TT 33: TR: Nanoelectronics I: Quantum Dots, Wires, Point Contacts 2

Time: Thursday 14:00–18:00 Location: H19

TT 33.1 Thu 14:00 H19

Negative tunneling magneto-resistance in spin-polarized transport across carbon nanotubes — •Sonja Koller[1], Jens Paaske[2], and Milena Grifoni[1] — [1]Universität Regensburg — [2]Nano-Science Center, University of Copenhagen

From experiments on carbon nanotube single electron transistors with ferromagnetic, collinearly polarized leads, it is known that the tunneling magneto-resistance (a measure for the ratio of current in the parallel to current in the anti-parallel contact configuration) exhibits a strong dependence on the gate voltage. In particular, for certain gate regions, the anti-parallel current can even exeed the parallel one, leading to negative values of the tunneling magneto-resistance. The origin of this effect are tunneling induced level shifts, that we are able to calculate theoretically within a diagrammatic perturbation approach to transport across quantum dots, by inclusion and summation of certain diagram types to all orders. A qualitative agreement with the experiment is obtained.

TT 33.2 Thu 14:15 H19

Spin-Orbit Effects in Carbon-Nanotube Double Quantum Dots — •Stephan Weiss[1], Emmanuel Rashba[2,3], Ferdinand Kuemmeth[2], Hugh Churchill[2], and Karsten Flensberg[1] — [1]Niels Bohr Institute & Nano-Science Center, University of Copenhagen — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [3]Center for Nanoscale Systems, Harvard University, Cambridge, Massachusetts 02138, USA

We study the spectrum of a carbon nanotube double quantum dot with one and two electrostatically confined electrons in the presence of spin-orbit and Coulomb interactions [1]. Compared to GaAs dots the spectrum exhibits a richer structure due to the valley degree of freedom in nanotubes. Starting with the envelope function approach near the graphene Dirac point, we numerically diagonalize the two particle Hamiltonian and explain its spectrum in terms of spin and orbital singlets and triplets. We also show how spin-orbit effects compete with finite exchange Coulomb interactions at weak magnetic fields. Inspired by recent experiments that measured the relaxation and dephasing times of Kramers doublets in nanotube quantum dots, we investigate the transition between (02) $\leftrightarrow$ (11)-configurations as a function of the inter-dot detuning.

[1] S. Weiss, E.I. Rashba, F. Kuemmeth, H.O.H. Churchill, and K. Flensberg, in preparation

TT 33.3 Thu 14:30 H19

Vibration-assisted transport properties of suspended carbon nanotube quantum dots. — •Abdullah Yar, Andrea Donarini, Sonja Koller, and Milena Grifoni — Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg,Germany

We investigate the transport properties of suspended armchair single-wall carbon nanotubes (SWNTs) weakly coupled to leads. In the low energy regime, such nano-electromechanical systems behave as quantum dot systems being highly sensitive to the influence of few vibrational modes. We performed a microscopic analysis of suspended metallic SWNTs and included Coulomb interaction effects beyond mean-field, by using bosonization techniques, yielding the spectrum and eigenfunctions of the isolated finite length SWNT. The theory predicts that strong electron-vibron coupling strongly suppresses the current flow at low biases, a collective behavior known as Franck-Condon blockade, in spite of the symmetric coupling to the leads. At larger values of the bias voltage interference between degenerate states can yield a characteristic current suppression.

TT 33.4 Thu 14:45 H19

Competing carbon nanotube quantum dots with different screening properties — •Karin Goss[1,3], Carola Meyer[1,3], Maarten R. Wegewijs[2,3], and Claus M. Schneider[1,3] — [1]Institute of Solid State Research (IFF-9), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Institute of Solid State Research (IFF-3), Forschungszentrum Jülich, 52425 Jülich, Germany — [3]JARA Jülich Aachen Research Alliance

We report quantum transport measurements on a carbon nanotube (CNT) quantum dot in the single electron tunneling regime. In addition to standard nanotube shell-filling effects, the stability diagram shows resonances in the Coulomb blockade regime. These resonances are not due to inelastic cotunneling through a single CNT as their finite slope and anomalous anticrossing with the diamond edges indicate. Instead, atomic force microscopy images suggest that the contacted device consists of a rope of nanotubes, based on the rather large diameter of ca. 7nm. In a constant interaction picture the observed transport phenomena can be attributed to two nanotubes acting as coupled quantum dots. The anticrossings of the additional resonances with the diamond edges indicate hybridization of states of the two dots. The difference of both the asymmetry of tunneling and screening properties between the two dots allows this hybridization to be probed.

TT 33.5 Thu 15:00 H19

Quantum Ratchets Driven by Tunnel Oscillations — •Sigmund Kohler and Michael Stark — Instituto de Ciencia de Materiales de Madrid, CSIC, Cantoblanco, 28049 Madrid, Spain

The ratchet effect, which is the induction of a dc current by an ac force in the absence of any net bias, represents one of the most intriguing phenomena in non-equilibrium transport. In the usual description, it is assumed that the ratchet is driven by a classical field, while the corresponding backaction can be ignored. Here we address the question whether the tunnel oscillations of a biased double quantum dot can be employed as driving source. Since such a driving source itself behaves quantum mechanically, its dynamics will be influenced by the ratchet and, thus, should be treated as a further degree of freedom. As a model, we use two capacitively coupled double quantum dots: a biased one that provides the ac force and an asymmetric, unbiased one that acts as ratchet in the predominantly coherent quantum regime. It turns out that the two-electron states of the coupled drive-pump Hamiltonian leave their fingerprints in the ratchet current.

TT 33.6 Thu 15:15 H19

High frequency pulsed-gate technique for the measurement of tunneling and relaxation rates in coupled quantum dots — •Daniel Harbusch[1], Stephan Manus[1], Peter Tranitz[2], Werner Wegscheider[3], and Stefan Ludwig[1] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität München, München, Germany — [2]Institut für Experimentelle Physik, Universität Regensburg, Regensburg, Germany — [3]Laboratory for Solid State Physics, ETH Zürich, Zürich, Switzerland

Tunneling frequencies and charge relaxation rates in a double quantum dot (QD) are directly probed by pulsing control gates of the double QD and measuring average charge occupations using a nearby quantum point contact (QPC) as detector.

Our nano-devices are electrostatically defined in the two-dimensional electron system of a GaAs/AlGaAs heterostructure. All measurements are performed at an electron temperature about $T \approx 100$ mK.

Our broadband sample holder is based on impedance matched micro strip lines optimized for pulsed gate experiments, covering the large bandwidth from dc to 18 GHz. We pulse individual gates of a double or triple QD occupied with only few electrons at pulse widths down to 150 ps and demonstrate a variety of applications. We directly measure tunneling and energy relaxation rates. Our results show the suitability of the setup for future experiments on the coherent charge transport of single electrons in a triple QD.

TT 33.7 Thu 15:30 H19

An electron avalanche amplifier in a two-dimensional electron system — •Daniela Taubert[1], Georg Schinner[1], Hans-Peter Tranitz[2], Werner Wegscheider[3], and Stefan Ludwig[1] — [1]Center for NanoScience and Fakultät für Physik, Ludwig-Maximilians-Universität, Geschwister-Scholl-Platz 1, 80539 München, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg, Germany — [3]Solid State Physics Laboratory, ETH Zurich, 8093 Zurich, Switzerland

A biased quantum point contact - a device that is widely used as detector of single electrons in quantum dot circuits - and its back-action on the quantum dots can only be fully understood if the relaxation mechanisms of the excited hot electrons emitted into its leads are known. We therefore study the behavior of hot electrons in two-dimensional mesoscopic structures, thereby considering a wide range of electron energies.

We observe scattering of excited charge carriers with the degenerate Fermi sea in a three-terminal device. Amplification of the injected electron current can be achieved by energetically separating the electrons excited from the Fermi sea from the conduction band holes they leave behind by means of a barrier. The observed amplification effect depends on the energy of the injected electrons, the injected current, and the height of the barrier used for separating electrons and holes. Our analysis is based on an energy-dependend electron-electron scattering length as well as neutralization of holes.

TT 33.8 Thu 15:45 H19

Adiabatic pumping through a double quantum dot with Coulomb interaction — •Roman-Pascal Riwar and Janine Splettstoesser — Institut für Theoretische Physik A, RWTH Aachen University, D-52056 Aachen, Germany

We consider adiabatic pumping through a double quantum dot coupled to normal metal or ferromagnetic contacts by means of a real-time diagrammatic approach, performing a rigorous expansion in the weak coupling regime. The electrons in the serially aligned dots, which are subject to Coulomb repulsion, are pumped by alternating the left and right dot energy levels. In the case of weak inter-dot coupling we observe tunnel-induced renormalisation effects due to a coherent superposition of pseudospin states. Real spin effects are seen when arbitrarily polarised ferromagnets are attached to the double dot, where we investigate the limit of strong inter-dot coupling. In particular, we study the spin valve effect which can be reversed in the pumping current.

15 min. break

TT 33.9 Thu 16:15 H19

Thermopower of a Cooper pair splitter — •Jens Siewert[1,2] and Evgeny Ya. Sherman[1,2] — [1]Departamento de Química Física, Universidad del País Vasco , Apdo. 644, 48080 Bilbao, Spain — [2]Ikerbasque, Basque Foundation for Science, Alameda Urquijo 36, 48011 Bilbao, Spain

A Cooper pair splitting device has been realized recently by connecting two quantum dots (formed by InAs nanowires [1] and single-wall carbon nanotubes [2]) to a single superconducting source electrode and two normal-conducting drain electrodes. The electrostatic potentials of the dots can be tuned by means of gate voltages. The dominant transport process at low temperatures and bias voltages is coherent Cooper-pair tunneling ('Andreev tunneling'). We study transport in this device at finite temperatures in the framework of a simple tunneling Hamiltonian model taking into account an extra tunneling term between the two quantum dots and possible asymmetries between the tunneling rates to the leads. We calculate the thermopower and address the question whether it provides a possibility to experimentally access the contribution of the crossed Andreev reflection process.

[1] L. Hofstetter, S. Csonka, J. Nygard, and C. Schönenberger, Nature **461**, 960 (2009).

[2] L.G. Herrmann, F. Portier, P. Roche, A. Levy Yeyati, T. Kontos, and C. Strunk, e-print arxiv0909.3243 (2009).

TT 33.10 Thu 16:30 H19

Two-Particle Nonlocal Aharonov-Bohm Effect from Two Single-Particle Emitters — •Janine Splettstoesser[1,3], Michael Moskalets[2], and Markus Buttiker[3] — [1]Institut für Theoretische Physik A, RWTH Aachen University, D-52074 Aachen — [2]Department of Metal and Semic. Physics, NTU Kharkiv Polytechnic Institute, 61002 Kharkiv, Ukraine — [3]Département de Physique Théorique, Université de Genève, CH-1211 Genève 4, Switzerland

High-frequency single-particle emitters have been realized experimentally in the integer quantum Hall effect regime [1]. These tools allow for the implementation of complex interferometers in mesoscopic systems showing two-particle interference effects. In the work presented here we explore the entanglement production from two uncorrelated sources. We therefore propose a mesoscopic circuit in the quantum Hall effect regime comprising two independent single-particle sources and two distant Mach-Zehnder interferometers with magnetic fluxes. This and the tunability of the single-particle sources allow in a controllable way to produce orbitally entangled electrons [2]. Two-particle correlations appear as a consequence of erasing of which-path information due to collisions taking place at distant interferometers and in general at different times. The two-particle correlations manifest themselves as an Aharonov-Bohm effect in the noise. In an appropriate time-interval the concurrence reaches a maximum, proving the existence of time-bin entanglement.

[1] G. Fève, et al., Science 316, 1169 (2007).

[2] J. Splettstoesser, M. Moskalets, and M. Buttiker, Phys. Rev. Lett. 103, 076804 (2009).

TT 33.11 Thu 16:45 H19

Tunneling into Nonequilibrium Luttinger Liquid with Impurity — •Stéphane Ngo Dinh[1,2], Dmitry A. Bagrets[3], and Alexander D. Mirlin[1,2,3] — [1]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [2]DFG Center for Functional Nanostructures, Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [3]Institut für Nanotechnologie, Karlsruhe Institute of Technology (KIT), 76021 Karlsruhe, Germany

We evaluate tunneling rates into/from a quantum wire containing a weak backscattering defect and biased by a voltage U. Interacting electrons in such a wire constitute a true *nonequilibrium* state of the Luttinger liquid (LL). This state is created due to inelastic electron backscattering leading to the emission of nonequilibrium plasmons with typical frequency $\hbar\omega \leq eU$. Using a real-time instanton approach we show that the tunneling rates are split into two edges. The tunneling exponent at the Fermi edge E_F is *positive* and equals that of the equilibrium LL, while the exponent at the side edge $E_F - eU$ is *negative* if Coulomb interaction is not too strong. We also calculate the nonequilibrium dephasing rate that governs the smearing of the power-law singularities.

The approach developed here will be useful for the analysis of tunneling and interference in a broad class of nonequilibrium LL structures with impurities and/or tunneling couplings.

TT 33.12 Thu 17:00 H19

Anisotropic exchange coupling in double quantum dots — •Fabio Baruffa[1], Peter Stano[2], and Jaroslav Fabian[1] — [1]Institute of Theoretical Physics, University of Regensburg, Germany — [2]Institute of Physics, Slovak Academy of Science, Bratislava, Slovak Republic

The electron spins in quantum dots are one of the candidates as a qubit for quantum computation [1]. In coupled quantum dots, the two-qubit quantum gate is realized by manipulating the exchange coupling which is due to the Coulomb interaction and the Pauli principle. The presence of the spin-orbit couplings change the magnitude of the exchange and lead to new term due to the lack of the spin-rotational symmetry, the anisotropic exchange [2]. We propose an accurate effective spin Hamiltonian for modeling spin-orbit-induced spin dynamics in the presence of the magnetic field [3]. We have also performed numerically exact calculations of the isotropic and anisotropic exchange coupling in realistic two-electron GaAs coupled quantum dots in the presence of both Dresselhaus and Bychkov-Rashba spin-orbit interactions [4]. The numerics allow us to establish the goodness of our model and to see the limits of previous statements. Furthermore we find that in zero magnetic field the second-order spin-orbit effects are absent at all interdot couplings. This work was supported by the DFG GRK 638.

[1] D. Loss and D. P. DiVincenzo, Phys. Rev. A 57, 120 (1998)

[2] K. V. Kavokin, Phys. Rev. B 64, 075305 (2001)

[3] F. Baruffa, P. Stano and J. Fabian, cond-mat/0908.2961

[4] J. Fabian et al., Acta Phys. Slov. 57, 565 (2007)

TT 33.13 Thu 17:15 H19

Spin Relaxation in Silicon based Quantum dots — •Martin Raith[1], Peter Stano[2], and Jaroslav Fabian[1] — [1]Institute for Theoretical Physics, University of Regensburg, 93053 Regensburg, Germany — [2]Institute of Physics, Slovak Academy of Sciences, 84511 Bratislava, Slovak Republik

Recent progress in manufacturing top-gated quantum dots based on Si/SiGe or Si/SiO_2 systems emphasized the importance of silicon as a possible host material for the creation of spin qubit arrays and the associated idea proposed by Loss and DiVincenzo (1998) for the realization of a quantum computer. Silicon is of special interest because of its small spin-orbit coupling and the availability of isotopes with zero nuclear spin. Therefore silicon based quantum dots imply long spin lifetimes and yield promising candidates for quantum information processing. We provide quantitative results of the characteristic energies in the presence of spin-orbit coupling and phonon-induced spin relaxation times for realistic silicon based single and double dot systems using analytical models and numerical methods. This work is supported by the DFG SPP 1285.

TT 33.14 Thu 17:30 H19

Control of Spin Blockade by AC Magnetic Fields in Triple Quantum Dots — •Maria Busl[1], Rafael Sánchez[2], and Gloria Platero[1] — [1]Instituto de Ciencia de Materiales Madrid, CSIC, 28049 Cantoblanco Madrid, Spain — [2]Département de Physique Théorique, Université de Genève, CH-1211 Genève 4, Switzerland

We analyze theoretically transport through a triangular triple quantum dot (TQD) determined by the interplay of coherent phenomena coming from dc and ac magnetic fields. A dc magnetic field applied perpendicularly to the dot area induces a flux Φ. In triangular TQDs with one extra electron, it was shown [1, 2] that current can be blocked when the electron drops into an eigenstate that is decoupled from transport, a so-called dark state. This blocking in turn can be destroyed by the flux piercing the TQD. We show that in a triangular TQD with two extra electrons, current will be blocked either by the formation of a two-electron dark state or by Pauli spin blockade, depending on the flux Φ. Spin blockade can be broken by ac magnetic fields, and a finite current can be generated [3]. Unexpectedly however, we demonstrate that an ac magnetic field is not only able to break spin blockade but also to induce it again, at a particular field frequency ω. Hence applying an ac magnetic field is a way of *controlling* spin blockade in a TQD [4].

[1] C. Emary, Phys. Rev. B **76**, 245319 (2007).
[2] M. Busl *et al.*, Physica E (in press).
[3] F.H.L. Koppens *et al.*, Nature **442**, 766 (2006).
[4] M. Busl *et al.*, arXiv:0907.0182.

TT 33.15 Thu 17:45 H19

Generation and detection of spin-polarized currents via double quantum dot structures — •Stefan Maier[1], Jan P. Dahlhaus[1,2], and Andreas Komnik[1] — [1]Ruprecht-Karls-Universität Heidelberg, Philosophenweg 19, 69120 Heidelberg, Germany — [2]Instituut-Lorentz, Universiteit Leiden, P.O. Box 9506, 2300 RA Leiden, The Netherlands

We propose a setup for generation and detection of spin-polarized currents. The structure we use is a double quantum dot with parallel topology. The filtering mechanism is based on the anti-resonance structure in the transmission coefficient. We show that the device remains fully operable also in the case of not too strong inter- as well as intradot electronic correlations. We discuss how the coupling asymmetry and finite temperature may affect the efficiency of the device and present estimations for the relevant device parameters necessary for its experimental realization.