Collaborative Workshop on

Modulation & Nanostructuring in Layered Materials

28-31, March 2012

Institute of Physics

Zagreb, Croatia

Program and Abstracts

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The collaborative workshop is organized by the Institute of Physics (Zagreb), *Laboratoire de Physicque de la Matière Complexe*, École Polytechnique Fédérale de Lausanne (Lausanne), *Physics Department*, Faculty of Science University of Zagreb (Zagreb) and *Department of Physics*, Faculty of Science, University of Split (Split).

The collaborative workshop is financed with the funds obtained from the ***Croatian Science Foundation*** (CSF).

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Modulation and Nanostructuring in Layered Materials

(*in short* "Workshop ModNanoLayered 2012")

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Contents

Dear Colleagues,

We are pleased to welcome you to the Collaborative Workshop on **Modulation and Nanostructuring in Layered Materials (*Workshop ModNanoLayered 2012*)**, **organized** by the Institute of Physics, Laboratoire de Physique de la Matière Complexe (LPMC), École Polytechnique Fédérale de Lausanne (EPFL), Physics Department, Faculty of Science, University of Zagreb and Department of Physics, Faculty of Science, University of Split and supported by the *Croatian Science Foundation* (CSF).

The main goal of the collaborative workshop is to gather people with background in physics of low-dimensional materials in order to push forward promising research topics. Paradigm that pushed the idea of the workshop is to unify expertise and know-how of both theoreticians and experimentalists in different fields (transport, ESR, neutron scattering, NMR,...), strengthened with sample production experts. The format of the meeting makes a mix of short presentations of participating laboratories, groups and research, and round-table discussions focused on selected topics.

Contributions cover the areas of various homogenous low-dimensional/layered crystalline materials, spontaneous nano-structuring in otherwise homogenous systems, and artificial nano-patterned materials.

We wish you a stimulating meeting and a pleasant stay in Zagreb.

Sincerely,

Ana Smontara and László Forró
Collaborative workshop organizers

Program

Wednesday, March 28 – Arrivals

18:00 -19:00	**Registration**
19:30 -	**Welcome drink/Dinner**

Thursday March 29 – morning

09:00	**WELCOME ADDRESS**
	Introduction by *László Forró, collaborative coordinator*
	Session I
09:10	**Petar Pervan** Presentation of the Institute of Physics (IP)
09:30	**Velimir Radmilović** (I) Polytypoid Layered Nanostructures
10:15	**Ivan Božović** (I) The Quest for novel HTS Materials
11:00	**Titusz Fehér** (I) Facilities at Budapest University of Technology and Economics
11:25-11:40	**Coffee break**
	Session II
11:40	**Martin Dressel/Rebecca Beyer** (I) IR spectroscopy
12:15	**Antonio Biancone** (C) Superstripes
12:35	**Zoran Radović** (I) Signature of long range triplet proximity effect in the density of states
13:00-15:00	**Lunch break**

I - Invited lecture, C - Contributed lecture

Thursday March 29 – afternoon

	Session III
15:00	**László Forró** (I) Nanoscale science and novel electronic materials at EPFL
15:40	**Kristijan Velebit** (C) Transport properties of the textured 1T-TaS_2 phase
16:00	**Peter Prelovšek** (I) Solid state theory: correlated physics
17:00-18:30	**Poster session and coffee break**
	Session IV
18:30	**Vittorio Cataudella** (C) Electron-phonon effects in perovskites and polaron theory
	Dinner and disscusions

Friday March 30 - morning

	Session V
09:00	**Hrvoje Buljan** (I) Optics and photonics theory group at UniZg
09:25	**Jean–Paul Pouget** (I) The influence of disorder and magnetic field on the inhomogeneous superconductivity in layered conductors
09:50	**Ivica Živković** (I) Magnetism research at IP
10:15	**Petar Popčević/Ana Smontara** (C) Transport measurements under high pressure and high magnetic field at IP
10:35	**Amit Keren** (I) New perspectives for cuprate research: CLBLCO single crystals
11:00-11:15	**Coffee break**
	Session VI
11:15	**Victor Kabanov** (I) Unconventional high-Tc superconductivity from repulsive interactions
11:35	**Denis Sunko** (C) Open problems in the research of high-temperature superconductors
11:55	**John R. Cooper** (I) QM group at Cavendish Laboratory, University of Cambridge
12:30-14:30	**Lunch break**

Friday March 30 - afternoon

	Session VII
14:30	**Ante Bilušić** (C) Presentation of the project proposal "thinSplit"
14.50	**Eduard Tutiš** (C) Modelling electronic processes and devices
15.10	**Dragan Mihailović** (I) CENN Nanocenter
15.35	**László Forró** (I) NanoCenter Belgrade
16:30-19:00	**Tour of old Zagreb** **Dinner and disscusions**

Saturday March 31 - morning

9:00-11:00	**Tour of Labs: Institute of Physics and Faculty of Science UniZg**
	Coffee break
	Session VIII
11:00	**Neven Barišić** (I) Psudogap phase and superconducting fluctuation regime of the cuprate superconductors
11:40	**Antonio Dulčić** (C) Microvawe and radiofrequency measurements in superconductors
12:00	**Ante Bilušić** (C) Grants' review
12.30	**Eduard Tutiš** (C) Short summary and conclusions

Invited Lectures

High-field studies of superconducting fluctuations in high-T_c cuprates

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We have used large pulsed magnetic fields up to 60 T to suppress the contribution of superconducting fluctuations (SCFs) to the *ab*-plane conductivity above T_c in a series of $YBa_2Cu_3O_{6+x}$ from the deep pseudogapped state to slight overdoping. Accurate determinations of the SCF contribution to the conductivity versus temperature and magnetic field have been achieved. Their joint quantitative analyses with respect to Nernst data allow us to establish that thermal fluctuations following the Ginzburg-Landau scheme are dominant for nearly optimally doped samples. The deduced coherence length. $\xi(T)$ is in perfect agreement with a Gaussian (Aslamazov-Larkinw) contribution for $1.01T_c \leq T \leq 1.2T_c$. A phase-fluctuation contribution might be invoked for the most underdoped samples in a T range which increases when controlled disorder is introduced by electron irradiation. For all dopings we evidence that the fluctuations are highly damped when increasing *T* or *H*. This behavior does not follow the Ginzburg-Landau approach, which should be independent of the microscopic specificities of the superconducting state. The data permits us to define a field $H_c'(T)$ and a temperature T_c' above which the SCFs are fully suppressed.The analysis of the fluctuation magnetoconductance in the Ginzburg-Landau approach allows us to determine the critical field $H_{c2}(0)$. The actual values of $H_c'(0)$ and $H_{c2}(0)$ are found to be quite similar and both increase with hole doping. These depairing fields, which are directly connected to the magnitude of the superconducting gap, do therefore follow the T_c variation which is at odds with the sharp decrease of the pseudogap T^* with increasing hole doping. This is on line with our previous evidence that T^* is not the onset of pairing. So the large gap seen by spectroscopic experiments in the underdoped regime has to be associated with the pseudogap. We finally propose here a three-dimensional phase diagram including a disorder axis, which makes it possible to explain most peculiar observations done so far on the diverse cuprate families.

Pseudogap phase and superconducting fluctuation regime of the cuprate superconductors

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The pseudogap phenomenon in the cuprates is one of the most investigated topics in the field of correlated materials. A related question is the extent to which superconducting fluctuation persist between the pseudogap temperature (*T**) and superconducting transition temperature (*Tc*). We have addressed this question by combining several experimental probes: planar dc-resistivity [1], microwave conductivity [2,3], and torque magnetometry [4]. Dc-resistivity measurements in the simple tetragonal model compound $HgBa_2CuO_{4+\delta}$ [5], which features the highest *Tc* (97 K) among all single-layer cuprates, reveal four characteristic temperatures: *T**, coincident with the onset of novel **q**=0 magnetic order revealed by neutron difraction [6]; a second, lower pseudogap temperature *T*** associated with a further rearrangement of the sates at the Fermi level; *T'*, which marks the onset of superconducting fluctuations; and finally *Tc*. Notably, *T'* lies only 10-20 K above *Tc* and closely tracks the superconducting dome with doping. The superconducting fluctuation regime is further investigated by microwave conductivity and torque magnetometry, and these results confirm the latter conclusion. The results for $HgBa_2CuO_{4+\delta}$ are complemented by a comprehensive investigation of other cuprates ($La_{2-x}Sr_xCuO_4$, $YBa_2Cu_3O_{6+\delta}$, $Bi_2Sr_{2-z}La_zCuO_{6+\delta}$), which leads to new insights into the phase diagram of cuprate superconductors.
This work was done in collaboration with G. Yu, D. Xia, Y. Li, X. Zhao, M. S. Grbić, M. Požek, A. Dulčić, and M. Greven.

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IR spectroscopy

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In our research we employ infrared spectroscopy (IR) to investigate the physics of novel electronic and magnetic materials. “Infrared” here is used colloquially since in fact our instruments allow us to cover much broader frequency range extending continuously from sub-THz to UV light. The infrared spectrum of a sample is recorded by passing a beam of infrared light through the sample. When the frequency of the IR is the same as the vibrational frequency of a bond, absorption occurs. Examination of the transmitted light reveals how much energy was absorbed at each frequency (or wavelength). This can be achieved by scanning the wavelength range using a monochromator. Alternatively, the whole wavelength range is measured at once using a Fourier transform instrument and then a transmittance or absorbance spectrum is generated using a dedicated procedure. Analysis of the position, shape and intensity of peaks in this spectrum reveals details about the molecular structure of the sample. Current research directions include: ordering phenomena in solids, organic conductors and superconductors, iron pnictides, optics of metallic nanostructures, low energy electrons in solids, carbon nanoelectronics and nanomagnetism [ref 1-6].

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The Quest for novel HTS Materials

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The goal of our research is to address some key open questions in HTS physics:

- What is the *dimensionality* of the HTS phenomenon?
- What are the *spin* and *charge* of free carriers?
- What is the nature of the *superconducting transition*?
- What is the role of *charge stripes* (if any) in the HTS state?
- What is the nature of the *overdoped metallic state* – a Fermi liquid?
- What is the '*glue*' (the bosons) responsible for electron pairing?
- What is the mechanism of the Giant Proximity Effect?

Our approach to this goal is to:

- utilize Molecular Beam Epitaxy (MBE) synthesis to fabricate atomically smooth HTS thin films, multilayers, superlattices, and combinatorial libraries;
- manufacture various HTS devices and nano-structures, and
- study the transport and other physical properties in
    - SIN, SIS, and SNS HTS junctions;
    - HTS nanolayers, nanowires, nanorings and nanodots; and
    - combinatorial libraries of overdoped HTS films (in the quest for purported Quantum Critical Points).

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Optics and photonics theory group at UniZg

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The topics of research that are investigated at the optics and photonics group at the Department of Physics, University of Zagreb, are presented. These include (i) propagation of light in photonic structures, (ii) dynamics of matter waves (ultracold atomic gases) in low dimensional trapping potentials (optical lattices), and most recently (iii) investigations of plasmons in graphene.

The group of topics under the title "propagation of light in photonic structures" include mainly dynamics of incoherent light in one- and two-dimensional photonic lattices. We have been investigating these topics from 2004 [1,2]. Our research has focused in most of our papers on the types of solitary waves that exist in these systems, and inherent instabilities that occur there. The models utilized are derived from Maxwell equations and they study dynamics of classical correlations in nonlinear systems.

The second group of topics include dynamics of ultracold atomic gases, mainly in one-dimensional trapping potentials. The models that were studied are the Lieb-Liniger and the Tonks-Girardeau models, and we focused on seeking exact time-dependent solutions for out of equilibrium dynamics [3-5]. The motivation is the fact that nonequilibrium dynamics is elusive in the strongly correlated regime, and exact solutions may provide an insight and also benchmark for approximation schemes; moreover these topics are in many ways analogous to those from the first group [3]. We have been studying these topics since 2005.

The last group of topics is focusing on graphene, and more specifically on plasmons in graphene [6]. There is hope that graphene may have advantageous properties as a novel plasmonic material over standardly used metals. It can be doped, losses can be changed by using doping, which holds great promise for applications.

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QM group at Cavendish Laboratory, University of Cambridge

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The Quantum Matter Group at the Cavendish Laboratory, University of Cambridge, studies matter under extreme conditions, i.e. at very low temperatures, high magnetic fields and high pressure, using advanced experimental techniques. The goal of this research is to understand new forms of magnetism and superconductivity and to find electrically conducting materials with new physical properties not described within the standard models of solid state physics. Some of the recent discoveries of the group are finding applications in the fields of refrigeration and detector technology.
Work focuses on two major themes in condensed matter research. The first is to understand the nature of quantum order in itinerant-electron systems on the border of magnetism at low temperatures. In recent years this area of research has led to the study of novel metallic states not described by Fermi liquid theory, anisotropic types of electron-electron and electron-hole pair condensates, and quantum critical phenomena. The second theme is studying the physics of novel superconducting materials, such as the high-T_c superconductors, MgB_2, graphite intercalates and the ruthenates.

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The physics of nanostructures created by novel technologies, beyond their fundamental importance in basic research, also raise the possibilities for promising industrial applications. Shrinking dimensions give rise to new type of behavior radically different from common macroscopic features: simple materials may realize unexpected functions on the nanoscale. A wide range of recent discoveries may serve technological development, including carbon and semiconductor nanostructures and a big variety of "bottom-up" self organizing nanoscale systems or the nanofabrication of devices from special materials. Some of the novel conceptions have already found their application in specific electronic devices.

The goal is the development and detailed experimental / theoretical study of such novel nanostructures, where understanding of nanoscale phenomena is not merely a challenge of fundamental research, but also carries the potential for later technological applications. In a range from atomic sizes to a few hundred nanometers, we not only apply the standard processes of modern nanotechnology (nanolithography, atomic layer deposition, chemical preparation) but also search for custom preparation techniques for contacting single molecules, creating self-organized structures or building atomic-scale switches. The nanostructures are characterized by self-developed scanning probe techniques, spectroscopic methods, electronic and magnetic measurements. A highlighted topic of our experimental studies is the investigation of spin-dependent phenomena: i., detection and manipulation of nanoscale magnetic domains by spin-polarized current, ii., measurement of spin-diffusion by ESR and Andreev spectroscopy, iii., study of phase-, spin-, and superconducting correlations in nanostructures (nanowires, graphene). The two opposite spin electrons of a Cooper pair can be a natural source for creating entangled electron pairs. Their investigation is touching such fundamental questions of quantum mechanics like the Einstein-Podolsky-Rosen paradox. The experimental identification of entangled electrons split from a Cooper pair has a fundamental importance in basic research, but it is also an essential step towards the establishment of qubits, the basic units of envisioned quantum computers at the same time.

Another important direction of our research is the development of reliable contacting techniques for single molecules applying self-designed break junction setups. Despite successes in recent activities in the field of molecular electronics, reliable and reproducible creation of molecular nanostructures is still an especially hard task, as – unlike pre-designed engineering of devices – it depends on the fine details of nanoscale chemical interactions and self-assembling properties. Therefore, detailed studies on the behavior of molecular nanostructures and comprehensive understanding of some reference systems have a fundamental role in the development of functional molecular electronic devices.

Unconventional high-Tc superconductivity from repulsive interactions

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Unconventional symmetries of the order parameter allowed some researchers to maintain that a purely repulsive interaction between electrons provides superconductivity without phonons in a number of high temperature superconductors. It is shown that the Cooper pairing in p and d states is not possible with the realistic Coulomb repulsion between fermions at relevant temperatures in any dimension.

New perspectives for cuprate research: (CLBLCO) single crystals

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Although high quality single crystals of cuprate superconductors have been available for quite some time, comparing the properties of different crystals often raised more questions than answers. The main problem is that many parameters differ between various cuprates simultaneously, and it is difficult to understand which material property is responsible for which physical property. A proper understanding of cuprate superconductivity can emerge only when it is possible to vary the material parameters one at a time preferably in single crystals. In this talk I'll describe the growth and characterization of large single crystals of a CLBLCO superconductor, in which it was previously demonstrated that the variable x changes only the Cu-O-Cu buckling angle and bond distance, and hence the super-exchange [1]. I also demonstrate that experiments such as neutron scattering, Raman scattering, and more can be performed on these crystals. The phase diagram of CLBLCO for various values of x shows when varying x, the amount of Lanthanum in the chemical formula remains constant, and therefore x stands for the Calcium-to-Barium ratio [2]. The parameter y controls the oxygen level and moves the system between the different phases. At around y = 7,15 each family has its maximum T_c [T_c^{max}]. Changing x from 0.1 to 0.4 varies T_c^{max} from 58 K to 80 K[3]; roughly a 30% increase. This T_c^{max} variation is achieved with no apparent structural changes. All CLBLCO compounds have YBCO-like structure with two CuO_2 planes and two disordered „chain" layers per unit cell. The symmetry is tetragonal for all values of x and y. The level of disorder is also similar for all families. Therefore, a priori, there is no reason for T_c^{max} to depend on x. However, increasing x increases the amount of the Ca^{2+} in the Y site of YBCO at the expense of La^{3+}. This charge transfer is equivalent to reducing the positive charge on the (YBCO) Y site and increasing it on the (YBCO) Ba site, and could alter the Cu-O-Cu buckling angle. Indeed, it was found by high resolution neutron diffraction that as x increases the Cu-O-Cu bond becomes shorter and straighter1, while other structural properties remain intact[5]. The bond length and buckling are the major factors that control the orbital overlap and, in turn, the hopping parameter t or the super-exchange J. Thus, the newly grown CLBLCO crystal can shed new light on the impact of t or J on properties such as: T_c^{max}, the structure of the Fermi surface, the magnetic resonance, the size of the gap/pseudogap, and more.

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The Centre of Excellence in Nanosciences and Nanotechnology (CE NS and NT)

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Globally proven successful scientific work of Slovenian researchers in nano-science and nanotechnology placed Slovenia in a very competitive position in nano-scale science and technology. By joining the efforts of a consortium of the best partners from universities, research institutes and industry, the Centre of Excellence NS and NT has set a clear goal of establishing technological infrastructure for the internationally competitive development of nano-sciences and nanotechnologies in Slovenia for the next decade and beyond. Our programme focuses on establishing new technologies for the synthesis, processing (nano-facture) and characterisation of substances; this is comparable with related centres worldwide, which will enable international competitiveness in the implementation of top research projects and programs, and in the development of new products.

Collaborations with the *CENN Nanocenter as a facility* are invited. Both use of, and/or participatation in the activities of the Nanocenter are available particularly: a) synthesis of nanomaterials, particularly using advanced techniques such as MBE, b) characterisation facilities, c) processing, particularly with optical nanolithography and d) modelling of various phenomena in nanomaterials, e.g. quantum transport, self-organisation, etc. Also, collaboration on *time-resolved spectroscopy* at the Complex Matter Department at the Jozef Stefan Institute - particularly investigations of phase transitions in time domain. Both experiment and theory collaborations are invited.

The influence of disorder and magnetic field on the inhomogeneous superconductivity in layered conductors

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Several experimental studies have shown the presence of spatially inhomogeneous phase coexistence of superconducting and non-superconducting domains in low dimensional organic superconductors. The superconducting properties of these systems are found to be strongly dependent on the amount of disorder introduced in the sample regardless of its origin. The suppression of the superconducting transition temperature T_C shows a clear discrepancy with the result expected from the Abrikosov–Gor'kov law giving the behavior of T_C with impurities. On the basis of the time dependent Ginzburg–Landau theory, we derive a model to account for this striking feature of T_C in organic superconductors for different types of disorder by considering the segregated texture of the system. I'll show that the calculated T_C quantitatively agrees with experiments. I'll also focus on the effect of superconducting fluctuations on the upper critical fields H_{c2} of layered superconductors showing slab structure where superconducting domains are sandwiched by non-superconducting regions.

Solid state theory: correlated physics

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Our research is focused on strongly correlated electron systems and high-temperature superconductors. Strong electron correlations appear when the kinetic energy in a system is comparable or smaller than the repulsive Coulomb interaction energies. Until a few years ago this behavior was attribute in transition metal compounds almost exclusively to materials with open 3d shells, and just a few studies on a limited amount of systems have been done outside of this play ground. Only recently, it has been noted that also systems with 4d or even 5d electronic states in the conduction bands can show very interesting and unexpected behavior. I will discuss the ruthenate materials, were heavy electron masses and very low coherence scales have been found in experiments. Second, I will look at the extraordinarily high magnetic transition temperature in technetium compounds. Cuprates, which become superconducting at high temperatures, still represent one of the major challenges within the solid-state theory. Besides not yet understood mechanism of superconductivity, also very anomalous normal-state electronic properties require proper theoretical description. We follow the wide-spread belief that strong correlations are responsible for non-Fermi-liquid behaviour of electrons in cuprates and analyse the prototype microscopic models, using mostly numerical methods for finite systems. Recenly, a novel aspect on these problems has been been opened by ARPES spectroscopy experiments on electron-doped cuprates. We evaluated model spectral functions, in particular the development of Fermi surface with doping, revealing the change of topology from a pocket-like to a large Fermi surface.

Polytypoid Layered Nanostructures

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Thermoelectric materials have generated interest as a means of increasing the efficiency of power generation through the scavenging of waste heat. Materials containing nanometer-sized structural and compositional features can exhibit enhanced thermoelectric performance due to the decoupling of certain electrical and thermal properties, but the extent to which these features can be controlled is often limited. Here we report a simple synthesis of $M_2O_3(ZnO)_n$ (M = In, Ga, Fe) nanowires with controllable polytypoid structures, where the nanostructured features are tuned by adjusting the amount of metal precursor. After the introduction of nanometer-scale features (individual atomic layers and alloying), thermal and electrical measurements on single $In_{2-x}Ga_xO_3(ZnO)_n$ nanowires reveal a simultaneous improvement in all contributing factors to the thermoelectric figure of merit, indicating successful modification of the nanowire transport properties.

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Signature of long range triplet proximity effect in the density of states

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We study the impact of the long range spin-triplet proximity effect on the density of states (DOS) in planar SF1F2S Josephson junctions that consist of conventional superconductors (S) connected by two metallic monodomain ferromagnets (F1 and F2) with transparent interfaces. We determine the electronic DOS in F layers for arbitrary orientation of the magnetizations using the solutions of Eilenberger equations in the clean limit and for a moderate concentration of impurities in ferromagnets.We find that a fully developed long range proximity effect occurs in Josephson junctions with a highly asymmetric ferromagnetic bilayer. For orthogonal magnetizations, the effect manifests itself as an enhancement in DOS and as a dominant second harmonic in the Josephson current-phase relation. Distinctive variation of DOS in ferromagnets with the angle between magnetizations is experimentally observable by tunneling spectroscopy. This can provide an unambiguous signature of the long range spin-triplet proximity effect.

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Magnetism research at the Institute of Physics, Zagreb

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The scope of the research in magnetism and magnetic materials at the Institute of Physics is presented. Several experimental techniques that are used at the Institute of Physics are mentioned, including the Faraday balance for the measurement of the magnetization, ac susceptibility setup based on the induction method and the torque setup for the measurement of the magnetic anisotropy.
Several examples of the low-dimensional magnetic systems studied so far by us are introduced. $Cu_2Te_2O_5X_2$ is a 3D network of 4-member clusters of copper ions forming a tetrahedron [1], with a 3D ordered state occurring at low temperatures. Cu_3TeO_6 has been demonstrated to exhibit a novel type of a magnetic lattice, named *spin web* [2]. The recent study of a quasi-1D magnetic lattice material $SeCuO_3$ has shown that it represents a rare example of macroscopic manifestations of quantum effects, where the formation of a singlet state between two magnetic moments on copper ions causes the rotation of magnetic axes [3].
At the end the future interest and perspective has been mentioned.

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Contributed lectures

Effect of thermal and quantum fluctuations on phase stiffness in layered superconductors

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One of important problems in layered high-T_c cuprate superconductors that is still under discussion is the origin of the observed linear low-temperature dependence of the phase stiffness (superfluid density). The latter is directly related to magnetic penetration depths, $\lambda_{\parallel}$ and $\lambda_{\perp}$, for a magnetic field screened by currents flowing in directions parallel and perpendicular to the superconducting planes, respectively [1] and [2]. This dependence is usually attributed to contribution of quasi-particles near the nodes of the d-wave gap. According to the alternative explanation suggested in Refs. [3] and [4] the linear decrease in the temperature dependence of $1/\lambda^2$ is induced entirely by classical thermal phase fluctuations. Recently the role of fluctuations was reconsidered [5] for a d-wave superconductor by means of a microscopic approach within a functional integral framework, and quantum phase fluctuations were found to lead to a sizeable renormalization of the superfluid density, the effect of thermal fluctuations being small for $T<T_c$.
We calculate suppression of inter- and intra-layer superconducting currents due to equilibrium phase fluctuations and find that, in contrast to a recent prediction, the effect of thermal fluctuations cannot account for linear temperature dependence of the superfluid density in high-T_c superconductors at low temperatures. Quantum fluctuations are found to dominate over thermal fluctuations at low temperatures due to hardening of their spectrum caused by the Josephson plasma resonance. Near T_c sizeable thermal fluctuations are found to suppress the critical current in the stack direction stronger than in the direction along the layers. Fluctuations of quasi-particle branch imbalance make the spectral density of voltage fluctuations at small frequencies non-zero, in contrast to what may be expected from a naive interpretation of Nyquist formula.

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Bipolarons and polarons in the Holstein-Hubbard model

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The single bipolaron problem is examined in the context of the 1D Holstein-Hubbard model, emphasizing analogies and differences with respect to the complementary single polaron physics. The bipolaron band structure below the phonon threshold is revealed, showing a complex relationship between numerous excited bands as the adiabatic limit is approached. Light bipolarons with significant binding energy, the stability of large bipolarons, the small to large bipolaron crossover as a function of the Hubbard repulsion, as well as the bipolaron dissociation, are investigated in detail, disentangling adiabatic, nonadiabatic and lattice coarsening effects. It is emphasized that condensation of bipolarons occurs in the dilute limit only at very low temperatures.

Superstripes

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Main contributions of the Rome research group Superstripes to the present understanding of the physics of cuprate superconductors.
Superstripes are metallic heterostructures at the atomic limit for the amplification of the superconducting critical temperature $T_{c.}$ Superstripes are formed by superlattices of superconducting units (layers, or stripes, or wires, or spheres or balls) separated by an intercalated material. Superstripes show multiband high T_c superconductivity driven by the Shape Resonance or Feshbach Resonance in the Interband Pairing that occurs by tuning the chemical potential at an "electronic topological transition" (ETT) where the Fermi surface topology of one of the bands changes its dimensionality. The maximum T_c amplification is reached in Superstripes tuning the chemical potential to "shape resonance" by changing: the charge density and/or the superlattice structural parameters.

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Presentation of the project proposal “thinSplit”

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University of Split is the second largest university in Croatia, with fast growing department of physics at the Faculty of Science. Its research activities are mostly theoretical within condensed matter and biophysics. The department’s strategic goal is to become a modern physics department open to an interdisciplinary research on micro- and nano- scale. Consequently, we have applied project “Boosting the thin-film and nanomaterial research at the University of Split” (“thin Split”) within the FP7 / Capacities / REGPOT 2012-2013-1 funding line. The ultimate goal of the project is to strengthen existing research potentials in thin films and nanomaterials at the University of Split in the interdisciplinary paradigm, and to further increase the existing innovation capacity. In that sense, besides the Physics Department of the Faculty of Science, three other departments from the University are included in the project implementation: departments for inorganic technology, and for physics from the Faculty of Chemistry and Technology, and the Department for Electronics from the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture. The Technology Transfer Office of the University of Split is responsible for implementation of the innovation capacity building component.

The project implementation includes:

- the strengthening cooperation with top-class European partnering organizations through two-way secondments (Sincrotrone Trieste, Fraunhofer Institute for Solar Energy Systems, Swiss Federal Institute of Technology in Lausanne, University of Regensburg, Chalmers University, and The Hebrew University in Jerusalem);
- attraction of three experienced researchers with background in thin-film, nanostructures and photovoltaics, and employment of two post-doctoral fellows;
- spreading the visibility of reached research potentials by organizing two scientific meetings, and by participation on scientific conferences;
- up-grading experimental potentials with state-of-the-art equipment for optical lithography laboratory with clean room, and cryogenic, X-ray diffraction and photovoltaic laboratories, together with employment of two technicians;
- contribution to the potentials of the national and European economic growth by increasing the innovation potential at the University of Split organizing related trainings and networking events, and strengthening cooperation with industry by defining joint research topics.

Electron-phonon effects in perovskites and polaron theory

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Our activity has been focused on the study of materials characterized by strong electron-phonon and electron-electron interactions with particular emphasis to perovskitic oxides of technological interest. The research themes can be summarized as follows:

- model systems with strong electron-electron and electron-phonon interactions (cuprates and manganites)
- Lanczos diagonalizations and optimized phonon basis for electron-phonon systems
- charge-ordered phases induced by electron-phonon coupling effects: Infrared absorption
- polaron properties in different electron-phonon models including optical conductivity

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Microwave and radiofrequency measurements in superconductors

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The long term interest of the present research group is in the field of high temperature superconductors. During the last decade we have investigated the surface impedance of single crystals and thin films of a number of diverse high temperature superconductors [1-6]. The measurements included temperature variations from 1.8 K to 300 K, and external magnetic field variation from zero up to 16 T. The resonant microvawe frequencies were in the range 10-17 GHz for various modes which can be excited in the cavity loaded with the sample.
The focus of our analysis was different in each particular case, and included the problems of the upper critical field [1], the interplay of superconducting and antiferromagnetic order parameters [3-4], and the superconducting fluctuations above the critical temperature [2,5-6]. In particular, we have observed that the superconducting fluctuations appear as three dimensional (3D) in their character, with the same anisotropy extending from the normal to the superconducting state.
More recently, we have extended our experimental method to the radiofrequency range in order to explore the possible frequency dependent response of intrinsically inhomegeneous underdoped high temperature superconductors.
The group has experienced many international collaborations with centers of excellence where high quality samples were synthesized, and measured by a number of complementary experimental techniques. With our specific experimental method end expertise, we stay open to future collaborations.

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Nanoscale science and novel electronic materials at EPFL

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Nanoscale Science and Novel Electronic Materials is seeking to build bridges between the physical and biological sciences, the hard and soft matter themes. For example, a strong program in crystal and film growth and characterization is crucial for our studies of correlated electron materials; serious research on nanostructures gives us tools to address important issues on biomolecules; similarly, all improvements in spectromicroscopy instrumentation enhance our research on biological samples. Ultimately, biomedical imaging and cell-research benefit from the progress in many sub-areas of condensed matter physics.
The sub-field of condensed matter which are addressed in the group are the following: novel electronic materials and functional nanomaterials. Novel Electronic Materials are strongly correlated electronic systems. The physical properties of many of these materials are determined by the interactions between charge, orbital and magnetic degrees of freedom. These characteristics can potentially be used to develop new electronic devices. Our group studies the growth mechanism of several filamentary nanostuctures (nanotubes, nanowires) and nanoparticles. We address the health hazard related to the large scale production and manipulation of these nanostructures. A experimental set-up has been developed for the measurement of the mechanical response of individual nanofilaments.
Studying the basic physical properties of novel electronic materials, one of our goals beyond the exciting physics they reveal, is to learn how one can improve the materials quality.

Transport properties under high pressure and high magnetic field at Institute of Physics

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Research in the field of low dimensional conductors revealed very interesting ground states and rich phase diagrams. Our laboratory participates in this research through investigation of transport properties (the electrical resistivity, thermal conductivity and thermopower) in a wide temperature range (1.5 K to 300 K), with the emphasis on the thermal conductivity. Recently, these techniques were upgraded with the introduction of the measurements under high hydrostatic pressure (up to 3 GPa for the thermopower and an order of magnitude higher for the electrical resistivity) and high magnetic fields (up to 10 T) that can be combined in the search for the new electronic states.

The goal of our research is twofold. The first one focuses on complex metallic alloys, among which quasicrystals are the most interesting family possessing long-range order with no translational periodicity [1].

The second goal of our research is ther study of low dimensional conductors with strongly correlated electronic systems from the family of pnictides and dichalcogenides as well as the magnetically frustrated systems. In $Co_{0.33}NbS_2$, geometrically frustrated Co ions, intercalated between NbS_2 host layers, order antiferromagnetically below 26 K [2]. This magnetic ordering is completely suppressed under pressure of 2 GPa, and at even higher pressures the Kondo-like behavior of the electrical resistivity takes place.

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Open problems in the research of high-temperature superconductors

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A brief presentation of the open problems which concern the solid state group at the Department of Physics, Faculty of Science, in particular that part which is involved in research on high-temperature superconductors, will be done. These are centered on the role of the in-plane oxygens in the electronic wave functions which are involved in the superconducting transition. The CLBLCO series of materials studied by A. Keren (Haifa) will be mentioned as particularly promising for a systematic investigation of two questions: the evolution of the charge distribution between the oxygen and copper sites with doping, and the effect of the direct overlap between the two planar oxygens in the unit cell.
Some cooperation among the meeting participants has already begun along these lines, and it is hoped that it may be widened in other directions, such as the charge stripes investigated by the group of A. Bianconi (Rome). In the course of focusing on these issues over the years, the group has developed a wide range of expertise in interpreting Raman, ARPES, and magnetic responses, and has used them to help interpret other materials, in particular $BaVS_3$, also interesting to participants in the meeting, notably J.-P. Pouget (Orsay).

Group for modeling of electronic processes and devices at IP and UniZG

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Electric and heat transport in complex crystal systems, electronic phase separation and superconductivity, strongly frustrated magnets and related materials, organic unordered materials, hopping transport and recombination near the media interfaces, numerical modeling and simulations of electronic devices.

Transport properties of the textured 1T-TaS_2 phase

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Transition-metal dichalcogenide 1T-TaS_2 is known to form a peculiar NCCDW phase in which the domains of commensurate charge density wave (CDW) phase, several nanometers in size, are separated by roughly triangular pieces of metallic phase. [1]
In pure 1T-TaS_2 this phase disappears around 180 K upon cooling, as the system enters commensurate-CDW/Mott state. However, the transition may be suppressed by pressure or by intercalation, leaving the sample in non-metallic nearly commensurate CDW (NCCDW) state down to very low temperatures, where it turns superconductive.[2] Surprisingly, the temperature of the superconducting transition is constant in pressure, although the resistivity changes by orders of magnitude,[3] suggesting that superconductivity arises in triangular metallic parts, while DC conductivity is dominated by weak links between them.
Here, in addition to the transport coefficients (dc conductivity, ...), we report the reflectance of pure and intercalated 1T-TaS_2, on the samples from the same batch, recently measured in the temperature range from 23 K to 290 K, over a frequency range of 30 cm^{-1} - 37000 cm^{-1} as well as the optical conductivity derived through Kramers-Kronig analysis.[4]
Contrary to simple expectations, the optical conductivity does not show the separate contribution from CDW and metallic regions. Instead, we observe a single, wide metallic contribution, extending to 400 cm^{-1}, on the top of which the phonon contribution shows above 40 cm^{-1}. This suggests that the largest contribution to optical conductivity also comes from connections between conducting areas.

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