Nonlinear spin and charge transport through nanoscopic systems

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Programme and book of abstracts

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“Nonlinear spin and charge transport through nanoscopic Systems”

Mallorca, June 6-9, 2011

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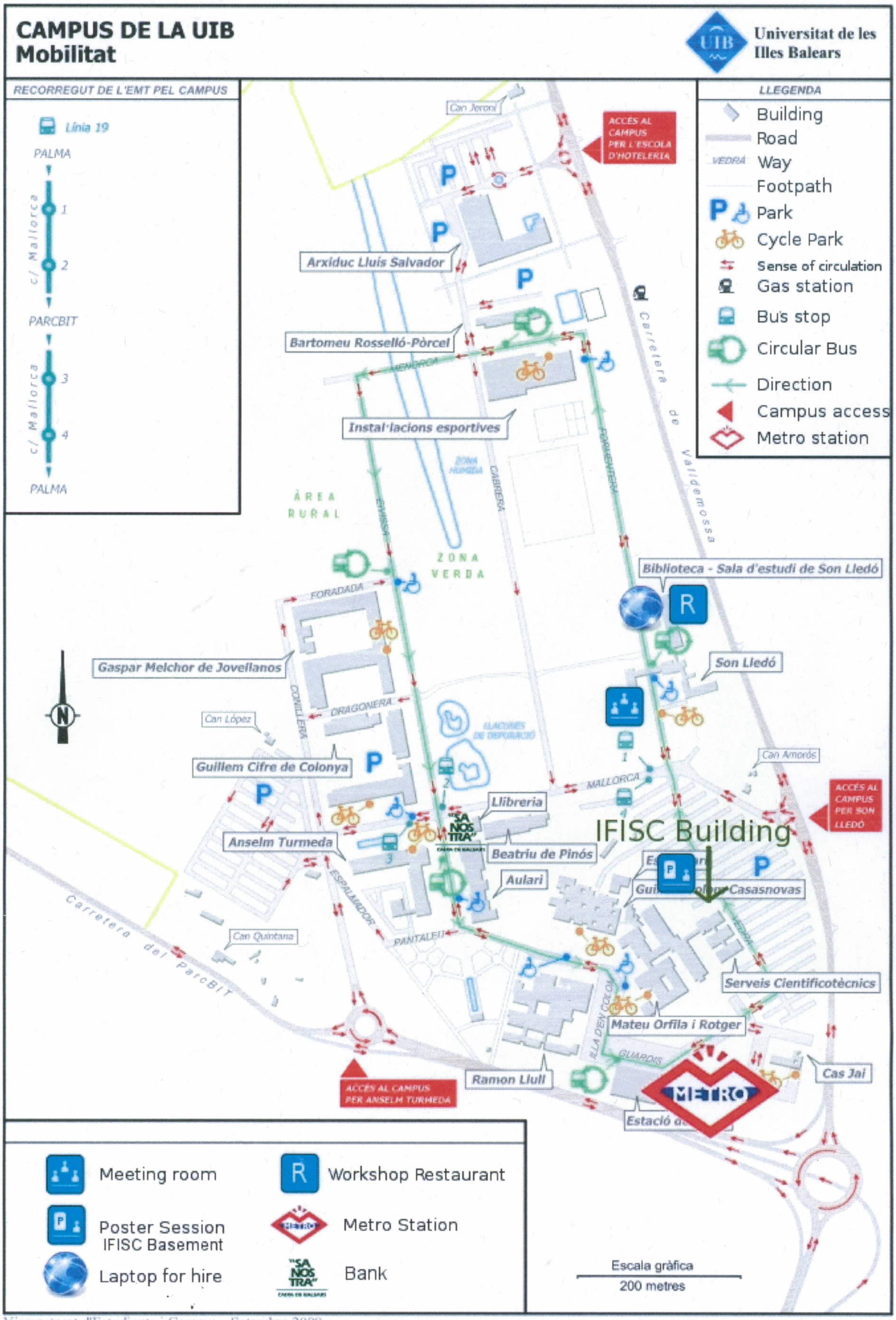

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TRANSPORT Programme

Nonlinear spin and charge transport through nanoscopic systems
Mallorca, June 6-9, 2011

SUNDAY

18:00-20:00	Reception

MONDAY

09:00	Opening
Chair Person	Rolf Haug
09:15	**Markus Buttiker** *Rectification and fluctuations relations in electrical conductors*
09:50	**Lukas Worschech** *Nonlinear transport and logic operations with nanoelectronic devices*
10:25	**Raúl Toral** *Fluctuation-dissipation relation in a random-field model*
11:00	Break
Chair Person	Bogdan Bulka
11:30	**Laurent Saminadayar** *Kondo effect in side-coupled quantum dots*
12:05	**Gergely Zarand** *Spin current noise spectra of interacting quantum dots*
12:40	**Sabine Andergassen** *Dynamical transport in correlated quantum dots: a renormalization-group analysis*
13:15	Lunch
Chair Person	Klaus Ensslin
15:00	**Yuli Nazarov** *Half-Josephson Laser*
15:35	**Audrey Cottet** *Inducing triplet superconducting correlations in a normal metal wire*
16:10	**Hongqi Xu** *Spin States, Spin Correlations, Supercurrent, and Multiple Andreev Reflections in InSb Nanowire Quantum Devices*
16:45	Return
20:00	Dinner

TUESDAY

Chair Person	Markus Buttiker
09:15	**Klaus Ensslin** *Transport through hybrid quantum dots*
09:50	**Tobias Brandes** *Feedback Control of Quantum Transport*

10:25	**Joerg P. Kotthaus** *Nonequilibrium interactions between GaAs-based quantum devices*
11:00	Break
Chair Person	Luis Bonilla
11:30	**Antti-Pekka Jauho** *Transport in graphene antidot lattices*
12:05	**Maura Sassetti** *Local Franck-Condon factors in suspended carbon nanotubes quantum dots*
12:40	**Guido Burkard** *Spin and valley control in carbon quantum dots*
13:15	Lunch
Chair Person	Gloria Platero
15:00	**Javier Tejada** *Magnetic Deflagration*
15:35	**Takis Kontos** *Dynamic response of a Kondo dot in a photonic cavity*
16:10	**Pascal Simon** *Nuclear spin ordering and Majorana edge states in interacting one-dimensional systems*
16:45	Return
20:00	Dinner

WEDNESDAY

Chair Person	Maura Sassetti
9:15	**Rolf Haug** *Spin Effects in Transport through Quantum Dots*
9:50	**Bogdan Bulka** *Spin Stark effect in nanostructures*
10:25	**Mircea Crisan** *Effect of electron-phonon interaction on non-equilibrium transport through single molecular dot in the Coulomb blockade regime*
11:00	Break
Chair Person	Tobias Brandes
11:30	**Luis Bonilla** *Spatially confined Bloch oscillations in semiconductor superlattices*
12:05	**Janine Splettstoesser** *Charge and spin dynamics of an interacting quantum dot*
12:40	**Gloria Platero** *Topology and phase: two ways to control the coherent dynamics of electrons*
13:15	Lunch
Chair Person	Tobias Brandes
15:00	**Jaroslav Fabian** *Spin-orbit coupling in nanostructures*
15:35	Poster Session

17:15	Return
20:00	Banquet

THURSDAY

Chair Person	Yuli Nazarov
9:15	**Hans W. Schumacher** *Semiconductor based quantized current and voltage sources*
9:50	**Mykhailo Moskalets** *Mesoscopic circuits with single-electron sources*
10:25	**Peter Samuelsson** *Proposal for non-local electron-hole turnstile in the Quantum Hall regime*
11:00	Break
Chair Person	Hongqi Xu
11:30	**Fabio Taddei** *Josephson quantum electron pump: theory and experiment*
12:05	**Ramon Aguado** *Josephson current in carbon nanotubes with spin-orbit interaction*
12:40	**Jan Martinek** *Molecular spintronics: Spin polarized transport through quantum dots and molecules*
13:15	Lunch
15:00	Departure

Ramon Aguado

CSIC - ICMM
Spain

Josephson current in carbon nanotubes with spin-orbit interaction

We demonstrate that curvature-induced spin-orbit (SO) coupling induces a $0-\pi$ transition in the Josephson current through a carbon nanotube quantum dot coupled to superconducting leads. In the non-interacting regime, the transition can be tuned by applying parallel magnetic field near the critical field where orbital states become degenerate. Moreover, the interplay between charging and SO effects in the Coulomb Blockade and cotunneling regimes leads to a rich phase diagram with well-defined (analytical) boundaries in parameter space. Finally, the 0 phase always prevails in the Kondo regime. Our calculations are relevant in view of recent experimental advances in transport through ultra-clean carbon nanotubes.

Sabine Andergassen

RWTH Aachen University - Institute for Theory of Statistical Physics
Germany

Dynamical transport in correlated quantum dots: a renormalization-group analysis

We present results for the nonlinear transport and the time evolution into the stationary state for two minimal models for quantum dots: the interacting resonant level model describing a dot dominated by charge fluctuations, and the Kondo model for a dot with spin fluctuations. Using recently developed renormalization-group approaches in non-equilibrium, the analytical solution of the corresponding flow equations allows to identify the microscopic cutoff scales that determine the relaxation and decoherence rates. Exploring the entire parameter space we find rich non-equilibrium physics which cannot be understood by simply considering the bias voltage as an infrared cutoff. The relaxation dynamics towards the steady state features characteristic voltage-dependent oscillations as well as an interplay of exponential and power-law decay.

Francesca Battista

Lund University - Lund University
Sweden

Proposal for non-local electron-hole turnstile in the Quantum Hall Regime

We present a theory [1] for a mesoscopic turnstile that produces spatially separated streams of electrons and holes along edge states in the quantum Hall regime. For a broad range of frequencies in the non-adiabatic regime the turnstile operation is found to be ideal, producing one electron and one hole per cycle. The accuracy of the turnstile operation is characterized by the fluctuations of the transferred charge per cycle. The fluctuations are found to be negligibly small in the ideal regime. [1] F. Battista, P. Samuelsson, PRB 83, 125324 (2011).

Christian Bergenfeldt

Lund University - Mathematical physics
Sweden

Electron transport through a quantum dot in a microwave transmissionline resonator

We investigate theoretically the electronic transport through a quantum dot coupled to a transmissionline microwave cavity. Within the framework of circuit quantum electrodynamics we derive a cavity-dot Hamiltonian for arbitrary strong coupling between the dot and the cavity. The dot is tunnel coupled to electronic reservoirs and the coherent dynamics of both the dot charge and cavity photons is described by a quantum master equation. The full statistics of the transferred electrons is investigated, with the focus on current and noise. Both few-level dots and metallic dots, single electron transistors, are described by the theory. We also investigate the state of the cavity modes. We find signatures in current, noise and in the cavity state of non-equillibrium electron-boson dynamics. In particular we find signatures in the current of coherences between degenerate photon states of the cavity.

Luis Bonilla

Universidad Carlos III de Madrid - G. Millan
Spain

Spatially confined Bloch oscillations in semiconductor superlattices

In a semiconductor superlattice with long scattering times, damping of Bloch oscillations due to scattering is so small that convective nonlinearities may compensate it and Bloch oscillations persist even in the hydrodynamic regime. In this case, numerical solutions show that there are stable Bloch oscillations confined to a region near the collector with inhomogeneous field, charge, current density and energy density profiles. These Bloch oscillations disappear as damping due to inelastic collisions becomes sufficiently strong.

Tobias Brandes

TU Berlin - TU Berlin
Germany

Feedback Control of Quantum Transport

Monitoring quantum systems during their time evolution usually introduces extra noise, but it also provides information that can be used to control the system dynamics. In this talk, I will discuss three models for closed-loop control of charge qubit states and of quantum transport through nanoscale structures. The first model is a scheme where a time-dependent signal is used to continuously adjust tunnel rates or energy levels. An error charge determines whether to speed up or slow down the transport process -- a form of feedback that is analogous to the centrifugal governor used, e.g., in thermo-mechanic machines like the steam engine. It generates a new kind of full counting statistics (FCS) where all the cumulants except the first are frozen in at large times. The second model is based on an instantaneous modification of quantum jumps by feedback loops that upgrade the FCS counting fields to super-operators in the underlying quantum master equation. A charge qubit is coupled to a detector (single electron dot and quantum point contact) . A feedback loop conditioned upon the detector signal can then be used to prepare pure, stationary qubit states. The third model applies the Wiseman-Milburn scheme to single electron transport through a double quantum dot. With an appropriate choice of feedback parameters, the FCS signal collapses to that of a single level dot and again pure stationary qubit states can be generated.

Bogdan Bulka

Polish Academy of Sciences - Institute of Molecular Physics
Poland

Spin Stark effect in nanostructures

We would like to present studies of the Stark effect on electronic structure in molecules and coherently coupled quantum dots. Our interest is focused on influence of an electric field on the spin system and on switching processes between different spin configurations. The studies are performed within the Hubbard model taking into account strong electron correlations. Using a canonical transformation we explicitly derive exchange couplings in an effective spin Hamiltonian. We show that the electric field can induced a singlet-triplet transition in triple quantum dots and in triangular molecules. The singlet-triplet switching results from competition between direct and super-exchange processes. Moreover we consider the case with three electrons (spins) in the system for which dark spin states can occur. The dark state can be formed either from a singlet state or two triplet states by adding third electron to unoccupied dot. The added spin is then uncoupled from the others. We present also a linear and nonlinear spin Stark effect, i.e. influence of the electric field and its orientation on spin-spin correlations. The model is also applied for studying electronic transport. Since electron transfer rates are anisotropic, the current characteristics are anisotropic as well, differing for small and large electric fields. We show how the singlet-triplet transition and the dark spin state can be observed in measurement of electric current.

Guido Burkard

University of Konstanz - University of Konstanz
Germany

Spin and valley control in carbon quantum dots

Nanostructures based on carbon have emerged as an interesting alternative material for spin qubits, due to both the low concentration of nuclear spins and relatively weak spin-orbit coupling. However, the formation of quantum dots in graphene is a non-trivial task due to the absence of a band gap and the related effect of Klein tunneling [1]. Interestingly, electrons in carbon-based quantum dots comprise a degree of freedom in addition to spin: The existence of two Dirac cones in the graphene band structure leads to the valley degree of freedom which can be coherently manipulated with oscillatory fields in a similar way as the spin in electron sipn resonance (ESR). We describe this electron valley resonance (EVR) and its detection in a transport measurement [2]. The valley degeneracy also enters the hyperfine interactions with remaining 13C nuclear spins as well as non-magnetic atomic impurities and plays an important role in the spin-valley blockade effect in double quantum dots formed in a carbon nanotube [3]. [1] B. Trauzettel, D. Bulaev, D. Loss, and G. Burkard, Nature Phys. 3, 192 (2007). [2] A. Pályi and G. Burkard, Phys. Rev. Lett. 106, 086801 (2011). [3] A. Pályi and G. Burkard, Phys. Rev. B 80, 201404 (2009); ibid. 82, 155424 (2010).

Maria Busl

ICMM CSIC - ICMM CSIC
Spain

Spin-polarized currents in double and triple quantum dots driven by ac magnetic fields

We analyze transport through both a double quantum dot and a triple quantum dot with inhomogeneous Zeeman splittings in the presence of crossed dc and ac magnetic fields. We find that strongly spin-polarized current can be achieved by tuning the relative energies of the Zeeman-split levels of the dots, by means of electric gate voltages: depending on the energy-level detuning, the double quantum dot works either as spin-up or spin-down filter. We show that a triple quantum dot in series under crossed dc and ac magnetic fields can act not only as spin filter but also as spin inverter.

Markus Buttiker

University of Geneva - Department of Theoretical Physics
Switzerland

Rectification and fluctuations relations in electrical conductors

Rectification and fluctuations relations in electrical conductors Markus Buttiker Université de Genève Typically electrical conductors rectify: the current-voltage characteristic contains even powers of voltage. The leading order term is second order in voltage. In recent years there has been much interest in the magnetic field symmetry of rectification coefficients: for a two-terminal conductor the conductance is an even function of magnetic field (an Onsager symmetry) but the second order rectification coefficient can have a contribution which is odd in magnetic field. Theory predicts that an odd contribution is a consequence of interaction. Such an odd contribution has been seen in a number of experiments in mesoscopic structures. At higher magnetic fields such a contribution can occur in classical systems. Of interest is the connection between rectification properties of an electrical conductor and its noise. We discuss a higher-order fluctuation dissipation relation [1-4] which relates the rectification coefficient to the derivative with respect of voltage of the noise and to the third cumulant of the equilibrium noise und discuss initial experiments. [1] H. Forster and M. Buttiker, PRL 101, 136805 (2008). See also arXiv: 0903.1431.; [2] D. Sánchez, Phys. Rev. B 79, 045305 (2009) [3] R. Sanchez, R. Lopez, D. Sanchez, and M. Buttiker, PRL 104, 076801 (2010). [4] K. E. Nagaev, O. S. Ayvazyan, N. Yu. Sergeeva, M. Buttiker, PRL 105, 146802 (2010)

Fabio Cavaliere

DIFI - Università di Genova
Italy

Transport properties of suspended carbon nanotubes

When electrons tunnel through a quantum dot embedded into a suspended carbon nanotube (CNT), quantized vibrational modes (vibrons) can be excited. In such systems, vibrons couple both to the total dot charge and to electron density fluctuations. However, the most common description of such a system, the Anderson-Holstein (AH) model, takes only into account the coupling of vibrons to the total charge. It gives rise to position-independent Franck-Condon (FC) factors and to the FC blockade phenomenon. In this work it will be shown that density fluctuations play a crucial role, especially when the size and location of the dot and of the vibron do not coincide. Position-dependent FC factors arise for a vibron smaller than the quantum dot, in sharp contrast with the predictions of the AH model. These position-dependent FC factors have profound consequences on the transport properties of suspended CNTs, which will be illustrated for both the lateral-contact geometry and for the case of tunneling via a STM tip.

Audrey Cottet

CNRS - Ecole Normale Supérieure
France

Inducing triplet superconducting correlations in a normal metal wire

Recently, the possibility of inducing triplet superconducting correlations with spin one in hybrid superconducting/ferromagnetic structures has been investigated theoretically and experimentally. Most of the features explored so far are quantitative. For example, it has been observed that, in certain conditions, ferromagnets can sustain a supercurrent on a much longer lenghtscale than expected. In these works, the triplet correlations with spin one appeared as the most plausible scenario for such a long-range superconducting proximity effect. However, it would be highly desirable to obtain qualitative experimental signatures of these unconventional correlations. Besides the supercurrent, the density of states would be a very interesting tool to probe the propagation of these correlations. In this work, we propose a new setup, where the superconducting correlations are induced in a normal metal wire in contact with a superconductor and several non-colinear ferromagnetic slabs. We describe the interfaces between the differents parts of the circuit with spin-dependent boundary conditions for isotropic superconducting Green\'s functions[1]. The spatial dependence of the density of states in the normal metal wire exibits qualitative features which are specific to triplet superconducting correlations with spin one. [1] A. Cottet, D. Huertas-Hernando, W. Belzig, and Y. V. Nazarov, Phys. Rev. B 80, 184511 (2009).

Mircea Crisan

University of Cluj - University of Cluj
Romania

Effect of electron-phonon interaction on non-equilibrium transport through single molecular dot in the Coulomb blockade regime

We present an analytical calculation of the conductance for a single molecular dot in Coulomb blockade regime taking into consideration the electron-phonon (EP) interaction. Using the method of equation of motion we calculate , in the Hartee-Fock approximation, the conductance and give the expression for the conductance in the presence of the Franck-Condon blockade.The side-band effect presents two logarithmic discontinuities. Tunneling magneto conductance has been also calculated and we showed that for symmetric model it is finite, but stile very large if the EP is considered.

Klaus Ensslin

ETH Zurich - Physics
Switzerland

Transport through hybrid quantum dots

In order to employ solid state quantum dots as qubits, both a high degree of control over the confinement potential as well as sensitive charge detection are essential. We demonstrate that by combining local anodic oxidation with local Schottky-gates, these criteria are nicely fulfilled in the resulting hybrid device. To this end, a quantum dot with adjacent charge detector is defined. After tuning the quantum dot to contain only a single electron, we are able to observe the charge detector signal of the quantum dot state for a wide range of tunnel couplings. A detailed investigation of the Coulomb peak width (direct current through the dot) as well as the transconductance (differential signal of the QPC detector) shows agreement of the two measurement techniques which is better than their agreement with calculated line-shapes taking tunneling coupling and temperature broadening into account. For strong coupling of the dot to source and drain as well as in the finite bias regime the dot signal and the QPC signal show pronounced differences.

Jaroslav Fabian

University Regensburg - University Regensburg
Germany

Spin-orbit coupling in nanostructures

The spin-orbit interaction is essential for understanding spin and magneto-transport on the nanoscale. Spin relaxation, g-factors, magnetoanisotropies, topological edge channels, but also fundamental spectral properties are determined by the (typically relatively weak) spin-orbit coupling. I will give an overview of intrinsic and extrinsic spin-orbit coupling in solids, and give examples from a variety of materials/materials structures, such as Fe/GaAs interfaces, bulk silicon, graphene, or semiconductor coupled quantum dots.

Sebastian Göpfert

Universität Würzburg - Fakultät für Physik und Astronomie
Germany

Room temperature memory and light sensing application of a single-electron memory with positioned InAs quantum dots

S. Göpfer(1), L. Worschech(1), S. Lingemann(1), C. Schneider(1), D. Press(2), S. Höfling(1), and A. Forchel1(1) 1 Technische Physik, Physikalisches Institut, Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, D-97074Würzburg, Germany 2 Stanford University, Edward L Ginzton Lab, Stanford, CA 94305 USA Memory operation of a flash memory with single InAs quantum dot is demonstrated up to room temperature. Light-controlled charging or discharging of the optically active quantum dots were observed. For this purpose single InAs QDs were centrally positioned in a quantum wire transistor by using a pattern of nanoholes on a modulation doped GaAs/AlGaAs heterostructure, as nucleation centers for QD growth. In combination with etching techniques a transistor structure was defined. The bottleneck structure of the transistor channel in combination with central positioned QDs result in a pronounced threshold hysteresis and single electron memory operation up to room temperature. A strong confinement for electrons and the proximity of the QDs to the surface result in long storage time and light sensing application for telecommunication wavelength at room temperature.

M. Magdalena Gelabert

Universitat de les Illes Balears - UIB

Spain

Magnetic properties in a hole system with Rashba interaction

We present calculations of the g factors for the lower conductance steps of 3D hole quantum wires. Our results prove that the anisotropy with magnetic field orientation, relative to the wire, originates in the Rashba spin-orbit coupling. We also analyze the relevance of the deformation, as the wire evolves from 3D towards a flat 2D geometry. For high enough wire deformations, the perpendicular g factors are greatly quenched by the Rashba interaction. On the contrary, parallel g factors are rather insensitive to the Rashba interaction, resulting in a high g factor anisotropy. For low deformations we find a more irregular behaviour which hints at a sample dependent scenario.

Rolf Haug

Leibniz Universität Hannover - Institute for Solid State Systems
Germany

Spin Effects in Transport through Quantum Dots

During the last years we have been interested in the spin structures of many-electron quantum dots, especially in high magnetic fields. In using the phenomena of spin blockade and Kondo effect we had been able to detect different spin structures in dependence of the number of electrons occupying the quantum dot [1]. Exchange and correlation effects were identified as being responsible for the observed changes in the spin structures of these quantum dots [2]. Very recently we used this knowledge to study spin-coupling effects between two quantum dots separated by an electronic island and we observed an influence of the chiral nature of the edge states connecting the two dots in high magnetic fields [3]. [1] M. Rogge et al. Phys. Rev. Lett. 97, 176901 (2006) [2] M. Rogge et al. Phys. Rev. Lett. 105, 046802 (2010) [3] D. Tutuc et al. arxiv 1010.5692

Antti-Pekka Jauho

Technical University of Denmark - DTU Nanotech
Denmark

Transport in graphene antidot lattices

I review the basic physics of graphene antidot lattices (GAL), also addressing some experimental challenges. I report on our recent work on electronic and phonon transport in these systems, and show that they may hold great potential for thermoelectric applications. I also discuss screening and plasmons in these systems.

Olov Karlström

Lund University - Physics
Sweden

Canyon of Current Suppression in an Interacting Two-Level Quantum Dot

Motivated by the recent discovery of a canyon of conductance suppression in a two-level equal spin quantum dot system [Nilsson et al. Phys. Rev. Lett. 104, 186804 (2010)] the transport through this system is studied in detail. At low bias and low temperature a strong current suppression is found around the electron-hole symmetry point independent of the couplings, in agreement with previous results. By means of a Schrieffer-Wolff transformation we are able to give an intuitive explanation to this suppression in the low-energy regime. In the general situation, numerical simulations are carried out using quantum rate equations. The simulations allow for the prediction of how the suppression is affected by the couplings, the charging energy, the position of the energy levels, the applied bias, and the temperature. We find that away from electron-hole symmetry, the parity of the couplings is essential for the current suppression. It is also shown how broadening, interference, and a finite interaction energy cause a shift of the current minimum away from degeneracy. Finally we see how an increased population of the upper level leads to current peaks on each side of the suppression line. At sufficiently high bias we discover a coherence-induced population inversion.

Takis Kontos

CNRS - Ecole Normale Supérieure
France

Dynamic response of a Kondo dot in a photonic cavity

The Kondo effect is the paradigm for strongly correlated electronic systems. Recently, progress in nanofabrication techniques have made it possible to study this phenomenon at the single impurity level with exquisite sensitivity through transport measurement in artificial atoms- quantum dots. So far, most measurements have focused on low frequency properties. Probing such systems at frequencies comparable to the characteristic energy scales involved would allow to directly access the dynamic aspects of the Kondo resonance. In open space, the interaction of the electromagnetic field

with a single Kondo "impurity" is a priori very small. In cavity quantum electrodynamics, single –real- atoms interact with photons thanks to the strong photon confinement. We used the same method with an artificial atom – a single wall carbon nanotube at low temperature- embedded in a microwave photonic cavity. We measure simultaneously the DC conductance and the two quadratures of the microwave signal (~GHz) scattered by the nanotube in the Kondo regime. The differences between the conventional transport spectroscopy and the "scattering phase" spectroscopy will be discussed

Joerg P. Kotthaus

LMU Munich - CeNS, LMU Munich
Germany

Nonequilibrium interactions between GaAs-based quantum devices

Jörg P. Kotthaus, Center for NanoScience and Fakultät für Physik, Ludwig-Maximilians-Universität München, Germany Quantum point contacts (QPCs) on GaAs-AlGaAs heterostructures, routinely employed as sensitive charge detectors for adjacent mesoscopic quantum devices, are shown to cause back-action phenomena when moderately biased. Recent studies of such non-equilibrium interactions caused by electrons ballistically injected across a QPC are discussed, in which currents induced in unbiased detector circuits, adjacent but electrically separated from the biased QPC emitter, are investigated. Incorporating suitable voltage-tunable barriers it becomes possible to energetically analyse the quanta generated in the emitter that cause the non-equilibrium in the detector. Our studies show conclusively that acoustic phonons, emitted by back-scattering of excited electrons, are a dominant cause of such non-equilibrium interactions, and can become detrimental to quantum coherent operations.

Jong Soo Lim

Universitat de les Illes Balears - UIB
Spain

Nonlinear fluctuation relations in a spin diode system

For an irreversible Markov chain, we study nonlinear fluctuation relations in the presence of a magnetic field. In order to do that, we analyze a spin diode system with incoherent spin relaxation term. In this case, although so-called fluctuation theorems are not satisfied, it is shown that there still exist nonlinear fluctuation relations and those relations exactly agree with the theory of H. Forster and M. Buttiker.

Rosa Lopez Gonzalo

Local Organizer - IFISC (UIB-IFISC) - IFISC (UIB-IFISC)
Spain

Jan Martinek

Polish Academy of Sciences - Institute of Molecular Physics
Poland

Molecular spintronics: Spin polarized transport through quantum dots and molecules

The manipulation of magnetization and spin is one of the fundamental processes in magneto-electronics and spintronics, providing the possibility of writing information in a magnetic memory, and also because of the possibility of classical or quantum computation using spin. In most situations, this is realized by means of an externally applied nonlocal magnetic field, which is usually difficult to introduce into an integrated circuit. We propose to control the amplitude and sign of the spin-splitting of a quantum dot induced by the presence of ferromagnetic leads, using a gate voltage without further assistance of a magnetic field. We study the effect of a gate voltage on the spin splitting of an electronic level in a quantum dot attached to ferromagnetic in the Kondo regime using a generalized numerical renormalization group technique. We extended Wilson's numerical renormalization group method, extended to handle leads with a spin asymmetric density of states. We give an analytical description of our numerical results using perturbative scaling analysis and explain how the effect arises due to spin-dependent charge fluctuations. A conceivable realization of proposed system might be carbon nanotubes or other systems as quantum point contacts, semiconducting nanowires in contact to ferromagnetic leads (ferromagnetic single-molecule transistor) and doped ferromagnetic tunnel junctions. New experimental results confirm the theoretical predictions. 1. J. Martinek, Y. Utsumi, H. Imamura, J. Barnas, S. Maekawa, J. König, and G. Schön, Phys. Rev. Lett. 91, 127203 (2003); 2. A. N. Pasupathy, R. C. Bialczak, J. Martinek, J. E. Grose, L. A. K. Donev, P. L. McEuen, and D. C. Ralph, Science 306, 86 (2004). 3. M. Sindel, L. Borda, J. Martinek, R. Bulla, J. König, G. Schön, S. Maekawa, and J. von Delft, Phys. Rev. B 76, 045321 (2007). 4. J. R. Hauptmann, J. Paaske, and P.E. Lindelof, Nature Physics, (2008). 5. M. R. Calvo et al. Nature 458, 1150 (2009). 6. A. Halbritter, P.

Makk, Sz. Mackowiak, Sz. Csonka, M. Wawrzyniak, and J. Martinek, Phys. Rev. Lett. 105, 266805 (2010). 7. H. Yang, S.-H. Yang, G. Ilnicki, J. Martinek, and S. S. P. Parkin, (submitted).

Mykhailo Moskalets

NTU Kharkiv - NTU
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Molecular spintronics: Spin polarized transport through quantum dots and molecules

The manipulation of magnetization and spin is one of the fundamental processes in magneto-electronics and spintronics, providing the possibility of writing information in a magnetic memory, and also because of the possibility of classical or quantum computation using spin. In most situations, this is realized by means of an externally applied nonlocal magnetic field, which is usually difficult to introduce into an integrated circuit. We propose to control the amplitude and sign of the spin-splitting of a quantum dot induced by the presence of ferromagnetic leads, using a gate voltage without further assistance of a magnetic field. We study the effect of a gate voltage on the spin splitting of an electronic level in a quantum dot attached to ferromagnetic in the Kondo regime using a generalized numerical renormalization group technique. We extended Wilson's numerical renormalization group method, extended to handle leads with a spin asymmetric density of states. We give an analytical description of our numerical results using perturbative scaling analysis and explain how the effect arises due to spin-dependent charge fluctuations. A conceivable realization of proposed system might be carbon nanotubes or other systems as quantum point contacts, semiconducting nanowires in contact to ferromagnetic leads (ferromagnetic single-molecule transistor) and doped ferromagnetic tunnel junctions. New experimental results confirm the theoretical predictions. 1. J. Martinek, Y. Utsumi, H. Imamura, J. Barnas, S. Maekawa, J. König, and G. Schön, Phys. Rev. Lett. 91, 127203 (2003); 2. A. N. Pasupathy, R. C. Bialczak, J. Martinek, J. E. Grose, L. A. K. Donev, P. L. McEuen, and D. C. Ralph, Science 306, 86 (2004). 3. M. Sindel, L. Borda, J. Martinek, R. Bulla, J. König, G. Schön, S. Maekawa, and J. von Delft, Phys. Rev. B 76, 045321 (2007). 4. J. R. Hauptmann, J. Paaske, and P.E. Lindelof, Nature Physics, (2008). 5. M. R. Calvo et al. Nature 458, 1150 (2009). 6. A. Halbritter, P. Makk, Sz. Mackowiak, Sz. Csonka, M. Wawrzyniak, and J. Martinek, Phys. Rev. Lett. 105, 266805 (2010). 7. H. Yang, S.-H. Yang, G. Ilnicki, J. Martinek, and S. S. P. Parkin, (submitted).

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Half-Josephson Laser

We describe a superconducting device capable of producing laser light in the visible range at half of the Josephson generation frequency with the optical phase of the light locked to the superconducting phase difference. It consists of two single-level quantum dots embedded into a p-n semiconducting heterostructure and surrounded by a cavity supporting a resonant optical mode. We study decoherence and spontaneous switching in the device.

Gloria Platero

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Topology and phase: two ways to control the coherent dynamics of electrons >

Gloria Platero Topology and phase: two ways to control the coherent dynamics of electrons The excellent coherence properties of low dimensional semiconductor nanostructures, together with the degree of control over their geometry and specifications, make them ideal candidates for studying coherent transport, where quantum interference is used to regulate the movement of particles. Such control is particularly vital for quantum information, in which the coherence and entanglement of the initial state must be preserved during the evolution of the system. A powerful method of manipulating the coherent dynamics of quantum particles is to control the phase of their tunnelling. In this work we show how such phases can be produced in two distinct and complementary ways. If we consider a particle hopping on a lattice, interference will occur if the hopping acquires a phase factor. A direct way of doing this is to apply a magnetic field, which produces the well-known Aharonov-Bohm (AB) phase. In Ref. [1] it was shown that such phases could produce a localization effect termed AB caging, in which destructive interference bounds the set of sites that can be visited by an initially localized wave packet. This caging effect has been observed in superconducting wire networks, mesoscopic semiconductor lattices, and arrays of Josephson junctions. AB caging is resistant to small quantities of disorder but is swiftly destroyed by interactions due to the formation of spatially extended states. A different form of localization, also arising from quantum interference, is termed ‘‘Coherent Destruction of Tunneling’’ (CDT). This arises in systems subjected to a time-periodic driving field. Tunneling processes acquire phase factors from the interaction of the system with the driving, producing an effective renormalization of the tunneling. In this talk we consider the dynamics of two interacting electrons hopping on a quasi one-dimensional lattice with a non-trivial topology threaded by a uniform magnetic flux, and study the effect of adding a time- periodic driving field. We will show that the dynamical phases produced by the driving field can combine with the familiar Aharonov-Bohm phases arising from the magnetic flux to restore AB caging [2]. This occurs when CDT causes the (repulsive) electrons to bind together into a composite object of charge 2e termed a ‘‘doublon,’’ which can then be caged by the magnetic flux. We then go on to consider the effect of a low-frequency driving field and show that this gives rise to an unusual form of propagation in which the doublon moves in steps of two lattice sites, via the virtual occupation of the intermediate sites. This permits the creation and control of spatially separated entangled states of two electrons via the beam-splitter effect, with many potential applications to quantum information. In summary, we show that the dynamical phases produced by the driving can combine with the Aharonov-Bohm phases to give precise control of the localization and dynamics of the particles, even in the presence of strong particle interactions. [1] J. Vidal, R. Mosseri, and B. Douc¸ot, Phys. Rev. Lett. 81, 5888 (1998). [2]C.E. Creffield and G. Platero, Phys. Rev. Lett. 105, 086804 (2010).

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Kondo effect in side-coupled quantum dots

We present the spectroscopy of the Kondo effect in two side-coupled quantum dots, a \"big\" one and a \"small\" one. The spectroscopy is carried out by measuring the current through the small dot only.When increasing the coupling between the two dots, the stability diagram evolves from the diagram of two uncoupled quantum dots (the well-known \"honeycomb\" diagram) to the stability diagram of a Kondo system. Interestingly, the Kondo ridges appear only at certain precise point of the diagram. We show that these points correspond to a very peculiar point of the diagram where the inter-dot charging energy is minimum. We have thus a \"boosting\" of the Kondo effect at these precises points.

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Proposal for non-local electron-hole turnstile in the Quantum Hall regime

We present a theory for a mesoscopic turnstile that produces spatially separated streams of electrons and holes along edge states in the quantum Hall regime. For a broad range of frequencies in the non-adiabatic regime the turnstile operation is found to be ideal, producing one electron and one hole per cycle. The accuracy of the turnstile operation is characterized by the fluctuations of the transferred charge per cycle. The fluctuations are found to be negligibly small in the ideal regime.

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Local Franck-Condon factors in suspended carbon nanotubes quantum dots

Electron and vibron coupling in suspended carbon nanotube quantum dots is considered, analyzing the crucial role of spatial fluctuations of the electronic density. Space-dependent Franck-Condon factors are discussed, and ensuing marked effects on transport are shown in comparison with recent measurements. Predictions on the spatial conductance pattern, obtained by scanning the system with an STM tip will be presented.

Rafael Sánchez

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Transport from hot spots

The proximity of two systems can affect the properties that one should expect from each of them separately. We find an example when considering Coulomb coupled conductors. Then, the nonequilibrium charge fluctuations in one of them break detailed balance in the other, which is manifested in a drag current[1]. The removal of this fundamental symmetry also appears when the two systems are in equilibrium but at different temperatures. We investigate a minimal model where heat flowing out of the hot system is transformed into directed electrical motion in the cold one. Exploiting energy discretization in quantum dots, heat to current conversion can be done at the highest thermodynamic efficiency[2]. [1] R. Sánchez, R. López, D. Sánchez, and M. Büttiker, Phys. Rev. Lett. 104, 076801 (2010). [2] R. Sánchez, and M. Büttiker, Phys. Rev. B 83, 085428 (2011).

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Semiconductor based quantized current and voltage sources

From the groundbreaking work of Josephson it became clear that superconducting solid state devices allow to generate a quantized voltage only defined by an applied excitation frequency f and two fundamental constants, namely the electron charge e and Planck constant h. The Josephson effect has been successfully applied in the field of electrical quantum metrology as voltage standard. Though superconductors show many other astonishing properties semiconductors have been the most relevant class of material for microelectronics. However, the generation of a quantized voltage by an all semiconductor device has not been possible yet. Here we report on the realization of a semiconductor quantized voltage source allowing to generate voltages V = f *(h/e) upon input of an AC voltage with frequency f [1]. The design of the device can be regarded as a semiconductor integrated quantized circuit. It consists of a non-adiabatic single-electron pump being able to drive quantized currents through high impedance loads. The pumping mechanisms and potential accuracy are discussed with respect to applications as a quantum current standard. When operating such a pump at frequency f and monolithically integrating it with a Quantum Hall device in series the functionality of quantized voltage generation can be implemented. The quantized output voltage is robust up to operation frequencies of a few GHz. [1] -F Hohls et al. arXiv:1103.1746v1

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Nuclear spin ordering and Majorana edge states in interacting one-dimensional systems

The interactions between the electrons of a one-dimensional conductor and its nuclear spins can lead to an ordered phase in which both degrees of freedom are tightly bound to each other. Experimentally available examples of such a system are GaAs-based quantum wires. In these systems the hyperfine interaction between the nuclear spin and the conduction electron spin is weak, yet it triggers a strong feedback reaction that results in an ordered phase consisting of a nuclear helimagnet that is inseparably bound to an electronic density wave combining charge and spin degrees of freedom. When this quantum wire is brought in proximity of s-wave superconductor, it supports Majorana edge states. We show that this Majorana edges states are extremely susceptible to electron-electron interactions. Strong interactions generically destroy the induced superconducting gap that stabilizes the Majorana edge states. For weak interactions, the renormalization of the gap is nonuniversal and allows for a regime, in which the Majorana edge states persist. We present strategies how this regime can be reached.

Janine Splettstoesser

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Charge and spin dynamics of an interacting quantum dot

The subject of this talk is the relaxation behavior of a quantum dot, brought out of equilibrium by a time-dependent modulation, e.g. by a gate potential. We study a single-level quantum dot with strong Coulomb interaction, weakly coupled to a single lead, taking the role of a mesoscopic capacitor. The transient response to a fast change, as well as the stationary ac-response to a slow harmonic variation of the gate potential are computed by means of a real-time diagrammatic expansion in the tunnel-coupling strength. We compare the response in the charge of the dot to a step potential with the RC time extracted from the ac response and find differences due to cotunneling contributions. This is in contrast to a classical capacitor, where these timescales are equal. Furthermore, we find that after a fast switching, the exponential relaxation behavior of charge and spin are governed by a single time constant each, which differ from each other due to Coulomb repulsion. A further relaxation rate is related to electron-hole correlations and can be extracted from deviations from the equilibrium charge.

Fabio Taddei

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Josephson quantum electron pump: theory and experiment

Pumping is a transport mechanism that exploits the time-dependence of some properties of a nano-scale conductor to produce a dc charge current in the absence of an applied voltage [1–3]. So far, nano-scale pumps have been realised only in systems exhibiting strong Coulombic effects, whereas evidence for pumping in the absence of Coulomb-blockade has been elusive. A pioneering experiment [4] evidenced the difficulty of modulating in time the properties of an open mesoscopic conductor at cryogenic temperatures without generating undesired bias voltages due to stray capacitances. One possible solution to this problem is to use the ac Josephson effect to induce periodically time-dependent Andreev-reflection amplitudes in a hybrid normal-superconducting system [5]. Here we report an experimental and theoretical investigation of charge flow in an unbiased InAs nanowire (NW) embedded in a superconducting quantum interference device (SQUID). In this system, pumping may occur via the cyclic modulation of the phase of the order parameter of different superconducting electrodes. The symmetry of the current with respect to the enclosed magnetic flux and bias SQUID current is a discriminating signature of pumping. Currents exceeding 20 pA are measured at 250 mK, and exhibit symmetries compatible with a pumping mechanism in this setup. We have extended the theoretical framework for pumping, based on the dynamical scattering approach, to take into account the fact that the normal and the superconducting parts of the circuit have no common ground. [1] D. J. Thouless, Phys. Rev. B 27, 6083 (1983). [2] M. Büttiker, H. Thomas, and A. Prêtre, Z. Phys. B 94,133 (1994). [3] P. W. Brouwer, Phys. Rev. B 58, R10135 (1998). [4] M. Switkes et al., Science 283, 1905 (1999). [5] S. Russo, et al., Phys. Rev. Lett. 99, 086601 (2010).

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Magnetic Deflagration

In my talk I will review on both theory and experiments on magnetic deflagration detected in different magnetic systems like molecular magnets, manganites and intermetallic compounds. The experimental observations have been performed using SQUIDS, Hall probes and coils and the ignition of the deflagration has been done using surface acoustic waves, heat and magnetic fields. An important ponit in our experiments is that the magnetic defñagartion is accompanied by the emission of microwaves, case of molecular magnets, colossal changes in the magnetoresistance, case of manganites, and structural modifications in the case of the intermetallic compounds. I will finish commenting the necessary ingredients to observe deflagration in any physical system.

Raul Toral

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Fluctuation-dissipation relation in a random-field model

We address a mean-field zero-temperature Ginzburg-Landau, or fi-4, model subjected to quenched additive noise, which has been used recently as a framework for analyzing collective effects induced by diversity. We first make use of a self-consistent theory to calculate the phase diagram of the system, predicting the onset of an order-disorder critical transition at a critical value of the quenched noise intensity, with critical exponents that follow Landau theory of thermal phase transitions. We subsequently perform a numerical integration of the system\'s dynamical variables in order to compare the analytical results (valid in the thermodynamic limit and associated to the ground state of the global Lyapunov potential) with the stationary state of the (finite size) system. In the region of the parameter space where metastability is absent (and therefore the stationary state coincide with the ground state of the Lyapunov potential), a finite-size scaling analysis of the order parameter fluctuations suggests that the magnetic susceptibility diverges quadratically in the vicinity of the transition, what constitutes a violation of the fluctuation-dissipation relation. We derive an effective Hamiltonian and accordingly argue that its functional form does not allow to straightforwardly relate the order parameter fluctuations to the linear response of the system, at odds with equilibrium theory. In the region of the parameter space where the system is susceptible to have a large number of metastable states (and therefore the stationary state does not necessarily correspond to the ground state of the global Lyapunov potential), we numerically find a phase diagram that strongly depends on the initial conditions of the dynamical variables. We conclude that structural diversity can induce both the creation and annihilation of order in a nontrivial way.

Daniel Tutuc

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Dipl. Phys.

We present measurement on a system consisting of two lateral quantum dots coupled via an open conducting reservoir. At zero magnetic field we study the interplay between Kondo effect and the RKKY interaction in the two quantum dots. In perpendicular magnetic field the dots are tuned in the so-called Kondo chessboard and we observe a chiral coupling between the quantum dots via the edge states formed in the central reservoir. We probe the presence of the exchange interaction by an analysis of the Kondo temperature obtained from temperature dependent measurements.

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Nonlinear transport and logic operations with nanoelectronic devices

Advanced lithographic techniques allow the fabrication of strongly confined semiconductor nanostructures. In the ballistic nonlinear transport regime, nanoelectronic devices show several electric properties very different from those of diffusive conductors. We focus on recent studies of hybrid quantum wires and Y-branches realized by electron beam lithography and etching techniques of modulation doped GaAs/AlGaAs heterostructures in relation to nanoelectronic applications, such as amplifiers, sensors and logics gates. Morphing logics based on a recently observed logic stochastic resonance and as well as supercycles in memory mode driven quantum dot arrays are discussed.

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Spin States, Spin Correlations, Supercurrent, and Multiple Andreev Reflections in InSb Nanowire Quantum Devices

Bulk InSb is one of the most promising materials for applications in spintronics and quantum information processing, due to the fact that it has the highest electron mobility, the smallest electron effective mass, and the largest electron magnetic moment among all III-V semiconductors. Here, we report on realization and electrical measurements of InSb quantum dots and superconductor/InSb/superconductor hybrid quantum devices. The devices are made on a SiO2-capped Si substrate from InSb segments of InAs/InSb heterostructured nanowires grown by metal-organic vapor phase epitaxy. Spin states, effective g-factors, and spin-orbit interaction energy are measured for the fabricated InSb nanowire quantum dots [1]. We have also studied strong correlation phenomena and observed a new spin-correlation-induced phenomenon in the devices, namely the conductance blockade at the degeneracy of two orbital states with the same spin [2]. We attribute this conductance blockade to the effect of electron interference between two equivalent, strongly correlated, many-body states in the quantum dots. In superconductor/InSb nanowire/superconductor hybrid devices, we have observed supercurrent and multiple Andreev reflections, and have found that the fluctuations in the supercurrent are correlated to the conductance fluctuations of the corresponding InSb nanowires in the normal state. We have also observed multiple Andreev reflections and interplay between the Kondo correlation and proximity effect in the Coulomb blockade regime. [1] H. A. Nilsson et al., Nano Lett. 9, 3151-3156 (2009). [2] H. A. Nilsson et al., Phys. Rev. Lett. 104, 186804 (2010).

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Spin current noise spectra of interacting quantum dots

We analyze the equilibrium and non-equilibrium frequency-dependent spin current noise and spin conductance through a quantum dot in the local moment regime. Spin current correlations behave markedly differently from charge correlations: First, equilibrium spin correlations are characterized by two universal scaling functions. One of these functions is related to charge correlations, while the other describes cross-spin correlations. We characterize these functions using a combination of perturbative and non-perturbative methods. We find that spin cross-correlations are suppressed at frequencies below the Kondo scale. For asymmetrical quantum dots a dynamical spin accumulation resonance is found at the Kondo energy, $\omega\sim T_K$. At higher temperatures surprising low-frequency anomalies related to overall spin conservation appear in the spin noise, and the Korringa rate plays a special role.

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