TT 102: Transport: Quantum Dots, Quantum Wires, Point Contacts 2 (jointly with HL)

Time: Thursday 15:00–18:30 Location: A 053

TT 102.1 Thu 15:00 A 053

Weak antilocalization and spin-orbit interaction in epitaxial nanowires — Brian Tarasinski[1], Ilse van Weperen[2], Debbie Eeltink[2], Vlad Pribiag[2], Erik Bakkers[2,3], Leo Kouwenhoven[2], and •Michael Wimmer[2] — [1]Leiden University, The Netherlands — [2]Delft University of Technology, The Netherlands — [3]Eindhoven University of Technology, The Netherlands

We develop a theory of weak antilocalization for three-dimensional nanowires that allows for a quantitative extraction of spin-orbit strength. To this end we perform numerical Monte Carlo simulations of classical trajectories that are used in the quasiclassical theory of weak antilocalization. In particular, we show that magnetoconductance in three-dimensional nanowires is very different compared to wires in two-dimensional electron gases

Focusing on the case of Rashba spin-orbit interaction, we then use this theory to extract the Rashba spin-orbit strength from weak antilocalization measurements in epitaxially grown InSb nanowires. We find a spin-orbit energy on the order of 0.25-1 meV.

TT 102.2 Thu 15:15 A 053

Tunable weak anti-localization in InAs nanowire device — •Libin Wang[1], Jingkun Guo[1], Sen Li[1], Ning Kang[1], Dong Pan[2], Jianhua Zhao[2], and Hongqi Xu[1] — [1]Key Laboratory for the Physics and Chemistry of Nanodevices and Department of Electronics, Peking University, Beijing 100871, China — [2]Institute of Semiconductors, Chinese Academy of Sciences, Beijing 100083, China

III-V semiconductor nanowire had attracted much attention as a possible building block for future electronic systems because of its high performance and possibility of gate voltage manipulation of electron spins. InAs nanowires are particularly attractive due to its strong spin-orbit interaction. We report the fabrication and magnetotransport measurement of individual InAs nanowires with diameter of 40 nm on a SiO_2/Si substrate with a globe back gate. The observed magnetoresistance at low temperature can be used to estimate the characteristic phase coherence length and the spin-orbit scattering length. We observe a crossover between weak anti-localization and weak localization with the change of temperature and applied electric field. Our results give information on the fundamental spin relaxation and quantum coherence effect of InAs nanowire.

TT 102.3 Thu 15:30 A 053

Full-counting statistics of Landau-Zener interference in quantum dot arrays — •Michael Niklas[1], Robert Hussein[2], and Sigmund Kohler[2] — [1]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Instituto de Ciencia de Materiales de Madrid, CSIC, 28049 Madrid, Spain

We investigate current cumulants for the transport in coupled quantum dots driven by a time-periodic field that sweeps the system repeatedly through an avoided crossing and, thus, acts like a beam splitter. Consequently, as a function of the detuning and the driving amplitude, the cumulants exhibit Landau-Zener-Stückelberg-Majorana (LZSM) interference patterns similar to those observed for the current in driven double quantum dots [1]. These patterns indicate regions with sub- and super-Poissonian noise level. As a flexible method that allows us to study driving fields with arbitrary shape, we developed a propagation scheme for the iterative computation of current cumulants. We demonstrate that it is applicable also for larger systems such as quantum dot arrays or dimer chains.

[1] F. Forster et al., Phys. Rev. Lett. **112**, 116803 (2014).

TT 102.4 Thu 15:45 A 053

Fractionalized double quantum wires — •Tobias Meng[1,2] and Eran Sela[3] — [1]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [3]Raymond and Beverly Sackler School of Physics and Astronomy, Tel-Aviv University, Tel Aviv, 69978, Israel

We discuss how electron-electron interactions can lead to novel phenomena in double quantum wire systems. Explicitly, we find that double wires with time reversal symmetry and strong electron-electron interactions can exhibit fractional conductances and cross-conductances in their normal state. They also allow to pump the fraction of a spin in their superconducting state. These effects are an extension of fractional helical Luttinger liquid physics, and can be understood as the one-dimensional cousins of bilayer fractional quantum Hall effects.

TT 102.5 Thu 16:00 A 053

Non-equilibrium Renormalization Group for Kondo Qdots in a Microwave Photon Field — •Andisheh Khedri[1,2,3], Ammar Nejati[1], and Johann Kroha[1] — [1]Universität Bonn — [2]RWTH Aachen — [3]FZ Jülich

Recent experiments on Kondo quantum dots in a static magnetic field and a microwave photon field show a resonant enhancement of the zero-bias differential conductance at a photon energy which scales with the applied magnetic field, but which is substantially larger than the bare Zeeman energy of the dot levels [1]. This behavior cannot be explained by direct, photoinduced spin-flip excitations of the dot. It points to a strong renormalization of the Zeeman energy (Landé factor) in the presence of the microwave field. We propose that the observed resonant conductance is caused by photo-assisted Kondo spin-flip scattering of the lead electrons, i.e., by electronic lead–dot transitions, assisted by coherent photon absorption and/or emission. We develop the non-equilibrium perturbative renormalization group (RG) theory [2] for this problem. The renormalization of the various coupling functions for spin vertices without photon processes as well as involving photon absorption, emission and scattering is anaylzed as well as the Qdot level shifts. We find a subtle interplay between Kondo scattering and coherent photoassisted processes, restoring the logarithmic RG flow and leading to strong renormalization of the Landé factor.

[1] B. Hemingway, S. Herbert, M. Melloch, A. Kogan, PRB **90**, 125151 (2014)
[2] A. Rosch, J. Paaske, J. Kroha, P. Wölfle, PRL **90**, 076804 (2003).

TT 102.6 Thu 16:15 A 053

Competing energy scales in the renormalization group flow of quantum dot setups with periodically varying parameters — •Katharina Eissing[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 (fRG) has proven to be a versatile tool to investigate correlated, low-dimensional systems in and out of equilibrium. It was recently extended to study quantum dot setups with explicitly time dependent Hamiltonians [Phys. Rev. B 85, 085113 (2012)]. In systems in which one or more of the dot or lead parameters are varied periodically in time a periodic steady state is reached after all transients have died out. However, due to the limited simulation time the physics of this state can only be described, if we take advantage of the periodicity by combining the Floquet theorem and set up a functional RG with Green functions written in the Floquet basis. For the interacting resonant level model which in equilibrium and if driven by a time constant bias voltage is characterized by power-law scaling of observables in the relevant energy scales (e.g. temperature T or bias voltage V_b, respectively) with interaction dependent exponents this allows to investigate if and how the driving frequency Ω acts as a cutoff of the underlying renormalization group flow. The competition of this scale with the emergent low-energy scale T_K (Kondo scale) is investigated. I discuss how this competition is reflected in the observables characterizing the stationary transport through the dot.

15 min. break.

Invited Talk TT 102.7 Thu 16:45 A 053

Microscopic Origin of the 0.7-Anomaly in Quantum Point Contacts: Correlations in 1D — Florin Bauer[1], Jan Heyder[1], Dawid Borowsky[1], D. Taubert[1], D. Schuh[2], B. Bruognolo[1], Werner Wegscheider[3], Jan von Delft[1], and •Stefan Ludwig[1] — [1]Fakultät für Physik, LMU München — [2]Institut für Angew. Physik, Universität Regensburg — [3]ETH Zurich, Switzerland

Quantum point contacts (QPCs), the ultimate building blocks of quantum electronic circuits, are 1D constrictions in a 2D electron system (2DES). When a QPC is pinched off, its conductance famously decreases in integer steps of the conductance quantum, $G_Q = 2e^2/h$. An unexpected kink of the pinch-off curve near $0.7G_Q$ with an intriguing dependence on temperature, magnetic field and source-drain voltage, the 0.7-anomaly, has been subject of debates for the last two decades [1]. In this talk I will show that the divergence of the 1D density of states (DOS) at low energies, a prerequisite of the quantized conductance, is also the origin of the 0.7-anomaly. It naturally arises from strong correlations fostered by an enhanced DOS. They cause an anomalous increase of the spin susceptibility and back-scattering. Our microscopic model is built on a combination of systematic measurements of a highly tunable QPC and detailed numerical calculations [2]. We discuss commonalities and differences to previous more phenomenological attempts to explain the 0.7-anomaly, namely the model of spontaneous spin polarization and the Kondo model [1].

[1] A. Micolich, J. Phys.: Condens. Matter **23**, 443201 (2011)
[2] F. Bauer et al., Nature **501**, 73 (2013)

TT 102.8 Thu 17:15 A 053

Spin dynamics in a quantum point contact showing the 0.7-anomaly — •Dennis Schimmel[1,2], Florian Bauer[1,2], Jan Heyder[1,2], and Jan von Delft[1,2] — [1]Ludwig-Maximilians-Universitaet Muenchen — [2]Arnold Sommerfeld Center for Theoretical Physics

The 0.7-anomaly in the first conductance step of a quantum point contact is believed to arise from an interplay of geometry, spin dynamics and interaction effects. Various scenarios have been proposed to explain it, each evoking a different concept, including spontaneous spin polarization, or a quasi-localized state, or ferromagnetic spin fluctuations, or a van Hove ridge (a geometry-induced maximum in the density of states). Though these scenarios differ substantially regarding numerous details, they all imply anomalous dynamics for the spins in the vicinity of the QPC. Our model consists of a one-dimensional system with a parabolic barrier. Interactions are restricted to a central region around the barrier and short-range. The leads are solved exactly and the central region is then treated using the functional renormalization group within a coupled ladder approximation scheme. Within this setup, we have performed a detailed study of the spin dynamics in the central region by calculating the dynamical spin-spin correlation function $\chi(x,x',\omega) = \int_0^\infty \langle S_z(x,t) S_z(x',0)\rangle e^{i\omega t}$. We will discuss its behavior as function of frequency, interaction strength and gate voltage and comment on the implications of these results for each of the above-mentioned scenarios.

TT 102.9 Thu 17:30 A 053

Nonequilibrium transport through Anderson impurities: A comparative study based on continuous-time quantum Monte Carlo simulations and hierarchical quantum master equations — •Rainer Härtle[1], Guy Cohen[2], David R. Reichman[2], and Andrew J. Millis[3] — [1]Institut für theoretische Physik, Georg-August-Universität Göttingen, Göttingen, Germany — [2]Department of Chemistry, Columbia University, New York, USA — [3]Department of Physics, Columbia University, New York, USA

The hierarchical quantum master equation approach [1,2] is a promising new method for describing quantum impurity systems under nonequilibrium conditions. It employs a hybridization expansion with an advanced truncation scheme [2] to determine the time evolution of the impurity's density matrix from a product initial state. The method is a systematic expansion for which convergence can be demonstrated so that numerically exact results can in principle be obtained. To elucidate the rigor of this procedure, we study the nonequilibrium dynamics of an Anderson impurity and benchmark the results with respect to continuous time quantum Monte Carlo methods [3]. The comparison shows excellent agreement as long as the temperature is above the Kondo scale. A discussion of the computational burden and of the scaling of numerical errors with truncation level is given. New results are presented for long-time dynamics arising in the presence of a magnetic field and/or an asymmetric coupling to leads.

[1] J. Jin et al., JCP 128, 234703 (2008).
[2] R. Härtle et al., PRB 88, 235426 (2013).
[3] G. Cohen et al., PRB 87, 195108 (2013).

TT 102.10 Thu 17:45 A 053

From thermal equilibrium to nonequilibrium quench dynamics: A conserving approximation for the interacting resonant-level — •Yuval Vinkler-Aviv[1,3], Avraham Schiller[3], and Frithjof B. Anders[2] — [1]Dahlem Center for Complex Quantum Systems and Fachberiech Physik, Freie Universität Berlin, 14195 Berlin, Germany — [2]Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44221 Dortmund, Germany — [3]Racah Institute of Physics, The Hebrew University, Jerusalem 91904, Israel

We develop a low-order conserving approximation for the interacting resonant-level model (IRLM), and apply it to (i) thermal equilibrium, (ii) nonequilibrium steady state, and (iii) nonequilibrium quench dynamics. The thermal equilibrium is used to carefully gauge the quality of the approximation by comparing the results with established methods such as renormalisation group approaches and establishes a good agreement for small interaction strengths. A closed expression for the nonequilibrium steady-state current is derived and analytically and numerically evaluated. We find a negative differential conductance at large voltages, and the exponent of the power-law suppression of the steady-state current is calculated analytically at zero-temperature. The response of the system to quenches is investigated for a single-lead as well as for two-lead setup at finite voltage bias, and results are presented for the time-dependent current for different bias and contact interaction strength.

[1] Phys. Rev. B **90**, 155110 (2014).

TT 102.11 Thu 18:00 A 053

Bound states in the continuum: Chiral lattices and van Hove singularities — •Jordi Mur-Petit and Rafael A. Molina — Inst. Estructura de la Materia, IEM-CSIC, Madrid, Spain

We present two distinct mechanisms for the formation of bound states in the continuum in lattices with van Hove singularities and/or chiral symmetry connected to leads. Bound states in the continuum (BICs) are square-integrable solutions of the time-independent Schrödinger equation with eigenenergies above the potential threshold. We derive some algebraic rules for the number of such states depending on the dimensionality and rank of the system Hamiltonian including the coupling to the leads. Next, we study the transport properties of relevant physical examples in square, honeycomb and triangular lattices, and propose different experiments to probe the presence of these BICs and related Fano resonances. Our results should find applications in a variety of set-ups, from semiconductor nanostructures to microwave resonator arrays, to cold atoms in optical lattices.

[1] V. Fernández-Hurtado, J. Mur-Petit, J.J. García-Ripoll, and R.A. Molina, New J. Phys. 16, 035005 (2014).
[2] J. Mur-Petit and R.A. Molina: Phys. Rev. B 90, 035434 (2014).

TT 102.12 Thu 18:15 A 053

Charge fluctuation effects in superconductor-quantum dot hybrid systems — •Sebastian Pfaller, Andrea Donarini, and Milena Grifoni — Institut I - Theoretische Physik Universität Regensburg

In a recent experiment [1] quasi particle transport through a carbon nanotube quantum dot coupled to superconducting (SC) leads was investigated both experimentally and theoretically. While most of the features could be explained by a perturbative theory up to lowest order in quasi particles tunnelling, other features like the broadening of the differential conductance peaks were not captured.

In order to account for these effects, we include charge fluctuation processes of quasi particles by extending the dressed second order theory of Kern *et al.* [2] to the case of SC leads. This yields an intrinsic broadening of the quantum dots energy levels, and, consequently, a renormalization of the sharp peaks coming from the BCS density of states. Moreover, new transport channels are obtained. They appear as peaks at zero and finite bias in the dI/dV-stability diagrams.

[1] M. Gaass, S. Pfaller, T. Geiger *et al.*, Phys. Rev. B **89**, 241405 (2014).
[2] J. Kern, and M. Grifoni, Eur. Phys. J. B **86**, 384 (2013).