TT 2: Transport: Nanoelectronics I - Quantum Dots and Wires, Point Contacts 1

Time: Monday 10:15–13:00 Location: HSZ 301

TT 2.1 Mon 10:15 HSZ 301

Friedel oscillations in quantum wires: interplay of interactions and non-equilibrium — Daniel F Urban[1] and •Andreas Komnik[2] — [1]Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg i. Br. — [2]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 19, 69120 Heidelberg

We discuss the electron density oscillations in an interacting one-dimensional electron system with an impurity [1]. Under appropriate conditions the wave vector is given by different values $k_F = k_{L/R}$ on left/right side of the scatterer, leading to a Landauer dipole formation. While in the non-interacting system the Friedel oscillations possess only one periodicity related to the local k_L on the left side, the interplay of the interactions and non-equilibrium effects generates an additional peak in the spectrum of density oscillations at k_R. The position and shape of this spectral feature, which in coordinate space is observable as a beating pattern in the Friedel oscillations, reveals many important details about the nature of interactions. We believe that it has a potential to become an investigation tool in condensed matter physics.

[1] D.F.Urban and A.Komnik, Phys. Rev. Lett. **100**, 146602 (2008)

TT 2.2 Mon 10:30 HSZ 301

Scanning probe measurements and electromigration of metallic nanostructures under ultra-high vacuum conditions — •Dominik Stöffler[1], Shawn Fostner[2], Hilbert v. Löhneysen[1,3], Peter Grütter[2], and Regina Hoffmann[1] — [1]Physikalisches Institut and DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe, D-76128 Karlsruhe, Germany — [2]Physics Department, McGill university, H3A-2T8 Montreal, Canada — [3]Forschungszentrum Karlsruhe, Institut für Festkörperphysik, D-76021 Karlsruhe, Germany

Quantum effects play an important role in metal contacts of nanometer size. We use e-beam litho-graphy as well as shadow evaporation through a stencil mask to fabricate nanobridges made of gold and platinum. The bridges are subject to feedback-controlled electromigration in ultra-high vacuum (UHV). While investigating the e-beam fabricated platinum structures with the scanning tunneling microscope (STM) in UHV we discovered dense topographically higher features in regions of anteceding STM scans, suggesting deposition of additional material, possibly carbon, of up to 10 nm thickness. We imaged these regions with STM as well as with scanning electron microscopy (SEM). To avoid such a deposition on the metallic bridges we used atomic force microscopy to investigate the electromigration in UHV. The gold wires show no fundamental difference to electromigration under ambient conditions. Platinum wires need a higher voltage to start the electromigraton process compared to gold wires. We have obtained images with 3 nm resolution and have observed conductance plateaus related to the atomic structure of the resulting gold nanocontacts.

TT 2.3 Mon 10:45 HSZ 301

Non-equilibrium transport through coupled quantum dot–metallic island systems — •Marco G. Pala[1], Michele Governale[2], and Jürgen König[2] — [1]IMEP-LAHC, INP MINATEC, Centre National de la Recherche Scientifique, 38016 Grenoble, France — [2]Theoretische Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany

We study transport through a system composed of a single-level quantum dot tunnel-coupled to a metallic island. Such a system is of interest since it can be used to model transport trough a large island in series with charge trap centers [1]. A real-time diagrammatic technique [2,3], capable of accounting for non-equilibrium, Coulomb interaction and high-order tunneling processes, is employed to investigate transport in the resonant tunneling regime under the influence of a finite interaction strength between the dot and the island.

[1] M. Hofheinz et al., Eur. Phys. J. B **54**, 299 (2006).
[2] J. König, H. Schoeller, and G. Schön, Phys. Rev. Lett. **76**, 1715 (1996).
[3] H. Schoeller and G. Schön, Phys. Rev. B **50**, 18436 (1994).

TT 2.4 Mon 11:00 HSZ 301

Error Acconting in Electron Counting Experiments — •Michael Wulf and Alexander B. Zorin — Physikalisch Technische Bundeanstalt, Bundesallee 100, 38116 Braunschweig

Electron counting experiments attempt to provide a current of a known number of electrons per unit time. We propose architectures utilizing a few readily available electron-pumps or turnstiles with the typical error rates of 1 part per 10^4 with common sensitive electrometers to achieve the desirable accuracy of 1 part in 10^8. This is achieved not by counting all transferred electrons but by counting only the errors of individual devices; these are less frequent and therefore readily recognized and accounted for. We thereby ease the route towards quantum based standards for current and capacitance.

TT 2.5 Mon 11:15 HSZ 301

Interaction-induced harmonic frequency mixing in quantum dots — •Michael Thorwart[1], Reinhold Egger[2], and Alexander O. Gogolin[3] — [1]FRIAS, Universität Freiburg — [2]Universität Düsseldorf — [3]Imperial College London

We show [1] that harmonic frequency mixing in quantum dots coupled to two leads under the influence of time-dependent voltages of different frequency is dominated by interaction effects. This offers a unique and direct spectroscopic tool to access correlations, and holds promise for efficient frequency mixing in nano-devices. Explicit results are provided for an Anderson dot and for a molecular level with phonon-mediated interactions.

[1] M. Thorwart, R. Egger, and A.O. Gogolin, Phys. Rev. Lett. **101**, 036806 (2008)

15 min. break

TT 2.6 Mon 11:45 HSZ 301

Nonequilibrium Transport in the Interacting Resonant Level Model — •Peter Schmitteckert — Institut für Nanotechnologie, KIT, Karlsruhe, Germany

The Density Matrix Renormalization Group (DMRG) method is now a well established method to study interacting, low-dimensional quantum systems. In this talk I review the linear conductance calculations of the Kubo approach and the finite bias conductance calculations from real time simulations within DMRG. I will then discuss the finite bias conductance of the interacting resonant level model and compare to analytical calculations based on integrability in the continuum limit. The two approaches are in excellent agreement, and uncover among other things a power law decay of the current at large voltages when $U > 0$.

[1] Edouard Boulat, Hubert Saleur, and Peter Schmitteckert, Twofold Advance in the Theoretical Understanding of Far-From-Equilibrium Properties of Interacting Nanostructures, Phys. Rev. Lett. **101**, 140601 (2008).

TT 2.7 Mon 12:00 HSZ 301

Application of the weak-coupling CTQMC method to a Quantum Dot coupled to superconducting leads — •David J. Luitz and Fakher F. Assaad — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, D-97074 Würzburg, Germany

We apply the weak-coupling continuous time quantum Monte Carlo (CTQMC) method to the Anderson-model extended by a BCS term to describe a quantum dot coupled to s-wave superconducting leads. As the superconducting gap Δ grows, our data shows a phase transition from the 0- to π-junction regime of the Josephson current. By examining various spectral functions, we confirm the traditional interpretation that the Kondo-effect at small Δ corresponds to the 0-junction-regime, while the formation of a magnetic moment on the quantum dot leads to the π-phase-shift at large Δ. At constant Δ, the double occupancy as a function of U shows a jump, thereby signaling a first order transition between the singlet and local moment doublet regimes.

Within DMFT, this impurity problem provides a link to the periodic Anderson model (PAM) with superconducting conduction electrons. The signature of this first order transition in the impurity model in the PAM will be discussed.

TT 2.8 Mon 12:15 HSZ 301

Weak localization in a two-dimensional hole gas — •Viktor Krückl, Michael Wimmer, Inanc Adagideli, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg

In several experiments the effect of weak localization is studied in two-dimensional hole gases but there are only few theoretical works which analyze the effects of the different hole types in a typical valence band structure. We investigate different materials modeled by the 4-band Luttinger Hamiltonian in a two-dimensional approximation. Transport properties in the diffusive regime as well as ballistic cavities are calculated in an effective tight-binding approximation by means of the Green function method. The influence of coupling between heavy holes and light holes leads to a decrease of the weak localization which is explained by the Berry curvature as well as a semiclassical description.

TT 2.9 Mon 12:30 HSZ 301

Tunneling through nanostructures: random matrix theory for the rate equation — •Carsten Timm — Institut für Theoretische Physik, Technische Universität Dresden

Under the conditions of weak hybridization and rapid dephasing, electronic tunneling through quantum dots or single molecules can be described by rate equations. Except for highly simplified models, one typically finds rather complex structures in the differential conductance. Random matrix theory has been used to describe statistical properties of the energy spectrum in such cases. Here, we follow a different approach: The rate equations for the probabilities P_n of states of the nanosystem can be written as $dP_m/dt = \sum_n A_{mn}P_n$. The eigenvalues of the stochastic matrix A describe the relaxational and oscillatory dynamics of the probabilities. We take A to be a random matrix. We discuss ensembles realized by these matrices and present results for the distribution and correlations of their eigenvalues.

TT 2.10 Mon 12:45 HSZ 301

Many-Body Effects in Quantum Heat Transport Through Nanostructures — •Haldun Sevinci, Rafael Gutierrez, and Gianaurelio Cuniberti — Institute for Materials Science and Max Bergmann Center of Biomaterials, Dresden University of Technology, D-01062 Dresden, Germany

Employing the nonequilibrium Green's function (NEGF) method at the atomistic level, we study the heat transport in nano-scale systems. Using diagramatic expansions of NEGFs we investigate the effects of anharmonic interactions in quantum thermal transport. The effects of nonlinear interactions on phononic transport are investigated. Specifically, the questions of thermal rectification and negative differential thermal resistance are addressed. Two possible schemes to control thermal rectification are discussed. The first one is by creating a mass gradient along the structure which is achieved experimentally by coating of a nanotube. The second one is modulating the width of the nanostructure along the transport direction which can be realized using graphene nanoribbons or Si nanowires.