HL 15: Quantum Dots and Wires: Growth and Properties

Time: Tuesday 9:30–11:00 Location: H13

HL 15.1 Tue 9:30 H13

Predictive theory of multi-particle states of GaAs quantum dots — •Petr Klenovsky — Masaryk University, Brno, Czech Republic — Czech Metrology Institute, Brno, Czech Republic

The correlated multi-particle electronic structure of GaAs quantum dots (QDs) in AlGaAs matrix is studied. GaAs QDs have unique physical properties, like an absence of built in strain as well as exhibiting the effects of the weak confinement, leading to the superradiance. GaAs QDs are an almost ideal candidate as a source of single and entangled photons for usage in quantum cryptography and computing. Unfortunately, so far current physics models of their electronic structure were not successful to *quantitatively* reproduce observed experimental results like, e.g., binding energies of trions (X+ and X-) and biexciton (XX) with respect to exciton (X) as well as the radiative emission of those complexes. We endeavored to change that and show in this contribution the results of our improved theory model based on $\mathbf{k}\cdot\mathbf{p}$ approximation and configuration interaction (CI) schemes. Using that we demonstrate computed binding energies of X+, X-, and XX in agreement with experiment which are also *converged* with respect to the size of CI basis, i.e., they include the effects of the Coulomb correlation. While the latter is found to be of a paramount role, surprisingly, we also find that the binding energies strongly depend on the way the electron-electron and hole-hole *exchange* integrals are calculated. Our results show very good agreement with photoluminescence and nuclear spin relaxation experiments on GaAs/AlGaAs QDs.

HL 15.2 Tue 9:45 H13

Electron capture and emission dynamics of self-assembled quantum dots far from equilibrium — •Maximilian Erdmann[1], Jan Lange[1], Lukas Berg[1], Laurin Schnorr[1], Thomas Heinzel[1], Severin Krüger[2], Arne Ludwig[2], and Andreas Wieck[2] — [1]Condensed Matter Physics Laboratory, Heinrich Heine University, Düsseldorf, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität, Bochum, Germany

The subject of the experiment were the electron capture and emission dynamics of Self-Assembled Quantum Dots (SAQD) far away from equilibrium conditions, at a temperature of 77 K. The SAQDs are located in a semiconductor structure that can be regarded as a Schottky diode. For analysing the capture and emission dynamics, the capacitance transients of this sample were investigated using the methods of Deep Level Transient Spectroscopy (DLTS).

HL 15.3 Tue 10:00 H13

Spatial Statistics of InAs Quantum Dots on GaAs(100) — •Normen Auler[1], Viktoryia Zolatanosha[2], and Dirk Reuter[1,2,3] — [1]Department Physik, Universität Paderborn, DE — [2]Institute for Photonic Quantum Systems (PhoQS), Universität Paderborn, DE — [3]Center for Optoelectronics and Photonics Paderborn (CeOPP), Universität Paderborn, DE

Self-assembled InAs quantum dots (QDs) on GaAs are potential building blocks for quantum technology applications. One interesting aspect is the spatial arrangement of the QDs.

In this contribution, we investigated the spatial distribution of QDs for samples with different QD densities by analyzing atomic force microscopy images. We evaluated Voronoi cell areas and nearest neighbor configurations. Contrary to the expected random distribution for Stranski-Krastanow-grown QDs, we observe deviations indicating an influence of strain fields and a corresponding effect on inter-island adatom diffusion on the final QD arrangement. We discuss the behavior for different densities in detail.

HL 15.4 Tue 10:15 H13

Epitaxial growth and in-situ integration of high-quality single InGaAs quantum dots on a silicon substrate — •Imad Limame[1], Peter Ludewig[2], Aris Koulas-Simos[1], Chirag C. Palekar[1], Wolfgang Stolz[2], and Stephan Reitzenstein[1] — [1]Technische Universität Berlin — [2]NAsP III/V GmbH, Marburg, Deutschland

For over two decades, the integration of light sources onto the silicon (Si) platform has garnered significant interest in both scientific and industrial communities. Despite the cost-effectiveness of Si and its extensive use in semiconductor technology, its indirect bandgap limits its potential for optoelectronic applications. The direct growth of III-V materials, which offer excellent optical properties, on Si is appealing but challenging due to factors such as lattice mismatch, differences in thermal expansion coefficients, Si surface reactivity, and dislocation formation. We report on the direct epitaxial growth of InGaAs QDs in both the 940 and 1300 nm ranges with excellent quantum optical properties on a Si substrate. The heteroepitaxy of GaAs heterostructures on Si is achieved using a GaP buffer layer. The resulting QDs exhibit outstanding optical properties, showcasing the significant potential of this approach. Furthermore, using a strain-reducing layer (SRL), we grow single QDs in the telecom O-band, which are then integrated via in-situ electron beam lithography (EBL) into circular Bragg gratings (CBG) to enhance extraction efficiency for quantum communication applications.

Our results represent a significant step toward scalable, cost-effective, and Si-compatible quantum photonics devices.

HL 15.5 Tue 10:30 H13

Electrostatic Inter-Layer Coupling between Self-Assembled Quantum Dots — •Jan Lange[1], Lukas Berg[1], Laurin Schnorr[1], Thomas Heinzel[1], Charlotte Rothfuchs-Engels[2], Nikolai Bart[2], Arne Ludwig[2], and Andreas Wieck[2] — [1]Condensed Matter Physics Laboratory, Heinrich Heine University, Düsseldorf, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität, Bochum, Germany

Electrostatic coupling between Self-Assembled Quantum Dots (SAQDs) in spatially separated layers is studied using transient capacitance spectroscopy. The coupling effect is analysed as a function of temperature, applied bias voltage, and the occupancy of the quantum dot layers. The observed interaction is attributed to the electric field modulation induced by charge redistribution in one layer, influencing the capture and emission dynamics in the other. A rate equation model was developed, incorporating self-consistent band bending calculations, to describe the impact of the inter-layer coupling on the charge transfer processes. The findings indicate that the coupling arises from the electrostatic field generated by the charged quantum dots in the adjacent layer, providing a quantitative explanation for the altered capacitance transients.

HL 15.6 Tue 10:45 H13

Photoluminescence from SiGe and Ge quantum dots on Si nanotips: role of composition and capping — •Diana Ryzhak[1], Johannes Aberl[2], Enrique Prado-Navarrete[2], Lada Vukušić[2], Agnieszka Anna Corley-Wiciak[1], Oliver Skibitzki[1], Marvin Hartwig Zoellner[1], Markus Andreas Schubert[1], Michele Virgilio[3], Moritz Brehm[2], Giovanni Capellini[1,4], and Davide Spirito[1] — [1]IHP Leibniz-Institut für innovative Mikroelektronik, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany — [2]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Altenberger Strasse 69, 4040, Linz, Austria — [3]Dipartimento di Fisica E. Fermi, Università di Pisa, Largo Pontecorvo 3, 56127, Pisa, Italy — [4]Dipartimento di Scienze, Università Roma Tre, V.le G. Marconi 446, 00146 Roma, Italy

Quantum dots (QDs) have been studied for their unique optical properties, which are essential for LEDs and lasers. The main challenge remains to control the fabrication processes of QDs. Therefore, we have used a nanoheteroepitaxy (NHE) approach and fabricated nearly strain-free SiGe and Ge QDs on Si(001) nanotip (NT) patterned substrates. The QDs were deposited by molecular beam epitaxy at 850°C, yielding defect-free structures selectively on the NTs as observed by transmission electron microscopy. Upon tuning the Si content, the photoluminescence (PL) peak emission shifted from 0.78 to 0.9 eV. The PL emission can be remarkably enhanced by capping the QDs with Al_2O_3 or Si_3N_4 for reduction of the surface recombination processes.