HL 61: Quantum Dots and Wires: Transport Properties

Time: Wednesday 14:45–17:30 Location: H16

HL 61.1 Wed 14:45 H16

Spin-triplet relaxation times of different shells in self-assembled quantum dots — •Kevin Eltrudis[1], Amran Al-Ashouri[1], Andreas Beckel[1], Arne Ludwig[2], Andreas D. Wieck[2], Axel Lorke[1], and Martin Geller[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany — [2]Chair for Applied Solid State Physics, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum, Germany

Self-assembled quantum dots (QDs) are among the promising candidates for quantum computation devices, which involve a two level quantum system. A possibility is the two-electron excited spin triplet and its singlet ground state. We demonstrate an all-electrical initialization of the spin triplet state and measure - by electrical means - the spin relaxation time in absence of a magnetic field after the injection of the second electron into the p- and the d-shell. We find a similar spin relaxation time of 25 μs (p-shell) and 23 μs (d-shell). The measurement technique we use is based on the time-resolved transconductance spectroscopy [1]. The InAs QDs are embedded in a GaAs/AlGaAs heterostructure (FET), where an electron reservoir (2DEG) coupled to the QDs serves as charge reservoir as well as sensitive detector for the electron states. By charging the QDs resonantly into the triplet states and observing the electron emission during discharge, we are able to record the relaxation of the triplet states. In future measurements in the presence of a magnetic field even longer spin-relaxation times are expected. [1] B. Marquardt. et al., Nature Commun. 2, 209 (2011)

HL 61.2 Wed 15:00 H16

Topological Blockade of Transport in Quantum Dot Arrays — •Mónica Benito[1], Michael Niklas[2], Gloria Platero[1], and Sigmund Kohler[1] — [1]Insituto de Ciencia de Materiales de Madrid, CSIC, 28049 Madrid, Spain — [2]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

We discuss a transport blockade mechanism in quantum dot arrays and conducting molecules based on an interplay of Coulomb repulsion and the formation of edge states. As a model we employ a dimer chain that exhibits a topological phase transition. The connection to strongly biased electron source and drain enables transport. The topological transition is manifest in the shot noise properties as it is accompanied by a crossover from bunched electron transport to a Poisson process. We develop for both regions a scenario that can be captured by a rate equation. The resulting analytical expressions for the Fano factor agree well with the numerical solution of a full quantum master equation.
[1] M. Benito, M. Niklas, G. Platero and S. kohler, arXiv:1511.01348 (2015)

HL 61.3 Wed 15:15 H16

Noise and Transport through self-assembled InAs Quantum Dot Systems — •Jan K. Kühne and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Hannover, Germany

We present transport and shot noise measurements through self-assembled single and double quantum dots of InAs at very low temperatures. Quantum effects like the Fermi-edge singularity (FES) lead to peaks in the current and to enhanced suppression of the shot noise in our systems [1]. Further we observe different behavior in the IV - characteristics and the Fano factor depending on the transport direction, due to the asymmetry of the quantum dot and the corresponding change in tunneling rates of the collector and emitter. Especially we compare the different influence of an applied magnetic field.

[1] N. Ubbelohde, K. Roszak, F. Hohls, N. Maire, R. J. Haug, and T. Novotny, Sci. Rep.2,374(2012)

HL 61.4 Wed 15:30 H16

Logical Stochastic Resonance and its Applications in a Coulomb-Coupled Quantum-Dot Rectifier — •Pierre Pfeffer[1], Fabian Hartmann[1], Igor Neri[2], Anne Schade[1], Monika Emmerling[1], Martin Kamp[1], Luca Gammaitoni[2], Sven Höfling[1,3], and Lukas Worschech[1] — [1]Technische Physik and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]NiPS Laboratory, Dipartimento di Fisica, Universita di Perugia, I-06100 Perugia, Italy — [3]SUPA, School of Physics and Astronomy, University of St Andrews, St Andrews, KY16 9SS, United Kingdom

Although noise is largely considered as an adverse factor in electronics, effects like logical stochastic resonance (LSR) can render electronic fluctuations useful. We observe LSR in a semiconductor system consisting of two Coulomb-coupled quantum dots (QDs) and show that voltage fluctuations applied to one of the QDs lead to a rectified and controllable current in the other QD. The system is able to offer several logic functionalities, among them the two universal logic gates NOR and NAND and the logic XOR, which can be accessed and switched between by applying suited noise and gate voltages. Benefiting from this, we demonstrate two different realizations of a half adder and examine their optimal modes of operation. As the presented devices draw their power solely from electronic fluctuations they can be considered as advancements in the field of energy efficient and autonomous electronics.

30 min. Coffee Break

HL 61.5 Wed 16:15 H16

Strongly interacting quantum wires with spin-orbit coupling — •Chris Pedder and Thomas Schmidt — Universite du Luxembourg, Luxembourg.

We study the effect of Rashba spin-orbit coupling on a quantum wire with strong interactions, which can be experimentally realised by depopulating a gated InSb or GaAs wire. When the wire carries a very low density of electrons, it is convenient to model the system in terms of a "Wigner crystal" of electrons localised on lattice sites. At the lowest densities, the Wigner crystal is a one dimensional entity, whereas at intermediate regimes it is known that a "zigzag" crystal consisting of two parallel rows of electrons can form. We investigate the effect of Rashba spin-orbit coupling, which plays an important role for both the spin and charge degrees of freedom, in both these systems with and without an applied magnetic field. We propose detection of these effects via measurement of spin-spin correlation functions of the quantum wire, e.g. by doing STM with a polarized tip.

HL 61.6 Wed 16:30 H16

Electronic Structure and Transport Properties of Thin Silicon Nanowires — •Florian Fuchs[1,2,3], Sibylle Gemming[1,3], and Jörg Schuster[4] — [1]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany — [2]Center for Advancing Electronics Dresden (cfaed), Dresden, Germany — [3]Institute of Physics, Technische Universität Chemnitz, Chemnitz, Germany — [4]Fraunhofer Institute for Electronic Nano Systems, Chemnitz, Germany

Silicon nanowires (SiNWs) are promising candidates as building blocks for electronic devices. For the simulation of SiNWs, numerical device simulations, based on the silicon bulk band structure, are often used. When the diameter of the wires is reduced, however, atomistic quantum simulations become mandatory at some point.

In the present work, thin hydrogen-passivated SiNWs with diameters between 1 and 6 nm are studied by means of density functional theory. It is shown that the band gap approaches the bulk value in the limit of infinitely thick nanowires and increases for thin wires due to quantum confinement. Using a radially resolved density of states it is demonstrated, that the density of states is highest in the nanowire center, where most of the current transport would occur, and decreases near the surface. Comparing the density of states between SiNWs with different diameters, the transition to bulk silicon can be observed. This justifies the use of bulk band structure approximations for thicker SiNWs, but also highlights the need for atomistic quantum simulations in case of thinner ones.

HL 61.7 Wed 16:45 H16

Universal Conductance Fluctuation in Ge-doped GaN Nanowires — •Patrick Uredat[1], Matthias T. Elm[1,2], Jan Binder[2], Lars Ostheim[1], Markus Schäfer[1], Pascal Hille[1], Jan Müssner[1], Jörg Schörmann[1], Martin Eickhoff[1], and Peter J. Klar[1] — [1]I. Physikalisches Institut, Heinrich-Buff-Ring 16, Justus-Liebig-Universität Gießen, 35392 Gießen — [2]Physikalisch-Chemisches Institut, Heinrich-Buff-Ring 17, Justus-Liebig-Universität Gießen, 35392 Gießen

Semiconducting III-V nanowires are not only an auspicious material system for future nanoelectronic devices, such as nanoscaled field-effect transistors, ultra-violet light-emitting diodes or other optoelectronic applications, but also an ideal model system for studying mesoscopic effects. Therefore, the transport properties of single Ge-doped GaN nanowires are investigated. Measurements reveal universal conductance fluctuations as well as a weak localization effect. The phase coherence length l_ϕ was obtained by analyzing the quantum interference effects. For slightly doped nanowires inelastic electron-electron scattering seems to be the dominant phase breaking mechanism at low temperatures, whereas for highly doped nanowires quasi-elastic Nyquist-scattering appear to be more prominent. Temperature dependent analysis of the UCFs for different doping levels reveal a quasi one-dimensional transport behavior due to a surface depletion layer in slightly doped nanowires. In contrast, highly doped nanowires seem to have a less confined transport channel.

HL 61.8 Wed 17:00 H16

Electronic structure and transport properties of III-V core/shell nanowires — •Florinda Viñas and Martin Leijnse — Division of Solid State Physics and NanoLund, Lund University, Box. 118, S-22100, Lund, Sweden

We have modeled electron structure and low-temperature transport in III-V core/shell nanowires to establish a relationship between electron-hole hybridization and signatures in thermoelectrical measurements. Nanowires with a GaSb core and an InAs shell (and inverted) are interesting for studies of hybridization effects due to the bulk broken band gap alignment at the material interface. By varying the core radius and shell thickness of such wires we can modify the size of the band gap and create wires with band structures that exhibit hole-electron hybridization states.

The band structures are obtained using 8-band $k \cdot p$ theory together with the envelope function approximation. The calculated energy dispersions are used as input to the Boltzmann equation to study thermoelectric transport quantities such as the Seebeck coefficient, in the diffusive limit.

HL 61.9 Wed 17:15 H16

Electrical transport characteristics and hysteresis in back-gated InAs nanowire FET devices — •Jonathan Becker, Stefanie Morkötter, Phillip Geselbracht, Julian Treu, Simon Hertenberger, Max Bichler, Jonathan J. Finley, Gerhard Abstreiter, and Gregor Koblmüller — Walter Schottky Institut und Physik Department, TU München, Garching, Germany

In this work we present recent results on the electrical transport of nominally undoped MBE grown InAs nanowires (NWs). In particular we explore the influence of growth parameters, microstructure and aspect ratio on the electrical properties of the NWs. Four-terminal measurements on planar, back-gated NW field effect transistor (NWFET) devices revealed room-temperature mobilities ranging from 500 to 2000 cm^2/Vs and on-off ratios of $>10^3$ at 4.2K. The obtained electron densities are in the order of $10^{17} cm^{-3}$. A strong effect of the diameter and the microstructure, altered by growth parameters, on the mobility was observed. The latter was investigated by HRTEM, simulations and temperature-dependent measurements in high detail. Here, the impact of band discontinuities induced by stacking faults and WZ/ZB crystal phase boundaries on electron scattering is evaluated. Furthermore we evaluate the prevalent hystersis in these devices and present techniques to overcome the opposed limitations, paving the way for novel sensing schemes.