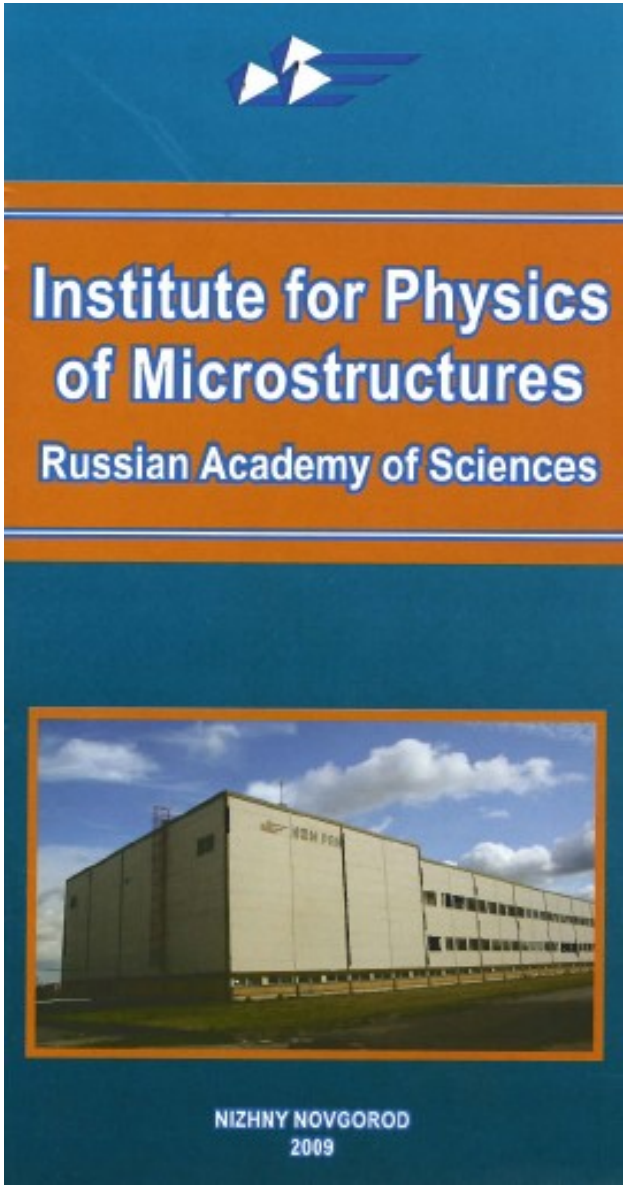
New Century of Superconductivity: Ideas, Materials, Technologies (SIMTECH)

Work package: Composite nano-superconductors

Partners: Uni-Bordeaux & IPM

Head of IPM team – Alexander Mel'nikov

Alexey Samokhvalov



Nizhny Novgorod, Russia

The staff of IPM consists of 250 employees, including more than 130 researchers (21 with doctoral decrees and 73 PhD).

The main scientific directions of the Institute:

- surface physics;
- solid-state nanostructures;
- superconductivity;
- multilayer x-ray optics,
- technologies and applications of thin films;
- surface and multilayer structures;

Institute for Physics of Microstructures

Scientific departments

- Department for physics of semiconductors
- Department for physics of superconductivity
- Multilayer X ray optics department
- Department for technology of nanostructures and devices
- Magnetic nanostructures department
- Terahertz spectroscopy department

Laboratory for theory of mesoscopic systems

Head of the laboratory **Alexander Mel'nikov** ,

D. Sc. in phys.& math

Staff of the laboratory: 7 researchers & 3 PhD students

Fields of research

- Vortex matter and exotic vortex states in layered and nanostructed superconductors;
- Hybrid structures such as "superconductor-ferromagnet" and superconductor-normal metal. Proximity effect.
- Josephson systems; Current-phase relations;
- Structure of single vortex (superconducting gap, Andreev states)
- Quantum transport theory. Weak localization.

SIMTECH

Alexander Mel'nikov (Prof)
Alexey Samokhvalov (Dr)
Ivan Khaimovich (PhD)
Denis Savinov (PhD)

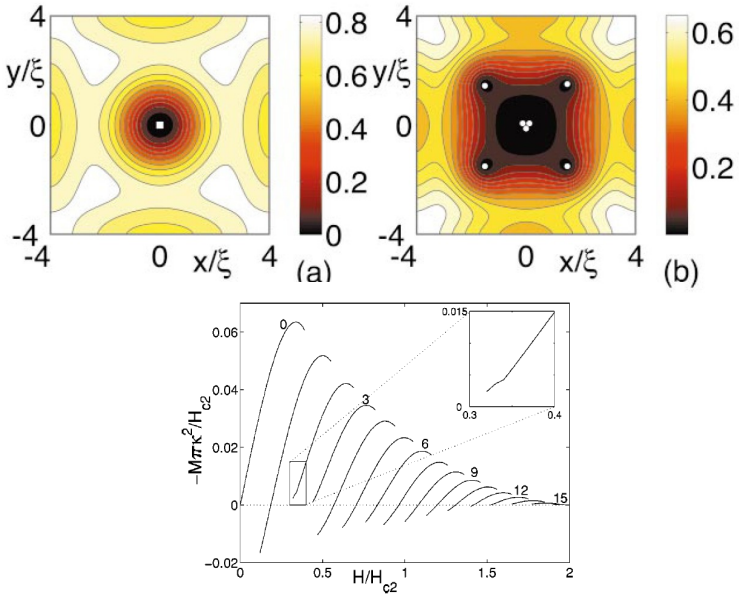
In collaboration with the group headed by Prof. A. Buzdin, (University of Bordeaux)

Vortex matter and exotic vortex states in layered and nanostructed superconductors

Vortex clusters or/and multiquanta flux lattice in layered superconductors

interplay between the long-range attraction and Pearl's repulsion of tilted vortex lines in thin films of anisotropic (layered) superconductors

[A.I.Buzdin, A.S.Mel'nikov, A.V.Samokhvalov, D.A.Savinov, PRB2009, 2010]

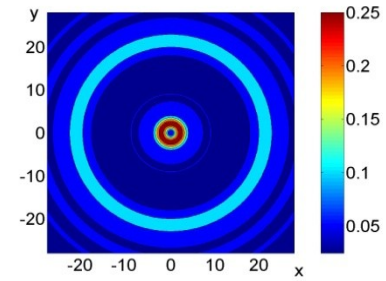


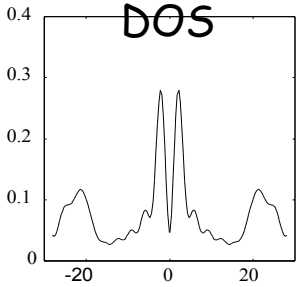
Multivortex configurations (vortex molecules and multiquanta vortex) in mesoscopic superconductors

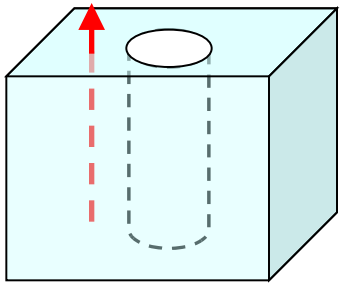
The structure of the vortex states in a square mesoscopic superconductor is analyzed in detail using the numerical simulation within the time-dependent Ginzburg-Landau (TDGL) theory. Various vortex states (vortices, vortex molecules, multiquanta vortices) are possible due to strong effect of sample boundary.

[A.S.Mel'nikov, et al. PRL, PRB2002-2010]

Electronic structure of Abrikosov vortex (quasiparticles, superconducting gap, Andreev states)







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<u>Quasiparticle spectrum in the vortex state of mesoscopic SC samples</u>

- the excitation spectrum and the field dependence of anomalous spectral branches for vortex molecules and multiquanta vortex;
- intervortex tunneling of quasiparticles;
- the transformation of anomalous branches due to the normal reflection at boundaries;
- heat transport of multivortex configurations

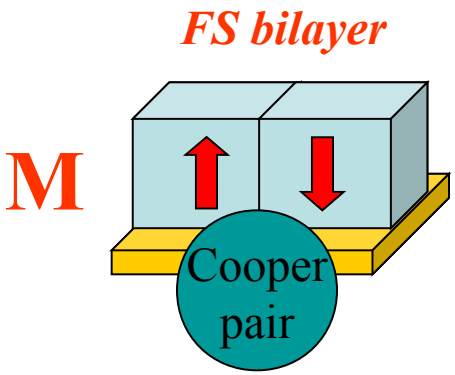
[A.S.Mel'nikov, et al. PRL, PRB2002-2010]

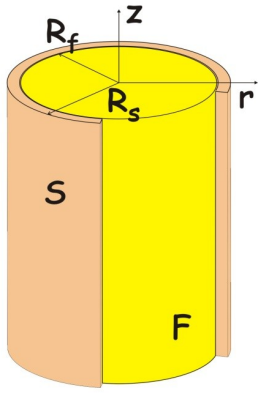
<u>Microscopic description of vortex pinning and vortex dynamics in the presence of columnar defects.</u>

- there is the minigap in the quasiparticle spectrum due to normal scattering quasiparticles at the defect.
- the model of vortex depinning via a set of quantum phase transitions in a trapped vortex core.

[A.S.Mel'nikov, A.V.Samokhvalov, PRB2009]

Hybrid structures: "superconductor-ferromagnet" and "superconductor-normal metal". Proximity effect.





Domain wall superconductivity in hybrid SF&SN structures

- problem of order parameter nucleation in hybrid SF systems with a domain structure in an applied external magnetic field;
- Vortex state structure in a spatially modulated magnetic field of domains or nanoparticles
- fluctuation corrections to the conductance of S/F structures near the superconducting phase transition;
- weak-localization phenomenon in 2D electron gas in a spatially modulated magnetic field

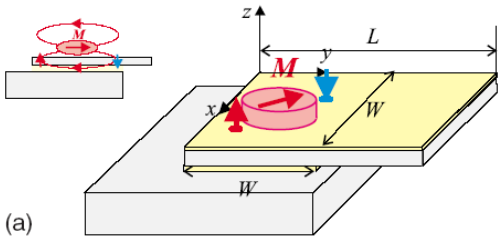
[A.I.Buzdin, A.S.Mel'nikov, A.V.Samokhvalov, PRB2003, 2007]

Multiply connected mesoscopic SF hybrids

- Little-Parks effect and the oscillations due to the exchange field and proximity effect;
- FFLO in mesoscopic superconductors

[A.I.Buzdin, A.S.Mel'nikov, A.V.Samokhvalov, PRB2007,2009,2010]

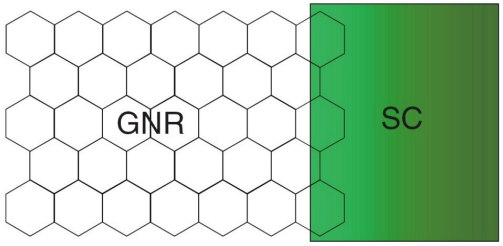
Hybrid structures: "superconductor-ferromagnet" and "superconductor-normal metal". Proximity effect.



Josephson junction coupled with magnetic dots

- influence of an array of ferromagnetic nanodots on the critical current of a Josephson junction;
- commensurability effects the magnetic-field-induced diffraction pattern;
- modification of current-phase relation;

[A.V.Samokhvalov, PRB2010]



Superconductivity in graphene and SC-graphene hybrids

- the electronic structure of vortex states in superconducting graphene was studied within the Bogoliubov–de Gennes theory applied to excitations near the Dirac point. [I.M.Khaymovich, A.S.Mel'nikov, PRB2009]
- localized subgap states in superconducting/graphene structures near the system edges or in magnetic field;
- proximity induced superconductivity in graphene;