TT 3: Transport: Quantum Dots, Quantum Wires, Point Contacts

Time: Monday 9:30–13:15 Location: HSZ 201

TT 3.1 Mon 9:30 HSZ 201

Unconventional superconductivity in quantum dot systems — •Stephan Weiss and Jürgen König — Theoretische Physik, Universität Duisburg-Essen and CENIDE, 47048 Duisburg, Germany

For ultra-small quantum dots we study the interplay between spin degrees of freedom and induced superconducting correlations in a nonequilibrium transport setup. Several scenarios of reduced spin symmetry and the consequences for induced even- and odd-frequency order parameters, the Andreev current as well as the shot noise are discussed. Spin symmetry is either reduced by external magnetic fields and/or ferromagnetic leads [1]. Due to the reduced level structure, the single dot case differs from the recently studied double dot system [2].

[1] S. Weiss and J. König, submitted (2016).
[2] B. Sothmann, S. Weiss, M. Governale, J. König, Phys. Rev. B **90**, 220501 (2014).

TT 3.2 Mon 9:45 HSZ 201

Violation of detailed balance for charge-transfer statistics in Coulomb-blockade systems — •Philipp Stegmann and Jürgen König — Theoretische Physik, Universität Duisburg-Essen and CENIDE, 47048 Duisburg, Germany

We discuss the possibility to generate in Coulomb-blockade systems steady states that violate detailed balance. This includes both voltage biased and non-biased scenarios. The violation of detailed balance yields that the charge-transfer statistics for electrons tunneling into an island experiencing strong Coulomb interaction is different from the statistics for tunneling out. This can be experimentally tested by time-resolved measurement of the island's charge state. We demonstrate this claim for two model systems.

[1] P. Stegmann and J. König, Phys. Status Solidi B (2016), doi:10.1002/pssb.201600507.

TT 3.3 Mon 10:00 HSZ 201

Franck-Condon blockade in driven quantum dots — Patrick Haughian[1], Stefan Walter[2], Andreas Nunnenkamp[3], and •Thomas Schmidt[1] — [1]Physics and Materials Science Research Unit, University of Luxembourg, 1511 Luxembourg, Luxembourg — [2]Institute for Theoretical Physics, University Erlangen-Nurnberg, Staudtstraße 7, 91058 Erlangen, Germany — [3]Cavendish Laboratory, University of Cambridge, Cambridge, CB3 0HE, United Kingdom

Electron-vibron coupling in quantum dots can lead to a strong suppression of the average current in the sequential tunneling regime. This effect is known as Franck-Condon blockade and can be traced back to an overlap integral between vibron states with different electron numbers which becomes exponentially small for large electron-vibron coupling strength. Here, we investigate the effect of a time-dependent drive on this phenomenon, in particular the effect of an oscillatory gate voltage acting on the electronic dot level. We find that the drive can lift the blockade by exciting vibrons. As a consequence, the relative change in average current grows exponentially with the drive strength. We show that this exponential response to a small drive amplitude has important consequences for charge pumping in Franck-Condon blockaded quantum dots.

TT 3.4 Mon 10:15 HSZ 201

Conductance through a helical state in an InSb nanowire — Jakob Kammhuber, Maja Cassidy, Adriaan Vuik, Michal Nowak, •Michael Wimmer, and Leo Kouwenhoven — QuTech and Kavli institute of nanoscience, TU Delft, Netherlands

The interplay of Rashba spin-orbit interaction and Zeeman splitting in nanowires gives rise to a so called "helical state", where carriers with opposite velocity have nearly opposite spins. In particular, this helical state should manifest itself in the quantum point contact (QPC) conductance as a dip in conductance from $2e^2/h$ to $1e^2/h$.

Here, we discuss theoretically how such a helical state can be identified in QPC conductance by rotating the magnetic field. Using this technique, we have found experimental signatures consistent with a helical gap in InSb nanowires, and extracted a value for the spin-orbit coupling strength.

TT 3.5 Mon 10:30 HSZ 201

Noise Properties of a Zeeman-split quantum dot coupled to a helical edge state — •Benedikt Probst[1], Pauli Virtanen[2], and Patrik Recher[1] — [1]Institut für Mathematische Physik, TU Braunschweig, 38106 Braunschweig, Germany — [2]NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, I-56127 Pisa, Italy

We consider a Zeeman-split quantum dot (QD) containing a single spin 1/2 weakly coupled to a helical Luttinger liquid (HLL) within a generalized master equation approach. The HLL induces a tunable magnetization direction on the QD controlled by an applied bias voltage when the quantization axes of the QD and the HLL are noncollinear [1]. In this talk we present the current fluctuations. To analyse the rich noise behaviour we calculate the $g^{(2)}$-function and find bunching as well as antibunching of the electrons.

[1] B. Probst, P. Virtanen, and P. Recher, Phys. Rev. B **92**, 045430 (2015).

TT 3.6 Mon 10:45 HSZ 201

Fano stability diagram of a symmetric triple quantum dot — •Michael Niklas, Andreas Trottmann, Andrea Donarini, and Milena Grifoni — Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany

The Fano factor stability diagram of a C_{3v} symmetric triangular quantum dot is analysed for increasing electron fillings N. At low filling, conventional Poissonian and sub-Poissonian behavior, caused by the interplay of electron-electron interactions and Fermi statistics, is found. At larger filling, $N \geq 2$, super-Poissonian noise and a peculiar bias voltage dependence of the Fano factor are observed at Coulomb and interference blockade. An analysis of the Fano map unravels a nontrivial electron bunching mechanism arising from the presence of degenerate many-body states combined with orbital interference and Coulomb interactions.

TT 3.7 Mon 11:00 HSZ 201

Dark states in spin-resolved transport through triple quantum dots — •Kacper Wrześniewski and Ireneusz Weymann — Faculty of Physics, Adam Mickiewicz University in Poznań, ul. Umultowska 85, 61-614 Poznań, Poland

We analyze the effect of dark states on spin-dependent transport properties of a triple quantum dot system. The considered quantum dot device is assumed to form a triangular geometry, resembling a simple planar molecule, and is weakly coupled to external ferromagnetic electrodes. The transport characteristics are studied by means of the real-time diagrammatic technique up to the second order of the perturbation theory with respect to the dot-lead coupling.

We examine transport in regimes where both one- and two-electron dark states occur, leading to the current rectification, negative differential conductance and super-Poissonian shot noise. Moreover, we compare the behavior of the tunnel magnetoresistance between different dark state regimes and in Coulomb blockade regime, predicting that the measurement of this quantity may indicate the mechanism of current blockade in similar devices. Finally, we consider the influence of external magnetic field on the formation of dark states and analyze how magnetic field can be used to manipulate coherent population trapping in the system.

15 min. break.

TT 3.8 Mon 11:30 HSZ 201

Levitons in the fractional quantum Hall regime — •L. Vannucci[1], F. Ronetti[1,2], J. Rech[2], D. Ferraro[2], T. Jonckheere[2], T. Martin[2], and M. Sassetti[1] — [1]Università di Genova and CNR-SPIN, Genova, Italy — [2]Aix Marseille Université, Université de Toulon, CNRS, CPT, Marseille, France

Single-electron sources are fundamental building blocks of electron quantum optics, which aims at manipulating electrons one by one in ballistic, coherent conductors. Single-particle excitations above the Fermi sea, devoid of accompanying particle-hole pairs, have been recently spotted through shot noise measurement in a quantum point contact (QPC), following the recipe provided by L. Levitov and collaborators in the '90s (hence the name 'levitons' for such excitations). However, questions can be raised about the robustness of levitons against electron-electron interactions. Here we study levitons in the edge states of the fractional quantum Hall effect (FQHE), where

strong Coulombian interactions give rise to exotic quasi-particles with fractional charge and statistic. It is shown that results by Levitov and coworkers are not affected by interactions, since integer levitons still represent minimal excitations states despite the highly non-linear physics occurring at the QPC due to the peculiar collective excitations of the FQHE. We use charge shot noise as well as heat and mixed correlations to shed light on the fascinating properties of Levitov's excitations. In addition, we probe them through Hong-Ou-Mandel (HOM) interferometry. The universal Pauli dip generated by HOM collisions at the QPC further demonstrates the uniqueness of levitons.

TT 3.9 Mon 11:45 HSZ 201

Optimal quantum interference thermoelectric heat engine with edge states — Peter Samuelsson[1], Sara Kheradsoud[1], and •Björn Sothmann[2] — [1]Lund University, 22100 Lund, Sweden — [2]Universität Duisburg-Essen, 47048 Duisburg, Germany

We show theoretically that a thermoelectric heat engine, operating exclusively due to quantum-mechanical interference, can reach optimal linear-response performance. A chiral edge state implementation of a close-to-optimal heat engine is proposed in an electronic Mach-Zehnder interferometer with a mesoscopic capacitor coupled to one arm. We demonstrate that the maximum power and corresponding efficiency can reach 90% and 83%, respectively, of the theoretical maximum. The proposed heat engine can be realized with existing experimental techniques and has a performance robust against moderate dephasing. [1] P. Samuelsson, S. Kheradsoud, B. Sothmann, arXiv:1611.02997 (2016).

TT 3.10 Mon 12:00 HSZ 201

Thermoelectric study of dissipative quantum dot heat engines — Bitan De and •Bhaskaran Muralidharan — Department of Electrical Engineering, IIT Bombay, Powai, Mumbai-400076, India

This talk examines the thermoelectric response of a dissipative quantum-dot heat engine [1] based on the Anderson-Holstein model in two relevant operating limits, (i) when the dot phonon modes are out of equilibrium, and (ii) when the dot phonon modes are strongly coupled to a heat bath. In the first case, a detailed analysis of the physics related to the interplay between the quantum-dot level quantization, the on-site Coulomb interaction, and the electron-phonon coupling on the thermoelectric performance reveals that an n-type heat engine performs better than a p-type heat engine. In the second case, with the aid of the dot temperature estimated by incorporating a thermometer bath, it is shown that the dot temperature deviates from the bath temperature as the electron-phonon interactions in the dot become stronger. Consequently, it is demonstrated that the dot temperature controls the direction of phonon heat currents, thereby influencing the thermoelectric performance. Finally, the conditions on the maximum efficiency with varying phonon couplings between the dot and all the other macroscopic bodies are analyzed in order to reveal the nature of the optimum junction.

[1] B. De and B. Muralidharan, Phys. Rev. B, 94, 165416 (2016).

TT 3.11 Mon 12:15 HSZ 201

Dynamic response functions, helical gaps, and fractional charges in quantum wires — •Christopher Pedder[1], Tobias Meng[2], Rakesh P. Tiwari[3], and Thomas L. Schmidt[2] — [1]Physics and Materials Science Research Unit, University of Luxembourg, L-1511 Luxembourg — [2]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [3]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

We show how experimentally accessible dynamic response functions can discriminate between helical gaps due to magnetic field, and helical gaps driven by electron-electron interactions ("umklapp gaps"). The latter are interesting since they feature gapped quasiparticles of fractional charge e/2, and - when coupled to a standard superconductor - an 8π-Josephson effect and topological zero energy states bound to interfaces.

TT 3.12 Mon 12:30 HSZ 201

Spin-dependent scattering in a nanowire — •Alba Pascual[1], Vitaly N. Golovach[1,2,3], Dario Bercioux[2,3], Juan José Sáenz[2,3], and Sebastián Bergeret[1,2] — [1]Centro de Física de Materiales (CFM-MPC) Centro Mixto CSIC-UPV/EHU,E-20018 Donostia-San Sebastián, Spain — [2]2Donostia International Physics Center (DIPC), E-20018 Donostia-San Sebastián, Spain — [3]IKERBASQUE, Basque Foundation of Science, E-48011 Bilbao, Spain

We study a quasi-one-dimensional quantum wire in the presence of an impurity and spin-orbit interaction. We solve the problem using a perturbative approach in order to obtain an effective Hamiltonian for the scattering problem. We solve that the scattering problem via the Lippmann-Schwinger equation at the leading order in spin-orbit. We focus on the scattering matrix of a spin-dependent transport setup and elucidate what we believe to be a suitable set of experiments aimed at a scattering matrix tomography.

TT 3.13 Mon 12:45 HSZ 201

Role of incoherent scattering on energy filtering in nanostructured thermoelectric generators — •Aniket Singha and Bhaskaran Muralidharan — Department of Electrical Engineering, IIT Bombay, Powai, Mumbai-400076, India

We employ the incoherent non-equilibrium Green's function formalism to investigate in detail the physics of energy filtering and how it leads to an enhancement in power generation across nanostructured thermoelectrics featuring a single planar energy barrier. In particular, we reinforce that the enhancement in the generated power via energy filtering is a characteristic of incoherent scattering and is absent in ballistic devices. By assuming an energy dependent relaxation time, $\tau(E) = kE^r$, we show that there exists a minimum value r_{min} for which the thermoelectric power generation is enhanced and thereby leading to a degradation in power generation for $r < r_{min}$. For bulk generators, we delve into the details of intermode scattering and show that such scattering processes between electrons in higher energy modes and lower energy modes have a finite contribution to the enhancement in the generated power. We also discuss realistic aspects such as finite width of energy barriers and imperfect energy filtering due to partial reflections. In particular, we show that such imperfect filtering and partial transmission of electrons near the top of the barrier affects the enhancement in the generated power drastically in the high efficiency regime of operation.

[1] A. Singha and B. Muralidharan, ArXiv: 1609.07894, (2016)

TT 3.14 Mon 13:00 HSZ 201

Iterative path integral calculation for the interacting resonant level model — Vytautas Abramavicus[1], •Stephan Weiss[2], and Michael Thorwart[3] — [1]Vilnius University, Faculty of Physics, Department of Theoretical Physics, Sauletekio 9, Lithuania — [2]Theoretische Physik, Universität Duisburg-Essen and CENIDE, 47048 Duisburg, Germany — [3]I. Institut für Theoretische Physik, Universitaät Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany

We calculate the tunneling current through the interacting resonant level model (IRLM) [1] by means of the iterative summation of path integrals (ISPI) scheme. Upon mapping the IRLM to a three dot system [2] with appropriate tunneling and interaction terms, we setup the ISPI scheme for this particluar model. Leads are integrated out exactly and the appearing two interactions of the model are decoupled by two independent Hubbard Stratonovich transformations. The remaining Keldysh path sum is then calculated using the numerically exact ISPI scheme, which relies on the truncation of lead induced correlations after a characteristic memory time τ. We compare our findings to the results of DMRG and fRG calculations.

[1] E. Boulat, H. Saleur, and P. Schmitteckert, Phys. Rev. Lett. **101**, 140601 (2008).

[2] T.J. Suzuki, D.M. Kennes, and V. Meden, Phys. Rev. B **93**, 085306 (2016).