TT 35: Transport: Nanoelectronics I - Quantum Dots, Wires, Point Contacts 3

Time: Thursday 14:00–18:30 Location: H 3010

TT 35.1 Thu 14:00 H 3010

Conductance of gold nanojunctions thinned by electromigration — •Regina Hoffmann[1,2], Daniel Weissenberger[2,3], Jacques Hawecker[2,3], Dominik Stöffler[1,2], and Hilbert v. Löhneysen[1,2,4] — [1]Physikalisches Institut, Universität Karlsruhe, 76128 Karlsruhe — [2]DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe, 76128 Karlsruhe — [3]Laboratorium für Elektronenmikroskopie, Universität Karlsruhe, 76128 Karlsruhe — [4]Forschungszentrum Karlsruhe, Institut für Festkörperphysik, 76021 Karlsruhe

Electromigration can in principle be used to fabricate arrays of nanocontacts for single-molecule junctions on the same chip, in contrast to the mechanically controllable break-junction technique. With this method, a Au nanowire prepared by electron beam lithography is heated resistively until thermally activated atoms diffuse under the influence of electromigration forces. Eventually, a nanogap is formed that can host a molecule. We report conductance histograms before a nanogap is formed that show oscillations as a function of the conductance for contacts in the ballistic regime. Obviously, heating enhances the probability of the atoms to reach equilibrium positions. The oscillations of the histogram as a function of the conductance have a period of slightly less than 1 G_0. This is typical for atomic shell structures. Similar oscillations have been observed for work-hardened Au wires while annealed Au shows oscillations typical for electronic shell structures [1].

[1] I.K. Yanson et al., Phys. Rev. Lett. 95, 256806 (2005).

TT 35.2 Thu 14:15 H 3010

Fabrication of nano-electrodes by means of controlled electrochemical deposition of gold — •Conrad R. Wolf, Daniel Gerster, Klaus Thonke, and Rolf Sauer — Institut für Halbleiterphysik, Universität Ulm, 89069 Ulm

In the emerging fields of nano- and molecular electronics a strong need for nano-electrodes arises from the wish to contact objects such as quantum dots or single molecules. In this contribution we show the use of a controlled electrochemical deposition scheme to fabricate stable electrodes with spacings below 10 nm. In our experiments we start with a pair of gold electrodes separated by a 200 nm gap prepared by electron beam lithography. These electrodes are immersed into a solution of KI and I_2 in ethanol which has been saturated by dissolving gold in it [1]. Both nano-electrodes are connected to the same DC potential, while an AC voltage between them is used to in-situ monitor the conductance with a lock-in amplifier. For the deposition a DC voltage is applied to the counter electrode until the recorded conductance reaches the desired value. It is also possible to reversibly close and open the electrode gap by applying positive and negative voltages, respectively, to the counter electrode. With this technique gaps of around 1 nm can be realized, as conductance measurements after rinsing and drying as well as SEM micrographs show. When the electrodes are grown together slowly, we observe a step-wise increase in the conductance which corresponds to integer multiples of the conductance quantum $2e^2/h$.

[1] A. Umeno and K. Hirakawa, Appl. Phys. Lett. 86, 143103 (2005).

TT 35.3 Thu 14:30 H 3010

Electrical conductance through nanocontacts between fcc(100) electrodes of gold — •Daniela Koudela[1], Olga Lopez-Acevedo[1], Michael Walter[1], and Hannu Häkkinen[1,2] — [1]Department of Physics, Nanoscience Center, P.O. Box 35, FIN-40014 University of Jyväskylä — [2]Department of Chemistry, P.O. Box 35, FIN-40014 University of Jyväskylä

Both experimental and theoretical work has been done to explain conductance curves for metal nanowires, giving presently a good model that allows to explain experimental results microscopically. For one atom contacts it has moreover been shown, theoretically and experimentally, a strong relation between the number of valence orbitals of the single atom and the maximum value of the conductance that can be obtained [1].

We have studied Au nanowires of different lengths connected to fcc(100) tips corresponding to possible configurations in the elongation process. For those systems we have calculated the self-consistent potential obtained with Density Functional Theory and used it to calculate the conductance using the recursion-transfer-matrix method [2]. Our results show that though gold has formally only one valence electron (6s), for wires shorter than 3 atoms there are 3 (partially) open eigenmodes. [3]

[1] E. Scheer et al., Nature 394, 154 (1998)

[2] M. Brandbyge, K. W. Jacobsen, J. K. Norskov, Phys. Rev. B 55, 2637 (1997)

[3] O. Lopez-Acevedo et al., in preparation.

TT 35.4 Thu 14:45 H 3010

Ohmic current trough 1D quantum constrictions in the nonlinear regime — •Afif Siddiki, Sefa Arslan, and Andreas Weichselbaum — Physics Department, Arnold Sommerfeld Center for Theoretical Physics, and Center for NanoScience, Ludwig-Maximilans-Universität, München

The electron and current density distributions in the close proximity of quantum point contacts (QPCs) are investigated. A three dimensional Poisson equation is solved self-consistently to obtain the electron density and potential profile in the absence of an external magnetic field for gate and etching defined devices. We observed the surface charges and their apparent effect on the confinement potential, when considering the (deeply) etched QPCs. In the presence of an external magnetic field, we investigated the formation of the incompressible strips and their influence on the current distribution both in the linear response and out of linear response regime. A spatial asymmetry of the current carrying incompressible strips, induced by the large source drain voltages, is reported for such devices in the non-linear regime.

TT 35.5 Thu 15:00 H 3010

Maximally-localized Wannier functions within the FLAPW method applied to ballistic transport in thin metallic wires — •Y. Mokrousov[1], N.-P. Wang[1], F. Freimuth[2], B. Hardrat[1], S. Blügel[2], and S. Heinze[1] — [1]Institute of Applied Physics, University of Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany — [2]Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich, Germany

We report on the development of a ballistic transport code for one-dimensional systems based on maximally-localized Wannier functions (MLWFs) [1] constructed within the full-potential linearized augmented plane-wave (FLAPW) method [2,3]. We describe the details of the MLWFs construction from the FLAPW wavefunctions choosing a monoatomic Pt chain as a model system. For the calculation of ballistic transport, we apply the Landauer formalism using Green's functions. The Hamiltonian of the system including a scattering region attached to semi-infinite leads is constructed from the MLWFs which serve as a localized basis set. The open boundary conditions are treated by replacing the leads by their self-energies obtained via the decimation technique. From the Green function we can immediately calculate the conductance of the system. As a first application of the approach, we study the transition from the contact to the tunneling regime in thin Pt wires by a stretched bond.

[1] N. Marzari and D. Vanderbilt, Phys. Rev. B 56, 12847 (1997)

[2] Y. Mokrousov *et. al.*, Phys. Rev. B 72, 045402 (2005)

[3] www.flapw.de

15 min. break

TT 35.6 Thu 15:30 H 3010

A nonequilibrium functional renormalization group study of the single impurity Anderson model — •Severin G. Jakobs, Mikhail Pletyukhov, Herbert Schoeller, and Volker Meden — Institut für Theortische Physik A, RWTH Aachen, Germany

We apply a nonequilibrium version of the functional renormalization group [1] to the problem of transport through the single impurity Anderson model at finite bias voltage, temperature and magnetic field. Apart from the flow of the self energy we investigate the flow of the frequency dependent two-particle vertex.

[1] S. G. Jakobs, V. Meden, H. Schoeller, Phys. Rev. Lett. **99**, 150603 (2007)

TT 35.7 Thu 15:45 H 3010

Novel iterative path-integral scheme for interacting quantum dots out of equilibrium — •Stephan Weiss, Jens Eckel, Michael Thorwart, and Reinhold Egger — Inst. f. Theoret. Physik IV, Heinrich-Heine Universität Düsseldorf

We have developed a novel numerically exact method to evaluate fermionic many-body path-integrals. This method (IPI), see also [1] allows to give benchmark results for the observables of interest, e.g. the current. We perform simulations for real-time path-integrals on the Keldysh contour in a non-equilibrium situation. As application, we focus on the single site Anderson impurity model, subject to an applied bias voltage. We calculate the steady state current as a function of various system parameters, such as gate voltage ϵ_0, temperature T, on-dot Coulomb interaction U and external magnetic field B. Furthermore we obtain the nonlinear differential conductance in the coherent tunneling regime as a function of these parameters.

[1] S. Weiss, J. Eckel, M. Thorwart, and R. Egger, submitted.

TT 35.8 Thu 16:00 H 3010

Competition between superconductivity and Kondo effect in a carbon nanotube quantum dot — Alexander Eichler[1], •Markus Weiss[1], Stefan Oberholzer[1], Christian Schönenberger[1], Alfredo Levy-Yeyati[2], Juan Carlos Cuevas[2], and Alvaro Martin-Rodero[2] — [1]Departement Physik, Universität Basel, Klingelbergstr. 82, CH-4056 Basel, Switzerland — [2]Departamento de Fisica Teorica de la Materia Condensada, Universidad Autonoma de Madrid, E-28049 Madrid, Spain

We present nonlinear transport measurements on a carbon nanotube contacted to superconducting electrodes. At low temperatures, the nanotube acts as a quantum dot with intermediate contact transparencies. While level spacing and the charging energy dominate, the contact transparencies are large enough for higher order processes like the Kondo effect to occur. With superconducting electrodes, signs of the superconducting gap become visible in nonlinear transport, and additional subgap features due to multiple Andreev refections appear. In addition, we see a striking difference between even and odd charge states, with the first Andreev process at V=Δ/e being strongly enhanced in states with odd electron number. Although direct signs of the Kondo effect, as the Kondo ridge around zero bias, are suppressed, we argue that this even-odd asymmetry is due to a hidden Kondo resonance that, due to contact asymmetries, survives only on one contact, and leads to strongly enhanced transport at V=Δ/e.

We find good agreement of our data with a single impurity Anderson model solved in a Slave Boson mean field approach.

TT 35.9 Thu 16:15 H 3010

Interaction Effects on Transport through an Electronic Mach-Zehnder Interferometer — •Vitaly Golovach and Florian Marquardt — Department of Physics, Arnold-Sommerfeld-Center for Theoretical Physics, and Center for NanoScience, Ludwig-Maximilians-Universität München, Theresienstrasse 37, 80333 Munich, Germany

We study theoretically transport through an electronic Mach-Zehnder interferometer in the presence of Coulomb interaction inside the interferometer, using a discrete wave-packet model. We find that the mutual capacitance between the arms of the interferometer leads to a suppression of the visibility of the Aharonov-Bohm oscillations at a large source-drain bias $\Delta\mu \gg \hbar v_F/L$, where L is the length of the arms and v_F is the electron drift speed. Our numerical simulations indicate that the visibility of the Aharonov-Bohm oscillations is a non-analytic function of the mutual capacitance strength, in the limit $\Delta\mu \to \infty$.

TT 35.10 Thu 16:30 H 3010

Effect of Magnetic field on edge channel interference in an electronic Mach-Zehnder interferometer — •Leonid Litvin, Andreas Helzel, Peter Tranitz, Werner Wegscheider, and Christoph Strunk — Institute of experimental and applied physics, University of Regensburg, D-93040 Regensburg, Germany

We study an electronic Mach-Zehnder Interferometer (MZI) employing the edge channels of a two-dimensional electron gas in the quantum Hall regime and quantum point contacts as tuneable beam splitters. In this system interference contrast up to 80% can be achieved at low temperatures. Two interferometers with the arm length of 14 and 9 μm were investigated. We found that the interference contrast depends strongly on interferometer size and filling factor. High visibility is restricted to a rather small interval of magnetic field, which approximately ranges from filling factor 2 to 1, with maximum near 1.5. The temperature dependences of visibility taken at fixed magnetic field show exponential damping above ≈45 mK. Below this value the visibility has much weaker T-dependence. This implies that two energy scales are responsible for the decay of visibility.

TT 35.11 Thu 16:45 H 3010

Bulk-edge coupling in the non-abelian $\nu = 5/2$ quantum Hall interferometer — •Bernd Rosenow[1], Bertrand I. Halperin[1], Steven H. Simon[2], and Ady Stern[3] — [1]Physics Department, Harvard University, Cambridge, MA 02138 — [2]Lucent-Alcatel Bell Laboratories, Murray Hill NJ, 07974 — [3]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot 76100, Israel

Recent schemes for probing non-abelian statistics in the $\nu = 5/2$ quantum Hall effect are based on geometries where current-carrying quasiparticles flow along edges that encircle N_{qp} bulk quasiparticles, which are localized. Here we consider one such scheme, the Fabry-Perot interferometer. In the limit of weak back-scattering, when N_{qp} is even the two back-scattering amplitudes interfere coherently, while when N_{qp} is odd they are incoherent, and thus do not interfere. In the former case, the back-scattered current oscillates with the area of the cell, while in the latter case it does not. This difference reflects the non-abelian nature of the quasiparticles.

In a real system, some degree of coupling between the edge and quasiparticles localized in the bulk is unavoidable. One may suspect that such a coupling would blur the distinction between bulk and edge quasiparticles and endanger the possibility of observing the even-odd effect. We find that at weak coupling the interference signal is indeed degraded, while for strong enough coupling the bulk quasiparticle becomes essentially absorbed by the edge and the even-odd effect survives. Furthermore, we find that the strength of the coupling can be tuned by the source-drain voltage.

15 min. break

TT 35.12 Thu 17:15 H 3010

Critical conductance of a one-dimensional doped Mott insulator — •Markus Garst[1], Dmitry Novikov[2], Ady Stern[3], and Leonid Glazman[2] — [1]Institut für Theoretische Physik, Universität zu Köln, 50938 Köln — [2]Department of Physics, Yale University, New Haven, Connecticut 06520, USA — [3]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot 76100, Israel

We consider the two-terminal conductance of a one-dimensional Mott insulator close to the commensurate-incommensurate quantum phase transition to a conducting state (arXiv:0708.0545). We treat the leads as Luttinger liquids. At a specific value of compressibility in the leads, corresponding to the Luther-Emery point, the conductance can be computed in terms of a scattering problem of non-interacting fermions with charge $e/\sqrt{2}$. The Mott insulator can be approximated as an effective point scatterer with a strongly energy dependent scattering matrix. At the Luther-Emery point, the temperature dependence of the conductance across the quantum phase transition is then described by a Fermi function. The deviation from the Luther-Emery point in the leads results in an interaction among the fermionic scattering states and changes the temperature dependence qualitatively. In the metallic state, the low-temperature conductance is determined by the properties of the leads, and is described by the conventional Luttinger liquid theory. In the insulating state, conductance still occurs via activation of $e/\sqrt{2}$ charges, and is independent of the Luttinger liquid compressibility.

TT 35.13 Thu 17:30 H 3010

Conductivity of a disordered fermion-gaugefield system — •Thomas Ludwig[1], Igor V. Gornyi[2], Alexander D. Mirlin[2,3], and Peter Woelfle[3] — [1]Instituut-Lorentz, Universiteit Leiden, The Netherlands — [2]Institut fuer Nanotechnologie, Forschungszentrum Karlsruhe, Germany — [3]Institut fuer Theorie der kondensierten Materie, Universitaet Karlsruhe, Germany

We present a discussion of the interaction correction to conductivity in a disordered system of fermions interacting via a Chern-Simons gauge field. To first order in the interaction, we find a large positive Hartree correction to the conductivity. To account for higher orders in the interaction, we discuss effects of dephasing (at high temperatures) and screening (at low temperatures) on the Hartree correction. At sufficiently high temperatures, the Hartree correction is strongly suppressed by dephasing. At very low temperatures, the correction changes its sign to negative due to screening.

TT 35.14 Thu 17:45 H 3010

Quantum Transport in a Multi Particle Triple Quantum Dot

— •Pöltl Christina, Emary Clive, and Brandes Tobias — Institut für Theoretische Physik, Hardenbergstr. 36, D-10623 TU Berlin, Germany

It is known that in the transport through triple quantum dot systems so-called dark states can occur [1, 2]. An electron entering such a state is trapped in the quantum dot system due to destructive interference and this leads to a blockade in current. Such states have previously been discussed only in the strong Coulomb blockade regime, where at most one excess electron is present in the system at any one time.

In this contribution, we discuss the effects of relaxing this condition, and permit multiple dot-occupancies. We use an number-resolved master equation approach to calculate the current, noise and counting statistics of the system, and show how the experimentally relevant quantities show a combination of dark-state and multiple-occupancy effects. We also consider signatures of electronic entanglement in the system.

[1] B. Michaelis, C. Emary and C. W. J. Beenakker, Europhys. Lett., 73 (5), pp. 677-683 (2006)

[2] C. W. Groth, B. Michaelis, and C. W. J. Beenakker, Phys. Rev B 74, 125315 (2006)

TT 35.15 Thu 18:00 H 3010

Electron Bunching in Stacks of Coupled Quantum Dots

— •Sigmund Kohler[1], Rafael Sánchez[2], Peter Hänggi[1], and Gloria Platero[2] — [1]Institut für Physik, Universität Augsburg — [2]Instituto de Ciencia de Materiales, CSIC, Madrid, Spain

In recent measurements of the electrical current through transport channels that are formed by self-assembled double quantum dots, super-Poissonian noise has been observed [1]. In this system, two physical ingredients seems to play a crucial role, namely Coulomb interaction between electrons in neighbouring transport channels and, as well, the coupling of the electrons to substrate phonons. In a corresponding theoretical analysis [2], we study the transport properties of two double quantum dots in a parallel arrangement, in which the transport channels can block each other. Our results show that phonon emission and absorption, however, can suspend this blocking, which leads to “phonon-induced channel opening”. This also affects the shot noise: For asymmetric coupling between the dots and the respective lead, the current noise is sub-Poissonian for resonant tunnelling, but super-Poissonian in the vicinity of the resonances. The both experimentally and theoretically observed asymmetry of the peaks at low temperatures stems from spontaneous emission.

[1] P. Barthold, F. Hols, N. Maire, K. Pierz, and R. J. Haug, Phys. Rev. Lett. **96**, 246804 (2006).

[2] R. Sánchez, S. Kohler, P. Hänggi, and G. Platero, arXiv:0706.2950 [cond-mat].

TT 35.16 Thu 18:15 H 3010

Violation of Wiedemann-Franz Law in a Single-Electron Transistor

— •Björn Kubala[1,2], Jürgen König[1], and Jukka Pekola[3] — [1]TP III, Ruhr-Universität Bochum, 44780 Bochum, Germany — [2]Physics Department, ASC, and CeNS, Ludwig-Maximilians-Universität, 80333 Munich, Germany — [3]Low Temperature Laboratory, Helsinki University of Technology, PO BOX 3500, 02015 TKK, Finland

We study the influence of Coulomb interaction on the thermoelectric transport coefficients for a metallic single-electron transistor [1]. By performing a perturbation expansion up to second order in the tunnel-barrier conductance, we include sequential and cotunneling processes as well as quantum fluctuations that renormalize the charging energy and the tunnel conductance. We find that Coulomb interaction leads to a strong violation of the Wiedemann-Franz law: the Lorenz ratio becomes gate-voltage dependent for sequential tunneling, and is increased by a factor 9/5 in the cotunneling regime. Finally, we suggest a measurement scheme for an experimental realization.

[1] B. Kubala, J. König, and J. Pekola, arXiv:0709.4181 (unpublished).