Journal Club, Christoph Orth, 30.07.2013

Transport via double constrictions in integer and fractional topological insulators

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arXiv:1307.0525

We study transport properties of the helical edge states of two-dimensional integer and fractional topological insulators via double constrictions. Such constrictions couple the upper and lower edges of the sample, and can be made and tuned by adding side gates to the system. Using renormalization group and duality mapping, we analyze phase diagrams and transport properties in each of these cases. Most interesting is the case of two constrictions tuned to resonance, where we obtain Kondo behavior, with a tunable Kondo temperature. Moving away from resonance gives the possibility of a metal-insulator transition at some finite detuning. For integer topological insulators, this physics is predicted to occur for realistic interaction strengths and gives a conductance G with two temperature T scales where the sign of dG/dT changes; one being related to the Kondo temperature while the other is related to the detuning.

Nonlocal resistance and its fluctuations in microstructures of band-inverted HgTe/(Hg,Cd)Te quantum wells

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arXiv:1307.6115

We investigate experimentally transport in gated microsctructures containing a band-inverted $HgTe/Hg_{0.3}Cd_{0.7}Te$ quantum well. Measurements of nonlocal resistances using many contacts prove that in the depletion regime the current is carried by the edge channels, as expected for a two-dimensional topological insulator. However, high and non-quantized values of channel resistances show that the topological protection length (*i.e.* the distance on which the carriers in helical edge channels propagate without backscattering) is much shorter than the channel length, which is ~ 100 μm. The weak temperature dependence of the resistance and the presence of temperature dependent reproducible *quasi*-periodic resistance fluctuations can be qualitatively explained by the presence of charge puddles in the well, to which the electrons from the edge channels are tunnel-coupled.

Harnessing nuclear spin polarization fluctuations in a semiconductor nanowire

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arXiv:1307.6007

Soon after the first measurements of nuclear magnetic resonance (NMR) in a condensed matter system, Bloch predicted the presence of statistical fluctuations proportional to $1/\sqrt{N}$ in the polarization of an ensemble of N spins. First observed by Sleator et al., so-called "spin noise" has recently emerged as a critical ingredient in nanometer-scale magnetic resonance imaging (nanoMRI). This prominence is a direct result of MRI resolution improving to better than $100nm^3$, a size-scale in which statistical spin fluctuations begin to dominate the polarization dynamics. We demonstrate a technique that creates spin order in nanometer-scale ensembles of nuclear spins by harnessing these fluctuations to produce polarizations both larger and narrower than the natural thermal distribution. We focus on ensembles containing $\sim 10^6$ phosphorus and hydrogen spins associated with single InP and GaP nanowires (NWs) and their hydrogen-containing adsorbate layers. We monitor, control, and capture fluctuations in the ensemble's spin polarization in real-time and store them for extended periods. This selective capture of large polarization fluctuations may provide a route for enhancing the weak magnetic signals produced by nanometer-scale volumes of nuclear spins. The scheme may also prove useful for initializing the nuclear hyperfine field of electron spin qubits in the solid-state.

Tunneling into the localized phase near Anderson transitions with Coulomb interaction

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arXiv:1307.5811

We study the tunneling density of states (TDOS) of a disordered electronic system with Coulomb interaction on the insulating side of the Anderson localization transition. The average TDOS shows a critical behavior at high energies, with a crossover to a soft Coulomb gap at low energies. The single-particle excitations experience a localization transition (which belongs to the non-interacting universality class) at an energy $E = \pm E_c$. The mobility edge E_c scales with the distance $\mu_c - \mu$ from the interacting critical point according to $E_c \propto (\mu_c - \mu)^{\nu z}$, where ν and z are the localization-length and the dynamical critical exponents. Local TDOS shows strong fluctuations and long-range correlations which reflect the multifractality associated with interacting and non-interacting fixed points as well the localization of low-energy excitations.

Numerical simulations of time resolved quantum electronics

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arXiv:1307.6419

This paper discusses the technical aspects - mathematical and numerical - associated with the numerical simulations of a mesoscopic system in the time domain (i.e. beyond the single frequency AC limit). After a short review of the state of the art, we develop a theoretical framework for the calculation of time resolved observables in a general multiterminal system subject to an arbitrary time dependent perturbation (oscillating electrostatic gates, voltage pulses, time-vaying magnetic fields) The approach is mathematically equivalent to (i) the time dependent scattering formalism, (ii) the time resolved Non Equilibrium Green Function (NEGF) formalism and (iii) the partition-free approach. The central object of our theory is a wave function that obeys a simple Schrodinger equation with an additional source term that accounts for the electrons injected from the electrodes. The time resolved observables (current, density. . .) and the (inelastic) scattering matrix are simply expressed in term of this wave function. We use our approach to develop a numerical technique for simulating time resolved quantum transport. We find that the use of this wave function is advantageous for numerical simulations resulting in a speed up of many orders of magnitude with respect to the direct integration of NEGF equations. Our technique allows one to simulate realistic situations beyond simple models, a subject that was until now beyond the simulation capabilities of available approaches.

Quantum synchronization of a driven self-sustained oscillator

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arXiv:1307.7044

Synchronization is a universal phenomenon that is important both in fundamental studies and in technical applications. Here we investigate synchronization in the simplest quantum-mechanical scenario possible, i.e., a quantum-mechanical self-sustained oscillator coupled to an external harmonic drive. Using the power spectrum we analyze synchronization in terms of frequency locking and frequency entrainment in close analogy to the classical case. We show that the quantum system exhibits frequency locking and that the synchronized (frequency-locked) region is reduced due to quantum noise.

Loschmidt Echo and the Many-Body Orthogonality Catastrophe in a Qubit-Coupled Luttinger Liquid

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Phys. Rev. Lett. 111, 046402 (2013)

We investigate the many-body generalization of the orthogonality catastrophe by studying the generalized Loschmidt echo of Luttinger liquids (LLs) after a global change of interaction. It decays exponentially with system size and exhibits universal behavior: the steady state exponent after quenching back and forth n times between 2 LLs (bang-bang protocol) is 2n times bigger than that of the adiabatic overlap and depends only on the initial and final LL parameters. These are corroborated numerically by matrix-product state based methods of the XXZ Heisenberg model. An experimental setup consisting of a hybrid system containing cold atoms and a flux qubit coupled to a Feshbach resonance is proposed to measure the Loschmidt echo using rf spectroscopy or Ramsey interferometry.

SiGe quantum dots for fast hole spin Rabi oscillations

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arXiv:1307.7196

We report on hole g-factor measurements in three terminal SiGe self-assembled quantum dot devices with a top gate electrode positioned very close to the nanostructure. Measurements of both the perpendicular as well as the parallel g-factor reveal significant changes for a small modulation of the top gate voltage. From the observed modulations we estimate that, for realistic experimental conditions, hole spins can be electrically manipulated with Rabi frequencies in the order of 100MHz. This work emphasises the potential of hole-based nano-devices for efficient spin manipulation by means of the g-tensor modulation technique.