TT 11: Quantum Impurities, Kondo Physics

Time: Tuesday 9:30–12:15 Location: H19

TT 11.1 Tue 9:30 H19

Simultaneous ferromagnetic and semiconductor-metal transition in EuO — Michael Arnold and •Johann Kroha — Physikalisches Institut, Nussallee 12, 53115 Bonn

We develop a theory for the simultaneous para-to-ferromagnetic and semiconductor to metal transition in O-depleted EuO. An analysis of the total charge conservation across the transition indicates that strong Coulomb correlations in the localized O-defect states must play a crucial role. This leads to a generalized Anderson impurity model with Stoner-like magnetic correlations in the conduction band and a dilute concentration of Anderson impurities in the semiconducting gap. We solve this model using a self-consistent Non-Crossing Approximation.

TT 11.2 Tue 9:45 H19

Random Kondo alloys — •Sebastien Burdin and Peter Fulde — Max-Planck-Institut fur Physik komplexer Systeme, Nothnitzer Strasse 38, 01187 Dresden, Germany

The interplay between the Kondo effect and disorder is studied. This is done by applying a matrix coherent potential approximation (CPA) and treating the Kondo interaction on a mean-field level. The resulting equations are shown to agree with those derived by the dynamical mean-field method (DMFT). By applying the formalism to a Bethe tree structure with infinite coordination the effect of diagonal and off-diagonal disorder are studied. Special attention is paid to the behavior of the Kondo- and the Fermi liquid temperature as function of disorder and concentration of the Kondo ions. The non monotonous dependence of these quantities is discussed.

TT 11.3 Tue 10:00 H19

Dephasing rate due to diluted Kondo impurities — Tobias Micklitz[2], Alexander Altland[2], •Theodoulos Costi[1], and Achim Rosch[2] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich — [2]Institut für Theoretische Physik, Universität zu Köln, 50937 Köln

We calculate the dephasing rate, $1/\tau_\varphi$, of electrons due to magnetic impurities in a weakly disordered metal as measured in a weak-localization experiment. For sufficiently low impurity concentrations, n_S, the dephasing rate is a universal function, $1/\tau_\varphi = (n_S/\nu) f(T/T_K)$, of T/T_K, where T_K is the Kondo scale and ν is the density of states [1,2]. Recent measurements of the dephasing rate due Fe impurities in Ag wires with $T_K = 4.3K$ [3] are shown to be well described by the above universal function for the fully screened Kondo model calculated with the numerical renormalization group method. Purely underscreened or overscreened Kondo impurities are ruled out for explaining the experiments, although a small fraction of underscreened Kondo impurities (sitting at lower symmetry sites, for example) might account for the observed slower than predicted decay of the dephasing rate at the lowest temperatures measured, $T < 0.1T_K$.

[1] T. Micklitz et al., Phys. Rev. Lett. **96**, 226601 (2006).
[2] T. Micklitz et al., cond-mat/0610304 (2006).
[3] F. Mallet et al., Phys. Rev. Lett. **97**, 226804 (2006).

TT 11.4 Tue 10:15 H19

2-channel Kondo behavior in quantum defects with partially broken SU(3) symmetry — •Tobias Langenbruch, Michael Arnold, and Johann Kroha — Physikalisches Institut, Universität Bonn, Germany

We propose an atomic rotational state defect embedded in a metal as a microscopic model to realize the 2-channel Kondo (2CK) effect. The model has a partially broken SU(3) symmetry, where the excited states of the bare defect are doubly degenerate due to space inversion symmetry.

Using perturbative renormalization group techniques we show that for a wide range of parameters this model has a stable two-channel Kondo fixed point. The stability is due to a correlation-induced crossing of the local levels. The energy dependence of the renormalized coupling functions is crucial for this stabilization.

We calculate the differential conductance of quantum point contacts with such defects, exhibiting spikes at elevated bias voltages due to fluctuations into excited local levels. We discuss the various energy scales involved in this system as well as the asymmetrical spike shape and conjecture that this model may provide a microscopic explanation for the longstanding puzzle of both, the 2CK signatures and the conductance spikes observed by Ralph and Buhrman [1] in ultrasmall quantum point contacts.

[1] D.C. Ralph and R. A. Buhrman, PRL 69, 2118 (1992); PRB 51, 3554 (1995).

TT 11.5 Tue 10:30 H19

Transmission through a two-level quantum dot — •Theresa Hecht[1], Christoph Karrasch[2], Andreas Weichselbaum[1], Yuval Oreg[3], Jan von Delft[1], and Volker Meden[2] — [1]Department für Physik, CeNS und Arnold Sommerfeld Center, Ludwig-Maximilians Universität München — [2]Institut für Theoretische Physik, Universität Göttingen — [3]Department of Condensed Matter Physics, The Weizmann Institute of Science, Israel

Measurements of the transmission phase shift of many-electron quantum dots revealed a "universal" phase behavior with phase lapses of π between consecutive resonances, whereas for dots with only a few electrons the phase behaves "mesoscopically" [1]. These generic features were reproduced in [2] for a spinless many-level Anderson model (AM) in the limits of $\delta/\Gamma \ll 1$ (universal) and $\delta/\Gamma \gg 1$ (mesoscopic), where δ is the mean level spacing, Γ the mean level width. Inspired by the experiment and based on [2], we now extend the studies to a many-level spinfull AM by means of Wilson's numerical renormalization group method and investigate the temperature dependence of the transmission through the quantum dot.

[1] M. Avinun-Kalish, M. Heiblum, O. Zarchin, D. Mahalu, V. Umansky, Nature 436, 529 (2005)
[2] C. Karrasch, T. Hecht, Y. Oreg, J. von Delft, and V. Meden (2006), cond-mat/0609191

15 min. break

TT 11.6 Tue 11:00 H19

Transconductance in a double quantum dot system in the Kondo regime — •Verena Koerting[1], Jens Paaske[2], and Peter Wölfle[1] — [1]Institut fuer Theorie der Kondensierten Materie, Universitaet Karslruhe, 76128 Karlsruhe, Germany — [2]The Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark

We consider a system of two lateral quantum dots in a spin 1/2 state, each contacted by two leads, and mutually coupled by spin exchange interaction K. The coupling to the leads is modeled by exchange tunneling (coupling J). We calculate the currents through both quantum dots as a function of the two bias voltages $V_{L,R}$ in renormalized perturbation theory in coupling functions $J(\omega)$, preserving the non-equilibrium physics at large voltages by taking into account the frequency dependence of the couplings. For sufficiently large antiferromagnetic K the groundstate of the double dot is a spin singlet. Since electron transport through e.g. the left dot requires triplet excitations we find a threshold in the differential conductance $G_L = dI_L/dV_L$ as a function of bias voltage V_L, with $G_L \approx 0$ if $eV_L \ll K$ and if the right dot is at low bias voltage $eV_R \ll K$. For increasing eV_R approaching K the triplet states get occupied and G_L rises rapidly. We will calculate this *transconductance* signal and show that Kondo correlations will significantly enhance dI_L/dV_R around $eV_R \approx K$. An outlook on experimental realization of this *quantum transistor* will be given.

TT 11.7 Tue 11:15 H19

The Kondo model in nonequilibrium: Decoherence, current, and noise — Thomas Korb[1], •Frank Reininghaus[1], Herbert Schoeller[1], and Jürgen König[2] — [1]Institut für Theoretische Physik A, RWTH Aachen, 52056 Aachen, Germany — [2]Institut für Theoretische Physik III, Ruhr-Universität Bochum, 44780 Bochum, Germany

We study the Kondo effect in nonequilibrium using the real-time renormalization group [1] and put special emphasis on the calculation of the decoherence rate Γ. We obtain expressions for the current and the finite-frequency noise which are valid for voltages $V \gg T_K$. While the decoherence rate cannot be detected by measuring the current in a two-terminal setup, which was calculated previously using other methods [2,3], we demonstrate that the frequency dependence of the noise has features which allow the identification of Γ.

[1] H. Schoeller and J. König, Phys. Rev. Lett. **84**, 3686 (2000)

[2] A. Rosch *et al.*, Phys. Rev. Lett. **90**, 076804 (2003)
[3] S. Kehrein, Phys. Rev. Lett. **95**, 056602 (2005)

TT 11.8 Tue 11:30 H19

A time-dependent Numerical Renormalization Group Analysis of Single Molecule Magnets — •David Roosen[1], Maarten Wegewijs[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, J. W. Goethe-Universität, D-60438 Frankfurt, Germany — [2]Institut für Theoretische Physik A, RWTH Aachen, D-52056 Aachen, Germany

It has recently become possible to perform experiments where single molecule magnets (SMMs), which exhibit a large intrinsic spin, are attached to metallic leads and electronic transport is measured [1]. Motivated by this, a simple quantum impurity model describing SMMs was studied theoretically and it was found that the anisotropy energies dramatically change the Kondo effect observed in such systems, even making a complete screening of the magnetic degrees of freedom possible [2].

We have investigated the *time-dependent* Kondo effect in a single molecule magnet strongly coupled to metallic electrodes, with a sudden perturbation at time $t = 0$. We use a generalization of the Numerical Renormalization Group for nonequilibrium situations [3]. Applying this method to a Kondo model with large spin $S > 1/2$ we systematically analyze the underscreening of the local moment and the effects of anisotropy terms on the real-time dynamics of the magnetization.

[1] H. Heersche et al. , Phys. Rev. Lett. **96**, 206801 (2006)
[2] C. Romeike, M. R. Wegewijs, W. Hofstetter and H. Schoeller, Phys. Rev. Lett. **96**, 196601 (2006)
[3] F. Anders and A. Schiller, Phys. Rev. Lett. **95**, 196801 (2005)

TT 11.9 Tue 11:45 H19

Matrix product state approach for a two-lead Anderson model — •Andreas Holzner[1,2], Andreas Weichselbaum[1], and Jan von Delft[1] — [1]LMU München, Lehrstuhl für Theoretische Festkörperphysik, Theresienstraße 37, D-80333 München, Germany — [2]Institut für Theoretische Physik C, RWTH Aachen, D-52056 Aachen, Germany

Both NRG and DMRG can be formulated using the matrix product state (MPS) formalism. Using this common basis, we apply DMRG techniques to the Anderson model after mapping the leads to Wilson-chains as in NRG. For calculating the ground state properties this method proves to be more efficient and more flexible than NRG. In this sense more complex systems are accessible. Specifically, we map a two-lead Anderson model onto a quasi-1-dimensional star geometry upon which we sweep similar in style to 1-site finite-size DMRG. We present results for the groundstate occupation of a spinful 4-level quantum dot.

TT 11.10 Tue 12:00 H19

Sum-rule Conserving Spectral Functions from the Numerical Renormalization Group — •Andreas Weichselbaum and Jan von Delft — Ludwig-Maximilians-Universität, Arnold Sommerfeld Center, 80333 München

We show how spectral functions for quantum impurity models, i.e. nanosystem embedded in fermionic or bosonic environment, can be calculated very accurately using a complete set of *discarded* numerical renormalization group (NRG) eigenstates, recently introduced by Anders and Schiller. The only approximation is to judiciously exploit energy scale separation. Our rigorous derivation avoids both the overcounting ambiguities and the single-shell approximation for the equilibrium density matrix prevalent in current methods including state of the art DM-NRG. The resulting procedure based on the full density matrix of the system (FDM-NRG) ensures that relevant sum rules hold rigorously and spectral features at energies below the temperature can be described accurately.