HL 24: Quantum dots and wires: Transport properties II

Time: Tuesday 14:00–17:00 Location: H15

HL 24.1 Tue 14:00 H15

The 0.7-anomaly in the conductance of a quantum point-contact and its interpretation in a Kondo model — •Monika Fleischer[1], Daniel Schefzyk[1], David Wharam[1], David Ritchie[2], and Michael Pepper[2] — [1]Institut für Angewandte Physik, Auf der Morgenstelle 10, 72076 Tübingen, Germany — [2]Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE, United Kingdom

Starting from the earliest transport measurements on quantum point-contacts, the existence of a so-called “0.7-anomaly” can often be observed in the differential conductance around $0.7{\cdot}2e^2/h$, in addition to the quantized steps at multiples of $2e^2/h$. This anomaly has since been found to be an intrinsic feature, presumably of spin-related origin. Still, there exists no theory to fully describe it. In a model suggested by Cronenwett et al. [1], it is analyzed in the framework of Kondo physics, postulating a localized spin-state in the point-contact region at low electron densities - a possibility which has recently been theoretically confirmed by Rejec and Meir [2]. In this talk, measurements are presented that exhibit a distinct 0.7-anomaly in the first and 0.7-analogue in the second step as well as a zero bias anomaly in the nonlinear data of the first step. An analysis of these characteristics in view of the proposed Kondo model shows that in many respects, the phenomenology of the data is well described by it, but that a number of open questions remain.

[1] S. Cronenwett et al., Phys. Rev. Lett. 88, 226805 (2002).
[2] T. Rejec and Y. Meir, Nature 442, 900 (2006).

HL 24.2 Tue 14:15 H15

Sound-wave-like collective electronic excitations in atomic-scale conductive chains — •Tadaaki NAGAO — National Institue for Materials Science (NIMS), Tsukuba

In his pioneering work in 1950, Tomonaga has theoretically proven the existence of a sound-wave like excitation in one-dimensional array of Fermi particles that follows Bose statistics [1]. We have been searching for such one-dimensional (1D) collective excitation in high electron density-limit in atomic-scale conductive chains supported on semiconductor substrates. Electron energy loss spectroscopy using highly collimated slow electron beam has detected a characteristic sound wave-like excitations that propagate along the chains showing strong anisotropy [2]. These excitations are strongly dipole active and their lifetime rapidly drops as a function of momentum. From these features, the observed losses are identified as one-dimensional collective excitation (plasmon) that Tomonaga has mentioned. These plasmons shows highly metallic feature such as high intensity near the elastic peak, but at low temperatures (<70K), some of these plasmons show reduced density of states which indicates gap opening at the Fermi level, due to Peierls-type metal to insulator transition. [1] S. Tomonaga, Progress of Theoretical Physics Vol. 5, No.4, 544 (1950). [2] T. Nagao, S. Yaginuma, T. Inaoka, S. Sakurai, Phys. Rev. Lett. 97, 116802 (2006).

HL 24.3 Tue 14:30 H15

Theory of super-Poissonian noise in tunneling through a quantum dot stack — •Gerold Kiesslich[1], Eckehard Schöll[1], Frank Hohls[2], and Rolf Haug[2] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin — [2]Institut für Festkörperphysik, Universität Hannover, Appelstr. 2, D-30167 Hannover

The tunneling current through two layers of self-organized quantum dots which are vertically aligned (quantum dot stacks) provides sharp resonances in the current-voltage characteristics when the bias voltage is varied. The additional measurement of the shot noise reveals positive temporal correlations (super-Poissonian noise) close to these current peaks [1] associated with a bunching of tunneling events. This phenomenon is discussed in terms of a sequential tunneling model for a single quantum dot stack demonstrating that it can be explained by the sole effect of Coulomb interaction between electrons inside the stack [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, F. Hohls, and R. J. Haug. in preparation (2007).

HL 24.4 Tue 14:45 H15

Full counting statistics on a single dot device — •C. Fricke[1], F. Hohls[1], M. Reinwald[2], W. Wegscheider[2], and R. J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, D-30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, D-93040 Regensburg

We show full counting statistics analysis on a coupled system including a quantum dot and a quantum point contact. We use a GaAs / AlGaAs heterostructure containing a two-dimensional electron system (2DES) 34 nm below the surface. The lateral quantum dot and the quantum point contact (QPC) are defined by the atomic force microscope (AFM) using local anodic oxidation (LAO). Our device allows us to control independently the quantum point contact and all tunnelling barriers of the quantum dot. We perform time resolved measurements [1] of the current through the QPC detector. We are able to detect individual electrons entering or leaving the dot up to a tunnelling rate of 30 KHz. We use these features to directly analyze counting statistic of single electrons passing through the quantum dot [2].

[1] L. M. K. Vandersypen et al., Appl. Phys. Lett. 85, 4394 (2004)
[2] S. Gustavsson et al., Phys. Ref. Lett. 96, 076605 (2006)

HL 24.5 Tue 15:00 H15

Quantum Description of Nuclear Spin Cooling in a Quantum Dot — Henning Christ, Ignacio Cirac, and •Geza Giedke — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, D-85748 Garching

We study theoretically the cooling of an ensemble of nuclear spins coupled to the spin of a localized electron in a quantum dot. We obtain a master equation for the state of the nuclear spins interacting with a sequence of polarized electrons that allows to study quantitatively the cooling process including the effect of nuclear spin coherences, which can lead to “dark states” of the nuclear system in which further cooling is inhibited. We show that the inhomogeneous Knight field mitigates this effect strongly and that the remaining dark state limitations can be overcome by very few shifts of the electron wave function, allowing for cooling far beyond the dark state limit. Numerical integration of the master equation indicates that polarizations larger than 90% can be achieved within a millisecond timescale.

HL 24.6 Tue 15:15 H15

Magnetic-field-induced modification of the wave-functions in InAs quantum dots — •Wen Lei[1], Oliver Wibbelhoff[1], Christian Notthoff[1], Axel Lorke[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Department of Physics, Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg, Germany — [2]Solid State Physics, Ruhr-Universität Bochum, Universitätsstrasse 150, D-44780 Bochum, Germany

The wave-function of electrons and holes in quantum dots (QDs) are very important for their properties and device applications. In this work, we present the wave-function mapping of InAs quantum dots by C-V spectroscopy under additional perpendicular magnetic field. Without perpendicular magnetic field, the energy states commonly labeled as ”p-states” show an x-y-symmetry, oriented along the [110] and [1-10] crystal axes. When a perpendicular magnetic field (Bz) is applied, the magnetic forces are expected to mix the x- and y- states such that two circularly symmetric states (P+ and P-) with different angular momenta (l=+1 and l=-1) develop. Contrary to these expectations, we observe that the wave-functions of P+ and P- states behave differently. With increasing the perpendicular magnetic field, the wave-function of P+ state gradually develops circular symmetry with a node in the center, as expected from the theory. Surprisingly, the P- state behaves similarly but exhibits the characters of a *s-state* under high perpendicular magnetic field. The possible reasons for this unusual behavior of P- state are proposed and discussed.

15 min. break

HL 24.7 Tue 15:45 H15

Simulation of quantum transport in semiconductor nanocolumns with non-uniform lateral confinement — •Katharina Peter, Klaus Michael Indlekofer, Jakob Wensorra, Mihail Ion Lepsa, Hans Lüth, and Detlev Grützmacher — Center of Nanoelectronic Systems for Information Technology (IBN-1), Forschungszentrum Jülich GmbH, D-52425 Jülich

Semiconductor nanocolumns have attracted great interest due to their unique transport properties.

We present a numerical simulation of electronic transport in semiconductor nanocolumns based on a Green's function approach. With this simulation we investigate the effects of the presence of a saddle-point in the potential caused by doping and Fermi-level pinning [1]. Due to this confining potential, mixing of the lateral modes can occur which gives rise to additional fine structures in the current-voltage characteristics.

Assuming cylindrical symmetry of the column we expand the lateral wave function in a basis of Bessel functions to calculate the non-equilibrium Green's functions, which provide the electron density and the current in the nanocolumn.

[1]K. M. Indlekofer, M. Goryll, J. Wensorra, M. I. Lepsa, cond-mat/0609057, submitted (2006)

HL 24.8 Tue 16:00 H15

Multiple Transitions of the Spin Configuration in Quantum Dots

— •Maximilian C. Rogge, C. Führer, and R. J. Haug — Institut für Festkörperphysik, Universität Hannover, Appelstr. 2, 30167 Hannover

We have found multiple transitions of the spin configuration in a lateral quantum dot in high magnetic fields reflecting a sort of Hund's rule. These transitions are detected in a combined spin blockade/Kondo effect chessboard pattern. Both effects show well known patterns of periodic features with equal periodicity. The transitions of the spin configuration appear either as a swap of the spin blockade pattern or as a swap in the Kondo pattern. These swaps reflect a change of the spin configuration at the edge of the two-Landau-level quantum dot with increasing electron number. A change of the spin polarization back and forth is observed rather than a continuously increasing spin polarization.

[1] M. C. Rogge, C. Führer, R. J. Haug, Phys. Rev. Lett. **97**, 176801 (2006)

HL 24.9 Tue 16:15 H15

Quantenkinetik eines Quantendraht-Quantenpunkt-Systems: Wellenfrontdynamik nach räumlich homogener Anregung

— •Doris Reiter, Vollrath Martin Axt und Tillmann Kuhn — Institut für Festkörpertheorie, Westfälische Wilhelms Universität Münster,Deutschland

Wir betrachten die räumlich homogene, optische Anregung eines Halbleiter Quantendrahts mit einem eingebetteten Quantenpunkt. Nach der Anregung führen phonon-induzierte Streuprozesse zu Übergängen zwischen den delokalisierten Drahtzuständen und den lokalisierten Zuständen im Quantenpunkt. Durch die Lokalität der Streuprozesse entstehen räumliche Inhomogenitäten in der Ladungsträgerdynamik, die u.a. zum Aufbau einer sich entlang des Drahtes ausbreitenden Wellenfront führen. Die Dynamik wird quantenkinetisch berechnet, so dass sowohl die Energie-Zeit als auch die Orts-Impuls Unschärfen vollständig berücksichtigt werden. Eine wichtige Rolle in der theoretischen Beschreibung spielen Kohärenzen zwischen den Zuständen. Es zeigt sich, dass auch im hier betrachteten Fall der homogenen Anregung Kohärenzen notwendig sind, um eine physikalisch sinnvolle Beschreibung der raumzeitlichen Dynamik des Systems zu erhalten.

HL 24.10 Tue 16:30 H15

Realistic simulation of nanowire transistors: A multi-configurational approach to Coulomb effects

— •Klaus Michael Indlekofer[1], Joachim Knoch[1], and Joerg Appenzeller[2] — [1]CNI, IBN-1, Research Center Jülich GmbH, D-52425 Jülich, Germany — [2]IBM T. J. Watson Research Center, P.O. Box 218, Yorktown Heights, New York 10598, USA

We employ a novel multi-configurational Green's function approach (MCSCG) [1,2] for the simulation of Coulomb effects in nanowire transistors. The improvement of the MCSCG stems from a self-consistent adaptive division of the large channel Hilbert space into a small subsystem of resonantly trapped states for which a many-body Fock space approach becomes numerically feasible and a strongly coupled rest which can be treated adequately on a mean-field level. The Fock space description allows for the calculation of few-electron Coulomb charging effects beyond mean-field.

We compare a conventional mean-field non-equilibrium Green's function calculation with the results of the MCSCG. Using the MCSCG method, Coulomb diamonds are obtained at low temperatures while under high temperature conditions the mean-field approximation is retained. From the simulated Coulomb-blockade characteristics we derive effective system capacitances. Quantum confinement effects give rise to corrections, which are crucial for the interpretation of experimentally determined capacitances.

[1] K.M. Indlekofer et al., Phys. Rev. B **72**, 125308 (2005).
[2] K.M. Indlekofer et al., Phys. Rev. B **74**, 113310 (2006).

HL 24.11 Tue 16:45 H15

Theory of quantum computation with all-electronic Mach-Zehnder interferometers

— •Tobias Zibold and Peter Vogl — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching

We present a realistic theoretical analysis of an all-electronic Mach-Zehnder interferometer realized by two electrostatically defined quantum wires in a GaAs/AlGaAs 2DEG. In contrast to electronic Mach-Zehnder interferometers based on quantum Hall edge channels, no magnetic fields are employed. The phase shift between the quantum wires can be controlled electrostatically by the same external gates that also define the quantum wires. This allows for a simple layout of the gates with none of the lateral scales below 40 nm. We calculate the ballistic I-V characteristics of the fully three-dimensional, open device using a single-band effective mass description for the electronic Hamiltonian including the Hartree potential self-consistently. We show that the interferometer can be employed as a single qubit gate. The DC I-V characteristics exhibit multiple pronounced switches that can be attributed to rotations of the qubit on the Bloch sphere. We find that these rotations depend critically on the crossing of two resonances in the coupling windows that connect the quantum wires and act as beam-splitters. Thus, the size of the coupling windows is most important for the operation of the Mach-Zehnder interferometer as a single qubit gate.