TT 20: Quantum Dots and Quantum Wires (joint session TT/HL)

Time: Monday 16:45–18:15 Location: H 3007

TT 20.1 Mon 16:45 H 3007

Quantum Dot Source-Drain Transport Response at Microwave Frequencies — •Harald Havir — Lund University

Quantum dots are frequently used as charge sensitive devices in low temperature experiments to probe electric charge in mesoscopic conductors where the current running through the quantum dot is modulated by the nearby charge environment. Recent experiments have been operating these detectors using reflectometry measurements up to GHz frequencies rather than probing the low frequency current through the dot. In this talk I will present the work "Quantum Dot Source-Drain Transport Response at Microwave Frequencies" where we use an on-chip coplanar waveguide resonator to measure the source-drain transport response of two quantum dots at a frequency of 6 GHz with the aim to further increase the bandwidth limit for charge detection. Similar to the low frequency domain, the response is here predominantly dissipative. For large tunnel coupling, the response is still governed by the low frequency conductance, in line with Landauer-Büttiker theory. For smaller couplings, our devices showcase two regimes where the high frequency response deviates from the low frequency limit and Landauer-Büttiker theory: When the photon energy exceeds the quantum dot resonance linewidth, degeneracy dependent plateaus emerge. These are reproduced by sequential tunneling calculations. In the other case with large asymmetry in the tunnel couplings, the high frequency response is two orders of magnitude larger than the low frequency conductance G, favoring the high frequency readout.

TT 20.2 Mon 17:00 H 3007

Relaxation to persistent currents in a Hubbard trimer coupled to fermionic baths — •Nikodem Szpak[1], Gernot Schaller[2], Ralf Schützhold[2,3], and Jürgen König[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, 47057 Duisburg, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

We consider a ring of fermionic quantum sites, modeled by the Fermi-Hubbard Hamiltonian, in which electrons can move and interact strongly via the Coulomb repulsion. The system is coupled to fermionic cold baths which by the exchange of particles and energy induce relaxation in the system. We describe the system effectively by the Lindblad master equations in various versions valid for different coupling parameter regimes. The early relaxation phase proceeds in a universal way, irrespective of the relative couplings and approximations. The system settles down to its low-energy sector and is consecutively well approximated by the Heisenberg model. In the late relaxation, different Lindblad approaches push the system towards different final states with opposite spin orders, from ferromagenetic to antiferromagnetic. Due to spin frustration in the trimer, degenerate ground states are formed by spin waves (magnons). The system described by the global coherent version of the Lindblad operators relaxes towards the final states carrying directed persistent spin currents.

[1] N. Szpak et. al., arXiv:2311.06331

TT 20.3 Mon 17:15 H 3007

Spatially-resolved dissipation in a quantum wire with a coherent scatterer — •Nico Leumer[1,2], Denis Basko[3], Rodolfo Jalabert[1], Dietmar Weinmann[1], and Robert Whitney[3] — [1]IPCMS, France — [2]DIPC, Spain — [3]LPMMC, France

The recent advent of astonishing measurement techniques allows the near-atomic resolution of tiny local temperature changes, even three orders of magnitude lower than the sample temperature itself [1]. The new approaches confirmed earlier estimations that dissipation (accompanying electric current) is not shared equally among two 1d wires attached to a point contact. Moreover, the formation of so called heat-spots (small and confined areas of increased temperature) were observed in the quantum regime [2]. Evidently, dc charge transport possesses the key to further unravel the microscopic mechanisms behind spatial dissipation profiles.

Based on a model of two 1d wires sandwiching a scatterer, we investigated the spatial distribution of the dissipated power for generic transmission of the scatterer. We present the mechanism behind the formation of heat/ cold spots and the key role of the electric potential, which is required to maintain the electric current against the increased wire's resistivity in close vicinity to the point contact. Additionally, we report on the self-consistent calculation of the steady state current which obeys a four-point Landauer type relation w.r.t. the voltage drop inside the scatterer.

[1] D. Halbertal et al., Nature 539 (2016) 407
[2] Q. Weng et al., Nat. Commun. 12 (2021) 4752

TT 20.4 Mon 17:30 H 3007

Multi-terminal interacting-quantum-dot-based devices — •Peter Zalom — Institute of Physics, Czech Academy of Sciences, Na Slovance 2, CZ-18200 Praha 8, Czech Republic

Recent breakthroughs in experimental physics pave the way for the creation of intricate nanoscale devices featuring three or more superconducting electrodes. Such multi-terminal systems differ markedly from conventional two-lead Josephson junctions due to the supercurrent distribution into the constituent terminals. Exerting full phase-control leads then to a multitude of practical applications.

In this talk, we explore the potential for using nanowires or carbon nanotubes in the central scattering region to enhance the existing functionalities via the underlying quantum phase transitions. Our findings, as elucidated in [1], lay the foundation for purely phase-controlled superconducting transistor and diode effects in three-terminal systems even in the absence of inter-lead couplings. Proceeding with more complex architectures requires, however, development of new Numerical Renormalization Group (NRG) methods to accommodate arbitrary gapped tunneling densities of states. This critical development, recently detailed in Ref. [2], significantly expands our theoretical understanding, particularly in devices incorporating topological effects.

[1] P. Zalom, M. Žonda and T. Novotný, arXiv:2310.02933 (2023).
[2] P. Zalom, Phys. Rev. B 108 (2023) 195123.

TT 20.5 Mon 17:45 H 3007

Ground state topology of a four-terminal superconducting double quantum dot — •Wolfgang Belzig[1], Lev Teshler[1], Hannes Weisbrich[1], Jonathan Sturm[2], Raffael Klees[3], and Gianluca Rastelli[4] — [1]Universität Konstanz — [2]Universität Würzburg — [3]Universität Augsburg — [4]CNR INO BEC Group Trento

In recent years, various classes of systems were proposed to realize topological states of matter. One of them are multiterminal Josephson junctions where topological Andreev bound states are constructed in the synthetic space of superconducting phases. Crucially, the topology in these systems results in a quantized transconductance between two of its terminals comparable to the quantum Hall effect. In this work, we study a double quantum dot with four superconducting terminals and show that it has an experimentally accessible topological regime in which the non-trivial topology can be measured. We also include Coulomb repulsion between electrons which is usually present in experiments and show how the topological region can be maximized in parameter space.

[1] L. Teshler, H. Weisbrich, J. Sturm, Raffael L. Klees, G. Rastelli, W. Belzig, SciPost Phys. 15 (2023) 214

TT 20.6 Mon 18:00 H 3007

Nonmonotonic buildup of spin-singlet correlations in double quantum dot — •Kacper Wrześniewski, Tomasz Ślusarski, and Ireneusz Weymann — Faculty of Physics, Adam Mickiewicz University, Poland

Dynamical buildup of spin-singlet correlations between the two quantum dots is investigated by means of the time-dependent numerical renormalization group method. By calculating the time evolution of the spin-spin expectation value upon a quench in the hopping between the quantum dots, we predict a nonmonotonic buildup of spin-singlet state. In particular, we find that in short timescales the effective exchange interaction between the quantum dots is of ferromagnetic type, favoring spin-triplet correlations, as opposed to the long-time limit, when strong antiferromagnetic correlations develop and eventually an entangled spin-singlet state is formed between the dots. We also numerically determine the relevant timescales and show that the physics is generally governed by the interplay between the Kondo correlations on each dot and exchange interaction between the spins of both quantum dots.

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[1] K. Wrześniewski, T. Ślusarski, I. Weymann, Rev. B 108 (2023) 144307.