QLIN-2019

The International Conference on New Trends in Quantum Light and Nanophysics

8th -13th July 2019, Acquafredda di Maratea, Italy

Program Chairmen

Galia Pozina
Linköping University, Sweden

Gora Shlyapnikov
Russian Quantum Center – Russia & LPTMS, CNRS, Orsay, France

Conference Organizers

Giuseppe Eramo & Stefano Bellocchio
Mediterranean Institute of Fundamental Physics, Italy

CONFERENCE TOPICS

- *2D crystals: graphene, silicene, germanene, transition metal dichalcogenides, hBN*
- *Nanophotonics*
- *Light-matter interactions in solids*
- *Quantum simulations*
- *Nonlinear and atomic optics*
- *New functional materials for electronics and photonics*

General Information

- **Conference Venue:** **8-13 July 2019**

  Hotel Villa del Mare, Acquafredda di Maratea

- **Welcome Reception:** **7 July 2019**

- **Conference Banquet:** **10 July 2019**

  We leave from the hotel at 19.30 to Agriturismo La Tenuta Del Barone, a local restaurant with a beautiful view over the historic center of Maratea.


- **Conference Excursion:** **11 July 2019**

Trip to Matera, the most spectacular city in Italy.

We leave from the hotel at 7.30. Lunch in a charming local Trattoria in Matera is included.

Matera was the capital of the province of Basilicata from 1663 to 1806. Its historical centre "Sassi" contains ancient cave dwellings from the Paleolithic period (10th millennium BC). Sassi, along with the park of the Rupestrian Churches, was awarded World Heritage Site status by UNESCO since 1993.


Program of QLIN-2019

Day 1 – Monday July 8, 2019

9.30-9.45	**Gora Shlyapnikov & Galia Pozina**	***Opening of the conference***
	Session 1 Chair Gora Shlyapnikov	
9.45-10.30	**Mikhail Glazov** Ioffe Institute, Russia ***Plenary talk***: *Phonon wind and phonon drag of excitons in monolayer semiconductors*	
10.30-11.00	**Tatiana Shubina** Ioffe Institute, Russia ***Invited talk***: *Excitons in bulk and nanostructures of monochalcogenides*	
11.00-11.30	**Coffee break**	
	Session 2 Chair Tatiana Shubina	
11.30-12.00	**Dmitrii Yakovlev** TU Dortmund, Germany ***Invited talk***: *Spin-dependent phenomena in colloidal semiconductor nanoplatelets*	
12.00-12.30	**Alexey Toropov** Ioffe Institute, Russia ***Invited talk***: *Extreme two-dimensional exciton confinement in a monolayer of GaN within AlN*	
12.30-13.00	**Leonardo Fallani** University of Florence, Italy ***Invited talk***: *Engineering synthetic quantum systems with atoms and light*	
13.00-15.00	**Lunch**	
	Session 3 Chair Alexey Toropov	
15.00-15.30	**Marina Semina** Ioffe Institute, Russia ***Invited talk***: *Control of exciton radiative lifetime in monolayer-thin semiconductors by tailoring the environment*	
15.30-16.00	**Carl Hemmingsson** Linköping University, Sweden ***Featured talk***: *Electrically active defects in wide band gap semiconductors*	
16.00-16.30	**Coffee break**	
16.30-19.30	**Round table discussion: next frontiers**	
19.30-21.00	**Dinner**	

Day 2 – Tuesday July 9, 2019

	Session 4 Chair Sergey Ganichev
9.45-10.30	**Igor Abrikosov** Linköping University, Sweden ***Plenary talk***: *Defects in SiC: a single optically addressable spin embedded in a high-performance electronic material*
10.30-11.00	**Sergey Tarasenko** Ioffe Institute, Russia ***Invited talk***: *Optics with spin-3/2 centers in SiC layers*
11.00-11.30	**Coffee break**
	Session 5 Chair Mikhail Glazov
11.30-12.00	**Sergey Ganichev** University of Regensburg, Germany ***Invited talk***: *Edge currents driven by terahertz radiation in hBN graphene in quantum Hall regime*
12.00-12.30	**Luba Kotova** Ioffe Institute, Russia ***Invited talk***: *Magneto-spatial dispersion of semiconductor quantum wells*
12.30-13.00	**Sylvain Ravets** Université Paris Saclay, France. ***Invited talk***: *Nonlinear optics in the fractional quantum Hall regime*
13.00-15.00	**Lunch**
	Session 6 Chair Sylvain Ravets
15.00-15.30	**Iouri Poussep** University of São Paulo, Brazil ***Invited talk***: *Spectroscopy of localized and extended states below the Fermi level*
15.30-16.00	**Natalia Abrikossova** Linköping University, Sweden ***Featured talk***: *Investigations of nanoparticle-cell interactions for biocompatible applications*
16.00-16.30	**Coffee break**
16.30-19.30	**MIFP members meeting**
19.30-21.00	**Dinner**

Day 3 – Wednesday July 10, 2019

	Session 7 Chair Igor Abrikosov	
9.45-10.30	**Georgy Shlyapnikov** ***Plenary talk**: New trends in nanophysics with cold atoms*	Russian Quantum Center, Russia & LPTMS, CNRS, Orsay, France
10.30-11.00	**Hadiseh Alaeian** ***Invited talk**: Hybrid Atomic-Photonics: New Paradigm for Integrated Quantum Optics*	Universität Stuttgart, Germany
11.00-11.30	**Coffee break**	
	Session 8 Chair Dmitrii Yakovlev	
11.30-12.00	**Nina Voronova** ***Invited talk**: High-Tc direct exciton Bose condensation*	National Research Nuclear University MEPhI, Russia
12.00-12.45	**Boris Altshuler** ***Plenary talk**: TBA*	Columbia University, USA
13.00-15.00	**Lunch**	
	Session 9 Chair Sergey Tarasenko	
15.00-15.30	**Igor Lukyanchuk** ***Invited talk**: Ferroelectrics at the nanoscale: negative capacitance, multi-bit logic, topology, and knotting*	Université de Picardie, France
15.30-16.00	**Andrey Varlamov** ***Invited talk**: Detection of topological phase transitions through entropy measurements*	University of Rome Tor Vergata, Italy
16.00-16.30	**Daoud Mezzane** ***Invited talk**: Very-low temperature synthesis of pure and crystalline lead-free BCZT ceramic for energy storage*	Ayyad University, Morocco
16.30-17.00	**Coffee break**	
17.00-19.30	**Poster session**	
19.30-23.00	**Conference Banquet**	

Day 4 – Thursday July 11, 2019

Excursion

Day 5 – Friday July 12, 2019

Session 10 Chair Galia Pozina	
10.00-10.30	**Alexey Kavokin** Westlake University, China ***Eco talk***: *Polariton Qubits*
10.30-11.00	**Evgeniy Sedov** Southampton University, UK ***Invited talk***: *Extrinsic spin-orbit coupling of exciton-polaritons in microcavities*
11.00-11.30	**Coffee break**
Session 11 Chair Marina Semina	
11.30-12.00	**Christophe Salomon** Ecole Normale Supérieure, France ***Invited talk***: *Quantum simulation with ultracold fermions*
12.00-12.30	**Azat Gubaydullin** Aalto University, Finland ***Invited talk***: *Rectification of photonic heat current*
12.30-13.00	**Vladimir Kuznetsov** Higher School of Economics and Institute of Solid State Physics, Russia ***Invited talk***: *Nonequilibrium Spin Polarization at Filling Factor of 3/2*
13.00-15.00	**Lunch**
Session 12 Chair Igor Lukyanchuk	
15.00-15.30	**Galia Pozina** Linköping University, Sweden ***Invited talk***: *Super radiance in a periodic structure composed of InAs monolayers embedded in a GaAs matrix*
15.30-16.00	**Gora Shlyapnikov, Galia Pozina** *Conference summary*
16.00-16.30	**Coffee break**
16.30-19.30	**MSCA network planning**
19.30-21.00	**Dinner**

Day 6 – Saturday July 13, 2019

Terrace session

10.00-13.00	**MSCA-Rise Project STONE meeting** *Presentation of reports by the project participants*

13.00-15.00	**Lunch**

Conference closing

Day 7 – Sunday July 14, 2019

Departure day

Mikhail Glazov

Prof. Mikhail Glazov is the leading scientific researcher at the Ioffe Institute (St.-Petersburg, Russia), also the professor at the Academic University; PhD in 2008 and habilitation (Dr. Sci.) in 2012 from Ioffe Institute. Since October 2016 Mikhail Glazov is the corresponding member of the Russian Academy of Sciences. The research interests of Mikhail Glazov include semiconductor theory, physics of graphene and two-dimensional materials, spin and light-matter coupling effects

Abstract

Phonon wind and phonon drag of excitons in monolayer semiconductors

M.M. Glazov

Ioffe Institute, 194021, St.-Petersburg, Russia

Transition-metal dichalcogenide monolayers demonstrate not only spectacular optical properties governed by robust excitons [1], but also intriguing excitonic diffusion [2]. Here we present the results of theoretical study of the non-equilibrium exciton transport in monolayer transition metal dichalcogenides. We consider the situation where excitons interact with non-equilibrium phonons, e.g., under the conditions of localized excitation where a ``hot spot" in formed. We develop the theory of the exciton drag by the phonons and analyze in detail the regimes of diffusive propagation of phonons and ballistic propagation of phonons where the phonon wind is formed. We demonstrate that a halo-like spatial distribution of excitons similar to observed in [2] can be formed as a result of the exciton drag by non-equilibrium phonons or Seebeck effect.

This work was partially supported by the Russian Science Foundation (project # 19-12-00051).

[1] Gang Wang, Alexey Chernikov, Mikhail M. Glazov, Tony F. Heinz, Xavier Marie, Thierry Amand, and Bernhard Urbaszek, Colloquium: Excitons in atomically thin transition metal dichalcogenides, Rev. Mod. Phys. **90**, 021001 (2018).
[2] Marvin Kulig, Jonas Zipfel, Philipp Nagler, Sofia Blanter, Christian Schueller, Tobias Korn, Nicola Paradiso, Mikhail M. Glazov, and Alexey Chernikov, Exciton Diffusion and Halo Effects in Monolayer Semiconductors, Phys. Rev. Lett. **120**, 207401 (2018).

Tatiana Shubina

Professor Tatiana Shubina is a Principal Researcher in the Laboratory for Quantum-size Heterostructures, Center for Physics of Nano-Heterostructures, Ioffe Institute. She is an expert in the physics of semiconductors, plasmonics and nanophotonics. During her 30 years career, she has specialized in the optical spectroscopy of various semiconductor compounds, heterostructures, and nanostructures, contributing to the studies of excitons in quantum dots, exciton-polaritons and slow light in wide-gap semiconductors, plasmonic effects in metal–semiconductor nanocomposites, and optical modes in microcavities for nanophotonic applications. Current research interests are focused on excitons in van-der-Waals nanotubes, bulk and 2D nanostructures of chalcogenides.

Abstract

Excitons in bulk and nanostructures of monochalcogenides

T.V. Shubina

Ioffe Institute, 194021, St.-Petersburg, Russia

Monochalcogenide compounds InSe and GaSe are the layered compounds that were in focus of basic researches in the physics of highly anisotropic semiconductors in the last century and that have recently attracted great interest as parent materials for two-dimensional (2D) crystals. In particular, InSe obeys high electron mobility, attractive quantum physics, tunable absorption, and extremely strong photoresponse. Both compounds, InSe and GaSe, are promising materials for many applications where the role of excitons is decisive.

In our experiments with bulk InSe, the sequential appearance in the luminescence of exciton, biexciton, and the P-band of exciton-exciton scattering has been observed in photoluminescence (PL) spectra with an increase in the excitation power. The strict energy and momentum conservation rules of the P band are used to reexamine the exciton binding energy. The new value ~20 meV is markedly higher than the currently accepted 14 meV, being however well consistent with the robustness of excitons up to room temperature. A peak controlled by the Sommerfeld factor, typical for 2D compounds, is found near the revised bandgap value

(~1.36 eV). Our findings supported by theoretical calculations, accounting the anisotropy of all material parameters, put the question on pure 3D character of the exciton in InSe, which has been assumed up to now. Our research shows that the exciton physics in InSe is far from trivial. It requires to combine the exciton wave function, elongated along the c axis due to the smaller reduced mass in this direction, with a large reduced mass in the x,y-plane, which leads to a high binding energy and temperature robustness of exciton. Thus, the exciton in InSe resembles in some sense a 1D exciton.

Van-der-Waals heterostructures, which have been now intensively studied, are, as a rule, the monolayers stacked together using the exfoliation method. In contrast to that, we focus on nano-heterostructures based on GaSe and InSe, created by the molecular beam epitaxy. The spectra of integrated PL, measured at different excitation levels and in a wide temperature range, exhibit the excitonic nature of the radiation, which is close to that is recorded in the high-quality bulk crystals, while the brightest luminescence was observed in nanoplatelet arrays. The study by transmission electron microscopy has revealed the presence of Ga_2Se_3 inserts in GaSe structures. The vacancy-ordered compound Ga_2Se_3 has a sphalerite structure, where a third of the gallium positions is not filled and represents structural vacancies that form a super-cell in the direction of the [011] axis. Micro-PL spectroscopy of such samples has demonstrated the presence of narrow exciton PL lines at the upper-energy edge of the emission spectrum, which are almost completely linearly polarized in the super-cell direction.

Summarizing, the novel method to determine the excitonic parameters in layered crystals via exciton-exciton scattering have been proposed. The refined character and new parameters of the exciton in InSe, as well as the possibility to create the epitaxial nano-heterostructures based on related monochalcogenide compounds such as Ga_2Se_3 and GaSe, are of paramount importance for the successful application of InSe, GaSe and similar layered compounds in nanophotonics.

Dmitri R. Yakovlev

Prof. Dmitri R. Yakovlev has been graduated from St. Petersburg Polytechnical University (1984) and got PhD (1988) and Doctor of Science (1998) degrees from Ioffe Physical-Technical Institute. Since 1990 he is working in Germany, first in Würzburg University (1990-2002) then in TU Dortmund University (since 2002) and continues to be in stuff of Ioffe Institute. Current research interests are at the spin-dependent phenomena in semiconductor nanostructures, including epitaxially-grown quantum wells and quantum dots, colloidal nanocrystals and perovskites, nonlinear optical phenomena on exciton resonances, magneto-optical studies in strong magnetic fields.

Abstract

Spin-dependent phenomena in colloidal semiconductor nanoplatelets

D. R. Yakovlev

Experimental Physics 2, TU Dortmund University, Dortmund, Germany

Ioffe Institute, Russian Academy of Sciences, St. Petersburg, Russia

A survey of our studies of exciton properties and spin-dependent phenomena in colloidal nanoplatelets measured mostly at low temperatures and in high magnetic fields up to 30 Tesla will be given. Several experimental techniques are used: polarized photoluminescence, fluorescence line narrowing, two-photon absorption, spin-flip Raman scattering and pump-probe Faraday rotation with picosecond time resolution. Exciton binding energy, exchange splitting of dark and bright exciton states, recombination times of dark and bright excitons are

measured. Spin structure of neutral and charged excitons and spin dynamics, including coherent spin dynamics are investigated. We evaluate the exciton and carrier g-factors, characteristic spin relaxation times and receive information on spin relaxation mechanisms. Magneto-optical study provides detailed information on type of nanoplatelet charging and its dynamics. Circular polarization degree of exciton emission in external magnetic fields shows unusual nonmonotonic behaviour, which is controlled by intrinsic Zeeman splitting of the excitons and by their exchange interaction with surface spins. Presence of paramagnetic centers in diamagnetic CdSe colloidal quantum dots have been recently reported by us, being provided by surface dangling bond spins. Here we show that this phenomenon is general and is documented experimentally for CdSe nanoplatelets.

This studies were performed in close collaboration of the experimentalists and theorists from the Ioffe Institute and the TU Dortmund University.

[1] D. Feng et al., Dynamic evolution from negative to positive photocharging in colloidal CdS quantum dots, NANO Letters 17, 2844 (2017).

[2] L. Biadala et al., Magnetic polaron on dangling bond spins in CdSe colloidal nanocrystals, Nature Nanotechnology 12, 569 (2017).

[5] E. V. Shornikova et al., Electron and hole g-factors and spin dynamics of negatively charged excitons in CdSe/CdS colloidal nanoplatelets with thick shells, NANO Letters 18, 372 (2018).

[6] E. V. Shornikova et al., Addressing the exciton fine structure in colloidal nanocrystals: the case of CdSe nanoplatelets, Nanoscale 10, 646 (2018).

[7] D. R. Yakovlev and A. V. Rodina, Spin dynamics of charged and neutral excitons in colloidal nanocrystals, J. Electronic Materials 47, 4260 (2018).

Alexey Toropov

Prof. Alexey Toropov is a principal researcher in the Laboratory for Quantum-size Heterostructures, Center for Physics of Nano- Heterostructures, Ioffe Institute, St. Petersburg, Russian Federation. He is also a professor at ITMO University. Prof. Toropov has around 300 published research papers in the field of solid-state physics.

Abstract

Extreme two-dimensional exciton confinement in a monolayer of GaN within AlN

A. A. Toropov

Two-dimensional semiconductor crystals demonstrate fascinating properties governed by robust excitons confined within a single monolayer. Until recently, this concept has been realized in monolayers of transition metal dichalcogenides. These structures, however, are usually limited in sample size and environmentally unstable, which hampers their applications in optoelectronic devices. In this work, we present a new two-dimensional excitonic material – single monolayer of GaN in AlN – which is perfectly suited for the light generation in the deep ultraviolet range. Optical studies in the samples fabricated by molecular beam epitaxy, supplemented by first-principle electronic calculations and a group-theory analysis, evidence a giant enhancement of the short-range electron-hole exchange interaction, that is the signature of the emergence of the extremely confined excitons. The practical significance of this approach is confirmed by detection of an internal quantum yield of the room-temperature excitonic emission as high as ~70% at 235 nm.

This work was supported by Russian Foundation for Basic Research (Project # 19-52-12057).

Leonardo Fallani

Leonardo Fallani is Professor of Physics at University of Florence (Italy) and Research Associate of LENS European Laboratory for Nonlinear Spectroscopy. His research interests are in the field of experimental AMO physics: precision spectroscopy, ultracold gases, disordered atomic systems, many-body atomic physics, quantum simulation with ultracold Bose and Fermi gases. Among his research achievements, there is the observation of Anderson localization of matter waves (2007) and the observation of edge states in neutral fermionic matter (2015). At University of Florence he is leading a research group focusing on quantum simulation with ultracold two-electron fermions, merging many-body physics and metrological techniques of quantum control. In 2016 he was awarded with an ERC Consolidator Grant for the investigation of topological states of matter with synthetic ultracold systems.

Abstract

Engineering synthetic quantum systems with atoms and light

Leonardo Fallani

Ultracold gases of neutral atoms are a powerful resource for engineering synthetic many-body quantum systems. In a “quantum simulation” perspective, it is possible to control the atomic state to provide almost exact realizations of fundamental theoretical models and to achieve new “extreme” states of matter with no counterpart in conventional materials.

In my talk I will focus on new directions which are opened by the coherent optical manipulation of internal states in ultracold Fermi gases of two-electron atoms.

I will present the results of recent experiments in which, by optical coupling of different internal states, we have demonstrated the possibility of engineering “synthetic dimensions”, in which lattice dynamics in a fictitious space are encoded in the *internal* Hilbert space of single atoms.

By using this new approach to the synthesis of quantum systems, we have studied artificial quantum Hall materials and observed the emergence of edge currents in fermionic ladders with large, tunable magnetic flux.

Finally, I will discuss ongoing experimental work studying strongly interacting states of multicomponent fermions with SU(N) and SU(N)-broken interaction symmetries.

Marina Semina

Dr. Marina is a senior researcher at Ioffe Institute, St. Petersburg, Russia. Her interests lay in the theory of semiconductors. She is a specialist in the theory of excitons and other Coulomb complexes in bulk, 2D semiconductors and in semiconductor nanostructures. Also, she studies the effects of external fields on single charge carriers as well as their complexes.

Abstract

Control of exciton radiative lifetime in monolayer-thin semiconductors by tailoring the environment

M.Semina

Ioffe Institute, Russian Academy of Sciences, St. Petersburg, Russia

The development of efficient and controllable sources of light is a key prerequisite for quantum optics studies. Two-dimensional transition metal dichalcogenides demonstrate robust excitonic resonances with a very large oscillator strength and with narrow spectrum of emission approaching the homogenous exciton linewidth. We demonstrate both theoretically and experimentally that the exciton radiative rate in these van der Waals heterostructures can be controlled by a variation of the hBN encapsulation layer thickness as a consequence of the Purcell effect. The quantum-electrodynamical treatment of the problem is in the excellent agreement with the transfer matrix calculations as well as with the simplified analytical approach which treats the substrate as a mirror. The time-resolved photoluminescence measurements together with cw reflectivity and photoluminescence experiments show that the neutral exciton spontaneous emission time can be tuned by one order of magnitude depending on the thickness of the surrounding hBN layers. The inhibition of the radiative recombination can yield spontaneous emission time up to 10~ps. These results are in very good agreement with the calculated recombination rate in the weak exciton-photon coupling regime. The analysis shows that we are also able to observe a sizeable enhancement of the exciton radiative decay rate.

Carl Hemmingsson

Prof. Carl Hemmingsson research at the Department of Physics, Chemistry and Biology at Linköping University, Sweden is focused on growth and defect studies of wide band gap semiconductors for diverse optoelectronic and electronic devices. Carl Hemmingsson has a solid industrial experience, especially in development of advanced electronics and materials for power devices.

Abstract

Electrically active defects in wide band gap semiconductors

Carl Hemmingsson

Department of Physics, Chemistry and Biology, Linköping University, 58183 Linköping, Sweden

Defects in material are important since they influence the electronic properties of semiconductors and depending on the origin, there are intrinsic defects and impurities. An impurity is one or several foreign atoms in the host crystal while an intrinsic defect is an imperfection in the host's crystal lattice. The presence of defects may give rise to energy levels in the bandgap that may trap electrons or holes. Normally, defects can be introduced either intentionally or unintentionally into semiconductors during the growth process, during processing of the device or from the working environment.

In order to study defects and to understand their origin, it is common to introduce them by electron irradiation. The most powerful technique for studying electronic properties of deep levels in semiconductors is deep level transient spectroscopy (DLTS), which was invented by D.V. Lang in 1974. This technique bases on the observation of the capacitance transient caused by the thermal emission process of charge carriers from deep levels. The advantage of this technique is that it is simple to obtain important information of defects such as activation energy, capture-cross section, defect concentration and depth profile of defects. In DLTS technique using Schottky diodes, deep levels related to trapping of majority charge carriers can be studied. To characterize minority carrier traps, another method, named minority charge carrier transient spectroscopy (MCTS) is commonly used.

Igor Abrikosov

Igor Abrikosov, professor of theoretical physics at Linköping University, member of The Royal Swedish Academy of Sciences from 2016 in the class of physics. Being elected as a member of the Academy is an exclusive recognition for the research efforts and promoting sciences. Igor Abrikosov and his group have used the computing power available from supercomputers for calculations and simulations that demonstrate that quantum spin in defects in different solid materials can have properties that fit for a q-bit.

Abstract

Defects in SiC: a single optically addressable spin embedded in a high-performance electronic material

I. A. Abrikosov[1,2]

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[2]*National University of Science and Technology 'MISIS', 119049 Moscow, Russia*
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Quantum devices of the next generation are expected to actively create, manipulate and read out quantum states of matter, processing of quantum information beyond today's limits. A basic unit of the quantum information processing – qubit – has to be stored in atomic- and subatomic-scale systems. Spins associated with defects in semiconductors are promising room-temperature qubits. In this talk, we demonstrate that SiC can, in principle, combine its well-developed semiconductor technology and the best of classic solid-state qubits, like NV-centres in diamond, allowing for a single optically addressable spin embedded in a high-performance electronic material. Recently, members of our team have for the first time successfully engineered single divacancies [1] and Si vacancies [2] in SiC. We discuss multiple advantages of the defects in SiC, including long spin coherence time even at room temperature with high-fidelity infrared spin-to-photon interface [3,4], highly spin-dependent photoluminescence with intensity contrasts of 15%–36% [7], high fidelity bi-directional nuclear qubit initialization [8] and optical control of the defect charge state [9]. Finally, we demonstrate our strategy for a systematic exploration of the vast yet unexplored alternative materials for the next generation quantum

technology via combined theoretical and experimental characterization of common point defects in wide-band gap semiconductors [10,11].

This work is supported by Knut and Alice Wallenberg Foundation project KAW 2018.0071. Contributions from all the team members, V. Ivády, J. Davidsson, R. Armiento, V. Darakchieva, M. Schubert, M. Bourennane, I. G. Ivanov, J. Ul Hassan, and N. T. Son are gratefully acknowledged.

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[9] B. Magnusson *et al.*, Phys. Rev. B 98, 195202 (2018).
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[11] J. Davidsson, *et al.*, New J. Phys. **20**, 023035 (2018); Appl. Phys. Lett. **114**, 112107 (2019).

Sergey Tarasenko

Prof. Sergey Tarasenko is a leading scientific researcher at Ioffe Institute in St. Petersburg and professor of the Russian Academy of Sciences. He was born in 1977 in Leningrad, graduated from St. Petersburg Polytechnic University in 2000, received his Ph.D. in 2003 and Dr. Phys.-Match. Sci. in 2009 from Ioffe Institute. His current scientific interests are in the areas of solid-state theory, spin-related optical and transport phenomena in semiconductors, quantum ratchet and photogalvanic effects.

Abstract

Optics with spin-3/2 centers in SiC layers

S.A. Tarasenko

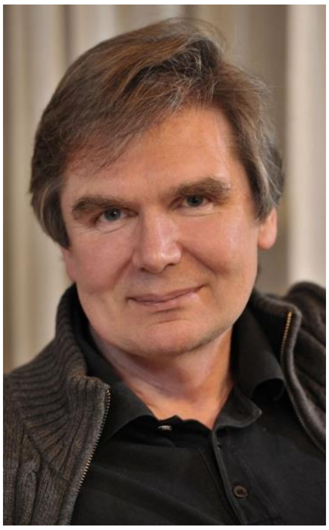
Ioffe Institute, 194021 St. Petersburg, Russia

The layers of C, Si, and SiC have been attracting growing attention because of their unique electric and optical properties. Of particular interest for applications in quantum technologies and sensorics are color centers associated with silicon vacancies (V_{Si}) in SiC. V_{Si} are natural spin-3/2 qudits whose spin states can be initiated, manipulated, and read-out by means of optically detected magnetic resonance (ODMR) technique.

Here, I present a brief overview of the recent theoretical and experimental study of the fine structure, spin dynamics and decoherence of V_{Si} centers, as well as their applications for magnetometry and thermometry [1]. We also discuss the way to further increase the sensitivity and overcome the restrictions imposed by inhomogeneous broadening in a spin center ensemble by applying the technique of spectral hole burning in the ODMR lines [2].

1. S.A. Tarasenko, A.V. Poshakinskiy, D. Simin et al., Spin and optical properties of silicon vacancies in silicon carbide - a review, Phys. Status Solidi B **255**, 1700258 (2018).
2. V.A. Soltamov, C. Kasper, A.V. Poshakinskiy et al., Excitation and coherent control of spin qudit modes with sub-MHz spectral resolution, Nature Commun. **10**, 1678 (2019).

Sergey Ganichev



Prof. Dr. Sergey Ganichev works at Institute for Experimental und Applied Physics at the University of Regensburg, Germany. His research interests are terahertz science and technology, nonequilibrium and nonlinear effects in semiconductors, tunnelling and photoelectrical phenomena in semiconductors and semiconductor nanostructures, electron gas heating, spin physics in semiconductors, physics of graphene and topological insulators, and ratchet phenomena.

Abstract

Edge currents driven by terahertz radiation in hBN graphene in quantum Hall regime

S.D. Ganichev[1]

[1]*Terahertz Center, University of Regensburg, 93040 Regensburg, Germany*

Email: sergey.ganichev@ur.de, web site: http://www.physik.uni-regensburg.de/forschung/ganichev/

The paper overviews experimental and theoretical studies of edge photocurrents induced in graphene by polarized terahertz (THz) radiation [1-4]. In this paper we give a general introduction to the second order opto-electronic phenomena, discuss the phenomenological and microscopic theory of several phenomena as well as present the state-of-the-art of the experiments aimed to the study of terahertz radiation induced non-linear electron transport.

We present an opto-electronic method to uniquely distinguish edge from bulk scattering by exploring edge photocurrents in graphene samples illuminated by THz radiation [1-3]. For circularly polarized light the edge current is observed to form a vortex winding around the edges of the square-shaped samples. Its direction reverses upon switching the radiation helicity from left- to right-handed. Evidently, the photocurrent is caused by the local symmetry breaking at

the sample edges resulting in an asymmetric scattering of carriers driven by the radiation electric field. It gives rise to a directed electric current along the sample boundary in a narrow stripe of width comparable to the mean free path. We show that the photocurrent measurements provide direct access to electron transport at the graphene edges and allow to map the variation of scattering times along the edges.

Most recently we observe that shining of THz laser radiation on the edges of unbiased graphene in the quantum Hall regime also results in an edge direct electric current, whose origin, however, is qualitatively different from the zero- or classical- magnetic fields [4]. This photocurrent is shown to be caused by an imbalance of persistent chiral edge currents driven out of thermal equilibrium due to indirect transitions within the edge channel. The direction of the edge photocurrent is dictated by the polarity of the external magnetic field while its magnitude depends on the radiation polarization. The developed microscopic theory describes well the experimental data.

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2. M.M. Glazov and S.D. Ganichev, Physics Reports **535**, 101 (2014).
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Lyubov Kotova

Dr. Lyubov Kotova works in Laboratory of Spectroscopy of Solid State at Ioffe Institute and at Laser Photonics and Optoelectronics Faculty of ITMO University. Her research interests are related to exciton spectroscopy in bulk and nanostructures, magneto-optics of semiconductor nanostructures and polarization spectroscopy of two-dimensional crystals.

Abstract

Magnetospatial dispersion of semiconductor quantum wells

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The experimental and theoretical study of the magnetospatial dispersion (MSD) effects of semiconductor quantum wells has been carried out. MSD manifests itself in the bilinear in the in-plane components of the magnetic field and the light wave vector dependence of the optical properties. This effect induces the polarization conversion or corrections to the diagonal reflection coefficient. It's detected in different experimental geometries. Reflection from asymmetric heterostructures is studied. The reflection coefficients are measured at oblique incidence of s and p polarized light. We demonstrate that MSD exists due to structure asymmetry. Effect's microscopic description bases on bulk and structure inversion asymmetry (BIA and SIA). The exciton resonances are investigated in geometry when the magnetic field has been applied in the plane of the quantum well either parallel or perpendicular to the plane of incidence. The effect is resonantly enhanced in the vicinity of the heavy hole exciton.

We demonstrated that the microscopic mechanism of the polarization conversion is a mixing of heavy- and light-hole states in the quantum well due to both orbital effect of the magnetic field and the in-plane hole motion. Analyzing the magnetic-field dependencies of the polarization conversion amplitudes we determined the degree of structure inversion asymmetry of the studied quantum wells [1]. While corrections to the reflection coefficient are induced by BIA of III-V and II-VI semiconductor quantum wells [2].

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Sylvain Ravets

Sylvain Ravets realized his PhD jointly between the Laboratoire Charles Fabry (Institut d'Optique, Palaiseau) and the Joint Quantum Institute (University of Maryland & NIST, Washington DC), where he worked on quantum engineering using individual neutral atoms. In 2015, he joined the quantum photonics group of ETH Zürich as a postdoctoral researcher, where he worked on the physics of exciton polaritons in the quantum Hall regime. In 2017, he became a CNRS researcher and joined the photonics department of the Centre for Nanoscience and Nanotechnology (C2N), where is currently interested in the development of new synthetic quantum materials in arrays of semiconductors microcavities.

Abstract

Nonlinear optics in the fractional quantum Hall regime

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We show experiments on a two-dimensional electron system (2DES) embedded in an optical cavity, where coupling of photons to Fermi polarons leads, in the strong coupling regime, to the formation of polaron polaritons [1,2]. Under an external magnetic field, the cavity-polaron coupling depends on the 2DES filling factor, leading to nonlinear energy shifts of the polariton lines around quantum Hall states [2,3]. We perform time resolved four-wave mixing experiments on the system and demonstrate that polariton-polariton interactions are strongly enhanced when the electrons are initially in a fractional quantum Hall state [4]. Our results are particularly promising in the context of realizing of strongly interacting photonic materials.

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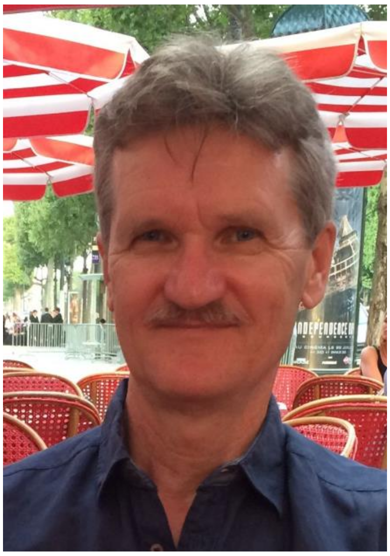
Yuri Pusep



Ph.D. in Solid State Physics at the Institute of Semiconductor Physics/Novosibirsk (1985). Post-doctoral as Fellow of the Alexander von Humboldt Fountation at the Max Planck Institute, Stuttgart (Germany) supervised by Prof. M. Cardona. Currently associate professor at the University of São Paulo. Area of research activity: magneto-transport and spectroscopy in low dimensional semiconductor systems.

Abstract

Spectroscopy of Localized and Extended States below the Fermi level

Yu. A. Pusep

Institute of Physics of São Carlos/Department of Physics and Material Sciences, University of São Paulo, 13566-590 São Carlos-SP, Brazil

Time-resolved photoluminescence is employed to examine a transition from localized to extended electron states below the Fermi level in multiple narrow quantum well GaAs/AlGaAs heterostructures, where disorder was generated by interface roughness. Such a transition resembles the metal-insulator transition profoundly investigated by electric transport measurements. Important distinction distinguishes the studied here localized-to-extended states transition: it takes place below the Fermi level in an electron system with constant concentration, which implies unchanging Coulomb correlations. A unique effect of the magnetic field on the momentum conservation rule in the presence of strong localization was observed: the magnetic-field-induced reduction of the spatial overlap of the localized electron wave functions results in a relaxation of the momentum conservation rule. Thus, time-resolved photoluminescence measurements provide insights into the evolution of the localized electron states below the Fermi level which are inaccessible with electric transport measurements. The demonstrated technique may be used as a tool to explore complicated physics related to the metal-to-insulator transition in a system with fixed disorder and Coulomb interaction.

Natalia Abrikossova

Dr. Natalia Abrikossova is a researcher at Department of Physics, Chemistry and Biology at Linköping University, Sweden. Her primary interest is related to studies of biocompatible nanoparticles to address challenging tasks within multidisciplinary projects that combine characterization of nanostructured materials with investigations of their potential biomedical applications.

Abstract

Investigations of nanoparticle-cell interactions for biocompatible applications

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Advances in fundamental understanding of materials with low dimensionality and novel technologies for synthesis of nanomaterials open exciting opportunities for their safe and efficient biomedical applications. For example, magnetic resonance imaging (MRI) contrast agents based on magnetic nanoparticles represent an efficient tool to improve image quality by enhancing the contrast between normal and diseased tissue, thereby increasing the utility of MRI [1]. Also, functionalization of the implant surface, e.g. via incorporation of nanoparticles of an average size of 500 nm or less containing an oxide of a non-toxic post-transition metal such as gallium can reduce the risk of a harmful infection caused by microbes when medical implants are in contact with living cells or tissues [2]. However, multiple preclinical and clinical studies, including studies in animal models and long-term toxicity studies, are required to proof the biocompatibility of the newly designed nanoparticles. Thus, the development of methodologies for efficient evaluation and improvement of biomedical performance of novel nanoparticles at the initial stages of their design is of primary importance. Evaluation of the biocompatibility of the newly designed nanoparticles is a complex process. A promising path presented in this work is to start with studies of nanoparticle interactions with isolated blood

cells [3]. In particular, the effect of sorbitol on the performance of Gd-oxide nanoparticles (GdNPs) as MRI contrast agents has been investigated. The results show that the presence of sorbitol as capping layer on GdNPs clearly improves the nanoparticle performance and biocompatibility [3]. At present, we are investigating the effect of the Ga_2O_3 nanoparticles on the viability of neutrophils with more conventional cytotoxicity assays.

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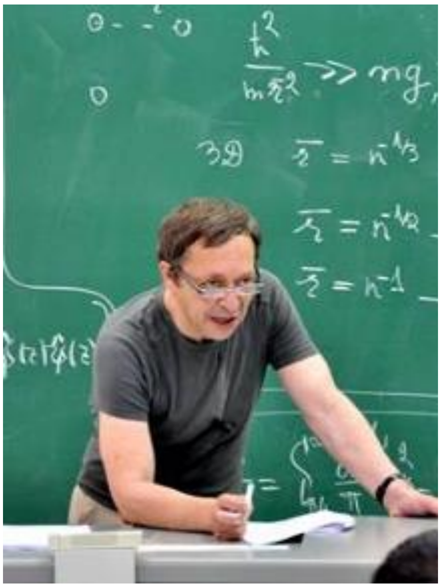
Georgy Shlyapnikov



Prof. Georgy Shlyapnikov is a famous physicist in the field of many-body physics. He is a head of the research group of the Russian Quantum Center, Director of research in the Laboratory of Theoretical Physics, National Center for Scientific Research of France.

Abstract

New trends in nanophysics with cold atoms

G. Shlyapnikov

Russian Quantum Center, Moscow Russia

LPTMS, CNRS, Univ. Paris Sud, Orsay, France

I will discuss novel results in the physics of ultracold atoms, focusing on atoms in disordered potentials. The overview will start with the first observation of Anderson localization in cold atom clouds and address the key question of the influence of interparticle interaction on localization properties. I then turn to the issue of possible disorder-related phase transitions and show that, aside from the famous Anderson localization-delocalization transition, there can be one more phase transition, namely ergodic-nonergodic transition between delocalized (conducting) states.

Hadiseh Alaeian

Hadiseh Alaeian is a group leader at the 5th Institute of Physics, University of Stuttgart, Germany. Her interdisciplinary research interest is along the interface of atomic physics and nano-photonics. There, she aims to combine the interesting features of atoms as identical quantum emitters and the controllable electromagnetic fields of nano-photonic devices to engineer atom-atom and photon-photon interactions in a unique and powerful scheme.

Abstract

Hybrid Atomic-Photonics: New Paradigm for Integrated Quantum Optics

Hadiseh Alaeian

5 Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Atoms with narrow-line resonances play a major role in high precision measurements like magnetometry and atomic clocks. Due to their long inherent coherence time, atoms can serve as quantum memories as well. Moreover, as they possess well-defined electronic levels, coherent interactions with the photon fields can be used to manipulate their quantum states very precisely. Besides, the capability of the optical excitation and read out, increase the spatial resolution of the atomic sensors. Within the last couple of decades interfacing atoms with engineered confined light fields has been a proper playground for investigating various quantum-electrodynamical effects. So far different strategies have been utilized successfully to integrate atoms with a confined light field, for example in high-finesse optical cavities, hollow core fibers, and tapered nanofibers.

While cold atom setups provide ideal conditions and controllability to explore different coupling regimes, the large setups required to cool and trap the atoms have hindered their scalability for any realistic quantum networks. Thermal vapors, on the other hand, allow for less precision and control, but their low technical complexity and suitable compatibility with miniaturization and integration make them a promising candidate for realizing scalable networks.

In this talk, I review our recent results on integrated thermal vapors with engineered light fields. Since the velocity of the atoms in a thermal vapor limits their coherence times a larger coupling rate is required to control the atoms efficiently. To achieve a larger Rabi frequency while still having reasonable laser power we have used Nano-photonic devices with tightly-focused electromagnetic fields and small mode-volumes. In particular, we have investigated the interaction between atomic transitions in the thermal vapor of rubidium (Rb) and optical modes of Si_3N_4 waveguides, ring resonators, and Mach-Zehnder interferometers. Moreover, I will briefly introduce the Monte-Carlo simulation method that has been developed in our group to model the interaction of the atoms with the device by properly incorporating the surface effects via Casimir- Polder potentials. In addition to the tailored atom-light manipulations, strong atom-atom interactions in particular between Rydberg atoms can be used to realize quantum devices and strong nonlinearities. Utilizing these features, we demonstrate a completely new single-photon source that benefits from four-wave mixing and Rydberg blockade to generate single photons in an on-demand time window. Besides, I will present some of our most recent results on two-photon spectroscopy and its potential and promise for compatibility with the well-established silicon photonics technology. The talk will be concluded with some of our ideas and perspectives for using this platform for cavity QED studies and devising new schemes for investigating atom-atom interactions in a low-dimensional light field.

Nina Voronova

Dr. Nina Voronova works since 2014 as associate professor at National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), currently at the department of Theoretical Physics. Her field of research and expertise embraces collective phenomena with excitons and microcavity exciton-polaritons, photon condensates, including topological defects, Josephson phenomena, and superfluidity.

Abstract

High-Tc direct exciton Bose condensation

Nina Voronova

National Research Nuclear University MEPhI, Moscow, Russia

In this work, we theoretically predict the possibility to observe superfluid state and Bose-Einstein condensation in a gas of two-dimensional direct excitons at elevated temperatures in a single quantum well, thanks to the dramatic increase of their lifetime in the off-resonant cavities that strongly suppress exciton radiative decay. We consider single GaAs quantum wells of different thicknesses embedded in a layered medium and show that exciton lifetimes in such heterostructures can be of the order of 150 ns, depending on the number of layers. With the use of quantum hydrodynamic approach, we find critical temperatures of Berezinskii-Kosterlitz-Thouless crossover as high as 4.8 K and 18.8 K for two different considered geometries. With the appearance of quasi-condensed fraction as the system is cooled below Tc, the intensity of luminescence from the structure (along direction normal to the layers) is shown to exhibit a manyfold increase that can be observed experimentally. The work is financially supported by the Russian Foundation for Basic Research grant No. 18-32-20180.

Boris Altshuler

Boris Altshuler is a professor of physics at Columbia University. His research includes different theoretical aspects of condensed matter physics. He is particularly famous for his work on disordered electronic systems and for his contribution to the theory of universal conduction fluctuations. He has pioneered the new field of many-body localization.

Igor Lukyanchuk

Prof. Igor Lukyanchuk got his Ph.D. 1990 in Theoretical and Mathematical Physics at a well-known L. D. Landau Institute for Theoretical Physics, Moscow, Russia. Since 2001 he has a professor position at Jules Verne University of Picardy, Amiens, France. His broad research interests are focused on different scientific fields including phase transition, superconductivity, nanostructures, nanotechnologies, 2D materials etc. One of the most important results is discovery of the electronic state "Dirac Fermion" in Graphite.

Abstract

Ferroelectrics at the nanoscale: negative capacitance, multi-bit logic, topology, and knotting

Igor Lukyanchuk

Université de Picardie, France

A pressing quest for overcoming Boltzmann tyranny in low-power nanoscale electronics ignited an extensive search for the devices possessing the negative circuit constants. The emergent concept of the ferroelectric-based negative capacitance triggered then the explosive activity in the field. However, most of the research addressed transient negative capacitance, leaving the basic question of the existence of the steady-state negative capacitance unresolved. Here, we show that the ferroelectric nanodot capacitor hosts a stable two-domain state realizing the static reversible negative capacitance device thus opening routes for the extensive use of the negative capacitance in domain wall-based nanoelectronics [1].

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Andrey Varlamov

Andrey Varlamov is a Research Director of the SPIN-CNR (Institute for Superconductivity and Innovative Materials of the Italian National Research Council, Rome, Italy). In 2009 he became a Corresponding Member of Italian Accademia di Scienze e Lettere "Brera". Andrey Varlamov is a well-known scientist in the field of theory of superconductivity, theory of phase transitions and condensed matter physics. The most important results Andrey Varlamov achieved in theory of fluctuations in superconductors, theory of superconductivity, theory of electronic topological transitions, heat transport in metals and superconductors.

Andrey Varlamov is an author of the monograph "Theory of Fluctuations in Superconductors", seven review articles, and more than 170 scientific papers. Andrey Varlamov also devotes a lot of time to popularization of physics. His popular-science book "The Wonders of Physics" in its first version was published in 1987 and during the following 30 years has been published in sixteen editions in eight languages. His article "The physics of baking good pizza" written in collaboration with Andreas Glatz and Sergio Grasso became bestseller of 2018.

Abstract

Detection of topological phase transitions through entropy measurements

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The entropy per particle is an important characteristic of any many body system that tells how the entropy of the ensemble of electrons changes if one adds one more electron. Recently, it has been demonstrated how the entropy per particle of a two-dimensional electron gas can be

extracted from the recharging current dynamics in a planar capacitor geometry. These experiments pave the way to the systematic studies of entropy in various crystal systems including novel two-dimensional crystals such as gapped graphene, germanene and silicene. Theoretically, the entropy per particle is linked to the temperature derivative of the chemical potential of the electron gas by the Maxwell relation. Using this relation, we calculate the entropy per particle in the vicinity of topological transitions in various two-dimensional electronic systems. We show that the entropy experiences quantized steps at the points of Lifshitz transitions in a two-dimensional electronic gas with a parabolic energy spectrum [1]. In contrast, in doubled-gapped Dirac materials, the entropy per particles demonstrates characteristic spikes once the chemical potential passes through the band edges [2]. The transition from a topological to trivial insulator phase in germanene is manifested by the disappearance of a strong zero-energy resonance in the entropy per particle dependence on the chemical potential [3]. We conclude that studies of the entropy per particle shed light on multiple otherwise hidden peculiarities of the electronic band structure of novel two-dimensional crystals.

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Daoud Mezzane

Prof. Daoud Mezzane works in Laboratoire de la Matière Condensée et Nanostructures (LMCN) at Cadi Ayyad University, Marocco. Main research interests of Prof. Mezzane are related to design and studies of functional ceramics with different dielectric and ferroelectric properties.

Abstract

Very-low temperature synthesis of pure and crystalline lead-free BCZT ceramic for energy storage

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[a] *LMCN, Cadi Ayyad University, Marrakesh, 40000, Morocco,*

[b] *Faculty of Physics, Southern Federal University, Rostov-on-Don, 344090, Russia*

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Lead-based ferroelectric materials, such as $Pb(Zr,Ti)O_3$ (PZT) have been widely studied as a potential technological materials in electrical energy storage [1]. Nevertheless, the high toxicity of lead can pollute environment, cause damage to brain and nervous system. Thus, due to environmental concern, an intensive research has been conducted to find the appropriate alternative to lead-based materials. A promising category of lead-free ceramic is the perovskite barium titanate ($BaTiO_3$). Moreover, $BaTiO_3$ is a bioceramic witch not contain any toxic or volatile element, and its properties can be easily tailored by site engineering. Based on this last characteristic, introducing new elements into the crystal lattice of $BaTiO_3$ can enhance the ferroelectric, dielectric and piezoelectric properties of these materials [2].

W. Liu and X. Ren have reported non-Pb ceramics of $Ba_{0.85}Ca_{0.15}Zr_{0.1}Ti_{0.9}O_3$ with high dielectric constant (18 000) and piezoelectric coefficient (620 pC/N) [3]. This promising finding has created a great interest around site-doping, phase's transitions, morphological engineering and sintering processes to develop BCT-BZT ceramic with highly enhanced ferroelectric and piezoelectric properties [4]. Although, the most of these studies have suffered from high-energy consumption, contamination or production scale.

In this study, we reported for the first time a new strategy for the synthesis of pure and crystalline BCZT lead-free ferroelectric powders at very low temperature (80 °C) (Fig. 1). The effects of the preparation temperature on the structure, crystallinity, purity, morphology, particles size distribution and dielectric properties of BCZT ceramics were studied [5].

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Alexey Kavokin

Alexey Kavokin is a Professor at the University of Southampton, UK and a Chair Professor and Director of the International Center for Polaritonics at the Westlake University, Hangzhou, China. He is a co-founder of the Mediterranean Institute of Fundamental Physics. He has more than 300 publications in peer-reviewed international scientific journals, including Science, Nature, Nature Physics, Nature Photonics, Nature Communications, Nano Letters, Physical Review Letters etc; He has more than 10000 citations and his h-index is 48. Besides his famous theoretical work in the field of light-matter interaction in solids, he is well-known for his novels, most famous is about adventures of "Saladin the Cat".

Abstract

Polariton Qubits

Alexey Kavokin

Westlake University, China

Polaritonics is an interdisciplinary research area at the boundary of optics and solid state physics. It is aimed at the studies of light-matter interaction and dynamics of exciton polaritons, or, shortly, polaritons: quasiparticles with bosonic statistics formed as a result of the light-exciton coupling. Nowadays, polaritonics represents an indispensable tool for investigation of quantum coherent and nonlinear phenomena occurring at the matterfield interface in various area of condensed matter physics, quantum and atom optics. Here, we propose a novel physical mechanism for the creation of long-lived macroscopic exciton-photon qubits in semiconductor microcavities with embedded quantum wells in the strong coupling regime. The polariton qubit is a superposition of lower branch and upper branch exciton-polariton states. We argue that the coherence time of Rabi oscillations can be dramatically enhanced due to their stimulated pumping from a permanent thermal reservoir of polaritons. We discuss applications of such qubits for quantum information processing, cloning, and storage purposes.

Evgeny Sedov

Dr. Evgeny Sedov has got his Ph.D. degree in Physics and Mathematics from the Prokhorov General Physics Institute of the Russian Academy of Sciences in 2015. Since 2016, he has been conducting research as a Research Fellow at the University of Southampton, UK. His study is focused on the problem of interaction of light with condensed matter at the microscopic level aimed in understanding of physics of light behaviour and developing methods of control of light. The most remarkable topics of his research are coherent and nonlinear properties of atomic and exciton polaritons in 2D polaritonic crystal structures, light manipulation in semiconductor hyperbolic metamaterials, spin-orbital effects in polaritonic structures, conductivity and superconductivity in mixed Bose-Fermi systems.

Abstract

Extrinsic spin-orbit coupling of exciton-polaritons in microcavities

Irina Sedova[1], Evgeny Sedov[1,2], Yuri Rubo[3], Sergey Arakelian[1] and Alexey Kavokin[4,5]

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The concept of polariton devices is based on manipulation by macroscopic coherent states of quasiparticles exciton-polaritons appearing under the strong coupling of excitons in semiconductor crystals with quantized light in optical microcavities. Polaritons inherit a spin degree of freedom from both their constituents which gives access to polarization properties of the emitted light. The effect of the spin-orbit coupling in polariton systems is that the internal degree of freedom of polaritons describing their polarization is able to influence external degrees of freedom associated with their macroscopic behavior. The influence is mutual. We theoretically predict the effect of appearance of unexpected oscillations in space of a trajectory of a polariton wave packet under the influence of its spin degree of freedom. We propose a novel photonic device, the polariton polarization rectifier, which allows to transform polariton pulses with arbitrary polarization to linearly polarized pulses. It is based on the interplay between the orbital motion of polaritons and the dynamics of their pseudospin.

Christophe Salomon

Christophe Salomon is research Director at CNRS, member of the Kastler Brossel laboratory at the Ecole Normale Supérieure in Paris, and member of the French Academy of Sciences.

A renowned specialist of laser cooled and trapped atoms, Christophe Salomon has studied quantum properties of Bose and Fermi gases at nanokelvin temperatures, in particular matter wave solitons, fermionic superfluidity, and Bloch oscillations. Ultracold gases are extremely well controlled systems that enable to test theoretical models in many-body physics, which are often developed to understand the properties of electrons in solids or of nuclear matter. Christophe Salomon also developed applications of cold atoms to the measurement of Time. In the frame of the European space project ACES/PHARAO, he is involved in ultrastable clocks on Earth and in space, and tests of fundamental physics and General Relativity.

Abstract

Quantum simulation with ultracold fermions

Christophe Salomon

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The quantum simulation program was introduced by Richard Feynman in a 1981 visionary paper. In these early days of computers, Feynman raised the simple but profound question: can one simulate a collection of interacting quantum systems with computers? Noticing the exponential growth of the Hilbert space with the number of particles, Feynman suggested to realize analog quantum simulators to gain information on complex many-body physics

problems. These are ubiquitous in Nature, and encountered in condensed matter systems, nuclear physics and neutron stars, as well as in high energy physics. In the recent years, a variety of experimental platforms for quantum simulation have been developed using trapped ions, superconducting circuits, polaritons or cold neutral atoms.

In this presentation, we will give two examples of quantum simulation with cold dilute gases. The first one will address the problem of superfluidity in spin ½ fermions with attractive and tunable contact interaction. We have made precision measurements of the equation of state (EoS) of the gas in the crossover between BCS pairing and the Bose-Einstein condensation of strongly bound fermion pairs. This EoS reveals beyond mean field effects and universal thermodynamics in the unitary limit where the scattering length diverges [1,2].

Second, we will describe the first production and study of a novel quantum system, a mixture of Bose and Fermi superfluids. Such a mixture had long been sought in liquid helium where superfluidity was only achieved separately in bosonic ^{4}He and fermionic ^{3}He. Using dilute quantum gases where interactions can be tuned, we have produced a Bose-Fermi mixture where both species are in the superfluid state [3]. By exciting center of mass oscillations of the mixture we probe the equation of state of the strongly correlated Fermi gas. The superfluid counterflow exhibits very small damping below a certain critical velocity [4]. This velocity is surprisingly high and is compared to a recent theoretical prediction [5]. Finally the lifetime of the Bose-Fermi mixture is governed by a very simple formula involving the fermionic two-body contact [6].

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Abstract

Rectification of photonic heat transport across superconducting circuits

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By integrating the tools of ultra-sensitive microwave bolometry with those of superconducting circuits, we have experimentally realised tunable photonic heat transport between mesoscopic thermal baths embedded in superconducting resonators, interfaced with a superconducting artificial atom (qubit). In the system with symmetric resonators, the flux-tunable transport depends on the role of the various coupling elements[1]. While the system with asymmetric resonators yields a rectification based on the direction of transport[2].

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Vladimir Kuznetsov

Vladimir Kuznetsov graduated from Moscow Institute of Physics and Technology in 2017, and he is now pursuing his PhD at the Higher School of Economics under supervision of Leonid Kulik. His research interests are related to optical spectroscopy of collective excitations in 2DEG in quantum Hall regime.

Abstract

Nonequilibrium Spin Polarization at Filling Factor of 3/2

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Interest in the physics of even-denominator fractional states is one of the modern trends in the study of the fractional quantum Hall effect. Except for the physical phenomena associated with the spatial anisotropy of the electron density distribution for even fractional states at Landau levels with large numbers (striped phases [1]), the even-denominator fractional states can be described in terms of the interaction of a pair of composite fermions (bound states of electrons and magnetic flux quanta) with the formation of composite bosons [2]. Such pairs turn out to be weakly bound, which determines ultralow temperatures for observing the even-denominator fractional states.

Surprisingly, 5/2 quantum Hall state was discovered prior to 3/2 state which is more simple and stable at first glance. First observation of 3/2 state required fine-tuning of Zeeman splitting energy in high-mobility ZnO/MgZnO heterostructures. When the electron system becomes spinpolarized, the formation of a 3/2 plateau in the Hall resistance is observed [3]. Despite this fact, resent magnetotransport experiments showed similar results in GaAs/AlGaAs heterostructures with the modified edge states [4]. Most likely, 3/2 state is formed in the bulk much often but special measured needed to observe this state in transport measurements.

We used optical methods of photoluminescence, resonance light reflection, and photoinduced light reflection as a probe for 3/2 state. One of the most interesting results is the existence of nonequilibrium spin excitations in a presence of optical pump (Fig. 1). Similar excitations were investigated near the filling factor of 2 [5]. In contrast to filling factor of 2, 3/2 excitations survive partial spin polarization of the ground state which makes us a hint on a local order in the ground state. The local order may exhibit similar behavior: both spin states in the lowest Landau level are filled, except for a single vacancy in the upper spin sublevel. Furthermore, the lifetime of spin excitations reaches 10 us [6]. Spin excitations also change the luminescence spectrum drastically, possibly due to nontrivial dispersion at fractional filling factor. We also propose numerical simulation of the ground state and spin excitations at filling factor of 3/2.

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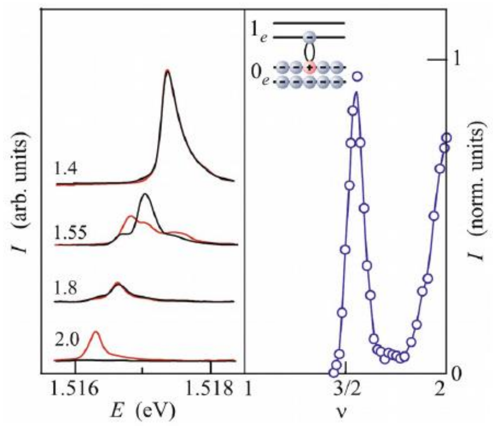

Fig. 1 (Left panel) Spectra of (black solid lines) resonant and (red solid lines) photoinduced resonant reflection including optical transitions from the lowest Landau level of the heavy hole valence band to the lowest Landau level of the conduction band of the quantum well at different filling factors for the two-dimensional electron system. (Right panel) Integral of the absolute value of the difference in intensities of the photoinduced resonant and resonant reflection lines versus the electron filling factor.

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Prof. Galia Pozina works at Department of Physics, Chemistry and Biology at Linköping University in the field of Material Physics. She has more than 20-years long experience in development of different materials for optoelectronic and electronic applications, such as efficient III-N LEDs or high frequency high power transistors and has both academic and industrial background. Galia Pozina has a long-term collaboration and more than 40 common papers with the Nobel Prize laureates in Physics 2014 Prof. I. Akasaki and Prof. H. Amano awarded for their input in development of efficient blue LEDs.

Abstract

Super radiance in a periodic structure composed of InAs monolayers embedded in a GaAs matrix

G. Pozina

Control over spontaneous emission rate is important for improving efficiency in different semiconductor applications including lasers, LEDs and photovoltaics. Usually, an emitter should be placed inside the cavity to increase the spontaneous emission rate, although it is technologically challenging. Here we experimentally demonstrate a phenomenon of super-radiance observed in a cavity-less periodic Bragg structure based on InAs monolayer-thick multiple quantum wells (MQW). The collective super-radiant mode shows enhanced emission rate for specific angles and frequencies. This behaviour correlates with the calculations demonstrating individual spots of the enhanced Purcell coefficient near the Bragg condition curve.