HL 17: Quantum Dots and Wires: Rings, Wires and Transport

Time: Tuesday 9:30–12:15 Location: POT/0251

HL 17.1 Tue 9:30 POT/0251

Growth of hexagonal Silicon Germanium quantum rings — •Marvin Marco Jansen[1], Mette F. Schouten[1], Denny Lamon[1], Wouter H.J. Peeters[1], Marcel A. Verheijen[1,2], and Erik P.A.M. Bakkers[1] — [1]Department of Applied Physics, Eindhoven University of Technology, Groene Loper 19, 5612AP Eindhoven, The Netherlands — [2]Eurofins Materials Science BV, High Tech Campus 11, 5656 AE Eindhoven, The Netherlands

Developing a silicon-based laser represents a key step toward commercially viable photonic circuits. A promising route is the recently discovered hexagonal silicon germanium (hex-SiGe) grown as shells around gallium arsenide (GaAs) nanowires (NWs), which has demonstrated efficient direct band-gap emission. In addition, type-I band alignment was demonstrated in hex-SiGe/Ge quantum wells (QWs), pushing the system closer to lasing. Theory predicts that combining hexagonal/cubic Ge(Si) QWs could further enhance optical performance. Here, we investigate the growth of hex-SiGe/Ge QWs on GaAs NWs that alternate between wurtzite (WZ) and zinc blende (ZB) crystal phases, forming ring-shaped hexagonal Ge QWs. These quantum rings feature two types of confinement: crystal-phase-induced axial confinement and radially controlled alloy composition. We explore several different WZ/ZB superlattice designs and TEM analysis confirms successful integration of hexagonal/cubic SiGe alloys and SiGe/Ge QW shells on the designed superlattices. Our results establish crystal-phase superlattice NWs as a promising platform realizing hex-Ge quantum rings and marking progress towards a hex-SiGe laser.

HL 17.2 Tue 9:45 POT/0251

A road to parallelisation - spin qubits as single electron pumps — •Dustin Wittbrodt[1], Johannes Christian Bayer[1], Lars Schreiber[2], Janne Lehtinen[3], and Frank Hohls[1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]JARA Institute for Quantum Information, Forschungzentrum Juelich, Germany — [3]SemiQon Technologies Oy, Espoo, Finland

The main workhorse of low current Ampere realization is the Single Electron Pump (SEP), which generates quantized currents based on the quantized transport of single charge carriers. The result are currents in the fA-pA range, measureable with a precision of as low as 0.1 ppm. For further improvement of accuracy and current output, parallelization of pumps is the necessary next step. Semiconductor spin qubit devices offer an interesting solution. In addition to sharing the same central building unit, the quantum dots, spin qubits also offer the possibility of incorporating CMOS logic and taking advantage of a mature, high-yield industry for large scale SEP manufacturing, thus allowing for the implementation of a high number of pumps with minimal control inputs. Various Si and Si-compound spin qubit technology platforms are being tested as SEP candidates, within the EU-funded AQuanTEC project. The focus of the activities includes the characterisation of these spin qubits in DC measurements and then in a series of AC measurements to characterise the pumping behaviour of these devices. We present the results of this effort here, offering a perspective on the potential application of Qubit technology for broader use as quantum metrological instruments.

HL 17.3 Tue 10:00 POT/0251

Using full counting statistics to identify interactions in the electron dynamics in a self assembled quantum dot — •Johann Zöllner, Hendrik Mannel, Daniel Oppers, Axel Lorke, Martin Geller, and Jürgen König — Faculty of Physics and CENIDE, University of Duisburg-Essen

We study interactions and electron dynamics in a self-assembled quantum dot using full counting statistics. Each tunneling event identified with a resonance-fluorescence-based continuous measurement [1]. Full counting statistics provides much more information than just the average current through the system. The details of the probability distribution obtained from full counting statistics depends on whether interactions play a role in electron transport or whether it can be modeled by noninteracting fermions [2,3]. This is reflected in sign changes of the factorial cumulants calculated from the probability distribution. Factorial cumulants are a measure for fluctuations and are particularly suited to characterize discrete distributions. We identify these sign changes predicted by theory in the experimental data. In this way, simply by observing individual tunneling events between the dot and a reservoir, we have gained information about the electron dynamiks like spin relaxation between Zeeman-split energy level and the presence of interactions.

[1] A. Kurzmann *et al.*, PRL **122**, 247403 (2019)
[2] D. Kambly *et al.*, PRB **83**, 075432 (2011)
[3] P. Stegmann *et al.*, PRB **92**, 155413 (2015)

HL 17.4 Tue 10:15 POT/0251

Effective Hamiltonians for Ge/Si core/shell nanowires from higher-order perturbation theory — Sebastian Miles[1], A. Mert Bozkurt[1], •Dániel Varjas[2,3,4], and Michael Wimmer[1] — [1]QuTech and Kavli Institute of Nanoscience, Delft University of Technology — [2]IFW Dresden and Würzburg-Dresden Cluster of Excellence ct.qmat — [3]Max Planck Institute for the Physics of Complex Systems — [4]Budapest University of Technology and Economics

We theoretically explore the electronic structure of holes in cylindrical Germanium/Silicon core/shell nanowires using a perturbation theory approach. The approach yields a set of interpretable and transferable effective low-energy model parameters for the lowest few sub-bands up to fifth order in perturbation theory for various experimentally relevant growth directions. In particular, we are able to resolve higher-order cross terms, e.g., the dependency of the effective mass on the magnetic field. Our study reveals orbital inversions of the lowest sub-bands for low-symmetry growth directions, leading to significant changes of the lower order effective coefficients. We demonstrate a reduction of the direct Rashba spin-orbit interaction due to competing symmetry effects for low-symmetry growth directions. Finally, we find that the effective mass of the confined holes can diverge, yielding quasi flat bands interesting for correlated states. We show how one can tune the effective mass of a single spin band allowing one to tune the effective mass selectively to its divergent points.

HL 17.5 Tue 10:30 POT/0251

Improving optical quality in highly strained GaAs/In_xAl_{1-x}As core/shell nanowires — Xiaoxiao Sun, •Alexej Pashkin, René Hübner, Finn Moebus, Yuxuan Sun, Andreas Worbs, Slawomir Prucnal, Shengqiang Zhou, Stephan Winnerl, Manfred Helm, and Emmanouil Dimakis — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

III-V semiconductor nanowires are promising for applications in photonics, electronics, and sensing. In lattice-mismatched GaAs/In_xAl_{1-x}As core/shell nanowires, tensile strain in the GaAs core enables substantial bandgap tuning across the near-infrared spectrum. However, In_xAl_{1-x}As shells are typically grown at low temperatures, which compromises their structural quality and induces non-radiative recombination. We present two strategies to mitigate it. The first employs a dual-shell architecture in which an intermediate Al_yGa_{1-y}As shell spatially separates carriers in the GaAs core from the In_xAl_{1-x}As shell [1]. Optimizing the spacer thickness significantly enhances photoluminescence efficiency and extends emission lifetimes. The second strategy focuses on optimizing the shell growth conditions. We show that higher growth temperatures improve the core/shell interface quality, reducing non-radiative recombination and carrier scattering, with optimal performance near 500°C [2]. This allows a simple single-shell structure to approach the performance of the more complex dual-shell design.

[1] X. Sun et al., *Adv. Funct. Mater.* **34**, 2400883 (2024).
[2] X. Sun et al., *Appl. Phys. Lett.* **127**, 182107 (2025).

HL 17.6 Tue 10:45 POT/0251

Quantum dot as a model system for a Hund's coupled impurity — •Olfa Dani[1], Johannes C. Bayer[1,2], Timo Wagner[1], Gertrud Zwicknagl[3], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Institut für Mathematische Physik, Technische Universität Braunschweig, Braunschweig, Germany

In this work, we investigate electron transport through the third shell [1] of a gate-defined GaAs quantum dot, where the exact electron number (N) is determined using a quantum point contact and tuned in a controlled manner by changing the applied gate voltages of the device

[2]. For N = 7-11, the addition energy shows a triangular evolution with a maximum at half-filling. This trend is reproduced by model calculations including Hund's rule exchange. In the same filling range, a zero-bias anomaly (ZBA) characteristic of the Kondo effect appears. Its width and amplitude display a similar triangular dependence, reflecting the particle-hole symmetry of the three spin-degenerate orbitals. The pronounced ZBA is attributed to the contribution of both the Kondo resonance and low-energy Hund satellite excitations associated with degenerate orbitals observed in the spectral function [3]. The quantum dot is viewed as a multi-orbital Kondo impurity with Hund's interaction and serves as a model system for a Hund's coupled impurity. [1] L. P. Kouwenhoven, et. al., Rep. Prog. Phys. 64 (2001). [2] T. Wagner, et. al., Nat. Phys.15 (2019). [3] O. Dani, et. al., arXiv: 2505.21675 (2025).

15 min. break

HL 17.7 Tue 11:15 POT/0251

Quantum stochastic resonance in a single-photon emitter — •H. Mannel[1], J. Zöllner[1], E. Kleinherbers[2], M. Zöllner[1], N. Schwarz[1], F. Rimek[1], A. Ludwig[3], A. Lorke[1], J. König[1], and M. Geller[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, 47057 Duisburg, Germany — [2]Department of Physics and Astronomy, University of California, Los Angeles, California 90095, USA — [3]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

Classical stochastic resonance (SR) describes how noise can enhance the response of a driven bistable system. Recently, it has been extended to the quantum regime, where fluctuations originate from single tunneling events [1]. Building on optical real-time charge detection in self-assembled quantum dots [2], we demonstrate quantum stochastic resonance in a single InAs/GaAs quantum dot, weakly tunnel-coupled to an electron reservoir. Periodic modulation of the gate voltage synchronizes the electron tunneling with the external drive, while resonance fluorescence provides a fully optical, high-resolution readout of the charge state. From the full counting statistics of the tunneling events, we observe a pronounced narrowing of the distribution at the resonance condition, marking the transition from stochastic to increasingly deterministic transport [3]. [1] T. Wagner et al., Nat. Phys. 15, 330 (2019). [2] A. Kurzmann et al., Phys. Rev. Lett. 122, 247403 (2019). [3] H. Mannel et al., Commun Phys 8, 404 (2025).

HL 17.8 Tue 11:30 POT/0251

Spin relaxation dynamics of the excited triplet state in self-assembeld quantum dots — •Carl Nelson Creutzburg[1], Arne Ludwig[2], Andreas D. Wieck[2], Martin Geller[1], and Axel Lorke[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany — [2]Chair of Applied Solid State Physics, Ruhr-University Bochum, Germany

The two-electron triplet state in self-assembled quantum dots (QDs) can pair with the singlet ground state to form an electrically addressable spin qubit candidate. Using such qubits for quantum information processing requires long coherence times T_2, ultimately limited by the spin relaxation time T_1. While T_1 has predominantly been probed using optical techniques, we here present an all-electrical approach to access the spin relaxation dynamics.

The QDs are embedded in an inverted high-electron-mobility transistor, allowing controlled electron tunneling between the dots and a coupled two-dimensional electron gas (2DEG), which also serves as a sensitive charge detector. Using time-resolved transconductance spectroscopy [1] with a three-level pulse sequence, we observe the relaxation from the excited triplet to the singlet state as a function of the charging interval. A rate-equation analysis yields the spin relaxation time T_1. This approach provides an independent and complementary route to previous studies [2] and may help refine key assumptions.

[1] B. Marquardt et al., Nature Commun. 2, 209 (2011)
[2] K. Eltrudis et al., Appl. Phys. Lett. 111, 092103 (2017)

HL 17.9 Tue 11:45 POT/0251

CMOS Compatible Short-Channel Junctionless Nanowire Transistors — •Sayantan Ghosh[1,2], Alessandro Puddu[1,2], Slawomir Prucnal[1], Yordan M. Georgiev[1], Ahmad Echresh[1], and Artur Erbe[1,2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [2]Technische Universität Dresden, 01069 Dresden, Germany

The demand for miniaturized, high-speed, and energy-efficient electronics is pushing conventional planar transistors to their scaling limits, where short-channel effects and fabrication complexity constrain performance. Junctionless nanowire transistors (JNTs) offer a promising alternative through simplified architecture, strong electrostatic control, and CMOS compatibility. Using uniformly doped channels and eliminating pn-junctions, JNTs reduce process complexity and improve scalability for next-generation nanoelectronics. In this work, short-channel silicon JNTs were fabricated on SOI substrates using a CMOS-compatible top-down method. The devices use 20 nm-wide n-type Si nanowires with channel lengths from 1000 nm to 50 nm. Back-gate operation shows clear ambipolar behaviour, while top-gate operation yields the unipolar response characteristic of true JNTs. The 50 nm device achieves a current on/off ratio $>$ 5 orders of magnitude and a subthreshold swing of around 200 mV/dec, demonstrating strong potential for low-power nanoscale technologies.

HL 17.10 Tue 12:00 POT/0251

Majorana bound states in 1D superconducting nanowires: detection, transport, and braiding — •Suhas Gangadharaiah — Indian Institute of Science Education and Research Bhopal India

Majorana bound states (MBSs) have emerged as promising candidates for robust quantum computation due to their topological protection. However, similar tunneling conductance features for both the MBSs and certain types of Andreev bound states have turned out to be a major obstacle in the verification of the presence of MBSs in semiconductor-superconductor heterostructures. In this talk, we will first discuss our protocol to probe properties specific to the MBSs and use it to distinguish the topological zero-bias peak (ZBP) from a trivial one [1]. We will next consider the dynamical transport of MBSs in the semiconductor-superconductor heterostructure in a realistic scenario involving noisy conditions and their role in inducing diabatic errors. We will discuss the scaling laws that relate these errors to the drive time [2]. Finally, we will discuss our ongoing work on MBS braiding in a trijunction geometry composed of three connected Kitaev chains.

1. Dibyajyoti Sahu, Vipin Khade, and Suhas Gangadharaiah. Effect of topological length on bound state signatures in a topological nanowire. Phys. Rev. B, 108:205426, Nov 2023.
2. Dibyajyoti Sahu and Suhas Gangadharaiah. Transport of Majorana bound states in the presence of telegraph noise. Physical Review B, 111(23):235306, June 2025.