DEPARTMENT OF SOLID STATE PHYSICS F-5

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

Head:
Prof. Igor Muševič

The experimental techniques used are:

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

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

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

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

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

In our research, we used the following experimental techniques:

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

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

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

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

The investigations were focused on the following research fields:

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

Quantum magnetism

Martin Klanjšek, Andrej Zorko and Denis Arčon, in collaboration with researchers from Slovenia and the UK, experimentally studied the spin dynamics of the layered material 1T-TaS_2. As each layer of the material in the charge-density wave state below 210 K exhibits a frustrated, triangular lattice of magnetic spins, it has been descibed as a possible platform for the realization of the enigmatic quantum spin-liquid (QSL) state for the past 40 years. To confirm this prediction, the authors conducted nuclear quadrupole resonance and muon-spin-relaxation experiments, which indeed revealed that the spins show gapless QSL dynamics and no long-range magnetic order, at least down to 70 mK. Canonical T^2 power-law temperature dependence of the spin relaxation dynamics characteristic of a QSL is observed down to 55 K. Below this temperature, a new gapless state is observed, signifying a new quantum spin order emerging from the QSL. The discovery was published in M. Klanjšek, A. Zorko, R. Žitko, J. Mravlje, Z. Jagličić, P. Kumar Biswas, P. Prelovšek, D, Mihailovic, D. Arčon. A high-temperature quantum spin liquid with polaron spins. *Nature Physics* 13 (2017), 1130.

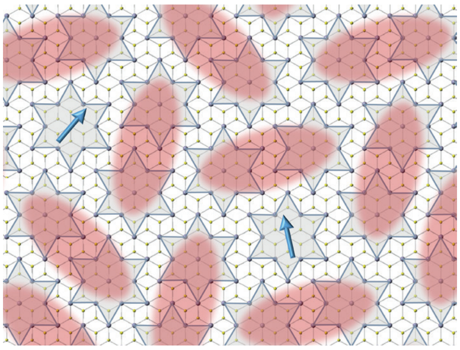

Figure 1: Low-temperature spin state of 1T-TaS_2 with the arrangement of the "Star-of-David" spin singlets (red shaded areas) in a spatially random manner. This state still exhibits a gapless behaviour for the low-energy spin excitations (blue arrows).

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

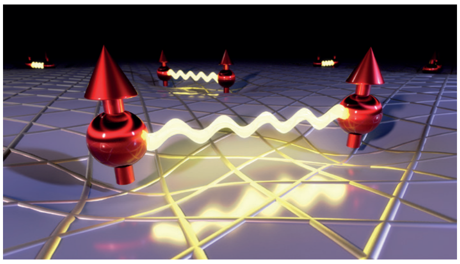

Figure 2: Illustration of the spinon-pairing instability observed in the kagome antiferromagnet Zn-brochantite. The process is a magnetic analoque of Cooper pairing in superconductors.

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

Andrej Zorko and Matjaž Gomilšek, in collaboration with partners from Croatia, USA and France, employed a combination of complementary torque magnetometry and electron spin resonance techniques to investigate single crystals of herbertsmithite, the closest realization to date of a quantum kagome antiferromagnet featuring a spin-liquid ground state. Their discovery of a magnetic response that contradicts the threefold symmetry of the ideal kagome lattice was shown to originate from a global structural distortion that might be related to the establishment of a spin-liquid ground state. These results were published in A. Zorko, M. Herak, M. Gomilšek, J. van Tol, M. Velázquez, P. Khuntia, F. Bert, P. Mendels. Symmetry reduction in the quantum kagome antiferromagnet herbertsmithite. *Physical Review Letters* 118 (2017), 017202. Andrej Zorko collaborated with researchers from Croatia, France and USA on a synthesis and characterization of a novel hetero-tetranuclear compound $[Cr_2(bpy)_4(\mu\text{-}O)_4Nb_2(C_2O_4)_4]\cdot 3H_2O$ (bpy = 2,2′-bipyridine). It was found that it consists of a square-shaped macrocyclic $\{Cr_2(\mu\text{-}O)_4Nb_2\}$ core in which Cr^{III} and Nb^{V} ions are alternately bridged by oxo ions and three uncoordinated water molecules. The resulting magnetic structure corresponds to weakly interacting chromium dimers. The results were published in M. Jurić, L. Androš Dubraja, D. Pajić, F. Torić, A. Zorko, A. Ozarowski, V. Despoja, W. Lafargue-Dit-Hauret, X. Rocquefelte. Experimental and Theoretical Investigation of the Anti-Ferromagnetic Coupling of Cr_{III} Ions through Diamagnetic $-O-Nb^{V}-O-$ Bridges. *Inorganic Chemistry* 56 (2017), 6879.

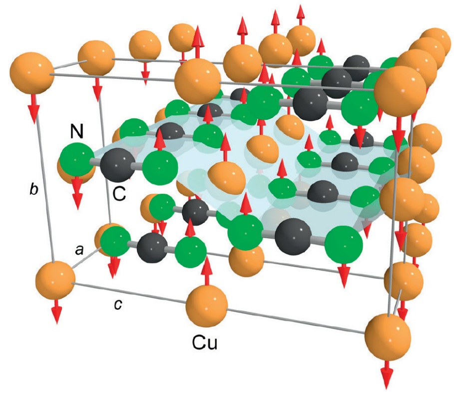

Figure 3: The crystal structure of CuNCN with Cu in dark-orange, C in black and N in green. The half-transparent surface is a guide for the eye to highlight the layered structure of the material. Γ point eigenvectors of the flexural vibration mode are depicted using arrows. These eigenvectors are clearly dominated by the rotations of the NCN^{2-} moieties around the a axis, accompanied by the parallel motions of the Cu atoms. Contributions in the c direction are small and no a components are present.

Magnetism of the $CoCrFeNiZr_x$ eutectic high-entropy alloys

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

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

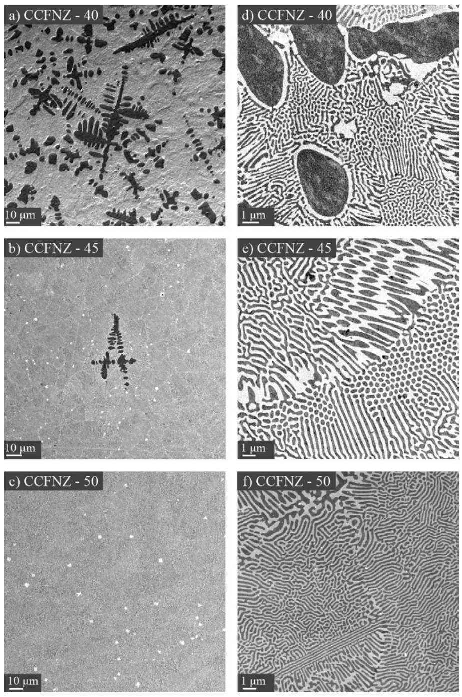

Figure 4: Microstructure of the CoCrFeNiZrx eutectic high-entropy alloy obtained by SEM backscattered electrons.

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

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

We also demonstrated that the gold nanoparticles can stabilize periodic defect structures, studies of which were published in M. Trček, G. Cordoyiannis, B. Rožič, V. Tzitzios, G. Nounesis, S. Kralj, I. Lelidis, E. Lacaze, H. Amenitsch, Z. Kutnjak. Twist-grain boundary phase induced by Au nanoparticles in a chiral liquid-crystal host. *Liquid Crystals* 44 (2017), 1575. B. Rožič, J. Fresnais, C. Molinaro, J. Calixte, S. Umadevi, S. Lau-Truong, N. Felidj, T. Kraus, F. Charra, V. Dupuis, T. Hegmann, C. Fiorini-Debuisschert, B. Gallas, E. Lacaze. Oriented gold nanorods and gold nanorod chains within smectic liquid-crystal topological defects. *ACS Nano* 11 (2017), 6728.

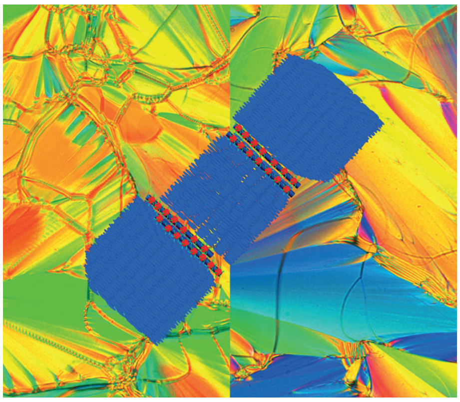

Figure 5: Texture of stabilized TGBA phase by gold particles. Front schematics show nanoparticle agglomeration in defect dislocation lines.

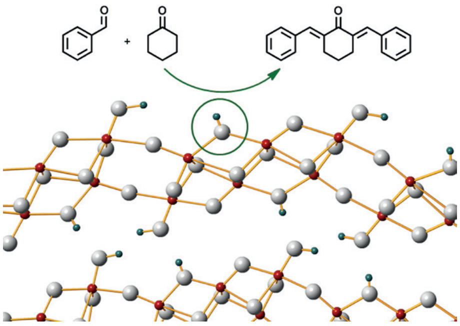

Figure 6: Surface -OH groups that are in a bridging configuration are crucial for high catalytic activity.

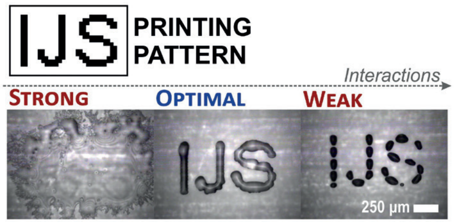

Figure 7: The impact of the ink–substrate interactions on the morphology and definition of the printed pattern. The indium-zinc oxide (IZO) ink (prepared by dissolving $In(NO_3)_3$ and $Zn(NO_3)_2$ in a solvent mixture of 2-methoxyethanol and 1,3-propanediol in a 45:55 volume ratio) spreads completely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

Research of the catalytic properties of 1D titanate nanostructures

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

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

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

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

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

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

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

Development of multilayer ceramic elements for electrocaloric cooling

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

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

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

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

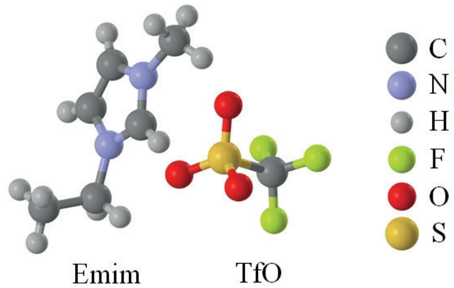

Figure 8: Schematic presentation of the ionic liquid [Emim][TfO] molecule.

^{14}N NQR lineshape in nanocrystals: An *ab-initio* investigation of urea

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

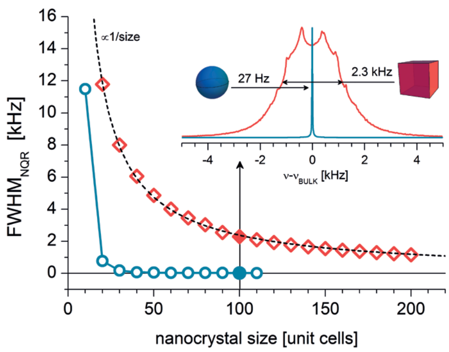

Figure 9: Two representative ^{14}N NQR spectra and the corresponding size-linewidth dependence for two nanocrystal geometries: (i) spheres (open blue circles) and (ii) cubes (open red squares). The representative spectra are calculated for a nanocrystal size of 100 unit cells.

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

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

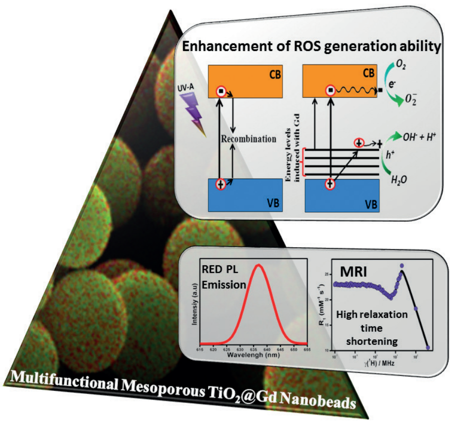

Figure 10: TiO_2 nanobeads doped with a low concentration of Gd.

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

R. Imani, R. Dillert, D. W. Bahnemann, M. Pazoki, T. Apih, V. Kononenko, N. Repar, V. Kralj-Iglič, G. Boschloo, D. Drobne, T. Edvinsson, A. Iglič. Multifunctional Gadolinium-Doped Mesoporous TiO_2 Nanobeads: Photoluminescence, Enhanced Spin Relaxation, and Reactive Oxygen Species Photogeneration, Beneficial for Cancer Diagnosis and Treatment. *Small* 13 (2017), 1700349.

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

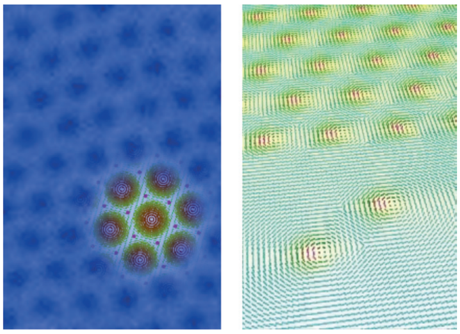

Figure 11: Optical image of the half-skyrmion lattice and simulation of the director field of the half-skyrmion lattice and individual defects.

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

Skyrmions in a thin layer of a highly chiral nematic

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

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

Topology of droplets with chiral nematic liquid crystals

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

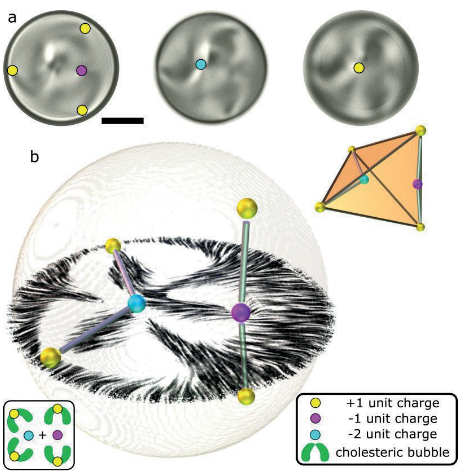

Figure 12: Point defects with higher topological charge in chiral nematic droplets.

Fractal nematic colloids

The generation of fractal topological states in nematic fluids was demonstrated (S. M. Hasheimi, U. Jagodič, M. R. Mozaffari, M. R. Ejtehadi, I. Muševič, and M. Ravnik, *Fractal nematic colloids, Nature Community* 8 (2017), 12106). For fractal colloidal particles in nematic liquid crystals numerical modelling based on mesoscopic phenomenological free-energy minimization with finite elements was used. On the experimental side two-photon laser polymerization was used to produce colloidal particles in the shape of fractal Koch snowflakes, which were then observed with optical microscopy techniques. The research was a combinations of numerical modelling and performed at the Faculty of Mathematics and Physics at the University of Ljubljana, with support from the group at Sharif University of Technology, and experiments, which were performed at the Department of Condensed Matter Physics at the Jožef Stefan Institute.

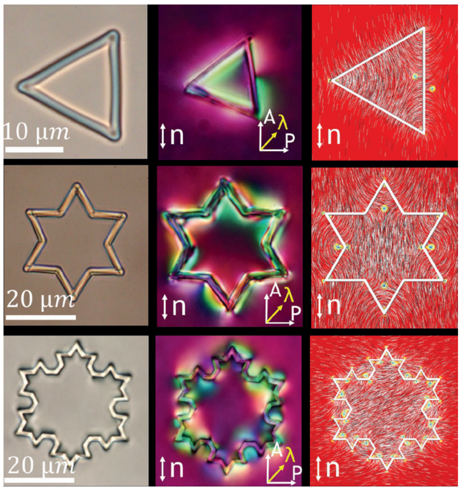

Figure 13: Nematic topological states stabilized by fractal Koch-star colloidal particles.

Topological defects in thin nematic films:

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

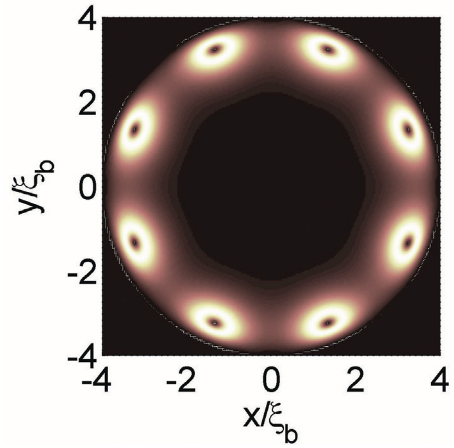

Figure 14: An enforced topological defect of charge 6 decays into 12 elementary defects, which are assembled at the confining boundary. This phenomenon is analogous to a Faraday cavity effect in electrostatics.

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

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

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

Improved method of simulating the polarized images

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

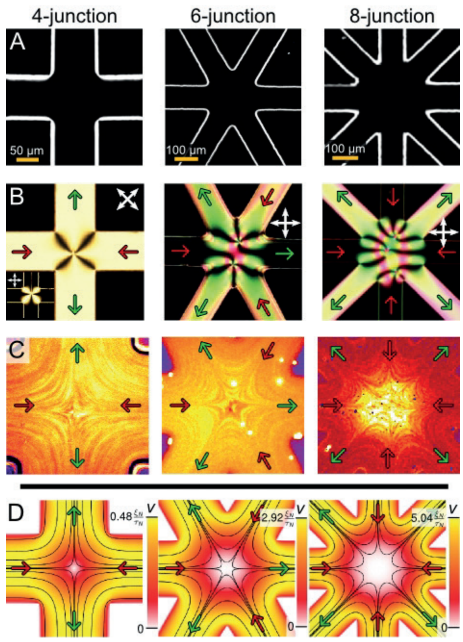

Figure 15: Emergence of nematic topological defects and hydrodynamic singularities at a microfluidic junction

Optothermally driven colloidal transport in a confined nematic liquid crystal

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

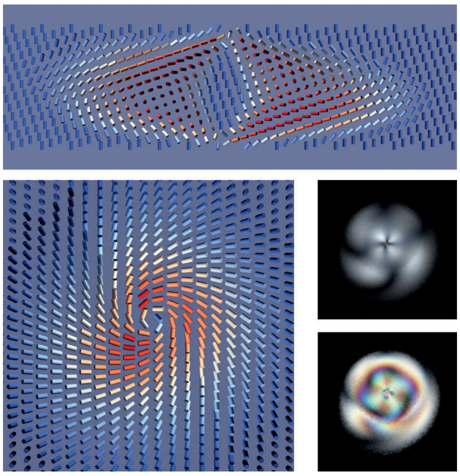

Figure 16: FCPM method allows the reconstruction of director fields from experimental data. The images show localized chiral structures in thin homeotropic layers.

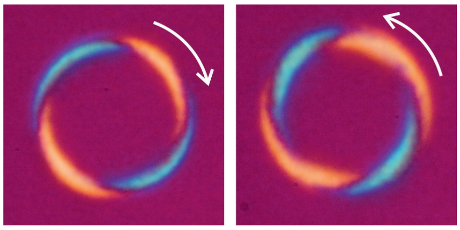

Figure 17: Circulation of the laser spot induces hydrodynamic flow in liquid crystal.

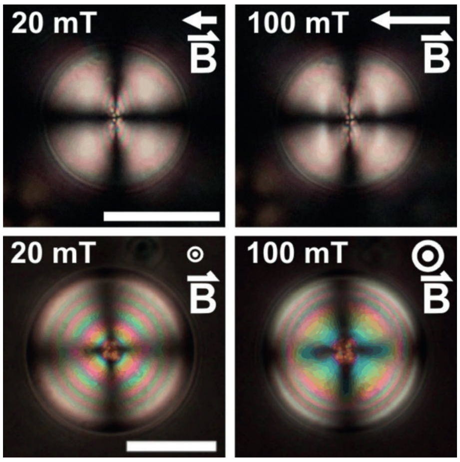

Figure 18: Elastic distortions in a ferromagnetic nematic droplet due to magnetic field.

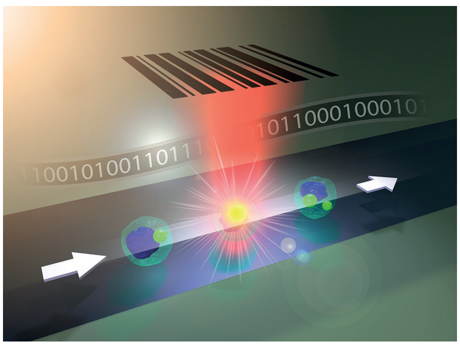

Figure 19: Cells containing small lasers inside a microfluidic channel. The lasers are used as barcodes to tag the cells.

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

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

Bio-lasers

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

Molecular motors

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

Tungsten oxide nanowires as electron field emitters

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

Low-friction nanomaterials

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

Nano safety

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

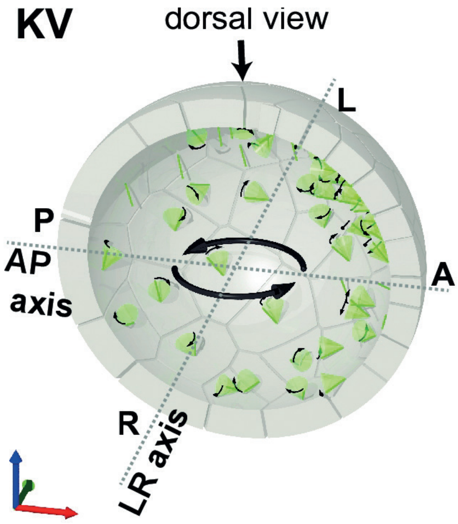

Figure 20: Schematic presentation of cilia motion in vesicle.

Growth and characterization of thin layers of transitional metal oxides

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

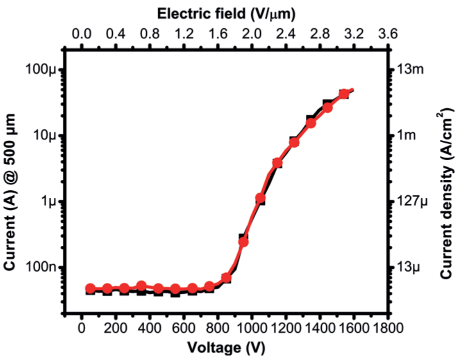

Figure 21: Emission current of nanowire and corresponding current density as a function of electric field.

Quasicrystals

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

Ultra-cold atoms

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

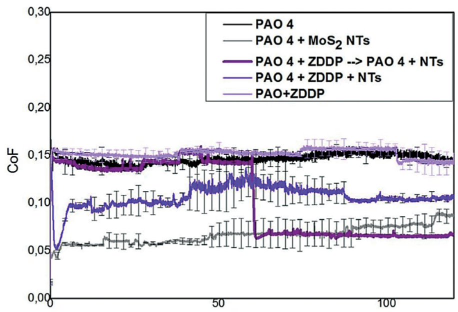

Figure 22: Adding nanoparticles decreases the friction coefficients of lubricants.

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

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

STED microscopy allowed us to directly observe a molecular event of lipid wrapping in the living pulmonary epithelium for the first time together with the subsequent uncontrolled relocation of the epithelial membranes across a lung's air-blood barrier. Using a special spectral analysis we developed a method and filed a patent for the identification of porous vessels in the retina on the basis of the analysis of retinal auto-fluorescence.

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

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

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

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

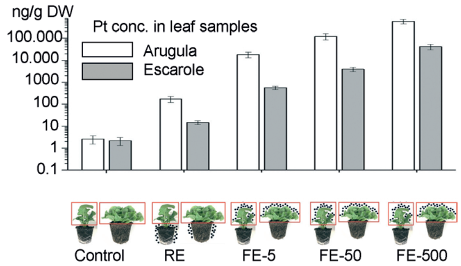

Figure 23: Platinum concentrations of arugula and escarole leaves after Pt NP foliar exposure (FE) or root exposure (RE).

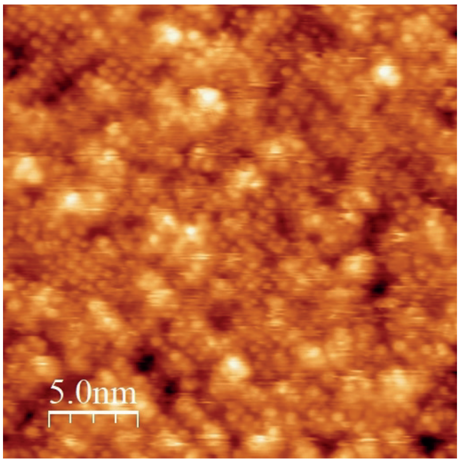

Figure 24: STM image of partially ordered surface of 10-unit-cell thick film of $SrRuO_3$

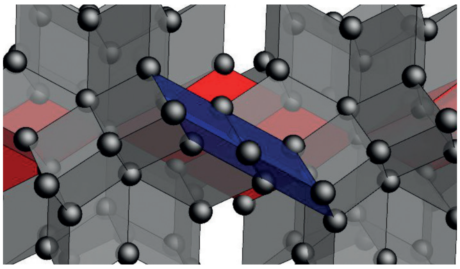

Figure 25: Stacking of two rhombic hexecontahedra, each composed of 20 twinned prolate rhombohedra, and 2 oblate rhombohedra.

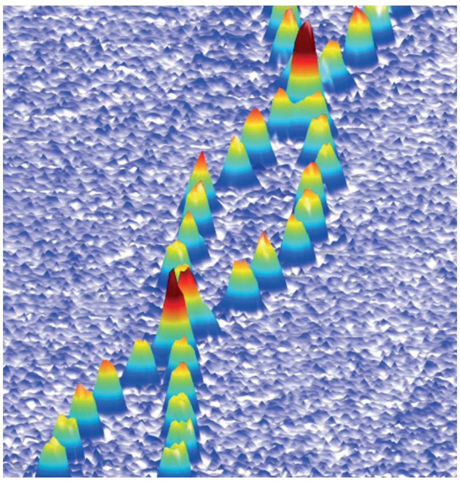

Figure 26: Colliding matter-wave solitons made of two independent Bose-Einstein condensates of caesium atoms.

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

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

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

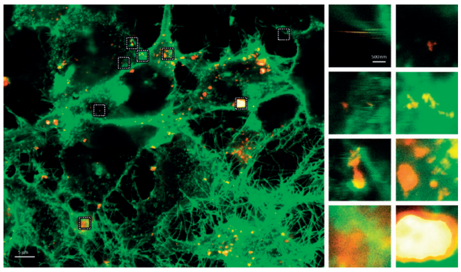

Figure 27: STED panorama of TiO_2 nanotubes (with diameter of 10 nm labelled with Alexa 647, red colour) interact with membranes (labelled with CellMask, green colour) close to the upper surface of the living LA4 lung epithelial cell layer. On the zoom-ins, nanoparticles can be located coated with lipids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

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

Characterization of nanomaterials by magnetic resonance

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

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

Electroporation treatment monitoring

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

The results of this research were published in the article M. Kranjc, S. Kranjc, F. Bajd, G. Serša, I. Serša, D. Miklavčič. Predicting irreversible electroporation-induced tissue damage by means of magnetic resonance electrical impedance tomography. *Scientific Reports* 7 (2017), 1-10.

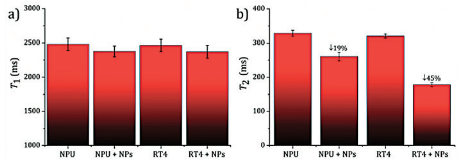

Figure 28: NMR relaxation times T1 and T2 of healthy cells (NPU) and cancer cells (RT4) and of both types of cells incubated with hybrid FePt/SiO2/Au nanoparticles at a concentration of 100 µgml for 24 h (in Kostevšek et al. Nanoscale, 2017).

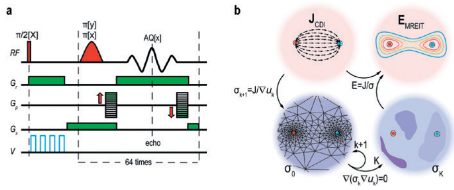

Figure 29: MRI pulse sequence for measuring the electric field in electroporation (a) and the procedure for calculating the electric field in the tumour from measurements of the current density and known geometry of the sample and electrodes (M. Kranjc et al., Scientific reports, 2017).

Advanced methods for translational dynamics measurements

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

Use of magnetic resonance in wood science

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

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

made the above studies possible.

Some outstanding publications in 2017

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

4. A. Zorko, M. Herak, M. Gomilšek, J. van Tol, M. Velázquez, P. Khuntia, F. Bert, P. Mendels. Symmetry reduction in the quantum Kagome antiferromagnet Herbertsmithite. *Physical Review Letter* 118 (2017), 017202.
5. M. Gomilšek, M. Klanjšek, R. Žitko, M. Pregelj, F. Bert, P. Mendels, Y. Li, Q. M. Zhang, A. Zorko. Field-induced instability of a gapless spin liquid with a spinon Fermi surface. *Physical Review Letter* 119 (2017), 137205.
6. L. Giomi, Ž. Kos, M. Ravnik, and A. Sengupta. Cross-talk between topological defects in different fields revealed by nematic microfluidics. *Proceedings of the National Academy of Sciences of the United States of America* 114 (2017), E5771-E5777.
7. S. M. Hasheimi, U. Jagodič, M. R. Mozaffari, M. R. Ejtehadi, I. Muševič, and M. Ravnik, Fractal nematic colloids. *Nature Communications* 8 (2017), 12106.
8. G. Posnjak, S. Čopar and I. Muševič. Hidden topological constellations and polyvalent charges in chiral nematic droplets. *Nature Communications* 8 (2017), 14594.
9. A. Nych, Jun-ichi Fukuda, U. Ognysta, S. Žumer, I. Muševič. Spontaneous formation and dynamics of half-skyrmions in a chiral liquid-crystal film. *Nature Physics* 13 (2017), 1215.
10. E. Sezgin, F. Schneider, V. Zilles, I. Urbančič, E. Garcia, D. Waithe, A.S. Klymchenko, C. Eggeling. Polarity-Sensitive Probes for Superresolution Stimulated Emission Depletion Microscopy. *Biophysical Journal* 113 (2017), 1321-1330.
11. M. Kranjc, S. Kranjc,F. Bajd, G. Serša, I. Serša, D. Miklavčič. Predicting irreversible electroporation-induced tissue damage by means of magnetic resonance electrical impedance tomography. *Scientific Reports* 7 (2017*)*, 1-10.

Some outstanding publications in 2016

1. A. Rešetič, J. Milavec, B. Zupančič, V. Domenici, B. Zalar. Polymer-dispersed liquid crystal elastomers. *Nature Communications* 7 (2016), 13140.
2. M. Jeong, M. Klanjšek et al. Dichotomy between attractive and repulsive tomonaga-luttinger liquids in spin ladders. *Physical Review Letters* 117 (2016), 106402.
3. F. E. Annanouch, P. Umek et al. Aerosol-assisted CVD-grown PdO nanoparticle-decorated tungsten oxide nanoneedles extremely sensitive and selective to hydrogen. *ACS Applied Materials & Interfaces* 8 (2016), 10413.
4. H. Uršič, V. Bobnar, B. Malič, C. Filipič, M. Vrabelj, S. Drnovšek, Jo Younghun, M. Wencka, Z. Kutnjak. A multicaloric material as a link between electrocaloric and magnetocaloric refrigeration. *Scientific Reports* 6 (2016), 26629.
5. M. Igarashi, P. Jeglič, A. Kranjc, R. Žitko, T. Nakano, Y. Nozue, D. Arčon. Metal-to-insulator crossover in alkali doped zeolite. *Scientific Reports* 6 (2016), 18682.
6. G. Posnjak, S. Čopar, I. Muševič. Points, skyrmions and torons in chiral nematic droplets. *Scientific Reports* 6 (2016), 26361.
7. L. E. Aguirre, A. de Oliveira, D. Seč, S. Čopar, P. L. Almeida, M. Ravnik, M. H. Godinho, S. Žumer. Sensing surface morphology of biofibers by decorating spider silk and cellulosic filaments with nematic microdroplets. *Proceedings of the National Academy of Sciences of the United States of America* 113 (2016), 1174.
8. S. Nizamoglu, M. Humar et al. Bioabsorbable polymer optical waveguides for deep-tissue photomedicine. *Nature Communications* 7 (2016), 10374.
9. S. Cho, M. Humar, N. Martino, S. H. Yun. Laser Particle Stimulated Emission Microscopy. *Physical Review Letter* 117 (2016), 193902.
10. B. Nitzsche, E. Dudek, L. Hajdo, A. A. Kasprzak, A. Vilfan, S. Diez. Working stroke of the kinesin-14, ncd, comprises two substeps of different direction. *Proceedings of the National Academy of Sciences of the United States of America* 113 (2016), E6582.

Some outstanding publications in 2015

1. M. Sluban, P. Umek, Z. Jagličić, J. Buh, P. Šmitek, C. Bittencourt, P. Guttmann, M.-H. Delville, D. Mihailović, D. Arčon. Controlling disorder and superconductivity in titanium oxynitride nanoribbons with anion exchange. *ACS Nano* 9 (2015), 10133.
2. M. Pregelj, A. Zorko, O. Zaharko, H. Nojiri, H. Berger, L. Chapon, D. Arčon. Spin-stripe phase in a frustrated zigzag spin-1/2 chain. *Nature Communications* 6 (2015), 7255.
3. M. Klanjšek, D. Arčon, A. Sans, P. Adler, M. Jansen, C. Felser. Phonon-modulated magnetic interactions and spin Tomonaga-Luttinger liquid in the p-orbital antiferromagnet CsO_2. *Physical Review Letters* 115 (2015), 057205.
4. R. H. Zadik, A. Potočnik, P. Jeglič, D. Arčon, et al. Optimized unconventional superconductivity in a molecular Jahn-Teller metal. *Science Advances* 1 (2015), e1500059.

5. M. Pregelj, A. Zorko, M. Gomilšek, et al. Controllable broadband absorption in the mixed phase of metamagnets. *Advanced Functional Materials* 25 (2015), 3634.
6. M. Nikkhou, M. Škarabot, S. Čopar, M. Ravnik, S. Žumer, I. Muševič. Light-controlled topological charge in a nematic liquid crystal. *Nature Physics* 11 (2015), 183.
7. S. Čopar, U. Tkalec, I. Muševič, S. Žumer. Knot theory realizations in nematic colloids. *Proceedings of the National Academy of Sciences of the United States of America* 112 (2015), 1675.
8. R. Podlipec, J. Štrancar. Cell-scaffold adhesion dynamics measured in first seconds predicts cell growth on days scale - optical tweezers study. *ACS Applied Materials & Interfaces* 7 (2015), 6782.
9. T. Koklič, R. Chattopadhyay, R. Majumder, B. R. Lenz. Factor Xa dimerization competes with prothrombinase complex formation on platelet-like membrane surfaces. *Biochemical Journal* 467 (2015), 37.
10. Z. Arsov, U. Švajger, J. Mravljak, S. Pajk, A. Kotar, I. Urbančič, J. Štrancar, M. Anderluh. Internalization and accumulation in dendritic cells of a small pH-activatable glycomimetic fluorescent probe as revealed by spectral detection. *ChemBioChem* 16 (2015), 2660.

Awards and appointments

1. Jani Bizjak, Matjaž Gams, Hristijan Gjoreski, Anton Gradišek, Luka Stepančič: best paper, Melbourne, Australia, 2nd International Workshop on Biomedical Informatics with Optimization and Machine Learning in Conjunction with 26th International Joint Conference on Artificial Intelligence, Smartwatch for Active Ageing as Part of an Open EU Framework
2. Uroš Jagodič, M. R. Ejtahadi, S. M. Hashemi, M. R. Mozaffari, Igor Muševič, Miha Ravnikar: EPS Poster Prize for the best PhD student poster, Ljubljana, LIQUIDS 2017, Fractal Nematic Colloids
3. Primož Koželj: The Young Scientist Best Oral Presentation, Athens, Greece, C-MAC Days 2017, Eutectic CoCrFeNiZrx High-Entropy Alloys: Magnetism Complicated by the Microstructure of a “Real” Multiphase HEA
4. Aleksander Matavž: award for presentation and poster, Ljubljana, 9. IPSSC Conference, Inkjet Printing Thin-Film Electronic Devices from Solution-Based Inks
5. Aleksander Matavž: 1st place award for contribution in an individual section, Portorož, 25. ICM&T, Inkjet Printing of Metal-Oxide-Based Electronic Devices
6. Slobodan Žumer: elected Fellow of the American Physical Society, USA, American Physical Society (APS), for theoretical contributions to the soft condensed matter physics of liquid crystal systems
7. Slobodan Žumer: Zois Award for lifetime achievements of the Republic of Slovenia, November 23, 2017

Organization of conferences, congresses and meetings

1. 10th Liquid Matter Conference, LIQUIDS 2017, Ljubljana, 16–21 July 2017
2. Exploring the Molecular World By Advanced Fluorescence Microscopy Approaches, JSI, 12–14 September 2017
3. Alpine NMR Workshop, Recent Advances in NMR Methods and Applications to Materials, Bled, 21–24 September 2017

Patent granted

1. Barbara Malič, Hana Uršič, Marija Kosec, Silvo Drnovšek, Jena Cilenšek, Zdravko Kutnjak, Brigita Rožič, Uroš Flisar, Andrej Kitanovski, Marko Ožbolt, Uroš Plaznik, Alojz Poredoš, Urban Tomc, Jaka Tušek, Method for electrocaloric energy conversion, EP3027980 (B1), European Patent Office, 18. 10. 2017.
2. Luka Drinovec, Griša Močnik, Anthony D. A. Hansen, Method and apparatus for the analysis of materials, US9671324 (B2), US Patent and Trademark Office, 06. 06. 2017.
3. Griša Močnik, Anthony D. A. Hansen, Jeffrey R. Blair, Method for automatic performance diagnosis and calibration of a photometric particle analyzer, US9804082 (B2), US Patent Office, 06. 06. 2017.

INTERNATIONAL PROJECTS

1. MERCK - AFM Investigations
   Asst. Prof. Miha Škarabot
   Merck Kgaa
2. Kimberly-Clark - confidential project
   Prof. Igor Muševič
   Kimberly-clark
3. 7FP - SIMDALEE2; Sources, Interaction with Matter Detection and Analysis of Low Energy Electrons 2
   Prof. Maja Remškar
   European Commission
4. 7FP - LIVINGLASER; A Laser made Entirely of Living Cells and Materials derived from Living Organisms
   Prof. Igor Muševič
   European Commission
5. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Prof. Maja Remškar
   European Commission
6. COST MP1308; Towards Oxide Based Electronics (TO-BE)
   Aleksander Matavž
   Cost Office
7. COST CA15107; Multi-Functional Nano-Carbon Composite Materials Network

Dr. Polona Umek
Cost Office
8. COST CA15209; European Network on NMR Relaxometry
Prof. Tomaž Apih
Institut Jožef Stefan
9. COST CA16109; Chemical On-Line Composition and Source Apportionment of Fine Aerosol
Asst. Prof. Griša Močnik
Cost Office
10. COST CA16218; Nanoscale Coherent Hybrid Devices for Superconducting Quantum Technologies
Dr. Abdelrahim Ibrahim Hassanien
Cost Office
11. COST CA16221; Quantum Technologies with Ultra-Cold Atoms
Dr. Peter Jeglič
Cost Association Aisbl
12. H2020 - SmartNanoTox; Smart Tools for Gauging Nano Hazards
Prof. Janez Štrancar
European Commission
13. H2020 - ENGIMA; Engineering of Nanostructures with Giant Magneto-Piezoelectric and Multicaloric Functionalities
Prof. Zdravko Kutnjak
European Commission
14. Investigating Catalytic and Physical Properties of CuGdCa Alloys
Prof. Tomaž Apih
Slovenian Research Agency
15. Aromatic Polymers with Ultrahigh Breakdown Field Strength, Low Dielectric Loss, and High Electric Energy Density
Prof. Zdravko Kutnjak
Slovenian Research Agency
16. Investigation of Complex Materials for Hydrogen Storage
Prof. Janez Dolinšek
Slovenian Research Agency
17. Lipid Wrapped Gold Nanoparticles and Activity of Factor Xa
Prof. Janez Štrancar
Slovenian Research Agency
18. Crystal and Electronic Structure of NbS_3 Phases
Dr. Erik Zupanič
Slovenian Research Agency
19. Lead-Free $(Ba_{0.8}Ca_{0.2})_{1-x}La_{2x/3}TiO_3$ Based Electrocaloric Materials for New Dielectric Cooling Technologies
Prof. Zdravko Kutnjak
Slovenian Research Agency
20. Stabilisation of Networks of Topological Defects
Prof. Samo Kralj
Slovenian Research Agency
21. Superconductivity and Magnetism: Two Faces of Electron Correlations in Carbon- and Fe-Based Superconductors
Prof. Denis Arčon
Slovenian Research Agency
22. Radiative forcing of desert mineral dust and PM10 concentrations over Southern Europe
Prof. Maja Remškar
Slovenian Research Agency

RESEARCH PROGRAMS

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

R & D GRANTS AND CONTRACTS

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

NEW CONTRACTS

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

VISITORS FROM ABROAD

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

7. Filippo Caracciolo, University of Pavia, Pavia, Italy, 2 May to 14 June 2017
8. Dr Stefan Fölsch, Paul Drude Institute for Solid State Electronics, Berlin, Germany, 4–7 May 2017
9. Dr Bouchra Asbani, University of Picardie Jules Verne, Laboratory of Condensed Matter Physics, Amiens, France, 7–20 May 2017
10. Mutsuo Igarashi, Gunma National College of Technology, Department of Applied Physics, Maebashi, Japan, 22–28 May 2017
11. Prof. Katsumi Tanigaki, Tohoku University, Department of Physics, Graduate School of Science, Sendai, Miyagi, Japan, 1–3 June 2017
12. doctoral student Milijana Savić, Vinča Nuclear Institute, Belgrade, Serbia, 10–14 July 2017
13. Prof. Jun-Ichi Fukuda, Kyushu University, Fukuoka, Japan, 11–16 July 2017
14. Mutsuo Igarashi, Gunma National College of Technology, Department of Applied Physics, Maebashi, Japan, 11–21 August 2017
15. Dr Magdalena Wencka, Institute of Molecular Physics, Polish Academy of Sciences, Poznan, Poland, 14–18 August 2017
16. Nikita Derets, Ioffe Physical-Technical Institute of the Russian Academy of Sciences, Saint Petersburg, Russia, 4–6 September 2017
17. Prof. John Georg Seland, University of Bergen, Bergen, Norway, 25 September to 1 October 2017
18. Dr Anna V. Ryzhkova, ASML Holding, Eindhoven, the Netherlands, 16 October to 11 November 2017
19. Dr Igor Lukyanchuk, University of Picardie Jules Verne, Laboratory of Condensed Matter Physics, Amiens, France, 25–31 October 2017
20. Dr Masoomeh Hashemi, Sharif University of Technology, Department of Physics, Tehran, Iran, 1 November 2017 to 31 January 2018
21. Dr Sharmisthe Ghosh, DST-INSPIRE Faculty, University of Calcutta, Kolkata, India, 5–11 November 2017
22. Dr Jakub Malohlava, Faculty of Medicine and Dentistry, Palacky University in Olomouc, Department of Medical Biophysics, Olomouc, Czech Republic, 26 November to 8 December 2017
23. Dr Venkata Subba Rao Jampani, University of Luxembourg, Physics and Materials Science Research Unit, Luxembourg, Luxembourg, 13 December 2017
24. Dr Mildred Quintana, The Autonomous University of San Luis Potosí, San Luis Potosí, Mexico, 19–21 December 2017
25. Dr Yaovi Gagou, University of Picardie Jules Verne, Laboratory of Condensed Matter Physics, Amiens, France, 19–22 December 2017

STAFF

Researchers

1. Prof. Tomaž Apih
2. Prof. Denis Arčon*
3. Asst. Prof. Zoran Arsov
4. Prof. Vid Bobnar
5. Prof. Janez Dolinšek*
6. *Dr. Cene Filipič, retired 01.06.17*
7. Dr. Anton Gradišek
8. Dr. Alan Gregorovič
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10. Dr. Peter Jeglič
11. Dr. Martin Klanjšek
12. Dr. Tilen Koklič
13. Prof. Samo Kralj*
14. Prof. Zdravko Kutnjak
15. Dr. Mojca Urška Mikac
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21. Dr. Matej Pregelj
22. Prof. Miha Ravnik*
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24. Prof. Igor Serša
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31. Prof. Boštjan Zalar
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34. Dr. Erik Zupanič
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Postdoctoral associates

36. *Dr. Franci Bajd, left 13.11.17*
37. Dr. Primož Koželj
38. Dr. Mitja Krnel
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48. Dr. Iztok Urbančič
49. Dr. Jernej Vidmar*
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51. Dr. Stanislav Vrtnik

Postgraduates

52. Nikita Derets
53. Matjaž Gomilšek, B. Sc.
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55. Saša Harkai, B. Sc.
56. Dr. Matjaž Humar
57. Uroš Jagodič, B. Sc.
58. Nejc Janša, B. Sc.
59. Tilen Knaflič, B. Sc.
60. Marta Lavrič, B. Sc.
61. Janez Lužnik, B. Sc.
62. Hana Majaron, B. Sc.
63. Bojan Marin*, M. Sc.
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65. Tadej Mežnaršič, B. Sc.
66. Maruša Mur, B. Sc.
67. Luka Pirker, B. Sc.
68. Jaka Pišljar, B. Sc.
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72. *Dr. Luka Drinovec*, left 01.07.17*
73. Dr. Maja Garvas
74. Dr. Andreja Jelen
75. Boštjan Kokot, B. Sc.
76. Ivan Kvasić, B. Sc.
77. Jože Luzar, B. Sc.
78. Jaka Močivnik, B. Sc.

Technical and administrative staff

79. Dražen Ivanov
80. Janez Jelenc, B. Sc.
81. Maša Kavčič, B. Sc.
82. Davorin Kotnik
83. Sabina Krhlikar, B. Sc.
84. Silvano Mendizza
85. Janja Milivojević
86. Ana Sepe, B. Sc.
87. Marjetka Tršinar

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Alen Ajanović, Jaka Konda, Gašper Fele-Žorž, Anton Gradišek, Matjaž Gams, Ana Peterlin, Karolina Počivavšek, Mojca Matičič, "Application for sexually transmitted infection risk assessment", *Informatica (Ljublj., Tisk. izd.)*, **41**, 2, 253-254, 2017.
2. Cristobal Alessandri, Sara Fathipour, Huamin Li, Iljo Kwak, Andrew Kummel, Maja Remškar, Alan Seabaugh, "Reconfigurable electric double layer doping in an MoS_2 nanoribbon transistor", *IEEE trans. electron devices*, **64**, 12, 5217-5222, 2017.
3. Fatima Ezahra Annanouch, Sergio Roso, Zouhair Haddi, Stella Vallejos, Polona Umek, Carla Bittencourt, Christopher Blackman, T. Vilic, Eduard Llobet, "p-Type PdO nanoparticles supported on n-type WO_3 nanoneedles for hydrogen sensing", *Thin solid films*, **618**, part B, 238-245, 2017.
4. Bouchra Asbani, Y. Gagou, J. -L. Dellis, Maja Trček, Zdravko Kutnjak, M. Amjoud, A. Lahmar, D. Mezzane, Mimoun El Marssi, "Lead free $Ba_{0.8}Ca_{0.2}Te_xTi_{1-x}O_3$ ferroelectric ceramics exhibiting high electrocaloric properties", *J. appl. phys.*, **121**, 6, 064103, 2017.
5. Franci Bajd, Martin Škrlep, Marjeta Čandek-Potokar, Igor Serša, "MRI-aided texture analyses of compressed meat products", *J. food eng.*, **27**, 108-118, Aug. 2017.
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