HL 30: Quantum dots and wires: Transport properties II

Time: Tuesday 14:15–17:45 Location: ER 164

HL 30.1 Tue 14:15 ER 164

Mesoscopic Optoelectronic Transport Across Lithographically Defined Quantum Wires — •K.-D. Hof[1], S. Manus[1], W. Wegscheider[2], J. P. Kotthaus[1], and A. W. Holleitner[3] — [1]Fakultat fur Physik and Center for NanoScience, LMU Munich. — [2]Institut fur Angewandte Physik, University Regensburg. — [3]TU Munich, Walter Schottky Institut, Am Coulombwall 3, 85748 Munich.

We report on optoelectronic transport phenomena in quasi one-dimensional wires which are lithographically defined in a quantum-well semiconductor heterostructure. The main focus of our experiments is to study mesoscopic transport phenomena of an optically induced, non-equilibrium charge population in the diffusive and the ballistic regime at the transition from a two-dimensional to a one-dimensional electron system [1,2]. We optically excite charge carriers in the quantum well at a specific distance to a quantum wire and measure the photo-induced conductance across the quantum wire. The electron dynamics are studied as a function of the excitation distance, photon wavelength, source-drain voltage, an external magnetic field, and a gate voltage applied to an electrode close to the quantum wire. We discuss effects of heat dissipation, excess charge tunneling, exciton recombination and non-equilibrium transport dynamics.

We gratefully acknowledge financial support from BMBF (nanoquit), DFG (Ho 3324/4), the Center of NanoScience (CeNS) in Munich, and the Nanosystem Initiative Munich (NIM).

[1] A. W. Holleitner et al., Phys. Rev. Lett. 97, 036805 (2006).
[2] K.-D. Hof et al., Physica E, in press.

HL 30.2 Tue 14:30 ER 164

Coherent Spin Rotations in Double Quantum Dots — •Rafael Sanchez, Carlos Lopez-monis, and Gloria Platero — Instituto de Ciencia de Materiales, CSIC, Madrid 28049, Spain

We analyze coherent spin rotations in a DC biased double quantum dot driven by crossed DC and AC magnetic fields. In this configuration, spatial delocalization due to inter-dot tunneling competes with intra-dot spin rotations induced by the time dependent magnetic field, giving rise to a complicated time dependent behavior of the tunnelling current which strongly depends on the ratio between the different Rabi frequencies involved. When the Zeeman splitting has the same value in both dots and spin flip is negligible, the electrons remain in the triplet subspace performing coherent spin rotations and current does not flow. This electronic trapping is removed either by finite spin relaxation or when the Zeeman splitting is different in each quantum dot. In the last case, we will show that applying a resonant bi-chromatic magnetic field, the electrons become trapped in a coherent superposition of states and electronic transport is blocked. Then, manipulating AC magnetic fields allows to drive electrons to perform coherent spin rotations which can be unambiguously detected by direct measurement of the tunnelling current.

HL 30.3 Tue 14:45 ER 164

Write/erase time of nanoseconds in quantum dot based memory structures — •Tobias Nowozin, Andreas Marent, Martin Geller, and Dieter Bimberg — Institut fuer Festkoerperphysik, TU Berlin, Hardenbergstr. 36, 10623 Berlin

We have developed a novel charge-storage memory concept based on III-V semiconductor quantum dots (QDs) [1] which has a number of fundamental advantages over conventional Si/SiO_2 floating gate memories (Flash): material-tunable and voltage-tunable barriers for improved intrinsic speed and/or storage time and high endurance. To investigate the potential of this new memory concept we have determined intrinsic write/erase times in memory structures based on InAs/GaAs and GaSb/GaAs QDs using capacitance-voltage spectroscopy. We measured a write time below 15 ns independent of the localization energy (i.e. the storage time) of the QDs. This write time is more than three orders of magnitude faster than in a Flash cell and already below the write time of a dynamic random access memory (DRAM). The erase time was determined to be 42 ns for InAs/GaAs QDs and 1.5 ms for GaSb/GaAs QDs for applied electric fields of 166 kV/cm and 206 kV/cm, respectively. From these results we derive an erase time of 1 ns in GaSb QDs for an electric field of 330 kV/cm.

[1] M. Geller, A. Marent, and D. Bimberg, "A non-volatile memory based on semiconductor nanostructure", CPT patent application, (2006).

HL 30.4 Tue 15:00 ER 164

Coulomb blockade energies in the shape-modified InAs quantum dots — •Razvan Roescu, Dirk Reuter, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, D-44780 Bochum, Germany

Rapid thermal annealing (RTA) and an Indium flush technique are methods commonly used to blue-shift the emission wavelengths for self-assembled InAs quantum dots (QDs). These methods induce modifications in the shape and the composition of the QDs. By employing capacitance-voltage spectroscopy we show that carrier-carrier interactions in such modified QDs are also affected. The Coulomb blockade energy in the ground state - the energy paid by the second electron (or hole) to enter the dot when there is already one carrier inside - is found to decrease significantly with decreasing emission wavelength if the RTA process was used, whereas it stays almost constant if the In flush technique was employed to shift the emission wavelength. These findings can be correlated to the differences in the resulting QD shape for the two different processes used. The decrease in Coulomb blockade energy for the RTA process is consistent with the results of wave function mapping, pointing to an increase in the wave function extension with decreasing emission wavelength.

HL 30.5 Tue 15:15 ER 164

Back-action of a biased quantum point contact on an unbiased double quantum dot — •Daniela Taubert[1], Daniel Harbusch[1], Hans-Peter Tranitz[2], Werner Wegscheider[2], and Stefan Ludwig[1] — [1]Center for NanoScience and Department für Physik, Ludwig-Maximilians-Universität, Geschwister-Scholl-Platz 1, 80539 München — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93040 Regensburg

We experimentally study the back-action of a quantum point contact (QPC) on a widely tunable double quantum dot (DQD) in the few electron regime. This nanostructure is electrostatically defined in the two-dimensional electron gas of a high mobility AlGaAs/GaAs heterostructure. The stability diagram of the unbiased DQD is measured using the QPC as charge detector. For this biasing the QPC is necessary, thus causing it to act additionally as a non-equilibrium energy source.

The influence of this source of energy can be seen in the stability diagram: In the regime of small tunnel coupling between one of the dots and the leads we observe disappearing charging linees. Increasing the QPC bias voltage causes reappearance and an additional shift of these charging lines which points to a non-equilibrium situation with modified tunneling rates.

Within a simple model we consider absorption of energy quanta originating from the non-equilibrium energy source by the DQD. The modification of tunneling rates caused by this energy transfer explains our findings.

HL 30.6 Tue 15:30 ER 164

Fermi-edge Singularity in 2D-0D Resonant Tunneling Through A Self-Assembled Quantum Dot — •Michael Rüth, Anatoliy Slobodskyy, Charles Gould, Georg Schmidt, and Laurens Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, Am Hubland, D-97074

We report on transport experiments on a single self-assembled CdSe quantum dot. In this sample, the zero-field signal displays clear resonant tunneling behavior, with a peak-to-valley ratio of 6.7 at T=1K. Moreover, the I/V-curve is clearly indicative of the occurrence of Fermi-edge singularity behavior in this system. No other resonance signal can be found within a range of 100mV, therefore we assume that only one quantum dot contributes to the tunneling transport in this voltage range. The effect shows high temperature stabilty, the peak current only decreases by a factor of 4 from 1K to 40K. For magnetic fields up to 16T, applied perpendicular to the surface, we observe multiple Landau level structures in the current-voltage characteristics, which provides evidence that the electrons in the ZnSe contact are confined to 2 dimensions. The maximum peak current occurs at B≈12T, a possible cause being a field enhanced FES [1].

[1] E.E. Vodin, Yu. N. Khanin, O.Makarovsky, Yu. V. Dubrovskii,

A. Patanè, L. Eaves, M. Henini, C.J. Mellor, K.A. Benedict and R. Airey, Phys. Rev. B75, 115315 (2007)

HL 30.7 Tue 15:45 ER 164

Two path transport measurements on a triple quantum dot — •Maximilian C. Rogge and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

We present a novel triple quantum dot device made with local anodic oxidation on a GaAs/AlGaAs heterostructure. The geometry provides two path transport via a three lead setup with each lead connected to one of the three quantum dots. In addition charge detection is implemented via a quantum point contact. One lead is used as a common source contact, the other two are used as two separate drain contacts with independent current measurement. Thus two paths are formed with two dots in each path. Along both paths serial transport is observed at the triple points of the two corresponding dots. With four side gates a wide tunability is given. Thus the system can be tuned in and out of triple dot resonances. When all three dots come into resonance, quadruple points are formed with simultaneous transport along both paths. The data are analysed in combined two colour plots and compared to the charge detection showing sets of three different lines, one for each dot. This way the two path setup allows to investigate the transition from double dot physics to triple dot physics.

15 min break

HL 30.8 Tue 16:15 ER 164

A GaAs/AlAs vertical resonant tunneling nano-transistor: processing and electrical characterization — Jakob Wensorra[1], •Mihail Ion Lepsa[1], Klaus Michael Indlekofer[1,2], Arno Förster[3], Hans Lüth[1], and Detlev Grützmacher[1] — [1]Center of Nanoelectronic Systems for Information Technology (IBN-1), Forschungszentrum Jülich GmbH, 52425 Jülich — [2]FH Wiesbaden, University of Applied Sciences, Information Technology and Electrical Engineering, Am Brückweg 26, D-65428 Rüsselsheim — [3]FH Aachen, University of Applied Sciences and Technology, Ginsterweg 1, 52428 Jülich

For our experiment, vertical sub-100nm nanoculumns have been processed firstly, starting from an MBE grown GaAs/AlAs resonant tunneling heterostructure [1]. The top down approach is based on electron-beam (E-B) lithography of hydrogen silsesquioxan (HSQ), as mask material, and subsequent dry etching processes for the column definition. HSQ have been used also to planarize and isolate the device electrodes. Metallic gates have been positioned around the nanocolumns, at the level of the double barrier quantum well structure, by precise etching of the dielectric and E-B lithography, with alignment accuracy less then 8nm. The electrical transport properties of the resonant tunneling nano-transistors have been investigated using DC measurements at room temperature. Preliminary results indicate that the gate voltage modulates the peak current and the peak to valley current ratio in the device I-V characteristics. [1] J. Wensorra, K.M. Indlekofer, M.I. Lepsa, A. Förster, and H. Lüth, Nano Letters, 5, 2470 (2005).

HL 30.9 Tue 16:30 ER 164

Electron counting statistic on a triple dot device — •Christian Fricke[1], Maximilian Rogge[1], Frank Hohls[1], Werner Wegscheider[2], and Rolf Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg

Current fluctuations in mesoscopic conductors can be used to reveal information which is not accessible through dc conductance measurements. Combining the mean current with the second moment of the distribution function the zero frequency shot noise can provide an insight into tunnelling rates in semiconductor quantum dots. Beside a direct measurement of the resonant tunnelling current through a quantum dot one can measure also the charge on the quantum dot using a nearby quantum point contact. For sufficiently low tunnelling rates and high detector bandwidth this allows to resolve individual tunnelling events onto and off the dot. This technique was used to measure the distribution function for tunnelling through a single [1,2] and double quantum dot [3]. We present first measurements on a system of three dots. One quantum point contact is used as a charge detector. The time resolved current through the quantum point contact is measured and analyzed.

[1]Gustavsson et al. Phys. Rev. Lett. 96, 076605 (2006)
[2]Fricke et al. Phys. Rev. B 76, 155307 (2007)
[3]Fujisawa et al. Science 312, 1634 (2006)

HL 30.10 Tue 16:45 ER 164

Electron and phonon correlations in a driven two level quantum dot — •Rafael Sanchez[1], Gloria Platero[1], and Tobias Brandes[2] — [1]Instituto de Ciencia de Materiales de Madrid-CSIC — [2]Technische Universität Berlin

We propose a solid state analogue to Resonance Fluorescence systems in a two-level quantum dot irradiated by a time-dependent monochromatic ac field where the statistics of the spontaneously emitted phonons and the transmitted electrons can be studied. Recent experiments have achieved to measure high order moments for the non-driven electronic case in similar systems[1], but the phonon case is still unchallenged. We develope a method that allows us to extract *simultaneously* the full counting statistics of the electronic tunneling and relaxation (by phononic emission) events as well as their correlation. We find that the quantum noise of both the transmitted electrons and the emitted phonons and electron-phonon correlation can be controlled and tuned back and forth between sub and super-Poissonian values by the manipulation of the external parameters: the driving field intensity and the bias voltage[2].

[1] S. Gustavsson *et al.*, Phys. Rev. Lett. **96**, 76605 (2006).
[2] R. Sánchez, G. Platero and T. Brandes, Phys. Rev. Lett **98**, 146805 (2007).

HL 30.11 Tue 17:00 ER 164

Noise measurements of a quantized charge pump — •Frank Hohls[1], Niels Maire[1], Bernd Kaestner[2], Hans Werner Schumacher[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, 30167 — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Delivering a quantized number of electrons per cycle reliable and with very high repetition would allow to define a quantum standard for the ampere. Recently a new promising way was demonstrated to achieve quantized charge pumping of a current $I = Nef_p$ at very high pumping frequencies f_p [1].

We performed low frequency ($f < 20$ kHz) current noise measurements of such a pump. We observe a strong suppression of the noise power S_I when the pumped current is quantized. This agrees well with the prediction for an ideal pump: S_I is expected to vanish if exactly N electrons are transferred in each cycle of the driving frequency. Furthermore we study also the current dependence of the noise power in between quantized current plateaus and find good agreement with a theoretical model.

[1] Blumenthal *et al.*, Nat. Phys. 3, 343 (2007); Kaestner *et al.*, cond-mat-0707.0993.

HL 30.12 Tue 17:15 ER 164

Noise enhancement due to quantum coherence in coupled quantum dots — •Gerold Kiesslich[1], Eckehard Schöll[1], Tobias Brandes[1], Frank Hohls[2], and Rolf J. Haug[2] — [1]Institut für Theroretische Physik, Technische Universität Berlin — [2]Institut für Festkörperphysik, Leibniz Universität Hannover

We show that the intriguing observation of noise enhancement in the charge transport through two vertically coupled self-assembled quantum dots [1] can be explained by the interplay of quantum coherent coupling between the dots and strong Coulomb blockade. We demonstrate that this novel mechanism for super-Poissonian charge transfer is very sensitive to decoherence caused by electron-phonon scattering as inferred from the measured temperature dependence [2].

[1] P. Barthold, F. Hohls, N. Maire, K. Pierz, and R. J. Haug, Phys. Rev. Lett. **96**, 246804 (2006).
[2] G. Kießlich, E. Schöll, T. Brandes, F. Hohls, and R. J. Haug, to be published in Phys. Rev. Lett. **99** (2007), cond-mat/0706.1737.

HL 30.13 Tue 17:30 ER 164

Spin properties of two electron lateral coupled quantum dots — •Fabio Baruffa[1], Peter Stano[2], and Jaroslav Fabian[1] — [1]Institute of Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Research center for quantum information, Slovak Academy of sciences, Bratislava, Slovakia

We report our numerical calculations of the exchange coupling in single and double quantum dots defined in GaAs heterostructures. In particular we examine the dependence of the exchange on the magnetic field. We use the exact diagonalization technique based on the finite-difference method, to solve for single-electron states, as well as the configuration interaction expansion to treat the two-electron system. Our results are of practical importance for quantum dot electron spin based quantum information processing. The work is supported by GRK 638 and SPP 1285.