TT 29: Transport: Quantum Dots, Wires, Point Contacts 3 (jointly with HL)

Time: Tuesday 9:30–12:30 Location: H20

TT 29.1 Tue 9:30 H20

Theory of Spin Relaxation in Two-Electron Laterally Coupled GaAs and Si Quantum Dots — •Martin Raith[1], Peter Stano[2,3], and Jaroslav Fabian[1] — [1]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Department of Physics, University of Basel, 4056 Basel, Switzerland — [3]Institute of Physics, Slovak Academy of Sciences, 845 11 Bratislava, Slovakia

We present quantitative results of the phonon-induced spin relaxation in two-electron lateral double quantum dots. Both spin-orbit coupling and hyperfine coupling are taken into account. Our analysis of GaAs [1] and silicon [2] based dots includes the variation of the electric field (detuning), the exchange coupling, and the magnetic field strength and orientation. We find that even in strong magnetic fields, the hyperfine coupling can dominate the relaxation rate of the unpolarized triplet in a detuned GaAs double dot. This feature is absent in silicon (we assume a ^{29}Si abundance of 4.7%). Where the spin-orbit coupling dominates, the rate is strongly anisotropic and its maxima and minima are generated by an in-plane magnetic field either parallel or perpendicular to the dots' alignment dependent on specifics, such as spectral (anti-) crossings (spin hot spots), or the detuning strength. We emphasize the differences between GaAs and Si based dots. This work marks a crucial step toward the realization of two-electron semiconductor qubits.

This work is supported by the DFG under grant SPP 1285.

[1] M. Raith et. al., PRL 108, 246602 (2012)
[2] M. Raith et. al., arXiv:1206.6906

TT 29.2 Tue 9:45 H20

Nonequilibrium effect in a NISIN turnstile — •Andreas Heimes[1], Ville Maisi[2,3], Jukka Pekola[2], Michael Marthaler[1], Dmitry Golubev[1], and Gerd Schön[1] — [1]Institut für Theoretische Festkörperphysik, Karlsruher Institut für Technologie, Wolfgang-Gaede-Str. 1, D-76128 Karlsruhe, Germany — [2]Low Temperature Laboratory (OVLL), Aalto University School of Science, P.O. Box 13500, 00076 Aalto, Finland — [3]Centre for Metrology and Accreditation (MIKES), P.O. Box 9, 02151 Espoo, Finland

A single electron transistor consisting of a superconducting island coupled to two normal leads is investigated. By periodically changing the gate voltage this setup works as a single electron pump. However during the turnstile operation quasiparticles are injected onto the superconductor, which relax via inelastic electron-phonon scattering and effectively heat up the island. We theoretically model the time evolution of the charge transport and the quasiparticle distribution during the pumping process. By analyzing the dependence on pumping frequency we discuss the experimental ability to measure the relaxation dynamics of quasiparticles in the superconducting island.

TT 29.3 Tue 10:00 H20

Keldysh effective action theory for universal physics in spin-1/2 Kondo dots — •Sergey Smirnov and Milena Grifoni — Institut I - Theoretische Physik, Universität Regensburg, Universitätsstraße 31, D-93040 Regensburg, Deutschland

We present a theory for the Kondo spin-1/2 effect in strongly correlated quantum dots. The theory is applicable at any temperature and voltage. It is based on a quadratic Keldysh effective action parameterized by a universal function. We provide a general analytical form for the tunneling density of states through this universal function for which we propose a simple microscopic model [1]. We apply our theory to the highly asymmetric Anderson model and describe its strong coupling limit, weak coupling limit and crossover region within a single analytical expression.

We further extend our theory to describe the Kondo regime when the quantum dot is placed in an external magnetic field. The modern experimental issues of the critical magnetic field, at which the zero bias maximum of the differential conductance starts to split into two maxima, as well as the distance between these maxima as a function of the magnetic field are also addressed.

[1] S. Smirnov and M. Grifoni, arXiv:1203.4360 (2012)

TT 29.4 Tue 10:15 H20

Superfermions in Liouville space as a powerful tool for investigating quantum transport out of equilibrium: new insights into the Anderson model — •Roman Saptsov[1,2] and Maarten Wegewijs[1,2,3] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA- Fundamentals of Future Information Technology — [3]Institute for Theory of Statistical Physics, RWTH Aachen, 52056 Aachen, Germany

Recently, we introduced a new formalism of superfermions in Liouville space for a renormalization group study of the non-linear transport through an Anderson quantum dot (QD) at zero temperature [1]. This formalism turns out to be a very useful tool to study other aspects of non-equilibrium phenomena, as well. In the wide band limit for a strongly interacting QD it allows one to sum up exactly temperature-independent contributions and obtain a general form of the QD effective Liouvillian as well as some exact relations for its eigenvalues. In the non-interacting case, U=0, our approach describes time evolution of the QD in the most simple way: we show that a "Pauli super-exclusion principle" for the superfermions leads to the exact truncation of the time-dependent perturbation series at the second order in a coupling constant. Using our approach we are able also to explore the time-evolution of the initial dot-reservoir correlations. We discuss the extension of this U=0 result to the case of finite U. Finally, we discuss other useful applications of our formalism, such as: path integrals in Liouville space and "super- mean-field theory".

[1] R.B. Saptsov, M.R. Wegewijs, arXiv:1207.3207

Invited Talk TT 29.5 Tue 10:30 H20

Nano-Conductors as Measurement Devices and Driving Sources — •Sigmund Kohler — Instituto de Ciencia de Materiales de Madrid, CSIC, 28049 Madrid, Spain

The capacitive coupling between electrically isolated nano-circuits bears a wealth of novel transport effects. One prominent realization is the coupling of a quantum dot to a quantum point contact, where the latter acts as charge monitor. Most interesting is the backaction of the point contact to quantum superpositions in the measured system and the decoherence induced in this way. For example, it has been predicted that, despite decoherence, a charge monitor may be used for qubit phase readout with good fidelity [1]. Moreover, a point contact may act upon a double or triple quantum dot not only as detector or decoherence source, but may also impose useful non-equilibrium driving and thereby, e.g., induce a pump current. This effect leaves its fingerprints in the charging diagram of double quantum dots [2] and in the full-counting statistics [3]. If the point contact is replaced by a double quantum dot, coherent tunnel oscillations in the latter may induce phenomena known from ac-driven transport.

[1] C. Kreisbeck and S. Kohler, PRB **81**, 125404 (2010)
[2] M. Stark and S. Kohler, EPL **91**, 20007 (2010)
[3] R. Hussein and S. Kohler, PRB **86**, 115452 (2012)

15 min. break

TT 29.6 Tue 11:15 H20

Electronic structure and the Aharonov-Bohm effect in inhomogeneous Möbius rings — •V. M. Fomin[1], S. Kiravittaya[1,2], and O. G. Schmidt[1,3] — [1]Institute for Integrative Nanosciences, IFW-Dresden, D-01069 Dresden, Germany — [2]Department of Electrical and Computer Engineering, Naresuan University, Phitsanulok 65000, Thailand — [3]Material Systems for Nanoelectronics, Chemnitz University of Technology, D-09107 Chemnitz, Germany

Nanostructure fabrication techniques can be exploited to generate non-trivially shaped objects with man-designed topological space metrics. A symbiosis of the geometric potential and an inhomogeneous twist renders an observation of the topology effect on the electron ground-state energy in microscale Möbius rings into the realm of experimental verification. We predict a 'delocalization-to-localization' transition for the electron ground state as the Möbius ring is made more inhomogeneous [1]. This transition can be quantified through the Aharonov-Bohm quantum-interference effect on the ground-state persistent current as a function of the magnetic flux threading the Möbius ring. Our theoretical considerations may receive practical relevance in view of the emerging experimental realizations of topologically nontrivial manifolds at the nanoscale.

[1] V. M. Fomin, S. Kiravittaya, and O. G. Schmidt, Phys. Rev. B 86, 195421 (2012).

TT 29.7 Tue 11:30 H20

Transport across an Anderson quantum dot in the intermediate coupling regime — •Johannes Kern and Milena Grifoni — Universität Regensburg, Institut für Theoretische Physik, 93040 Regensburg

We describe transport across a quantum dot coupled to leads at different chemical potentials. For this we use the master equation approach. The current is determined via the reduced density matrix by "kernels", the contributions to those are visualized by diagrams. Because of the huge variety and complexity of the diagrams, we take into account only the diagrams within a selection which we call the "dressed second order" (DSO)[1]. We apply this to the case of the single impurity Anderson model and show that the DSO allows the description of various effects: the transition from thermally broadened to tunnel broadened peaks of the linear conductance as well as of the differential conductance as function of the bias; the shift of the conductance peaks with temperature; a zero bias anomaly in the differential conductance; the splitting of this anomaly in case a magnetic field is applied. To conclude, we see the strength of the DSO in its simplicity as well as in its applicability to various problems including the transport across more complicated quantum dots.

[1] J. Kern and M. Grifoni, arXiv:1209.4995.

TT 29.8 Tue 11:45 H20

Helical nuclear spin order and conduction reduction in two subband quantum wires — •Tobias Meng and Daniel Loss — Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

In quantum wires, the hyperfine coupling between conduction electrons and nuclear spins can lead to an ordering of the latter at low temperatures. This order acts back onto the electrons and gaps out part of their spectrum. In the presence of two subbands with distinct Fermi momenta k_{F1} and k_{F2}, we discuss how the nuclear spins order in a superposition of two helices with pitches π/k_{F1} and π/k_{F2}, thus exhibiting a beating patter. This ordering results in a reduction of the electronic conductance in two steps of e^2/h upon lowering the temperature.

TT 29.9 Tue 12:00 H20

Electron Waiting Times in Non-Markovian Quantum Transport — •Konrad Thomas and Christian Flindt — Département de Physique Théorique, Université de Genève, 1211 Genève, Switzerland

We formulate a quantum theory of electron waiting time distributions for charge transport in nano-structures described by non-Markovian generalized master equations. We illustrate our method by calculating the waiting time distribution of electron transport through a dissipative double quantum dot, where memory effects are present due to a strongly coupled heat bath. We consider the influence of non-Markovian dephasing on the distribution of electron waiting times and discuss how spectral properties of the heat bath may be detected through measurements of the electron waiting time.

TT 29.10 Tue 12:15 H20

Coherence and indistinguishability of single electron wavepackets emitted by independent sources — Erwann Bocquillon[1], Vincent Freulon[1], Jean-Marc Berroir[1], Pascal Degiovanni[2], Bernard Plaçais[1], Antonella Cavanna[3], Yong Jin[3], and •Gwendal Feve[1] — [1]Laboratoire Pierre Aigrain, Ecole Normale Supérieure, Paris, France — [2]Laboratoire de Physique de l Ecole Normale Supérieure de Lyon, Lyon, France — [3]Laboratoire de Photonique et Nanostructures, Marcoussis, France

Using two independent on-demand electron sources [1], two single-electron wavepackets are emitted on one-dimensional chiral edge channel located at at different inputs of an electronic beamsplitter. Whereas classical particles would be randomly partitioned by the splitter, we observe two-particle interferences resulting from quantum exchange in this electronic analog [2,3] of the optical Hong-Ou-Mandel [4] experiment. Both electrons, emitted in indistinguishable wavepackets with synchronized arrival time on the splitter, exit in different outputs as recorded by the low frequency current noise. Full random partitioning is recovered when the arrival of one electron is delayed with respect to the other. This two-electron interference experiment demonstrates the possibility to generate on-demand coherent and indistinguishable single-electron wavepackets in a quantum conductor.

[1] G. Fève et al., Science 316, 1169 (2007)
[2] Ol'khovskaya et al., Phys. Rev. Lett. 101, 166802 (2008)
[3] T. Jonckheere et al., Phys. Rev. B 86, 125425 (2012)
[4] C. K. Hong et al., Phys. Rev. Lett. 59, 2044 (1987)