HL 17: Quantum wires: Optical and transport properties

Time: Tuesday 10:00–13:00 Location: BEY 154

HL 17.1 Tue 10:00 BEY 154

Growth and Optical Properties of GaN Nanodisks in GaN/AlGaN Nanowires — •Florian Furtmayr[1], Christoph Stark[1], Martin Stutzmann[1], Sònia Conesa-Boj[2], Francesca Peiro[2], Jordi Arbiol[2], Joan Ramon Morante[2], and Martin Eickhoff[1,3] — [1]Walter Schottky Institut, Technische Universität München, 85748 Garching — [2]EME/CeRMAE/IN2UB, Dept. d'Electronica, Universitat de Barcelona, E-08028 Barcelona, Spain — [3]I. Physikalisches Institut, Justus-Liebig-Universität, 35392 Giessen

We report on the self-assembled growth of GaN/AlGaN and GaN/AlN nanowires with embedded GaN nanodisks (NDs) by plasma assisted molecular beam epitaxy (PAMBE) on Si(111). GaN multi quantum wells with different thicknesses were formed between barriers of AlN or $Al_xGa_{x-1}N$ in different compositions. The samples were analyzed by high resolution transmission electron microscopy (HRTEM) and photoluminescence (PL). The PL emission energy of the NDs at 3.53 eV to 3.70 eV can be controlled by the variation of the Al-content in the barrier. Its intensity exceeds that of the GaN base of the NW (3.40 eV - 3.47 eV) by about a factor of ten. The FWHM increases with the Al-content and varies between 21 meV and 70 meV at 4K. Due to the presence of polarization fields, the emission energies show a red shift, which increases with increasing well-thickness. HRTEM analysis reveals well defined flat GaN NDs with sharp interfaces. Whereas the radial growth rate of the GaN region is almost zero, it is 11% of the axial growth for the AlN region, leading to the formation of an AlN shell around the NW.

HL 17.2 Tue 10:15 BEY 154

Optical Studies on Single GaN Nanowires — •Carsten Pfüller, Oliver Brandt, Caroline Chèze, Lutz Geelhaar, and Henning Riechert — Paul-Drude-Institut für Festkörperelektronik Berlin, Germany

The self-organized formation of GaN nanowires (NWs) offers the unique possibility to fabricate strain- and defect-free GaN crystals on foreign substrates like Si. Here, we present a detailed investigation of the photoluminescence (PL) of GaN NWs grown directly on Si(111) by plasma-assisted molecular beam epitaxy.

The temperature and power-dependent PL spectra of the NW ensemble are compared with those of a reference layer grown by hydride vapor phase epitaxy. The spectral position of the dominant donor-bound exciton emission at 3.472 eV demonstrates the NWs to be free of strain. The evolution of the PL intensity with temperature or excitation intensity for the NWs is clearly different from that of the reference layer, indicating the participation of different nonradiative recombination channels possibly related to the free surface.

For a more detailed understanding, we have examined the PL of individual NWs which have been dispersed on a Si(111) substrate. The spectra of single NWs vary widely from wire to wire in intensity, peak energy and peak width. The frequently observed peak broadening compared to the ensemble reveals that individual NWs may be severely affected by strain induced by the interaction with the underlying substrate.

HL 17.3 Tue 10:30 BEY 154

Laser oscillation thresholds for ZnO nanowires — Mariano A. Zimmler[1], Jiming Bao[1], Kristen A. Sunter[1], Federico Capasso[1], Sven Müller[2], and •Carsten Ronning[3] — [1]School of Engineering and Applied Science, Harvard University — [2]II. Institute of Physics, University of Göttingen — [3]Institute of Solid State Physics, University of Jena

In our work, we will present direct evidence of the transition from ASE to laser action in optically pumped ZnO nanowires at room temperature. The optical power evolves from a superlinear to a linear regime as the pump power exceeds threshold, concomitant with a transition to directional emission along the nanowire and the emergence of well defined cavity Fabry-Perot modes around a wavelength of 385 nm. The laser oscillation threshold is found to be strongly dependent on the nanowire diameter, with no laser oscillation observed for diameters and lengths smaller than ˜150 nm and ˜3 microns, respectively. Furthermore, we will present an alternative *head on* detection geometry for measuring the output power of a single nanowire laser, which provides a useful benchmark for the future development of these nanoscale devices.

HL 17.4 Tue 10:45 BEY 154

Edge-disorder-induced conduction gap in bilayer graphene nanoribbons — •Hengyi Xu[1], Thomas Heinzel[1], and Igor Zozoulenko[2] — [1]Heinrich-Heine Universität, Düsseldorf, Germany — [2]Department of Science and Technology, Linköping University, Sweden

Graphene bilayers are interesting because they show some anomalous properties compared with single layers. We study the energy spectra of the Bernal-type bilayers with zigzag and armchair edges within the tight-binding model. Furthermore, a recursive Green's function (RGF) method for bilayer graphene nanoribbons (GNRs), which provides an efficient way to account for the effects due to the bilayer leads, is developed based on our implementation in the monolayer case. By means of the newly-developed RGF technique, the magnetoelectronic properties are examined. An important work in graphene engineering is to tune the electronic properties of GNRs by introducing an energy gap. There has been many attempts to induce an energy gap in monolayer graphene by various ways, in particular, it is shown that a modest edge disorder is sufficient to induce the conduction energy gap in the otherwise metallic graphene nanoribbons. We further study the electronic transport behaviors of bilayer GNRs with edge imperfections and discuss the possibilities of opening energy gaps by the edge disorder in bilayers. The conductance of realistic edge-disordered bilayer GNRs is calculated numerically and dependency of the gap width on the strength of the disorder is investigated systematically.

15 min. break

HL 17.5 Tue 11:15 BEY 154

Modelling Quantum Transport Through Nano-Structures by Finite Elements: Getting the Boundaries Right — •Stephan Kramer, Oliver Bendix, Kai Bröking, Ragnar Fleischmann, and Theo Geisel — Max-Planck-Institut für Dynamik und Selbstorganisation, 37073 Göttingen

For simulating the electronic transport through a ballistic semiconductor device quantum mechanically, one has to solve the stationary Schrödinger equation in a complex geometry with intricate boundary conditions. We are especially interested in the transmission properties of scattering states, e.g. as in [1]. For their computation we employ higher order finite element methods which make it possible to properly incorporate curvilinear boundaries and spatial adaptivity.

Scattering experiments in semiconductor devices can be described by a finite domain containing scatterers and leads of semi-infinite length providing a source for incoming plane waves and a sink for outgoing scattered waves. As FEMs are capable only of describing problems on a finite domain, the leads must be cut off after some finite distance. Because of this, their infinite extent has to be modelled by suitable boundary conditions. For semi-infinite leads, these are provided by the *Sommerfeld radiation condition.*

We apply our approach to electron transport in the presence of static magnetic fields and show how to set up the correct boundary conditions for different complex geometries.

[1] Nature Physics 3, 464 - 468 (2007)

HL 17.6 Tue 11:30 BEY 154

Evanescent channels and scattering in cylindrical nanowire heterostructures — •Paul Nicolae Racec[1,2], Elena Roxana Racec[3,4], and Hagen Neidhardt[1] — [1]Weierstraß-Institut für Angewandte Analysis und Stochastik, Mohrenstr. 39 10117 Berlin, Germany — [2]National Institute of Materials Physics, PO Box MG-7,077125 Bucharest Magurele, Romania — [3]Institut für Physik, Technische Universität Cottbus, Postfach 101344, 03013 Cottbus, Germany — [4]Faculty of Physics, University of Bucharest, PO Box MG-11,077125 Bucharest Magurele, Romania

We investigate the scattering phenomena produced by a general finite range non-separable potential in a multi-channel two-probe cylindrical nanowire heterostructure. The multi-channel current scattering matrix is efficiently computed using the R-matrix formalism extended for cylindrical coordinates. Considering the contribution of the evanescent channels to the scattering matrix, we were able to put in evidence the specific dips in the tunneling probability in the case of an attractive scattering potential. The cylindrical symmetry cancels the "selection rules"known for Cartesian coordinates. Detailed maps of the localization probability density sustain the physical interpretation of the resonances. We present numerical results for a quantum dot embedded into the nano-cylinder and a double barrier along the nano-cylinder.

HL 17.7 Tue 11:45 BEY 154

Magnetic barriers in quantum wires — •Mihai Cerchez[1], Hengyi Xu[1], Alexey Tarasov[1], Thomas Heinzel[1], Stefan Hugger[2], Igor Zozoulenko[3], Dirk Reuter[4], and Andreas Wieck[4] — [1]Heinrich-Heine-Universität, Düsseldorf, Germany — [2]Fraunhofer Institut für Angewandte Festkörperphysik, Freiburg, Germany — [3]Linköping University, Norrköping, Sweden — [4]Ruhr-Universität Bochum, Bochum, Germany

A strongly localized, spatially varying magnetic field (magnetic barrier, MB) is created by the stray field at the edge of a magnetised ferromagnetic material aligned across a quantum wire (QWR). The quantum wire is produced by local anodic oxidation of a GaAs/AlGaAs heterostructure with a two-dimensional electron gas below the surface. We find pronounced and reproducible conductance fluctuations of the QWR as a function of the MB height tuned by the field applied, for various values of the electronic wire width tuned by the in-plane gates. The conductance fluctuations are strongly temperature dependent but visible up to 10 K. The findings differ both from what is expected from larger size samples and from homogenous magnetic fields. Our analysis supported by simulations using the recursive Green's functions technique shows that the observed effects are caused by the coherent part of the electron wave function which, by scattering in the impurity potential landscape creates an interference pattern depending on the position of the scatterers and the height of the MB. The MB acts like a repulsive scatterer which can be tuned to form a resonator inside the QWR.

15 min. break

HL 17.8 Tue 12:15 BEY 154

Phase-coherent transport in InN nanowires: Analysis by four-terminal measurements — •Robert Frielinghaus[1,2], Sergio Estévez Hernández[1,2], Raffaella Calarco[1,2], Stefan Trellenkamp[1,2], Thomas Schäpers[1,2], and Detlev Grützmacher[1,2] — [1]Institute of Bio- and Nanosystems (IBN-1), Research Centre Jülich, 52425 Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology

Bottom-up assembled nanowires receive an increasing interest as possible candidates for future semiconductor nanoscale devices. Especially InN nanowires are interesting due to their surface accumulation layer which inhibits Schottky barriers [1]. Yet, contact resistances prove to be spread in a wide range as can be shown in multi-terminal measurements.

At low temperatures phase-coherence leads to universal conductance fluctuations in the magnetoconductance. While they are fully symmetric in a two-terminal setup this feature is gradually lost when turning to three- or four-terminal measurements. Using the latter configuration the temperature dependence of the electron phase-coherence in the nanowire itself can be determined, i.e. without any contact resistance contribution.

[1] Th. Richter et al.: Nano Letters **8**, 2834 (2008)

HL 17.9 Tue 12:30 BEY 154

Non-local Aharonov-Bohm conductance oscillations in an asymmetric ballistic quantum ring — •S. S. Buchholz[1], S. F. Fischer[1], U. Kunze[1], D. Reuter[2], and A. D. Wieck[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum

We investigate ballistic transport and quantum interference in a nanoscale quantum wire loop fabricated as a GaAs/AlGaAs field-effect heterostructure [1]. Our device consists of two equally wide electron waveguides, a bent and a straight one, which orthogonally intersect twice forming an asymmetric ring like structure. Four-terminal measurements of current and voltage characteristics as a function of top gate voltages show negative remote bend resistance as a clear signature of ballistic transport. In perpendicular magnetic fields phase-coherent transport leads to Aharonov-Bohm (AB) conductance oscillations which show equal amplitudes in the local and the non-local measurement at a temperature of 1.5 K and above. We attribute this novel observation to the symmetry of the orthogonal cross junctions connecting the four quantum wire leads with the asymmetric quantum wire ring. [1] S.S. Buchholz, S.F. Fischer, U. Kunze, D. Reuter, A.D. Wieck, arXiv:0811.3150 (2008).

HL 17.10 Tue 12:45 BEY 154

Classical ballistic transport in a triangular shaped cavity — •Martin Richter and Roland Ketzmerick — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Recent magneto-resistance measurements on semiconductor heterostructures with a triangular shaped gate revealed an unexpected splitting of a commensurability peak [D. Maryenko et al., unpublished]. We explain this splitting in the context of classical ballistic transport. The importance of the phase-space structure, width of the openings, and softness of the potential is stressed.