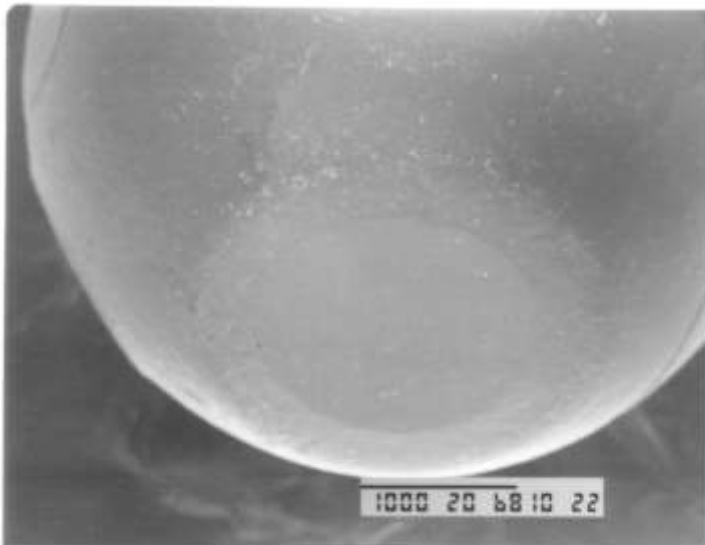
Co-workers

Dr. Jadranko Gladić, Dr. Davorin Lovrić

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

Fundamental aspects of growth of monocrystals at constant temperature have been studied on Cu_{2-x}Se monocrystals, which are superionic conductors with high diffusivity of metallic ions at temperatures between 420 K and 1450 K,



thus having fast shape equilibration. Our experiments have shown the oscillations in facet growth rate during growth and require continuous in situ measurements of both position and diameter of the facet. This has been accomplished by simultaneous measurement of crystal diameter using microscope and CCD camera (resolution of 2-5 μm) and of facet advancement by digital laser interferometry.

In situ measurements of copper selenide monocrystals growth

In situ measurements of the growing copper selenide monocrystals Cu_{2-x}Se belongs to a group of superionic conductors having high diffusivity of metallic ions, enabling fast relaxation of surface perturbations during growth at high temperatures of specimen of mm dimensions. The only other materials featuring this property are ^4He crystals growing at mK temperatures, on which a new facet growth mode, called eruptive has been found. This mode could not be understood in classical terms, since it was found that the threshold pressure for facet advancement was higher for higher growth temperature. On the other hand our experiments on Cu_{2-x}Se monocrystals at high temperatures (about 800 K) have shown oscillations in facet growth rate, similar to the low temperature ^4He case. Since our high growth temperatures exclude quantum effects, the explanation for the behavior of the threshold potential for facet advancement should be found within the classical physics. To this end, very precise in situ measurements of both facet diameter and its position during growth are performed.

Phase unwrapping

In interferometry data analysis, the generally unsolved phase unwrapping problem requires special attention.

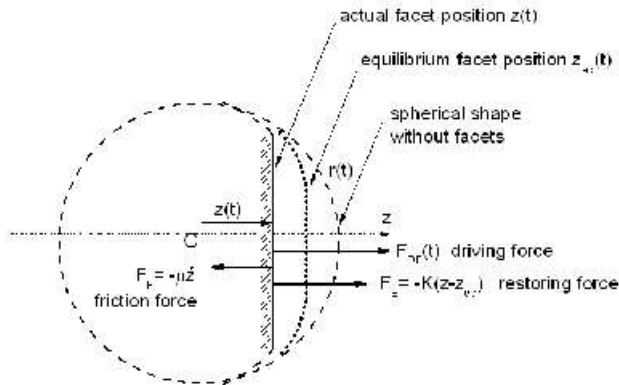
From interferograms one gets wrapped phase field which must be unwrapped to get true mean phase related to facet displacement. In standard commercial algorithms artificial jumps of $\pm n$ influence the mean phase field value. The changes of mean value in time give the displacement trajectory. Improved unwrapping is needed for correcting phase field and phase temporal changes.

We work with differences of two consecutive phase fields, thus eliminating systematic errors. The difference phase field consists of two smoothly varying 'base planes' with a number of artificial jumps. Our algorithm recognizes and unwraps them by adding $\pm n$ when difference between neighboring values is greater than threshold chosen by minimizing standard deviation of each unwrapped field.

The phase displacements trajectory still has noise and some artificial jumps of $\pm n$, indicated by standard deviation peaks. As they originate from the 'base planes' ambiguity, we are allowed to correct them.

Facet equation of motion

By monitoring in situ the growth of Cu_{2-x}Se crystals from almost a seed to a sphere-like crystal having 2 mm in diameter, a strong and continuous deformation of the spherical shape to a polyhedral one has been noticed. By treating the growing crystal as a self-regulating system, we have described the facet kinetics by a macroscopic equation of motion containing three forces which simultaneously govern facet motion. Such global treatment of the facet kinetics enables one to study the facet motion without the inclusion of local supersaturation into equation. The solution shows that the facet behaves as a forced harmonic oscillator with critical damping and is in excellent agreement with our experiments. The microscopic background of such anomalous facet kinetics, i.e. of the facet inertia is the effect called kinetic faceting.



Forces acting on facet

Radiation measurements around X-ray cabinet systems

In collaboration with the scientist from the Institute of Medical Research and Occupational Health the exposure of airport security personnel operating X-ray units for control of hand luggage and personal items to scattered X-ray radiation has been studied. By using the active electronic dosimeters a new approach to investigations of the directions of breaches of scattered X-ray radiation has been made. Time dependent dose rates have showed a very good correlation with the number of passengers undergoing security control. It has been shown that the increase in the dose rate during the rush hours is caused by scattered radiation passing through incompletely closed lead curtains. The doses at the entrance of the inspection tunnels have been 50% higher than the ones at the exit, due to the incoherent operational characteristics of X-ray cabinet systems.

Radionuclides studies of the influence of phosphogypse disposal site in nature park Lonjsko polje

The influence of phosphogypse disposal site on ecosystem of the nature park Lonjsko polje has been investigated by use of radionuclides. A model for measurements and data analysis has been constructed as a model of quasistationary diffusion as a matrix for measurements of anisotropic deviations of possible contaminations. The study has been accepted as a prototype study for treatment of other similar disposal sites.

Improvement of measurements of dose rates on the deposition site of unknown radiological contents covered by soil

Investigations of the methodological and measurement elements and procedures for improvement of spatial resolution of surface measurements of dose rates on the deposition site of unknown radiological contents covered by soil have been continued. Particular study for the location of abandoned chemical factory in Kaštela has been accomplished.

PROJECTS

Title: Investigations of shape and growth kinetics of equilibrium-like superionic conductor crystals

Project type: MZOŠ (035-0352851-3215)

Head researcher(s): Z. Vučić (IP)

Duration: 2008-2011

SCIENTIFIC COLLABORATION

- 1) Radiation measurements around X-ray cabinet systems
Z. Vučić and I. Prlić, IMI, Zagreb, Croatia
- 2) Radionuclides studies of the influence of phosphogypse disposal site on nature park Lonjsko polje
Z. Vučić and I. Prlić, Zagreb, Croatia
- 3) Improvement of measurements of dose rates on the deposition site of unknown radiological contents covered by soil
Z. Vučić and I. Prlić, Zagreb, Croatia

TEACHING

MENTORSHIP

- 1) Z. Vučić
 - I. Prlić, doctoral thesis
Physics Department, Faculty of Science, University of Zagreb
 - T. Bituh, doctoral thesis
'Radionuclides studies of the influence of phosphogypse disposal site on ecosystem'
Biology Department, Faculty of Science, University of Zagreb

MISCELLANEOUS

- 1) Z. Vučić
 - Member of the Executive Board of the Croatian Physical Society
- 2) J. Gladić
 - Contact person for dissemination of information on EU Framework projects for research and technology development
 - Member of the Board for intellectual property
 - Expert advisor of the library of the IP
- 3) D. Lovrić
 - Editor of the IP's web pages
 - Coworker on annual selfevaluation of the IP

STATISTICAL PHYSICS GROUP

HEAD

Dr. Katarina Uzelac

Co-workers

Dr. Osor S. Barišić, Dr. Ivan Balog, Dr. Juraj Szavits-Nossan

Co-workers from other institutions

Dr. Zvonko Glumac, Josip Juraj Strossmayer University, Osijek

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

Studies involve theoretical investigations of fluctuation driven phenomena and processes, by using the combination of analytic approaches, specialised many body methods such as renormalisation group and numerical simulations. Investigations were continued along several lines belonging to topics of mayor current interest in statistical physics. Within the to two of these lines, two doctoral theses were successfully completed and defended in 2011 by the graduate students in the group, Ivan Balog and Juraj Szavits-Nossan.

Nonequilibrium phenomena

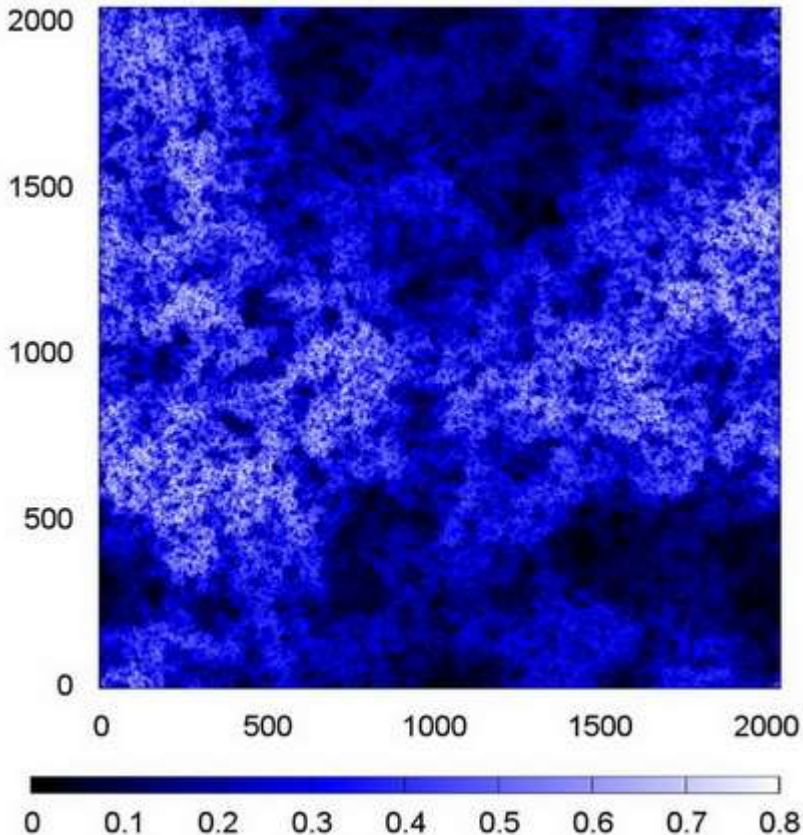
Studies of phenomena out of equilibrium were focused on phase transitions far from equilibrium in simple models of driven diffusive systems, such as the model of asymmetric exclusion process (ASEP). The investigations on the influence of both single defects and finite concentration of impurities leading to a quenched disorder were continued on several generalizations of ASEP model in one and two dimensions. The results on the possibility of the formation of macroscopic shocks and phase separation in the long-range generalization of ASEP model in one dimension and in the anisotropic limits of 2d model were published. In this line of investigations, the doctoral thesis by Juraj Szavits-Nossan, entitled "Phase transitions in driven diffusive systems far from equilibrium" was completed and defended in the fall of 2011.

Disorder and geometrical aspects of phase transitions

Peculiar and still unresolved properties of equilibrium phase transitions in systems with ferromagnetic interactions in presence of quenched disorder were studied using simple Potts model and related random cluster model. The intensive numerical study was performed using the earlier constructed Equilibrium-like Invaded Cluster (EIC) MC algorithm based on geometrical properties of the transition.

Designed to avoid the self-averaging problems, the EIC algorithm was able to provide the first systematic analysis of the critical behaviour where the

disorder average is taken over quantities measured at individual, sample-dependent critical temperatures. New results covering several aspects of the transition were obtained involving the intrinsic critical exponent, distribution of the local order parameter, importance of the inhomogeneity at all scales. First in the series of papers on these results was accepted for publication. The doctoral thesis on this subject entitled: "Continuous phase transition induced by the quenched disorder" was defended by Ivan Balog in the spring of 2011.



Yang-Lee zeros

Yang-Lee zeros related to the complex phase diagram of the classical q -state Potts model were studied on the example of the infinite-range model, that may be approached both analytically and numerically. The analysis revealed multiple contours of zeros in the complex activity plane, observed in literature in numerical calculations performed on small systems. The critical exponents in different critical regimes could also be reproduced from the finite-size scaling properties of zeros closest to the real axis.

Low dimensional quantum systems

Previous investigations have been continued in three main directions. a) In collaboration with the group of prof. Barisic at the Faculty of Science the electronic properties of high- T_c cuprates have been modelled using the 3-

band Emery model and slave fermion technique. A diagrammatic theory has been developed and important properties of electron spectra have been derived. In particular, band renormalizations and incoherent, non dispersive spectral weight have been observed. b) Investigations of polaron and bipolaron related problems have been concluded with a preparation of a comprehensive article, entitled "Bipolarons and polarons in the Holstein-Hubbard model: Analogies and differences". The properties of polarons and bipolarons have been compared and the bipolaron band structure has been discussed as a function of the Hubbard repulsion, including the most intriguing adiabatic limit. c) In collaboration with prof. Prelovsek at the Institute Josef Stefan new problems related to spin chains have been defined.

PROJECTS

Title: Theory of critical phenomena and modelling in many body systems
Project type: MZOŠ (035-0000000-3187)
Head researcher: Katarina Uzelac (IP)
Duration: 2008-2011

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) J. Szavits-Nossan and K. Uzelac:
Absence of phase coexistence in disordered exclusion processes with bypassing
J. Stat. Mech. P05030 (2011).

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) Juraj Szavits-Nossan, participation to the workshop:
Foundations and Applications of Non-Equilibrium Statistical Mechanics,
NORDITA Program, October 3-14, 2011, Stockholm, Sweden

TEACHING

MENTORSHIP

- 1) K. Uzelac
 - Ivan Balog, doctoral thesis:
"Continuous phase transition induced by the quenched disorder",
Department of Physics, Faculty of Science, University of Zagreb
(17/4/2011)
 - J. Szavits-Nossan, doctoral thesis:
"Phase transitions in driven diffusive systems far from equilibrium",
Department of Physics, Faculty of Science, University of Zagreb
(20/10/2011)

SCIENTIFIC VISITS

- 1) • Ivan Balog
Laboratoire de Physique Théorique de la Matière Condensée,
Université Paris 6, Francuska
September-October 2011 • Ecole Polytechnique Fédérale de Lausanne,
- 2) • Prof. G.Schütz,
Institute of Complex Systems, Jlich and
Interdisziplinäres Zentrum für Komplexe Systeme, Universität Bonn

ORGANIZATION OF SCIENTIFIC MEETINGS AND BOARD MEMBERSHIPS

- 1) Katarina Uzelac:
 - Member of the International Advisory Board of the
Middle European Cooperation in Statistical Physics

REVIEWING

- 1) Katarina Uzelac:
 - Physical Review B
 - Physical Review E
 - Physical. Review Letters
 - Physica A
 - Physics Letters

POPULARIZATION OF PHYSICS

- 1) Osor S. Barišić
 - *Organization of the Institute of Physics Open day, 25/3/2011*

MISCELLANEOUS

- 1) Katarina Uzelac
 - Member of the American Physical Society
- 2) P. Popčević
 - Member of the Societ\'e Fran\c caise de Physique

GROUP FOR MODELING OF ELECTRONIC PROCESSES AND DEVICES

HEAD

Dr. Eduard Tutiš

Co-workers

Ivan Jurić, B.Sc

Co-workers from other institutions

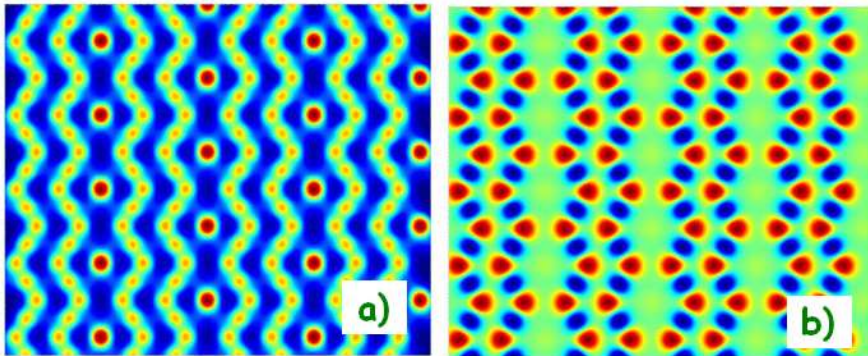
Prof. dr. Ivo Batistić, University of Zagreb

Prof. dr. Ante Bilušić, University of Split

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

The activities of the group are based on intertwining the theoretical and the experimental work on novel electronic phases in crystalline materials, as well as on transport in disordered organics. The previous



The textured ground state for Hubbard-Holstein model on kagome lattice at $2/3$ filling for finite Hubbard U . The search for energy minimum was done within the manifold of states accessible and valued through Hartee-Fock approximation. The states at the boundary between anti-ferromagnetic (AF) phase and bi-polaron phases exhibit the periodic mixture of both. Figure shows (a) the charge density and (b) spin density in the plane. The red dots in (a) stand for bipolarons, appearing as mute in spin density in (b). The zig-zag patterns represent anti-ferromagnetically ordered electrons. (I.B and E.T., 2011).

expertise in systems with strong electron-electron and electron-phonon interactions has been recently complemented by a number of *ab initio* methods for calculating electronic structure and phonon

modes, aiming at prompt parameterization and model-building for new materials.

Current work is mostly related to layered materials, in particular on some compounds showing kagome structure, and some transition metal dichalcogenides exhibiting peculiar electronic order. The members of the group have been recently involved in setting new high pressure lab at the Institute, and on theoretical modelling of phase transitions under pressure in particular materials.

The interest in disordered organic materials is currently directed towards time dependent spectroscopy (dark injection spectroscopy, DITS; time of flight experiments, etc), where the modelling and numerical simulations are expected to reveal the nature of carrier trapping dynamics.

PROJECTS

Title: *New electronic states driven by frustration in layered materials*

Project type: UKF project 1B "Cooperability" Grant-65/10

Head researcher(s): E. Tutiš, L. Forró, N. Barišić, A. Smontara

Duration: June 15, 2010- June 15, 2012

Title : *Modeliranje fizikalnih svojstava materijala s izraženom frustracijom ili neredom* (in Croatian)

Head researcher: E. Tutiš

Vrsta projekta: MZOŠ

Vrijeme trajanja: 2007- 2011

SCIENTIFIC COLLABORATION

- Laboratory of Physics of Complex Matter ,EPF, Lausanne i 1. Physikalisches Institut, Universität Stuttgart (*within project UKF 65/10*)
- Laboratoire de Physique des Lasers, Institut Galilée, Université Paris 13, Francuska, & Laboratoire de photonique quantique et moléculaire, Ecole Normale Supérieure de Cachan, Paris, Francuska (*informal collaboration*)

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) N. Barišić, I. Smiljanić, P. Popčević, A. Bilušić, E. Tutiš, A. Smontara, H. Berger, J. Jačimović, O. Yuli, L. Forró
High pressure study of transport in $Co_{1/3}NbS_2$
Phys. Rev. B **84** (2011) 075157

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) E. Tutiš, I. Batistić, L. Forro
Slabo i jako korelirani elektroni na kagome rešetci (in Croatian)
7th Scientific Meeting of CPS, Primošten, Croatia, 2011 (invited talk)
- 2) I. Krešić, I. Batistić, E. Tutiš
Elektronska struktura čistih i interkaliranih dihalogenida prijelaznih metala (in Croatian),
7th Scientific Meeting of CPS, Primošten, Croatia, 2011 (poster)
- 3) N. Barišić, I. Smiljanić, P. Popčević, A. Bilušić, E. Tutiš, A. Smontara, H. Berger, J. Jačimović, O. Yuli, H. Berger, L. Forró
Mjerenja transportnih svojstava $Co_{1/3}NbS_2$ u ekstremnim uvjetima (in Croatian), 7th Scientific Meeting of CPS, Primošten, Croatia, 2011, (poster)
- 4) P. Popčević, I. Smiljanić, A. Bilušić, A. Smontara, I. Batistić, H. Berger, R. Gaal, J. Jačimović, O. Yuli, L. Forró, E. Tutiš, N. Barišić
Pressure study of $Co_{1/3}NbS_2$
The second international workshop on "Recent advances in broad-band solid-state NMR of correlated electronic systems", Trogir, Croatia, 2011 (poster)
- 5) P. Popčević, N. Barišić, L. Forró, E. Tutiš, A. Smontara
Mjerenja u ekstremnim uvjetima - visoki tlakovi, visoka magnetska polja, široki temperaturni opseg (in Croatian)
7th Scientific Meeting of CPS, Primošten, Croatia, 2011 (poster)

LECTURES AND SEMINARS

- 1) Ivo Batistić, EPFL, Lausanne, CH, April 12, 2011,
Electronic structure calculations in $CoNb_3S_2$,
- 2) Ivo Batistić, EPFL, Lausanne, CH, April 12, 2011,
Polaron formations in graphene nano-ribbons
- 3) Ivan Jurić, NPL, London, UK, June 2012
Transport and recombination in organics: new insights from numerical simulations

TEACHING

COURSES

- 1) E. Tutiš
• *Fizika poluvodiča* (in Croatian)
Postgraduate studies of Natural sciences, Physics, PMF, Zagreb
- 2) Ivan Jurić
• *Statistička fizika, vježbe* (in Croatian)
Faculty of Natural sciences, Physics, Zagreb

MENTORSHIP

The work of Ivan Jurić, Ph. D. student, is supervised and mentored by E. Tutiš

SCIENTIFIC VISITS

- 1) Ivan Jurić, visited National Physics Laboratory, London, June 2011
- 2) E. Tutiš, I. Batistić - several visits to Ecole Polytechnique Fédérale de Lausanne, Switzerland, within collaborative project UKF 65/10

AWARDS

I. Jurić won the EURAMET grant, to support his six-month stay and research at the National Physics Laboratory, London, UK

GROUP FOR STATIC MAGNETIC MEASUREMENTS

HEAD

Dr. Đuro Drobac

Co-workers

Dr. Mirta Herak, Dr. Marko Miljak, retired

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

Laboratory for static magnetic measurements comprises two experimental techniques: Faraday technique for measuring the magnetic susceptibility and torque magnetometry for measuring the magnetic anisotropy. During 2011 these techniques continued to be employed in investigation of low-dimensional spin systems. Main contribution to accomplished results, however, came from collaboration with ESR group from Jožef Stefan Institute in Ljubljana where M. Herak spent her postdoctoral research during large part of 2011. A step towards investigating multiferroic systems using torque magnetometry was also taken.

Quantum spin tetramere CuSeO₃

The diversity of ground states found in low-dimensional quantum spin systems presents a continuous challenge for the condensed matter physicists. The dimensionality of a magnetic lattice and anisotropy of exchange paths can lead to interesting magnetic behaviour even in paramagnetic state where

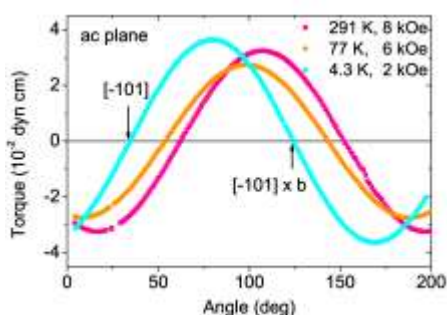


Fig 1. Influence of temperature on the position of magnetic axis (zeros of sine curves) in CuSeO₃ as revealed by torque magnetometry.

there is no long range magnetic order and only short range correlations between spins prevail. In collaboration with I. Živković, D. Starešinić and D. Dominko from the Institute of physics, D. Pajić from the Faculty of Science and Mathematics and D. Djokić and L. Forro from EPFL the new low-dimensional spin tetramer system CuSeO₃ was investigated. Torque

magnetometry revealed strange rotation of magnetic axes in paramagnetic state which was confirmed by ESR measurements (Fig 1.). The results were presented at several conferences and a manuscript recently submitted to Phys. Rev. B. The investigation of this system using torque magnetometry was also the theme of the postgraduate seminar written and held by student M. Čulo.

Investigation of CuSe2O5 by magnetic resonance techniques

Investigating magnetism using only macroscopic static techniques has many limitations. Use of resonance techniques such as electron spin resonance (ESR) and nuclear magnetic resonance (NMR) presents an advantage since these are local techniques able to identify the spin-spin interactions in materials. An introduction to the possibilities of these techniques was postdoctoral project by M. Herak funded by HRZZ. In collaboration with D. Arčon, A. Zorko, M. Pregelj, A. Potočnik, Z. Jagličić and M. Klanjšek from Jožef Stefan Institute in Ljubljana and O. Zaharko from PSI, Switzerland, the quasi-one-dimensional CuSe2O5 system was investigated using magnetic resonance techniques. ESR and NMR were measured at JSI and neutron and μ SR measurements were performed at PSI. The magnetic hamiltonian of the system was determined from ESR measurements and published in Phys. Rev. B [1].

Multiferroics

Possibility of controlling the magnetic order by applying electric field and vice versa can be realised in multiferroics - systems in which magnetic and electric long range order coexist. In collaboration with D. Pajić from Faculty of science and mathematics in Zagreb and prof. Z. Trontelj from FMF in Ljubljana, we have started to investigate magnetic anisotropy of K3Fe5F15, a system which is a multiferroic below the temperature of long range magnetic order (120 K). Main results are expected during 2012.

PROJECTS

Title: *Defects and exchange interaction in low dimensional ($D < 3$) magnetic systems*

Project type: MZOŠ (035-0352843-2846)

Head researcher(s): Đuro Drobac (IP)

Duration: 2007-2011

Title: *Investigation of magnetic ground state of low-dimensional system CuSe2O5 using magnetic resonance techniques*

Project type: HRZZ, Postdoc project

Head researcher(s): Mirta Herak (IP)

Duration: 2011/2012

Title: *Complex magnetic systems*

Project type: HRZZ

Head researcher(s): I. Živković (IP)

Duration: 2011-2014

SCIENTIFIC COLLABORATION

- 1) *Mirta Herak and prof. Denis Arčon (Postdoc visit to ESR group at Jožef Stefan Institute in Ljubljana)*

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) M. Herak, A. Zorko, D. Arčon, A. Potočnik, M. Klanjšek, J. van Tol, A. Ozarowski, and H. Berger
Symmetric and antisymmetric exchange anisotropies in quasi-one-dimensional CuSe₂O₅ as revealed by ESR
Physical Review B 84, 184436 (2011)
- 2) Mirta Herak
Cubic magnetic anisotropy of the antiferromagnetically ordered Cu₃TeO₆,
Solid State Communications 151, 1588-1592 (2011)

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) 1. Dominko, Damir; Starešinić, Damir; Živković, Ivica; Herak, Mirta, Low temperature heat capacity in some low-dimensional systems with unusual magnetic order, 1st Central and Eastern European Conference on Thermal Analysis and Calorimetry, Craiova, Romania, 1st Central and Eastern European Conference on Thermal Analysis and Calorimetry, 2011. 248-248 (poster).
- 2) 1. Herak, Mirta, Magnetska anizotropija izotropnih Heisenbergovih antiferomagneta s bakrenim spinom $S=1/2$, 7.znanstveni sastanak Hrvatskog fizikalnog društva, A. Gajović (ur.). Primošten, 2011. (invited talk).
- 3) 1. Herak, Mirta; Pajić, Damir; Živković, Ivica; Berger, Helmuth. Magnetic anisotropy of low-dimensional CuSeO₃, 2nd workshop on recent advances in broad-band solid-state NMR of correlated electronic systems, Trogir, 2011. 44 (poster).
- 4) 1. Živković, Ivica; Herak, Mirta; Starešinić, Damir; Pajić, Damir; Cinčić, Dominik, Niskodimenzionalno ponašanje u CuSeO₃: slučaj tetramera, 7. znanstveni sastanak Hrvatskog fizikalnog društva, A. Gajović (ur.). Primošten, 2011. (poster).
- 5) Herak, Mirta; Starešinić, Damir; Živković, Ivica; Pajić, Damir; Cinčić, Dominik. Low-dimesional behavior in SeCuO₃: the case of tetramers, 26th International Conference on Low Temperature Physics (LT26), Beijing, China, 2011 (poster).

TEACHING

MENTORSHIP

- 1) Mirta Herak

- Matija Čulo, Magnetic anisotropy of CuSeO₃, seminar at postgraduate course Experimental research in solid state physics, 20/04/2011.

SCIENTIFIC VISITS

- 1) Mirta Herak
 - Jožef Stefan Institute, Ljubljana, Slovenija
(01/03/2011-01/03/2012)
 - Paul Scherrer Institute, Villigen, Switzerland
(01/08/2011 - 12/08/2011)

LABORATORY FOR MAGNETIC AC SUSCEPTIBILITY

HEAD

Dr. Mladen Prester

Co-workers

Dr. Đuro Drobac, Dr. Željko Marohnić, Dr. Ivica Živković

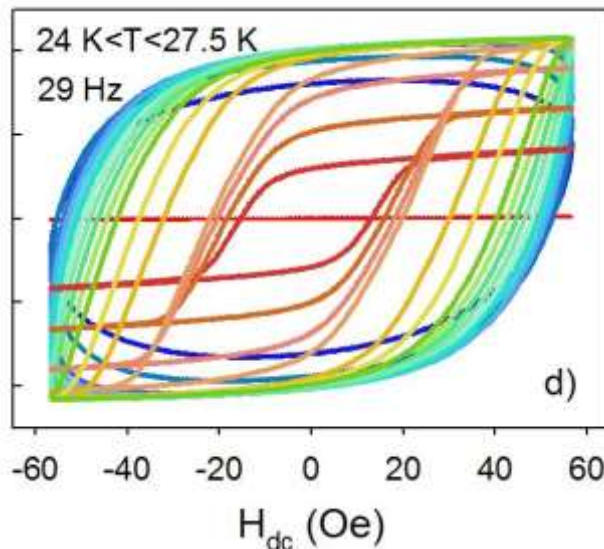
MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

In AC susceptibility laboratory there are several activities going on in parallel- investigation of fundamental properties of new, interesting magnetic systems, like $\text{Co}_7(\text{TeO}_3)_4\text{Br}_6$, $\text{Ca}_3\text{Co}_2\text{O}_6$, $\text{Fe}_8\text{Te}_{12}\text{O}_{32}\text{Cl}_6$, $\text{Yb}_2\text{Sn}_2\text{O}_7$, SeCuO_3 .., design and manufacturing of new, ac-susceptibility-related measuring devices and options, as well as a contract-based experimental work and/or consulting with a pharmaceutical company and with CryoBIND, a spin-off initiative of Institute of Physics, Zagreb.

Magnetic dynamics by ac susceptibility studies

Several years spent in research of magnetic dynamic of new cobalt-based oxohalide $\text{Co}_7(\text{TeO}_3)_4\text{Br}_6$ has been finalized by detailed model analysis of the parameters of measured dynamic hysteresis (coercive field, hysteresis



Set of dynamical hysteresis curves of $\text{Co}_7(\text{TeO}_3)_4\text{Br}_6$ taken in the narrow temperature interval below the ferromagnetic transition ($T_c=27.5$ K).

geometric area) in their dependence on relevant variables (applied field strength, temperature, frequency). Our original general model for dynamic hysteresis has been developed and applied.

The results have been presented in an extensive article, published in 2011. in Phys.Rev.B. In the course of model development its generality has been noted, as well as its potential for magnetic dynamic studies of other magnetic systems. On this track, experimental investigations of another cobalt-based system, $\text{Ca}_3\text{Co}_2\text{O}_6$, revealing important but not yet resolved low-temperature magnetic properties, have been initiated. Another general subject, starting attracting our interest last year, was magnetic dynamics of magnetic nanoparticles and some introductory studies have been performed.

New measuring devices for magnetic susceptibility

For the purpose of planned studies of magnetic dynamics of magnetic nanoparticles in 2011. we started with designing and prototype-level manufacturing of the appropriate high-frequency AC susceptibility device. The primary task was a design of the primary and secondary coils that has to comply with the demands on the measuring field (its strength and frequency range). In parallel, we have been developing the appropriate measuring algorithm which had to take account non-negligible sample contribution to the primary coil inductance. Preliminary tests on the copper sample standard showed entirely satisfactory measuring performance of the prototype device. Within the UKF project we have been also working on the development of a new method of measuring the magnetization at ultra low temperature (below 1 K) using the SQUID-amplifier. The movement of the sample through the detection coils is performed with a piezo-motor. The whole setup is easy to mount and dismount onto the dilution refrigerator.

Magnetism of low-dimensional and frustrated systems

We have measured the magnetic susceptibility of several compositions in the pyrochlore system $\text{Er}_2(\text{Ti},\text{Sn})_2\text{O}_7$. Replacing Ti with Sn induces the reduction of the transition temperature leading to the conclusion that for $x(\text{Sn}) = 1.8$ there exists the quantum critical point. In manganites we have been searching for the change of the transition temperature, related to the metal-insulator transition, with respect to the doping with various rare-earth elements. $\text{Bi}(\text{Cu},\text{Zn})_2\text{PO}_6$ is a weakly coupled spin-ladder system which shows a non-magnetic, singlet state at zero temperature. With Zn doping some of the magnetic moments are left unpaired. We have investigated the composition with $x(\text{Zn}) = 0.05$ and a consequent ground state below 4 K for which we have concluded that it shows the characteristic s of a spin-glass. A new set of coils for the susceptibility in transverse magnetic fields has been made. It allowed us to study how the dynamics of $\text{Ca}_3\text{Co}_2\text{O}_6$ changes when the quantum-mechanical tunnelling through the barrier is enhanced. In the magnetoelectric system Cu_2OSeO_3 we have investigated the behaviour of single crystals in various directions and established the existence of two consecutive transitions. We have begun with the initial investigation of a planar hexagonal system $\text{Fe}_8\text{Te}_{12}\text{O}_{32}\text{Cl}_6$. In collaboration with prof. M. Pozek from the Faculty of Science we have started the NMR investigation of a tetramer system SeCuO_3 .

PROJECTS

Title: Quantum Magnets: Competing Ground States

Project type: MZOS (035-0352843-2845)

Head researcher(s): M. Prester

Duration: 2007-2011

Title: New generation of cryostats for ac susceptibility

Project type: BICRO (POC_01_05-U-1)

Head researcher(s): M. Prester

Duration: 2010-2011

Title: Magnetization of quantum magnets at ultra low temperatures

Project type: UKF, 3A 'My first research topic' Grant 3A, 55

Head researcher(s): dr.sc. Ivica Zivkovic

Duration: 2009 - 2011

Title: Complex Magnetic Systems

Project type: Croatian Science Foundation, start-up grant

Head researcher(s): dr.sc. Ivica Zivkovic

Duration: 2011 - 2014

SCIENTIFIC COLLABORATION

- 1) UKF, Ivica Zivkovic and prof.dr. Henrik Ronnow (EPFL, Lausanne, Switzerland)

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) M. Prester, I. Živković, Đ. Drobac, V. Šurića, D. Pajić, H. Berger
Slow magnetic dynamics and hysteresis loops of the bulk ferromagnet
 $\text{Co}_7(\text{TeO}_3)_4\text{Br}_6$
Phys. Rev. B (2011) 064441.

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) M. Prester, I. Živković, Đ. Drobac, D. Pajić, H. Berger
Dynamic Minor and Major Hysteresis Loops of New Ferromagnetic Oxide
System $\text{Co}_7(\text{TeO}_3)_4\text{Br}_6$
LT26, Beijing, China, 2011
(poster)
- 2) I. Zivkovic, J. Lago, B.Z. Malkin, J. Rodriguez Fernandez, P. Ghigna, P.
Dalmas de Reotier, A. Yaouanc, T. Rojo
First Observation of the Spin Ice State in a Spinel Structure
Physics of Magnetism, Poznan, Poland, 2011
(lecture)
- 3) I. Zivkovic, M. Herak, D. Staresinic, D. Pajic, D. Cincic
Low-dimensional behavior in SeCuO_3 : the case of tetramers
Low Temperature Physics, Beijing, China, 2011
(poster)

TEACHING

MENTORSHIP

- 1) I. Živković
 - I. Levatić, diploma thesis
"Influence of the transverse magnetic field on the magnetic ordering of a quantum magnet Ca₃Co₂O₆"
Department of Physics, Faculty of Science, University of Zagreb
(7/7/2011)

ORGANIZATION OF SCIENTIFIC MEETINGS AND BOARD MEMBERSHIPS

- 1) M. Prester
 - Member of the Scientific Board of the 7th HFD scientific meeting, Primošten (13-16/10/2011)

REVIEWING

- 1) I. Živković
 - Journal of Magnetism and Magnetic Materials
 - Journal of Physics Conference Series
 - Materials Letters
- 2) M. Prester
 - Current Nanoscience

PATENTS

- 1) Patent application:
Cryostat with PTR cooling and two stage sample holder
(DZIV, April 2011)

POPULARIZATION OF PHYSICS

- 1) I. Živković
 - 100 Years of Superconductivity
Summer School for Young Physicists of the Croatian Physical Society,
Mali Losinj, (19 - 25/6/2011)
- 2) D. Drobac
 - Lecture on Galileo Galilei, Science Festival, Rijeka (14.4. 2011.)
- 3) D. Drobac
 - Lecture on ac methods in magnetism studies for the 3rd year physics students within the course on experimental methods in physics

MISCELLANEOUS

- 1) M. Prester and Đ. Drobac
 - Consulting activities within the collaboration between IF and CryoBIND/Sistemprojekt company.
- 2) Ž. Marohnić,
 - Permanently involved in experimental work in physics education with high-school students and their experimental projects.

GROUP FOR DIELECTRIC SPECTROSCOPY AND MAGNETOTRANSPORT PROPERTIES

HEAD

Dr. Silvia Tomić

Co-workers

Dr. Bojana Hamzić, Dr. Tomislav Vuletić, Dr. Tomislav Ivek, Matija Čulo, B.Sc., Danijel Grgičin, B.Sc., Ida Delač Marion B.Sc.

Co-workers from other institutions

Dr. Sanja Dolanski Babić, School of Medicine, University of Zagreb

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

The main activity of the group is divided into several themes that are carried out in three laboratories: Laboratory for dielectric spectroscopy in solid state (Condensed matter physics I - S. Tomić leading scientist), Laboratory for biological physics (Soft matter physics I - S. Tomić leading scientist, Soft matter physics II - T. Vuletić leading scientist) and Laboratory for magnetotransport measurements (Condensed matter physics II – B. Hamzić leading scientist)

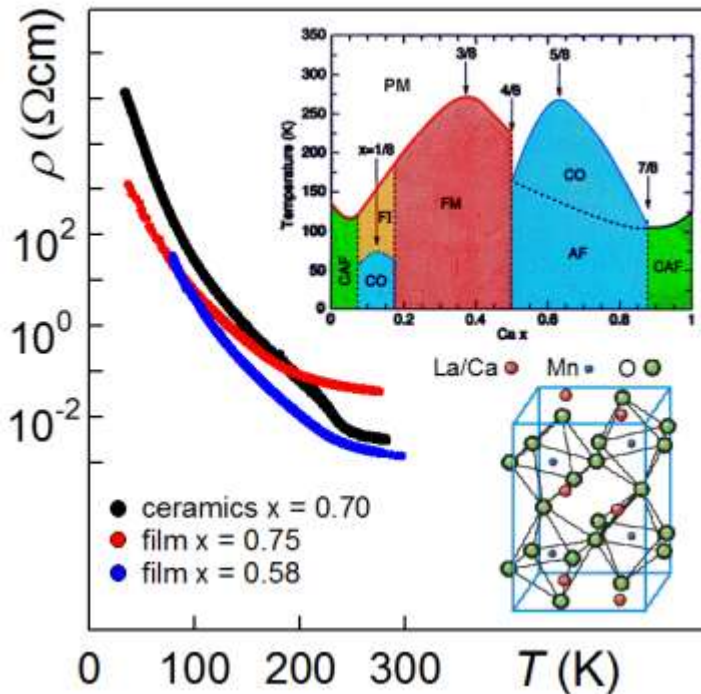
Condensed matter physics I

In the field of condensed matter, we initiated studies of the electrical conductivity in the high varying electric field of quasi-2D organic systems with strong electron correlations such as α -(BEDT-TTF) 2I3. The aim is to establish the existence of nonlinear effects, and thus further characterize the electronic excitations in the charge ordered phase in 2D. The results show the existence of nonlinearities different than those so far observed in quasi-1D with charge-density waves systems. Analysis of the results is in progress. We have also begun investigations of overdoped manganites " $\text{La}_{1-x}\text{Ca}_x\text{MnO}_3$ " in which the charge ordered phase occurs, whose electronic structure is not clear yet. Preliminary dielectric spectroscopy measurements were made on ceramic sample with $x = 0.7$.

Condensed matter physics II

Using TTF-TCNQ nano-particles prepared in the form of film the resistivity measurements have shown minimum in resistivity above room temperature and semiconducting behavior below with no indication of phase transitions. These results are opposed to TTF-TCNQ single crystals, demonstrate the characteristics of granular materials and suggest exploration of the relationship between nanoparticle size and physical properties. We also started the research of the series of manganite samples ($\text{La}_{1-x}\text{Ca}_x\text{MnO}_3$) with different concentrations and synthesis methods (ceramic or film). It is well

La_{1-x}Ca_xMnO₃

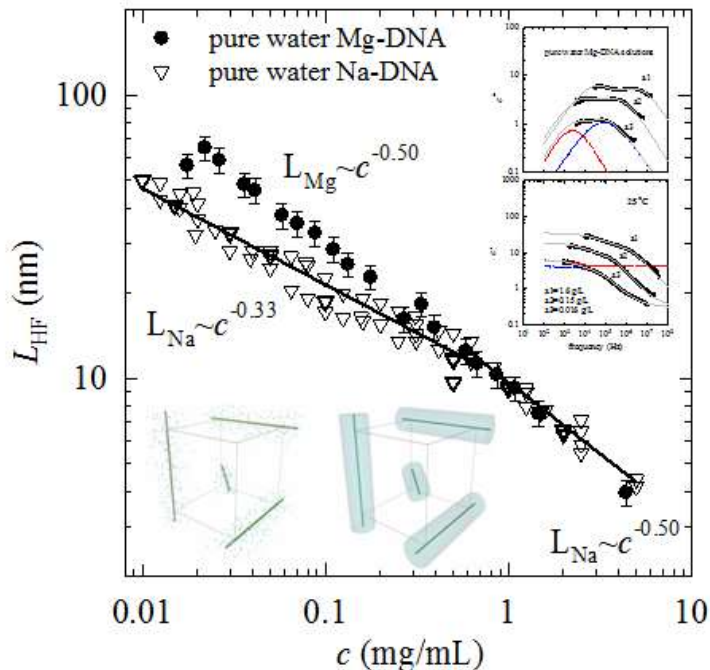


started the research of the series of manganite samples (La_{1-x}Ca_xMnO₃) with different concentrations and synthesis methods (ceramic or film). It is well known that for $x = 0.3$ the compound shows colossal magnetoresistance. Also, while increasing x , magnetoresistance decreases. The very rich phase diagram is not yet adequately investigated for $x > 0.5$ that is a focus of our investigations. We expect that the results of resistivity, magnetoresistance and Hall effect should provide additional information on the nature of this compound especially in the charge ordered and antiferromagnetic phases.

Soft matter physics I

Research was focused on defining the dynamics and thus the structure of DNA solution in the limit of attractive Coulomb interactions. In this respect it is interesting to determine how the choice of polyvalent counterions affects the structure and dynamics of DNA in relation to the well-known Na-DNA in which the repulsive Coulomb interaction dominates. The samples of pure Mg-DNA solutions were prepared from the initial Na-DNA using several different protocols of preparation. Measurements using ion chromatography method confirmed the successful preparation of Mg-DNA samples. The dc electrical conductivity and complex conductivity measurements were performed in a wide frequency range. Analysis of results showed an increased stability of Mg-DNA in the low-salt limit (relative to the Na-DNA) in accordance with theoretical predictions. Also, the pure aqueous Na-DNA solutions were prepared using two different protocols with the aim to test the possible

influence of preparation protocol on the stability of the DNA double helix conformation.



Soft matter physics II

Studies of Manning condensation for rodlike, monodisperse, 150 bp DNA with divalent, Mg^{++} counterions complement previous study of DNA with monovalent Na^+ . Results support a basic theoretical proposition that condensation should increase with counterion valency. We also studied characteristic length scales of semidilute polyelectrolytes, DNA and hyaluronic acid. Study was based on small-angle X-ray scattering experiments performed in collaboration with K. Salamon (IF) and with G. Pabst (OeAW, Graz). We found strong correspondence between the SAXS correlation peaks in DNA and shoulders in HA spectra as theoretically predicted and also with our previous results on characteristic length scales inferred from our Dielectric Spectroscopy studies. We thus covered polyelectrolytes in a broad concentration range 0.01--100 mM. A new version of the dielectric spectroscopy chamber, with a faster temperature response was built. A gel electrophoresis system and a UV-spectrophotometer were installed.

PROJECTS

Title: Strongly correlated inorganic, organic and biomaterials
 Project type: MZOŠ (035-000000-2836)
 Head researcher(s): S. Tomić (IF)
 Duration: 2007-2011

Title: Terahertz spectroscopy of collective excitations in ordered phases of overdoped manganites
Project type: DFG
Head researcher(s): M.Dressel , B. Gorshunov, S.Tomić (IF)
Duration: 2011-2013

SCIENTIFIC COLLABORATION

- 1) Magnetotransport properties
B.Hamzić and M.Basletić, E.Tafra, A.Hamzić (Physics Department Faculty of Science, Zagreb)
- 2) Dynamics of biosystems
S. Tomić and R. Podgornik (University of Ljubljana and Institute Jozef Stefan)

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) T. Vuletić,, S. Dolanski Babić, D. Grgičin, D. Aumiler, J. Raedler, F. Livolant, S. Tomić
Manning free counterion fraction for a rodlike polyion: Aqueous solutions of short DNA fragments in presence of very low added salt
Phys.Rev. E 83 (2011) 041803
- 2) T. Ivek, B.Korin-Hamzić, O.Milat, S.Tomić, C.Clauss, N.Drichko, D.Schweitzer and M.Dressel
Electrodynamic Response of the Charge Ordering Phase: Dielectric and Optical Studies of alpha-(BEDT-TTF)₂I₃
Phys.Rev.B 83 (2011) 165128
- 3) S. Tomić, D. Grgičin, T. Ivek, S. Dolanski Babić, T.Vuletić, G. Pabst
Dynamics and Structure of Biopolyelectrolytes characterized by Dielectric Spectroscopy
Macromolecular Symposia 305 (2011) 43-54

EXPERT ARTICLES

- 1) S. Tomić
The Croatian Physical Society, a small but vibrant and innovative association
Europhysics News 42 (2011) 22
- 2) S. Tomić
Croatian Physical Society: present status and prospects
Il Nuovo Saggiatore 27 (2011) 58

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) S. Tomić
Dynamics and Structure of Biopolymers in Aqueous Solutions: Collective and Single-Chain Properties
ECRYS2011, 15-27August 2011, Cargese (France)
(invited lecture)

- 2) T.Vuletić, S. Dolanski Babić, D. Grgičin, D. Aumiler, S. Tomić
Electrical transport in polyelectrolytes (in Croatian)
7th meeting of Croatian Physical Society, Primošten
(lecture)
- 3) D. Grgičin, S. Dolanski Babić, T. Vuletić, S. Tomić
The dynamics and structure of aqueous solutions of DNA with univalent
and bivalent counterions (in Croatian)
7th meeting of Croatian Physical Society, Primošten
(poster)
- 4) K.Salamon, T. Vuletić
Fundamental length scales obtained by X-ray scattering and dielectric
spectroscopy studies of polyelectrolytes
6th Christmas Biophysics Workshop, Varaždin, Croatia
(lecture)
- 5) D. Grgičin, S. Dolanski Babić, T. Vuletić, I. Ladan, S. Tomić
Dynamics and structure of Mg-DNA aqueous solutions
6th Christmas Biophysics Workshop, Varaždin, Croatia
(lecture)
- 6) T. Ivek, I. Kovačević, M. Pinterić, B. Korin-Hamzić, S. Tomić, D.
Schweitzer, M. Dressel
Charge ordering in alpha-(BEDT-TTF)₂I₃: electric transport and dielectric
response (in Croatian)
7th meeting of Croatian Physical Society, Primošten
(lecture and poster)
- 7) M. Čulo, E. Tafra, M. Basletić, A. Hamzić, B. Korin-Hamzić
The importance of choice of geometry for reliable measurements of Hall
effect of highly anisotropic systems – example of an organic conductor
TTF-TCNQ
7th meeting of Croatian Physical Society, Primošten
(poster)
- 8) M. Čulo
Participated in the workshop "Concepts of pulsed nuclear magnetic
resonance spectroscopy" organized by SOLeNeMaR project, PMF Zagreb,
23-27 January 2011
- 9) I. Delač, D. Afanassenkau, A. Offenhaeuser
Spatially Controlled Preparation of Supported Lipid Bilayers for
Neuroscience Studies
6th Christmas Biophysics Workshop, Varaždin, Croatia
(lecture)
- 10) I. Delač, SY. Hong, J. Dadap, PC. Yeh, R. Osgood, M. Kralj
Studying nonlinear optical properties of graphene on silicon substrate with
SHG (in Croatian)
7th meeting of Croatian Physical Society, Primošten
(poster)

LECTURES AND SEMINARS

- 1) T. Vuletić
 - DNA melting in very low salt: intermediate DNA
Institut für Theoretische Physik I, Universität Erlangen, Germany
(14/4/2011, seminar)
- 2) B. Hamzić

- Magnetotransport measurements of the quasi-1D organic conductors (in Croatian)
UKF workshop-Novel materials for electronics: from production to device
Institute of Physics, Zagreb
(06/06/2011, lecture)

TEACHING

COURSES

- 1) M. Čulo
 - Laboratory Practicum 3 (for teachers)
assistant, undergraduate studies, Faculty of Science, University of Zagreb
(2011/2012)
 - Advanced Laboratory Practicum 2 (for teachers)
assistant, undergraduate studies, Faculty of Science, University of Zagreb
(2011/2012)
- 2) D. Grgičin
 - Advanced Laboratory Practicum 1
assistant, undergraduate studies, Faculty of Science, University of Zagreb
(2011/2012)
- 3) I. Delač Marion
 - Advanced Laboratory Practicum 1
assistant, undergraduate studies, Faculty of Science, University of Zagreb
(2011/2012)

MENTORSHIP

- 1) S. Tomić
 - T. Ivek, doctoral thesis
"Charge orderings in strongly correlated systems"
Department of Physics, Faculty of Science, University of Zagreb
(30/6/2011)
 - I. Kovačević, diploma thesis
"Electrical transport in charge-ordered phase in organic conductor
alpha-(BEDT-TTF)₂I₃"
Department of Physics, Faculty of Science, University of Zagreb
(13/7/2011)
 - D. Grgičin, doctoral study, Physics Department, Faculty of Science, Univ. of Zagreb
- 2) B. Hamzić
 - M. Čulo, doctoral study, Physics Department, Faculty of Science, Univ. of Zagreb
- 3) T. Vuletić
 - I. Delač Marion, doctoral study, Physics Department, Faculty of Science, Univ. of Zagreb
 - D. Vurnek, undergraduate studies, diploma student
Physics Department, Faculty of Science, Univ. of Zagreb

- Ana Sučić, undergraduate studies, diploma student
Physics Department, Faculty of Science, Univ. of Zagreb

SCIENTIFIC VISITS

- 1) S. Tomić

Physikalisches Institut, Universität Stuttgart, Germany
(20-31. October 2011)

- 2) T. Vuletić
Institut für Theoretische Physik I, Universität Erlangen, Germany
(8-17. April 2011)
- 3) T. Ivek
1. Physikalisches Institut, Universität Stuttgart, Germany
(20-31. October 2011)
- 4) Prof. dr. Martin Dressel
1. Physikalisches Institut, Universität Stuttgart, Germany
(29-30/6/2011)
- 5) Ida Delač Marion
II. Physikalisches Institut, Universität Köln, Germany
(20-30. November 2011)

AWARDS

- 1) T. Ivek
3rd award for presentation of young researchers
7th meeting of Croatian Physical Society, Primošten

ORGANIZATION OF SCIENTIFIC MEETINGS AND BOARD MEMBERSHIPS

- 1) T. Vuletić
 - Member of the Organization Board of the 7th Meeting of Croatian Physical Society, Primošten, Croatia (5-8/10/2011)
 - Member of the Organization Board of the 6th Christmas Biophysics Workshop, Varaždin, Croatia (12-13/12/2011)
- 2) S. Tomić
 - Member of the International Advisory Board of International Conference on Science and Technology of Synthetic Metals 2012 (ICSM 2012), Atlanta, USA

REVIEWING

- 1) T. Vuletić
 - Phys.Rev.B; Polym. Int.
- 2) S. Tomić
 - Phys.Rev.B
- 3) B. Hamzić
 - Phys.Rev. Letters, Phys.Rev.B

POPULARIZATION OF PHYSICS

- 1) T. Vuletić
 - EM launch
Summer School of Science, Višnjan, 5/8/2011
 - Electromagnetic Gun (in Croatian)
Open Day, Institute of Physics, 25/3/2011
- 2) T. Ivek
 - Presentation of the Laboratory for dielectric spectroscopy in solid state
Open Day, Institute of Physics, 25/3/2011
- 3) D. Grgičin
 - Presentation of the Laboratory for biological physics
Open Day, Institute of Physics, 25/3/2011
- 4) M. Čulo
 - Demonstration experiment: Non-Newtonian fluids
Open Day, Institute of Physics, 25/3/2011
 - Demonstration experiment: Ferrofluids
Open Day, Institute of Physics, 25/3/2011

MISCELLANEOUS

- 1) S. Tomić
 - Member of the Committee for Elections in Scientific Titles Code and Ph.D. (University of Zagreb)
 - Referee Doctorate of Science and a member of the Committee on Defense (Université Paris-Sud, October 2011.)
 - Elect Chair, Scientific Advisory Committee of the European Physical Journal (SAC Meeting, Lisbon (April 2011), EPL Editorial Board Meeting, Munich (May 2011))
 - Member of the Council of doctoral studies "Biophysics" at the University of Split
 - Member of the Executive Board of the Croatian Physical Society
- 2) B. Hamzić
 - Member of the pilot group organised by European Commission: "Human Resources Strategy for Researchers incorporating the Charter and Code
- 3) T.Vuletić
 - Secretary, Croatian Biophysical Society

GROUP AND LABORATORY FOR STUDIES OF STRONGLY CORRELATED ELECTRON SYSTEMS

HEAD

Dr. Miroslav Očko

Co-workers

Dr. Ivica Aviani

Co-workers from other institutions

Sanja Žonja, B. Sc. FER, Zagreb

Dr. Mirko Stubičar, retired

Dr. Nada Stubičar, retired

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

The main activities during 2011 were the investigations of the materials which assume some of the good thermoelectric properties:

-Heavily doped silicon thin films

-Kondo system YbAl₃

-Investigations of some other Kondo systems like URu₂Si₂

-But the most experimental time was devoted to the investigation of some very strange but interesting effect found in a lightly doped silicon thin film.

A lot of time we spent in writing the proposal for HRZZ funds.

With much care was prepared the talk and poster for Hvar 2011 where we explained our idea on using silicon as thermoelectric material.

Thermoelectric properties of the doped silicon thin films

Because of the high thermal conductivity which considerably destroys TE property, silicon was not considered as a possible TE material. Yet recently, initiated by serious lack of energy, serious world pollution and by difficulties in obtaining a Z=3 TE material, some laboratories in the world turned to investigate silicon in order to get a TE material as cheap as possible; certainly cheaper than Bi₂T₃ which has Z=1. Hence, at the moment, for Si, Z=3 is not basic priority. In addition, the technology which can diminish the large thermal conductivity of Si is already developed. Our previous investigations indicated the concentration range of dopant (P, B) where one could find a material with good TE properties in polysilicon thin films obtained by LPCVD [*]. By various treatments of the samples in this concentration region, we believe we would obtain a good TE material. This idea, formulated in 2011 determines our main future scientific activities.

[*] M. Očko, S. Žonja, M. Ivanda,

Thermoelectric materials: problems and perspectives,
talk on MIPRO 2010, Opatija, Croatia.

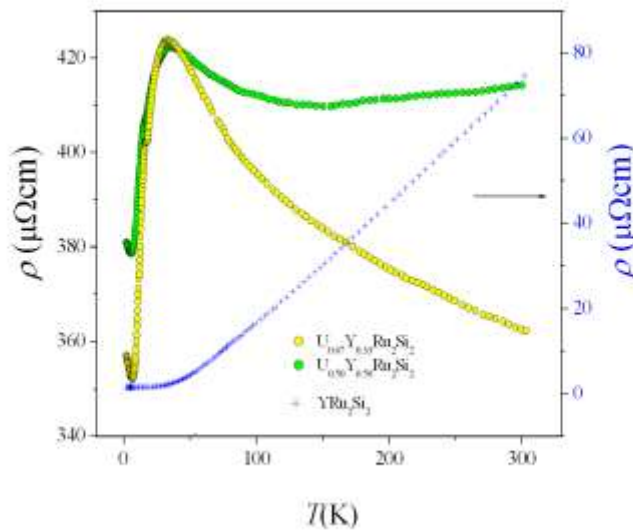
Energy scales of the Kondo lattice systems

Since it was recognized that YbAl₃, a valence fluctuated system, assumes power factor even higher than Bi₂Te₃ (a semiconductor which is practically the only material used nowadays in thermoelectric (TE) devices), YbAl₃ becomes one of the most interesting and most investigated metallic compound.

But we have found an interesting scientific point of this compound concerning Kondo lattice systems. We have observed that in YbAl₃ the characteristic energies of Kondo lattice systems can be related as: $T_0 > T_K > T_{FL}$. Such relation is somewhat strange and observed so far only in YbInCu₄. The justification of the relation $T_0 > T_K$ one can find within the Burdin-Zlatić theory. $T_0 \neq T_{FL}$, i.e., $T_{FL} < T_0$ we try to explain by strong electron-phonon interaction, which destroys the coherence state in YbAl₃. We think that our result is a good justification of the Burdin-Zlatić theory. Here we have presented that thermopower is a proper experimental technique which can reveal the relationship among characteristic temperatures of a Kondo lattice systems: T_0 , T_K and T_{FL} .

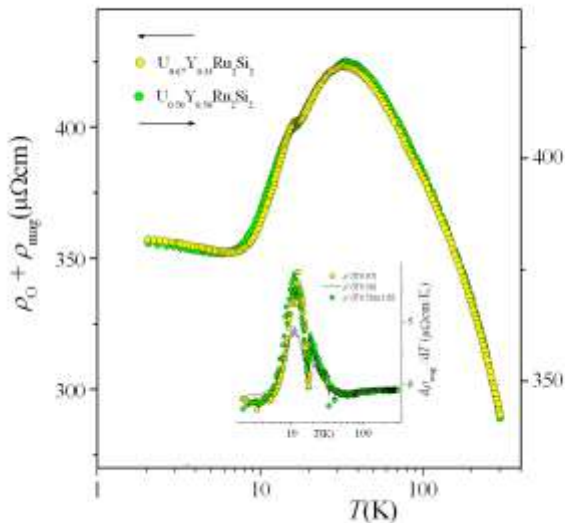
On the Kondo character of the uranium ion

In order to understand the physics of URu₂Si₂, a 40.-years old unsolved problem of the Kondo physics, we have sought to find the properties of the single U ion in the YRu₂Si₂ nonmagnetic matrix. Yet for $x = 0.33$ and $x = 0.67$ in U_xY_{1-x}Ru₂Si₂, we have found clear characteristics of the solid solution phase in resistivity although microstructural analysis showed the existence of the two different phases.



General feature of the magnetic resistivity is explained by the ordinary one-channel Kondo scattering mechanism in the presence of CEF split energy

levels of the U⁴⁺ ion, i.e., by Coqblin-Schrieffer theory. The magnetic resistivity is described by the doublet ground state, the first excited state at about 36 K, and the overall CEF splitting of about 300 K.



The main points of the paper are:

- a) Problems in understanding URu₂Si₂ comes from a second phase which has ferro- or antiferromagnetic character and which is inherently present in U containing compounds.
- b) But more fundamental is that the U⁴⁺ ion behaves as an ordinary Kondo ion although it has two electrons in 5f-shell.

PROJECTS

Title: Materijali sa elektronskom strukturom modeliranom modernim tehnikama priprave

Project type: MZOŠ

Head researcher(s): Miroslav Očko

Duration: 2007-2011

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) M. Očko, S. Žonja, I. Aviani, E. D. Bauer, J. L. Sarrao
Transport properties of the YbAl₃ compound: On the energy scales of YbAl₃ from thermopower data
Journal of alloys and compounds. 512 (2012) , 1; 79-84
- 2) M. Očko, Z. Samardžija, S. Žonja, I. Aviani
Structural and electronic properties of the highly concentrated U_xY_{1-x}Ru₂Si₂ alloy system

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) M. Očko, S. Žonja, M. Ivanda
Silicon goes thermoelectric
ARW Workshop on new materials for thermoelectric application
(lecture)
- 2) S. Žonja, M. Ivanda, M. Očko, T. Suligoj, M. Koričić, P. Biljanović
Structural and Electronic Properties of Heavily Phosphorus Doped
Polycrystalline Silicon Thin Films
Proceedings of 34th International Convention MIPR
(poster)
- 3) S. Žonja, M. Očko, M. Ivanda, T. Suligoj, M. Koričić, P. Biljanović
Heavily phosphorus doped polycrystalline silicon with the application in
the field of Thermoelectric
ARW Workshop on new materials for thermoelectric appli
(poster)
- 4) M. Stubičar, M. Očko, N. Stubičar, A. Milinović, D. Krumes
Mikrotvrdoća : mjerenja i primjena metode (in Croatian)
Knjiga sažetaka 7. znanstvenog sastanaka HFD-a
(poster)
- 5) M. Stubičar, N. Stubičar, A. Milinović, D. Krumes, M. Ivanda, S. Žonja, M.
Očko
Synthesis and Characterization of some Clathrate Compounds
Knjiga sažetaka 7. znanstvenog sastanaka HFD
(poster)
- 6) S. Žonja, M. Očko, M. Ivanda, T. Suligoj, M. Koričić, P. Biljanović
Tanki slojevi fosforom visokodopiranog polikristalnog silicija s mogućom
primjenom na području termoelektrika
Knjiga sažetaka 7. znanstvenog sastanaka HFD-a.
(poster)

REVIEWING

- 1) M. Očko
 - J.Phys. D: Appl. Phys., J.Phys:
 - Nanoscience technology
 - J. Phys.: Cond. Matter
 - New Journal of Physics

SAX LABORATORY FOR CRYSTALLOGRAPHIC AND NANOSTRUCTURAL ANALYSIS

HEAD

Dr. Ognjen Milat

Co-workers

Dr. Krešimir Salamon, Dr. Nazif Demoli

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

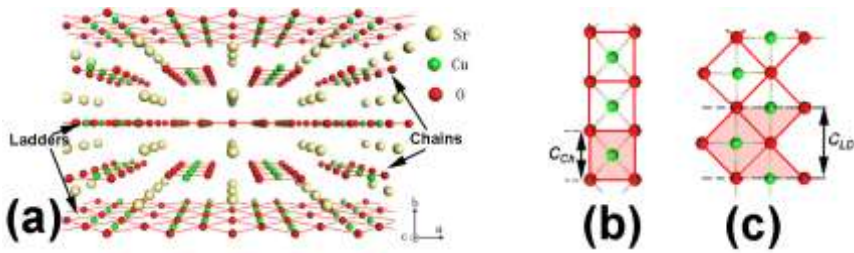
Structural complexity of materials with reduced dimensionality is studied in relation with their unconventional physical properties. Crystallographic anisotropy is usually accompanied by exhotic charge/spin ordering, charge/spin-density waves, magnetic susceptibility, optical conductivity, superconductivity, ...

A number of structural parameters are studied in thin films and multilayers as a function of depth and thickness.

Materials are synthesized in collaboration with other groups. Structural studies are performed by using a number of microscopy, scattering, and diffraction techniques.

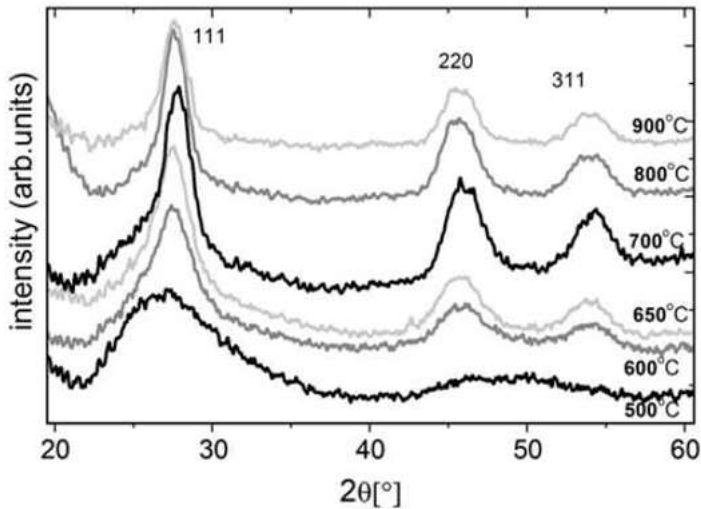
Rational approximations of 1-D incommensurate (Sr/Ca)₁₄Cu₂₄O₄₁ structure

Structural consideration of the cuprate compound with traditional formula (Sr/Ca)₁₄Cu₂₄O₄₁ reveals that an alternative notation: [(Ca/Sr)₂Cu₂O₃]_xCuO₂ ($x \approx 1/\sqrt{2}$) represents much better its 1D incommensurate composite structure. It consists of two subsystems: "(Ca/Sr)₂Cu₂O₃-ladders" and "CuO₂-chains", based on two sublattices with unique a and b, while different c parameters: $c_{Ld} \approx \sqrt{2} c_{Ch}$. Furthermore, it was shown that a series of hypothetical commensurate superstructures should be possible for c_{Ch}/c_{Ld} values that belong to the set of integer number ratios (5/7, 7/10, 9/13, 12/17, 17/24, 19/27). The most prominent commensurate superstructure should appear for the particular case of $c_{Ch}/c_{Ld} = 5/7$, corresponding to the nominal formula (Sr/Ca)₁₀Cu₁₇O₂₉. Therefore widely accepted notation (Sr/Ca)₁₄Cu₂₄O₄₁ rather masks substantial incommensurability of this composite crystal by implying a commensurate superstructure [(Sr/Ca)₂Cu₂O₃]_{0.7}[CuO₂], with the c_{Ch}/c_{Ld} ratio invariably fixed to 7/10 regardless of the Ca for Sr substitution, what is in disagreement with the most of observations, so far.



Lateral and normal ordering in Ge:SiO₂/SiO₂ thin films and multilayers

Self-assembly of semiconductor Ge-quantum dots, and metallic Ni-nanoparticles is studied in (Ge+SiO₂)/SiO₂, and (Ni+SiO₂)/SiO₂ amorphous multilayers. It is found that tuning of basic structural properties of the quantum dots is possible; as found by electron microscopy and GISAXS, the sizes, distances, and arrangement type of the quantum dots follow simple rules dependent on the irradiation and the multilayer properties. The presented results enable engineering and simple production of functional materials or simple devices interesting for applications in nanotechnology. It was found that the optical properties of the Ge:SiO₂/SiO₂ multilayers can be well correlated with structural changes induced by thermal treatment. Variation of refractive index through the layers were related with the measurements of grazing incidence wide angle X-ray scattering.



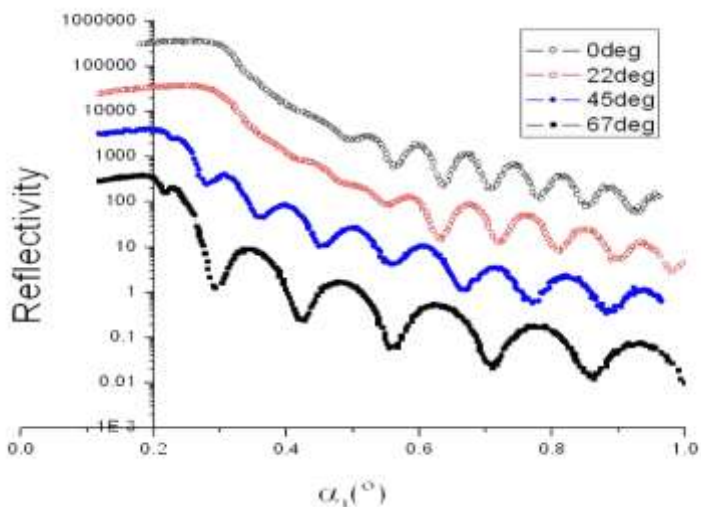
Charge ordering versus anisotropy of crystal structure in α -(BEDT-TTF)₂I₃

Crystallographic characterisation of a layered organic conductor α -(BEDT-TTF)₂I₃ has supported interpretation of unusual structure and dynamics of charge and lattice in the observed normal and charge ordered phases. Anisotropy of charge ordering in the horizontal stripe domains, were

determined by dc resistivity and dielectric and optical spectroscopy, as a function of frequency and temperature.

Morphology of thin Ti-films deposited by DPL ablation

Morphology of thin Ti-films, deposited in vacuum by dual-pulse laser ablation of titanium target on mono-Si substrate, was studied using x-ray reflectivity, and atomic force microscopy. It was found that angular distribution of ejected plume strongly depends on energy fluencies of both laser pulses, as well as on the delay time of the second pulse; all morphological parameters of deposited film are consequently affected.



PROJECTS

Title: Structure-properties relations in materials with controlled dimensionality (in croatian)

Project type: MZOŠ ((035-0352843-2844)

Head researcher(s): O. Milat (IF)

Duration: 2007-2011

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) M. Buljan, I. Bogdanović-Radović, M. Karlušić, U. Desnica, N. Radić, M. Jakšić, K. Salamon, G. Dražić, S. Bernsdorf, V. Holy
Design of quantum dot lattices in amorphous matrices by ion beam irradiation
Physical Review B84 (2011), 155312-1-8
- 2) V. Janicki, J. Sancho-Parramon, , H. Zorc, K. Salamon, M. Buljan, N. Radić, U. Desnica
Ellipsometric study of thermally induced redistribution and crystallization of Ge in Ge:SiO₂(2) mixture layers

- Thin solid films. 519 (2011), 5419-5423
- 3) T. Ivek, B. Korin-Hamzić, O. Milat, S. Tomić, C. Clauss, N. Drichko, D. Schweitzer, M. Dressel
Electrodynamic response of the charge ordering phase: Dielectric and optical studies of alpha-(BEDT-TTF)₂I₃
Physical Review B83 (2011) 165128
 - 4) D. Dominko, D. Starešinić, K. Salamon, K. Biljaković, A. Tomelj, H. Schafer, T. Huber, J. Demsar, G. Socol, C. Ristoscu, I. N. Mihailescu, et al.
Detection of charge density wave ground state in granular thin films of blue bronze K_{0.3}MoO₃ by femtosecond spectroscopy
Journal of Applied Physics 110, 014907, 2011

BOOKS / CHAPTERS IN BOOKS

- 1) O. Milat, S. Gajović and D. Bauman (eds)
Electron microscopy in Croatia (a chapter in the monography: ISBN 978-953-57138-0-7)
Croatian Microscopy Society, Zagreb, 2012

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) N. Radić, K. Salamon, P. Dubček, O. Milat, M. Jerčinović, G. Dražić, S. Bernsdorf
Nanoscale multilayers as optical elements for X-ray photolithography
34. MIPRO 2011, Opatija 23-27.05. 2011. pp 27
(Invited lecture)
- 2) O. Milat, K. Salamon, S. Tomić, T. Vuletić, T. Ivek
Commensurate superstructures in the [(Ca/Sr)₂Cu₂O₃][CuO₂]_x√2 composite crystal
10th MCM2011 Urbino, Italy, September 4-9th, 2011, pp 41
(Poster)
- 3) N. Krstulović, K. Salamon, M. Modič, M. Biščan, O. Milat, S. Milošević
Morphology of thin Ti-films produced by double-pulse laser deposition
18th Slo-Cro Vacuum meeting, Bohinj (Slovenija), 2-3.06.2011
(Poster)
- 4) K. Salamon, O. Milat, N. Radić, P. Dubček, M. Jerčinović, S. Bernsdorf
Characterization of W/C X-ray multilayer mirrors by Small Angle X-ray Scattering techniques
18th Slo-Cro Vacuum meeting, Bohinj (Slovenija), 2-3.06.2011
(Invited lecture)

LECTURES AND SEMINARS

- 1) O. Milat
 - Croatian contributions at MCM 2011, in Urbino, Italy (in Croatian)
216. monthly meeting of Croatian Microscopy Society, Zagreb
(18/10/2011, seminar)
 - Quasicrystals - ordered structures with translation symmetry at six-dimensional lattice (in Croatian)
 - Nobel prizes (Nobelove nagrade na "Ruđeru"), IRB, Zagreb
(20/10/2011, lecture)

ORGANIZATION OF SCIENTIFIC MEETINGS AND BOARD MEMBERSHIPS

- 1) O. Milat
 - Member of the International Organizing Committee of the 14th Joint Vacuum Meeting (JVC14); Dubrovnik, Croatia (2012)
 - Chairman of the Congress Session: M6- Ceramics, Composites, Minerals, at the MCM 2011, in Urbino, Italy, 4-9.09. (2011)

REVIEWING

- 1) O. Milat
 - Kemija u industriji
 - Physical Review B
 - Physica Status Solidi

LABORATORY FOR THE PHYSICS OF TRANSPORT PHENOMENA

HEAD

Dr. Ana Smontara

Co-workers

Dr. Jovica Ivkov, Dr. Petar Popčević, Kristijan Velebit, B.Sc

Co-workers from other institutions

Dr. Neven Barišić, CEA Saclay France; Dr. Željko Bihar, Faculty of Textile Technology, Zagreb; Dr. Boran Leontić, Prof. emeritus, Faculty of Science, University of Zagreb, Zagreb; Dr. Jagoda Lukatela, in retirement

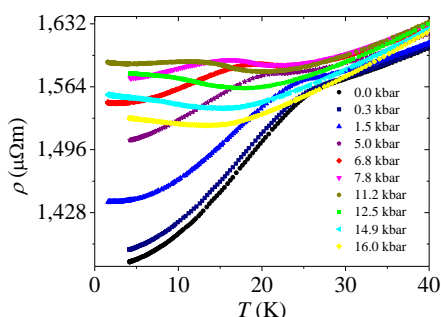
MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

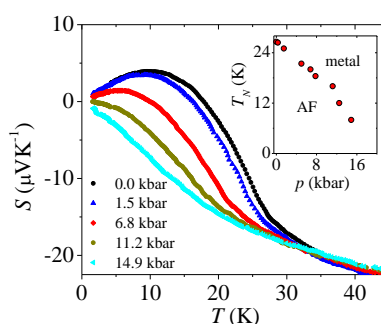
Activities continue to be focused on the investigation of new complex metallic alloys (quasicrystals, their approximants,...) through measuring transport properties (electrical and thermal conductivity, thermopower and Hall coefficient). Major effort was put in the realization of the UKF project 1B# 65/10 within which a new laboratory for transport measurements under high pressure and magnetic field was established and low dimensional electronic systems from dichalcogenides family were investigated. K. Velebit was awarded a DAAD grant, enabling us to broaden the investigation of dichalcogenides started within UKF.

Transition metal dichalcogenides

Research of transition metal dichalcogenides (TMD) has continued, extending the previous investigation of transport properties of $\text{Co}_{0.33}\text{NbS}_2$. This material



Pressure dependence of the low temperature dc-resistivity.



Thermoelectric power and its pressure behaviour in the low-T range. *Inset*: Phase diagram of $\text{Co}_{0.33}\text{NbS}_2$.

has the antiferromagnetic (AFM) order (with the temperature of the magnetic ordering of 26 K) which can be suppressed by applying the hydrostatic pressure, as seen from the electrical resistivity data. This peculiar behavior unseen in any other TMD before is most probably due to several competing interactions which affect the coupling of the magnetic Co ions and itinerant electrons. To be able to determine the nature of the interactions we have investigated the neutron scattering under pressure (*paper in preparation*). TaS₂ was selected for investigation due to its peculiar nano-textured phase in which insulating CDW parts coexist with the metallic ones. To get better insight into this phase we made optical measurements on the pure 1T-TaS₂ as well as 1T-TaS₂ doped with the small amount of Cu atoms. Doping suppresses the Mott phase, extending the nano-textured phase down to low temperatures where superconductivity arises.

Decagonal quasicrystal d-Al-Co-Ni

We investigated the transport properties of a *d*-Al-Co-Ni single crystal of exceptional structural quality along the 10-fold periodic direction (P) and along three specific crystallographic directions within the quasiperiodic plane (QP), corresponding to the 2 and 2' twofold symmetry directions and their bisector. The results confirm that a solid of decagonal point group symmetry should exhibit isotropic physical properties within the QP and anisotropy between the in-plane and the P direction. *d*-Al-Co-Ni is an anisotropic diamagnet with stronger diamagnetism for the magnetic field along the P. Charge and thermal transport are strongly metallic along the P, but are largely suppressed within the QP due to the lack of translational periodicity that hinders the propagation of electrons and phonons in a non-periodic lattice. Hall-coefficient shows sign-reversal anisotropy related to the direction of the magnetic field, when applied along the P or within the QP. The observed anisotropy should be a general feature of solids with broken translational periodicity in 2D (*paper submitted in Phys. Rev. B*).

PdGa intermetallic hydrogenation catalyst

PdGa intermetallic compound is a highly selective and stable heterogeneous hydrogenation catalyst for the semi-hydrogenation of acetylene. Since the underlying bulk is influencing the catalytic properties of the surface, we have determined bulk physical properties of single-crystalline PdGa (in collaboration with group of prof. dr. J. Dolinšek (EN-FIST Centre of Excellence, Ljubljana) and prof. dr. Z. Jagličić (Center for Magnetic measurements-CMag, Ljubljana)), that can be used in future atomistic-level studies of the catalytic processes on well-oriented surfaces of this material. The isotropy of the physical properties was confirmed by the measurements of the electrical resistivity and Hall effect along different crystallographic directions. The results show that PdGa is a diamagnet with metallic electrical resistivity and moderately high thermal conductivity. The thermoelectric power is negative with complicated temperature dependence, whereas the Hall coefficient is positive and temperature-dependent, indicating complexity of the Fermi surface (*paper submitted in J. Phys. Cond. Matter.*).

δ -FeZn₁₀ a new phase of the Fe–Zn system

The zink-rich domain of the Fe–Zn system has been intensively studied in the past, due to its technological importance in the field of anticorrosion techniques. It comprises of several different phases, among which the δ -FeZn₁₀ phase possesses high structural complexity: a large unit cell comprising of 556 atoms, a polyhedral atomic order with icosahedrally-coordinated environments, fractionally occupied lattice sites and statistically disordered atomic clusters that introduce intrinsic disorder into the structure. Its physical properties remained unknown and we investigate the electrical, magnetic and thermal properties of this interesting new intermetallic. Structural disorder results in the suppression of electrical and heat transport phenomena, making δ -FeZn₁₀ phase poor electrical and thermal conductor. Structural complexity results in complex electronic structure that is reflected in the opposite-sign thermoelectric power and Hall coefficient. The δ -FeZn₁₀ phase is paramagnetic down to the temperature of 2 K with significant interspin coupling of an AFM type (*paper in preparation*).

Metallic glasses Cu₅₅Hf_{45-x}Ti_x

In collaboration with prof. dr. E. Babić (Faculty of Science, University of Zagreb, Zagreb) and prof. dr. R. Ristić (Department of Physics, University of J. J. Strossmayer Osijek, Osijek) J. Ivkov also investigated electrical transport properties (electrical resistivity and Hall effect from 90 to 350 K) of Cu₅₅Hf_{45-x}Ti_x metallic glasses with 0 ≤ x ≤ 45. These glasses revealed the formation of bulk metallic glasses (BMG) for 15 ≤ x ≤ 30. As BMG generally consist of four or more components this rather simple system appears convenient for the investigation of the composition dependence of physical properties. However, the investigated properties have shown only monotonic variations with x with no particular features in the bulk metallic glasses composition range, and hence do not indicate BMG compositions.

PROJECTS

Title: *Transport of charge and heat in strongly frustrated magnets and similar materials*

Project type: MZOŠ (035-0352826-2848)

Head researcher: A. Smontara (IP)

Duration: 2007-2011

Title: *New electronic states driven by frustration in layered materials*

Project type: UKF project 1B "Cooperability" Grant-65/10

Head researchers: E. Tutiš (IP); L. Forró (LPMC, EPFL, Lausanne); N. Barišić (CEA Saclay, France); A. Smontara (IP)

Duration: 15.06. 2010-15.06. 2012

Title: *Modulation and Nanostructuring in Layered Materials*

Project type: International Collaborative Workshops

Head researchers: A. Smontara (IP); L. Forró (LPMC, EPFL, Lausanne)

Duration: 01.10.2011-1.4.2012.

PARTICIPATION IN RESEARCH NETWORKS

Title: *Complex Metal Alloys (CMA)*

Network type: EU Network of excellence (NoE CMA), No. NMP3-CT-2005-500140

Member: A. Smontara (visiting member with full rights)

Duration: 2005-2011

Title: *European Integrated Centre for the Development of Metallic Alloys and Compounds (C-MAC)*

Network type: EU Network (successor organization of the European Network of Excellence Complex Metallic Alloys, NoE CMA, No. NMP3-CT-2005-500140)

Member Institute of Physics (responsible person: A. Smontara (IP))

Duration: 2009-present

SCIENTIFIC COLLABORATION

- 1) *Strengthening the Solid-state research capacities in Zagreb by the introduction of the Nuclear Magnetic Resonance method (SOLENeMaR)*, EU-projekt (Research potential of Convergence Regions FP7-REGPOT-2008-1 Grant agreement no.: 229390)
A. Smontara (IP, Croatian partner), prof. dr. M. Požek (Department of Physics, Faculty of Science, Zagreb; Coordinator)
Duration: 01.03.2009.-28.02.2012.
- 2) *Electrical properties of amorphous alloys*
J. Ivkov, prof. dr. E. Babić (Faculty of Science, University of Zagreb, Zagreb) and prof. dr. R. Ristić (Department of Physics, University J. J. Strossmayer Osijek, Osijek, Croatia)
- 3) *Physical properties of the δ -FeZn₁₀ complex intermetallic phase*
A. Smontara, P. Popčević, J. Ivkov (IP), doc. dr. D. Stanić (Department of Physics, University J. J. Strossmayer Osijek, Osijek, Croatia) and dr. M. Heggen and dr. M. Feuerbacher (Institut für Festkörperforschung, Forschungszentrum Jülich, Jülich, Njemačka)
- 4) *Bulk physical properties of the PdGa intermetallic system*
A. Smontara (IP) and prof. dr. P. Gille (Ludwig-Maximilians-Universität München, München, Germany) and M. Armbrüster, Max-Planck-Institut für Chemische, Dresden, Germany)
- 5) *Magnetic properties of complex metallic systems*
A. Smontara (IP) and prof. dr. Z. Jagličić (Center for magnetic measurements, Institute of Mathematics Physics and Mechanics Ljubljana, Slovenia) and prof. dr. J. Dolinšek (Institut "Jožef Stefan", Ljubljana, Slovenia)
- 6) *Heat transport in complex systems*
A. Smontara, P. Popčević, K. Velebit (IP) and prof. dr. A. Bilušić (Faculty of Science, University of Split, Split)

7) *Properties of novel electronic materials*

A. Smontara, P. Popčević, K. Velebit (IP) and prof. dr. L. Forró (IPMC, EPFL, Lausanne, Switzerland)

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) N. Barišić, I. Smiljanić, P. Popčević, A. Bilušić, E. Tutiš, A. Smontara, H. Berger, J. Jačimović, O. Yuli, L. Forró
High pressure study of transport in $Co_{1/3}NbS_2$
Phys. Rev. B **84** (2011) 075157.
- 2) J. Dolinšek, A. Smontara
Decagonal Quasicrystals and Approximants: Two-Dimensional or Three-Dimensional Solids?
Isr. J. Chem. **51** (2011)1246.
- 3) J. Ivkov, P. Popčević, D. Stanić, B. Bauer, P. Gille, J. Dolinšek, A. Smontara
Anisotropic Hall effect in $Al_{13}TM_4$ approximant.
Philos. Mag. **91** (2011) 2739.
- 4) P. Popčević, D. Stanić, Ž. Bihar, A. Bilušić, A. Smontara
Heat transport in aluminum based quasicrystals i -AlPdMn, i -AlCuFe, and d -AlCoNi
Isr. J. Chem. **51** (2011) 1340.
- 5) A. Smontara, P. Popčević, D. Stanić, K. Velebit, J. Dolinšek
Anisotropic Transport Properties of the $Al_{13}TM_4$ and T-Al-Mn-Fe Complex Metallic Alloys
Philos. Mag. **91** (2011) 2746.
- 6) P. Gille, B. Bauer, M. Hahne, A. Smontara, J. Dolinšek
Single crystal growth of Al-based intermetallic phases being approximants to quasicrystals
J. Crys. Growth **318** (2011) 1016.

BOOKS / CHAPTERS IN BOOKS

- 1) J. Dolinšek and A. Smontara
Anisotropic Physical Properties of Complex Metallic Alloys
Complex Metallic Alloys Fundamentals and Applications
Dubois Jean-Marie; Belin-Ferre, Esther (Eds.).
Weinheim : WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2011, p. 117-153.

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) A. Smontara
CMAC Days 2011 - The University of Liverpool, Liverpool, UK, 2011
(participation at CMAC Science Board and Governing Board)
- 2) D. Stanić, P. Popčević, J. Ivkov, A. Smontara, M. Bobnar, S. Vrtnik, M. Feuerbacher, Z. Jagličić, J. Dolinšek
Magnetic and transport properties of δ -FeZn₁₀
CMAC Days 2011 - The University of Liverpool, Liverpool, UK, 2011

- 3) N. Barišić, I. Smiljanić, P. Popčević, A. Bilušić, E. Tutiš, A. Smontara, H. Berger, J. Jačimović, O. Yuli, H. Berger, L. Forró
Mjerenja transportnih svojstava $Co_{1/3}NbS_2$ u ekstremnim uvjetima (in Croatian)
7th Scientific Meeting of CPS, Primošten, Croatia, 2011
(poster)
- 4) P. Popčević, J. Ivkov, D. Stanić, K. Velebit, D. Cmrk, A. Smontara
Anizotropija transportnih svojstava monokristala dekadagonalnog kvazikristala $d-Al_{70}Co_{10}Ni_{20}$ (in Croatian)
7th Scientific Meeting of CPS, Primošten, Croatia, 2011
(poster)
- 5) P. Popčević, D. Stanić, K. Velebit, A. Smontara
Porijeklo anizotropije transportnih svojstava kompleksnih intermetalika iz obitelji $Al_{13}TM_4$ (in Croatian)
7th Scientific Meeting of CPS, Primošten, Croatia, 2011
(poster)
- 6) D. Stanić, J. Ivkov, P. Popčević, A. Smontara
Anizotropni Hallov efekt u aproksimantima dekadagonalnih kvazikristala (in Croatian)
7th Scientific Meeting of CPS, Primošten, Croatia, 2011
- 7) N. Barišić, D. Wu, M. Dressel
Fermi-liquid resistivity in the normal state of iron-pnictides
E-MRS 2011 FALL MEETING, Warsaw, Poland, 2011
(invited lecture)
- 8) P. Popčević, I. Smiljanić, A. Bilušić, A. Smontara, I. Batistić, H. Berger, R. Gaal, J. Jačimović, O. Yuli, L. Forró, E. Tutiš, N. Barišić
Pressure study of $Co_{1/3}NbS_2$
The second international workshop on "Recent advances in broad-band solid-state NMR of correlated electronic systems", Trogir, Croatia, 2011
(poster)
- 9) P. Popčević, N. Barišić, L. Forró, E. Tutiš, A. Smontara
Mjerenja u ekstremnim uvjetima - visoki tlakovi, visoka magnetska polja, široki temperaturni opseg (in Croatian)
7th Scientific Meeting of CPS, Primošten, Croatia, 2011
(poster)

LECTURES AND SEMINARS

- 1) K. Velebit
 - *Effect of pressure on the magnetic phase transition of the intercalated dichalcogenide $Co_{1/3}NbS_2$*
Doctoral School, Faculty of Science, University of Zagreb, Zagreb
(16/3/2011, seminar)
 - *Presentation of the transition dichalcogenide samples*
1. Physikalisches Institut, University Stuttgart, Germany
(10/5/2011, seminar)
 - *Presentation of the DAAD project "Optical properties selected layered materials dichalcogenides"*
Institute of Physics, Zagreb, Croatia
(4/7/2011, seminar)
 - *Optical measurements of layered dichalcogenides*
Physikalisches Institut, University Stuttgart, Germany
(20/12/2011, seminar)

TEACHING

MENTORSHIP

- 1) A. Smontara, P. Popčević (co-mentor)
 - D. Kolarić, diploma work (graduation thesis)/ integral study
Kvazikristali kao potencijalni termoelektrični materijali (in Croatian)
Department of Physics, Faculty of Science, University of Zagreb
(11/7/2011)
- 2) A. Smontara, J. Ivkov (co-mentor)
 - D. Cmrk, diploma work (graduation thesis)/ integral study
Hallow efekt monokristala kompleksnih metalnih slitina (in Croatian)
Department of Physics, Faculty of Science, University of Zagreb
(13/7/2011)
- 3) A. Smontara
 - K. Velebit, doctoral study in physics
Department of Physics, Faculty of Science, University of Zagreb

SCIENTIFIC VISITS

- 1) K. Velebit
 - 1. Physikalisches Institut, Universität Stuttgart, Germany
(1/9/2011-31/12/2011)
 - 1. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany
(2/5/2011-30/6/2011)
- 2) P. Popčević
 - Ecole Polytechnique Fédérale de Lausanne,
Lausanne, Switzerland
(4/4/-24/4/2011)
 - Ecole Polytechnique Fédérale de Lausanne,
Lausanne, Switzerland
(11/05/-28/05/2011)
 - Institut Laue-Langevin (ILL), Grenoble, France and Ecole Polytechnique
Fédérale de Lausanne, Lausanne, Switzerland
(18/7/-25/7/2011)
- 3) A. Smontara
 - Ecole Polytechnique Fédérale de Lausanne,
Lausanne, Switzerland
(4/04/-10/04/2011)
 - Institut "Jožef Stefan", Ljubljana, Slovenia
(a few short visit during the year 2011)
- 4) N. Barišić
 - 1. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany
(18/9/2011-22/9/2011)
(2/11/2011-4/11/2011)
- 5) A. Bilušić
 - Faculty of Science, University of Split, Split, Croatia

(several short visit during the year 2011)

- 6) J. Dolinšek
 - Institut "Jožef Stefan", Ljubljana, Slovenia (20/7/2011)
- 7) D. Stanić
 - Department of Physics, University J. J. Strossmayer Osijek, Osijek, Croatia (several short visit during the year 2011)

AWARDS

- 1) K. Velebit
 - DAAD (Deutscher Akademischer Austausch Dienst) Grant

ORGANIZATION OF SCIENTIFIC MEETINGS AND BOARD MEMBERSHIPS

- 1) A. Smontara
 - Member of the Governing and Science Board, European integrated centre for the development of Metallic Alloys and Compounds (C-MAC)
 - Member of Advisory board, EU project Strengthening the SOLidstate research capacities in Zagreb by the introduction of nuclear Magnetic Resonance method

REVIEWING

- 1) J. Ivkov
 - Journal of Physics: Condensed Matter
 - Physica Scripta
- 2) A. Smontara
 - Thin films
 - Philos. Mag. Lett.
 - J. Alloys Compound
 - ESF projects

POPULARIZATION OF PHYSICS

- 1) P. Popčević
 - *Presentation of cryogenic plant*
 - Open Days of the Institute of Physics, IP, Zagreb (25/03/2011)

MISCELLANEOUS

- 1) J. Ivkov
 - Member of the European integrated centre for the development of Metallic Alloys and Compounds (C-MAC)
- 2) P. Popčević

- Member of the European integrated centre for the development of Metallic Alloys and Compounds (C-MAC)
 - Member of the Scientific Council of the Institute of Physics (IP) as one of the representatives of research assistants
- 3) A. Smontara
- Member of the European integrated centre for the development of Metallic Alloys and Compounds (C-MAC)
 - Member of the Editorial board of the Matematičko-fizički list (MFL) (in Croatian)
- 4) K. Velebit
- Member of the European integrated centre for the development of Metallic Alloys and Compounds (C-MAC)

LABORATORY FOR COMPLEX SYSTEMS

HEAD

Dr. Katica Biljaković

Co-workers

Dr. Damir Starešinić, Damir Dominko, B.Sc.

Co-workers from other institutions

Maja Đekić, M.Sc., PMF, Sarajevo

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

We have investigated the thermodynamic and transport properties of several anisotropic (quasi one- and two-dimensional) systems with the emphasis on the influence of defects, magnetic field and reduced dimensionality on the ground state and low energy excitations. We have continued international collaboration on the production and characterization of thin films of Q1D charge density wave (CDW) systems. We have contributed to two interdisciplinary project proposals to the Croatian science foundation and mentored two diploma works.

Nonlinear conductivity of CDW systems with defects

The nonlinear conductivity of the CDW system o-TaS₃ doped with 0.2% and 0.5% Nb has been measured in a wide temperature and voltage range, including the pulsed method for very high electric fields up to 1000 V/cm. In doped samples the nonlinear conductivity can be observed only below 50 K, the temperature of the CDW glass transition T_g in o-TaS₃, and it is similar to the nonlinear conductivity of pure samples. Above T_g the conductivity is linear up to the highest field of 200 V/cm, above which the sample heating occurs, as compared to the threshold field below 1 V/cm at which nonlinear conductivity is observed in pure samples. The absence of the nonlinear conductivity in doped samples is consistent with previous measurements of the dielectric response, where we did not observe the relaxation process characteristic for pure samples above T_g.

Low energy excitations in incommensurate systems

Very similar low temperature properties of the heat capacity of CDW systems and recently investigated incommensurate (IC) dielectrics were associated with the typical behaviour in glasses. Therefore we are generally referring to the common characteristics of the low-energy excitations of the phase and the amplitude of the order parameter in the new structure, or superstructure, of the IC ground state. We established collaboration with A. Cano, theorist from ESRF in Grenoble, on the interpretation of the characteristic behaviour of low temperature heat capacity of the IC materials which takes into account the dominant influence of damping on these excitations.

Nanocrystalline thin films with CDW ground state

Good understanding of how properties can be tuned by changing the size of material is the basic prerequisite for the production of new materials with designed superior properties. Systems with CDW ground state, a type of coupled electronic-lattice instability, are especially interesting due to their exceptional properties such as giant dielectric constant, nonlinear transport, memory effects, unusual electro-mechanical and thermoelectric properties, all of conceptual importance in various thin film applications. On the other hand, CDW films open the door for studying of meso- and micro-scale aspects of CDW physics caused by finite size effects. We have continued our international collaboration on the production and characterization of thin films of CDW prototype system $K0.3MoO_3$ (blue bronze) prepared by pulsed laser deposition which led to one published work. The last series of films, characterized by GI-XRD, electric transport and AFM at the Institute, yielded the optimal parameters for their deposition.

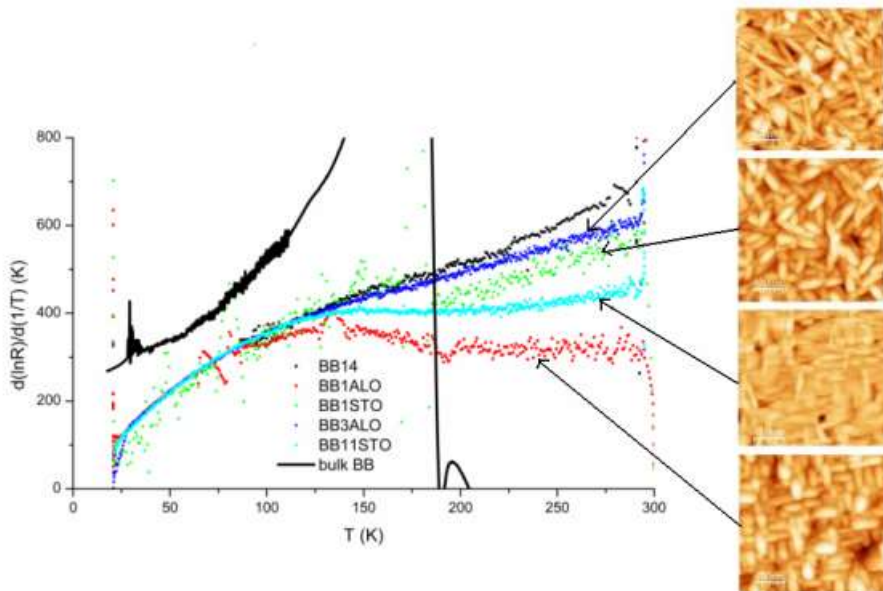


Figure 1. The derivative of the logarithm of the resistance in respect to the inverse temperature for the bulk (black) demonstrates sharp CDW transition in contrast to smeared transitions in films. The best film (red) shows also the best AFM texture.

Specific heat of new 2D magnetic system

There is an increased interest for the investigation of the magnetic materials with reduced dimensionality due to their potential applications in electronics. We have measured the heat capacity of magnetic insulator telurit-halide $Fe_8Te_{12}O_{32}Cl_6$ which is the member of family of Q2D materials. The magnetic phase transition at $T_c=30$ K is sensitive to moderate magnetic fields, which reduce T_c as well as the amplitude of the anomaly. Surprisingly for an insulating system, there is a low temperature linear contribution to the heat capacity indicating existence of 1D spin wave excitations.

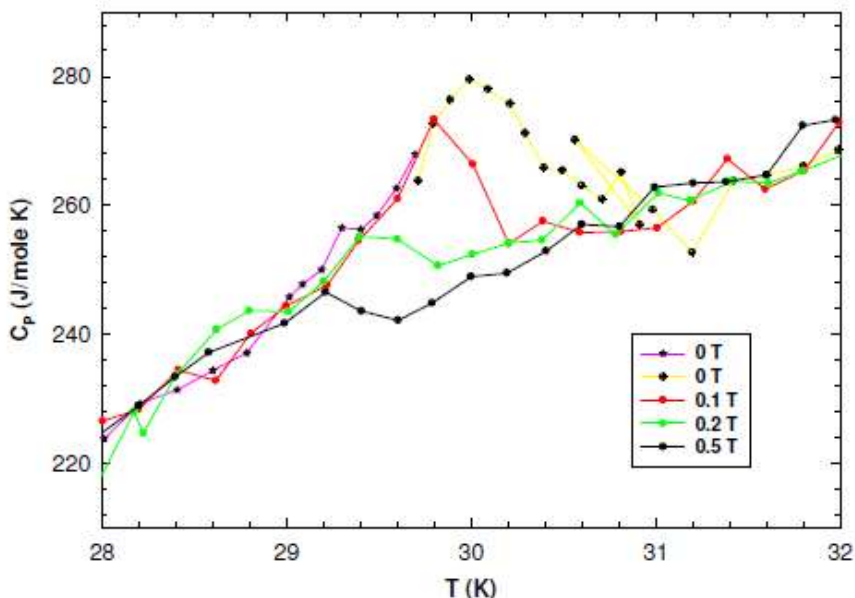


Figure 2. The magnetic phase transition seen in the specific heat of $\text{Fe}_8\text{Te}_{12}\text{O}_{32}\text{Cl}_6$ is destroyed by moderate magnetic field.

PROJECTS

Title: Complex modulated systems: new ground states, defects and magnetic effects

Project type: MZOŠ (035-0352827-2842)

Head researcher(s): K. Biljaković (IP)

Duration: 2007-2011

Title: Photolithographic synthesis and electronic properties of graphene based devices and related structures

Project type: UKF 1B Cooperability

Head researcher(s): T. Valla (BNL, Brookhaven, USA)

Duration: 2010.-2012.

SCIENTIFIC COLLABORATION

- 1) Ultrafast dynamics of charge density wave systems
K. Biljaković (IP) and J. Demšar (Konstanz University, Germany)
- 2) Production and characterization of thin films of charge density wave systems
K. Biljaković (IP), M. Jakšić (RBI), I. Mihailescu (INFLPR Magurele, Romania), J. Demšar (Konstanz University, Germany)
- 3) Contribution of damped phase and amplitude excitations to heat capacity of incommensurate systems
K. Biljaković (IP) and A. Cano (ESRF, Grenoble, France)

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) D. Dominko, D. Starešinić, K. Salamon, K. Biljaković, A. Tomelj, H. Schaefer, T. Huber, J. Demšar, G. Socol, C. Ristoscu, I. N. Mihailescu, et al.
Detection of charge density wave ground state in granular thin films of blue bronze $K_{0.3}MoO_3$ by femtosecond spectroscopy
J. Appl. Phys. 110 (2011) 014907

EXPERT ARTICLES

- 1) K. Biljaković, D. Starešinić, D. Dominko, I. Crljenica, B. Podobnik, A. Golub
Wild fires in Croatia: spatial and temporal analysis (in Croatian)
Proceedings of 2nd Conference of the Croatian platform ...

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) K. Biljaković, D. Starešinić, J.C. Lasjaunias, G. Remenyi, R. Melin, P. Monceau, S. Sahling
Charge density glass dynamics - Soft potentials and soft modes
ECRYS-2011, Cargese, France, 2011
(invited lecture)
- 2) G. Remenyi, S. Sahling, K. Biljaković, D. Starešinić, J. E. Lorenzo, P. Monceau
Observation of phason and amplitudon modes in the heat capacity of incommensurate $ThBr_4$
ECRYS-2011, Cargese, France, 2011
(poster)
- 3) D. Dominko, D. Starešinić, K. Biljaković, Z. Siketić, M. Jakšić, P. Lunkenheimer, A. Loidl
Tuning charge density wave glass transition by introducing lattice disorder
ECRYS-2011, Cargese, France, 2011
(lecture)
- 4) D. Starešinić, D. Dominko, K. Salamon, K. Biljaković, A. Tomelj, H. Schäfer, J. Demšar, G. Socol, C. Ristoscu, I. N. Mihailescu, Z. Siketić, et al.
Charge density waves in nanocrystalline thin films of blue bronze $K_{0.3}MoO_3$
ECRYS-2011, Cargese, France, 2011
(poster)
- 5) D. Starešinić, K. Biljaković, J. C. Lasjaunias, P. Monceau
Glass-like features in the heat capacity of charge density wave systems
CEEC-TAC1, Craiova, Romania, 2011
(poster)
- 6) D. Dominko, D. Starešinić, I. Živković, M. Herak
Low temperature heat capacity in some low-dimensional systems with unusual magnetic order
CEEC-TAC1, Craiova, Romania, 2011
(poster)

- 7) D. Dominko, D. Starešinić, K. Salamon, K. Biljaković, A. Tomelj, H. Schäfer, J. Demšar, G. Socol, C. Ristoscu, I. N. Michailescu, Z. Siketić, et al.
Charge density waves in nanocrystalline thin films of blue bronze $K_{0.3}MoO_3$ (in Croatian)
7. Scientific meeting of CPS, Primošten, Croatia, 2011

LECTURES AND SEMINARS

- 1) D. Starešinić
• Microfabricated devices for thermal measurements
Novel materials for electronics: from production to devices, UKF project workshop
(06/06/2011, lecture)

TEACHING

MENTORSHIP

- 1) K. Biljaković
• I. Gašparlin, diploma work
"Heat capacity of ternary metallic glasses Cu-Hf-Ti"
Department of Physics, Faculty of Science, University of Zagreb
(21/1/2011)
• J. Bušljeta, diploma work
"Thermodynamic investigation of telurit halide $Fe_8Te_{12}O_{32}Cl_6$ "
Department of Physics, Faculty of Science, University of Zagreb
(18/11/2011)
• M. Đekić, doctoral thesis
"Production and characterization of thin films of quasi-1D systems with charge density waves"
Department of Physics, Faculty of Science, University of Sarajevo
- 2) D. Starešinić
• D. Dominko, doctoral thesis
"Influence of crystal defects on the properties of charge density waves"
(in Croatian)
Department of Physics, Faculty of Science, University of Zagreb

SCIENTIFIC VISITS

- 1) K. Biljaković
• Institut Neel, Grenoble, France
(14/11/2011-26/11/2011)
• Montpellier University, France
(27/11/2011-06/12/2011)
- 2) D. Starešinić
• INFLPR, Magurele, Romania
(11/09/2011-15/09/2011)
- 3) D. Dominko
• INFLPR, Magurele, Romania
(11/09/2011-15/09/2011)
- 4) Y. Toda
Hokkaido University, Sapporo, Japan

- (10.01. - 11.01. 2011.)
- 5) G. Logvenov
Max Planck Institute for Solid State Research, Stuttgart, Germany
(04.04. - 06.04. 2011.)
 - 6) M. Đekić
Department of Physics, Faculty of Science, University of Sarajevo, Bosnia
and Herzegovina
(20.05. - 23.05. 2011.)
 - 7) M. Đekić
Department of Physics, Faculty of Science, University of Sarajevo, Bosnia
and Herzegovina
(29.08. - 02.09. 2011.)

ORGANIZATION OF SCIENTIFIC MEETINGS AND BOARD MEMBERSHIPS

- 1) K. Biljaković
 - Member of the International Advisory Committee of the International Workshop of Electronic Crystals (ECRYS-2011), Cargese, France (2011)
 - Member of the Organizing Committee of 3rd Conference of the Croatian Platform for disaster risk reduction, Zagreb, November 2011

REVIEWING

- 1) D. Starešinić
 - Physcal Review Letters

POPULARIZATION OF PHYSICS

- 1) D. Starešinić
 - From crystals to glasses (lecture, in Croatian)
Open day of the Institute of physics, Zagreb, 25/03/2011
- 2) D. Dominko
 - Non-Newtonian liquids (presentation, in Croatian)
Open day of the Institute of physics, Zagreb, 25/03/2011

MISCELLANEOUS

- 1) K. Biljaković
 - Member of the Commission of the National Programme "For women in science" L'Oreal & Unesco
 - Member of the Committee of the Croatian Platform for disaster risk reduction
 - President of the Scientific council (until 25. April, 2011.)
 - Chairman of the Commission for monitoring the work of assistants
- 2) D. Starešinić
 - Assistant director of the Institute of physics
- 3) D. Dominko
 - Representative of the graduate students in the Scientific council

LABORATORY FOR PHYSICS OF SURFACES AND SUPPORTED NANOSTRUCTURES

HEAD

Dr. Petar Pervan

Co-workers

Dr. Milorad Milun, Dr. Marko Kralj, Dr. Ivo Pletikosić, B.Sc, Marin Petrović, B.Sc, Iva Šrut, B.Sc, Ida Delač, B.Sc.

Co-workers from other institutions

Dr. Vesna Mikšić-Trontl, FER, Zagreb

MAJOR RESULTS

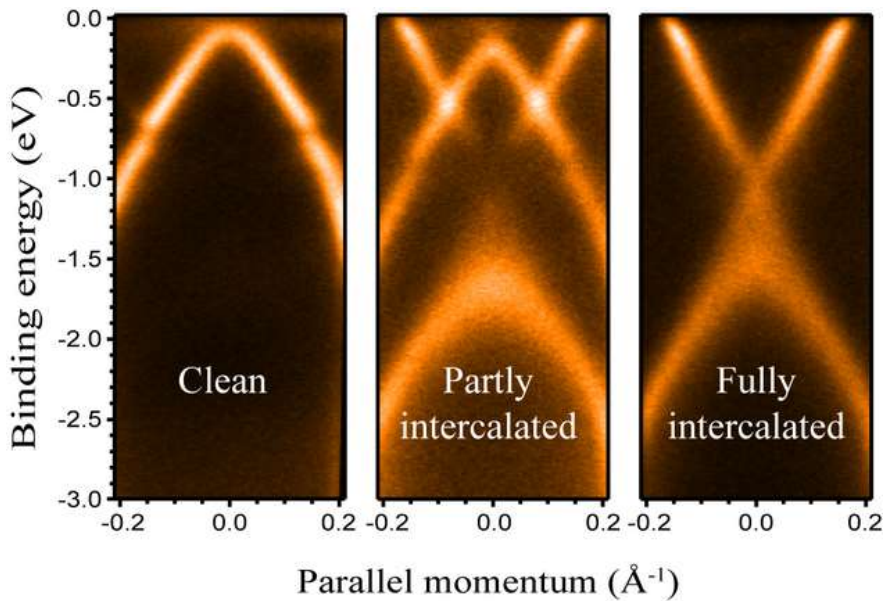
GENERAL OVERVIEW OF ACTIVITIES

Activities in the laboratory are focused to studies of epitaxial graphene systems, mostly in the context of a model system to form hybrid structures, e.g. protected sandwiched atomic layers of alkali atoms, noble-metal atoms and even oxygen. Main tools to study properties of such samples are ARPES and STM. In addition, through UKF project, access to nanocharacterization tools at Brookhaven Laboratory Nanocenter became accessible where LEEM and micro-Raman techniques have been extensively applied to study our samples.

ARPES studies

Studies of the electronic structure of graphene hybrids has been extensively studied by ARPES. Experiments were focused to the K-point of graphene and experimental scans have been performed along the G-K high-symmetry line. Our studies performed in the previous year on the intercalated alkali layers, have been extended now by oxygen and gold intercalation. For those systems, we find prominent hole-doping effects.

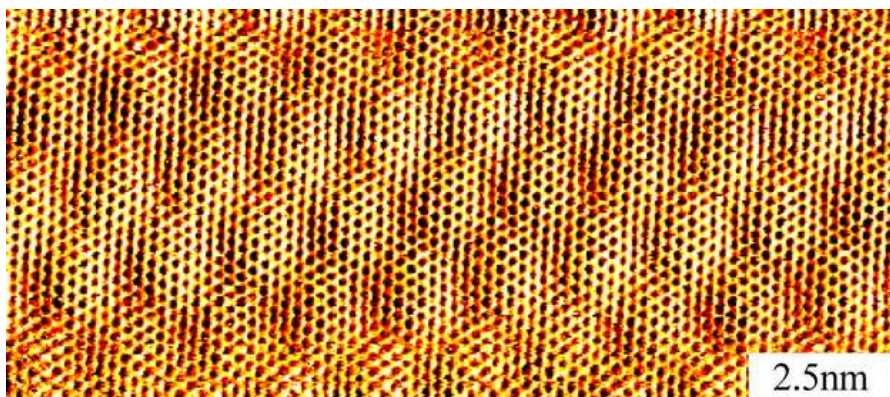
Although the G-K experimental geometry enables fast scanning of high symmetry directions in the Brillouin zone, it does not allow mapping, especially when important features are out of the Brillouin zone center, which is the case of graphene. In addition, small sample tilt or misorientation with respect to the Gamma-K direction leads to errors, which may lead to some wrong conclusions, e.g. band gap at the Dirac point of graphene can be overestimated. That is why we have adjusted our ARPES system (by rotating the analyser for 90°) to scan perpendicular to the Gamma-K geometry and made test measurements in this geometry by the end of the year.



Different levels of intercalation of epitaxial graphene on Ir(111) and corresponding electronic structure effects: from almost neutral to heavily electron-doped graphene. ARPES spectra were imaged perpendicular to the Gamma-K high symmetry direction, in a geometry ideal for the bandstructure mapping.

STM studies of vicinal studies

Ir(332) and graphene growth on Ir(332) surface has been in the focus of STM research. We have started systematic studies of graphene structures with respect to the preparation conditions (hydrocarbon pressure and temperature, in particular). Main aim is to form long-range periodic structures which can act as uniaxial periodic perturbation potential to the graphene pi-bands, which may lead to novel phenomena in the modified band-structure of graphene. STM system was also used to study standing waves patterns at low temperature on surfaces of topological insulator samples which were obtained through the collaboration with Brookhaven lab. It turned that STM experiments on those layered materials are difficult due to the fact that interaction with STM tip often leads to local sample cleavage, which makes STM experiments unstable and irreproducible.



Atomically resolved topograph of graphene lattice of graphene grown on Ir(332). Along with the honeycomb structure of carbon atoms, a hexagonal moiré structure is clearly resolved.

Photolithography development

Most of lab co-workers were involved in the UKF project "Photolithographic synthesis and electronic properties of graphene-based devices and related structures" which had two main aspects. One is development of lab space for the implementation of photolithography techniques, which will allow micro-fabrication of devices and structures for transport measurements and other applications (e.g. photovoltaics, sensors,...). This task was successfully accomplished by the end of the year, when photolithography lab was officially open. Another task within this project was nanocharacterization of graphene devices and hybrid epitaxial graphene system by techniques of micro-Raman and LEEM, respectively.

Scanning probes under ambient conditions

Motivated by successful application of STM technique under ambient conditions to study structures of self-assembled layers of organic molecules on solid surfaces, we have extensively studied two-dimensional ordering of semiconducting quantum-dot systems in the form of semiconducting clusters. Understanding two-dimensional nucleation of the quantum-dot array is important for the effects of three-dimensional ordering in the form of stacks of two-dimensional layers. Different samples studied were prepared on different types of patterned template surfaces, different growth conditions (temperatures), etc.

Our continuous efforts in application of scanning tunneling microscopy on a wide scope of sample surfaces, involving UHV and ambient imaging, was also an important factor in Institute's joint acquisition of the atomic force microscope (AFM), which was purchased at the end of the year.

Atmospheric pressure chemical vapour deposition

Triggered by new possibilities which are implemented through UKF project (device fabrication) and ever growing interest in epitaxial graphene production, we have started new collaboration with D. Čapeta from Physics Department at the University, in a direction of cost-effective graphene

production for large-scale applications. This implies graphene growth under ambient pressure in a tube furnace. Our expertise in graphene growth in UHV, helps us to explore rich variety of conditions for high-quality graphene growth on metal foils, a research with great importance for future applications. This is one research direction which we intend to develop more in the upcoming years.

PROJECTS

Title: Electronic and crystal structure of supported self-organized nanosystems

Project type: MZOŠ (035-0352828-2840)

Head researcher(s): Petar Pervan

Duration: 2007-2011

Title: Photolithographic synthesis and electronic properties of graphene-based devices and related structures

Project type: UKF projekt (66/10)

Head researcher(s): Tonica Vala (BNL), Marko Kralj (IF)

Duration: 2010-2012

Title: Epitaxial-graphene-enabled tunable metamaterials

Project type: NSF-MZOŠ, bilateral USA-Croatia

Head researcher(s): M. Kralj (IF) i R.M. Osgood (Columbia)

Duration: 2009-2012

Title: Graphene-cluster hybrids

Project type: DAAD-MZOŠ, bilateral Germany-Croatia

Head researcher(s): M. Kralj (IF) i C. Busse (Uni Köln)

Duration: 2010-2011

SCIENTIFIC COLLABORATION

- 1) Modeling of electronic structure of alkali-doped graphene, Laboratory IF i dr.sc. R. Brako i D. Šokčević (Institut Ruđer Bošković, Zagreb)
- 2) Self-organisation of semiconducting nano-particles, M. Kralj, I. Delač sa dr. sc. Maja Buljan (Institut Ruđer Bošković)
- 3) Atmospheric pressure chemical vapor deposition graphene M. Kralj sa D. Čapeta (Physics Department, University of Zagreb)

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) M. Kralj, I.Pletikosić, M.Petrović, P.Pervan, M.Milun, A.T. N'Diaye, C. Busse, T. Michely, J. Fujii, I. Vobornik
Graphene on Ir(111) characterized by angle-resolved photoemission
Phys.Rev. B 84 (2011) 075427
- 2) I. Biljan, M. Kralj, T. Mišić Radić, V. Svetličić, H. Vančik
Dimerization of Nitrosobenzene Derivatives on Au(111) Surface

EXPERT ARTICLES

- 1) M. Kralj
Grafen: zvijezda je rođena (Nobelova nagrada za fiziku 2010. godine)
Matematičko-fizički list LXI 4 (2010.-2011.) 234-241

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) M. Petrović, I. Šrut, P. Pervan, S. Runte, C. Busse, T. Michely, M. Kralj
Graphene flakes growth study by ARPES
75. Jahrestagung der DPG und DPG Frühjahrstagung, Dresden
(talk)
- 2) I. Šrut, M. Petrović, P. Pervan, M. Milun, D. Forster, C. Busse, T. Michely, M. Kralj
Doping of epitaxial graphene on Ir(111)
75. Jahrestagung der DPG und DPG Frühjahrstagung, Dresden
(talk)
- 3) M. Kralj
From neutral to chemically doped epitaxial graphene
Japanese-Croatian Workshop on Material Science, Zagreb
(talk)
- 4) M. Kralj, M. Petrović, D. Niesner, T. Fauster, J.R. Dadap, K. Knox, N. Zaki, R.M. Osgood
Stanja zrcalnog potencijala grafena na Ir(111)
7. znanstveni sastanak HFD-a, Primošten
(poster)
- 5) M. Petrović, I. Šrut, P. Pervan, J. Sadowski, T. Valla, M. Kralj
Epitaksijalni grafen na Ir(111) - Karakterizacija rasta i strukture
7. znanstveni sastanak HFD-a, Primošten
(talk)
- 6) I. Šrut, M. Petrović, P. Pervan, M. Milun, R. Brako, D. Šokčević, T. Valla, J. Sadowski, M. Kralj
Efekti dopiranja epitaksijalnog grafena na Iridiju (111)
7. znanstveni sastanak HFD-a, Primošten
(poster)
- 7) I. Delač, S.-Y. Hong, J.R. Dadap, P.-C. Yeh, R.M. Osgood, M. Kralj
Upotreba SHG metode za proučavanje nelinearnih optičkih svojstava grafena na silicijevoj podlozi
7. znanstveni sastanak HFD-a, Primošten
(poster)

LECTURES AND SEMINARS

- 1) M. Kralj
 - Era grafena: nezaustavljiva zvijezdu u usponu
Gimnazija Čakovec, Čakovec (invited by Melita Sambolek & Dejan Vinković)
(22/01/2011, lecture)
 - Grafen: baza za novu elektroniku i nove tehnologije
Meeting of Croatian Vacuum Society, Zagreb (invited by Ognjen Milat)

- (26/01/2011, lecture)
 - Electronic properties of high-quality monolayer graphene on Ir(111)
Max-Planck-Institut für Festkörperforschung, Stuttgart (invited by Ulrich Starke)
(19/05/2011, seminar)
 - Ugljik uzvraća udarac
26. Ljetna skola mladih fizicara, Mali Lošinj (invited by Mario Basletić)
(20/06/2011, lecture)
 - From neutral to chemically doped epitaxial graphene
Center for Integrated Science & Engineering - Columbia University, New York, US (invited by Richard
(22/09/2011, seminar)
- 2) M. Kralj - nastavak
- Grafenska zemlja čudesa
Gimnazija Sisak - Ž.S.V. nastavnika i učitelja fizika, Sisak (invited by Blaženka Slovenec)
(26/10/2011, lecture)
 - Understanding intercalation of epitaxial graphene in real space and real time
II. Physikalisches Institut - Universität zu Köln, Köln, Germany (invited by Carsten Busse)
(07/12/2011, seminar)

TEACHING

COURSES

- 1) M. Milun
- Nanotechnologies
Uni Zagreb, PMF Zagreb, Chemistry dept. - doctoral studies
(2010/2011)
 - Chemical and physical properties of surfaces and nanostructures
Uni Zagreb, FKIT Zagreb, graduate studies
(2010/2011)
 - Chemical and physical properties of surfaces and nanostructures
Uni Zagreb, FKIT Zagreb, doctoral studies
(2010/2011)

MENTORSHIP

- 1) Petar Pervan
- I. Pletikosić, Physics Department, Faculty of Science, University of Zagreb
- 2) M. Kralj
- M. Vojnić-Kortmiš, diploma thesis:
"Međudjelovanje grafena sa metalnom površinom: utjecaj na svojstva Diracovih fermiona"
Department of Physics, Faculty of Science, University of Zagreb
(07/02/2011)
 - mentor to PhD students:
Marij Petrović
Iva Šrut

- co-mentor (with T. Vuletićem) to PhD student:
Ida Delač

SCIENTIFIC VISITS

- 1) M. Kralj
 - Friedrich-Alexander-Universität Erlangen-Nürnberg
(01/03/2011-31/05/2011)
 - Columbia University, New York
(16/09/2011-24/09/2011)
 - Universität zu Köln, Köln
(05/12/2011-16/12/2011)
- 2) M. Petrović
 - Brookhaven National Laboratory, Upton
(20/05/2011-05/06/2011)
 - Universität zu Köln, Köln
(08/06/2011-01/07/2011)
 - Brookhaven National Laboratory, Upton
(13/11/2011-27/11/2011)
- 3) I. Šrut
 - Brookhaven National Laboratory, Upton
(20/05/2011-05/06/2011)
 - Universität zu Köln, Köln
(03/07/2011-31/07/2011)
 - Brookhaven National Laboratory, Upton
(13/11/2011-27/11/2011)
- 4) I. Delač
 - Columbia University, New York
(08/04/2011-06/05/2011)
 - IHRS Biosoft Summer school, Forschungszentrum Jülich, Jülich
(01/08/2011-07/10/2011)
 - Universität zu Köln, Köln
(20/11/2011-30/11/2011)
- 5) T. Valla
Brookhaven National Laboratory, Upton
(03-07/06/2011 & 21-30/12/2011)
- 6) K. Wandelt
Universität Bonn, Bonn
(18-20/07/2011)
- 7) D. Niesner
Friedrich-Alexander-Universität Erlangen-Nürnberg
(26/09-07/10/2011)
- 8) F. Craes
Universität zu Köln, Köln
(01-14/11/2011)
- 9) C. Busse
Universität zu Köln, Köln
(21-27/11/2011)

REVIEWING

- 1) Petar Pervan

- Physical Review Letters, Physical Review B
- 2) M. Kralj
 - Surface Science, Physical Review B, Physical Review Letters
 - HRZZ projects
- 3) M. Milun
 - Journal of Physics and Chemistry of Solids, Polimeri, Physical Review Letters, HRZZ projekt Gost, IRB evaluacija

POPULARIZATION OF PHYSICS

- 1) P. Pervan
 - Fame Lab - jury member
- 2) M. Kralj
 - Era grafena: nezaustavljiva zvijezdu u usponu
Gimnazija Čakovec, Čakovec (22/01/2011)
 - Ugljik uzvraća udarac
26. Ljetna skola mladih fizicara, Mali Lošinj (19-25/06/2011)
- 3) M. Milun
 - Nanotehnologies - 2 talks
Festival znanosti Sinj 12.4.2011
 - Nanotehnologies
Međužupanijski aktiv nastavnika fizike, Zagreb, 4.1.2011

MISCELLANEOUS

- 1) P. Pervan
 - Member of the Committee for the supervision of Framework programs, Ministry of Science, Education, Sport
 - Member of Croatian Science Foundation Advisory Board
 - Member of the Editorial Advisory Board , Vacuum- Elsevier
- 2) M. Kralj
 - Member of the Executive Board of the Croatian Vacuum Society
- 3) M. Milun
 - National Council for High Education - member
 - FP7 NMP PC, member
 - ,Croatian Natural Society, Executive Council, member
 - Croatian Metrology Institute, President of the Board

GROUP FOR THEORETICAL PHYSICS OF CRYSTAL, NANOSTRUCTURE AND BIOLOGY SURFACES

HEAD

Dr. Branko Gumhalter

Co-workers

Sanjin Marion, M.Sc.

Co-workers from other institutions

Ante Bilić, CSIRO Math Informat & Stat, Clayton, Australia

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

In 2011 our research activities were focused on the quantum-mechanical descriptions of inelastic scattering of low-energy noble gas atoms from vibrating corrugated crystal surfaces (Research topic 1), and on nonadiabatic dynamics and decoherence of electrons in quasi-two dimensional surface bands on metals (Research topic 2).

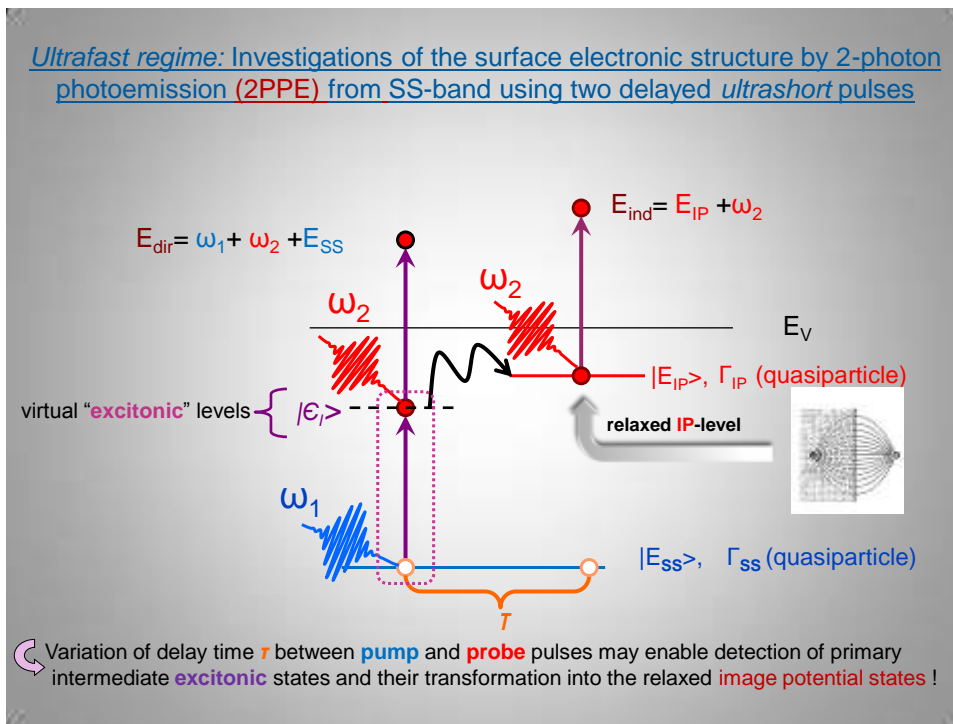
Quantum-mechanical descriptions of inelastic scattering of low-energy noble gas atoms from vibrating corrugated crystal surfaces

We have developed a strictly quantum mechanical formula for the energy and parallel momentum resolved scattering spectrum that combines the effects of the diffraction of atoms from corrugated surfaces and multiple inelastic scattering by dispersive phonons. The final result is expressed in the compact and numerically tractable form of a Fourier transform of a cumulant expansion in which each term embodies an interplay between the processes of projectile diffraction and multiphonon scattering to all orders in the respective interaction potentials. The Debye-Waller reduction of the intensities of diffraction peaks is explicitly formulated.

Nonadiabatic dynamics and decoherence of electrons in quasi-two dimensional surface bands on metals

Mechanisms of electron decoherence at surfaces are manifold as they may originate from the various complex interactions of electrons with the static crystal structure and dynamical degrees of freedom of the environment. Electronic propagation in quasi-two-dimensional image potential bands (IS-bands) on flat low index surfaces of some metals is subject to an efficient decoherence mechanism that can be controlled externally by careful dosing the concentration (i.e. the coverage) of adsorbates on clean surfaces, which act as randomly distributed scatterers. Thereby one can tune the strength of incoherent IS-electron scattering from defects. Such processes in IS-bands on Cu(100) surface have been investigated by two-photon-photoemission

spectroscopy. We employ the propagator approach to describe electron decoherence and demonstrate that it produces a very good agreement between the theoretical and experimental results for the electron scattering cross sections. This enables us to discuss the temporal stages of electron dynamics and decoherence in surface bands.



PROJECTS

Title: FY2009 Strategic Japanese-Croatian Cooperative Program on "Materials Sciences"

Project type: Bilateral cooperation

Head researcher(s): Branko Gumhalter

Duration: Three years

SCIENTIFIC COLLABORATION

- 1) "Modelling of dynamical electronic response of Cu(111) and Ag(111) surfaces"
B. Gumhalter, S. Marion and V.L. Silkin (DIPC, San Sebastian, Spain)
- 2) "Van der Waals interactions at surfaces within the density functional theory approach"
B. Gumhalter, R. Brako and P. Lazić (Ruđer Bošković Institute, Zagreb)

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) B. Gumhalter
Multiphonon atom-surface scattering from corrugated surfaces: derivation of the inelastic scattering spectrum for diffraction states
J. Phys. Cond.M
- 2) S. Marion , B. Gumhalter
Electron scattering by random adsorbates: a tunable decoherence mechanism in surface bands, Phys. Stat. Solidi B, published in 2012.

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) S. Marion, B. Gumhalter
"Temporal stages of electron scattering from adsorbates in image potential bands: Calculations of total cross-sections for comparison with experiment"
ECOSS-28, Wroclaw (Poland), Aug. 28-Sept. 2, 2011.
(lecture)
- 2) S. Marion, B. Gumhalter
"Scattering of image potential band electrons by adatoms: A controllable decoherence mechanism in 2PPE from surfaces"
OSI-9, Akumal(Mexico), Sept. 19-23, 2011.
(lecture)
- 3) B. Gumhalter
"Time-dependent approach to description of ultrafast spectroscopies of surfaces"
David Langreth Memorial Symposium, Rutgers University, (NJ)
(invited lecture)

LECTURES AND SEMINARS

- 1) B. Gumhalter
 - Ultrafast electron dynamics in pump-probe spectroscopies of surfaces: crossover from transient excitonic to quasi-stationary I image potential states University of Pittsburgh, Department of Physics and Astronomy
(1/11/2011, seminar)

TEACHING

COURSES

- 1) B. Gumhalter
 - Localized and dynamical processes at surfaces
lecturer, postgraduate studies, Faculty of Science, University of Zagreb (2010/2011)

MENTORSHIP

- 1) B. Gumhalter
 - Sanjin Marion, B.Sc. thesis:
"Scattering of electrons by impurities and application to two-photon photoemission from surfaces"
Department of Physics, Faculty of Science, University of Zagreb, 17 June 2011.

SCIENTIFIC VISITS

- 1) B. Gumhalter
Department of Physics and Astronomy, University of Pittsburgh
(Nov. 2011)

ORGANIZATION OF SCIENTIFIC MEETINGS AND BOARD MEMBERSHIPS

- 1) B. Gumhalter:
 - Member of the Programme Committee of ECOSS-28, Wroclaw (Poland), Aug. 28-Sept. 2, 2011.
 - Organiser of the "Ultrafast Surface Dynamics Session" at ECOSS-28, Wroclaw (Poland), Aug. 28-Sept. 2, 2011.
 - Organiser of the "Croatian-Japanese Workshop on Materials Science", Institute of Physics, Zagreb, 06 -07 Oct. 2011

REVIEWING

- 1) B. Gumhalter
 - Phys. Rev., Phys. Rev. Lett., J. Phys. :Cond. Matt., Surf. Sci.
 - Evaluator of the R. Bošković Institute, Zagreb

MISCELLANEOUS

- 1) B. Gumhalter:
 - Member of the Board of the Surfaces and Interfaces Section of the EPS
 - Member of the Croatian Physical Society
 - Member of the Croatian Vacuum Society

GROUP FOR NANOSCIENCE

HEAD

Dr. Antonio Šiber

MAJOR RESULTS

GENERAL OVERVIEW OF ACTIVITIES

Activities in the Group for Nanoscience were focused on self-assembly, stability, and structure of viruses. We have investigated a plausible path for disassembly/rupture of highly charged, tethered (crystalline) and liquid spherical shells, and found that the rupture instability may be directly related to the line tension of the edge of the structure exposed to the solution. The simplified systems we examine correspond to (empty) viruses (tethered; capsids) and (lipid) vesicles (liquid), but our approach to electrostatics of ruptured structures is of more general nature and we expect it to be of use in other contexts also. Effects of charge on the structure of viruses were also examined in the context of DNA condensation in bacteriophages. For that purpose, an extension of the Ubbink-Odijk free-space toroidal DNA condensation model was formulated, so to account for condensation in the geometrical constraint imposed by the stiff protein capsid. A phase-space diagram of shapes, depending on the elasticity and surface tension of the DNA and attractive DNA-capsid interaction, was constructed. Comparisons of the prediction of the model with high-quality cryo-EM experimental images taken in the laboratory of F. Livolant (CNRS, France) show that the physical properties of DNA condensate, reflected in the shape of the toroid, strongly depend on the condensation agent (polyethylene glycol vs. spermine).

Activities related to large deformation of soft elastic objects, which started in year 2006 with the investigations of elastic properties of virus capsids, continued this year also on a particularly simple benchmark system – a thin-walled hollow cylinder/tube compressed between two plates parallel to the tube axis. The system that we have chosen is meant to model cases of large deformations in materials that are made of thin sheets, such as carbon nanotubes, fullerenes, and other similar structures made of graphene sheets, cellular membranes and vesicles (made of a lipid bilayer), and protein shells (made of protein sheets), such as virus capsids and microtubules. The energy and deformation of the system was studied theoretically, but also experimentally, using a custom-built experimental setup.

Physics of viruses

A special numerical routine for solving the Poisson-Boltzmann equation in complicated geometries was developed in order to study the energetics of a ruptured structure. The electrostatic potentials obtained from the routine were used to construct the free energy of these structures. An illustration of the complexity of the calculation is shown in Fig. 1 below which presents the equipotential surfaces of the ruptured capsid/vesicle (radius 10 nm, opening angle 0.235π , surface charge density $0.4 e_0/\text{nm}^2$, and the bulk concentration of monovalent salt 10 mM).

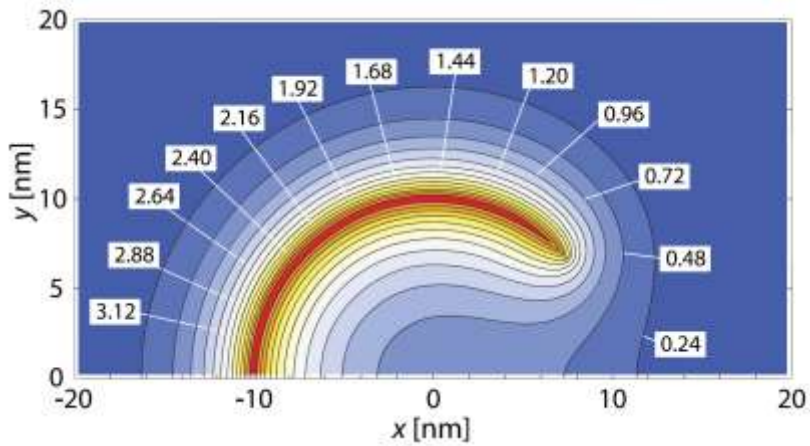


Figure 1. The solution of the PB equation (thermally scaled electrostatic potential in a salty solution) for ruptured, infinitely thin spherical shell, modeled as a spherical cap.

Dedicated minimization routines were developed in order to determine the optimal shape of the DNA toroid condensed in a protein capsid. The results of these numerical procedures enable one to reconstruct the full 3D shape of the DNA toroid, as is shown in the example in Fig. 2.

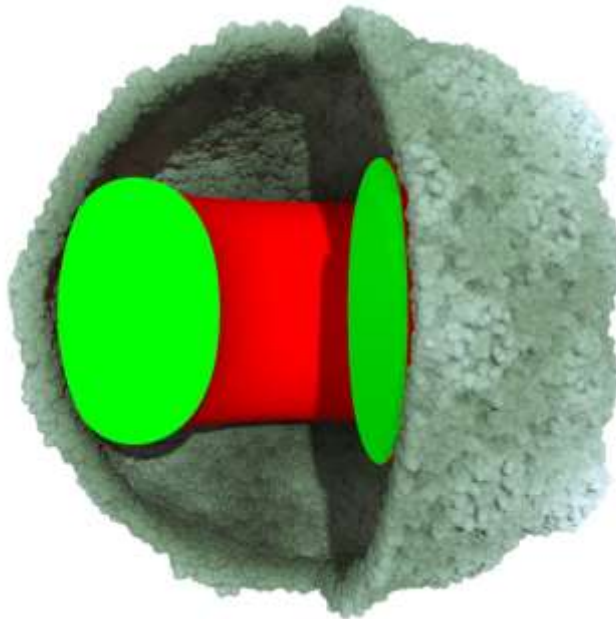


Figure 2. The optimal shape of the DNA toroid (yellow-green and red) constrained in a bacteriophage capsid (greyish green). The shape optimizes the elastic energies of the wound DNA genome, the surface energy of the exposed DNA strands, and the adhesion-like energy of the DNA-capsid interaction. The diameter of the capsid is ~ 80 nm.

Large and possibly non-linear deformations of soft systems

Dr. Tomislav Vuletić has been of great assistance to us in constructing a precise, yet exceptionally cheap experimental setup for measuring the forces taking place in large deformations of soft systems. The same setup is used in ongoing research and we intend to extend it. The scheme of the setup is shown in Fig. 3.

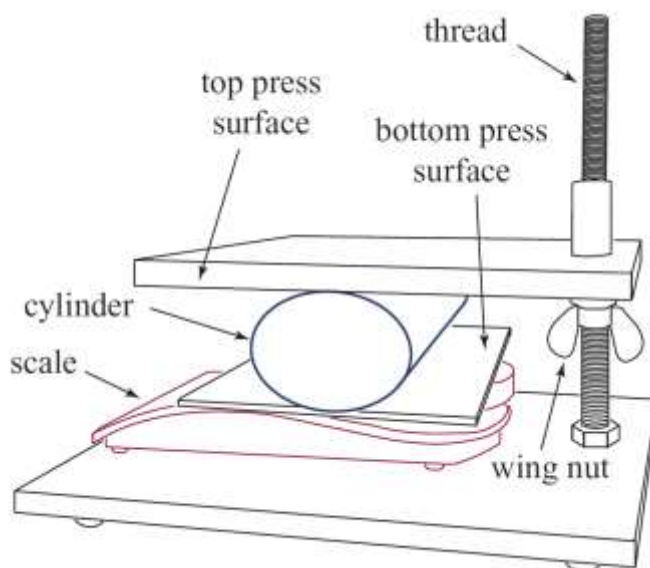


Figure 3. A scheme of the experimental setup for measuring the forces in large deformations of soft systems.

PROJECTS

Title: Shapes and structures of nanoscale systems dictated by competition of energies

Project type: MZOŠ (035-0352828-2837)

Head researcher(s): Antonio Šiber (IF)

Duration: 2007-2011

PUBLICATIONS

SCIENTIFIC ARTICLES

- 1) A. Šiber and H. Buljan, Theoretical and experimental analysis of a thin elastic cylindrical tube acting as a non-Hookean spring, *Phys. Rev. E* 83, 067601 (2011), selected also for *Virtual Journal of Nanoscale Science & Technology*
- 2) A. Lošdorfer Božič, A. Šiber, and R. Podgornik "Electrostatic self-energy of a partially formed spherical shell in salt solution: Application to stability of tethered and fluid shells as models for viruses and vesicles", *Phys. Rev. E* 83, 041916 (2011).

- 3) A. Leforestier, A. Šiber, F. Livolant, and R. Podgornik "Protein-DNA Interactions Determine the Shapes of DNA Toroids Condensed in Virus Capsids", *Biophys. J.* 100, 2209 (2011).

PARTICIPATION IN SCIENTIFIC MEETINGS

- 1) A. Šiber
In viro DNA condensation in the extended Ubbink-Odijk model
Christmas Biophysics Workshop, December 2011, Varaždin, Croatia
(lecture)

TEACHING

COURSES

- 1) A. Šiber
 - Molekularna biofizika (Molecular Biophysics)
Phd study in biophysics, PMF Zagreb
(2011/2012)

MENTORSHIP

- 1) A. Šiber
 - Diploma work of Berislav Buča (September 2011), „Elementi teorije stohastičkih procesa u biofizici i ekonofizici“, (Elements of theory of stochastic processes in biophysics and econophysics), University of Zagreb, Faculty of mathematics and natural sciences, Physics department.
 - Diploma work of Bruno Paun (September 2011), „Istraživanje kaustike metodom praćenja svjetlosnih zraka i usporedba s eksperimentom“, (Investigation of caustics by ray-tracing and comparison with experiments), University of Zagreb, Faculty of mathematics and natural sciences, Physics department.

SCIENTIFIC VISITS

- 1) A. Šiber
 - Faculty of Mathematics and Physics, Ljubljana, Slovenia
(Apr – Jun 2011)

REVIEWING

- 1) A. Šiber
 - Physical Review Letters, Physical Review B, Physical Review E, Nanotechnology
 - Romanian National Council for Development and Innovation
 - Hrvatska zaklada za znanost

POPULARIZATION OF PHYSICS

- 1) A. Šiber
 - „Konstrukcija stvarnosti: Postmoderno u modernoj fizici“ (Construction of reality: Postmodern in modern physics)
Retrospective exhibition of Ivan Ladislav Galeta “Zero-point landscape: experiments and research”, Museum of contemporary art, Zagreb.
 - “Kako sam gradio da Vincijev hram” (How I built da Vinci’s temple)
Open Day of the Institute of Physics, Zagreb
 - “Uvod u fiziku virusa” (Introduction to Physics of Viruses)
Institute „Ruđer Bošković“, Zagreb, Croatia
 - “Viruses and life”, ~ 5 min guest appearance
“Trenutak spoznaje” broadcast, Croatian National Television

MISCELLANEOUS

- 1) A. Šiber
 - President of the Organizing Committee of 6th Christmas Biophysics Workshop, December 2011, Varaždin, Croatia

OTHER ACTIVITIES

LIBRARY

LIBRARIAN:

Marica Fučkar-Marasović, prof., dipl. bibl.

Professional consultant:

Jadranko Gladić, PhD

Library is open from 9.00 to 17.00 for Institute employees and external users (students, other institutes and faculties staff).

Users can loan only books. Scientific journals, reference materials and theses cannot be borrowed, but can be used in reading room and photocopied or scanned in library. Loan period depends on user status: Institute employees can borrow books for six months and external users for one month (with receipt which they can get in the library of their institution).

Sabre Foundation gave in 2011 a valuable donation of books to the library that covered physics science. Books have been classified through INSPEC classification, cataloged and given on disposal to the users.

In 2011. library was intensively working on implementation of Aleph® integrated library system for universities and research libraries in Croatia. Databases of books (LIBRI), journals (PERI) and theses were converted to new system and the National and University Library in Zagreb provided training for the library staff to work in Aleph. After conversion, records need to be checked and fixed or updated and this will be finished in 2012.

New catalogue can now be searched on <http://knjiznica.ifs.hr/>.

LIBRARY STATISTICS

	Collections
Books in library	
Books held January 1, 2011	4711
Books added during year	200
Books held December 31, 2011	4911
Periodicals (hard copy)	
Number of titles	310
Number of current titles	2
Periodical catalogues	24
Theses	
Graduation theses	679
Master theses	130
Dissertations	119
Subscriptions:	

E-journals	113
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Access to subscribed e-resources

Number of Successful Full-text Article Requests

IOP science	1942
NPG Journals	1037
APS Journals	5353

Circulation

Number of circulations	
Books	75
Journals	201

Interlibrary loan

Received from other libraries	56
Provided to other libraries	89

Users

Institute employees	60
Students	120
Others	33

MULTIMEDIA LABORATORY

HEAD:

Berti Erjavec, Senior Associate

GENERAL ACTIVITIES

The main goal of this laboratory is a transfer of the recent scientific knowledge and practical skills related to areas of the Institute activities. We develop demonstration kits and accompanying educational materials, organizing workshops and lectures for teachers in elementary and secondary schools. This Institute gives its contribution to lifelong learning for teachers and curriculum development through the acquisition of new knowledge. These activities complement the popularization work with students through Open Days and visits of the Institute. Laboratory intends to achieve international cooperation in the field of educational projects and cooperation with relevant science and educational institutions.

PROJECTS

PHYSICS IN COLORS

The authors of the project: *Berti Erjavec, Slobodan Milošević (Institute of Physics)*

Collaborators on the project: *Sergej Jakovljević, Dominik Ivošević, and physics teacher Mrs. Bernarda Mlinarić (15. Gymnasium Zagreb).*

The new project is created in collaboration with *Slobodan Milošević* and partly relies on his previous project "*Spectroscopy in School*". The basic idea is the creation of digital spectroscope including accessories with which anyone can explore the colors and spectra of radiation. The project involved gifted students *Sergej Jakovljević* and *Dominik Ivošević* with their physics teacher *Mrs. Bernarda Mlinarić*. By the end of the year we made a prototype of a digital spectroscope (Figure 1) connected to the computer with the original software that runs in real time (Figure 2). Spectroscope receives radiation spectra in the visible part of the spectrum (Figure 3).



Figure 1: Digital spectroscope on tripod.



Figure 2: Spectroscope connected to the computer performs in real time.

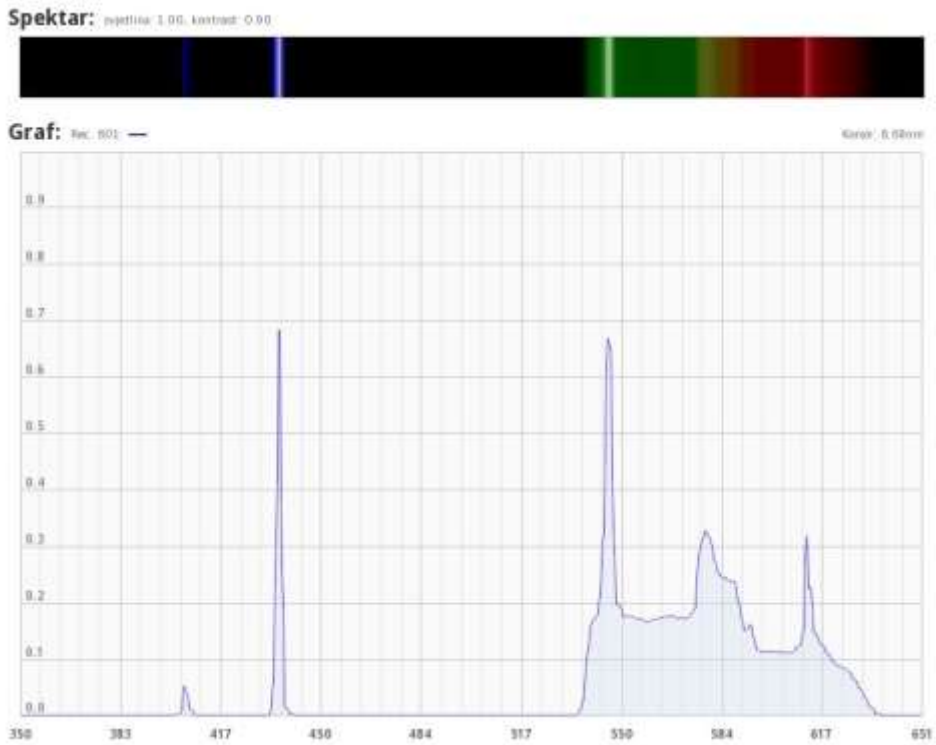


Figure 3.

Spectrum of the bulb savings visible on monitor clearly shows mercury peaks.

DEMONSTRATION KIT FOR MAGNETISM (DKM)

Authors of the project: *I. Aviani, B. Erjavec*

Collaborators on the project: *I. Bagarić, P. Milašin, N. Margetić, K. Drvodjelić, I. Čičko*



Figure 4.
Magnetism demonstration kit

Activities to promote the set

- Open Day of the Institute of Physics (25/03/2011).
- Croatian Symposium on Physics Education, Zadar, April 27 -29, 2011, Workshops
- Summer School of Science, Višnjan, August 4, 2011 Workshop (*N. Margetić, P. Milašin*)
- Night of the researchers, September 23, 2011, Slavonski Brod, Workshops (*B. Erjavec, N. Margetić, P. Milašin*)

Manufacturing new sets

After collecting a sufficient number of interested schools and institutions for DKM, we approached the purchase of materials and construction of twenty new sets in the workshop of the Institute. Unfortunately, due to lack of money, kits are not completed yet.

OPEN DAY 2011 - "FROM IF TO YOU"

Coordinator: *Osor Barišić*

Institute's Open Day held on March 25, 2011 under the heading "From IF to You". The organization took place under the guidance of *Osor Barišić*, who took over the content for the occasion, while Berti Erjavec communicates with schools and concerns about reports, schedule tours, lectures and informing visitors. Open day responded to over 1000 visitors from Croatia's elementary and secondary schools. Event was attended by many citizens with their children, who have joined student groups at the entrance of Institute. Age of

visitors ranged from the smallest ones that have just started primary school, through secondary school to the students of some faculties in Zagreb.



Figure 5 Open Day 2011 poster

FERROFLUIDS

Berti Erjavec designed and coordinated the project. For the purposes of the Open Day and training in the field of magnetism was acquired ferrofluid. We have designed and make the exhibit (Figure 6) in which the magnetic field controls formation of the ferrofluid. Electromagnet with a core was made by *Dr. Đ. Drobac*, and a source with the associated electronics was made by *M. Vukelić*. The project was presented at the Open Day by *Matija Čulo*, *Miss Ivana Gašparlin* and *Goran Gatalica*. The project is designed in the way that in the future it will be a part of permanent educational exhibit.

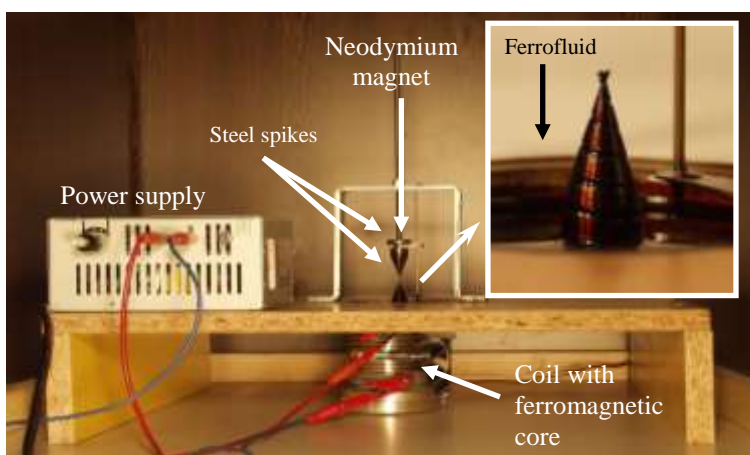


Figure 6
Educational exhibit: Ferrofluid

POPULARISATION - MONITORING THE ACTIVITIES

Scientists of the Institute of Physics in addition to its basic scientific research activities often contribute to the popularization of physics through various forms of activities in television and radio broadcasts. To make this activity permanently visible, I have recorded, processed and upload about thirty video clips in 2011. Those videos are visible on the website:

<http://www.ifs.hr/Page.aspx?p=269>

TV SHOWS

In a TV show about magnetism (May 31, 2011) I prepared a workshop in which students are fourth graders from elementary school. They used equipment and experiments from the set of magnetism that was created at the Institute of Physics (authors *I. Aviani and B. Erjavec*). The show demonstrates that even a younger age of the students can successfully explore nature, and at the same time magnetism is very suitable for stimulating interest in science. Here is the link:

<http://www.youtube.com/watch?v=biXz6kPRXWA>

PARTICIPATION IN TEACHING

Multimedia Lab is open for all students. In the course Multimedia Presentations students perform recording, photographing and processing of digital content.

COURSE

B. Erjavec

- Multimedia Presentations (summer semester)

Teaching Assistant, undergraduate studies, education department,
Department of Physics, Faculty of Science, University of Zagreb

- Mentoring-Assistance

Neva Margetić, Graduate Work, Methodical analysis of motion using the video recordings, Physics Department, Faculty of Science, University of Zagreb
(November 24, 2011)

Leader: *I. Aviani*

PUBLICATIONS

I. Aviani and B. Erjavec An easy method to show the diffraction of light, Physics Education 46, 134 (2011).

In March, published technical papers on simple diffraction method using a powerful green laser that has achieved quite great popularity, and a few months was the most read articles.

MEETINGS AND MANIFESTATIONS

10th Symposium on the Physics Education Demonstration kit for magnetism, Zadar, April 27– 29, 2011 (Workshops).

Two Workshops were held for a total of forty teachers. Teachers were independently performed experiments and responded to the questions. At the end of the Workshop followed a lecture and discussions of the results.

Manifestation "Night of the Researchers", Slavonski Brod, September 23, 2011

Workshops are held in Slavonski Brod as a part of manifestation "Night of the Researchers". The Workshop was organized and prepared by *Berti Erjavec*, but physics students *Neva Margetić* and *Petra Milašin* helped to carry out the Workshops. Due to the great interest we held two Workshops (instead of one) and the audience was very diverse, from preschool through the students. The Workshop used experiments and demonstration supplies from DKM, the educational project of the Institute of Physics (2010.).

STUDY VISITS

Ljubljana, Slovenia, Jun 29-30, 2011

In the framework of international activities, I visited the "House of Experiments" and established contact with Director *Dr. Miha Kos*. We examined the possibilities of cooperation in popularization projects and activities. I have also visited Institute Jožef Štefan in Ljubljana, where I met their leader of popularization, *Dr. Tomaž Ogrin*. I have participated in some of his activities to popularize science between school population. We expressed willingness to cooperate and exchange experiences on the popularization of science among our institutions.

WORK WITH TALENTED STUDENTS

Institute of Physics and XV. Gymnasium Zagreb for many years informally collaborates through various forms of cooperation by providing teachers and students scientific support and technical assistance.

Aware of the importance about collaboration between scientific and educational institutions we signed on December 20, 2011 the agreement and launched activities aimed at identifying and encouraging gifted students and their guidance in the natural science.

Twenty selected gifted students interested in physics under the supervision of their physics teachers *Ms. Bernarda Mlinarić* and *Ms. Ines Dukić* in coordination with *Mr. Berti Erjavec* and scientists from the Institute participate in four pilot projects:

- Magnetic Interaction (*Dr. I. Aviani, B. Erjavec*)

- Spectroscopy (*Dr. S. Milošević, B. Erjavec*)
- Holography (*Dr. N. Demoli*)
- Graphene (*Dr. M. Kralj*)

The goal of project is the active care and support for talented students who will be in a supportive environment to meet with scientific work and make their first steps in that direction. All work and achievements was publicly presented and published at the end of the school year. We hope, as planned, that talented students from other schools will soon join the projects too.

PROFESSIONAL TRAINING

I have participated in a cycle of workshops on entrepreneurial skills "From Scientific Ideas to Successful Businesses" which included eight modules and is organized by Center for Research, Development and Technology Transfer under the auspices of the University of Zagreb.

POSTGRADUATE STUDIES

Since the Autumn 2011 I enrolled in first year of Postgraduate Studies in Physics, with the following Courses:

- Data Analysis in Geophysics (*Dr. Z. Pasarić*)
- Seminar in Geophysics 1 (*Dr. D. Herak, Dr. B. Grisogono*)
- Seminar in Geophysics 2 (*Dr. M. Herak, Dr. M. Orlić*)
- Physics of the Earthquake (*Dr. M. Herak*)
- Seismotectonic Parameters and Earthquake Magnitude (*Dr. B. Tomljenović*)
- Planetary Magnetism (*Dr. G. Verbanac*)

MISCELLANEOUS

B. Erjavec, Senior Associate

- Deputy Union Commissioner affiliates of the Institute of Physics
- Member of the Editorial Board "Mathematical-Physical letter" magazine
- Associate of the "E-school Physics" Croatian Physical Society
- Member of the Commission for Occupational Safety

E-school Physics organized a contest for best photo in physics. After selecting the best forty photos exhibitions are organized in various cities. So, I organized an exhibition "Physics & Photo" at the City Museum of Pakrac in September 2011. The Exhibition was visited by many people and pupils from primary and secondary schools.

SEMINARS GIVEN AT THE INSTITUTE

10/1/2011 15:00

- Time-resolved spectroscopy using Topological light-waves

Dr. Yasunori Toda

Department of Applied Physics, Hokkaido University, Sapporo, Japan

14/2/2011 14:30

- Kuglice, vrećice i loptice (Beads, bags and balls)

Prof. dr. sc. Ana Sunčana Smith

Friedrich-Alexander-Universität Erlangen-Nürnberg, Cluster of Excellence Engineering of Advanced Materials Erlangen, Germany

15/2/2011 15:30

- Elastičnost na nano skali: grafen, virusi i plastične boce (Elasticity on nanoscale: graphen, viruses and plastic bottles)

Dr. Antonio Šiber

Institute of Physics, Zagreb, Croatia

25/2/2011 15:00

- An Introduction to the Ionization Energy Theory: Applied to Nanomaterials, Chemical Reactions and Beyond

Dr. Andrew Das Arulsamy

The Jožef Stefan Institute, Dpt of Surface Engineering and Optoelectronics, Ljubljana, Slovenia

5/4/2011 15:00

- Synthesis of complex oxides thin films and heterostructures in Max Planck Institute

Gennady Yu. Logvenov

Max Planck Institute for Solid State Research, Germany

13/4/2011 15:00

- Aspects of Nonequilibrium Physics: Ultrafast Population transfer and Quantum Hall effect

Dr. Christoph Uiberacker

Montanuniversität Leoben, Institut für Physik, Leoben, Austria

18/4/2011 15:00

- Bezaperturna bliskopoljna mikroskopija (s-SNOM) (Scanning Near-field Optical Microscope)

Dr. Antonija Cvitković and dr. Nenad Ocelić

Neaspec GmbH, Martinsried (München), Germany

19/4/2011 15:00

- Aspects of Nonequilibrium Physics: Quantum Hall effect

Dr. Christoph Uiberacker

Institut für Physik, Leoben, Austria

17/5/2011 15:00

- A new renormalization group approach to strongly correlated Fermi liquids

Dr. Alex C. Hewson

Department of Mathematics, Imperial College, London, U. K.

27/5/2011 10:00.

- Doping, Strains, Disorder and Electric Field Effect on Superconductivity in Ultra-Thin $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ Films

Dr. Davor Pavuna

Physics of Complex Matter, Station 3, EPFL, Lausanne, Switzerland

9/6/2011 15:00

- Transport i rekombinacija u organskim uređajima: novi uvidi iz numeričkih simulacija (Transport and recombination in organic devices: New insight from numerical simulations)

Ivan Jurić, M.Sc.

Institute of Physics, Zagreb, Croatia

15/6/2011 15:00

- Mikrotubuli traže izgubljene kinetohore pivotirajući oko pola diobenog vretena (Microtubules are searching for lost kinetochores by pivoting around the mitotic spindle)

Dr. Nenad Pavin

Physics Department, Faculty of sciences, University of Zagreb, Croatia

30/6/2011 15:00

- Unoccupied electronic states in graphene systems

Dr. Vyacheslav M. Silkin

Donostia International Physics Center, San Sebastián, Spain

7/7/2011 15:00

- Photo-induced phase transitions in electron-lattice and electron-hole systems

Dr. Tetsuo Ogawa

Department of Physics, Osaka University, Toyonaka, Osaka, Japan, Photon Pioneers Center, Osaka University, Suita, Osaka, Japan

19/7/2011 15:00

- Future Challenges of Surface Science

Prof. Klaus Wandelt

Institute of Physical and Theoretical Chemistry, University of Bonn, Germany, Institute of Experimental Physics, University of Wrocław, Poland

15/9/2011 15:00

- Detection of dissolved metals using a liquid electrode dielectric barrier discharge (LE-DBD) and Characterization of a DBD plasma jet for soft ionization

Tobias Krähling MSc. and Saskia Müller, MSc.

Leibniz-Institut für Analytische Wissenschaften – ISAS, Dortmund, Germany

19/10/2011 15:00

- Space-time correlations in the ASEP conditioned on carrying a large flux

Dr. Gunter M. Schütz

Institute of Complex Systems, Forschungszentrum Jülich, Jülich, Germany

29/11/2011 15:00

- Predstavljanje projekta Hrvatske zaklade za znanost: 'Kompleksni magnetski sustavi' (Presentation of the Croatian Science Foundation project "Complex magnetic systems")

Dr. Ivica Živković

Institute of Physics, Zagreb, Croatia

19/12/2011 15:00

- Transient Excitons on Metals: Fact or Fiction?

Dr. Hrvoje Petek

Department of Physics and Astronomy, University of Pittsburgh, USA