TT 21: Transport: Nanoelectronics I - Quantum Dots, Wires, Point Contacts 3

Time: Tuesday 9:30–13:00 Location: BH 334

TT 21.1 Tue 9:30 BH 334

Quantum spin relaxation by a nonequilibrium current — •Daniel Becker[1,2], Stephan Weiss[2], Michael Thorwart[2], and Daniela Pfannkuche[2] — [1]Department Physik, Universität Basel, 4056 Basel, Schweiz — [2]I. Institut für Theoretische Physik, Universität Hamburg, 20355 Hamburg

For a Coulomb-interacting single-level quantum dot in contact with two metallic leads and a spin-1/2 magnetic impurity, which is exchange-coupled to the electron spin, the interplay between the correlated charge- and (interaction-induced) real-time impurity dynamics is studied. To this end, the numerically exact, non-perturbative scheme of iterative summation of path integrals (ISPI)[1,2] is employed in a regime, where all appearing energy scales are of the same order of magnitude. A systematical investigation of the mutual dependencies between charge current and impurity relaxation dynamics is provided. By comparison to a perturbative theory both for (a) the case of either vanishing Coulomb- or electron-impurity interaction and (b) nonvanishing interactions, it is clearly shown that correlation effects due to the on-dot interactions considerably affect the system behavior. In particular, our approach reveals how a quantum spin relaxes to its stationary state under the influence of a nonequilibrium current.

[1] S. Weiss et al., Phys. Rev. B 77, 195316 (2008)
[2] D. Becker et al., J. Phys.: Conf. Ser. 245 012021 (2010)

TT 21.2 Tue 9:45 BH 334

Current from hot spots — •Rafael Sánchez[1] and Markus Büttiker[2] — [1]Instituto de Ciencia de Materiales de Madrid (ICMM-CSIC) — [2]Département de Physique Théorique, Université de Genève

In electrical circuits hot spots occur naturally at places where energy is dissipated. Here we propose a controlled experiment which can demonstrate the appearance of directed current as a consequence of a hot spot. We investigate transport generated in Coulomb coupled electrical conductors from excess fluctuations at the coupling capacitance. If one of the conductors supports a bias voltage, out of equilibrium charge fluctuations remove detailed balance in the unbiased system manifested in a drag current. Non linear fluctuation relations can nevertheless be obtained [1].

Coulomb coupled conductors permit separate directions of the heat and current flux [2]. In our model, one of the conductors is connected via only one lead to a hot reservoir. The other conductor connects to two leads. We investigate the minimal conditions needed to generate directed current flow for a system of two quantum dot conductors in which both energy and charge states are quantized. In quantum dots energy to current conversion can be optimal with one electron transferred for every heat quantum given up by the hot reservoir. We show that at the point of maximum power extraction the efficiency approaches one half of the Carnot efficiency.

[1] R. Sánchez, R. López, D. Sánchez, and M. Büttiker, Phys. Rev. Lett. 104, 076801 (2010)
[2] R. Sánchez, and M. Büttiker, Phys. Rev. B 83, 085428 (2011)

TT 21.3 Tue 10:00 BH 334

Nonequilibrium transport through quantum dots with Dzyaloshinsky-Moriya-Kondo interaction — •Mikhail Pletyukhov and Dirk Schuricht — Institut für Theorie der statistischen Physik, RWTH Aachen, Physikzentrum, D - 52074 Aachen

We study nonequilibrium transport through a single-orbital Anderson model in a magnetic field with spin-dependent hopping amplitudes. In the cotunneling regime, it is described by an effective spin-1/2 dot with a Dzyaloshinsky-Moriya-Kondo (DMK) interaction between the spin on the dot and the electron spins in the leads. Using a real-time renormalization group technique we show that at low temperatures (i) the DMK interaction is strongly renormalized, (ii) the renormalized magnetic field acquires a linear voltage dependence, and (iii) the differential conductance exhibits a voltage asymmetry which is strongly enhanced by logarithmic corrections. We propose transport measurements in which these signatures can be observed.

TT 21.4 Tue 10:15 BH 334

Zero bias anomalies in electron transport across quantum dots — •Johannes Kern and Milena Grifoni — Universität Regensburg, D-93040 Regensburg, Germany

We describe the electron transport across a quantum dot which is coupled to two contacts at different chemical potentials using a diagrammatic approach. By summing up a subclass of diagrams of all orders in the tunneling Hamiltonian, we are able to describe a low temperature regime where the differential conductance develops a maximum at zero bias. We exemplify our theory for the case of the single impurity Anderson model and compare our results with experimental findings.

TT 21.5 Tue 10:30 BH 334

Nanocaloritronic performance analysis of an interacting quantum dot thermoelectric system — •Bhaskaran Muralidharan and Milena Grifoni — nstitut I - Theoretische Physik Universität Regensburg D-93040 Regensburg

By subjecting a weakly coupled quantum dot system to an applied voltage and temperature gradient, we present notable subtleties involved in its thermoelectric energy conversion efficiency. First, is the well known, but non-intuitive aspect in the non-interacting case, of achieving a reversible operation with Carnot efficiency. Second, is the rather surprising result in the presence of Coulomb interactions that similar operating conditions lead to zero efficiency [1]. It is then shown that even in this case, operating efficiencies close to the Carnot value may be attained, but, under non-equilibrium conditions [1]. Consequently, the inadequacies of traditionally employed performance metric zT in capturing the aforementioned non-equilibrium conditions are pointed out.

[1] B. Muralidharan and M. Grifoni, cond-mat/1110.4357 (2011).

TT 21.6 Tue 10:45 BH 334

Time scales in the dynamics of an interacting quantum dot — •Janine Splettstoesser[1], Debora Contreras-Pulido[1], Michele Governale[2], Jürgen König[3], and Markus Büttiker[4] — [1]Theorie für Statistische Physik, RWTH Aachen University — [2]School of Physical and Chemical Sciences, Victoria University, Wellington, New Zealand — [3]Theoretische Physik, Universität Duisburg-Essen — [4]Physique Théorique, Université de Genève, Switzerland

The subject of this presentation is the relaxation behavior of an interacting quantum dot, brought out of equilibrium by a fast switch, e.g. of the gate potential [1,2]. We study a single-level quantum dot with strong Coulomb interaction, weakly coupled to a single lead, taking the role of a mesoscopic capacitor. The transient response to the fast change of an external parameter is computed by means of a real-time diagrammatic expansion in the tunnel-coupling strength. We find that the exponential relaxation of the dot state is governed by three different time scales: Charge and spin relaxation depend on the final state of the dot and they differ from each other due to Coulomb repulsion. A further, gate-independent relaxation rate is related to electron-hole correlations and can be extracted, e.g., from deviations from the equilibrium charge. We study different setups and driving schemes to address the three independent decay rates separately.

[1] J. Splettstoesser, M. Governale, J. König, and M. Büttiker, Phys. Rev. B **81**, 165318 (2010).
[2] L.-D. Contreras-Pulido, J. Splettstoesser, M. Governale, J. König, and M. Büttiker, arxiv:1111.4135.

TT 21.7 Tue 11:00 BH 334

Cotunneling conductance of nonabelian excitations in fractional quantum Hall edge systems — •Robert Zielke[1], Bernd Braunecker[2], and Daniel Loss[1] — [1]Department of Physics, University of Basel, Switzerland — [2]Departamento de Física Teórica de la Materia Condensada, Facultad de Ciencias, Universidad Autónoma de Madrid, Spain

We consider theoretically a fractional quantum Hall (FQH) system at filling fraction 5/2, containing a dot or antidot in the bulk. We look for specific signatures of the Moore-Read state, which is the most prominent candidate state for the 5/2-FQH system and supports nonabelian excitations. Two different setups are considered: (a) cotunneling of electrons between two different FQH samples via a dot and (b) cotunneling of fractional charges between the edge states of one single FQH sample via an antidot. Both setups lead to characteristic tunneling currents with line shapes significantly different from the one of a Fermi liquid.

15 min. break.

TT 21.8 Tue 11:30 BH 334

Scanning probe microscopy imaging of metallic nanocontacts prepared by electromigration — •Dominik Stöffler[1], Shawn Fostner[2], Hilbert v. Löhneysen[1,3], Peter Grütter[2], and Regina Hoffmann-Vogel[1] — [1]Karlsruher Institut für Technologie, Physikalisches Institut, 76131 Karlsruhe — [2]Department of Physics, McGill University, Montreal, Canada — [3]Karlsruher Institut für Technologie, Institut für Festkörperphysik, 76021 Karlsruhe

Controlled electromigration of thin metallic films represents a promising technique for fabricating nanometer-sized gaps for possible applications in molecular electronics. We show scanning force microscopy measurements of metallic nanocontacts that are formed during controlled electromigration cycles. The nanowires used for the thinning process are fabricated by shadow evaporation. During the first few electromigration cycles an overall slit in the nanocontact is formed, with a few grains still maintaining metallic contact. At a later stage the remaining grains disintegrate and their remnants accumulate in regions away from the slit. Resistance measurements during the electromigration cycle suggest that first the whole wire is heated. During the subsequent thinning process the current apparently passes through several smaller contacts and less power is needed for electromigration. We also discuss the influence of the environment (ambient, ultra-high vacuum) on the electromigration process.

TT 21.9 Tue 11:45 BH 334

Readout of carbon nanotube vibrations based on spin-phonon coupling — •Christoph Ohm[4], Christoph Stampfer[2,3], Janine Splettstoesser[1], and Maarten R. Wegewijs[1,3] — [1]Institut für Theorie der Statistischen Physik, RWTH Aachen University, Germany — [2]II. Physikalisches Institut B, RWTH Aachen University, Germany — [3]Peter Grünberg Institut, Forschungszentrum Jülich, Germany — [4]Institut für Quanteninformation, RWTH Aachen University, Germany

We theoretically study a carbon nanotube (CNT) double quantum dot consisting of a suspended and a non-suspended part. We propose a scheme for spin-based detection of the CNT bending motion in which the vibrational frequency is converted to a lower, more accessible frequency range. We make use of the spin-orbit coupling in CNTs. In the presence of vibrations, this yields a weak effective spin-phonon coupling. Classical vibrations of the CNTs are shown to induce a time dependent field acting on the electrons confined to the suspended dot, thereby generating spin flips. Within a rotating-wave approximation we find that the weakness of the spin-phonon coupling results in an effective down-mixing of the high vibrational frequency to a much lower spin-flip frequency. The latter can be controlled by the strength of an external magnetic field. We propose to read out the vibration-induced spin flips by measuring the leakage current through the double dot tuned to the spin-blockade regime as a function of the magnetic field. From a master equation we predict that the leakage current shows a pronounced peak allowing to read out the vibrational frequency.

TT 21.10 Tue 12:00 BH 334

Coulomb blockade of non-local electron transport in metallic conductors — •Dmitry Golubev and Andrei Zaikin — Institut für Nanotechnologie, Karlsruhe Institut für Technologie, Karlsruhe

We consider a metallic wire coupled to two metallic electrodes via two junctions placed nearby. A bias voltage applied to one of such junctions alters the electron distribution function in the wire in the vicinity of another junction thus modifying both its noise and the Coulomb blockade correction to its conductance. We evaluate such interaction corrections to both local and non-local conductances demonstrating non-trivial Coulomb anomalies in the system under consideration. Experiments on non-local electron transport with Coulomb effects can be conveniently used to test inelastic electron relaxation in metallic conductors at low temperatures.

TT 21.11 Tue 12:15 BH 334

Cooperative Emission in Transport Setting through a Quantum Dot — •Martin J. A. Schuetz, Eric M. Kessler, Geza Giedke, and Juan Ignacio Cirac — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

We theoretically show that intriguing features of coherent many-body physics can be observed in electron transport through a quantum dot (QD). In particular, we show that electron transport in the Pauli-blockade regime is coherently enhanced by hyperfine interaction (HF) with the nuclear spin ensemble in the QD. For an initially polarized nuclear system this leads to a strong current peak in close analogy with superradiant emission of photons from atomic ensembles. This effect could be observed with realistic experimental parameters and would provide clear evidence of coherent HF dynamics of nuclear spin ensembles in QDs.

TT 21.12 Tue 12:30 BH 334

Spin-active scattering in ferromagnet-quantum dot-superconductor junctions — •Henning Soller — Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, D-69120 Heidelberg

Based on the Hamiltonian formalism we study spin-active scattering in a ferromagnet-quantum dot-superconductor junction. Compared to simple tunnel contacts quantum dot junctions exhibit a strongly energy-dependent transmission that is further affected by the presence of the ferromagnetic correlations and on-site Coulomb interaction on the dot. We derive an effective model for a quantum dot in an even charge state. We find a qualitatively new subgap conductance feature related to spin-active scattering and compare our findings to recent experimental results.

TT 21.13 Tue 12:45 BH 334

Keldysh field integral theory for the Kondo effect in interacting nanoscopic systems — •Sergey Smirnov and Milena Grifoni — Institut für Theoretische Physik, Universität Regensburg

We derive a nonequilibrium Keldysh field theory valid for a system with finite electron-electron interactions much stronger than the coupling of the system to contacts. Finite electron-electron interactions are treated involving as many slave-boson degrees of freedom as one needs for a concrete many-body system. For clarity the theory is presented for the Kondo regime of the single impurity Anderson model. The effective Keldysh action takes into account weak slave-bosonic oscillations excited by the electronic tunneling between the nanoscopic system and contacts. This allows us to derive an analytical expression for the tunneling density of states at temperatures close to and above the Kondo temperature [1,2]. The differential conductance is then obtained as a function of an external voltage. We also obtain the temperature dependence of the linear conductance and compare it with the one obtained in numerical renormalization group calculations. We find that our Keldysh field integral theory predicts a universal temperature dependence of the linear conductance and that the scaling of this dependence is given by the standard Kondo temperature.

[1] S. Smirnov and M. Grifoni, Phys. Rev. B 84, 125303 (2011).
[2] S. Smirnov and M. Grifoni, arXiv:1109.1540.