Research Departments at the Institute of Experimental Physics, SAS, Košice:

- Department of Space Physics
- Department of Subnuclear Physics
- Department of Magnetism
- Department of Low Temperature Physics
- Department of Metal Physics
- Department of Biophysics
- Department of Theoretical Physics
- Laboratory of Experimental Chemical Physics
- Laboratory of Materials Physics
- Laboratory of Nanomaterials and Applied Magnetism

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Institute of Experimental Physics

Slovak Academy of Sciences, Košice

Main Building, 47 Watsonova Street, Košice

Branch location on Lomnický Peak

Premises, 2-6 Bulharská Street, Košice

Premises, 9 Park Angelinum, Košice

Introduction

The Institute of Experimental Physics of the Slovak Academy of Sciences (IEP SAS) in Košice was established by the SAS Presidium on January 1st, 1969. The Institute, which has since grown considerably, was originally a branch office of the Institute of Physics, SAS, Bratislava. The latter was created in Košice in 1964 with a focus on physical sciences in the fields of cosmic radiation, ferromagnetism and high energy physics. Prof. Juraj Dubinský became the first director of the Institute and held this office until 1979. Between 1980-1985 the Institute was headed by Prof. Vladimír Hajko, from 1986 to 1990 by Dr. Michal Seman, and from 1991 to 2007 by Dr. Peter Kopčanský. Since 2007 the director has been Dr. Karol Flachbart.

The present research activities of the Institute cover basic research in several fields of modern physics (condensed matter, subnuclear physics, space physics and biophysics), as well as in selected fields of chemical sciences, biological sciences and nanotechnology. The current organization of the Institute presents 7 research departments and 3 laboratories:

- Department of Space Physics
- Department of Subnuclear Physics
- Department of Magnetism
- Department of Low Temperature Physics
- Department of Metal Physics
- Department of Biophysics
- Department of Theoretical Physics
- Laboratory of Experimental Chemical Physics
- Laboratory of Materials Physics
- Laboratory of Nanomaterials and Applied Magnetism

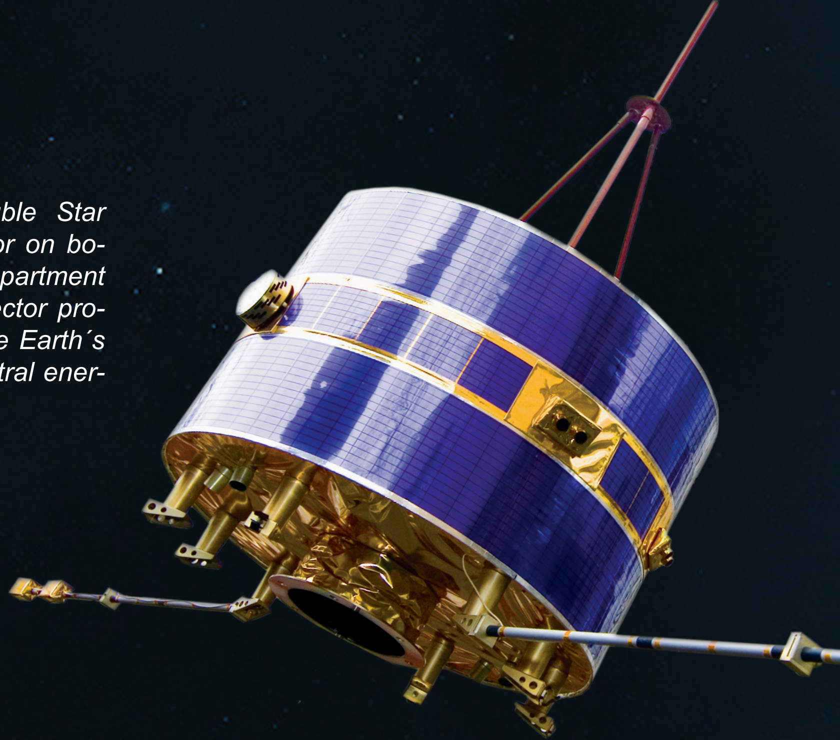
Currently the Institute employs about 130 people, more than half being research scientists, and about 15 post-graduate students. Its main premises are located at 47 Watsonova Street, Košice. The Department of Low Temperature Physics operates in the same premises and shares research laboratories with the Institute of Physics, Faculty of Natural Sciences, University of P. J. Šafárik (FNS UPJS). The Departments of Biophysics and Space Physics are located separately in the reconstructed premises at 2-6 Bulharská Street, where the Operational Workshops of the Institute are also located.

The accreditation of the SAS Institutes ranks the IEP among the top workplaces within SAS. The Institute enjoys a highly respectable position at both the national and international level, and has a well established experimental infrastructure. Several of the experimental devices constructed at the Institute are unique. The Institute is, for example, one of the few physics workplaces with a very low temperature capability (a thousandth of a degree above absolute zero, –273.15 ˚C), thus allowing the study of materials under extreme conditions. A wide range of applications of modern physics for condensed systems are under investigation including high-temperature superconductivity, magnetic fluids, amorphous metal systems, micro- and nanocrystalline materials. Scientific equipment developed at the Institute has been successfully deployed on orbital satellites and have been invaluable tools in contributing to our knowledge of the physical properties of interplanetary space. Furthermore, the Institute has a keen interest on solving the fine structure of matter, with our investigators utilizing the giant particle accelerators in centres such as FERMILAB in Batavia, USA or CERN in Geneva, Switzerland. In addition, we have research programs based on solving the problems of contemporary biophysics and chemical physics.

During forty years of its existence IEP SAS has developed fruitful foreign cooperation with working contacts in all of the developed countries of the world. Within Slovakia, members of the institute intensively collaborate with Šafárik University and the Technical University in Košice, as well as with several institutes of both Sections I (Physical, Space, Earth, and Engineering Sciences) and II (Life, Chemical, Medical, and Environmental Sciences) of the Slovak Academy of Sciences.

The Institute sponsors doctoral studies (in cooperation with the Faculty of Natural Sciences, Šafárik University) in three study streams: 1)Physics of Condensed Matter and Acoustics; 2)Nuclear and Subnuclear Physics; and 3)General and Mathematical Physics.

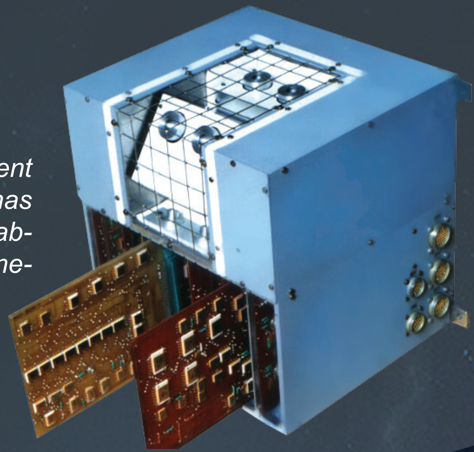
Chinese-European satellite Double Star TC-2 carries the NUADU detector on board, largely developed at the Department of Space Physics IEP. The detector provides panoramic snapshots of the Earth´s magnetosphere by means of neutral energy atoms.



Department of Space Physics

Research focuses on the physical processes that take place in the extreme conditions found in space that typically cannot be observed under laboratory conditions. Our goal is to gain novel information on cosmic energy particles including cosmic radiation. This is accomplished via the analysis of ground and satellite measurements, personal observations, simulation of physical processes in the Earth's heliosphere and magnetosphere, and preparation of new cosmic experiments.

The Department has participated in developing and implementing key components of experimental equipment placed on 14 satellites, two space probes and two high altitude rockets. Ground measurements are continuously collected from a neutron monitor at Lomnický Peak, with real-time data available at http://neutronmonitor.ta3.sk. For further information about the Department see http://space.saske.sk.



Spectrometer of cosmic energetic particles DOK-2, developed at the Department of Space Physics IEP, has provided a wealth of valuable data on the Earth´s magnetosphere.

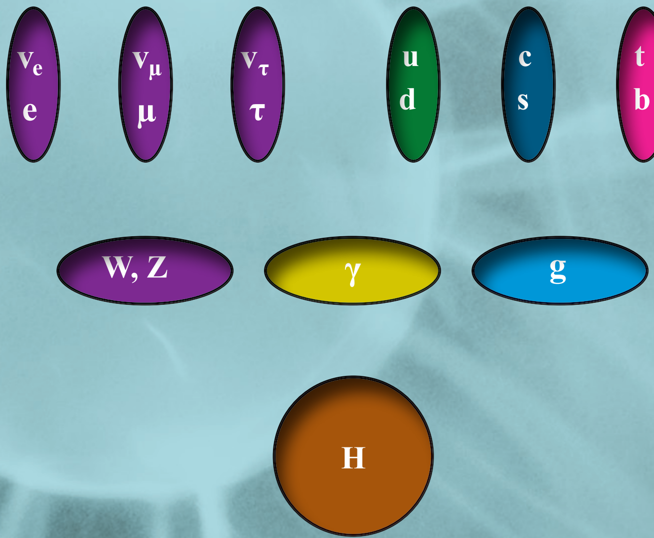
Laboratory testing of space technology in the space simulator SPACEVAC.

Main fields of research:

- variations in the low-energy component of space radiation and effects of processes in the Earth's heliosphere and magnetosphere
- acceleration, transport and losses of medium-energy particles (between solar wind and space radiation) in the Earth´s magnetosphere and near its border areas
- acceleration processes on the solar surface and their responses in the interplanetary environment and near the Earth with particular regard to high-energy neutral emissions (neutrons, gamma radiation)
- links between cosmic energy particles and cosmic weather
- processes in space plasma formations near other planets

Top quark

Knowing the elementary units of the structure of matter has been the goal of science since the time of Demokritos, more than 2000 years ago. However, only in the last 100 years due to radical advances in the field, has this effort produced real results. Atoms were once considered the most basic units of matter,
but it was subsequently discovered that nuclei exist inside atoms, nucleons inside nuclei, and quarks inside nucleons.



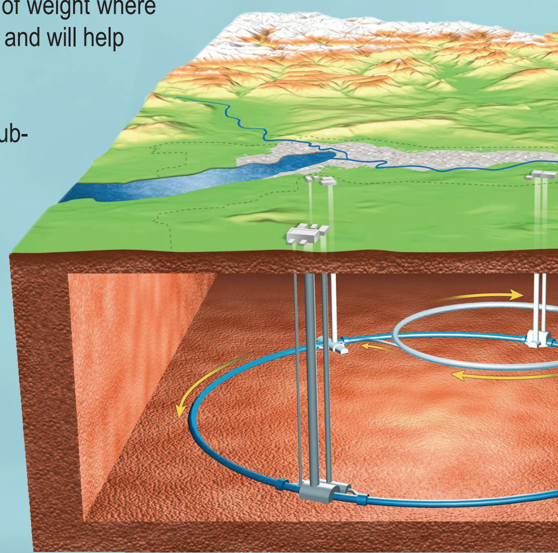
The picture above displays a contemporary view of the structure of matter. The first line is represented by quarks and leptons, the second line by particles mediating interactions between quarks and leptons, and the last line by a single particle whose existence is theoretically predicted, but has not been experimentally discovered yet – the so-called Higgs boson. The importance of this particle's discovery is underlined by the fact that it is the main goal of the multi-billion LHC project at CERN in Geneva.

Department of Subnuclear Physics

The Department of Subnuclear Physics actively participated in the most significant discovery in high-energy physics in the last twenty years – the top quark discovery and exploration of its characteristics. Top quark was experimentally discovered in 1995 by the CDF and D0 collaborations using the TEVATRON accelerator complex in Batavia, USA.

Compared to other quarks, top quark has a number of unique characteristics. Its weight is approximately the same as the tungsten nucleus. It decays very quickly, so it cannot become bound with another quark. From top quark decay products it is possible to reconstruct its original parameters, which are not deformed by a bound state. For example, precise measurement of the top quark weight will specify the area of weight where the Higgs boson could be situated and will help its discovery at the LHC.

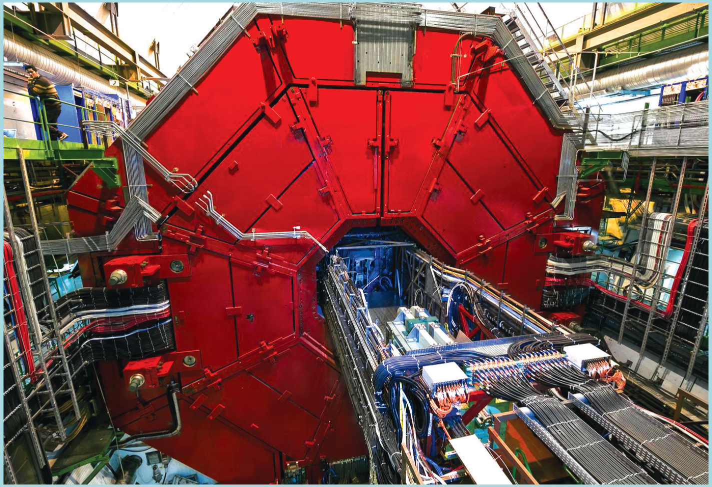
A group from the Department of Subnuclear Physics has focused on the measurement of top quark parameters – weight, charge, spin characteristics. It has developed several original methods for measuring these parameters and the results (besides being published in reputable journals) have also won the "Result of the Week" award in Fermilab's Today magazine several times.



Schematic picture of the LHC (Large Hadron ment at the CERN Institute in Geneva.

Department of Subnuclear Physics

Research focuses on the structure of elementary particles and nuclear matter and involves ambitious collaborative experimental projects with world class accelerator centres such as the former Joint Institute for Nuclear Research in Dubna near Moscow or the Deutsches Elektronen Synchrotron Institute in Hamburg. Our current partners are the Fermilab Institute in Batavia, USA, and especially CERN in Geneva. At present two main research topics drive the Department, namely the study of top quark characteristics and the exploration of nuclear matter characteristics under extreme conditions.

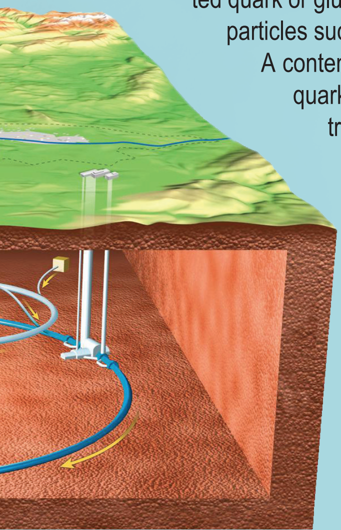


Detector of the ALICE experiment at the LHC accelerator at CERN, Geneva for the study of heavy ion collisions.

Exploration of the new state of nuclear matter

Protons and neutrons consist of quarks held together by the strong force known as the strong interaction. The interchange of particles called gluons is its source. No isolated quark or gluon have been observed so far – they are confined within composite particles such as protons and neutrons.

A contemporary theory of the strong interaction predicts the “liberation“ of quarks and gluons at temperatures exceeding 2000 billion K and the transformation of nuclear matter into the quark-gluon plasma state. Such extreme conditions existed in nature for a few millionths of a second after the Big Bang. The collision of two lead nuclei accelerated in the LHC close to the speed of light will enable us to gain a speck of this hot matter the size of an atomic nucleus, and to observe how it goes through the process of expansion and cooling into the state of normal matter. By studying such collisions at the LHC, the ALICE experiment will allow us to peer deep into the processes evoked by the strong interaction and glimpse matter the way it was immediately after the Big Bang. Our participation in the ALICE experiment is the continuation of twenty years of cooperation with CERN on the HELIOS, WA-94, WA-97 and NA-57 experiments. Our results led to an official announcement in 2000 by CERN that a new state of matter with quark-gluon plasma characteristics had been created in the laboratory. Our results were given the SAS Award in 2002.



Collider) accelerator place-

The Tevatron accelerator at the Fermilab Institute in Batavia for the study of proton-antiproton collisions – the place of the top quark discovery.

1. Magnetic fluids

Today the Department is capable of preparing magnetic fluids based on various basic liquids (e.g. water, kerosene, mineral oil, wax) with magnetite as a magnetic moment carrier. Besides the preparation of magnetic particles of various shapes and parameters (5-300 nm) the Department also studies basic physical properties, aggregation processes of magnetic particles, magneto-optical and magneto-dielectric properties of magnetic fluids and their composite systems with liquid crystals. The properties of magnetic fluids can be easily influenced by external magnetic fields and thus are widely applicable in industrial practice as well as biomedicine, especially in the targeted transport of drugs in cancer treatment, cardiovascular disease treatment and radiodiagnostics. For the results the team achieved, it was given an SAS award for significant contribution to international cooperation and was conferred the right to organize the International Conference on Magnetic Fluids ICMF 11 in Košice in 2007.

2. Molecular magnets

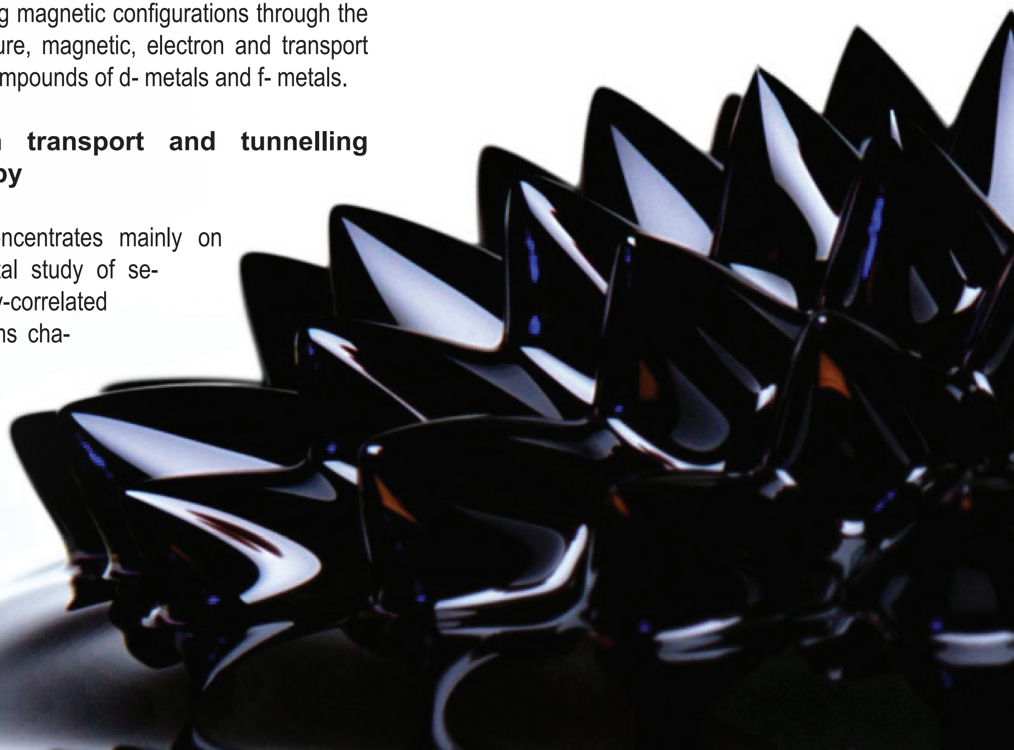
The properties of rare-earth ferricyanides have been intensively investigated in the field of molecular magnetism. Detailed knowledge of the crystal structure of these materials can significantly contribute to the understanding of physical processes and phenomena taking place within them, to their interpretation in the field of basic research, but also to optimalization of the utility properties of prepared materials for their application in practice.

3. Intermetallic compounds

Research in the field of intermetallic compounds focuses mainly on the study of cooperative phenomena and strong electron correlations in selected systems comprising 4f- and 5f- components, aiming to contribute to the understanding of phenomena such as heavy fermion behaviour, Kondo grids, spin fluctuations and far-reaching magnetic configurations through the study of structure, magnetic, electron and transport properties in compounds of d- metals and f- metals.

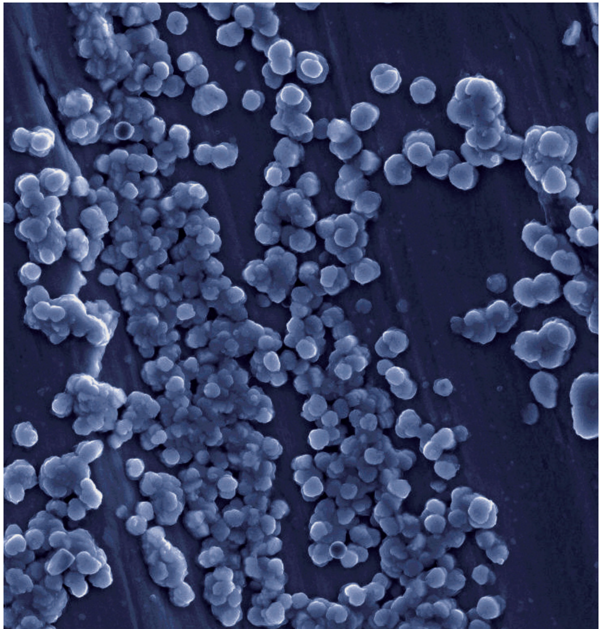
4. Electron transport and tunnelling spectroscopy

This group concentrates mainly on the experimental study of selected strongly-correlated electron systems characterized by anomalous transport properties associated with metal-insulator transition, heavy fermion superconductivity or colossal magnetoresistance. One of the group´s most significant areas of interest involves the development and implementation of a new experimental method – tunnelling calorimetry – enabling the exact determination of the heat generated in individual tunnel electrodes. The results of a systematic study indicate that generated heat represents the energy of quasi-particles originating from inelastic processes accompanying the process of elastic tunnelling.

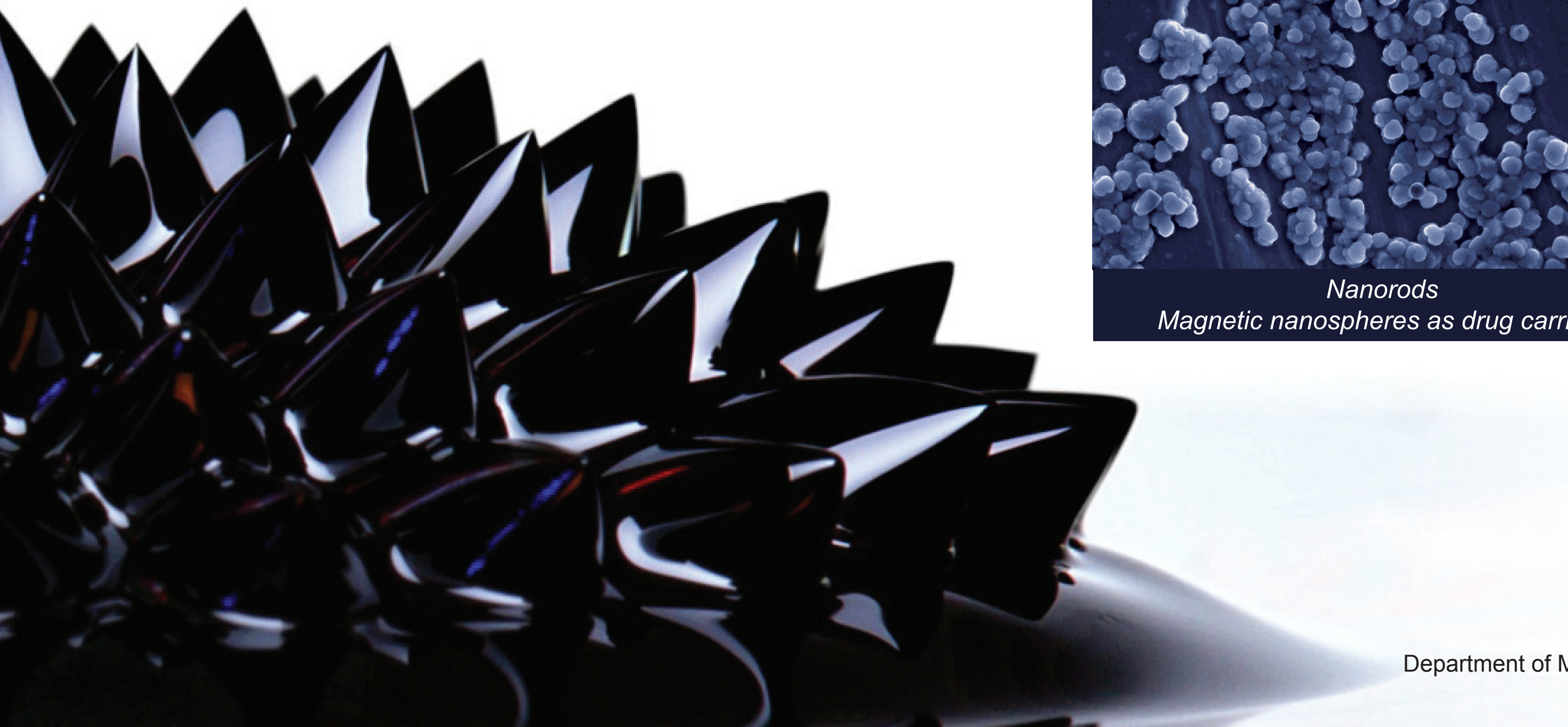


Department of Magnetism

The original form of this Department was established as early as 1964 within the branch office of the Institute of Physics, SAS, Bratislava in Košice. In 1969, when the Institute of Experimental Physics was established, the magnetism group became an autonomous Department. Today, 4 main research streams are handled within the Department: magnetic fluids, molecular magnets, intermetallic materials, and electron transport and tunnelling spectroscopy. In these fields the Department has won awards for its scientific results in Slovakia and abroad. Furthermore, within the framework of bilateral and multilateral projects (projects 5RP and 6RP), we have developed broad international collaborations with several prominent institutes including GHMFL and CRETA CNRS Grenoble, IFM PAN Poznan, KFKI Budapest, Polytechnic University of Timisoara - Romania, A. Mickiewicz University of Poznan, Jean Monnet University, St. Etienne, Charles University, Prague, Institute of Physics, Academy of Sciences, Czech Republic.

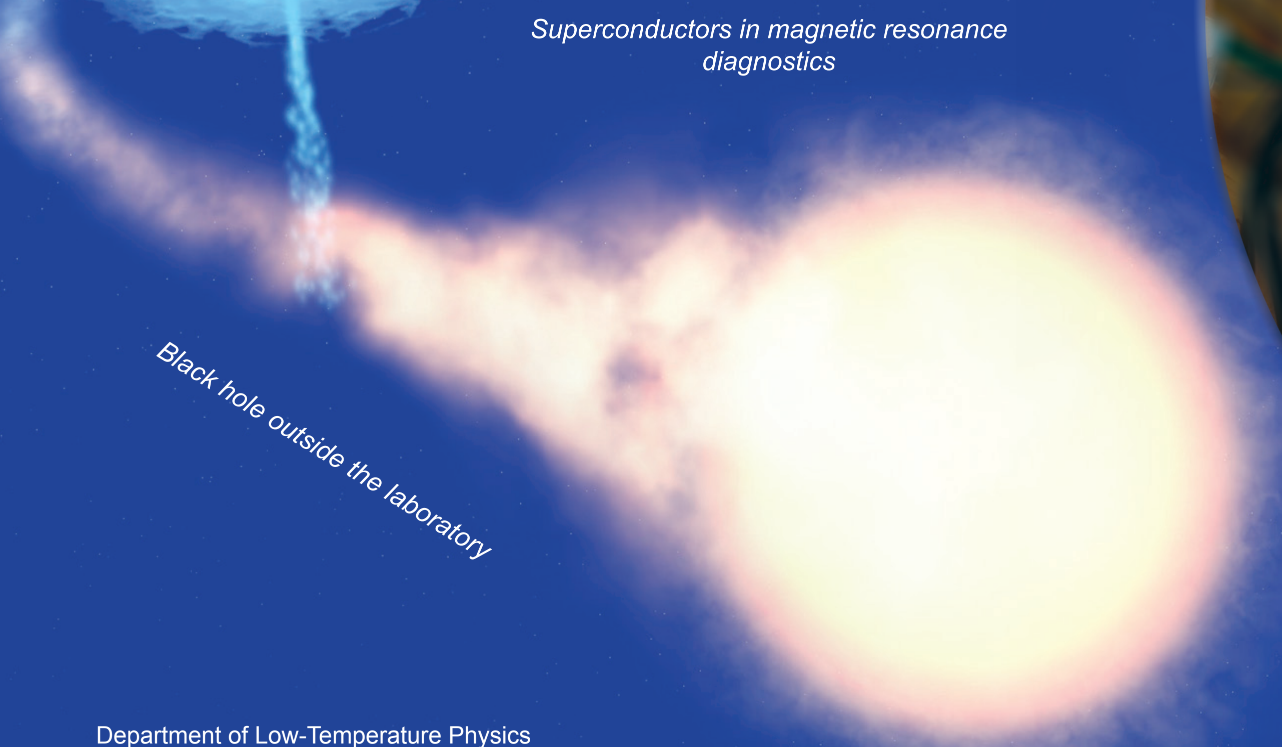


Nanorods
Magnetic nanospheres as drug carriers



Superconductors in magnetic resonance diagnostics

The coldest place in Central Europe



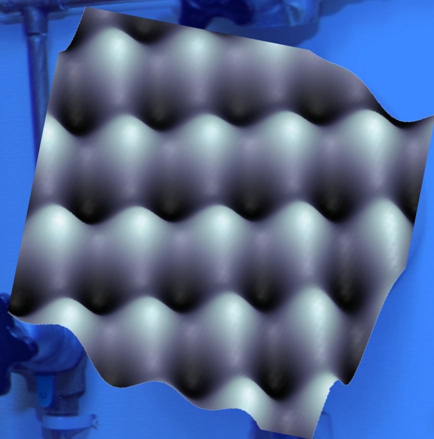
Black hole outside the laboratory

Department of Low-Temperature Physics

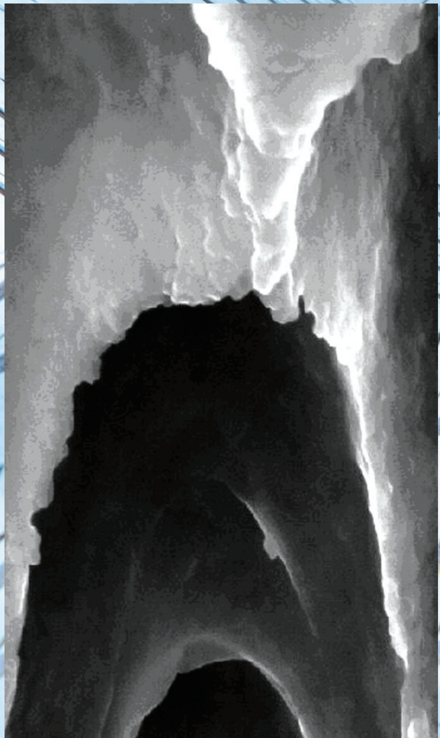
Department of Low-Temperature Physics

Just as blood is a life-giving fluid for our body, liquid helium is important for experiments at very low temperatures. Liquid helium ($T = 4.2$ K) is obtained in the liquefier which is part of the Department´s infrastructure, and its annual production is about 30000 litres. This is distributed not only to individual laboratories of the centre, but also to hospitals where it serves for cooling the magnets in magnetic resonance tomographs. These magnets, as well as those used in different research (e.g. at CERN), are made of superconductors. For several years superconductors' physical properties have been intensively studied by various methods in this country (microcontact spectroscopy, AC calorimetry, or most recently scanning tunnelling microscopy – STM). Probably the most significant results have been achieved in the study of the superconducting material MgB_2. MgB_2 has been quickly adopted for use in superconducting magnets thanks to its comparatively high critical temperature and magnetic field values.

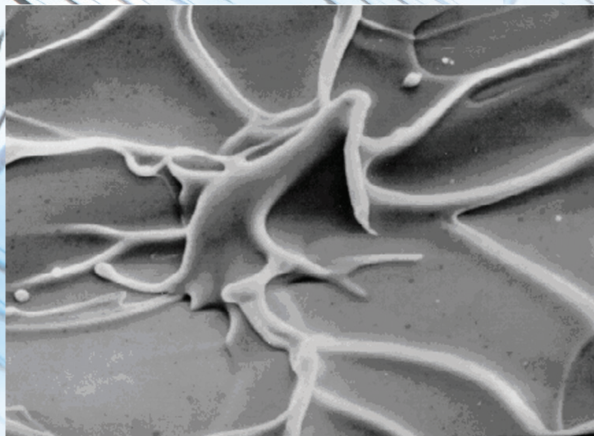
The characteristics of space may also be explored indirectly in the laboratory at ultra-low temperatures (below 1 mK), for example when the rare isotope ^{3}He turns superliquid. In such a macroscopic quantum system, we can realistically simulate and observe for instance turbulences and fluctuations of the physical vacuum, phenomena associated with the black-hole event horizon, symmetry breaking after the Big Bang, or the phenomena inside neutron stars. Ultra-low temperatures also provide suitable conditions for the experimental study of quantum bits – qubits produced either directly in superliquid ^{3}He or based on nano-SQUIDs. Besides extremely low temperatures and high magnetic fields the Department concentrates on research into strongly correlated systems at extremely high pressures (up to about 10 GPa) when unexpected properties are observed. Most recently the Department has concentrated its research on the study of reduced-dimension materials. All these research fields at our centre cannot go on without cooperation with top laboratories in the world (especially Berlin, Grenoble, Lancaster, Madrid, Vienna, Santander, Ames, Pohang, Shanghai and Helsinki) and our results have been presented in the most prestigious physics journals.

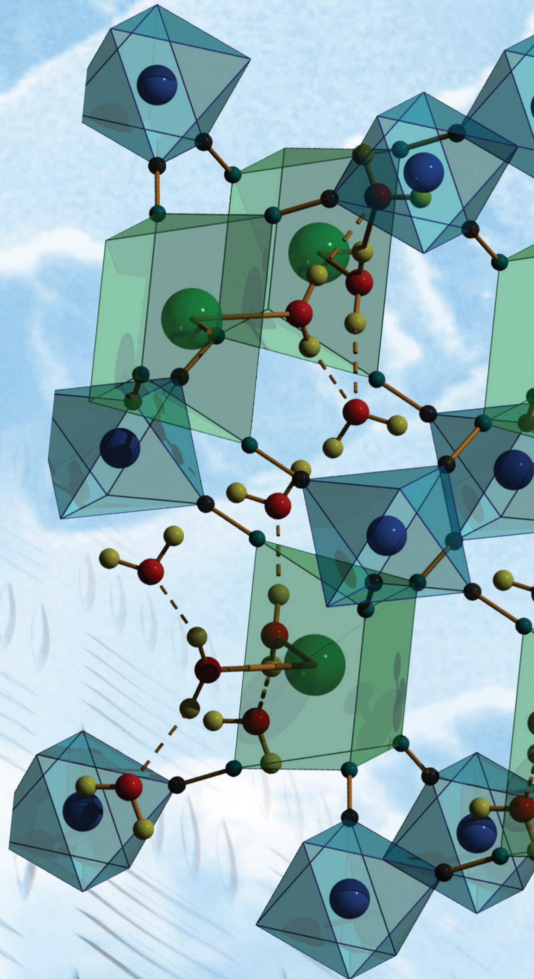


STM microscope can "see" atoms



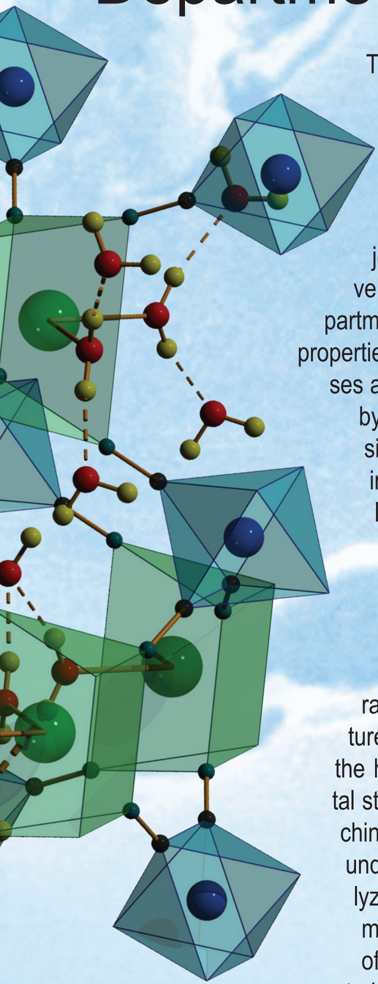
Fractures in amorphous metals detected by means of scanning electron microscope



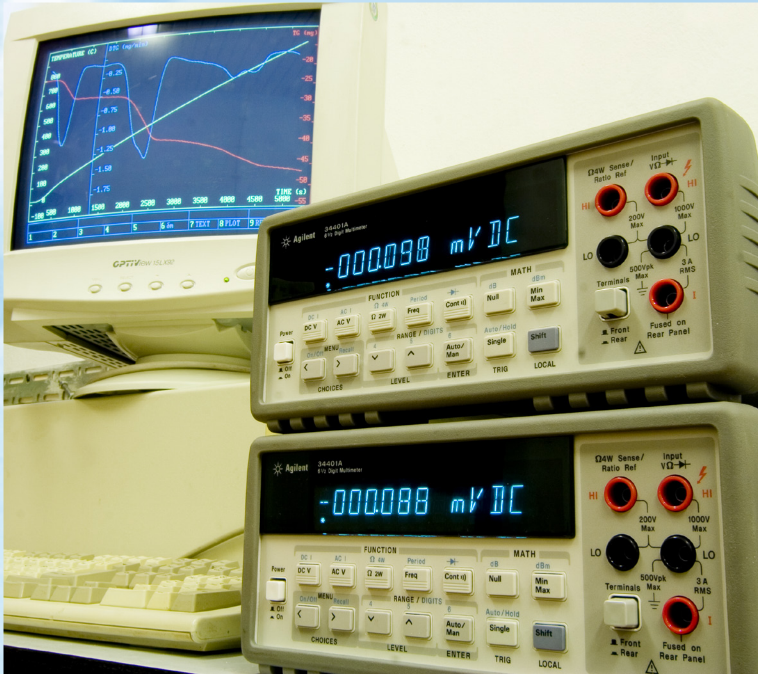


Crystal structure of rare-earth ferricyanide $Pr[Fe(CN)_6].4D_2O$

Department of Metal Physics

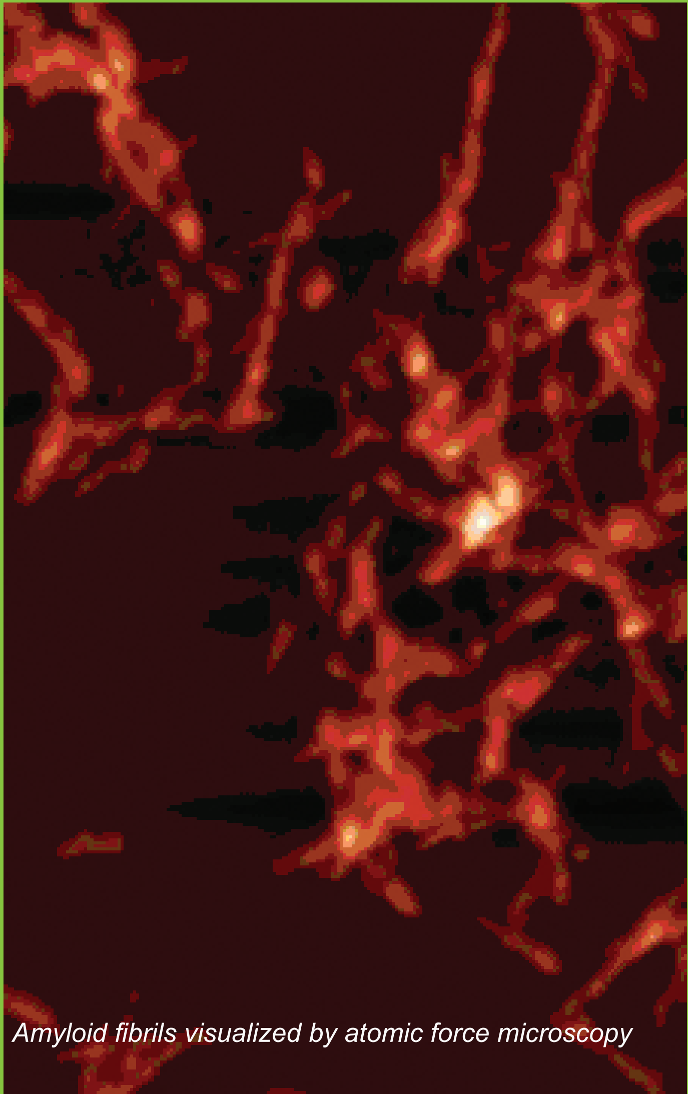


The Department´s research activities focus on the linkage between the structures and properties of metallic materials. Metastable amorphous metallic materials, typically prepared by rapid cooling of the hot melt, were discovered in the 1960s. Since then, they have progressively become the subject of intense interest for physicists, technologists, development and construction workers. Currently the Department´s main research area is the study of mechanical properties, plastic and inelastic deformation, fracturing processes and stability of amorphous metallic materials prepared by rapid cooling. The methods of fractographic analysis and quantitative statistical fractography are used in the study of fracture surfaces in amorphous metals, the shape of thin ribbons and bulk alloys breaking at a wide range of temperatures, and deformation speed under various types of straining. The processes of formation and extension of unstable fission in amorphous metal structure are investigated by mechanical testing of amorphous metallic materials at temperatures above 4.2 K and by the application of linear fracture mechanics methods. The Department also studies the homogeneous plastic deformation of amorphous metal structure and properties of deformation defects by watching the processes of inelastic deformation and flowing under the influence of mechanical pressure, and by analyzing these processes using numerical methods presuming the existence of an activation energy spectrum of thermally-activated processes. Nanocrystalline materials form a particular group of metallic materials with structural states considerably distant from equilibrium state.



The Department studies fracture regularities in these materials. Their structural stability is explored using thermal analysis methods. The study of coherence between the properties of crystalline materials and their structure concentrates mainly on the specification of structure based on the results of neutron and X-ray diffraction experiments. In studying these issues the Department has developed active and long-term cooperation with the B. Verkin Institute for Low Temperature Physics and Engineering, National Academy of Sciences of Ukraine, Kharkov (Ukraine), Voronezh State Technical University (Russian Federation) and the University of Groningen (Netherlands).

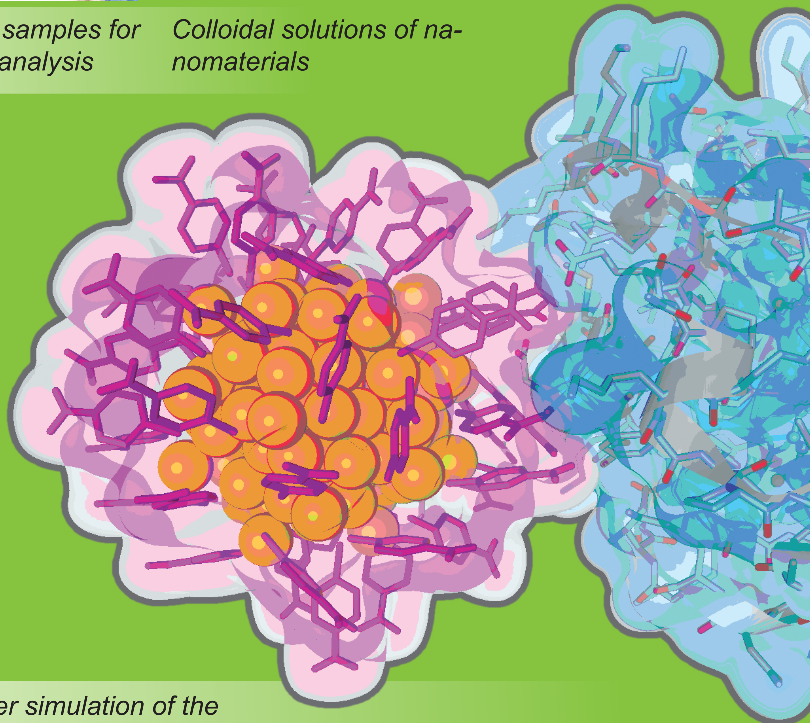
Department of Metal Physics



Amyloid fibrils visualized by atomic force microscopy

Preparation of samples for spectroscopic analysis

Colloidal solutions of nanomaterials

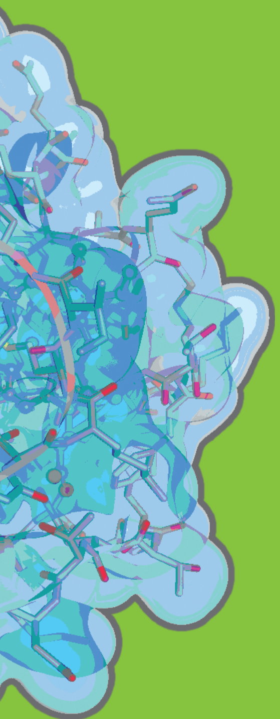


Computer simulation of the interaction between a gold nanoparticle (with violet surface) and the cytochrome c protein (with blue surface)

Department of Biophysics

Research fields of deparment:

- amyloid structures
- nanoparticles
- protein stability
- image analysis
- molecular modelling



Changes in protein structures initiate intermolecular interactions that result in the formation of protein deposits – amyloid aggregates - in the human body. Amyloid formation is associated with several serious neurodegenerative diseases (e.g. Alzheimer´s disease) and other diseases (e.g. type II diabetes).

Alzheimer´s disease

Today, about 40 million people (one in four persons aged over 85) in the world suffer from Alzheimer´s disease. If a cure is not discovered, the number will increase fourfold by the year 2050.

Applications:

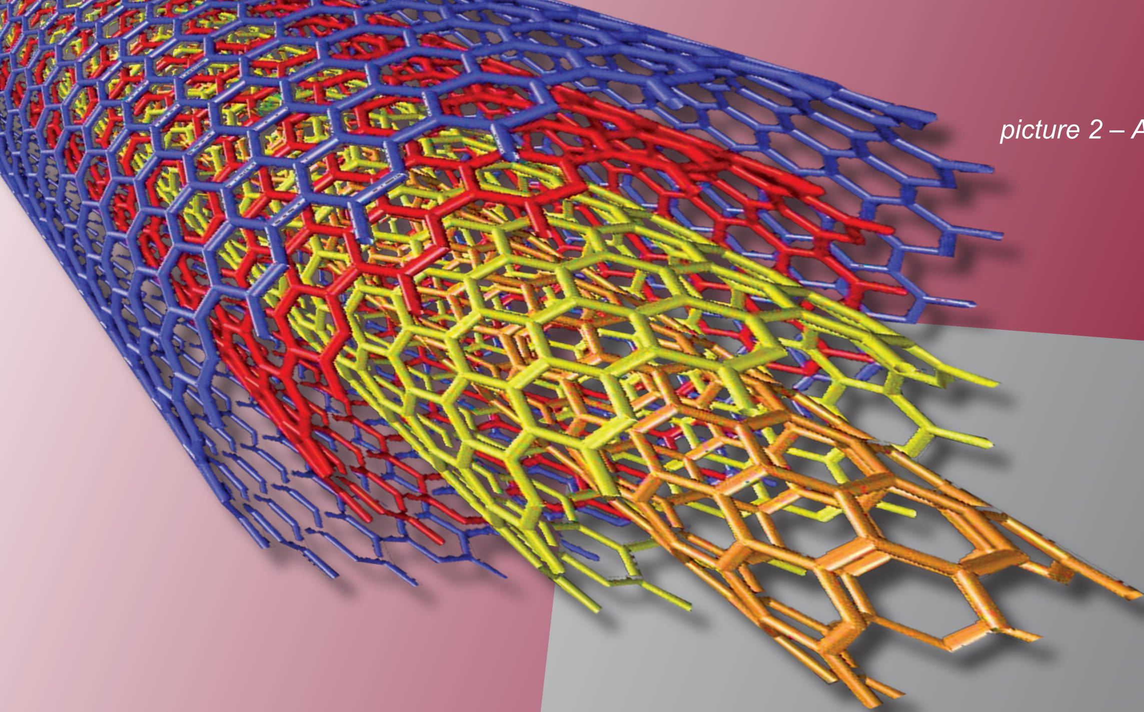
Understanding the transformation of native proteins into amyloid aggregates as a pathological hallmark of amyloid-related diseases will facilitate the development of effective therapeutics.

Modern computational methods allow us to predict the properties of molecules that could be used as scaffolds for new therapeutics. Computer-aided drug design accompanied with modern simulation technologies accelerates the development of potent lead molecules, saving thus funds required for laboratory testing.

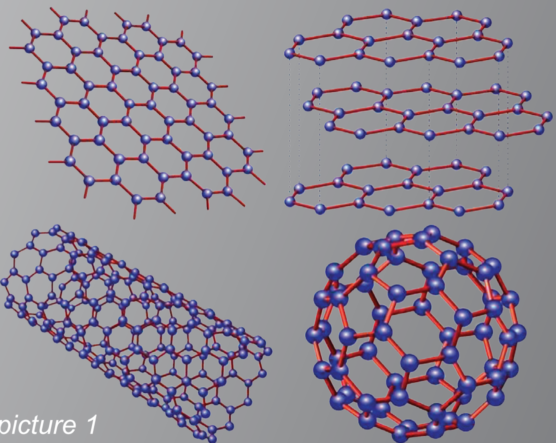
Cancer

According to WHO, around 10 million new cases of cancer are diagnosed in the world every year. Detailed understanding of the structure/function relationships of studied molecules will aid the development of more powerful, safer and economic drugs.

Stereo 3D visualization of a protein-ligand complex



picture 2 – A



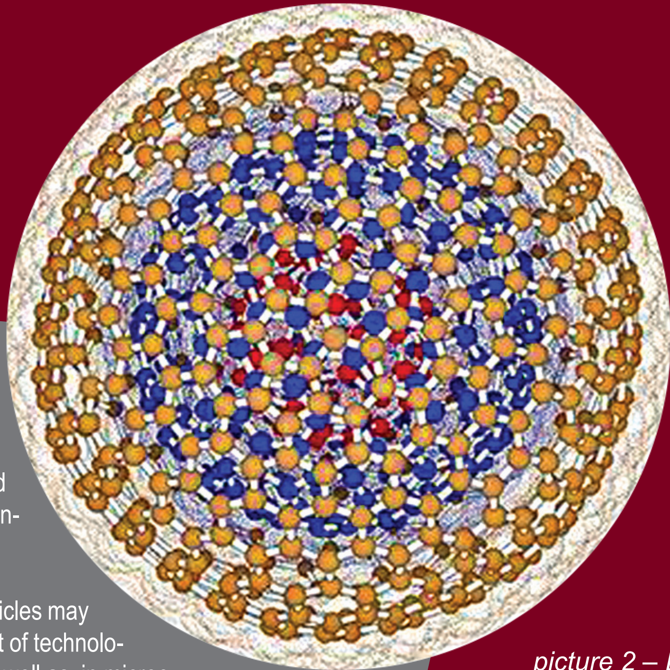
picture 1

Carbon nanostructures

Carbon compounds are one of the most studied nanomaterials today. These structures have unique properties within solid substances. The geometric structure of these compounds strongly influences their physical properties. These may also be affected by electromagnetic fields. Carbon nanotubes and fullerenes are among the most interesting and popular nanostructures. Carbon nanotubes were first isolated and described by Ijima in 1991 and fullerene C60 was first discovered as early as 1985. This discovery was awarded the Nobel Prize. The diameter of carbon nanotubes is expressed in nanometres, whereas their length can reach up to several micrometres and they are 100 times stronger than steel. Depending on their diameter they may have the properties of metals or semiconductors without the requirement for additional doping. The width of the forbidden band gap of semiconductor nanotubes depends on their diameter and chirality. One can imagine the smallest semiconductor devices being constructed from carbon nanomaterials. Some other carbon compound struc-

Department of Theoretical Physics

The Department of Theoretical Physics has multidisciplinary character and specializes in a wide range of physics problems such as condensed matter physics, stochastic processes like turbulence, particle and space physics, as well as the definition of electronic properties of nanostructures. It uses various methods for tackling the given tasks. The following part of this short Departmental presentation focuses on the theme of carbon nanostructures.



picture 2 – B

tures such as cones and fullerenes made of the graphene honeycomb lattice also have similar properties. To obtain such structures it is necessary to create one or several topological defects (e.g. pentagons or heptagons) in the hexagonal lattice of graphene, or deform it for example by rolling the lattice (see picture 1).

Topological defects evoke changes in the geometry of carbon materials that may exhibit strong effect on their electronic properties. Twelve pentagons in the graphene lattice together with 20 hexagons form the fullerene C60 molecule. Fullerenes have interesting properties that could be used in various areas of nanoindustry. Fullerene C60 can be grouped to ferromagnetic materials such as iron or cobalt, or iron-cobalt alloy, that can make thin films with the required magnetic properties. Some fullerene compounds show superconductive characteristics. Interesting properties are also found in nanotubes and fullerenes (see picture 2), in which the outer layer is charged positively and inner layer negatively as a result of different Fermi levels in separate nanostructures, and also of interactions between individual layers.

In the future carbon nanoparticles may be helpful in the development of technologies utilizing solar energy, as well as in microelectronics and nanomedicine. Our group from the Department of Theoretical Physics has been participating actively in research into the electronic properties of carbon nanostructures, as attested by our publications in renowned international journals and our winning the award for the best theoretical result in 2007 at the Joint Institute for Nuclear Research in Dubna, Moscow Region. Our Department has collaborated with this Research Institute for many years.

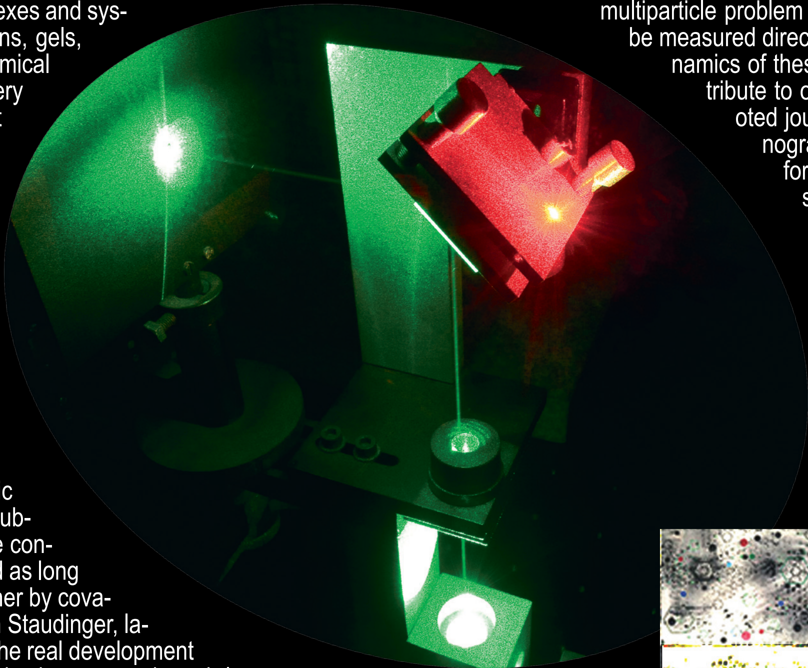
The principal methods used in the Laboratory involve laser scattering (static, dynamic and electrophoretic), making use of several properties of laser radiation such as small wavelengths of approximately hundreds of nanometres, monochromaticity and coherence. Static scattering provides structural information in the range of approximately 20 nm to microns, dynamic scattering carried out in the form of photon correlation spectroscopy gains information on dynamic processes with relaxation times in the range of many orders (from the submicrosecond range to seconds) and indirect structural information from 1 nm.

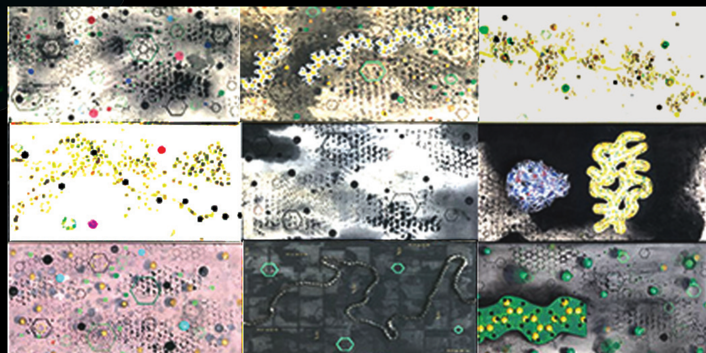
The electrophoretic scattering method is used for measuring the dynamics of molecules and nanoparticles in electric fields, and provides information on charges which are considerably different from so-called chemical charges (expected on the basis of chemical structure) due to various physical effects. These principal methods are supported by other analytical and preparative approaches.

Laboratory of Experimental Chemical Physics

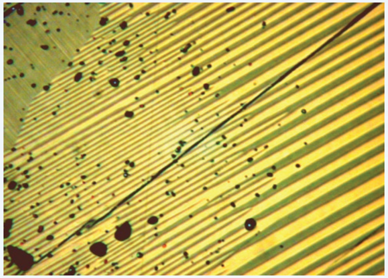
Laboratory of Experimental Chemical Physics

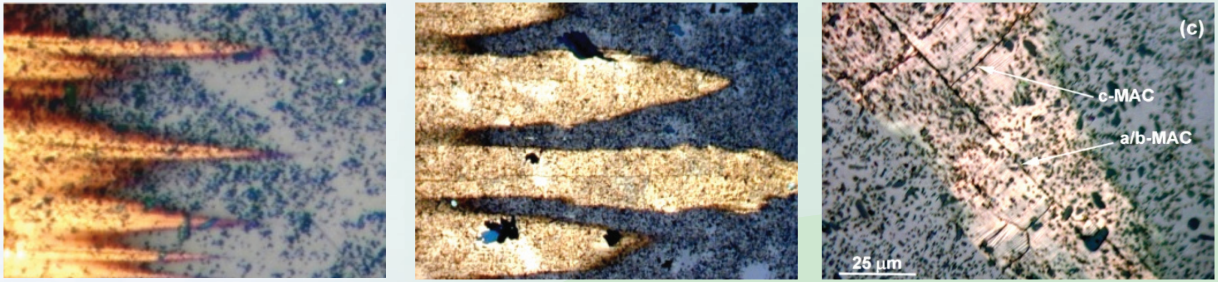
Chemical physics is a scientific discipline which utilizes physical methods to gain insight into the nature of molecules. This encompasses the study of the simplest water-type (H_2O) to macromolecules (polymers) and their complexes and systems (solutions, suspensions, gels, polymer melts). The chemical physics research area is very close to the concept of soft matter physics. This laboratory devotes itself mainly to polymers. While biological polymers (nucleic acids, proteins, polysaccharides) are an integral part of living organisms and have been on Earth for a long time, synthetic polymers saw the light of day at the beginning of the 20th century. Although the first synthetic polymer (bakelite) was publicly introduced in 1907, the concept of the polymer, defined as long chains of atoms held together by covalent bonds (1922, Hermann Staudinger, later Nobel Prize laureate). The real development of polymer chemistry and physics occurred much later in the 20th century (Nobel Prizes – chemists Giulio Natta and Karl Ziegler, 1963,physicists Paul Flory, 1974 and Pierre-Gilles de Gennes, 1991). Polymeric macromolecus demonstrate such properties and behaviour that bear no resemblance to small “classical” molecules. Although research studies of synthetic and biological polymers were carried out either in parallel or independently, it turned out that these polymers exhibit many common phenomena and properties. The Laboratory focuses especially on ionic polymers (polyelectrolytes). The presence of charges in these molecules enables water solubility, ecological applications, and biological functions of biopolymers. Macromolecules and especially their systems (solutions) represent a complex multiparticle problem for physicists. Multiparticle collective interactions cannot be measured directly, and therefore the information on the structure and dynamics of these systems gained experimentally in our Laboratory contribute to our knowledge about them. In addition to some often-quoted journal articles, we have published several chapters in monographies from renowned publishing houses (Clarendon Oxford, Marcel Dekker New York). In the recent past, we have succeeded in reorienting our long-term basic research findings also towards applications. We have created and patented a new mechanism for forming polymer nanoparticles of adjustable parameters out of ionic polymer chains – building units, based on physical bonds (not chemical reactions). Currently polymer nanoparticles find applications in many fields, with targeted transport of drugs and medical imaging probably being the most important.





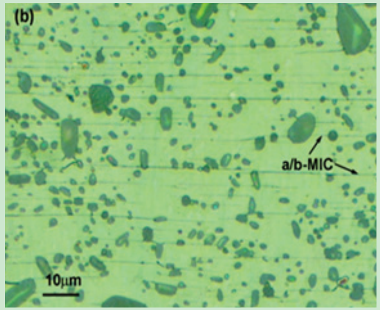
Laboratory of Experimental Chemical Physics

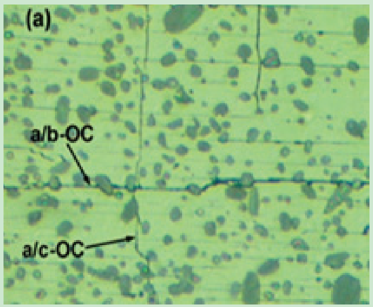




Picture 2. Formation of oxygenation cracks in YBCO MMS at annealing in oxygen at 400 °C

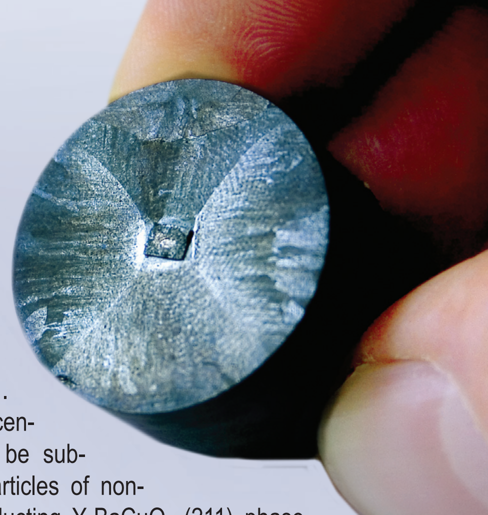
Picture 1. 211 particles and twin structure





Picture 3. Increasing the critical current density by eliminating oxygenation cracks with high-pressure oxidation

Laboratory of Materials Physics



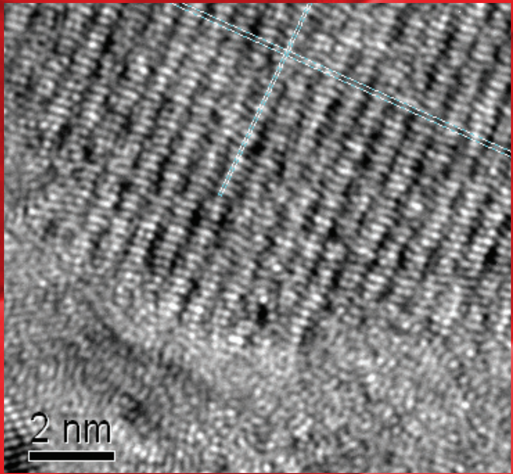
This Laboratory concentrates on oxidic functional ceramic materials. The Laboratory´s principal activities are preparing and studying the relationship between the microstructure and superconducting properties of YBCO massive single-grain superconductors (MSS). In this field the Laboratory has achieved scientific results valued in Slovakia and also abroad, developed wide international cooperation (ISTEC Tokyo, Argonne National Laboratory, USA, Oxford University, Cambridge University, IPHT Jena, IFW Dresden, ATI Vienna, ICMAB Barcelona, CRETA CNRS Grenoble) within multilateral projects (projects 5RP and 6RP) and built the infrastructure necessary for the research and development of these materials.

YBCO MSS (YBCO is the abbreviation for the high-temperature superconductor $YBa_2Cu_3O_7$, referred to below as Y123) are suitable for practical applications mainly as superconducting permanent magnets. Part of their unique properties, as a consequence of strong pinning of magnetic flux lines, is their ability to trap one order higher magnetic fields than the best permanent magnets (up to 17 Tesla at 30 K temperature, even 100 times higher energy density), to levitate or suspend stably in an non-homogeneous magnetic field (high levitation force) and to move without friction in a homogeneous magnetic field. The main application possibilities are in the construction of efficient electric rotary machines, magnetic separators, levitation devices such as frictionless bearings, flywheel energy reservoirs, and magnetic levitation transport systems (e.g. MAGLEV trains).

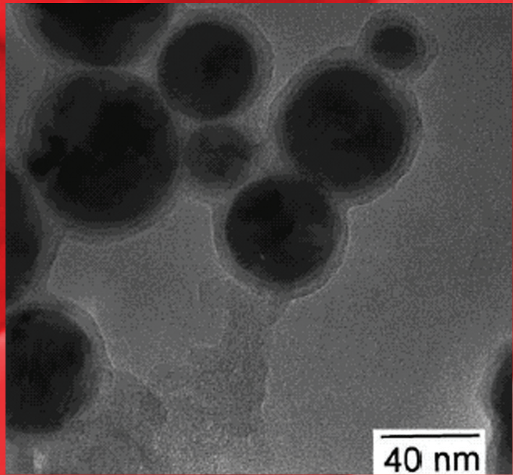
High-temperature superconductors are generally characterized by small coherence length, a parameter which limits the maximum distance of electrons in a Cooper pair (2,7 nm at 77 K for Y123). This parameter fundamentally specifies requirements for the superconductor preparation technology, which must produce single-crystalline material with nanosized pinning centres.

We can ideally imagine YBCO MSS (superconducting magnet) as a cylindrical $YBa_2Cu_3O_7$ single-crystal with a diameter of 30 to 100 mm, in which the pining centres are scattered. These centres may be submicron particles of non-superconducting Y_2BaCuO_5 (211) phase (Picture 1), or the so-called chemical pinning centres: nano-sized areas with a distorted crystal lattice formed by substitute atoms.

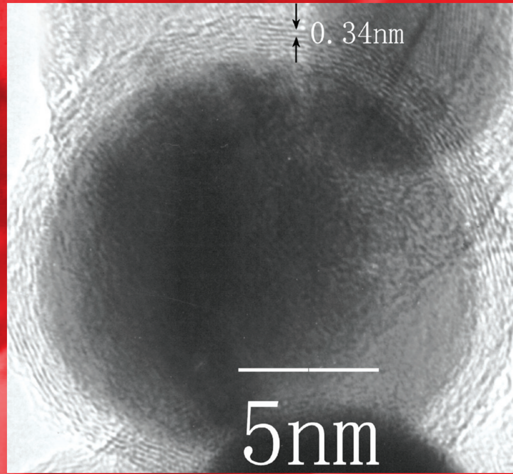
As grown massive YBCO single-grain samples prepared with so-called Top-Seeded Melt-Growth process have a low oxygen content and are non-superconducting. They must be oxygenated and, as we have shown, oxygenation cracks are created in this process as a consequence of shortening of lattice parameters (Picture 2). These cracks diminish the efficient sample cross section to one third, but are necessary for successful oxidation. If only bulk oxygen diffusion would provide oxygenation, the MSS oxygenation would last more than a thousand years. We have recently demonstrated that high-pressure, high-temperature oxidation may suppress the formation of oxygenation cracks and increase critical current density threefold (Picture 3). We have also found new possibilities of creating chemical pinning centres by microalloying.



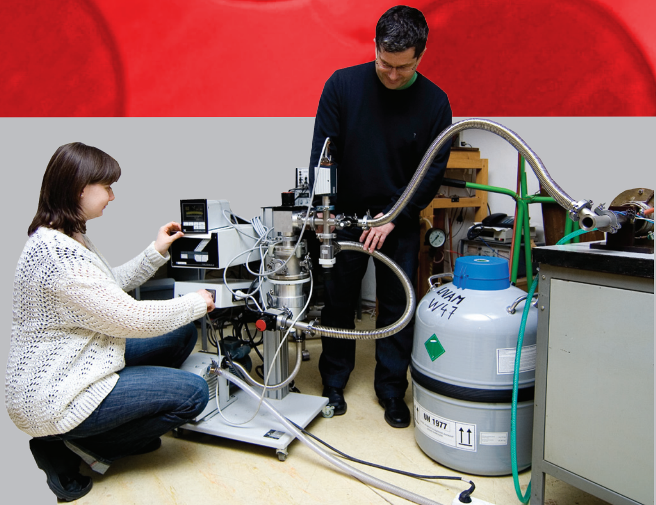
HRTEM micrograph of FeNiNbB nanocrystalline alloy



Fe-based magnetic nanocapsules



Gd-based magnetic nanoparticle covered with carbon



Laboratórium nanomateriálov a aplikovaného magnetizmu

Part of the Laboratory´s research activities is devoted to Fe(Co)Pt-based hard magnetic nanocomposites where the L10 face-centered tetragonal FePt phase with very large magnetocrystalline anisotropy (K ~7 MJ/m^3) assures excellent hard magnetic characteristics. On the other hand, our recently developed nanocrystalline FeNi-based alloys represent an example of an extremely soft magnetic material with the coercive field value below 1 A/m, which is more than a million-fold lower value as compared to that for Fe(Co)Pt-based nanocomposites.

The Laboratory has recently concentrated its attention also on the development of new materials for magnetic refrigeration. This unconventional cooling technology is based on using the magneto-caloric effect occurring under adiabatic conditions. Here the material temperature change is caused by an external magnetic field change. If magnetic material is exposed to an external magnetic field, then the reduction in magne-

Laboratory of Nanomaterials and Applied Magnetism

The Laboratory´s research activities focus on development and characterization of new magnetic materials which can be potentially used in technical practice. Special attention is devoted to nanocomposites and nanoparticle systems with the building blocks in the range 1 – 100 nanometers (10^{-9} - 10^{-7} m).
Our long-term interest is focused on nanocrystalline Fe-based metallic alloys prepared by a method of controlled crystalization of amorphous precursors. Besides high magnetic induction values, these alloys show particularly good soft magnetic properties (high permeability, low values of coercive field and premagnetization losses). This combination makes them attractive materials for use in several technical applications such as high-frequency transformers, magnetic sensors, various components of telecommunication and electronic devices, or magnetic shielding. Regarding the potential use of these materials at elevated temperatures, interesting results have been obtained after substituting a portion of the iron atoms with cobalt in original three-component FeNbB alloys. We have obtained the stability of good soft magnetic properties up to temperatures exceeding 500°C in these alloys. Furthermore, after their heat treatment in a longitudinal magnetic field, we have obtained material with the coercive field of 3 A/m, which is a record low value for HITPERM-type alloys.

The utilization of heat treatment of nanocrystalline magnetic materials in an external magnetic field for the purpose of tailoring their properties is one of the main current research objectives for the Laboratory. The laboratory belongs to the European consortium GAMAS (“GROUP FOR THE APPLIED MAGNETOSCIENCES”) and also participates in application oriented research focusing on new magnetic materials development for industrial sensor systems.

tic spin entropy results in an increase of lattice entropy, which shows itself in rising temperature while demagnetization causes temperature decreases. Our recent results have shown that the systems of ultra-fine superparamagnetic particles show prospective magneto-caloric properties at low temperatures. By coupling spins into a superparamagnetic cluster, magnetic moments can be more easily aligned into a direction of the applied field than in paramagnetic systems, and consequently the spin entropy can change markedly under the influence of a lower external field. The Laboratory has also been developing iron-based amorphous and nanocrystalline alloys for magnetic refrigeration at room temperature. These alloys are characterized by relatively low price, good chemical stability and the possibility to control the Curie temperature. This makes them interesting candidates for magneto-caloric applications despite the lower values of magnetic entropy change as compared to those found in rare earth based materials.

Laboratórium nanomateriálov a aplikovaného magnetizmu