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

The experimental techniques used are:

- One (1D) and two (2D) dimensional nuclear magnetic resonance (NMR) and relaxation, as well as quadrupole (NQR) resonance and relaxation,
- Multi-frequency NMR in superconducting magnets of 2T, 6T and 9T, as well as the dispersion of the spin–lattice relaxation time $T_1$ via field cycling,
- Nuclear double resonance and quadrupole double resonance such as $^{17}$O–H and $^{14}$N–H,
- Fast field cycling NMR relaxometry,
- Frequency-dependent electron paramagnetic resonance (EPR) and 1D and 2D pulsed EPR and relaxation,
- MR imaging and micro-imaging,
- Measurement of the electronic transport properties,
- Magnetic measurements,
- Fluorescence microscopy and microspectroscopy,
- Linear and non-linear dielectric spectroscopy in the range $10^{-2}$ Hz to $10^9$ Hz,
- Electron microscopy and scanning tunnelling microscopy,
- Atomic force microscopy and force spectroscopy,
- Dynamic specific heat measurements.

The research program of the Department of Solid State Physics at “Jozef Stefan Institute” is performed in close collaboration with the Department of Physics at the Faculty of Mathematics and Physics of the University of Ljubljana, Institute of Mathematics, Physics and Mechanics and the J. Stefan International Postgraduate School. In 2016, the research was performed within three research programs:

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

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

The research of the program group Magnetic Resonance and Dielectric Spectroscopy of Smart New Materials was focused on the study of physical phenomena in condensed matter at the atomic and molecular levels. The purpose of the investigations was to discover the basic laws of physics governing the behaviour of the investigated systems. The attained knowledge provides the key to the understanding of the microscopic and macroscopic properties of various types of solids and is an important condi-

The research group has discovered new quantum phenomena in the magnetism of low-dimensional spin systems. It has studied physical properties of a novel type of nanomaterials suitable for gas sensors and has discovered new materials with a giant electrocaloric effect for applications in cooling devices. The group has developed new polymer-dispersed liquid-crystalline elastomers. The Schottky effect has been demonstrated in quasicrystals, which fundamentally changes the interpretation of their low-temperature electronic and magnetic properties. The research has included pharmaceutical and biological substances.
Inkjet printing of uniform dielectric oxide structures

Inkjet printing of high-dielectric-constant metal-oxide layers will enable the low-cost deposition of the essential building blocks in electronics. We have developed an ink formulation suitable for the printing of tantalum-oxide-based dielectric layers. Our goal was to improve the thickness uniformity of dried deposits via optimization of the ink’s solvent composition. We have shown that in addition to designing the solvent mixture according to the viscosity and surface-tension criteria, the volatility of solvents has to be considered, as it strongly influences the thickness uniformity. By rigorously adjusting the solvent composition, we were able to tailor the topology of the deposits and print 45-nm-thick, flat and uniform capacitors with functional properties comparable to spin-coated films. We published our discoveries in Inkjet printing of uniform dielectric oxide structures from sol-gel inks by adjusting the solvent composition (A. Matavž, R. C. Frunză, A. Drnovšek, V. Bobnar, B. Malič, Journal of Materials Chemistry C 4, 5634 (2016)).

Development of an eco-friendly material for flexible energy-storage devices

Nanocomposite films were fabricated by incorporating ammonia-functionalized graphene oxide (NGO) into the native (CNF) and TEMPO-oxidized (TCNF) cellulose nanofibrils matrices using a solvent-casting method. The structural and morphological analysis revealed good dispersibility of the NGO sheets in the randomly distributed CNF, and the dense and parallel-oriented TCNF nanofibrils. Such a synergistic effect of both components contributed to ultra-strong and stiff films with good mechanical and thermal stability. Due to the Maxwell-Wagner polarization, the dielectric constant strongly increases already at a low NGO content. Thus, this mechanically strong, flexible, and thermally stable composites are suitable, cost-effective, alternative green materials for flexible energy-storage devices. This research was published in the paper Mechanically strong, flexible and thermally stable graphene oxide/nanocellulosic films with enhanced dielectric properties (Y. Beeran P. T. et al., RSC Advances 6, 49138 (2016)).

Stable dielectric response of newly developed low-loss polymer thin films

We have investigated the dielectric properties of aromatic polythiourea (ArPTU, polar polymer
containing high dipolar moments with very low defect levels) thin films that were developed on a Pt/SiO₂ substrate. The detected response was compared to the response of commercially available polymers, such as high-density polyethylene (HDP) and polypropylene (PP), which are at the present both used in foil capacitors. Stable values of the dielectric constant (being two times higher than in HDP and PP) over broad temperature and frequency ranges and dielectric losses as low as in commercial systems suggest that ArPTU is a promising candidate for future use in a variety of applications. The findings were published in Stable dielectric response of low-loss aromatic polythiourea thin films on Pt/SiO₂ substrate (A. Eršte et al., Journal of Advanced Dielectrics 6, 1650003 (2016)).

Study of nanostructured materials and materials with large electrocaloric effect and its application in a solid-state cooling device:

Using direct measurements, we showed the coexistence of both the electrocaloric and magnetocaloric effect in multiferroic PFN-PMW. We were among the first to demonstrate the existence of a large electrocaloric effect in liquid crystals and of a large elastocaloric effect in liquid-crystal elastomers. In addition, we have analysed the working cycle of a prototype of a cascade electrocaloric device exploiting both the electrocaloric and electromechanic effects. In 2016, the Gorenje d.d. company bought our Patent application US 2016/0187034 A17700, 2016, (B. Malič et al.). The above results were published in 11 articles in international scientific journals, among which we must mention Perovskite ferroelectrics and relaxor-ferroelectric solid solutions with large intrinsic electrocaloric response over broad temperature ranges (H. Khassaf et al., P. Journal of Materials Chemistry C 4 (2016), 4763), A multicaloric material as a link between electrocaloric and magnetocaloric refrigeration (H. Uršič et al., Scientific Reports, 6 (2016), 26629-1-26629-5), Ba₂ZrO₃TiO₂O, Lead-free relaxor ferroelectric or dipolar glass (C. Filipič, Z. Kutnjak, R. Pirc, G. Camu, J. Petzetl, Physical Review B 93 (2016), 224105-1-224105-8), and Electrocaloric and elastocaloric effects in soft materials (M. Trček et al., Philosophical Transactions A, 374 (2016), 20150301). Recent publications on electrocalorics and TGB and blue phases have been cited more than 100 times in 2016.

Nanomaterials for gas-sensor applications

Polona Umek collaborated with colleagues from Great Britain, Czech Republic, Belgium, France and Spain in the research of gas sensors based on WO₃ nanoneedles (NN) decorated with PdO nanoparticles (NP). Morphological, structural, and elemental composition analysis revealed that a Pd(acac)₃ precursor was very suitable to decorate WO₃ NNs with uniform and well-dispersed PdO NPs. Gas-sensing results revealed that the decoration with PdO NPs led to an ultrasensitive and selective hydrogen (H₂) gas sensor with a low operating temperature (150 °C). The response of the decorated NNs is 755-times higher than that of bare WO₃ NNs. Humidity measurements showed that PdO/WO₃ sensors displayed low cross-sensitivity towards water vapour, compared to bare WO₃ sensors. The addition of PdO NPs helps to minimize the effect of ambient humidity on the sensor response. The research was published in the article Aerosol-assisted CVD grown PdO nanoparticle-decorated tungsten oxide nanoneedles extremely sensitive and selective to hydrogen (F. E. Annanouch et al., ACS Applied Materials & Interfaces 8, 10413 (2016)).

Pharmaceutical substances studied by NQR spectroscopy

¹¹N NQR is a useful tool to characterize pharmaceutical substances and the method of their preparation. In combination with other experimental techniques and quantum chemical calculations, the electronic structure of these molecules and the properties of functional groups can be determined, as shown in the article Polymorphism and Thermal Stability of Natural Active Ingredients 3,3'-Diindolylmethane (Chemopreventive and Chemotherapeutic) Studied by a Combined X-Ray, ¹H - ¹¹N NMR NQR, DSC and Solid-State DFT/3D HS/QTAIM/RDS Computational Approach (J. N. Latosinska, M. Latosinska, M. Szafranski, J. Seliger, V. Zagar, Cryst. Growth Des. 16, 4336-4348 (2016)). The compound 3,3'-diindolylmethane (DIM) is a major in vivo product of the digestion of indole-3-carbinol (I3C) and a main mediator of its chemopreventive and chemotherapeutic effects. In this paper, the co-influence of two factors, polymorphism and temperature, on the topology, nature, and strength of the interaction pattern in DIM are in our area of interest. Upon polymorph screening, it has been found that DIM crystallizes in two polymorphic forms, form I (already known) and form II (newly obtained). Differential scanning calorimetry indicated a slightly lower melting point for form I than for
form II (436 versus 440 K) and the lack of phase transitions in both polymorphs. The crystal and molecular structures of both polymorphs have been determined as a function of temperature from a single-crystal X-ray diffraction. The structure of polymorph I is monoclinic, space group C2/c, while polymorph II is orthorhombic, space group P212121. The key interaction that determines the crystalline packing in both polymorphs of DIM is the NH...π one. The factor responsible for the locked conformation of DIM in both forms is the electrostatic potential complementarity of the regions of N–H...π, linking neighbouring molecules, which permits easy overcoming of any repulsive interactions that may force the rotation of the molecule. The commercial sample of DIM was found to contain approximately 50% of form I and 50% of form II.

Nuclear magnetic resonance study of molecular dynamics in ammine metal borohydride Sr(BH$_4$)$_2$(NH$_3$)$_2$

Borohydrides are promising hydrogen-storage materials due to their high hydrogen content and relatively low decomposition temperature. In the article Nuclear magnetic resonance study of molecular dynamics in ammine metal borohydride Sr(BH$_4$)$_2$(NH$_3$)$_2$ (A. Gradišek, L. H. Jepsen, T. R. Jensen, M. S. Conradi, J. Phys. Chem. C, 2016, 120, 24646-24654), we investigated Sr(BH$_4$)$_2$(NH$_3$)$_2$, a novel system that contains hydrogen in two molecular groups – BH$_4$ and NH$_3$. Molecular dynamics was studied by means of $^1$H and $^{18}$B NMR spectra and spin-lattice relaxation. We identified activation energies for the rotations of BH$_4$ tetrahedra around two different symmetry axes. Low-temperature measurements unveiled that there are some motions still present around 4 K. In addition, we studied a partially deuterated modification of the compound to further distinguish dynamic processes.

Polymorphism of caffeine

The polymorphism of anhydrous caffeine has been studied by $^1$H–$^{14}$N NMR–NQR (Nuclear Magnetic Resonance–Nuclear Quadrupole Resonance) double resonance and pure $^{14}$N NQR (Nuclear Quadrupole Resonance) and by computational modelling (Density Functional Theory) in the solid state. The assignment of NQR signals detected in stable phase I and in metastable phase II to particular nitrogen sites was verified with the help of DFT. The commercial pharmaceutical sample was found to contain approximately 20–25% of phase I and 75–80% of phase II. The orientational disorder in phase II with a local molecular arrangement mimics that in phase I. Substantial differences in the intermolecular interaction phases I and II of caffeine were analysed using a computational (DFT/QTAIM/RDS) approach and the maps of the principal component of the EFG tensor and its asymmetry parameter at each point of the molecular system were calculated and visualized. The relevant maps calculated for both phases I and II indicate a small variation in electrostatic potential upon phase change. These small differences between packings in phases only slightly disturb the neighbourhood of the N(1) and N(7) nitrogens, and are thus meaningless.
from the biological point of view. The composition of the two phases in pharmaceutical material should not be an obstacle, which is relevant from the point of view of the pharmaceutical industry.

The study was published in the article "Polymorphism and disorder in natural active ingredients. Low and high-temperature phases of anhydroxy caffeine: Spectroscopic (1H-13C NMR, 14N NQR) and solid-state computational modelling (DFT, QM/MM, DFT) study" (J. Seliger et al., European Journal of Pharmaceutical Sciences, 85 (2016), 18).

**Polymer-dispersed liquid-crystal elastomers**

We have experimentally investigated the orientational ordering of thermomechanically active liquid-crystal elastomer microdispersions in a PDMS elastomer, using quadrupole-perturbed deuteron NMR. We have also developed a theoretical model of the behaviour of orientational order parameter $Q$ in the external magnetic field $B$ as a function of the microdomain nematic order parameter $\hat{S}$ and diamagnetic anisotropy $\Delta\mu$, the viscosity of the uncured matrix resin $\eta$, and of the curing process kinetic factor $k$. By comparing theoretical predictions with the experimentally determined values of $Q(B)$, we have demonstrated that the degree of orientational ordering and, consequently, the effective thermomechanical response of the composite material can be tailored by controlling the external magnetic field as well as by properly adjusting the curing time. The research on polymer-dispersed liquid crystal was published in two articles: *Deuteron NMR resolved mesogen vs. crosslinker molecular order and reorientational exchange in liquid single crystal elastomers* (J. Milavec, V. Domenici, B. Zupančič, A. Rešetič, A. Bubnov in B. Zalar, Physical Chemistry Chemical Physics 18, 4071-4077 (2016)) and *Polymer-dispersed liquid crystal elastomers* (A. Rešetič, J. Milavec, B. Zupančič, V. Domenici in B. Zalar, Nature Communications 7, 1340 (2016)).

**Quantum magnetism**

Matej Pregelj, Matjaž Gomilšek, Andrej Zorko, and Denis Arčon, in collaboration with partners from Switzerland, Croatia and France, investigated the mechanism responsible for the occurrence of an unusual spin-stripe phase in the $\beta$-TeVO$_4$ compound, which represents a model system of the frustrated ferromagnetic spin-$1/2$ chain. A combination of magnetic-torque, neutron-diffraction, and spherical-neutron-polarimetry measurements was employed to determine all the magnetic structures that the system develops on cooling in the absence of a magnetic field, i.e., in the vector-chiral phase, in the spin-stripe phase and in the collinear amplitude-modulated phase. Based on these results, they developed a phenomenological model that revealed the anisotropy of the exchange interaction as the key ingredient for the spin-stripe formation in frustrated spin systems. Their discovery was published in the article "Exchange anisotropy as mechanism for spin-stripe formation in frustrated spin chains" (M. Pregelj et al., Phys. Rev. B 94, 081114(R) (2016)).

Matjaž Gomilšek, Martin Klanjšek, Matej Pregelj, and Andrej Zorko collaborated with researchers from China, United Kingdom, and Switzerland in an in-depth investigation of magnetic properties of Zn-brochantite. This is a new realization of the quantum kagome antiferromagnet, a paradigm of geometrical frustration in two dimensions, that was synthesized by the Chinese collaborators in 2014. With the use of various experimental techniques, including nuclear magnetic resonance, muon spin relaxation/rotation, and neutron scattering, they established that the ground state of this material is magnetically disordered and dynamical. They observed a quantum-critical behaviour at high temperatures and various spin-liquid instabilities that the system goes through with lowering temperature. Their discovery was published in the article "Instabilities of spin-liquid states in a quantum kagome antiferromagnet" (M. Gomilšek et al., Phys. Rev. B 95, 060405(R) (2016)).

Additionally, they showed that the low-temperature spin-liquid phase behaves like a spinon metal, which is a novel type of behaviour for the kagome lattice. This observation was published in the paper "μSR insight into the impurity problem in quantum kagome antiferromagnets" (M. Gomilšek et al., Phys. Rev. B 94, 024438 (2016)).

Andrej Zorko, Matjaž Gomilšek, and Matej Pregelj, in collaboration with researchers from Germany, USA, Moldova, and Switzerland investigated new functionality of layered metamagnets, with the use of electron spin resonance in high magnetic fields. The properties of the mixed antiferromagnetic/ferromagnetic phase that is stabilized in a finite range of applied fields around 0.8 T at low temperatures and is characterized by enhanced microwave absorption were thoroughly investigated. They showed that thermal fluctuations play an important role in destabilizing the
highly absorbing mixed phase. Their discovery was published in the paper "Electron spin resonance insight into broadband absorption of the CuBi(SeO$_3$)$_2$ Br metamagnet" (A. Zorko et al., AIP Advances 6, 056210 (2016)).

Andrej Zorko collaborated with researchers from France, USA and Switzerland in an in-depth neutron scattering investigation of magnetically and structurally chiral Fe langasite, which is a model system of triangle-based frustrated magnets with a strong potential for multiferroicity. They observed bunching of the helical modulation along the c axis and the in-plane distortion of the 120° Fe-spin arrangement. These observations enabled a refinement of the spin Hamiltonian, thus providing a link to the magnetically induced electric polarization observed in these systems. The results of this investigation were published in the paper "Helical bunching and symmetry lowering inducing multiferroicity in Fe langasites" (L. Chaix et al., Phys. Rev. B 93, 214419 (2016)).

Martin Klanišek in collaboration with French and Swiss colleagues studied a difference in the magnetic response of the systems (C$_2$H$_6$N)$_2$CuBr$_2$ (BPCB) and (C$_2$H$_6$N)$_2$CuBr$_2$ (DIMPY), both containing the spin-1/2 ladders, where the exchange interactions along the rungs are stronger than those along the legs in the first case, and conversely in the second case. They confirmed that the spin ladders in both cases behave as a Tomonaga-Luttinger liquid of spinons. Nevertheless, the systems exhibit markedly different magnetic fluctuations, which can be directly probed by measurements of the spin-lattice relaxation time $T_1$ in nuclear magnetic resonance. The observed difference emerges from the difference of interactions between the spinons in both cases: these are expectedly repulsive in the first case and surprisingly attractive in the second case. The work is published in "Dichotomy between Attractive and Repulsive Tomonaga-Luttinger Liquids in Spin Ladders" (M. Jeong et al., Phys. Rev. Lett. 117, 106402 (2016)).

Denis Arčon collaborated with groups from USA (Princeton University, University of Houston) and Israel (The Hebrew University of Jerusalem) on the evolution of magnetic fluctuations in systems, where we induce a transition between the paramagnetic and ferromagnetic metal using some external parameter (e.g., doping or pressure). Theoretical models in such cases predict the closeness of the quantum critical point (QCP) and strong deviations from the Fermi liquid behaviour. The research focused on two model systems, i.e., Fe-doped Cr$_2$B and YFe$_2$(Ge,Si)$_2$. In the former case we used $^8$B nuclear magnetic resonance data to discover the presence of both ferromagnetic and antiferromagnetic fluctuations. The latter are suppressed with Fe doping, before the ferromagnetic ones finally prevail for $x > x_c$. Indications for non-Fermi-liquid behaviour, usually associated with the proximity of a quantum critical point, were found for all samples, including undoped Cr$_2$B. The sharpness of the ferromagnetic-like transition changes on moving away from $x_c$, indicating significant changes in the nature of the magnetic transitions in the vicinity of the quantum critical point. Our data provided some important constraints for understanding quantum phase transitions in itinerant ferromagnets in the limit of weak quenched disorder. The results were published in "Evolution of magnetic fluctuations through the Fe-induced paramagnetic to ferromagnetic transition in Cr$_2$B" (D. Arčon et al., Phys. Rev. B 93, 104413 (2016)). The research of the YFe$_2$(Ge,Si)$_2$ system had similar goals. The additional importance of these experiments lies in the fact that these structures are isostuctural to some iron-based superconductors. We used $^{19}$Y NMR to show the presence of ferromagnetic fluctuations, which may have an impact on our understanding of the formation of Cooper pairs in this and other related compounds. The article was submitted to Phys. Rev. Lett. (J. Srpčič et al., arXiv:1608.01150 (2016)).

Zeolites

Peter Jeglič and Denis Arčon, in collaboration with researchers from Slovenia and Japan, studied Na-type low-silica X (LSX) zeolite loaded with guest Na atoms. They unambiguously confirmed a metallic ground state for higher loading levels. By extracting the density-of-states at the Fermi level as a function of the sodium loading level, they discovered a continuous (crossover-like) evolution across the metal-to-insulator transition. These results reveal a complex loading level dependence of electronic correlations and disorder due to electron confinement to zeolite cages and were published in the paper "Metal-to-insulator crossover in alkali doped zeolite" (M. Igarashi et al., Sci. Rep. 6, 18682 (2016)).
II. Research programme “Physics of Soft Matter, Surfaces, and Nanostructures”

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

Topology of liquid crystals: Singular points, skyrmions and torons

Chiral nematic liquid crystals exhibit rich topological phenomena, which were predicted and partially observed in chiral nematic droplets and thin liquid-crystal layers on patterned surfaces. It has been predicted that knots and links are stable in chiral nematic droplets, but this was difficult to observe because of the lack of appropriate experimental methods. We have developed a new method for the reconstruction of the director field, which is based on Fluorescent Confocal Polarisation Microscopy (FCPM) imaging in low birefringent liquid crystals with added fluorescent dyes. A new approach was taken in reconstructing the director field in chiral nematic droplets based on a simulated annealing algorithm. This combined method proved to be very efficient in reconstructing experimental 3D FCPM images. We observed that in chiral nematic droplets, topological singularities always appear in a form of point defects or simple rings, which are never knotted or linked. The complexity of the topological structures in chiral nematic droplets depends on the ratio of the helical pitch of the liquid crystal and the diameter of the droplet. In the case of low chirality, the number of point defects is small and they tend to be expelled to the surface of the droplet. The number of defects is always odd, which is due to the conservation of the total topological charge. We successfully reconstructed droplet structure with three point defects, which showed a cross-section of the Bloch skyrmion, which is similar to skyrmion structures in chiral magnets. When the number of point defects is increased to five for higher chirality, we observed another topological structure, which is akin to the toron structure observed in thin chiral nematic layers. Both skyrmion and toron structures are smoothly embedded in spherical confinement. This work presents the first exact reconstruction of the topology of 3D director in chiral nematic droplets and was published in Scientific Reports (G. Posnjak, S. Čopar and I. Muševič, Scientific Reports 6: 26361 (2016)).

Skyrmion structures were also observed in thin nematic LC films on chemically patterned patchy surfaces. When the sample was quenched from the fully aligned state using a strong external electric field, the director on the patterned patches spontaneously relaxed into a vortex-like structure, centred on the patch, as shown in the crossed-polarised image in Figure 17. This work was published in Cattaneo et al., Soft Matter 12, 853 (2016).

Sensing surface morphology of biofibers by decorating spider silk and cellulosic filaments with nematic microdroplets

Liquid-crystal droplets deposited on microthin biofibres – including spider silk and cellulosic fibres – were shown to reveal characteristics of the fibres’ surface, performing as simple but sensitive surface sensors. By combining experiments and numerical modelling, different types of fibres are identified through the fibre-to-nematic droplet interactions, including perpendicular and axial or helicoidal planar molecular alignment. The nematic droplets as sensors also directly reveal the chirality of the cellulosic fibres. Different fibre entanglements can be identified by depositing droplets exactly at the fibres’ crossings. More generally, the presented method can be used as a simple but powerful approach for probing the surface properties of small-size bio-objects, opening a route to their precise characterization. This work is a collaboration between the soft matter program and the group with expertise in liquid crystals and photomedicine. We explored the working mechanism of the motor protein kinesin-14, new low-friction and low-dimensional nanomaterials.

Porous nematic microfluidics for the generation of defect lattices as photonic crystals

Porous nematic microfluidics was demonstrated as a novel route for controlling the microstructure of the nematic order. Specifically, we showed the emergence of regular networks of topological defects, ranging in symmetry from triangular, square, to even kagome. This approach shows interesting possibilities as flow-tunable photonic crystal. The work was published in Porous nematic microfluidics for generation of umbilic defects and umbilic defect lattices (J. Aplinc, S. Morris and M. Ravnik, Phys. Rev. Fluids 1, 023303 (2016)).

Annihilation dynamics of topological monopoles on a fibre in a nematic liquid crystal

We studied the dynamics of topological defects on a glass fibre immersed in a nematic liquid crystal. We have used the laser tweezers to create isolated pairs of topological monopoles with the opposite topological charge and we have observed their annihilation process. When the fibre was set perpendicular to the nematic director, the monopoles were point defects in a form of radial and hyperbolic hedgehog and they attracted at small separations with an elastic force, which is proportional to the inverse square of the separation, following the Coulomb law for electric monopoles. The work was published in M. Nikkhou et al., Phys. Rev. E 93, 062703 (2016). In the case of a parallel fibre to nematic director the monopoles are in the form of Saturn ring and Saturn anti-ring. Here in thick cells we again observe a Coulomb-like attraction, while in thin cells there is an additional string-like force attributed to the formation of defect lines, connecting both monopoles. This force is independent of the separation between monopoles and prevails Coulomb-like attraction at large separations. These findings were published in M. Nikkhou et al., Phys. Rev. E 93, 062703 (2016).

We found that the dynamics of topological monopole annihilation on a fibre is very different for thick and thin nematic layers in thick cells, the two defects show a Coulomb-like pair attraction with no background force, which decays as an inverse square of the defect separation. However, for cell thickness comparable to the glass fibre diameter, there is another dominant type of force which is string-like and independent of the defect separation. It turns out that this constant force of attraction in thin cells is due to the interconnection of topological defects by additional defect lines which are running along the fibre surface. This work was published in M. Nikkhou et al., Eur. Phys. J. E 39: 100 (2016).

Topological defects in thin nematic shells

We studied numerically topological defects (TDs) in effectively two-dimensional closed soft films exhibiting in-plane orientational ordering. We introduced the Effective Topological Charge Cancellation mechanism controlling the localized positional assembling tendency of TDs and the formation of pairs defect-antidefect on curved surfaces and/or the presence of relevant "impurities" (e.g., nanoparticles). For this purpose an effective topological charge $m_{\text{eff}}$ is defined consisting of real, virtual and smeared curvature topological charges within a surface patch identified by the characteristic spatially varied local Gaussian curvature $K$. We demonstrate a strong tendency enforcing $m_{\text{eff}} \rightarrow 0$ on surfaces composed of surface patches exhibiting significantly different values of $K$. For non-zero $m_{\text{eff}}$ we estimate a critical depinning threshold to form pairs of defect-antidefect using the electrostatic analogy. The work was presented in two invited lectures and in the publication L. Mesarec et al., Scientific Reports 6, no. 27117, 1-9 (2016).

Biodegradable optical waveguides for use in photomedicine

A new class of optical waveguides for use in deep-tissue photomedicine were demonstrated (S. Nizamoglu, et al., Nature Communications 7, 10374, 2016). These waveguides were made out of biocompatible and biodegradable polymer materials, which can be implanted into the body and are naturally degraded over time. The waveguides enable the use of a number of medical laser treatments and diagnostics deep into the body, which were till now only limited to the surface due to limited penetration of light into the tissues. As an example of a possible application, laser wound closure is demonstrated, which could lead to faster healing and less scarring. Biocompatible and biodegradable waveguides can also be directly applied to other light-based diagnostics, surgery and therapeutics.
Optical super-resolution microscopy based on microlaser particles

A novel imaging technique was developed which instead of standard fluorescent molecules, uses small lasers embedded in the sample as probes [S. Cho et al., Phys. Rev. Lett. 117, 193902 (2016)]. The main characteristics of the microlasers are their very nonlinear response to the incoming pump beam intensity. The pump beam is scanned across the sample to form a 2D or 3D image. If the pump beam is set just above the laser threshold, only microlasers exactly in the center of the beam will emit laser light. This makes it possible to achieve super-resolution as well as to get confocal images with low background without the need for pinholes. Images at a resolution six times higher than that of fluorescence-based microscopes were demonstrated by using a nanowire laser. The new technique was termed laser particle-based stimulated emission microscopy (LASE).

Liquid-crystal microphotonics

We continued our studies of the possible application of liquid crystals and their structures such as droplets and fibres in photonics. We numerically demonstrated wave guiding of laser beams by birefringent profiles of the escaped topological defect lines. The radially escaped nematic director profiles of a liquid crystal with negative birefringence are able to focus and guide light with radio polarisation, whereas the opposite-azimuthal polarisation passes through unaffected. Lensing by liquid-crystal structure was also demonstrated, which could be controlled by an external electric field. The light attenuation is low and these escaped defect lines have the potential for application in photonic waveguiding. We have also studied the lasing properties of chiral nematic 3D microlasers which were polymerised, as shown in Figure X3. The lasing shows two distinct mechanisms, namely the photonic band edge lasing and lasing from the whispering gallery modes. It was demonstrated that the polarisation of the liquid crystal greatly increases the lasing stability.

We also published an extended review paper on liquid-crystal microphotonics (I. Muševič, Liquid Crystal Reviews 4, 1 (2016)). This work summarises the main aspects of liquid-crystal microphotonics including nematic colloids and liquid-crystal dispersions.

Molecular motors

In collaboration with researchers from Dresden and Warsaw we investigated the working mechanism of the motor protein kinesin-14. Even though the main task of most cytoskeletal motors is longitudinal motion, many of them also exert a torque on their filaments, leading to helical motion. The significance of this torque is still unknown, but it might be involved in the establishment of body chirality in certain organisms. In our motility assay the motors are attached to the surface and move microtubules, whose longitudinal and angular motion is simultaneously observed through attached quantum dots and FLIC microscopy. Unexpectedly, the period of the helical motion strongly depends on the ATP concentration. We developed a minimal mechano-chemical model for kinesin-14, which allows us to explain this dependence and also to reconstruct the motor’s working cycle. Our results demonstrate how measurements on large ensembles can be used to infer the properties of individual molecules. The work was published in Proc. Natl. Acad. Sci. USA 113, E6582–E6589 (2016).

Low-friction nanomaterials

Hard coatings have been used as wear-protection coatings for decades but without optimization of conventional lubrication systems. In the paper “Tribological performance of TiN, TiAlN and CrN hard coatings lubricated by MoS$_2$ nanotubes in Polyalphaolefin oil”. Wear, vol. 352-353, p. 72, by S. Paskvale, M. Remskar, M. Čekada, we reported that the addition of MoS$_2$ nanotubes in polyalphaolefin (PAO) oils leads to a significant reduction in friction and to a decrease in the wear behaviour of tool steel AISI D2 coated with TiN, TiAlN and CrN hard coatings. Comparative tests using conventional MoS$_2$ platelets in PAO oil was performed on these hard coatings. In all cases, the MoS$_2$ nanotubes substantially decreased friction (on CrN for 55%, on TiN for 65%, and on TiAlN for 25%), while the MoS$_2$ platelets were less efficient or even increased friction.

In the paper Transitioning to sustainable production – Part III: developments and possibilities for integration of nanotechnology into material processing technologies (P. Krajnik et al., J. of Cleaner Production 112, 1156 (2016)) we reported on the superior tribological properties of cooling-lubricating fluids based on biodegradable vegetable oils with added functionalised MoS$_2$ nanotubes, to those of conventional metalworking fluids.
Low-dimensional materials

Molybdenum trioxide, MoO$_3$, belongs to semiconductors with a wide energy band gap. It is used in photovoltaics, as sensors and for energy storage. In the article “Oxygen deficiency in MoO$_3$ polycrystalline nanowires and nanotubes”, Materials Chemistry and Physics 170 (2016) 154, by A. Varlec, D. Arčon, S.D. Škapin and M. Remškar, we reported on the first synthesis route of the orthorhombic MoO$_3$ nanotubes by oxidation of molybdenum-sulphur-iodine nanowires. Oxygen deficiency was determined by electron-paramagnetic resonance observing paramagnetic defects (Mo, Ga) and explained using Raman spectroscopy by appearance of a new resonant band (1004 cm$^{-1}$).

Superstructures observed by scanning tunnelling microscopy on graphite have been reported several decades ago, but the interest in these superstructures recently intensified due to their occurrence in graphene grown on different substrates. In the article Influence of surface defects on superlattice patterns in graphene on graphite (M. Remškar and J. Jelene, Surface Science 651, 51 (2016)) we reported experimental findings that the orientation of the superstructure is influenced by surface defects and edges of graphene. Superstructures in graphene put on graphite exist even if the graphene is not supported by graphite over its entire area. The modulation of the density of states influences the strength of intra-layer carbon bonds in such a way that the graphene breaks along the superstructure minima.

Nanosafety

In the telecast When science explodes, aired on the national television (Slo1) on 17 Dec, 2016 as a part of education program Bite into science, and in the telecast Black market flourishes, fireworks also have a dark side aired by a commercial TV (POP TV) in broadcast Inspector on Dec. 22, 2016, M. Remškar reported on air pollution by nanoparticles released during use of fireworks and sparklers.

Small structures and 1D chains of organic molecules

By carefully controlling the growth conditions, we can fabricate different nanostructures and 1D chains of organic BETS molecules (Fig. ) on silver (111) surfaces. We are studying the structure and properties of such formations using low-temperature scanning tunnelling microscopy and spectroscopy. We measured a narrow gap in the density of states, which indicates the chains to be semiconducting. As previously observed on monolayer islands, grown from same material (single crystals of (BETS),GaCl$_4$), the GaCl$_4$ molecules can fill the gaps between pairs of BETS molecules and greatly influence the electronic properties of molecular chains.

Ultra-cold atoms

For the first time in the Laboratory for Cold Atoms at Jožef Stefan Institute caesium atoms were evaporative cooled to temperatures of about 1 nK. Simultaneously, their density was increased, which leads to formation of Bose-Einstein condensate (Figure 29). Currently, we are trying to increase the number of atoms in the condensate and to achieve the condensation at even higher temperatures.

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

The program "Experimental biophysics of complex systems and imaging in biomedicine" combines the research of the processes and structure of the biological systems with the development of advanced experimental techniques, especially microspectroscopies, super-resolution microscopies, and imaging techniques. Our group is mainly focused on understanding the response of the molecular and supra-molecular structures to the interaction between materials and living cells, and to the interaction between light and living cells. We are interested in mechanisms of this response, time scales and conditions as well as its application in medicine, especially in the field of medical materials and devices, and in healthcare in general. With the development of spectroscopic, microscopic and microspectroscopic techniques, we aim to provide a new understanding of biological systems, which will open up new possibilities in the design of novel medical devices for therapy, diagnostics and regeneration – one of the main health issues among the aging population of the developed world. Our group mastered various spectroscopic techniques, such as the EPR and FTIR, microscopic and microspectroscopic fluorescence techniques such as FMS and many special MRI techniques and we have introduced super-resolution microscopic techniques such as the STED, FCS and STED.

Figure 26: Coefficients of friction and wear at the 4N and 20N loads at the contact between CrN hard coating and steel (100Cr6) ball. We used the following lubricants: pure PAO oil, PAO oil with 2 wt.% of MoS$_2$ platelets (MoS$_2$+PTs) or standard MoS$_2$ nanotubes (PAO+NTs).

Figure 27: STM picture of a superstructure in graphene lying on graphite substrate.

Figure 28: High-resolution STM image showing molecular chains of organic BETS and GaCl$_4$ molecules on Ag(111) surface (25 × 25 nm$^2$; T = 4.2K).

Figure 29: Velocity-distribution images showing about 50,000 caesium atoms being evaporative cooled to temperatures around 1 nK, where the transition to a Bose-Einstein condensate occurs.

Figure 20: Coefficient of friction and wear at the 4N and 20N loads at the contact between CrN hard coating and steel (100Cr6) ball. We used the following lubricants: pure PAO oil, PAO oil with 2 wt.% of MoS$_2$ platelets (MoS$_2$+PTs) or standard MoS$_2$ nanotubes (PAO+NTs).

Figure 21: STM picture of a superstructure in graphene lying on graphite substrate.

Figure 22: High-resolution STM image showing molecular chains of organic BETS and GaCl$_4$ molecules on Ag(111) surface (25 × 25 nm$^2$; T = 4.2K).

Figure 23: Velocity-distribution images showing about 50,000 caesium atoms being evaporative cooled to temperatures around 1 nK, where the transition to a Bose-Einstein condensate occurs.
FCS, together with the novel two-photon STED and spectral sensitive STED. Among the methods of magnetic resonance imaging, a new method, which enables the monitoring of the electric field in tumours during their treatment by electroporation high-voltage electric pulses, has been developed. In addition, we have developed a method of multiparametric magnetic resonance imaging, which has been found to be very efficient in the characterization of food, drugs and various processes. By using high spatial resolution magnetic resonance imaging, we can monitor the efficiency of the surface treatment, formation and dissolution of gel layers as well as diffusion measurements in samples with restricted geometry.

Cell-material interaction studies

The cell-material interaction studies, especially from the viewpoint of bioactivity and biocompatibility, are undoubtedly one of the hottest biophysics research topics. We have previously shown that titanium dioxide nanoparticles strongly interact with lipid membranes from either model vesicles or even live cells - they can adsorb to the membrane and wrap themselves by a lipid corona. We have recently indisputably corroborated this idea with additional experiments using original approaches, such as fluorescence (micro)spectroscopy with in-house-designed and synthesized environment sensitive molecular probes, and state-of-the-art biophysical methods, such as fluorescence cross-correlation spectroscopy (FCCS) and super-resolution fluorescence imaging (STED). For the latter two, we teamed with the renowned prof. Christian Eggeling from the University of Oxford (UK) to foster the transfer of knowledge on these advanced techniques, which will also be available in our laboratory.

Many studies on the safety of engineered nanomaterials focused only on finding correlations between nanomaterial properties and adverse health outcomes, without taking into account underlying molecular events. A consortium of research institutions (including our group) and companies teamed up for the SmartNanoTox project with a common goal of identifying molecular initiating events and key events on a cellular level and connecting them to adverse health outcomes after inhalation of the nanomaterial. This approach should therefore yield a mechanistic picture of nanomaterial toxicity, which will lead to the discovery of causal links between molecular initiating events from the in-vitro models and the adverse health outcomes determined with animal models. Using the existing literature, we have identified the most suitable cell-based and cell-free in-vitro models of the lung. Some of the molecular initiating events identified are: nanomaterial - lipid interaction including corona formation after exposure of a nanoparticle to lung surfactant, cellular uptake of nanoparticles, and lysosomal destabilization. We have successfully labelled TiO₂ nanotubes with different fluorophores, which are also suitable for high-resolution STED imaging. Our preliminary data show that the nanotubes enter the cells as single nanotubes – an event that cannot be resolved from confocal microscopy (see Figure 30).

Fluorescence microspectroscopy (FMS)

Fluorescence microspectroscopy (FMS) reveals physical properties of molecular environment of fluorescent probes. For example, we have developed probes that are sensitive to the local pH value. They only activate at low pH. In addition, their spectral properties change, if they aggregate. There are a number of mechanisms being exploited with these probes to study molecular vicinity. Widely used is fluorescence resonance energy transfer (FRET). Lately, contact- or aggregation-based mechanisms are also being utilized. In the case of rhodamine probes, aggregate formation leads to non-fluorescent ground-state complexes or spectral shifts. With calibration of concentration and pH dependence, the developed probes will be useful for a quantitative determination of the level of aggregation, i.e., as sensors for the detection of molecular contact.

Multiparametric detection of the impact of the high-intensity light source on biological systems

A new experimental system for multiparametric detection of the impact of the high intensity light source on biological systems was developed. Common fluorescence detection of individual structures of the retina before and after the injury with a strongly focused high-intensity light source was changed and improved with fluorescence micro-spectral detection. The system was developed on an existing fluorescence microspectroscopy (FMS) machine with a newly installed near-IR laser source with a well-defined spatiotemporal resolution. Using this system, we were able to successfully characterize the interaction of the light source with biological matter. In addition, a new method for the localization and dynamics monitoring of blood clotting following the blood vessel injury was introduced, based on the optical tweezers and their mechanical manipulation of individual or multiple erythrocytes.
To mimic the \textit{in vivo} coagulation processes during vessel disruption, we used retinal tissue samples from \textit{ex vivo} porcine eyes. The detection of blood coagulation was performed by the fluorescence microspectroscopy (FMS) system developed in our laboratory. In order to identify the extent of the clot formation after the accurately localized vessel rupture in the intact retina, we measured the auto-fluorescence contrast inside the blood vessel indicating a blood flow. A significant decrease in the negative contrast as detected after one minute is the result of the decreased number of erythrocytes in the volume. The observed blood flow showed the inability of the formed clot to completely seal/close the vessel. Using the negative contrast fluorescence technique, it is difficult to distinguish between the non-coagulated and coagulated region inside the ruptured vessel, but with the FMS blood-clot characterization technique, the differences between the non-coagulated blood (blue colour) and coagulated blood (green colour) in the initial clot localization could be easily observed. The measured red spectral shift of $\Delta \lambda \approx 1-2 \text{ nm}$ in the damaged region directly indicates the changed absorption properties of hemoglobin and thus the local physio-chemical changes, which means the onset of the clot formation. We can see that part of the targeted region just below the ruptured vessel wall remains non-coagulated (blue colour).

In order to confirm the initial clot formation, we used optical tweezers. Strong binding between individual erythrocytes a few tens of $\mu$m outside of the ruptured vessel formed on a minute timescale after a vessel injury. Optical tweezers manipulation in a vertical direction (see cross-locator in Figure 31), with trapping force of $F \approx 10 \text{ pN} (P \approx 50 \text{ mW})$, used the concurrent movement of a group of more than 10 closely packed erythrocytes. The optical force was unable to detach single erythrocytes from the bulk, which indicates strong adhesion, i.e., the initial state of the clot formation. For comparison, erythrocytes inside the vessel, a few tens of microns away from the ruptured site, did not aggregate. Our results show that the initial clot formation is in agreement with our hypothesis that the initial clot formation is localized to the site where the plasma calcium concentration is decreased in the region where blood plasma is diluted with released cytoplasm of injured tissue surrounding the blood vessel.

Based on our collaboration with the Smithies’ lab from the University of North Carolina and our work published in the Langmuir journal, we were invited to describe and film all the details of our method for the Size Controlled Synthesis of Stable Oligomeric Clusters of Gold Nanoparticles under Ambient Conditions (J. Vis. Exp. 2016 (108):e53388). In this work, we described how reducing dilute aqueous HAuCl$_4$ with sodium thiocyanate (NaSCN) under alkaline conditions produces 2–3-nm-diameter nanoparticles and stable grape-like oligomeric clusters of yellow nanoparticles. The produced yellow oligoclusters range in size from $\sim 3$ to $\sim 25 \text{ nm}$. This size range can be further extended by an add-on method utilizing hydroxylated gold chloride (Na$^+$(Au(OH)$_2$)$_x$Cl$_{4-x}$) to autocatalytically increase the number of subunits in the as-synthesized oligocluster nanoparticles, providing a total range of 3 nm to 70 nm. We were able to concentrate the oligoclusters more than 300 fold without aggregation and the crude reaction mixtures remained stable for months without further processing.

**Diffusion measurement by modulated gradient**

We improved our method for diffusion measurement by modulated gradients. In some of our experiments, especially those on bulk liquids, we found that the method gives overestimated results for the diffusion constant with higher frequencies of modulated gradients. In the study, we showed that the origin of the error is in neglecting the off-resonance contributions to the signal of multiple spin echoes in a high magnetic field gradient. Because of these contributions, the total signal was decaying faster than was predicted by our theory, which led to the overestimated calculated diffusion constant. We found a solution to the problem in zero frequency filtering of the spin echo signals, which removed most of the off-resonance signals and therefore made our theoretical model valid again. The results of the study were published in the Journal of Magnetic Resonance, 2016, 270: 77-86.

**Dry-curing of different meat products**

By using multiparametric magnetic resonance imaging, we studied dry-curing of different meat products. Relaxation time $T_1$ and $T_2$ mapping, and the apparent diffusion constant (ADC) mapping were used to find the differences between two different ham muscles (biceps femoris and semimembranosus) at two different stages of salting (low and high). We showed that the maps can be converted into one-dimensional distributions of the parameters $T_1$, $T_2$ and ADC, and in two-dimensional correlations between the parameters ADC-T2, ADC-T1, T1-T2, which show characteristic peaks in the distribution. The location and distribution of these peaks are very sensitive to both the tissue type and the influence of the salting. The characterization was better with the two-dimensional correlation than with one-dimensional distributions. To these three mapping methods, we also added quantitative magnetization transfer imaging, which was found to be efficient for determining the protein content. We concluded that these methods, having greater accessibility to NMR / MRI systems, could serve as an effective tool for monitor-
In 2016, the Department had cooperation with 108 partners from Slovenia and abroad. Among them:

- Also supported within the bilateral Slovenian – USA, Slovenian – German and Slovenian – Greek and other scientific cooperations.

We also investigated the influence of the highly soluble pentoxifylline drug on the dynamics of medium penetration into the tablet and the formation of the gel layer in xanthan tablets.

**Influence of the highly soluble pentoxifylline drug on the dynamics of medium penetration into the tablet and the formation of the gel layer in xanthan tablets**

Xanthan is an anionic polymer that exhibits pH- and ionic-strength-dependent swelling. For this reason, the impact of the medium properties on xanthan swelling has also been studied. For hydrophilic polymers, it is generally accepted that, once in contact with a body fluids, they hydrate and swell, forming a gel layer that regulates the penetration of body fluids into the tablet and the dissolution of the incorporated drug. Therefore, the knowledge of the gel layer characteristics is of crucial importance for the use of controlled drug-delivery systems. A combination of different MRI methods enables an accurate determination of the medium penetration into the tablet, as well as hydrogel formation *in situ*. The results of xanthan swelling and pentoxifylline release kinetics were compared to the mathematical model, which combines the polymer swelling kinetics and drug diffusion and solubility to obtain the release mechanism. In water and diluted acid medium (pH >3) with low ionic strength, the main release mechanism is erosion, whereas in acid medium (pH 1.2) and in media with high ionic strength (µ >0.2), the diffusion mechanism dominates, owing to the changes in the polymer structure in media with different pH and ionic strength. The results were published in a paper entitled *The Influence of other high loading and xanthan tablets and media with Different physiological pH and ionic strength on swelling and release* in the Journal of Molecular Pharmaceutics, 2016, 13: 1147. This study was performed in collaboration with our colleagues from the Faculty of Pharmacy, University of Ljubljana.

**Penetration of tung oil into various wood species**

Furthermore, we studied the penetration of tung oil into various wood species. Tung oil is used as environmentally friendly wood preservatives. However, tung oil does not penetrate deeply into the wood due to its high viscosity. Magnetic resonance imaging was applied to elucidate the influence of the applied impregnation method (immersion in oil or vacuum impregnation with oil) and on the wood species used. It has been shown that the oil penetrated deeply in the wood after the impregnation process than after the immersion process, where the oil remained only on the sample surface. In addition, the depth of penetration of the oil into the wood also depends on the wood species and on the orientation of the sample. Since wood is an anisotropic material, the penetration of the oil is the largest in the axial direction. The results of the research were combined in an article accepted for publication in the Journal Industrial Crops and Products, 2017, 96: 149. The study was performed in collaboration with our colleagues from the Department of Biotechnical Faculty.

Our research has been supported by a number of international projects financed by the European Union. It was also supported within the bilateral Slovenian – USA, Slovenian – German and Slovenian – Greek and other scientific cooperations. In 2016, the Department had cooperation with 108 partners from Slovenia and abroad. Among them:

- The high magnetic field centres in Grenoble, France, and Nijmegen, The Netherlands
- The high magnetic field centre at the University Florida, Tallahassee, Florida, USA
- The ETH, Zürich, Switzerland
- The Ioffe Institute in St. Petersburg, Russia
- The University of Duisburg, the University of Mainz and the University of Saarbrucken in Germany
- The University of California, the University of Utah and the Liquid Crystal Institute, Kent, Ohio, USA,
- National Institute for Research in Inorganic Materials, Tsukuba, Japan
- NCSR Demokritos, Athens, Greece
- Institut für Biophysik und Nanosystemforschung OAW, Graz, Austria
Some outstanding publications in 2016


Some outstanding publications in 2015


Some outstanding publications in 2014


Awards and appointments

1. Dr. Matjaž Humar: 1st Place Poster Prize at prestigious Nobel Laureate Meeting 2016, Lindau, Germany. Matjaž presented a poster about lasers embedded into single live cells for the first time. He has also demonstrated that fat cells already present in the human body already contain tiny lasers, which only need to be activated.
2. Dr. Matjaž Humar: Bronze Award from community Šempeter-Vrtojba for 2016, Šempeter-Vrtojba. The prize for the high successes in the world scale in recent years and as a stimulation for further scientific work.
3. dr. Janez Pirš, Honorary distinction of ’Jožef Stefan’ Institute, Ljubljana, Slovenia, Honorary distinction for his successful contribution for developing new high-tech products based on scientific and technological achievements of the ’Jožef Stefan’ Institute.

Organization of conferences, congresses and meetings

1. 6th Workshop on Liquid Crystals for Photonics, 14. 9. – 16. 9. 2016, Ljubljana, Slovenia
2. 10. Conference of physicists in basic research, 16. 11. 2016, Otočec, Slovenia

Patent granted

INTERNATIONAL PROJECTS

1. FP7 - ENSNM: Electron Spin Noise Scanning Tunneling Microscopy
   Profs. Janez Dolinšek
   European Commission

2. FP7 - NanoMag: Magnetic Nanoparticles and Thin Films for Spintronic Applications and High-Performance Permanent Magnets
   Profs. Janez Dolinšek
   European Commission

3. FP7 - SIMBALLE2: Sources, Interaction with Matter Detection and Analysis of Low Energy Electrons
   Profs. Maja Remškar
   European Commission

4. FP7 - LIVINGLASER: A Laser made Entirely of Living Cells and Materials derived from Living Organisms
   Profs. Igor Muševič
   European Commission

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

   Dr. Polona Umek
   COST Office

7. COST CA15107: Multi-Functional Nano-Carbon Composite Materials Network
   Dr. Polona Umek
   COST Office

8. COST CA15209: European Network on NMR Relaxometry
   Prof. Tomaž Apšel
   COST Office

9. COST CA16109: Chemical On-Line C0mp0sition and Source Apportionment of fine aerosols.
   Dr. Greta Močnik
   COST Office

10. H2020 - SmartNanoTox: Smart Tools for Gauging Nano Hazards
    Prof. Janez Strancar
    European Commission

11. Solar Cell Application of Rotating Plasma Modified Inorganic Nanotubes
    Prof. Maja Remškar
    Slovenian Research Agency

12. Spin liquid ground state of Quantum Kagome Antiferromagnets from a Local-probe Perspective
    Asst. Prof. Andraž Zorko
    Slovenian Research Agency

13. Controlled Nanoparticle Assemblies in Complex Soft Matrices
    Prof. Samo Kralj
    Slovenian Research Agency

    Prof. Tomaž Apšel
    Slovenian Research Agency

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

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

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

18. Crystal and Electronic Structure of NiS2 Phases
    Dr. Erik Zupanič
    Slovenian Research Agency

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

20. Lead-free (Ba0.8Ca0.2)1-xLax/3TiO3 based electrocaloric materials for new dielectric cooling technologies
    Prof. Zdravko Kuncnik
    Slovenian Research Agency

21. Stabilization of lattices of topological defects
    Prof. Samo Kralj
    Slovenian Research Agency

RESEARCH PROGRAMS

1. Physics of Soft Matter, Surfaces and Nanostructures
   Prof. Slobodan Žumer

2. Experimental Biophysics of Complex Systems
   Prof. Janez Strancar

3. Magnetic resonance and dielectric spectroscopy of „smart” new materials
   Prof. Janez Dolinšek

R & D GRANTS AND CONTRACTS

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

2. Thermophoretic guidance, accumulation and sorting of biomolecules in microfluidic devices
   Asst. Prof. Andrej Vilen

3. Intra-pocket-targeted nanomedicines for treatment of periodontal disease
   Prof. Maja Remškar

4. New advanced electrocaloric materials for novel environmentally-friendly dielectric refrigeration technology
   Prof. Zdravko Kuncnik

5. The textural analysis of spatiotemporal changes for breast lesions diagnosis on ultrafast breast MRIs
   Prof. Igor Seria

6. Role of Calcium and lipid membranes in survival of critically ill patients
   Dr. Tilen Kokič

7. Multifunctional materials for actuator and cooling devices
   Prof. Zdravko Kuncnik

8. High-Entropy Alloys
   Dr. Stanislav Tyrnak

9. Metamaterials from liquid crystal colloids
   Asst. Prof. Miha Ravnik

10. Optimization strategies in biological and artificial microfluidic systems
    Asst. Prof. Andrej Vilen

11. Water exclusion efficacy, measure for prediction of wood performance against wood decay fungi
    Prof. Igor Seria

12. Micro-electromechanical and electrocaloric layer elements
    Prof. Zdravko Kuncnik

13. Performance of wood and lignocelullosic composites in outdoor applications
    Prof. Igor Seria

14. Advanced electrocaloric energy conversion
    Prof. Zdravko Kuncnik

15. Microscopy-based optimization of the effects of laser pulses on the retina
    Prof. Janez Strancar

16. SCOPE3: Spin liquid and Spin ice States in Frustrated Rare-earth and Transition Metal Spinels
    Dr. Matej Pregelj
    Swiss National Science Foundation

17. Irradiation and Analysis of Nano SiC Samples
    Snf- Swiss National Science Foundation

18. Experimental Biophysics of Complex Systems
    Prof. Slobodan Žumer

19. Physics of Soft Matter, Surfaces and Nanostructures
    Prof. Slobodan Žumer

20. Building blocks, tools and systems for the Factories of the Future - GOSTOP
    Prof. Janez Strancar

NEW CONTRACTS

1. MRI scanning of samples
   Prof. Igor Seria
   KREA, TOVARNA ZDRAVIL, D.D.

2. Analyzes with nuclear quadrupole resonance (NQR)
   Prof. Tomaž Apšel
   LEX d.d.

3. Measurement of optical transmissivity
   Prof. Igor Muševič
   RLS Merilna Tehnika d.o.o.

4. Microscopy-based optimization of the effects of laser pulses on the retina
   Prof. Janez Strancar
   OPTOTEX d.o.o.
VISITORS FROM ABROAD

5. dr. Tima Ivanović, Faculty of Natural Sciences of Vukovar University, Vukovar, Croatia, 1. 2. 2016 – 31. 3. 2016
7. dr. Siniša Janković, University of Novi Sad, Faculty of Physics, Novi Sad, Serbia, 15. 3. 2016 – 31. 3. 2016

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65. Muhammad Saqib, B. Sc.
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70. Dr. Ana Varlec, left 03.03.16

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ORIGINAL ARTICLE


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