Theory of the Pseudospin Resonance in Semiconductor Bilayers

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The pseudospin degree of freedom in a semiconductor bilayer gives rise to a collective mode analogous to the ferromagnetic resonance mode of a ferromagnet. We present a theory of the dependence of the energy and the damping of this mode on layer separation d. Based on these results, we discuss the possibility of realizing transport-current driven pseudospin-transfer oscillators in semiconductors.

Decoherence by Quantum Telegraph Noise

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We analyze the effect of quantum telegraph noise, produced by a single electronic defect level, on the decoherence of a charge qubit. In contrast to earlier works, [1], [2], [3], we describe the full time-evolution of the coherence factor even at short and intermediate times. In striking contrast to the well-known case of decoherence by a bath of harmonic oscillators, the coherence factor displays oscillations as a function of time and other parameters. We analyze these in detail using a numerical evaluation of the exact solution for the density matrix of the qubit.

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Carrier transport in graphene

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We contend that most of the observed [1] transport properties in graphene can be understood theoretically using a self-consistent RPA-Boltzmann transport theory [2]. We find that transport close to the Dirac point is dominated by two distinct effects of charged impurities that are invariably present in the system. First, the induced graphene carrier density is self-consistently determined by the screened charged impurity potential, and second, the conductivity is determined by charged impurity scattering. We provide analytic results for (i) graphene mobility, (ii) threshold voltage, (iii) minimum conductivity and (iv) plateau width that are all in good agreement with recent experiments.

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[2] S. Adam, E. H. Hwang, V. M. Galitski, and S. Das Sarma, arXiv:0705.1540 (2007)

Devices with precisely placed carbon nanotubes of known chiral vector

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Single walled carbon nanotubes (swcnt's) have received a great deal of both theoretical and experimental interest since their discovery in 1991 yet there is still great difficulty in fabricating devices from individual swcnt's with known chiral vector. We are developing a technique which allows for determination of the chiral vector of individual tubes via electron diffraction followed by placement of the desired tube to within 100 nm. Single walled carbon nanotubes are grown by chemical vapour depositi

Demonstration of one-parameter scaling at the Dirac point in graphene

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We numerically calculate the conductivity σ of an undoped graphene sheet (size L) in the limit of vanishingly small lattice constant. We demonstrate one-parameter scaling for random impurity scattering and determine the scaling function $\beta(\sigma) = d\ln\sigma/d\ln L$. Contrary to a recent prediction, the scaling flow has no fixed point ($\beta > 0$) for conductivities up to and beyond the symplectic metal-insulator transition. Instead, the data supports an alternative scaling flow for which the conductivity at the Dirac point increases logarithmically with sample size in the absence of intervalley scattering without reaching a scale-invariant limit.

Transport through quantum dots and quantum wires with spin-orbit coupling and electron correlations

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We investigate the influence of the spin-orbit coupling on the transport properties of correlated electrons in mesoscopic quantum dots and quantum wires. As a prominent example for many-body effects in interacting electron systems, we analyze the Kondo effect, which is seen in the linear conductance as a function of an external gate voltage, of a serial double dot at $T = 0$ and its modification in presence of spin-orbit coupling using the functional renormalization group method to accurately treat the electron correlations. We next discuss, for a continuum model, the effect of the lateral confinement which leads from the two-dimensional electron gas to a quasi one-dimensional quantum wire, analyze the spin polarization at a potential step in the presence of a magnetic field and introduce a corresponding lattice model which shows similar physics and which can be used to investigate correlation effects.

Efficient production and manipulation of entanglement in electron spin quantum dots

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Multipartite entanglement is a necessary prerequisite for quantum computation as well as quantum communication. Motivated by recent experimental advances in the control of electron spin qubits in quantum dots, we investigate the most feasible and efficient ways to generate and detect multi-partite entanglement in a linear array of quantum dots. We show how to create and manipulate multipartite entangled states (such as GHZ-, W-states and Cluster-states) using the least number of single-qubit rotations and two-qubit square-root of swap-operations, which constitute the basic operations of quantum computation in quantum dots. We check the feasibility by calculating the fidelity including slight errors in these basic operations.

Electrical Manipulation of Electron Spins in Quantum Dots

Massoud Borhani

An alternating electric field, applied to a quantum dot, couples to the electron spin via the spin-orbit interaction. We analyze different types of spin-orbit coupling known in the literature and find two efficient mechanisms of spin control in quantum dots. The linear in momentum Dresselhaus and Rashba spin-orbit couplings give rise to a fully transverse effective magnetic field in the presence of a Zeeman splitting at lowest order in the spin-orbit interaction. The cubic in momentum Dresselhaus terms are efficient in a quantum dot with non-harmonic confining potential and give rise to a spin-electric coupling proportional to the orbital magnetic field. We derive an effective spin Hamiltonian, which can be used to implement spin manipulation on a timescale of 10 ns with the current experimental setups.

Spin and rotational symmetries in the unrestricted Hartree-Fock states of quantum dots

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Ground state energies and spin–resolved densities are obtained using the projected Hartree-Fock (PHF) method [1] for up to 12 interacting electrons parabolically confined in a quantum dot subject to a magnetic field. At zero magnetic field, we recover Hund's rule which were claimed to be violated in previous unrestricted HF (UHF) calculations. In the presence of magnetic field, ground states transitions are identified, that are not reproduced by UHF. A spin–blockade in the $6 \rightarrow 7$ electrons transition at the onset of dot filling factor two is observed.

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Electron Spin Resonance of Single-walled Carbon Nanotubes and Related Structures

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Single-walled carbon nanotubes (SWNTs) are expected to show a Luttinger-liquid behavior and onedimensional electronic instability, as an archetypical 1D system. Here we report electron spin resonance measurements on purified single-walled carbon nanotubes. Furthermore, in order to minimize the effect of eventual imurities we have prepared C60 filled SWNTs,so-called peapods, and by high temperature treatment, the C60 was transformed into an ultrapure inner nanotube (the assembly forms a double walled carbon nanotube). A small ESR line is present in well purified samples and its temperature dependence reveals a striking 'super-Curie' paramagnetic rise what we identify as a fingerprint of a Lutinger-liquid behavior. In addition, we identify a narrower line in peapod and DWNT samples, which displays similar behavior. The linewidth of both inner and outer species are metallic and the outer tube's resonance broadens upon growth of the inner tubes. We observe a sudden decrease of relaxation rate below 20 K, in accordance with the opening of a spin-gap characteristic for a 1D system.

The distribution of the electrical resistances of disordered nanowires

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Motivated by recent experiments on nanowires and carbon nanotubes, we study theoretically the effect of strong, point-like impurities on the electrical resistance R of finite nanowires in the low-field regime. R has huge sample-to-sample fluctuations and we derive analytically and check numerically its statistical distribution in different temperatures regimes built up by Coulomb blockade and cotunneling. At low temperatures the distribution is similar to the one of standard Variable Range Hopping behaviour found long ago in dopes semiconductors; we point out that a result by Raikh and Ruzin does not apply. At higher temperatures, the distribution is very close to a Gumbel extreme values distribution already for wires with a few tens impurities.

Quantum charge diffusion in underdamped Josephson junctions and superconducting nanowires

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We study the effect of quantum fluctuations on the current-voltage characteristic of Josephson junctions and superconducting nanowires in the underdamped limit. Quantum fluctuations induce transitions between a zero–current finite–voltage branch corresponding to Coulomb blockade and a supercurrent branch corresponding to Bloch oscillations of the voltage, and can significantly modify the shape of current-voltage characteristics in the case of a highly resistive environment. We develop a unifying non-perturbative approach based on the Keldysh formalism that enables us to obtain quantitative results for a wide range of parameters. Our analysis provides a quantum Smoluchowski equation which describes the leading quantum corrections to the quasicharge dynamics. Owing to the phase-charge duality, our results can be directly extended to the opposite overdamped limit.

Spin gap and Luttinger liquid description of the NMR relaxation in carbon nanotubes

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Recent NMR experiments by Singer et al. [1] showed a deviation from Fermi-liquid behavior in carbon nanotubes with an energy gap evident at low temperatures. Here, a comprehensive theory for the magnetic field and temperature dependent NMR 13C spin-lattice relaxation is given in the framework of the Tomonaga-Luttinger liquid. The low temperature properties are governed by a gapped relaxation due to a spin gap (30K), which crosses over smoothly to the Luttinger liquid behaviour with increasing temperature.

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Double non local Andreev reflection and quantum interference effects in superconductors hybrids

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We study the non local conductance in superconductors hybrids. We try to explain the Delft experiment [1] on a three terminal junction normal metal - superconductor - normal metal. A non zero signal for the non local resistance is measured despite [2] no signal in the lowest order in the tunneling pertubation theory. Effectively, the elastic cotunneling process and the crossed Andreev reflection process cancel. We study the N-S-N junction at higher order: a new process appears the double Andreev reflection. On the other hand, in considering quantum interference effects we study weak localization-like processes for the N-S-N junction and for one other system. Weak localization-like processes allow to explain the magnetoresistance oscillations of a charge density waves pierced by nanoholes [3].

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[3] Latyshev, *et al.*, PRL. **78**, 919 (1997).

Effect of measurement probes upon the transmission of an interacting nano-system: Detection of an attached ring by non local many body effects

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We consider a nano-system connected to measurement probes via leads. When a magnetic flux is varied through a ring attached to one lead at a distance L_c from the nano-system, the effective nano-system transmission $|t_s|^2$ exhibits Aharonov-Bohm oscillations if the electrons interact inside the nano-system. These oscillations can be very large, if L_c is small and if the nano-system has almost degenerate levels which are put near the Fermi energy by a local gate.

Interaction-Induced Strong Localization in Quantum Dots

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We investigate the electronic properties of quantum dots in the low density regime up to $r_s \sim 55$ using variational and diffusion quantum Monte Carlo methods. Quantum dots are highly tunable systems that allow the study of the physics of strongly correlated electrons. We show that as the electronic density is decreased, (i) electrons localize at their classical positions and (ii) the addition energy shows a clear progression from features associated with shell structure to those caused by commensurability of a Wigner crystal. The cross-over occurs near $r_s \sim 20$. As the addition energy is directly measurable in Coulomb blockade conductance experiments, this provides a direct probe of correlation-driven localization in the low density electron gas.

Finite size effects, super- and sub-poissonian noise in a nanotube connected to leads

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The injection of electrons in the bulk of carbon nanotube which is connected to ideal Fermi liquid leads is considered. While the presence of the leads gives a cancellation of the noise cross-correlations, the auto-correlation noise has a Fano factor which deviates strongly from the Schottky behavior at voltages where finite size effects are expected. Indeed, as the voltage is increased from zero, the noise is first super-poissonian, then sub-poissonian, and eventually it reaches the Schottky limit. These finite size effects are also tested using a diagnosis of photo-assisted transport, where a small AC modulation is superposed to the DC bias voltage between the injection tip and the nanotube. When finite size effects are at play, we obtain a stepwise behavior for the noise derivative, as expected for normal metal systems, whereas in the absence of finite size effects, due to the presence of Coulomb interactions, a smoothed staircase is observed. The present work shows that it is possible to explore finite size effects in nanotube transport via a zero frequency noise measurement.

[1] M. Guigou, A. Popoff, A. Crépieux and T. Martin, Phys. Rev. B **76**, 045104 (2007).

Nonlinear Response due to Exchange Effects

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We study the full counting statistics for the transmission of two identical particles with positive or negative symmetry under exchange for the situation where the scattering depends on energy. We find that, besides the expected sensitivity of the noise and higher cumulants, the exchange symmetry has a huge effect on the average transmitted charge; for equal-spin exchange-correlated electrons, the average transmitted charge can be orders of magnitude larger than the corresponding value for independent electrons. A similar, although smaller, effect is found in a four-lead geometry even for energy-independent scattering.

Quantum Lattice Exciton-Polaron Problem by Monte Carlo

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Exciton-polaron formation in one-dimensional lattice models with short or long-range carrier-phonon interaction is studied by quantum Monte Carlo simulations. Depending on the relative sign of electron and hole-phonon coupling, the exciton-polaron size increases or decreases with increasing interaction strength. Quantum phonon fluctuations determine the (exciton-)polaron size and yield translation-invariant states at all finite couplings.

Matrix product state approach for a two-lead Anderson model

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Both the numerical renormalization group (NRG) and the density matrix renormalization group (DMRG) can be formulated using the matrix product state (MPS) formalism. We demonstrate how the MPS description arises naturally from chain models. The generalization to a multi-lead geometry is straightforward and leads to a quasi-1-dimensional star geometry in MPS formulation. Using this common basis, we apply DMRG techniques to the Anderson model after mapping the leads to Wilson chains as in NRG. For calculating 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 treat a two-lead Anderson model by sweeping similar in style to 1-site finite-size DMRG. We present results for the groundstate occupation of a spinful 4-level quantum dot.

Generation and Characterization of non-classical Surface-Plasmon-Polaritons

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Surface-Plasmon-Polaritons (SPPs) are quasi particles described by the interaction of electron oscillations and electromagnetic waves at the boundary of a metal and a dielectric. By producing a heterostructure of the form dielectric-metal-dielectric the losses of the system can be reduced and the system becomes feasible for applications in quantum information science. In this context we first plan to study the noise properties of SPPs by exciting them with a coherent light source and measuring the reemitted light field. In a next stage of the project we plan to generate and characterise non-classical SPPs by means of squeezed light.

Nonequilibrium functional renormalization group for interacting quantum systems

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We propose a nonequilibrium version of functional renormalization group within the Keldysh formalism by introducing a complex valued flow parameter in the Fermi/Bose functions of each reservoir. The new cutoff scheme provides a unified approach to equilibrium and nonequilibrium situations and is numerically stable. We apply it to nonequilibrium transport through an interacting quantum wire coupled to two reservoirs and show that the nonequilibrium occupation induces new power law exponents for the conductance.

'Attractors' in Superconducting Qubits

Catherine Jarvis
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We present a scheme by which homodyne measurement of a microwave resonator can be used to generate entanglement between two superconducting charge qubits coupled to this resonator. The non-interacting qubits are initialised in a product of their ground states, the resonator is initialised in a coherent field state, and the state of the system is allowed to evolve under a rotating wave Hamiltonian. Making a homodyne measurement on the resonator at a given time projects the qubits into an state of the form $|gg\rangle + e^{-i\phi}|ee\rangle/\sqrt{2}$. This protocol can produce states with a fidelity as high as required, with a probability approaching 0.5. Although the system described is one that can be used to display revival in the qubit oscillations, we show that the entanglement procedure works at much shorter timescales.

Mesoscopic to universal crossover of transmission phase of multi-level quantum dots

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Transmission phase α measurements [1] of many-electron quantum dots (small mean level spacing δ) revealed universal phase lapses by π between consecutive resonances. In contrast, for dots with only a few electrons (large δ), the appearance or not of a phase lapse depends on the dot parameters. We introduce a model of a multi-level quantum dot with local Coulomb correlations and arbitrary level-lead couplings [2]. Using the functional RG to tackle the two-particle interaction we reproduce the generic features of the experimentally observed behavior. The fRG results are backed up by NRG calculations.

[1] M. Avinun-Kalish et al., Nature 436, 529 (2005).
[2] C. Karrasch et al., Phys. Rev. Lett. 98, 186802 (2007).

Alternating level repulsion of transmission eigenvalues in open mesoscopic systems with lead-transposing symmetry

Marten Kopp
Lancaster University

Systems with discrete symmetries can usually be desymmetrized, but this approach fails when considering transport through open mesoscopic systems with a symmetry that maps the openings onto each other. We derive the joint probability function of transmission eigenvalues for such systems in random-matrix theory. The result manifests level repulsion only between every second transmission eigenvalue, not between nearest neighbours. This effect is confirmed by numerical computations of the transmission eigenvalue spacing distribution for quantum billiards and the open kicked rotator.

Shot noise in superconductors above the critical temperature

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Shot noise in a voltage biased tunnel junction above the critical temperature is considered. There are two major effects, which modify current noise signal. The first one is due to the superconductive fluctuations, which redistribute electronic energy states near the Fermi level. Sharp dip in the density of states translates into the moderate logarithmic in temperature suppressive at small voltages correction to the noise. The second source for the noise signal modification is the fluctuating Josephson current, which manifests in the form of the peak in the noise power spectrum at the Josephson frequency, with the peak height being strongly dependent on temperature.

Ballistic quantum transport through graphene nanostructures

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The experimental realisation of single-layer sheets of graphite, i.e. graphene, has created a rapidly growing new field of study. Nanostructured graphene is a promising candidate for future nanoelectronic devices. We have developed a tight-binding description of ballistic transport properties of large, arbitrarily shaped graphene-based quantum dots. We investigate the influence of different edge structures on the "conical" dispersion relation near the Dirac point. We include additional on-site potentials to simulate the effect of impurity atoms at the edge of the graphene ribbon. By explicitly calculating the scattering states inside the nanostructure, we can determine the effect of these impurities on the transport properties.

Pseudospin Magnetism in Graphen

Hongki Min, Giovanni Borghi, Marco Polini, A.H. MacDonald

We predict that neutral graphene bilayers are pseudospin magnets in which the charge density-contribution from each valley and spin spontaneously shifts to one of the two layers. The broken symmetry state has a k-space vortex and a novel origin related to the unusual way in which interactions compete with kinetic energies. We discuss the possibility of realizing a pseudospin version of ferromagnetic metal spintronics in graphene bilayers based on hysteresis associated with this broken symmetry.

Real-time evolution for the nonequilibrium Hubbard model in infinite dimensions

Michael Moeckel, Stefan Kehrein

Recent experiments with cold atomic gases loaded onto optical lattices have opened up a new line of research into nonequilibrium properties of closed quantum systems. Motivated by these results we study the Hubbard model in infinite dimensions for a weak two-particle interaction $U\Theta(t)$ which is switched on instantaneously in time. We address the question of its real-time evolution by means of the flow equation technique and calculate the time-dependent momentum distribution function. After an initial buildup of a correlated distribution on a time scale set by U^{-1} a nonequilibrium transient state extends on a long time scale proportional to U^{-4}. It resembles an interacting Fermi liquid at zero temperature but its quasiparticle residuum mismatches the value for the correlated equilibrium state. Finally, a process which could lead to thermalization is identified.

Nanoscale Ferromagnetism in Semiconductors without Magnetic Dopants

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We have considered the possibility of ferromagnetism in a generalized Hubbard model with and without positional disorder, aimed at the system of hydrogenic centers in semiconductors. The Hubbard model on a hypercubic lattice in two and three dimensions is believed to have a ferromagnetic phase away from half filling, though its extent and precise location has remained controversial. We present our results showing the effects of positional disorder, of electron-hole asymmetry, and other properties applicable to real experimental systems of doped semiconductors.

Photon transport in low-dimensional nanostructures

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At low temperatures when the phonon modes are effectively frozen, photon transport is the dominating mechanism of thermal relaxation in metallic systems. Starting from a many-body Hamiltonian using the equation-of-motion technique for nonequilibrium Green's functions, we study the energy transport by photons in nanostructures. We obtain a formal expression for the energy current between a metallic island and a one-dimensional electromagnetic field supported by a parallel strip transmission line. From this expression we derive the quantized thermal conductance as well as show how the electron shot noise affects the photon transport. Frequency-dependent current noise essentially determines the transport process, thus providing a close connection between electronic fluctuations and photon transport.

Performance optimization of holonomic quantum gates in dissipative environments

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We study the performance of holonomic quantum gates, driven by lasers, under the effect of a dissipative environment modeled as a thermal bath of oscillators. As a consequence of our analysis, we show that, for super-Ohmic bath, the disturbance of the environment can be (approximately) suppressed and the performance of the gate optimized by a suitable choice of the experimental parameters. We consider a different type of optimization, which is independent from the bath spectral nature. By exploiting the full geometrical structure of Holonomic quantum computation, we show how the performance of a holonomic gate can be enhanced by suitable choice of the loop in the manifold of the parameters. For a simplified, albeit realistic model, we find the surprising result that for a long time evolution the performance of the gate increases.

Nonperturbative interaction corrections to thermodynamic quantities of disordered wires

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We study interaction corrections to thermodynamic quantities of multichannel disordered wires in the presence of long-range electron-electron interactions using Finkelstein's nonlinear sigma model. In the limit of infinite number of transverse channels in the wire, we find the exact finite action soliton solutions for the extrema of the sigma-model action. For large, but finite number of channels, and in the weakly localized regime, we obtain the leading correction to the thermodynamic quantities due to the presence of the solitons. Our results suggest there is a crossover in the behavior of such nonperturbative corrections: at high temperatures the solitons form a dilute gas of soliton-antisoliton pairs, and at low temperatures the state of the system corresponds to a plasma of solitons and antisolitons. The corresponding crossover temperature is parametrically larger than the single particle mean level spacing of a wire segment of length equal to the localization length, the latter being the temperature scale governing the conventional perturbative corrections.

Phase switching in a biased Aharonov-Bohm interferometer

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We study non-equilibrium transport through an Aharonov-Bohm interferometer with a quantum dot embedded in one of its arms. In recent experiments by M. Sigrist et al. [Phys. Rev. Lett. 98, 36805 (2007)] Aharonov-Bohm phase of such an interferometer was shown to switch its value between zero and pi as a function of the bias voltage. Using a multi-level dot, we attribute this phenomenon to the fact that different levels, with perhaps different symmetry, dominate the transport as the occupation of the states evolves with increasing bias. Such a several-level dot leads to rich behavior with number of switching events not necessarily equal to that of inelastic onsets, which in turn may be different than the number of levels.

We discuss the design of experiment that would discriminate between the explanation above and conductance switching due to electrostatic AB effect [W. G. van der Wiel et al., Phys. Rev. B 67, 033307 (2003)]. Breaking of phase rigidity in non-equilibrium transport and the role of decoherence are also discussed.

Real-time renormalization group and cutoff scales in nonequilibrium

T. Korb, F. Reininghaus (Aachen), H. Schoeller, J. König (Bochum)

We apply the real-time renormalization group in nonequilibrium to an arbitrary quantum dot in the Coulomb blockade regime. We find that relaxation and dephasing rates generically cut off the RG flow. In addition, we include all other cutoff scales defined by temperature, energy excitations, frequency, and voltage. We study transport through single molecular magnets, calculate the differential conductance as function of bias voltage V and discuss a quantum phase transition which can be tuned by changing the anisotropy parameters. Finally we calculate the noise $S(\Omega)$ at finite frequency Ω for the isotropic Kondo model and find that the dephasing rate determines the height of the shoulders in $dS(\Omega)/d\Omega$ near $\Omega = V$.

Anderson orthogonality catastrophe in mesoscopic systems

Georg Röder and Martina Hentschel

Anderson orthogonality catastrophe (AOC) is an universal many-body response of an electron gas subject to a sudden, localized perturbation. It refers to the vanishing of the overlap of the unperturbed and perturbed many-body ground states in the thermodynamic limit. We study AOC in mesoscopic systems, where the finite number of electrons, the confining geometry, interference effects and mesoscopic fluctuations give rise to novel behavior not seen in bulk systems. In particular we consider an integrable, ballistic disk-like quantum dot with hard walls. We obtain a broad distribution of Anderson overlaps and compare the results with the previously studied chaotic case. AOC contributes to Fermi edge singularities in x-ray emission and absorption spectra which constitute our prospective research topic.

Resonant Cooling of Nuclear Spins in Quantum Dots

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We propose to use the spin-blockade regime in double quantum dots to reduce nuclear spin polarization fluctuations in analogy with optical Doppler cooling. The Overhauser shift brings electron levels in and out of resonance, creating feedback to suppress fluctuations. Coupling to the disordered nuclear spin background is a major source of noise and dephasing in electron spin measurements in such systems. Estimates indicate that a better than 10-fold reduction of fluctuations is possible.

Thermoelectric effect in Mott-insulator/ band-insulator superlattices

Andreas Rüegg and Manfred Sigrist

We investigate the low temperature electric and thermal transport properties in atomically precise heterostructures, which are modeled by an extended Hubbard Hamiltonian including long-range Coulomb interactions. Using the quasiparticle properties derived from the slave-boson mean-field approximation we solve the Boltzmann transport equation in the relaxation time approximation considering s-wave impurity scattering. In the quantum well structure we find an enhancement of the thermopower and of the thermoelectric figure of merit due to strong electron-electron interactions as compared with the non-interacting case.

Matrix product states for comparing NRG to DMRG

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Wilson's Numerical Renormalization Group (NRG) method for solving quantum impurity models can be turned into a variational method whithin the set of so-called Matrix Product States (MPS) with significantly more flexibility and efficient use of numerical resources. Since White's Density Matrix Renormalization Group (DMRG) for treating quantum lattice problems can likewise be reformulated in terms of MPSs, these can be seen as a common underlying algebraic structure, namely both are built on MPS. This enables us to compare the NRG approach for the Single Impurity Anderson model (SIAM) to the DMRG approach and also to see how 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. In particular, we also compare the truncation criterion of NRG to the DMRG one and demonstrate how the sharp feature of NRG truncation criterion compares to DMRG in energy space.

Optimized non-adiabatic Cooper pair pumping

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We show that the quantum optimal control theory makes it possible to pump one Cooper pair per cycle accurately. Optimized gate voltages are obtained in an array of Josephson junctions in non-adiabatic regime. Stability against $1/f$ noise on gate voltages is aslo addressed, and high accuracy for pumping one Cooper pair is found.

Correlation effects in charge and spin transport properties of quantum impurity models

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We have investigated the spin and charge transport properties of the Anderson impurity model (AIM) under non-equilibrium conditions. While in the non-interacting case the spin-resolved full counting statistics (FCS) is described by a purely binomial distribution, a small Coulomb interaction U induces correlated electron-pair transport which changes the FCS profoundly. In order to address the complementary large-U domain, we analysed the strong-coupling Kondo fixed point and derived an exact result for a special choice of parameters. The results agree for all regimes. Finally, we propose an experimental setup based on a Hanbury Brown and Twiss interferometer in which these effects can be observed.

Low Temperature Scanning Probe Microscopy on Low Dimensional Structures

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Although few electrons can be captured on quantum dots, most quantities measured are macroscopic and contain no spatial information about microscopic properties. To investigate the local electronic structure of a quantum dot, one needs to take a different approach. An option is scanning probe microscopy, where a metallic tip is used as a movable gate. A problem to interpret the data is the lack of knowledge about the tip-induced potential. Recently we were able to measure this potential quantitatively. It has been found that the tip-induced potential often consists of one part that depends on the tip bias and one part that is independent of tip bias. We will discuss new questions such as: Can the tip be altered in situ? Is it possible to build a tip with a sharper potential?

Coherence and charging effects in transport across a mesoscopic island

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A Green's functions technique, well known to describe transport through a single quantum-point contact, is extended and combined with a rate-equation method to model two contacts in series with a mesoscopically large metallic island between them in the superconducting as well as the normal-conducting state. Higher-order processes get included nonperturbatively and thus the formalism is valid for transport channels with arbitrary transmission in the contacts. Current-voltage characteristics are marked by an interplay of Coulomb blockade and multiple Andreev-reflections, neither of which generally suppressing the other [1].

[1] U.Schröter and E.Scheer, Phys.Rev.B 74, 245301 (2006).

Absence of the Mott glass phase in 1d disordered fermionic systems

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The results of our studies on the competition between the Mott and the Anderson insulating state in a one-dimensional disordered fermionic system are presented. The notorious difficulties associated with strong coupling phases are avoided by using a new description in terms of the kink energies (or instanton surface tension) of the electronic displacement pattern. The approach has some similarities to the description of the flat phase of surfaces undergoing a roughening tranition. Tracing back both, a finite compressibility and a nonzero ac-conductivity to a vanishing kink energy, we exclude the existence of an intermediate Mott glass phase in systems with short range interactions.

Surface and corner multifractality in disordered critical electronic systems

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Exact field-theoretic description of many two dimensional (2D) Anderson localization transitions is still absent. Two well known examples are the integer quantum Hall plateau transition and metal-insulator transition in systems with time reversal symmetry but broken spin-rotation symmetry (a.k.a. the symplectic class). A characteristic feature of these transitions is the multifractal behavior of electronic wavefunctions. We investigate this multifractal behavior near the boundaries in semi-infinite geometries. This is done for certain exactly solvable models analytically and otherwise numerically. In the process, we develop the concept of surface and corner multifractality. Studying boundary effects in these two dimensional systems can be particularly important. This is because the corresponding critical field theories are expected to have an infinite-dimensional conformal symmetry and boundary critical phenomena in such theories can be used as a starting point to understand bulk critical behavior.

[1] Phys. Rev. Lett. 96, 126802 (2006).
[2] Phys. Rev. Lett. **98**, 156802 (2007).
[3] Phys. Rev. B **75**, 094204 (2007).

Single photon microwave source

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The generation of single photons could be an important resource for scalable quantum computing. Common at optical frequencies, a single photon source has not yet been demonstrated at the microwave frequencies relevant to superconducting qubits. One possible implementation of a single photon source would be to use the spontaneous relaxation of a qubit itself.

Our qubit, a two-level quantum system, consists of two Al/AlO/Al Josephson junctions in a loop geometry. The junction and loop parameters must be carefully chosen and fabricated. The qubit is inserted in a resonant niobium coplanar waveguide such that the microwave cavity so formed can be used for exciting the qubit. The photon subsequently emitted through spontaneous relaxation is confined in the output waveguide. We report the design, fabrication and first tests of the device.

Magnetic Oscillations in Quantum Nanowires

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We summarise recent work on De-Haas Van-Alphen oscillations for free electrons confined within clean, metallic nanowires in a longitudinal magnetic field. The effects of two forms of boundary conditions are examined – those of a 'soft' parabolically confining potential, and a non-linear approximation to the 'hard' boundary conditions of an infinite round well. The appearance of additional frequencies of oscillation due to the effects of confinement is observed, as is the occurrence of additional resonances at particular values of the magnetic field.