Quantum Physics
for Advanced Materials Engineering

Master program

Condensed Matter Physics
for Quantum Technologies

Graduate program

MIS&S

Inspired by the works of Professor A.A. Abrikosov, the Nobel Prize winner, who held the Chair of the Department of Theoretical Physics from 1975 to 1990, we provide a competitive training program in modern Condensed Matter Physics and Material Science.

This booklet introduces English-language master and post-graduate programs at the department of Theoretical Physics and Quantum Technologies at National University of Science and Technologies "MISIS" which is located in the center of Moscow, Russia.

You can also download and share this booklet freely with your colleagues

http://misis.ru/portals/0/Kaf_TFiKT/files/booklet_en.pdf

Contents:

Master program: "Physics of nanosystems"

Program objectives

Master's program "Physics of nanosystems" is devoted to the study of new physical phenomena discovered in nanostructured materials and quantum devices created last 20-30 years in the search for components for quantum electronics. At the same time the program addresses the basic physical principles of electronic systems and devices of quantum electronics, as well as some important manufacturing techniques and measurements of physical and chemical characteristics of quantum-sized structures and materials. The program is designed for students trained in the amount of university courses in general physics and introduction to theoretical physics for a Bachelors, which includes the courses: theoretical mechanics and the theory of elasticity, electrodynamics, quantum mechanics and statistical physics. The program does not involve a starting special training of students in the condensed matter physics, because it includes basic courses in:

- modern quantum physics of solids,
- electronic theory of metals,
- technology and materials of quantum electronics,
- spectroscopic methods of materials characterization.

The urgency and necessity

A distinctive feature of this Master's program is to focus on the study of new physical phenomena in quantum-sized materials and devices, all of which are overlooked in traditional courses of solid state physics. These objects of study appeared in the last 20-30 years due to development of tools and methods of measurement and conversion of properties of materials in the nanometer range of distances. Although the physical phenomena and processes observed in the new materials and nanostructures are described in the framework of well-established fundamental concepts of quantum and classical physics, they could not become an object of study of traditional training courses on condensed matter physics, which were created in the middle of the twentieth century, simply because most of these facilities and adequate measurement tools for their research were not yet developed. The circle of new physical phenomena studied in special courses of this master's program includes the effects of size quantization in low-dimensional structures, in particular: the quantum Hall effect, quantum charge fluctuations, Coulomb blockade and Landauer quantum conductance of the contacts of atomic size, the Wigner-Dyson statistics of electronic energy levels in the nanoclusters, the Rabi oscillations in two-level systems, the spectra of quantum dots, wells and wires in a magnetic field, phonons in fractal structures, Einstein modes in thermoelectric semiconductor materials with complex crystal cell, etc.

Developing skills

This master's program enables students to orient themselves in the modern scientific and applied research and development of quantum-sized materials and devices through the acquisition of skills in both theoretical calculations in the field of quantum physics of nanosystems as well as experimental measurements using modern equipment in the field of electron and scanning probe microscopy and spectroscopy.

List of courses at a glance

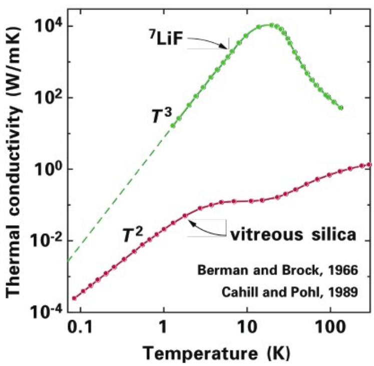
Basic courses:

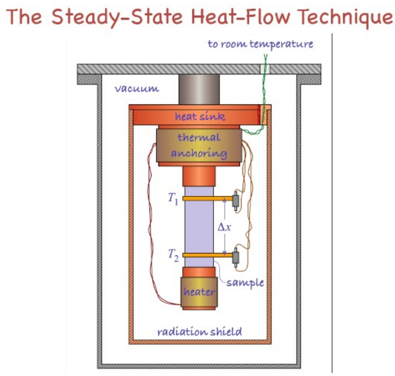
Elective courses:

Courses

Modern quantum physics of solids

Introduces into: different aspects of modern solid state physics, including phenomena in the objects of atomic size, including those considered in the following topics: quantum Hall effect, graphene and carbon nanotubes, Landauer quantum conductance of atomic size contacts, quantum magnets (spin chains), magnetism of frustrated systems, magnetic semiconductors, including silicon doped with manganese, colossal magnetoresistance, quantum phase transitions, the low-energy excitations in disordered media and fractal structures, granular conductors, metals with heavy fermions, the Kondo semiconductors, quasicrystals and structurally complex alloys;

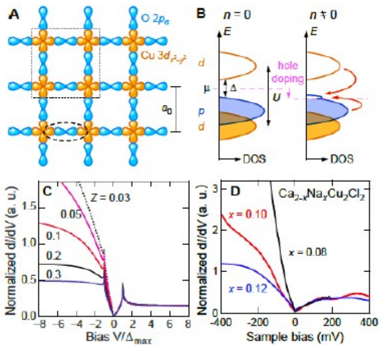


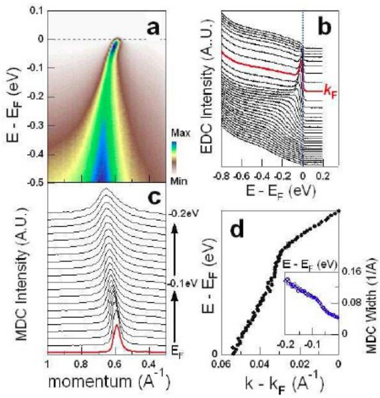


Web page of the course:
http://en.misis.ru/academics/programs/quantum-physics/courses/modern-quantum-physics-of-solids

Electron theory of metals

Introduces into: basic methods and results of the electron theory of metals, that are in the focus of the current research of quantum properties of solids and use the concept of Landau quasi-particles and Fermi-liquid theory to describe the properties of normal metals; description of phenomena in superconductors, based on the concept of spontaneous symmetry breaking and Bose-condensation of Cooper pairs in the framework of the theory of Bardeen, Cooper and Schrieffer, with application of the equations of the Ginzburg and Landau; foundations of the Green's functions technique and its applications for prediction and interpretation of experiments involving the scattering of photons, neutrons, muons and measuring the current-voltage characteristics of the tunneling microcontacts;

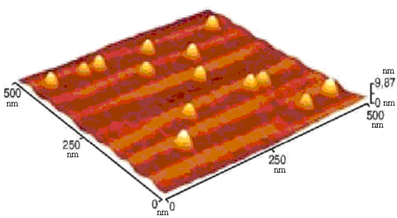


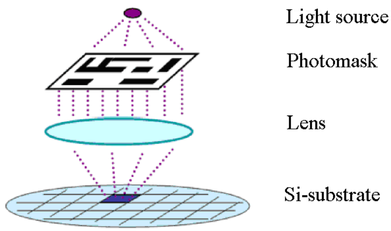


Web page of the course:
http://en.misis.ru/academics/programs/quantum-physics/courses/electron-theory-of-metals

Technologies and Materials of Quantum Electronics

Introduces into: physical properties of basic semiconductor materials and methods of nanotechnology in relation to the creation of the base elements of nanoelectronics, optoelectronics, quantum devices, in particular, including the study of changes in the electrical and optical properties of bulk materials when they are produced in the form of low-dimensional structures (quantum wells, wires and dots) due to the effects of quantum-size effect; with the emphasis on C, Si, solid solutions GeXSi1 -X , compounds and solid solutions A2B6 and A3B5; also considered are basic technologies of manufacturing of quantum-sized structures: liquid phase epitaxy, molecular beam epitaxy, vapor phase epitaxy of organometallic compounds, nanolithography, self-organization of quantum wires and dots; outline of the use of low-dimensional structures in the devices of micro-and nanoelectronics; also considered are emitting diodes and lasers for the infrared, visible and ultraviolet spectral regions, photodetectors and transistors;

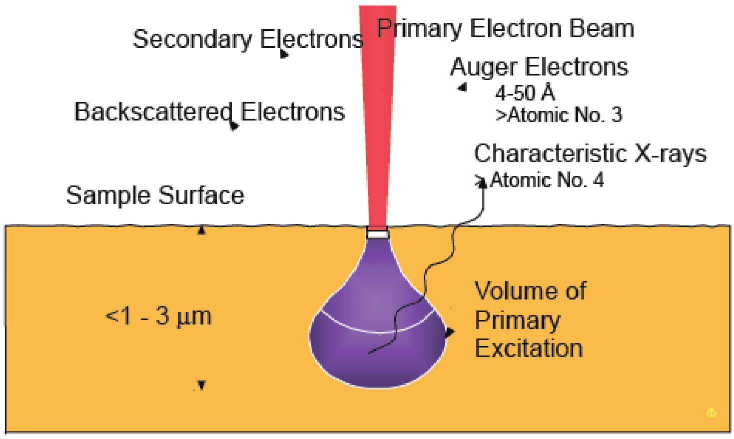




Web page of the course:
http://en.misis.ru/academics/programs/quantum-physics/courses/technology-and-materials-of-quantum-electronics

Spectroscopic methods for analysis of materials

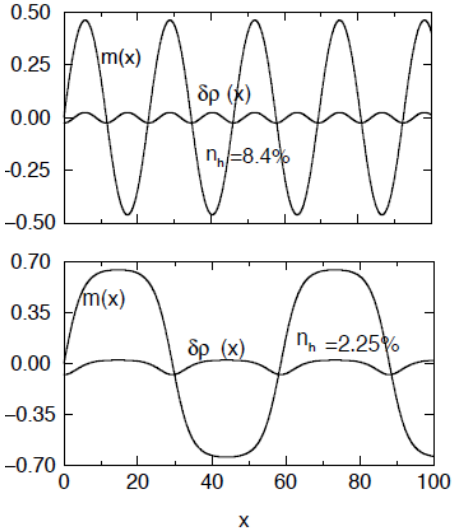
Introduces into: the fundamentals of modern spectroscopic methods of analysis of materials, such as Auger electron spectroscopy (AES), X-ray photoelectron spectroscopy (XRF), secondary ion mass spectrometry (SIMS), transmission electron microscopy (TEM), scanning ion microscopy (SIM), i.e. methods that allow us to investigate elemental, chemical composition, atomic structure, structural perfection of the surfaces of solids, surface layers, interphase boundaries and nanostructures.



Web page of the course:
http://en.misis.ru/academics/programs/quantum-physics/courses/spectroscopic-methods-for-materials-characterization

Quantum electronic properties of nanosystems

Introduces into: theory of electronic quantum phenomena in nanosystems: random Hamiltonian matrices of Wigner-Dyson and thermodynamics of nanoclusters, Peierls transitions in quasi one-dimensional conductors, transitions of Ising and Berezinskii-Kosterlitz-Thouless in two-dimensional lattice systems, the theory of spin fluctuations in one-dimensional Ising chain, the theory of Landauer quantum conductance of quantum point contact;

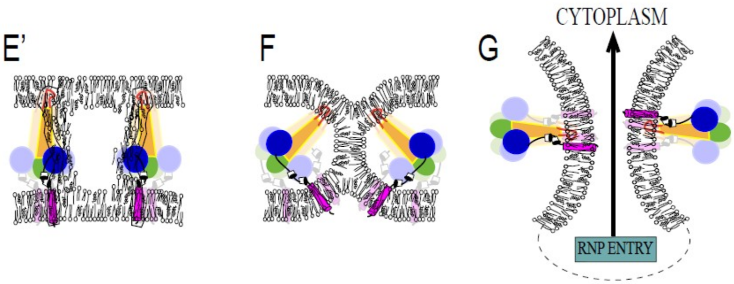


. Solitonic spin-charge coupled superstructures

Web page of the course:
http://en.misis.ru/academics/programs/quantum-physics/courses/electronic-properties-of-nanosystems

Physics of liquid-crystal membranes

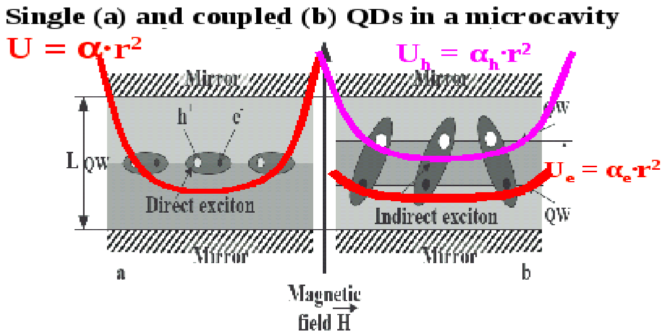
Introduces into: physics of liquid crystals and its applications to the theory of lipid membranes, in particular, into fundamentals of elasticity of liquid crystals adapted to describe bilayer membranes, thermodynamics and kinetics of phase transitions in multicomponent systems, Gibbs phase diagrams and various two-dimensional lattice models; basic theory of wetting, adapted to biomembranes, mechanisms of protein-lipid interactions and conditions of formation of macroscopic wetting films, the dependence of the rate of cellular processes on the energy of forming membrane structures using exo-and endocytosis as example;



Web page of the course:
http://en.misis.ru/academics/programs/quantum-physics/courses/physics-of-liquid-crystal-membranes

Physics of Low-Dimensional Systems

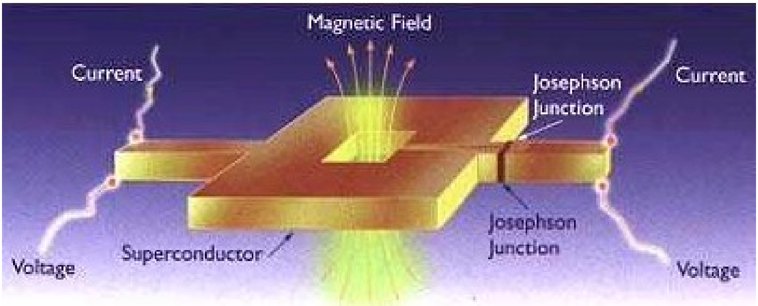
Introduces into: low-dimensional systems - quasi-two-dimensional quantum wells, one-dimensional quantum wires and quasi zero-dimensional quantum dots, in particular, with the quantum-mechanical phenomena in such systems and the influence of external electric and magnetic fields, methods of computer modeling and calculations from first principles of parameters of the low-dimensional systems: resonant frequencies, the energy spectra and wave functions of electronic and excitonic systems with carriers incoupled quantum wells and coupled quantum dots; evolution of the spectrum and restructuring of the spin states of molecules consisting of horizontally and vertically coupled quantum dots;



Web page of the course:
http://en.misis.ru/academics/programs/quantum-physics/courses/physics-of-low-dimensional-systems

Experimental Methods in the physics of low-dimensional systems

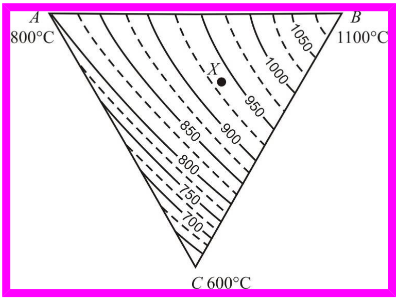
Introduces into: methods of experimental studies of transport and magnetic properties of solids, including: galvanomagnetic effects (magnetoresistance, Hall effect, de Haas-van Alphen effect, Shubnikov-de Haas effect), electrodynamics of metals, nuclear magnetic resonance, nuclear gamma-resonance; equipment and experimental techniques of measurement of weak signals in the presence of noise, resistance measurement, thermometery, application of high magnetic fields; methods of choice of appropriate measurement technology for research, experimental design, design scheme of the experimental setup, processing and interpretation of the results of the experiment, the course also teaches methods of analysis of surfaces of solids, including: classification of methods of analysis of materials surface, ion-beam probe (inverse Rutherford scattering, channeling, mass spectroscopy of secondary ions), electron-beam probe (characteristic loss spectroscopy, secondary electron emission, Auger spectroscopy), electromagnetic radiation probe, tunneling microscopy;

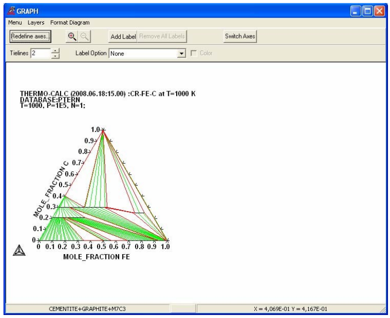


Web page of the course:
http://en.misis.ru/academics/programs/quantum-physics/courses/experimental-methods-in-low-dimensional-systems

Phase diagrams of multicomponent systems

Introduces into: analysis of phase diagrams of multicomponent systems, including applied to real materials and processes based on software packet calculation methods "Thermo-Calc", as well as the original techniques focused on the use of widespread program EXCEL; methods of solution of the following tasks: analysis of phase composition of multicomponent materials at different temperatures; graphical estimate and calculation of the liquidus, solidus, and other critical temperatures of phase transformations; construction of insulated and polythermal cuts of triple, quadruple and five fingers systems using both graphical and computational methods; calculation of the mass and volume fractions of phases in multicomponent systems, a critical analysis of information on phase diagrams and finding errors in the prediction of phase equilibria in unexplored multicomponent systems.

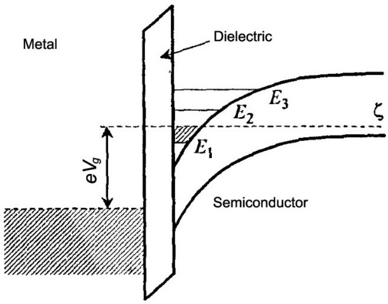


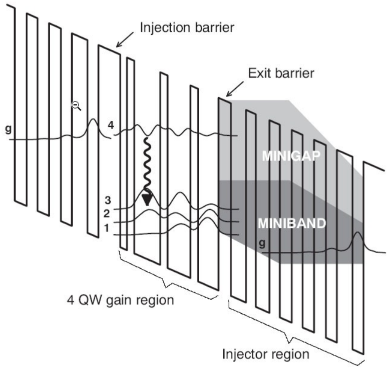


Web page of the course:
http://en.misis.ru/academics/programs/quantum-physics/courses/phase-diagrams-of-multicomponent-systems

Electronic properties of quantum confined semiconductor heterostructures

Introduces into: physics of low dimensional quantum confined heterostructures, that are the structures where the carrier motion is restricted in one or more directions at the distances of the order of de Broglie wavelength; electron transport and optical transitions in low dimensional electronic systems, and the difference between the electronic properties of low dimensional structures and those of bulk semiconductors; applications of quantum dots and wells in photovoltaics and laser techniques.

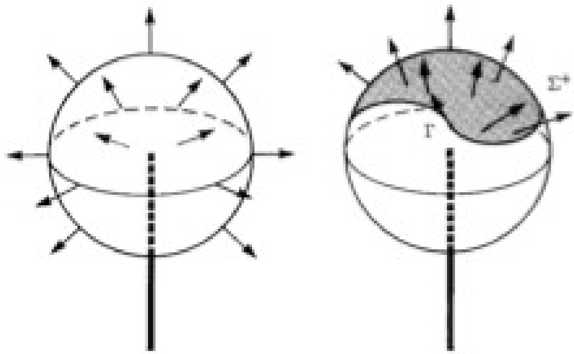




Web page of the course:
http://en.misis.ru/academics/programs/quantum-physics/courses/electronic-properties-of-heterostructures

Introduction to path integral methods in condensed matter physics

Motivation and contents: The idea of the course is to get students acquainted with path integral approach to problems of contemporary condensed matter physics. The aim is to give students firm command of this approach via carefully selected examples and problems. The course contains mathematical digression into complex calculus, the basics of second quantization, field quantization, path integral description of quantum statistical mechanics, finite temperature perturbation theory, theory of linear response, basics of renormalization group analysis and effective field theory. The final project consists of the theoretical description of single electron transistor via effective Ambegaokar-Eckern-Schoen action.



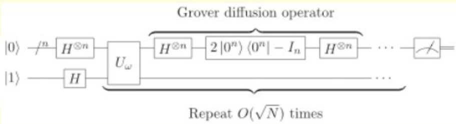
Web page of the course:
http://en.misis.ru/academics/programs/quantum-physics/courses/introduction-to-path-integral-methods

Physical Principles of Quantum Information and Macroscopic Quantum Phenomena in Superconducting Systems

Learning the physical principles of quantum information and macroscopic quantum phenomena in superconducting (Josephson) systems is the main aim of the course. The course of lectures will provide students with a basic understanding of various phenomena in the field of quantum information. The lectures material will address the principles of "quantum computer", "adiabatic quantum computer", quantum logic and algorithms, "quantum games" quantum teleportation and quantum cryptography. The second part of the course will be devoted to the theoretical foundations of the various superconducting systems in the macroscopic quantum regime. Will be addressed issues related to the choice of the parameters of these systems, the effect of temperature and dissipation, the interaction with the microwave radiation and the measurement of macroscopic quantum effects. Motivated and talented students may conduct research work in the Superconducting Metamaterials laboratory at MISIS under supervision of senior research fellows.

- **Hadamard gates**
- **Phase shift operators**

$$U_f|a\rangle = (-1)^{f(a)}|a\rangle.$$



- **Diffusion transformation**

$$D_{ij} = \frac{2}{N} \quad \text{if } i \neq j \quad \text{and} \quad D_{ii} = -1 + \frac{2}{N}.$$

Perspectives

General remarks

The XXI century is famous being a start to conversion of quantum mechanics of the world of microscopic particles into industrial power of the macroand mega-sized world. This conversion is mostly pronounced now in the field of construction of nano-electronic devices and new materials based on the novel states of electrons revealed in the form of their collective behavior, or "quantum matter" behavior as it is fashionable now to name it. The examples range from 3D nano chips design to quantum magnets and superconducting quantum bits (spin qubits), and single-electron transistors and cooper pair boxes as charge qubits for quantum computers. Also solar energy conversion into electricity using quantum wells, that provide discrete gaps between electronic energy levels, adjustable by external magnetic field is another example of materials engineering using quantum physics. Hence, the future career opportunities in quantum physics for materials engineering are very diverse and range from PhD and postdoctoral research at the universities and scientific labs to engineering companies of contemporary electronics.

Rapid development of biological knowledge supplies a lot of "problems" for other sciences, such as chemistry and physics. Many of these problems are condensed matter problems, which has a century of development, but was mostly concerned with a solid state bodies. This knowledge properly applied to a biological problems might enrich both sciences to a great benefit of the human race.

ASIIN certification

This March is the final stage of the two-year long ASIIN[1] certification of our master program. After this our diploma will be valid throughout the Europe.

Department Alumni

Here's a list of some of our best students:

- Maxim Belov graduated in 2012, currently works in Linköping Univsity (Sweden)
- Ivan Bleskov graduated in 2010, currently works in Max Plank University (Germany)
- Nina Bondarenko graduated in 2008, currently works in Uppsala University (Sweden)
- Svetlana Baoukina graduated in 2005, currently works in Calgary University (Canada)

How to get enrolled

Previous year (2014) we started to teach our master program in English. Currently we have three students studying. The next enrollment is going to be on the summer 2015.

The first step to get enrolled is to fill the application here:

http://en.misis.ru/admissions/rules

The prices are:

1 http://www.asiin-ev.de/pages/en/asiin-e.-v/programme-accreditation.php

- semester — $7,500
- complete program (two years) — $15,000

A limited scholarship will also be available in 2015. Information about the scholarship conditions see at:

http://en.misis.ru/scholarships

More information about the program see at:

http://en.misis.ru/academics/programs/quantum-physics

List of laboratories

Laboratory of bioelectrochemistry

Web page:
http://eng.phyche.ac.ru/?page_id=3331

This is a famous laboratory named after Alexander Naumovich Frumkin, which is lead by a prof., associate member of the Russian Academy of Science, Yurii Alexandrovich Chizmadzhev.

Main directions of research: investigation of lipid/protein membrane nanostructures responsible for fusion, fission and active membrane transport. Study of the: mechanism of viral infection, fission of membrane tubules (endocytosis); development of the theory of lipid/protein nanodomains (rafts); study of the mechanism of Na/K-ATPase action.

Citation index of some members of the lab for the last ten years:

- Yu.I. Chizmadzhev – 1592
- V.S. Sokolov – 218
- V.A. Frolov – 194
- P.I. Kuzmin – 183
- Yu.A. Ermakov – 143
- A.A. Scherbakov – 74
- A.V. Indenbom – 48
- G.I. Maksaev – 22

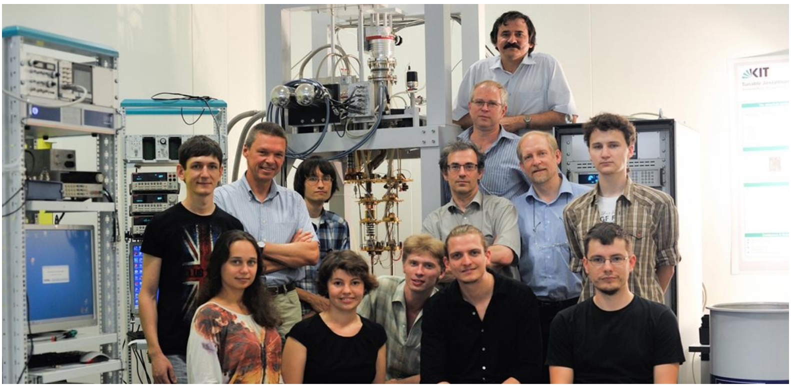
Laboratory of superconducting metamaterials

Web page:
http://smm.misis.ru

The lab of superconducting metamaterials was created at National University of Science and Technology "MISIS" in November 2011 under the mega-grant of Russian government.

The topic of mega-grant: “Superconducting metamaterials: development of superconducting structures with unique electromagnetic features and analysis of their physical properties”.

The main field of lab’s work is an experimental research of electromagnetic features of superconducting metamaterials in the range of ultrahigh rates with a usage of one-dimensional and two-dimensional structures.



Laboratory of modelling and development of new materials

Web page:
http://mmdl.misis.ru

Main research of the lab is development of efficient ab initio methods, their implementations in the form of robust computer codes, and the applications for the description and understanding of materials properties. The investigations are largely focused on electronic structure problems for condensed crystalline systems.The main goal of the research is to deepen a fundamental understanding of materials properties from the basic principles of quantum mechanics, and to deliver this knowledge to applied materials science, adjacent scientific disciplines, and to the industry.

Laboratory of synthesis of quasicrystals, manganites and spin ladders

Web page:
http://www.misis.ru/tabid/6600

Laboratory of synthesis was founded in the mid 80s, and was primarily concerned with high-T_c superconductors. Currently laboratory is focused on synthesis of quasicrystals, manganites and, recently, spin ladders.

Lab's equipment includes floating zone melting, annealing ovens and presses.

Laboratory of material science and metallurgy

Web page:
http://www.centremisis.ru/equipment-list

List of equipment:

- Electronic Auger spectrometer PHI-680 by Physical Electronics
- High Resolution X-Ray Diffractometer Bede D1 System by Bruker
- Scanning ion microscope Strata 201 SIMSmapIIIxP by FEI Company
- Scanning electron microscope JSM-6700F by Jeol
- Scanning electron microscope JSM-6480LV by Jeol
- Electron microscope JEM-2100 by Jeol

- FT-IR-Spektrometer IFS-66V/S by Bruker
- Scanning probe microscopy NTEGRA by NT-MDT
- Sequential X-ray Fluorescence Spectrometer XRF-1800 by Shimadzu
- Optical microscope Axio Imager D1 by Carl Zeiss
- Device for carbon nanotubes synthesis ULVAC CN-CVD-100
- Mechanical tests equipment
- X-ray photoelectron spectroscopy system PHI-5500 by Physical Electronics
- Secondary ion mass spectrometry system PHI-6600 by Physical Electronics

Laboratory for non-equilibrium and nonlinear phenomena

Web page:
http://www.lebedev.ru/en/structure.html?id_level=81

Lab activity is dedicated to the study of cascades of quantum wells.

Regarding experiment, laboratory does:

- Growth of GaN and InGaN nanostructures using molecular beam epitaxy (MBE) and their application towards water splitting.

- High resolution X-ray diffraction studies on epitaxial thin films including reciprocal space mapping (RSM) analysis, Photo and cathodoluminescence studies on II-INitrides.

Research topics

Physics of liquid-crystalline membranes

Description

In Group of Dr. S.A. Akimov membrane studied from the point of view of the theory of elasticity. The essence of the theory is that it is divided arbitrary state membrane into three basic deformations: torsion, bending and shear. For each type of formula containing a given ratio. The coefficient of each type of deformation is to be measured experimentally. Knowing the coefficient can calculate energy conformation. Comparing the energies of different conformations can be concluded about the relative profitability of energy-term one state over another. Thus, one can explain some of the microbiological phenomena, such as the small size of the so-called rafts - sphingomyelin-enriched lipid domains. The theory can also point to new phenomena that should be checked by means of experiment.

Leading scientist

S.A. Akimov. List of publications since 2013:

1. Shnyrova AV, Bashkirov PV, Akimov SA, Pucadyil TJ, Zimmerberg J, Schmid SL, et al. Geometric catalysis of membrane fission driven by flexible dynamin rings. Science. 2013;339: 1433–1436. doi: 10.1126/science.1233920
2. Horner A, Akimov SA, Pohl P. Long and Short Lipid Molecules Experience the Same Interleaflet Drag in Lipid Bilayers. Phys Rev Lett. 2013;110: 268101. doi:10.1103/PhysRevLett.110.268101
3. Frolov VA, Escalada A, Akimov SA, Shnyrova AV. Geometry of membrane fission. Chemistry and Physics of Lipids. 2014; doi:10.1016/j.chemphyslip.2014.07.006
4. Panov PV, Akimov SA, Batishchev OV. Isoprenoid lipid chains increase

membrane resistance to pore formation. Biochem Moscow Suppl Ser A. 2014;8: 304–308. doi:10.1134/S1990747814050067

5. Akimov SA, Mukovozov AA, Voronina GF, Chizmadzhev YA, Batishchev OV. Line tension and structure of through pore edge in lipid bilayer. Biochem Moscow Suppl Ser A. 2014;8: 297–303. doi:10.1134/S1990747814050018
6. Akimov SA, Molotkovsky RJ, Galimzyanov TR, Radaev AV, Shilova LA, Kuzmin PI, et al. Model of membrane fusion: Continuous transition to fusion pore with regard of hydrophobic and hydration interactions. Biochem Moscow Suppl Ser A. 2014;8: 153–161. doi:10.1134/S1990747814010024
7. Molotkovsky RJ, Akimov SA. Stabilization of a complex of fusion proteins by membrane deformations. BIOPHYSICS. 2013;58: 653–659. doi:10.1134/S0006350913050096
8. Galimzyanov TR, Molotkovsky RJ, Kheyfets BB, Akimov SA. Energy of the interaction between membrane lipid domains calculated from splay and tilt deformations. Jetp Lett. 2013;96: 681–686. doi:10.1134/S0021364012220031

Home page:
http://en.misis.ru/academics/departments/tpqt/staff/sergei-akimov

Strongly correlated electron systems

Examples: high-Tc superconductors, multiferroic compounds with topological defects, spintronics in Josephson networks

Description

As an example, macroscopic quantum condensates in many-body systems can result in technologies developed for quantum information processing, as well as new experimental data on the behavior of high-temperature superconductors based on lightly doped transition metal ceramics (cuprates). In particular, modern photonics exploring the possibilities of quantum tomography, which allows to determine the phase factors quantum superposition of coherent light beams (photonic analog "Schrödinger's cat"). Development of techniques for measuring the quantum entanglement of photons ("entanglement") is the basis for the construction of devices for quantum information processing and transmission of quantum information from a distance. At the same time, in the high-temperature superconducting cuprates traces of the so-called "hidden" order parameter ("hidden order"), which is manifested in the appearance of a gap in the electron spectrum at the Fermi level, but can not be directly defined, such as the usual order parameters: the magnetization or the density of the charge density wave. New theoretical results obtained in the department TFKT indicate that the implementation of ordering ("condensation" of the order parameter) as a quantum superposition of quasi-classical states of photons or electrons can be described in terms of crystallization in the Euclidean space. And "Euclidean crystal" differs from the conventional in that it is not periodic ordering occurs along a spatial axis, and the axis "imaginary time" ("Matsubara time"), appearing in the description of the thermodynamics of quantum systems. Now the department conducted research aimed at building "Elasticity" Euclidean crystals and their interaction with the outside world (the response function to external influences).

Leading scientist: theory

Prof. S.I. Mukhin. List of publications since 2013:

1. Mukhin SI. Euclidean action of Fermi-system with “hidden order.” Physica B: Condensed Matter. 2014; doi:10.1016/j.physb.2014.11.086
2. Mukhin SI, Kheyfets BB. Pore formation phase diagrams for lipid membranes. Jetp Lett. 2014;99: 358–362. doi:10.1134/S0021364014060095
3. Mukhin SI. Euclidian Crystals in Many-Body Systems: Breakdown of

Goldstone's Theorem. J Supercond Nov Magn. 2013; 1–6. doi:10.1007/s10948-013-2416-9

4. Mukhin SI, Galimzyanov TR. High Superconducting T c and Suppressed Isotope Effect in the Instantonic Condensate State of the Fermi-System: Analytic Solution. J Supercond Nov Magn. 2013;26: 2679–2683. doi:10.1007/s10948-013-2159-7
5. Mukhin SI, Fistul MV. Generation of non-classical photon states in superconducting quantum metamaterials. Supercond Sci Technol. 2013;26: 084003. doi:10.1088/0953-2048/26/8/084003

Home page:
http://en.misis.ru/academics/departments/tpqt/staff/sergei-mukhin

Leading scientist: experiment

Prof. A.V. Karpov. List of publications since 2013:

1. Maleeva N, Fistul MV, Karpov A, Zhuravel AP, Averkin A, Jung P, et al. Electrodynamics of a ring-shaped spiral resonator. Journal of Applied Physics. 2014;115: 064910. doi:10.1063/1.4863835
2. Averkin AS, Karpov A, Shulga K, Glushkov E, Abramov N, Huebner U, et al. Broadband sample holder for microwave spectroscopy of superconducting qubits. Review of Scientific Instruments. 2014;85: 104702. doi:10.1063/1.4896830

Home page:
http://smm.misis.ru/persons/?person_id=11

The physical properties of quasicrystals

Description

Discovery by Shechtman, Blech, Gratias and Cahn quasicrystalline phase with the icosahedral-symmetry of the binary system Al-Mn showed that periodicity is not a necessary condition for the formation of long-range order in solids, and led to a substantial revision of the understanding of the nature of the crystalline state. Quasicrystals possess many properties characteristic of solids with a periodic structure, such as cutting and diffraction pattern with sharp peaks. The correlation length of the structure of quasicrystals, as determined by the results of X-ray diffraction, can reach several micrometers, which puts them on the structural quality on a par with the most advanced periodically ordered crystals. At the same time, the quasi-received fundamentally different from periodically ordered crystals lack of translational symmetry. They have a special type of aperiodic long-range order and may have rotational symmetry, is not compatible with the frequency. In addition to the icosahedral quasicrystals are so axial phase with octagonal, decagonal and dodeca-gonal structures. Currently, the department conducted research TFiKT various physical properties of quasicrystals.

Leading scientist

Prof. MA Chernikov. List of publications since 2013:

1. Shulyatev D, Nigmatulin A, Chernikov M, Klyueva M, Shaitura D, Golovkova E. Formation of the Icosahedral Al–Cu–Fe Phase by Solid State Reaction. Acta Physica Polonica, A. 2014;126.
2. Poluektov PP, Shirokov SS, Kholopova OV, Chernikov MA, Savin SK, Shirokova EV. Liquid treatment of radionuclide-contaminated items of complex geometry in apparatuses with pulsed oscillating

flow of reagents. Radiochemistry. 2014;56: 308–310. doi:10.1134/S106636221403014X

3. Shulyatev DA, Chernikov MA, Korovushkin VV, Kozlovskaya NA, Klyueva MV. Synthesis, X-Ray analysis, and Mössbauer investigation of Al-Cu-Fe quasicrystals. J Synch Investig. 2013;7: 434–436. doi:10.1134/S1027451013030129

Home page:
http://en.misis.ru/academics/departments/tpqt/staff/mikhail-chernikov

Sources and detectors of terahertz radiation

Description

Despite significant progress in the development of quantum cascade lasers, including the Terahertz range, however, does not cease to be urgent task of creating tunable solid-state sources of coherent terahertz radiation. This study aims to develop a new mechanism induced generation of coherent terahertz electromagnetic radiation in transitions between Landau levels in the resonant tunneling structures of quantum wells. The mechanism allows continuous frequency tuning by varying the intensity of the magnetic field applied to the structure.

Leading scientist

Prof. M.P. Telenkov. List of publications since 2013:

1. Telenkov MP, Mityagin YA. Resonant-tunneling structure of quantum wells in the p-i-n photovoltaic element. Bull Lebedev Phys Inst. 2013;40: 346–353. doi:10.3103/S106833561312004X
2. Telenkov MP, Mityagin YA, Kartsev PF. Carrier kinetics and population inversion in Landau level system in cascade GaAs/AlGaAs quantum well

structures. Opt Quant Electron. 2013;46: 759–767. doi:10.1007/s11082-013-9784-z

3. Telenkov MP, Mityagin YA, Kartsev PF. Carrier dynamics and stimulated radiative terahertz transitions between Landau levels in cascade GaAs/Al-GaAs quantum well structures. Phys Solid State. 2013;55: 2154–2160. doi:10.1134/S1063783413100326

Home page:
http://en.misis.ru/academics/departments/tpqt/staff/maksim-telenkov

Photovoltaic converters of solar radiation

Description

The project is devoted to the study of the kinetics and transport of charge carriers in the structures of the tunnel-coupled quantum wells placed in the pin junction and exposed to broadband electromagnetic radiation in the visible and near-IR. The urgency of the problem stems from the fact that the introduction of such structures in the active region of the semiconductor photovoltaic cells is one of the ways to enhance their effectiveness due to the generation of photocarriers additional absorption of radiation by interband transitions in quantum wells wavelength region of the spectrum. The main difficulty here - to ensure efficient recovery of photocarriers of quantum wells in the region of the continuous spectrum, avoiding the recombination processes in the pits. The aim of the project - to develop the configuration structure that provides efficient recovery of photocarriers from the deep quantum wells.

Leading scientist

Prof. M.P. Telenkov. List of publications since 2013 and a link to a home page see at §*Sources and detectors of terahertz radiation* on page 29.

Synthesis of quasicrystals, manganites and spin ladders

Description

Laboratory of synthesis was founded in the mid 80s, and was primarily concerned with high-T_c superconductors. Currently laboratory is focused on synthesis of quasicrystals, manganites and, recently, spin ladders.

Leading scientist

Assistant professor D.V. Shulyatev. List of publications since 2013:

1. Shulyatev D, Nigmatulin A, Chernikov M, Klyueva M, Shaitura D, Golovkova E. Formation of the Icosahedral Al–Cu–Fe Phase by Solid State Reaction. Acta Physica Polonica, A. 2014;126.
2. Shulyatev DA, Chernikov MA, Korovushkin VV, Kozlovskaya NA, Klyueva MV. Synthesis, X-Ray analysis, and Mössbauer investigation of Al-Cu-Fe quasicrystals. J Synch Investig. 2013;7: 434–436. doi:10.1134/S1027451013030129

Home page:
http://en.misis.ru/academics/departments/tpqt/staff/dmitry-shulyatev

Postgraduate program

Courses

We don't have special courses for postgraduate students, but our master program English-language courses, see p. 3, welcome grad. students too.

Perspectives

If you join a research group you'd get responsibility and a share in group's grants. You can teach in our English-language courses and participate in the rich scientific activity throughout the Moscow.

How to get enrolled

The first step to get enrolled is to fill the application here:

http://en.misis.ru/admissions/rules

You wouldn't have to pay to the University. On the contrary — the research group you'd join will probably pay you for your job. A low-cost dormitory should also be provided.

$$E = mc^2 = \sqrt{m_0^2 c^4 + p^2 c^2}$$

$$F_G = G\frac{m_1 m_2}{r^2}$$

$$U^{3\beta}_{\delta_1 \rho_1} + \frac{1}{8\pi 2}\int_{\alpha_2}^{\alpha_2} d\alpha_2' \left[\frac{U^{2\beta}_{\delta_1 \rho_1} - \alpha_2' U^{1\beta}_{\rho_1 \sigma_2}}{U^{0\beta}_{\rho_1 \sigma_2}}\right]$$

$$F_G = G\frac{m_1 m_2}{r^2}$$

$$\int_{-\infty}^{\infty} e^{-x^2}\, dx = \sqrt{\pi}$$

$$\rho\left(\frac{\partial \vec{v}}{\partial t} + \vec{v}\cdot\nabla\vec{v}\right) = -\nabla p + \mu\nabla^2\vec{v} + \rho\vec{g}$$