TT 19: Transport: Quantum Dots, Quantum Wires, Point Contacts II (organized by TT)

Time: Monday 16:00–18:30 Location: HSZ 204

TT 19.1 Mon 16:00 HSZ 204

A two-atom electron pump — Benoit Roche[1], Roman-Pascal Riwar[1], Benoit Voisin[1], Eva Dupont-Ferrier[1], Romain Waquez[3], Maud Vinet[3], Marc Sanquer[1], •Janine Splettstoesser[2], and Xavier Jehl[1] — [1]SPSMS, UMR-E, CEA Grenoble, INAC, Grenoble, France — [2]MC2, Chalmers University of Technology, Göteborg, Sweden — [3]CEA, LETI, MINATEC, Grenoble, France

In recent years there has been a lot of interest in time-dependently driven quantum systems, such as quantum-dot pumps, both in the adiabatic regime of slow driving as well as in the high-frequency regime. However, all experiments so far were carried out in either one of these regimes, but were not subsequently tuned to both. I will present an experimental realization [1] of electron pumping through two phosphorus donors in series implanted in a silicon nanowire. While quantized pumping is achieved in the low-frequency adiabatic regime, remarkable features are observed at higher frequency, when the charge transfer is limited either by the tunnelling rates to the electrodes or between the two donors. We model the transitions between quantum states involving a Landau-Zener transition, allowing to reproduce in detail the characteristic signatures observed in the non-adiabatic regime. Interestingly, the breakdown of the adiabatic limit can thus accurately be associated to the relation of the respective time-scales of tunneling to the electrodes or between the donors, compared to the time-scales of the driving. Consequently, information on the time-scales can be extracted from a detailed inspection of the pumping signal.

[1] B. Roche, *et al.*, Nat. Commun. 4, 1581 (2013)

TT 19.2 Mon 16:15 HSZ 204

Functional renormalization group in Floquet space and its application to periodically driven quantum dots — •Katharina Eissing[1,2], Stefan Göttel[1,2], Dante Marvin Kennes[1,2], and Volker Meden[1,2] — [1]Institut für Theorie der Statistischen Physik, RWTH Aachen University, 52074 Aachen, Germany — [2]JARA Fundamentals of Future Information Technology, 52056 Aachen, Germany

The functional renormalization group (RG) was recently extended to study interacting, low-dimensional systems out of equilibrium. This includes correlated quantum dot setups with explicitly time-dependent Hamiltonians as e.g. realized in quantum quenches or in the presence of time-dependent bias voltages [Phys. Rev. B 85, 085113 (2012), Phys. Rev. B 85, 245101 (2012)]. However, following this route periodic pumping processes, which are of particular interest in e.g. nanoelectronics and quantum information science, can only be described in an inefficient way. Taking advantage of the periodicity, we combine the Floquet theorem with the functional RG. This allows us to transform the double-time self-energy and Green functions in the Floquet basis [J. Phys.: Condens. Matter 20 085224] and the functional RG treatment resembles the stationary formalism. This makes it feasible to study transport in periodically driven systems. In my talk, I will shortly introduce this Floquet theorem based functional RG and present first results on transport through a quantum dot described by the interacting resonant level model.

TT 19.3 Mon 16:30 HSZ 204

Interplay of edge state polarization and a Zeeman split quantum dot — •Benedikt Probst[1], Pauli Virtanen[2], and Patrik Recher[1] — [1]Institute for Mathematical Physics, TU Braunschweig, Braunschweig, Germany — [2]O.V. Lounasmaa Laboratory, Aalto University, Finland

Topological insulators are a novel state of matter showing interesting physics. One of the effects realized in these materials is the quantum spin Hall effect in which electrons with different spin propagate in different directions on the edge of the system. Applying a bias to the system therefore leads to a spin bias for the edge state. We consider a system in which a quantum dot in the Coulomb blockade regime is attached to a helical Luttinger liquid. This quantum dot is treated as a localized spin, which can be manipulated by a magnetic field. The dynamics of the dots are described by setting up a general master equation. From the steady state of the system the polarization of the dot and the differential edge conductance is calculated. We discuss a regime in which the dot polarization exhibits a strong bias dependence and a regime in which the transport shows a characteristic bias asymmetry which allows to identify the relative orientation of the spin polarization in the edge state with respect to the magnetic field.

15 min. break.

TT 19.4 Mon 17:00 HSZ 204

Entanglement detection in an interacting beam-splitter device — •Alexander Schroer[1], Bernd Braunecker[2], Alfredo Levy Yeyati[3], and Patrik Recher[1] — [1]Institute for Mathematical Physics, TU Braunschweig, Germany — [2]Department of Theoretical Condensed Matter Physics, Universidad Autónoma de Madrid, Spain — [3]School of Physics & Astronomy, University of St Andrews, UK

We investigate a tunnel contact between two Luttinger liquids, e.g. realized as two crossed one-dimensional nanowires. When injecting one of two electrons with opposite spin in each wire, the current measured behind the crossing differs for singlet, triplet or product states. This is an apparent non-Fermi liquid feature because the current has been shown to be independent of spin-entanglement for Fermi liquid beam-splitters before. It can be understood in terms of collective excitations and by taking spin-charge separation into account. This behavior may offer an easier alternative to traditional entanglement detection schemes based on current noise, which turns out to be suppressed by the electron-electron interaction.

TT 19.5 Mon 17:15 HSZ 204

Hierarchical Equation of Motion Investigation of Decoherence and Relaxation Dynamics in Nonequilibrium Transport through Interacting Quantum Dots — •Rainer Härtle[1,2], Guy Cohen[3], David R. Reichman[3], and Andrew J. Millis[2] — [1]Institut für theoretische Physik, Georg-August-Universität Göttingen, Göttingen, Germany — [2]Department of Physics, Columbia Universtiy, New York, USA — [3]Department of Chemistry, Columbia Universtiy, New York, USA

A recently developed hierarchical quantum master equation approach [1,2] is used to investigate nonequilibrium electron transport through an interacting double quantum dot system in the regime where the inter-dot coupling is weaker than the coupling to the electrodes. The corresponding eigenstates provide tunneling paths that may interfere constructively or destructively, depending on the energy of the tunneling electrons [3]. Electron-electron interactions are shown to quench these interference effects in bias-voltage dependent ways, leading, in particular, to negative differential resistance, population inversion and an enhanced broadening of resonances in the respective transport characteristics [2]. Relaxation times are found to be very long, and to be correlated with very slow dynamics of the inter-dot coherences. The ability of the hierarchical quantum master equation approach to access very long time scales is crucial for the study of this physics.

[1] J. Jin *et al.*, J. Chem. Phys. 128, 234703 (2008).
[2] R. Härtle *et al.*, arXiv:1309.1170 (2013)
[3] R. Härtle *et al.*, Phys. Rev. B 87, 085422 (2013)

TT 19.6 Mon 17:30 HSZ 204

Detection of the decay rates in interacting quantum dots — •Jens Schulenborg[1,2], L. Debora Contreras- Pulido[3], Michele Governale[4], and Janine Splettstoesser[1,2] — [1]Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, Göteborg, Sweden — [2]Institut für Theorie der Statistischen Physik, RWTH Aachen University, Germany — [3]Institut für Theoretische Physik, Universität Ulm, Germany — [4]School of Physical and Chemical Sciences, Victoria University of Wellington, New Zealand

Over the past years, potential applications in nanoelectronics, metrology and quantum information sparked great interest in studying the *dynamics* of time-dependently driven quantum dots. Recently, the relaxation rates in the dynamical response of an interacting single-level quantum dot, weakly tunnel coupled to an electronic reservoir and brought out of equilibrium by a step pulse, have been investigated [1].

This theoretical work focuses on the readout of these relaxation rates with a capacitively coupled sensor quantum dot (SQD). Using a generalized master equation approach for the combined system of dot and SQD, we investigate the measurability of the dot relaxation behavior via the SQD current, especially accounting for back-action effects.

Our results reveal parameter regimes in which back-action leads to a decrease of the dot decay rates and to a mixing of relaxation modes that decay independently in the absence of a measurement. However, avoiding these regimes, we show that the original dot rates can still be extracted from the SQD current.

[1] L. D. Contreras-Pulido et al., Phys. Rev. B **85**, 075301 (2012).

TT 19.7 Mon 17:45 HSZ 204

Hybrid Microwave Cavity Heat Engine — Christian Bergenfeldt[1], Peter Samuelsson[1], •Björn Sothmann[2], Christian Flindt[2], and Markus Büttiker[2] — [1]Physics Department, Lund University, Box 118, SE-22100 Lund, Sweden — [2]Département de Physique Théorique, Université de Genève, CH-1211 Genève 4, Switzerland

We propose and analyze the use of hybrid microwave cavities as quantum heat engines. A possible realization consists of two macroscopically separated quantum dot conductors coupled capacitively to the fundamental mode of a microwave cavity. We demonstrate that an electrical current can be induced in one conductor through cavity-mediated processes by heating up the other conductor. The heat engine can reach Carnot efficiency with optimal conversion of heat to work. When the system delivers the maximum power, the efficiency can be a large fraction of the Carnot efficiency. The heat engine functions even with moderate electronic relaxation and dephasing in the quantum dots. We provide detailed estimates for the electrical current and output power using realistic parameters.

[1] C. Bergenfeldt, P. Samuelsson, B. Sothmann, C. Flindt and M. Büttiker, arXiv:1307.4833v1 (2013).

TT 19.8 Mon 18:00 HSZ 204

Vibration-induced thermoelectric effects in quantum dots — •Matti Laakso and Volker Meden — Institut für Theorie der Statistischen Physik, RWTH Aachen, Aachen, Germany

We study the thermoelectric transport through a quantum dot coupled to a single vibrational mode described by the Anderson-Holstein model. We use analytical methods in the linear response regime as well as the functional renormalization group (FRG) in the non-linear regime. We predict relatively large thermoelectric effects in the parameter regime where the phonon-mediated electron-electron interaction dominates over the bare Coulomb repulsion.

TT 19.9 Mon 18:15 HSZ 204

Superexchange transport and blockade in triple quantum dots — •Rafael Sánchez[1], Ghislain Granger[2], Fernando Gallego-Marcos[1], Sergei A. Studenikin[2], Andrew S. Sachrajda[2], and Gloria Platero[1] — [1]Instituto de Ciencia de Materiales de Madrid, CSIC, E-28049 Madrid, Spain — [2]National Research Council Canada, Ottawa, ON K1A 0R6 Canada

We present recent experimental evidence of long range transport in triple quantum dots. Superexchange is responsible for the spin-dependent indirect coupling of the two outer quantum dots, mediated by virtual transitions through the middle one. They are manifested in the form of sharp current resonances at the degeneracy points of states with left-right symmetric charge distributions [1,2]. The transition can take two paths: two electrons in different dots tunnel simultaneously [1] or a single electron tunnels twice [2].

We analyze a configuration where the two paths with different virtual intermediate states are possible and lead to quantum interference. Remarkably, we find conditions where the destructive interference of these transitions completely cancels the transport, what we call superexchange blockade [3]. Spin correlations play an essential role by avoiding certain transitions. This effect, known as spin blockade, leads to the suppression of certain resonances whose observation gives a measure of spin decoherence times.

[1] M. Busl et al., Nature Nanotech. 8, 261 (2013).
[2] R. Sánchez et al., submitted.
[3] R. Sánchez, F. Gallego-Marcos and G. Platero, submitted.