TT 37: Correlated Electrons: Quantum Impurities, Kondo Physics

Time: Friday 10:15–13:00 Location: H 2053

TT 37.1 Fri 10:15 H 2053

Quantum Transport through Nanodevice — •Frithjof Anders — Institut für Theoretische Physik, Universität Bremen, P.O. Box 330 440, D-28334 Bremen

The electronic transport though nanodevices such as quantum dots and carbon nanotubes are dominated by their small capacitance at low temperatures. The Kondo effect is now a classical hallmark of many-body physics in nanoscale devices governing the crossover between the Coulomb blockade regime and perfect transmission. We present numerical renormalization group (NRG) calculation for the temperature evolution zero-bias conductance which agrees beautifully with recently published experiments on semiconducting carbon nanotube quantum dots.

Furthermore, we discuss a novel approach to steady-state non-equilibrium dynamics at finite bias, based on a combination of an NRG approach to open quantum system and the recently developed time-dependent NRG. The current-voltage characteristics can be obtained for a tunneling junctions as well as symmetric single-electron transistors at arbitrarily low temperatures.

TT 37.2 Fri 10:30 H 2053

Transport through Semiconductor Nanowire Quantum Dots in the Kondo Regime — •Stefan Schmaus, Verena Koerting, and Peter Wölfle — Institut für Theorie der Kondensierten Materie, Universität Karlsruhe, Wolfgang-Gaede-Straße 1, 76131 Karlsruhe, Germany

Recent experiments on quantum dots made of semiconductor nanowires in the Coulomb blockade regime have shown the influence of several approximately equidistant levels on the conductance. We study a model with three levels occupied by three electrons. At finite bias voltage charge energy conserving excitations into several higher lying states occur leading to features in the differential conductance. We restrict our study to the six lowest lying states by performing a Schrieffer-Wolff type projection onto this subspace. The emerging effective Kondo Hamiltonian is treated in non-equilibrium perturbation theory in the coupling to the leads. For convenience we use a pseudoparticle representation and an exact projection method. The voltage-dependence of the occupation numbers is discussed. The density matrix on the dot turns out to be off-diagonal in the dot eigenstate Hilbert space in certain parameter regimes. The dependence of the differential conductance on magnetic field and temperature is calculated in lowest order in the dot-lead coupling and the results are compared with experiment.

TT 37.3 Fri 10:45 H 2053

Stable Two-Channel Kondo Fixed Point of an SU(3) Quantum Defect in a Metal: Renormalization-Group Analysis and Conductance Spikes — •Katinka Ballmann, Tobias Langenbruch, Michael Arnold, and Johann Kroha — Physikalisches Institut, Universität Bonn, Germany

We propose a physical realization of the two-channel Kondo (2CK) effect, where a rotational defect in a metal has a unique ground state and twofold degenerate excited states [1]. In a wide range of parameters the interactions with the electrons renormalize the excited doublet downward below the bare defect ground state, thus stabilizing the 2CK fixed point. In addition to the Kondo temperature T_K the three-state defect exhibits another low-energy scale, associated with ground-to-excited-state transitions, which can be exponentially smaller than T_K. Using the perturbative nonequilibrium renormalization group we demonstrate that this can provide the long-sought explanation of the sharp conductance spikes observed by Ralph and Buhrman in ultrasmall metallic point contacts. In addition, we investigate the effect of an applied magnetic field coupling to the angular magnetic moment of the defect, lifting the degeneracy of the excited states, which can lead to a splitting of the sharp conductance spikes even when the Zeeman energy is less than T_K.

[1] M. Arnold, T. Langenbruch, and J. Kroha, PRL **99**, 18660 (2007).

TT 37.4 Fri 11:00 H 2053

Non-Equilibrium Scaling Analysis of a Kondo Dot in a Magnetic Field — •Peter Fritsch and Stefan Kehrein — Physics Department, ASC, and CeNS, Ludwig-Maximilians-Universität, Theresienstrasse 37, 80333 Munich, Germany

By using infinitesimal unitary transformations (flow equations) [1] we derive a perturbative scaling picture of a Kondo dot in a magnetic field. Within this single scaling picture we are able to study both equilibrium and non-equlibrium (dc voltage bias) situations. As main result, we work out the spin-spin correlation function and the T-Matrix as functions of magnetic field, voltage bias and temperature.

This work is a generalization of the previous flow equation analysis of the non-equilibrium Kondo Model [2].

[1] S. Kehrein, The Flow Equation Approach to Many-Particle Systems, Springer Tracts in Modern Physics 217

[2] S. Kehrein, Phys. Rev. Lett. 95, 056602 (2005)

TT 37.5 Fri 11:15 H 2053

Coupled-Cluster Method for the Anderson Impurity Model — •Jin-Jun Liang, Clive Emary, and Tobias Brandes — Sekr. PN 7-1, Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 BERLIN

The coupled-cluster method (CCM) is one of the most powerful and numerically accurate approximation methods for describing many-body quantum systems. It is popular in nuclear physics, quantum chemistry and quantum magnetism. However, the method has been rarely applied to models with continua, like the Anderson impurity model. In this talk, we will present our work on applying the CCM to the Fano-Anderson model and the Anderson model with Coulomb interaction. Results are mainly for ground state properties, including ground state energies and impurity occupation numbers. The method will also be compared with some other more traditional methods in quantum impurities, such as Green's function and self-consistent perturbation theory.

15 min. break

TT 37.6 Fri 11:45 H 2053

Quantum systems coupled to baths: A novel Chebyshev space description — •Andreas Alvermann and Holger Fehske — Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald, Germany

We propose a new concept for the dynamics of a quantum bath, the Chebyshev space method. Relying on Chebyshev expansions the Chebyshev space representation of the bath degrees of freedom has very favorable properties with respect to extremely precise and efficient numerical calculations of groundstate properties, static and dynamical correlations, and time-evolution for a great variety of quantum systems. In particular we can address important topics like transport through quantum systems coupled to fermionic baths, the solution of quantum impurity models, or the non-equilibrium dynamics of mesoscopic devices coupled to leads.

TT 37.7 Fri 12:00 H 2053

Matrix product state comparison of the numerical renormalization group and the density matrix renormalization group — •Hamed Saberi, Andreas Weichselbaum, and Jan von Delft — Physics Department, Arnold Sommerfeld Center for Theoretical Physics, and Center for NanoScience, Ludwig-Maximilians-Universität, Munich, Germany

Wilson's numerical renormalization group (NRG) method for solving quantum impurity models can be turned into a variational method within the set of so-called matrix product states (MPS) with significantly more flexibility and efficient use of numerical resources. White's density matrix renormalization group (DMRG) for treating quantum lattice problems can likewise be reformulated in terms of MPSs. Thus, the latter constitute a common algebraic structure for both approaches. We exploit this fact to compare the NRG approach for the single-impurity Anderson model to the DMRG approach. We explore to what extent NRG results can be improved upon systematically by performing a variational optimization in a space of variational matrix product states of the same structure as those used by NRG. We also compare the truncation schemes of NRG and DMRG, which are formulated in terms of energy eigenvalues or density matrix eigenvalues, respectively, and establish how many of the latter need to be kept to reproduce NRG eigenspectra using DMRG.

TT 37.8 Fri 12:15 H 2053

Dephasing rates within nonequilibrium RG: A generic approach — •Frank Reininghaus, Herbert Schoeller, and Thomas Korb — Institut für Theoretische Physik A, RWTH Aachen, 52056 Aachen, Germany

We consider a generic model for a local quantum system coupled to reservoirs and present a general solution to the problem how relaxation and dephasing rates can be implemented within nonequilibrium renormalization group. Generalizing previous RG-methods [1,2] to a specific frequency representation and using a cutoff on the imaginary frequency axis [3], we show that decay rates always cut off the RG flow and find the physical meaning of these rates. We illustrate the method for the nonequilibrium Kondo model.

[1] Herbert Schoeller and Jürgen König, Phys. Rev. Lett. **84**, 3686 (2000)
[2] Thomas Korb, Frank Reininghaus, Herbert Schoeller, and Jürgen König, Phys. Rev. B **76**, 165316 (2007)
[3] Severin G. Jakobs, Volker Meden, and Herbert Schoeller, Phys. Rev. Lett. **99**, 150603 (2007)

TT 37.9 Fri 12:30 H 2053

Kondo screening cloud in a one-dimensional wire: Numerical renormalization group study — •László Borda — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn, Germany — Department of Theoretical Physics, TU Budapest, H1111 Budapest, Budafoki út 8. Hungary

We study the Kondo model -a magnetic impurity coupled to a one-dimensional wire via exchange coupling- by using Wilson's numerical renormalization group technique. By applying an approach similar to which was used to compute the two-impurity problem we managed to improve the poor spatial resolution of the numerical renormalization group method. In this way we have calculated the impurity-spin-conduction-electron-spin correlation function which is a measure of the Kondo compensation cloud whose existence has been a long-standing problem in solid-state physics. We also present results on the temperature dependence of the Kondo correlations.

TT 37.10 Fri 12:45 H 2053

Low temperature Kondo phyiscs in mesoscopic systems — •Rainer Bedrich, Sebastien Burdin, and Martina Hentschel — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

We study the Kondo effect in a quantum dot with discrete energy levels coupled to a single magnetic impurity. The electronic occupation can be changed by tuning the gate voltage that is applied to the dot. Solving the Hamiltonian within a mean-field approximation, we compute various physical quantities, e.g. the magnetic susceptibility, the conductance and the local density of states in the Kondo regime. Finite size effects lead to deviations from the universal behavior which would be expected for a bulk system. They are investigated by varying the number of energy levels and the mean level spacing.