# TT 29: TR: Nanoelectronics I: Quantum Dots, Wires, Point Contacts 1

Time: Thursday 9:30–13:00 Location: H19

TT 29.1 Thu 9:30 H19

**Hyperfine-induced valley mixing and the spin-valley blockade in carbon-based quantum dots** — •Andras Palyi and Guido Burkard — Department of Physics, University of Konstanz, Germany

Hyperfine interaction (HFI) in carbon nanotube and graphene quantum dots is due to the presence of $^{13}C$ atoms. We theoretically show [1] that in these structures the short-range nature of the HFI gives rise to a coupling between the valley degree of freedom of the electron and the nuclear spin, in addition to the usual electron spin-nuclear spin coupling. We predict that this property of the HFI affects the Pauli blockade transport in carbon-based double quantum dots. In particular, we show that transport is blocked only if both the spin and the valley degeneracies of the quantum dot levels are lifted, e.g., by an appropriately oriented magnetic field. The blockade is caused by four "supertriplet" states in the (1,1) charge configuration.

[1] A. Palyi and G. Burkard, Phys. Rev. B **80**, 201404(R) (2009)

TT 29.2 Thu 9:45 H19

**AC-Conductance through an Interacting Quantum Dot** — •Björn Kubala and Florian Marquardt — Physics Department, Arnold Sommerfeld Center for Theoretical Physics, and Center for NanoScience, Ludwig-Maximilians-Universität, 80333 Munich, Germany

We investigate the linear ac-conductance for tunneling through an arbitrary interacting quantum dot in the presence of a finite dc-bias [1]. In analogy to the well-known Meir-Wingreen formula for the dc case, we are able to derive a general formula for the ac-conductance. It can be expressed entirely in terms of local correlations on the quantum dot, in the form of a Keldysh block diagram with four external legs. We illustrate the use of this formula as a starting point for diagrammatic calculations by considering the ac-conductance of the noninteracting resonant level model and deriving the result for the lowest order of electron-phonon coupling. We show how known results are recovered in the appropriate limits.

[1] Björn Kubala and Florian Marquardt, arXiv:0910.2844 (unpublished).

TT 29.3 Thu 10:00 H19

**Nonequilibrium quantum transport through nanoscale junctions within the scattering-states numerical renormalization group approach** — •Sebastian Schmitt and Frithjof B. Anders — Lehrstuhl für Theoretische Physik II, Technische Universität Dortmund, Otto-Hahn-Str. 4, 44221 Dortmund

We employ the recently developed scattering-states numerical renormalization group approach to open quantum systems to study nonequilibrium Green functions and current-voltage characteristics of nanoscale junctions for intermediate and large values of the Coulomb interaction $U$. In particular, the influence of charge fluctuations when approaching the strong-coupling regime is discussed.

TT 29.4 Thu 10:15 H19

**Non-equilibrium current and relaxation dynamics of a charge-fluctuating quantum dot** — •Sabine Andergassen[1], Christoph Karrasch[1], Mikhail Pletyukhov[1], Dirk Schuricht[1], Laszlo Borda[2], Volker Meden[1], and Herbert Schoeller[1] — [1]Institut für Theoretische Physik A und JARA - Fundamentals of Future Information Nanotechnology, RWTH Aachen University — [2]Physikalisches Institut, Universität Bonn

We study the steady-state current in a minimal model for a quantum dot dominated by charge fluctuations and analytically describe the time evolution into this state. The current is driven by a finite bias voltage across the dot. The Coulomb interaction of the localized dot electron with the lead electrons is treated using two complementary renormalization group methods. We find interesting non-equilibrium effects which can in general not be explained by simply considering the bias voltage as an additional infrared cutoff. The relaxation dynamics shows characteristic oscillations as well as an interplay of exponential and power-law decay.

TT 29.5 Thu 10:30 H19

**Non-equilibrium transport through a two-level quantum dot: a renormalization-group analysis** — •Sarah Müller[1], Sabine Andergassen[1], Verena Koerting[2], and Dirk Schuricht[1] — [1]Institut für Theoretische Physik A und JARA - Fundamentals of Future Information Nanotechnology, RWTH Aachen University — [2]Niels Bohr Institute, Universitetsparken 5, 2100 København Ø, Denmark

Transport through quantum dots is in general characterized by asymmetric couplings to the leads. In particular, in molecules and nanowires the coupling of each individual orbital level can be different. Motivated by recent experiments, we therefore study the effects of asymmetric hopping parameters on the non-equilibrium current and occupation probabilities of a two-level quantum dot. Starting from a two-level Anderson model, we perform a generalized Schrieffer-Wolff transformation to derive an effective Kondo model. A first perturbative analysis of the cotunneling current allows to determine a regime of negative differential conductance arising for couplings being both asymmetric with respect to the leads as well as to the quantum dot levels. Due to the non-equilibrium occupation of the levels inelastic cotunneling transitions are allowed not only from the ground state but from the excited state. The dependence of this cascade resonance on the magnetic field is discussed in detail. Since we expect the cotunneling lines to be measured experimentally for strong values of the couplings, we study the logarithmic enhancement of the ascribed signatures by means of a poor-man's renormalization-group treatment out of equilibrium.

TT 29.6 Thu 10:45 H19

**Symmetry of the scattering states in defected metallic carbon nanotubes** — •Leonhard Mayrhofer[1] and Dario Bercioux[2] — [1]Fraunhofer IWM, Wöhlerstraße 11, D-79108 Freiburg, Germany — [2]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität, D-79104 Freiburg, Germany

In the last decade, several STM experiments [1-3] on metallic carbon nanotubes have given the opportunity to study the properties of scattering states induced by tube ending and local defects. Of particular interest is the possibility of reconstructing the electronic spectrum via Fourier analysis. The experimental results show a lack of the electronic branches depending of the tube chirality and the nature of the defect. We have performed an in depth analysis of the properties of the scattering states as a function of the symmetry properties of single- and double-vacancy defects. Our results are based on the comparison of a numerically exact tight-binding procedure with an analysis of the carbon nanotube symmetry groups.

[1] M. Ouyang,*et al.*, Phys. Rev. Lett. **88**, 066804 (2002).
[2] J. Lee *et al.*, Phys. Rev. Lett. **93**, 166403 (2004).
[3] G. Buchs, *et al.*, Phys. Rev. Lett. **102**, 245505 (2009).

TT 29.7 Thu 11:00 H19

**Crossover between the Kondo effect for quantum dots and the 0.7 conductance anomaly for quantum point contacts** — •Jan Heyder, Florian Bauer, and Jan von Delft — Ludwig Maximilians Universitaet , Muenchen

It has been conjectured that the 0.7 conductance anomaly for transport through a quantum point contact (QPC) is closely related to the Kondo effect for transport through a quantum dot (QD) [1,2,3]. To study the relation between these two effects explicitly, we consider a 1-D quantum wire modeled by a tight-binding chain with short-ranged Coulomb interactions and a prescribed onsite potential, whose shape can be varied to mimick the smooth crossover from a double-barrier potential (QD geometry) to a single barrier potential (QPC geometry) as the bottom of the central valley is raised until the central valley disappears completely. We use the functional renormalization group to calculate the conductance, local density and local magnetization at zero temperature as a function of magnetic field, Coulomb interaction and potential shape. Our results reveal both striking similarities and striking differences between the parameter-dependencies of the 0.7 anomaly and the Kondo effect.

[1] Y. Meir, K. Hirose, N.S. Wingreen, Phys. Rev. Lett.,89, 196802 (2002).

[2] K. Hirose, Y. Meir, N. S. Wingreen, Phys. Rev.Lett.,90, 026804 (2003).

[3] T. Rejec, Y. Meir, Nature, 442, 900 (2006).

**15 min. break**

TT 29.8 Thu 11:30 H19

**Spin-dependent transport through quantum-dot Aharonov-Bohm interferometers** — •Bastian Hiltscher[1], Michele Governale[2], and Jürgen König[1] — [1]Theoretische Physik, Universität Duisburg-Essen and CeNIDE, 47048 Duisburg, Germany — [2]School of Chemical and Physical Sciences, Victoria University of Wellington, PO Box 600, Wellington 6140, New Zealand

We adress the issue of coherence of transport through interacting quantum dots. For that purpose we consider an Aharonov-Bohm interferometer (ABI) with a single-level quantum dot embedded in one of the arms. For studying the role of spin we choose one lead to be ferromagnetic. We employ a diagrammatic real-time formalism where a perturbation expansion in the tunnel-coupling strength between dot and leads is performed, taking into account the Coulomb interaction non perturbatively [1].

Cotunneling through a quantum dot yields dephasing whenever the spin on the dot is flipped [2]. In the absence of Coulomb interaction transport is fully coherent and the total current is flux dependent. For an infinite interaction on the dot the AB oscillations are strongly influenced by the polarization and the transport direction. We discuss for different transport regimes which information the AB amplitude provides about coherence.

[1] König and Gefen, PRL **86**, 3855 (2001) and PRB **65**, 045316 (2002).
[2] Aikawa *et al.*, PRL **92**, 176802 (2004); Ihn *et al.*, NJP **9**, 111 (2007).

TT 29.9 Thu 11:45 H19

**Transport properties of normal-quantum dot-superconductor hybrid structures** — •Henning Soller and Andreas Komnik — Institut für Theoretische Physik, Philosophenweg 19, 69120 Heidelberg

We discuss the transport properties of a quantum dot coupled to normal as well as superconducting electrodes in the multi-terminal geometry. The system exhibits interesting effects already in the non-interacting case due to the energy-dependence of the superconducting density of states competing with the energy-dependent transmission through the resonant level. We analyze the full counting statistics of the system allowing for a possible inclusion of interactions and a magnetic field and provide explicit results for the current, noise and cross correlations.

TT 29.10 Thu 12:00 H19

**Thermolelectric transport through strongly correlated quantum dots** — •Theo Costi[1] and Veljko Zlatić[1,2] — [1]Institut für Festkörperforschung and Institute for Advanced Simulation (IAS), Forschungszentrum Jülich, 52428 Jülich, Germany — [2]Institute of Physics, 10001 Zagreb, Croatia

We use the numerical renormalization group method to calculate thermoelectric transport through a strongly correlated quantum dot described by a single level Anderson impurity model attached to non-interacting leads[1]. We compare and contrast the results with the well known ones for the case of dilute magnetic impurities in non-magnetic metals. In the Kondo regime, we find significant differences in the height of the "charge-fluctuation" peak of the thermopower for these two different situations. The thermal conductivity for the quantum dot exhibits a richer behaviour than for the case of magnetic impurities. We discuss favourable conditions of gate voltage and temperature for achieving a large figure of merit for quantum dot systems.

[1] T. A. Costi and V. Zlatić, preprint (2009).

TT 29.11 Thu 12:15 H19

**Two-Particle Dark States in the Transport through Quantum Dot systems** — •Christina Pöltl, Clive Emary, and Tobias Brandes — Institut für Theoretische Physik, Hardenbergstr. 36, D-10623 TU Berlin, Germany

Dark states (DSs) are originally a quantum optic phenomenon discovered as a dark line in the fluorescence of sodium atoms. The concept of the Dark states has been generalized to mesoscopic transport as coherent superpositions that block current flow. The triple quantum dot (TQD) in a triangular geometry is a system where several transport DS phenomena have been studied e.g. [1].

In this contribution, we apply bias such that both singly- and doubly- charged states participate in the transport through the TQD and focus on the formation of a two-electron DS [2].We discuss the conditions under which such a state forms and describe the signatures that it leaves in transport properties such as the differential conductance and shot noise. Our finite-bias calculations facilitate the experimental investigation of DS effects such as the break up of Coulomb blockade diamonds in the stability diagram of the TQD due to one- and two-electron DSs. However it shows that this two-electron DS is a product state of a spin-up and a spin-down single-particle DS. Therefore we also introduce a quantum dot system which allows to configure a spin entangled two-electron DS due to an exchange interaction between the electrons.

[1] B. Michaelis, et al. Europhys. Lett., 73, 677 (2006),
[2] C. Pöltl, et al. Phys. Rev. B 80, 115313 (2009)

TT 29.12 Thu 12:30 H19

**Quantum Monte Carlo simulations for contacted quantum dots** — •Lothar Mühlbacher[1] and Klaus Ferdinand Albrecht[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität, Freiburg, Germany — [2]Institut für theoretische Physik, Ruprecht-Karls-Universität, Heidelberg, Germany

Correlated transport through nanostructures can prototypically be studied in the framework of the Anderson impurity model. It comprises of a single, spin degenerate electronic level which couples via tunneling to two (or more) metallic electrodes. Although analytic solutions exist for many of its equilibrium properties, the non-equilibrium case, when the electrodes are subject to a finite voltage bias, is yet to be fully understood.

In recent years, real-time diagrammatic Monte Carlo (MC) techniques have emerged as a new and promising tool for a quantitative analysis of the non-equilibrium transport properties. For a large range of parameters, the transient as well as stationary transport properties can be calculated in a numerically exact way. Since diagrammatic MC schemes impose rather few restrictions with respect to the modeling of the electrodes, they also allow to include time-dependent tunneling couplings or to measure the quantum dot's spectral density via a three-terminal setup. Furthermore, in combination with path-integral techniques, diagrammatic MC methods are also capable of accessing the dynamics of a quantum dot coupled to a heat reservoir. Thus, in addition to electronic correlations, the influence of electron-phonon interactions on the transport properties can be studied as well.

TT 29.13 Thu 12:45 H19

**Theory of the Topological Anderson Insulator** — •Michael Wimmer[1], Christoph W. Groth[1], Anton R. Akhmerov[1], Jakub Tworzydło[2], and Carlo W. J. Beenakker[1] — [1]Instituut-Lorentz, Universiteit Leiden, The Netherlands — [2]Institute of Theoretical Physics, Warsaw university, Poland

We present an effective medium theory that explains the disorder-induced transition into a phase of quantized conductance, discovered in computer simulations of HgTe quantum wells [1,2]. It is the combination of a random potential and quadratic corrections $\propto p^2\sigma_z$ to the Dirac Hamiltonian that can drive an ordinary band insulator into a topological insulator (having an inverted band gap). We calculate the location of the phase boundary at weak disorder and show that it corresponds to the crossing of a band edge rather than a mobility edge. Our mechanism for the formation of a topological Anderson insulator is generic, and would apply as well to three-dimensional semiconductors with strong spin-orbit coupling.

[1] J. Li *et al.* Phys. Rev. Lett. **102**, 136806 (2009).
[2] H. Jiang *et al.* Phys. Rev. B **80**, 165316 (2009)