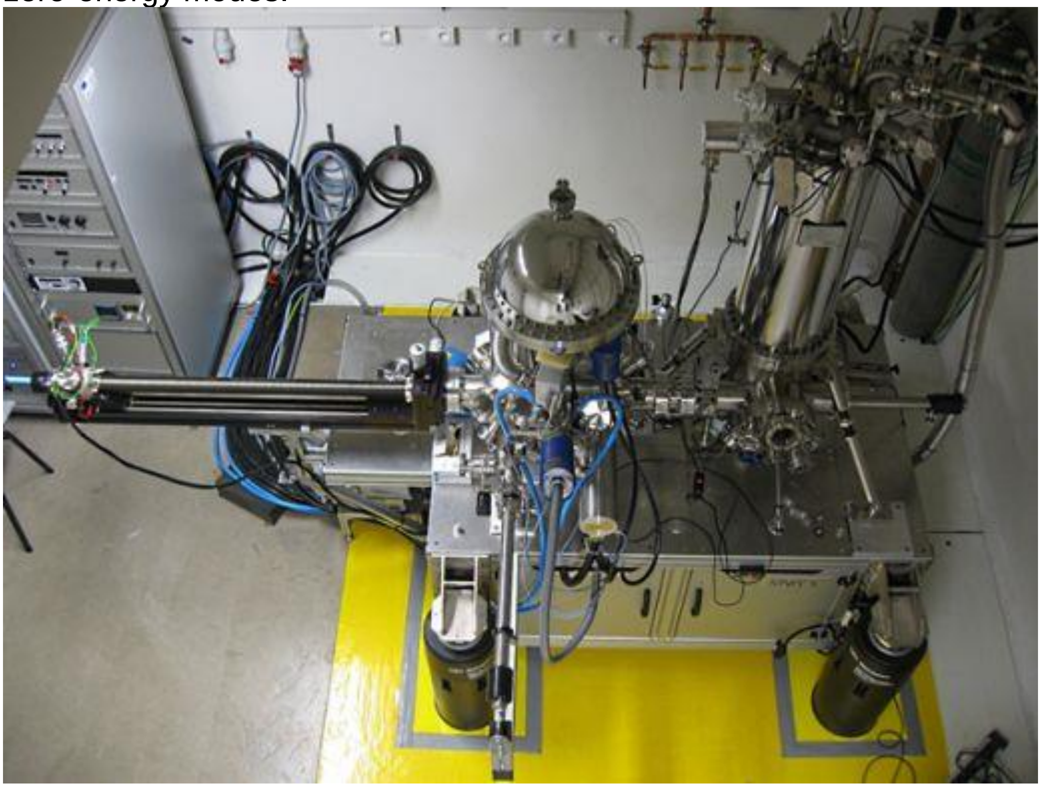
CONDENSED MATTER PHYSICS

Topologically nontrivial magnetic and superconducting nanostructures
supervisor**:** Mgr. Tomáš Samuely, PhD. (tomas.samuely@upjs.sk)
consultant: prof. RNDr. Peter Samuely, DrSc.
study form: full time
Annotation: Topological nanostructures are prospective hosts of the putative Majorana zero-energy modes and can serve as a basis of topologically protected qubits. We will focus on several materials which can be constituents in such nanostructures, the $(LaSe)(NbSe_2)_n$ misfit layer compounds, in particular. These are bulk single crystals but still behave like completely 2D superconductors with a potential strong spin – orbit coupling. By means of scanning tunneling microscopy in ultra-high vacuum, we will study their spin polarized band structure and fermiology, electronic and superconducting anisotropy etc. Further, we will prepare and characterize 1D and 2D topologically nontrivial nanostructures using different magnetic atoms on different superconducting substrates potentially hosting Majorana zero-energy modes.

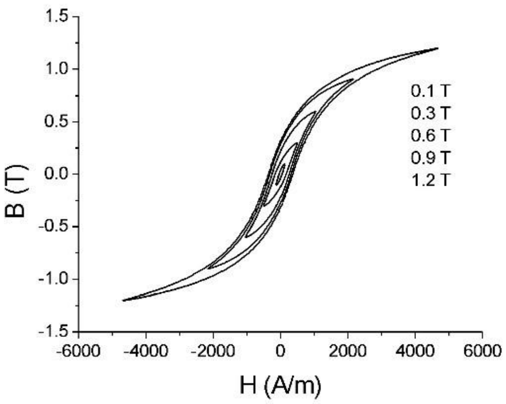


Ultra-high vacuum system featuring a complete set of experimental techniques for in-situ sample preparation, surface characterization and scanning tunneling microscopy.

Experimental study of lattice dynamics and magnetic properties of selected metallo-organic frameworks.
supervisor: doc. RNDr. Alžbeta Orendáčová, DrSc. (alzbeta.orendacova@upjs.sk)
consultant: RNDr. Robert Tarasenko, PhD.
study form: full time
Annotation: In the last time the attention of magnetic quantum community focuses more and more on the lattice dynamics and its role in the affecting magnetic properties. Besides the need to know the vibrational spectrum and accordingly to design magnetic system to minimize the interaction between spins and lattice resulting in the maximizing spin-lattice relaxation [Phys. Rev. B 103 (2021) 014401],the activities develop also from other side of spectrum. More specifically, it is the study of magnetic systems with inclusion of strong spin-lattice coupling which

leads to the formation of new interesting quantum states which cannot exist in the rigid spin models [Phys. Rev. B 99 (2019) 144421]. In our work we will perform parallel study of both (spin and lattice) subsystems or their mutual mixing in the selected class of metalo-organic frameworks when considering the choice of linkers and type of magnetic ion. The effects of these subsystems will be experimentally studied by means of Raman and infrared spectroscopies, thermodynamic quantities and magnetic resonance. The obtained data will be analyzed within the existing models. In the process of the analysis, depending on the student's affinity to software applications, various program packages can be used (Origin, Mathematica, Easyspin, etc.). The results will be published in the scientific journals and presented at the conferences and workshops.

Magnetization processes of compacted powder and composite materials.
supervisor: prof. RNDr. Peter Kollár, DrSc. (peter.kollar@upjs.sk)
study form: full time
Annotation: The work is focused on the investigation of the peculiarities of magnetization reversal processes in soft magnetic compacted and composite materials depending on the size of the magnetic field during magnetization reversal processes on hysteresis loops at non-saturated state in DC and AC magnetic fields. The aim is to investigate the influence of the internal demagnetization field on reversible and irreversible magnetization processes.



The study of relaxation process in magnetic nanoparticles for biomedical applications.
supervisor: doc. RNDr. Adriana Zeleňáková, PhD. (adriana.zelenakova@upjs.sk)
study form: full- time
Annotation: Magnetic nanoparticles provide a unique combination of small size and responsiveness to magnetic fields making them attractive for applications in medicine. The magnetic ground state ofnanoparticles can be severely altered with respect to the conventional assumption that they are single magnetic domains, having the same basic spin orientation and moments found in bulk materials.The relaxation of metastable magnetization states in a collection of nanoparticles is a fundamental problem, which is closely related to biomedical applications.
The PhD. study is oriented on investigation of dynamic magnetic properties and analyses of relaxation processes in superparamagnetic iron oxide/cobalt oxide nanoparticles.For biomedical application of superparamagnetic nanoparticles is necessary to study the possibility of change in relaxation processes by controlling the inter-particle interactions, energy barrier distribution, particles size, and surface coating.

Studies of induced superconductivity in topological materials
supervisor: prof. RNDr. Peter Samuely, DrSc. - Institute of Experimental Physics Slovak Academy of Sciences Košice (samuely@saske.sk)
consultant: Mgr. Pavol Szabó, CSc.
study form: full time - Institute of Experimental Physics Slovak Academy of Sciences Košice
Annotation: A solution of the Dirac equation for massless particles was found in 1929 by Hermann Weyl. A group headed by Zahid Hasan at Princeton University evidenced that Weyl fermions exist as quasiparticles – collective excitations of electrons – in the semimetal tantalum arsenide (TaAs) (Xu, S. Y. et al., Science 349, (2015), 613). Weyl fermions reveal unique topological properties that could make them useful for creating high-speed electronic circuits and quantum computers. Very recently emergence of a tip-induced superconductivity in Dirac Weyl semimetals has been indicated in mesoscopic point contacts between Ag and TaAs. Coexistence of superconductivity and high transport spin polarization at TaAs point contacts has been detected which makes the Weyl semimetals particularly interesting for spintronic applications. We will check the possible mesoscopic superconductivity and its character Weyl materials by means of the point-contact as well as the tunneling spectroscopy. Further development of the point-contact technique at very low temperatures will be a part of the disertation.

Classical to quantum crossover in mechanical resonators
supervisor: RNDr. Peter Skyba, DrSc. - Institute of Experimental Physics Slovak Academy of Sciences Košice (skyba@saske.sk)
consultant: RNDr. Marcel Človečko, PhD., Institute of Experimental Physics Slovak Academy of Sciences Košice
study form: full time - Institute of Experimental Physics Slovak Academy of Sciences Košice
Annotation: The material variability and dimensional diversity of mechanical resonators allows us to deliberately change their physical and geometric properties. Thus by reducing their mass / energy content (i.e. by decreasing their size) while simultaneously cooling them to temperatures close to absolute zero, it is possible to use them as a tool to study the crossover between classical and quantum dynamics. The aim of this dissertation is (i) the study of nonlinear processes in macroscopic resonators based on piezomaterials, (ii) the study of the transition between classical and quantum dynamics by using our custom made mechanical micro and nanoresonators and (iii) to deepen the understanding of fundamental processes of the energy exchange between these resonators and the thermal reservoir leading to the decoherence.