HL 64: Quantum Wires: Transport

Time: Wednesday 16:30–19:30 Location: POT 251

HL 64.1 Wed 16:30 POT 251

Electronic Transport Properties of Nb/InAs-Nanowire/Nb Josephson Junctions — Yusuf Günel[1], Igor Batov[2], •Hilde Hardtdegen[1], Kamil Sladek[1], Andreas Einden[1], Gregor Panaitov[3], Detlev Grützmacher[1], and Thomas Schäpers[1] — [1]Instut für Halbleiter Nanoelektronik, Peter Grünberg Institut - 9 und Jülich Aachen Research Alliance on Fundamentals of Future Information Technology (JARA-FIT) Forschungszentrum Jülich, 52525 Jülich — [2]Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka, Moscow district, Institutskaya 2, 142432 Russia — [3]Institut für Bioelektronik, Peter grünberg Institut - 8 and JARA-Fundamentals of Future Information Technology, Forschungszentrum Jülich, 52425 Jülich

We experimentally studied the electronic transport properties of Nb/InAs-Nanowire/Nb Josephson junctions. Highly doped InAs nanowires were used as a weak link between two superconducting electrodes, in order to form a Josephson junction (JJs). At temperatures below the critical temperature of Nb (Tc~7K) a clear supercurrent was observed in the current *voltage characteristics. In addition, we analyzed the temperature and magnetic field dependence of the Josephson supercurrent. A complete suppression of the supercurrent was observed at a temperature of around 7 K and a magnetic field of 0.5 T, respectively. In detailed magnetic field dependent measurements clear oscillations were observed in the differential resistance. Furthermore, at zero magnetic field the differential resistance revealed characteristic features of multiple Andreev reflections.

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Mode-filtered electron injection into a waveguide interferometer — •S.S. Buchholz[1], S.F. Fischer[1], U. Kunze[1], D. Reuter[2], and A.D. Wieck[2] — [1]Werkstoffe und Nanoelektronik — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum

Injection of mode-filtered electrons into a phase-sensitive waveguide Aharonov-Bohm (AB) ring is studied for the lowest one-dimensional (1D) transport mode. An individually tuneable quantum point contact (QPC) couples coherently to 1D modes in the ring. Thus, we demonstrate single-mode transport in a multi-mode waveguide structure.

QPCs and electronic waveguides (EWGs) show the distinctive property of quantized transverse momentum resulting in conductance quantization, which makes them attractive as electronic beam splitters and sensitive single charge detectors. QPCs in the "0.7-anomaly" have been discussed as all-electrical spin polarizers. The degree of spin polarization can be probed in a quantum ring - quantum dot device.[1] However, in order to investigate QPCs as spin polarizers, firstly their application as mode-filters in the lowest subband calls for experimental realization.

Here, we study transport in an EWG interferometer[2] (etched from a GaAs/AlGaAs-heterostructure) in which a QPC is embedded in one of the waveguide leads. The QPC was tuned to the regime of the first and second subbands. By means of bend resistance and electron interference, we show that the selective coupling of 1D subbands in the EWGs to modes in the QPC leads to coherent mode-filtered transport.

[1] B. Hiltscher et al., Phys. Rev. B 82, 165452 (2010).
[2] S.S. Buchholz et al., Phys. Rev. B 82, 045432 (2010).

HL 64.3 Wed 17:00 POT 251

Quantum Faraday Effect and Gauge Invariance in Aharonov-Bohm loops — •Kicheon Kang — Department of Physics, Chonnam National University, Gwangju 500-757, Republic of Korea — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

We investigate an isolated Aharonov-Bohm (AB) loop composed of tunnel-coupled two quantum dots with a flux Φ penetrating the loop. Let us consider the following experiment of the state evolution with a flux switching: Initially, the loop is in the ground state at finite value of the flux Φ_i. Then, the flux is suddenly switched to another value Φ_f. Finally, the charge in one of the two dots ($n_j(t)$, $j = 1, 2$) is measured as a function of time.

We find that the flux $\Phi(t)$ does not uniquely determine the physics of this system, and Faraday induction should be taken into account. Indeed, the Faraday induction gives additional phase shift of the wave function. The Faraday-induced phase shift depends on the geometry of the system as well as the amount of the flux change. For identical tunnel couplings with circular symmetric flux, $n_i(t)$ shows a $2\Phi_0$ periodicity.

In addition, we show that the Faraday-induced phase shift is directly observable with an adiabatic change of the flux, for a nonstationary initial state. Interestingly, this *quantum Faraday effect* can be understood in terms of a nontopological geometric phase.

HL 64.4 Wed 17:15 POT 251

Single ion implantation in semiconductor nanowires — •Raphael Niepelt, Andreas Johannes, Martin Gnauck, Irma Slowik, Sebastian Geburt und Carsten Ronning — Institut für Festkörperphysik, Friedrich-Schiller-Universität, Max-Wien-Platz 1, 07743 Jena

Ion implantation is well established as a standard doping technique for semiconductor nanowires. The concentration of dopant atoms per area is typically determined by total beam current monitoring during the irradiation. However, at extremely low ion fluencies, it is not possible to distinguish the exact number of implanted ions in a nanometer sized structure, as the ions are distributed statistically over the irradiated area that is usually far wider than the nanostructure of interest. In our experiments we implanted electrically contacted semiconductor nanostructures that were connected to a preamplifier/amplifier setup. As with every impinging ion a certain amount of energy is deposited inside the material, one can detect signals directly induced by the ion implantation and the nanostructures themselves can act as a radiation sensor. This leads to a countable and very precisely adjustable ion dose during the implantation down to doping with single ions.

HL 64.5 Wed 17:30 POT 251

Persistent Ion Beam induced Conduction in Semiconductor Nanowires — •Andreas Johannes, Raphael Niepelt, Martin Gnauck, Irma Slowik, Andreas Thielmann, Sebastian Geburt, Ulrich Schröder, David Stoll, and Carsten Ronning — Institut für Festkörper Physik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743

The electrical conductance of single, semiconductor nanowires is investigated in-situ during ion beam exposure. A stark increase in conductance proportional to ion flux and ion energy is observed. The increase in conductance shows remarkable similarities to the persistent photoconduction effect (PPC), which is well known yet not comprehensively understood. Especially ZnO nanowires show a strong increase in conductance (photo and ion induced) that only decays over days. Experiments are performed to investigate the parallels between ion and photo induced conductivity and to examine the underlying mechanisms. The decay rate is very sensitive to the external environment so that surface effects are considered to cause the conduction enhancement.

HL 64.6 Wed 17:45 POT 251

Efficient simulation of cylindrical nanowire heterostructures by means of the R-matrix formalism — •Paul Nicolae Racec, Hans-Christoph Kaiser, and Klaus Gärtner — Weierstrass Institute, Mohrenstr. 39, 10117 Berlin, Germany

The Landauer-Bütiker formalism is a well established method for describing ballistic transport in semiconductor nanostructures in the framework of scattering theory. However, direct 2d and 3d simulations of complex heterostructures with this method require a considerable computational effort. The R-matrix formalism is a potent means to reduce the computational costs to the solution of an eigenproblem for the electronic Schrödinger operator in effective mass approximation on a bounded domain with mixed Dirichlet and Neumann boundary conditions. For complex heterostructures this eigenproblem has to be solved numerically and provides the real Wigner-Eisenbud eigenfunctions and -energies. Our numerical approach is based upon a Delaunay triangulation of the rotational symmetric device domain and a finite volume discretization. Thus we can describe any complex geometry and take into account the inhomogeneities and the anisotropy of material properties, like the effective mass. The Wigner-Eisenbud functions and energies are used further on to compute explicitly the energy dependent scattering matrix elements and wave functions which feed into the Landauer-Bütiker formalism. We present results (tunneling coefficients and resonant scattering states) for cylindrical nanowires with embedded substructures like double barriers, quantum dots or quantum rings.

15 min. break

HL 64.7 Wed 18:15 POT 251

Anomalous structures in the conductance of Si/SiGe quantum wires — •Joeren von Pock[1], Daniel Salloch[1], Gang Qiao[1], Ulrich Kunze[1], and Thomas Hackbarth[2] — [1]Lehrstuhl für Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]DaimlerChrysler Forschungszentrum Ulm, D-89081 Ulm

We observe an anomaly in the differential conductance below the first plateau at $G_0 = 4e^2/h$ in Si/SiGe quantum wires (QWRs), in contrast to [1]. This anomaly is investigated in its magnetic ($B \leq 15$ T) and thermal behaviour (20 mK $\leq T \leq$ 4200 mK). The QWRs are fabricated from Si/SiGe heterostructures with an electron mobility of $\mu = 207{,}000$ (125,000) cm^2/Vs and a density of $n_{2D} = 8.4 \cdot 10^{11}$ $(2.3 \cdot 10^{11})$ cm^{-2} at 1.5 K. The QWRs are constricted by an etch transfer in a low damage CF_4/O_2-Plasma, which causes a strong 1D-confinement potential. The anomalous conductance plateau is located near 0.6 G_0 at $B = 0$ T. As B increases parallel to the wire, the anomaly shifts down to 0.5 G_0, indicating Zeeman splitting. Our results are similar to the 0.7 anomaly in GaAs/AlGaAs quantum point contacts and QWRs [2]. Additional to the 0.7 anomaly a zero bias anomaly [3] is observed in transport spectroscopy at $T = 22$ mK. This anomaly is investigated as a function of magnetic field and temperature. At $B > 1.5$ T the anomaly splits into two peaks, and at $T > 100$ mK it does the same, which is untypical for GaAs/AlGaAs.

[1] S. Scappucci *et al.*, Phys. Rev. B **74**, 035321 (2006)
[2] K. J. Thomas *et al.*, Phys. Rev. Lett. **77**, 135 (1996)
[3] S. M. Cronenwett *et al.*, Phys. Rev. Lett. **88**, 226805 (2002)

HL 64.8 Wed 18:30 POT 251

Electronic transport in tapered triangular-shaped InN nanowires — •Christian Blömers[1], Jia Grace Lu[2], Christopher Witte[2], Hans Lüth[1], Detlev Grützmacher[1], and Thomas Schäpers[1] — [1]Institute of Bio- and Nanosystems (IBN-1) and JARA - Fundamentals of Future Information Technology, Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany — [2]Department of Physics and Astronomy, University of Southern California, Los Angeles, CA 90089-0484, USA

Among the group-III nitrides InN exhibits the lowest effective mass and the highest predicted electron mobility and peak drift velocity. Recently intense research has been carried out to elucidate the usability of InN nanowires for several applications, e.g. high density and low power consuming FET devices, high efficiency solar cells or high sensitivity detectors. We report on electrical measurements on triangular-shaped InN nanowires grown by chemical vapor deposition. The wires are tapered with triangle side lengths ranging from 300 nm down to 40 nm. We obtain an unexpected increase in resistivity with decreasing cross section area for wire segments with a side length smaller than $l_t = 80$ nm. Additionally, we analyzed the temperature dependence of the resistivity and found a transition from metal-like to semiconductor-like behavior at the same transition side length $l_t = 80$ nm. We explain our observations in terms of quantum confinement and donor deactivation.

HL 64.9 Wed 18:45 POT 251

Formation of p-Si/ZnO nanowire heterostrcutures for light emitting devices — •Yaser Haj Hmeidi, Rapheal Niepelt, Martin Gnauck, Frank Schmidl, and Carsten Ronning — Institut für Festkörperphysik, Universität Jena, Max-Wien-Platz 1, 07743 Jena

The development of scalable techniques for assembling nanowire devices needs practical circuits, which are highly parallel and reproducible overlarge areas. *ZnO* nanowires can be grown easily via vapor-liquid-solid (VLS) mechanism and are suitable for this application. Furthermore, they have an emission wavelength in the UV, but p-type doping is not possible so far. Therefore, light emitting devices must be based on heterostructures with other suitable p-type materials. In this presentation, we will demonstrate p-n heterojunctions between n-type *ZnO* nanowires and highly doped p-type *Si* substrates. We developed a simple and powerful approach on the basis of spin-on-glass SiO_2 [1]. This approach is intrinsically scalable since every step involved can be carried out in parallel over an entire wafer. The challenge in this particular geometry is the fabrication of top metallic contacts on top of the nanowires in a way that the contact dose not short with the substrate. The resulting devices exhibit rectifying properties and under certain conditions, also light emission.

HL 64.10 Wed 19:00 POT 251

Coupling molecular spin states by photon-assisted tunneling — •Lars Schreiber[1], Floris Braakman[1], Tristan Meunier[1], Victor Calado[1], Jeroen Danon[2], Jake Taylor[3], Werner Wegscheider[4], and Lieven Vandersypen[1] — [1]Kavli Institute of Nanoscience, TU Delft, The Netherlands — [2]Dahlem Center for Complex Quantum Systems, FU Berlin, Germany — [3]Joint Quantum Institute of Standards and Technology, University of Maryland, USA — [4]Solid State Physics Laboratory, ETH Zurich, Switzerland

Artificial molecules containing just one or two electrons provide a powerful platform for studies of orbital and spin quantum dynamics in nanoscale devices. A well-known example of these dynamics is tunneling of electrons between two coupled quantum dots triggered by microwave irradiation. So far, these tunneling processes have been treated as electric dipole-allowed spin-conserving events.

Here we report that microwaves can also excite tunneling transitions between states with different spin. In this work, we create an artificial hydrogen molecule by a gate-defined double quantum dot formed in a GaAs/(Al,Ga)As 2DEG. The dominant mechanism responsible for violation of spin conservation is the spin-orbit interaction. These transitions make it possible to perform detailed microwave spectroscopy of the molecular spin states and open up the possibility of realizing full quantum control of a two spin system via microwave excitation.

HL 64.11 Wed 19:15 POT 251

The 0.7-anomaly of quantum point contacts — towards understanding its microscopic origin — •David Borowsky[1], Enrico Schubert[1], Daniela Taubert[1], Werner Wegscheider[2], and Stefan Ludwig[1] — [1]Center for NanoScience and Fakultät für Physik, Universität München, Germany — [2]Solid State Physics Laboratory, ETH Zürich, Switzerland

The 0.7-anomaly of a quantum point contact (QPC) has been a subject of intense research since it was first studied in 1996 [1], but its microscopic origin is still controversially discussed. The temperature dependence of the conductance G at the 0.7-anomaly revealed a scaling behaviour reminiscent of the Kondo effect [2], which lead to an interpretation in terms of a quasi-bound state in the Kondo regime [3].

Motivated by many unanswered questions, we used highly tunable QPCs in the 2D electron system (2DES) of a GaAs/AlGaAs heterostructure to study the 0.7-anomaly. We measured G at the 0.7-anomaly as a function of the microscopic confinement potential and in-plane magnetic field. Our experiments show scaling behaviour as a function of magnetic field similar to the temperature dependence [2]. Our results favor a model predicting a magnetic susceptibility enhancement at the 1D-constriction which leads to phenomenologically similar behaviour as the Kondo effect of a quasi-bound state [4].

[1] Thomas et al, Phys. Rev. Lett., 1996, **77**, 135 - 138
[2] Cronenwett et al, Phys. Rev. Lett., 2002, **88**, 226805
[3] Meir et al, Phys. Rev. Lett., 2002, **89**, 196802
[4] Jan von Delft (private communication)