HL 46: Quantum Dots and Wires: Transport

Time: Wednesday 14:00–17:45 Location: H17

HL 46.1 Wed 14:00 H17

Study of two-Kondo impurities coupled via an open conducting reservoir — •Daniel Tutuc[1], Werner Wegscheider[2], and Rolf J. Haug[1] — [1]Institut für Feskörperphysik, Leibniz Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg

We present measurements on a structure consisting of two quantum dots connected via an open conducting region, in Kondo regime. The sample is created by Local Anodic Oxidation with an AFM on a GaAs/AlGaAs heterostructure with a 2DEG 37nm beneath the surface. The measurements have been performed with the standard lock-in technique, in a dilution refrigerator, at about 200 mK electron temperature. At finite magnetic fields both dots exibit the so-called Kondo chessboard pattern and we investigate the effective interaction between the dots as a function of edge states direction and tunnel coupling to the central region.

[1] N. J. Craig et al., Science 304, 565 (2004)
[2] P. Simon, et al., Phys. Rev. Lett. 94, 086602 (2005)
[3] M. G. Vavilov and L. I. Glazman, Phys. Rev. Lett. 94, 086805 (2005)

HL 46.2 Wed 14:15 H17

Interaction-induced spin selection in quantum dots — •Maximilian C. Rogge[1], Esa Räsänen[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstrasse 2, 30167 Hannover, Germany — [2]Nanoscience Center, Department of Physics,University of Jyväskylä, FI-40014 Jyväskylä, Finland

We present a combined work of theory and experiment concerning the spectrum of electronic states of a many-electron lateral quantum dot in high magnetic fields. We performed magnetotransport measurements on a quantum dot made with local anodic oxidation and electron beam lithography. Several Coulomb blockade peaks are analyzed in terms of the energetic properties of the involved states. In the $4 > \nu > 2$ regime with two Landau levels (LL), with ν being the filling factor of the dot, a pronounced zig-zag pattern is found. This can roughly be understood with the constant interaction model, that uses the single electron excitation spectrum (Fock-Darwin) plus a constant Coulomb repulsion energy. However, detailed analysis reveals, that this model can only be applied to the data from the zeroth LL with a spin-dependent bimodal structure. Data from the first LL show different behavior without bimodality. To understand this phenomenon, many-electron calculations within spin-density-functional theory were performed. As a result, interaction-induced spin polarization is found in the first LL.

HL 46.3 Wed 14:30 H17

Adiabatic pumping through an interacting quantum dot with spin-orbit coupling — •Stephan Rojek and Jürgen König — Theoretische Physik, Universität Duisburg-Essen and CeNIDE, 47048 Duisburg, Germany

We study adiabatic pumping through a two-level quantum dot coupled to two normal leads in the presence of spin-orbit coupling. Varying the two energy levels of the dot periodically in time can generate finite charge and spin currents. To calculate the pumped charge and spin we use a generalization of Brouwer's formula for interacting systems relates the pumped charge to the instantaneous Green's functions of the dot [1]. We calculate the latter by means of an equation-of-motion technique. In order to investigate the influence of Coulomb interaction we study the limits of noninteracting and strongly interacting electrons on the quantum dot. We find that the sign of the pumped charge and spin can change with regard to the spin-orbit coupling strength and we discuss differences between the charge and spin transport characteristics.

[1] J. Splettstoesser *et al.*, Phys. Rev. Lett. **95**, 246803 (2005).

HL 46.4 Wed 14:45 H17

Electron-phonon interaction in a triple quantum dot interferometer — •Fernando Dominguez and Gloria Platero — Instituto de ciencia de materiales de Madrid (ICMM)

In this work we analyze the effect of electron-phonon interaction on the electronic transport through a triple quantum dot in closed loop configuration. We consider that one of the quantum dots contains a mechanical degree of freedom, while the rest are fixed to the electronic leads. Under appropriate energetic conditions and in the absence of the electron-phonon interaction, an electron becomes coherently trapped in the system. As the electron-phonon interaction is switched on, the mechanical degree of freedom interacts with the electronic charge in the oscillating quantum dot. Thus, the interaction acts on the system as a "which path" detector, leading to the destruction of the coherent superposition, i.e., of the dark state, giving rise to current. By means of the Generalized Density Matrix formalism, we calculate the current density and the shot noise.

HL 46.5 Wed 15:00 H17

Electronic and transport properties of Ge nanoparticle pellets structured by focused ion beam — •Andreas Gondorf, Martin Geller, and Axel Lorke — Universität Duisburg-Essen, Duisburg

Semiconductor nanoparticles are of interest for future electronic and optoelectronic devices, especially low cost, flexible, printable electronics. We investigate here the transport properties (charge carrier concentration and mobility) of Ge nanoparticles, which were synthesized in the gasphase and pressed into pellets. The nanoparticles inside these pellets sinter into a sponge-like structure, that may exhibit unusual magneto-transport properties similar to the strong magnetoresistance observed in nanoporous gold [Fujita, PRL 101, 166601 (2008)]. The measurements are made on directly contacted macroscopic pellets and on Hallbar-microstructures fabricated by a focused ion beam (FIB). In the FIB fabrication process, a lamella is cut out of a pellet and positioned onto a prestructured substrate with metal contacts. The sample is connected with the contacts by deposition of platinum. Finally the disk is etched by FIB into a Hallbar shape. We use I-V and Hall-measurements and find a very weak but measurable Hall-effect and a negative magnetoresistance of about 0.01% at 2.5T. At room temperature, Ge nanoparticles show a charge carrier concentration of about $4 \cdot 10^{14}$ cm^{-3}, comparable to the intrinsic charge carrier concentration in bulk germanium. Ge nanoparticles have a very low mobility of 0.1 cm^2/Vs at 25°C, which is comparable to the mobility of organic semiconductors, so that Ge nanoparticles may be suitable in some applications which are presently based on organic semiconductors.

HL 46.6 Wed 15:15 H17

Spatially resolved flow of ballistic electrons measured by quantized photocurrent spectroscopy — Klaus-Dieter Hof[1], Franz J. Kaiser[2], •Markus Stallhofer[3], Dieter Schuh[4], Werner Wegscheider[4,5], Peter Hänggi[2], Sigmund Kohler[2,6], Jörg P. Kotthaus[1], and Alexander W. Holleitner[1,3] — [1]Fakultät für Physik and Center for NanoScience (CeNS), LMU München — [2]Institut für Physik, Universität Augsburg — [3]Walter Schottky Institut and Physik Department, TUM Garching — [4]Institut für Experimentelle und Angewandte Physik, Universität Regensburg — [5]Laboratorium für Festkörperphysik, ETH Zürich, Switzerland — [6]Instituto de Ciencia de Materiales de Madrid, CSIC, Spain

Quantum point contacts (QPCs) have recently been exploited in very sensitive detection schemes to quantify charge and spin states in nanoscale circuits and to monitor the coherent charge flow in two-dimensional electron gases (2DEGs). Here, we demonstrate the use of GaAs-based QPCs to laterally resolve the ballistic flow of photo-generated electrons in a 2DEG. To this end, electron-hole pairs are optically created in a 2DEG, and the resulting current through an adjacent QPC is measured as a function of the laser spot position. The transmission of photo-generated electrons through the QPC is governed by the quantized energy and momentum values of the electron modes in the QPC. Hereby, the measured photocurrent across the QPC exhibits quantization steps. We observe that photo-generated electrons can ballistically propagate across several micrometers, before they tunnel through the QPC.

HL 46.7 Wed 15:30 H17

Spectroscopy of non-equilibrium charging states of self-assembled quantum dots — •Bastian Marquardt[1], Martin Geller[1], Axel Lorke[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Experimental Physics and CeNIDE, University Duisburg-Essen — [2]Chair of Applied Physics, Ruhr University Bochum

Electron-electron (or hole-hole) interaction in confined electron systems like self-assembled quantum dots (QD) has been a topic of continuing interest for roughly 15 years [1, 2]. The Coulomb repulsion between the charge carriers has dramatic effects on the conductance through a QD, as evidenced, by the so called Coulomb blockade. However, measurements of the QD states without the influence of Coulomb repulsion has not been studied yet. Using, for instance, pulsed time-resolved measurement to prepare a non-equilibrium situation between the QD states and the chemical potential enables us to study dot states in transport measurements without Coulomb blockade. We study charge tunneling of self-assembled InAs QDs through large tunneling barriers resulting in charging times between 1 ms and 100 s. These long times allow us to adjust the chemical potential on time scales much faster than the average charge tunneling time of the dots. This way, non-equilibrium situations can be realized where the chemical potential in the reservoir is higher than all states in the dot. On the basis of the measured transients non-equilibrium dot states can be identified for different applied magnetic fields.

[1] D. Bimberg et al., Quantum Dot Heterostructures (Wiley, Chichester, 1998). [2] D. Reuter et al., Phys. Rev. Lett. 94, 026808 (2005).

15 Min. Coffee Break

HL 46.8 Wed 16:00 H17

High-order cumulants in the counting statistics of asymmetric quantum dots — •Christian Fricke, Frank Hohls, Nandhavel Sethubalasubramanian, Lukas Fricke, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

Current fluctuations in mesoscopic systems allow to obtain information on transport that is not accessible from the average current alone. Further understanding in electron transport can be gained from higher moments of the transport statistics. With the use of a quantum point contact as a non-invasive charge detector the full counting statistic (FCS) is now experimentally accessible in quantum dot physics. These techniques made the extraction of high-order cumulants possible, revealing an oscillating behavior as function of integration time. The theoretical treatment has shown that these oscillations are a universally expected phenomenon for most physical systems and that in quantum dots they should show up prominently as function of the barrier asymmetry. We carried out FCS measurements on a quantum dot with tunable barrier asymmetry and present the asymmetry dependence of high-order cumulants up to the 15^{th} order.

HL 46.9 Wed 16:15 H17

Quantum Jitter of a single electron source — Adrien Mahé[1], François Parmentier[1], Erwann Bocquillon[1], Jean-Marc Berroir[1], Christian Glattli[1,2], Takis Kontos[1], •Bernard Placais[1], and Gwendal Fève[1] — [1]Laboratoire Pierre Aigrain, ENS, 24 rue Lhomond 75005 Paris, France — [2]Service de Physique de l'Etat Condensé, CEA, 91192 Gif-sur-Yvette, France

Coherent ballistic electronic transport along the quantum Hall edge states of two dimensional electron gases bears strong analogies with the propagation of photons, well illustrated in electronic Mach-Zehnder interferometers. The quantum optic variant would be the realization of Hanbury-Brown and Twiss or Hong Ou Mandel experiments where one or few electrons would be coherently manipulated.

The first step toward this goal has been the realization of a single electron emitter based on fast gating of single quantum dot states [1]. This work addresses the second step by demonstrating measurement of the output correlations in the current generated by the source. The first result is the qualification of the single electron source by the absence of multiple events in the shot noise. The second one is the revealing of quantum fluctuations in the emission time. This "quantum jitter" is a high frequency noise that dominates in single electron sources, and constitutes the basic limitation for a future coherent single electronics.

[1] G. Fève, A. Mahé, J.-M. Berroir, T. Kontos, B. Plaçais, D. C. Glattli, A. Cavanna, B. Etienne, Y. Jin, Science 316, 1169 (2007).

HL 46.10 Wed 16:30 H17

A Single-Electron-Transistor with current gain — Armin C. Welker[1] and •Jürgen Weis[2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart

Quantum-dot systems are model systems for single-molecule experiments. Here, a new application of a quantum-dot system in electrical transport measurements is presented. The model system, a quantum dot with three leads, is used as a new type of current-gain transistor by using excited states of electron systems inside the quantum dot. We are able to prove experimentally and theoretically for certain cases that with each single-electron exchange with the base lead in fact more than one single-electron transfer is possible from source to drain (current gain).

HL 46.11 Wed 16:45 H17

Electronic Transport in Fully Oxidized Silicon Nanowires — •Mohammad Koleini[1], Lucio Colombi Ciacchi[1], and Marivi Fernandez-Serra[2] — [1]Hybrid Materials Interfaces (HMI), Faculty of Production Engineering and Bremen Center for Computational Materials Science, University of Bremen, 28359 Bremen, Germany — [2]Department of Physics and Astronomy and New York Center for Computational Science, Stony Brook University, Stony Brook, New York 11794-3800, USA

We present the first realistic model of an ulta-thin Silicon Nanowire (SiNW) grown along the <100> crystallographic direction with a natively fully oxidized surface. Ballistic transport in such SiNW has been studied by ab initio modeling, combining density functional theory and nonequilibrium Green's function techniques. A comparison with the pristine SiNW reveals the effect of oxidation on the electronic properties of the wire. The effect of p- and n-type dopants on the conductance of the oxidized SiNW has been studied extensively. The results indicate a strong coupling between the electronic properties of the dopants and the wire oxide shell, showing the need to explicitly consider the core-shell structure of SiNWs in theoretical transport studies.

HL 46.12 Wed 17:00 H17

Electronic phase coherence in InAs nanowires — •Christian Blömers, Mihail Ion Lepsa, Steffi Lenk, Hans Lüth, Thomas Schäpers, and Detlev Grützmacher — Institute of Bio- and Nanosystems (IBN-1) and JARA - Fundamentals of Future Information Technology, Forschungszentrum Jülich GmbH, D-52425 Jülich

We report on magnetotransport measurements on InAs nanowires grown by molecular beam epitaxy. Among the III-V semiconductor materials, InAs is particularly interesting because of its low direct band gap and its low effective mass. Additionally InAs is known to show a strong quantum confinement in devices of mesoscopic dimensions. A well known quantum effect revealed by magnetotransport measurements at low temperatures are the universal conductance fluctuations (UCF), resulting from electron interference. By analyzing the UCFs it is possible to draw conclusions about the phase coherence length of the electrons in the device. In the special case of a magnetic field in parallel to the wire, Altshuler-Aronov-Spivak oscillations were found in lithographically defined InAs columns. These oscillations are known to result from the surface 2DEG, which is present in those columns. In contrast the present InAs wires do not show this behavior. The explanation is given in terms of the high density of stacking faults, which were observed in transmission electron microscopy. The stacking faults are due to transitions between wurtzite and zincblende structure. The wurtzite segments are origins of polarization charges which most probably mask the effect of surface states, being the reason for the surface 2DEG.

HL 46.13 Wed 17:15 H17

Aharonov-Bohm phase shift in an asymmetric quantum ring — •S.S. Buchholz[1], S.F. Fischer[1], U. Kunze[1], D. Reuter[2], and A.D. Wieck[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum

The phase evolution of the electron wave function can be used to study fundamental interaction effects in quantum coherent transport. Therefore, we investigate a multi-terminal quantum ring which allows phase shift measurements in Aharonov-Bohm (AB) experiments. We focus on non-local measurements in an asymmetric four-terminal electron wave guide geometry [1].

The device was fabricated from a GaAs/AlGaAs heterostructure and is covered with a global Au gate. The quantum ring is linked to two-dimensional reservoirs via quantum wire leads. Transport measurements were performed at 23 mK with lock-in technique. AB resistance oscillations prove coherence in two- and four-terminal probe configurations [1] and obey time reversal symmetry: Two-probe measurements show phase rigidity. The ring's asymmetry allows modulating the phase of the interference pattern electrostatically: Via the gate voltage we can tune the electrons' Fermi wavelength along the unequally long paths and observe a gradual phase shift in the non-local measurement configuration. Numerical results from a time-dependent wave packet approach (see contribution by Ch. Kreisbeck) qualitatively reproduce our results in phase shift, phase jumps and the observation of higher harmonics.

[1] S.S. Buchholz et al., Appl. Phys. Lett. 94, 022107 (2009).

HL 46.14 Wed 17:30 H17

Phase Behavior of Aharonov-Bohm Oscillations in Four-Terminal Nanodevices — •Christoph Kreisbeck[1] and Tobias Kramer[1,2] — [1]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Department of Physics, Harvard University, Cambridge, MA 02138, USA

We discuss recent experiments on four terminal Aharonov-Bohm rings, based on GaAs/AlGaAs heterostructures. The phase of the AB oscillation shows a rich structure with variation of the top gate voltage. Even though the phase should be continuously adjustable in a four terminal setup, strong phase rigidity prevails in the local setup.

To explain this behavior within the Landauer-Büttiker formalism requires to go beyond simplified 1D-models and the scattering matrix in a realistic 2D-setup has to be computed. Provided that we include depletion effects and rounded crossings, we reproduce the experimental observed phase changes and explain the underlying mechanism. As a consequence the phase behavior fundamentally relies on the device geometry. Finite temperature and finite bias voltage does break symmetry in the local setup and the phase rigidity is slightly lifted. We computed the scattering matrix by an efficient time-dependent approach, based on wave packet propagation. Hence, simulation of complicated 4-terminal geometries for a large range of gate voltages have become accessible for the first time.