HL 17: Quantum Dots and Wires 4: Devices

Time: Wednesday 9:30–12:30 Location: H32

HL 17.1 Wed 9:30 H32

Highly Pure and Bright Emission of a Telecom C-Band Quantum Dot in a Circular Bragg Grating Cavity — •Raphael Joos, Cornelius Nawrath, Sascha Kolatschek, Stephanie Bauer, Pascal Pruy, Robert Sittig, Ponraj Vijayan, Jiasheng Huang, Michael Jetter, Simone L. Portalupi, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen (IHFG), Center for Integrated Quantum Science and Technology (IQST) and SCoPE, Universität Stuttgart

Quantum communication schemes, which can prospectively guarantee secure communication by physical laws, rely on the availability of single-photons utilized as flying qubits. For this purpose, InAs quantum dots (QDs) can be employed as single-photon source, particularly, providing access to emission at telecom wavelengths which is highly sought-after for fiber-based applications and will, thus, most probably be the operating regime for real-world applications. However, simple planar QD structures suffer from a low collection efficiency due to the high refractive index contrast at the semiconductor/air interface. This issue can be tackled by the application of photonic nanostructures. This contribution deals with the optical and quantum optical investigation of telecom C-band QDs embedded in circular Bragg grating cavities, which allow for strongly increased light collection in a broad range of wavelengths as well as Purcell enhanced emission of the QDs. In this way, QD emission with a near perfect single-photon purity as well as very high collection efficiency is achieved leading to megahertz count rate of actual single-photons available for further applications.

HL 17.2 Wed 9:45 H32

Realization of Gaussian-shaped micro-cavities for Quantum Dots emitting in the telecom C-band — •Jens Jakschik — Institut für Halbleiteroptik und funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Germany

Semiconductor quantum dots (QDs) are a prime candidate for the generation of efficient single, indistinguishable photons. When utilizing these QDs for e.g. long-distance quantum communication, it is important to operate at the transmission loss minimum of the existing global optical fiber network. Therefore, the QDs have to emit in the telecom C-Band (~1550 nm). To keep the advantages of the mature GaAs technology, the QDs are grown on an InGaAs metamorphic buffer (MMB) layer with high In-content on GaAs. The emission of QDs can be optimized by confining them into cavities. In this work novel Gaussian-shaped micro-cavities based on high-reflective DBRs are used. To reach high quality factors and increase the extraction efficiency in Gaussian-shaped cavities, the radial symmetry given by the wet-chemically etched Gaussian-shaped microlens, forming the center of the cavity has to be preserved over multiple layers of top DBR growth. This has to be realized despite the varying growth rates of InGaAs along different crystal axes. In this contribution, we present the results of the optical simulations for optimizing these cavities for the telecom C-Band, as well as the effect of different growth conditions on the overgrowth of InGaAs on wet-chemically pre-structured substrates to enable the fabrication of novel Gaussian-shaped micro-cavities.

HL 17.3 Wed 10:00 H32

Optically induced in-situ strain-tuning of InGaAs quantum dots for nanophotonic devices — •Ching-Wen Shih[1], Marco Holzer[2], Imad Limame[1], Lasse Kosiol[1], Sourish Banerjee[2], Aris Koulas-Simos[1], Veeresh Deshpande[2], Cathrine Dubourdieu[2,3], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany — [3]Freie Universität Berlin, Physical Chemistry, Berlin, Germany

Self-assembled semiconductor quantum dots (QDs) have been widely incorporated in solid-state cavities to enable quantum technologies. However, the nature of self-assembled QDs poses a big challenge to achieving controlled emitter-cavity and emitter-emitter coupling as it not only requires an accurate spatial positioning, but also a precise spectral matching of the system. Here, we report on the MOCVD growth and fabrication of micropillar-like nanophotonic light sources consisting of strain-tunable InGaAs QDs with ALD-deposited HfO2 thin film cladding. We show that the emission energy of QDs can be in-situ tuned by thermally annealing the HfO2 film with a focused laser beam integrated in a μ-photoluminescence setup under cryogenic temperature. We demonstrate a tunability up to 2 meV without QDs degradation. Furthermore, we successfully tuned two separated QD emission peaks from the same structure into resonance. The developed technique paves the path for scaling up the number of coupled QDs in semiconductor nanophotonic devices.

HL 17.4 Wed 10:15 H32

Optical properties of In(Ga)As QDs emitting in the telecom C-band grown on a non-linear metamorphic buffer layer — •Pascal Pruy, Cornelius Nawrath, Robert Sittig, Simone Luca Portalupi, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology(IQST) and SCopE, University of Stuttgart, Allmandring 3, 70569 Stuttgart

Semiconductor Quantum Dots (QDs) are excellent structures for the generation of non-classical light states with outstanding performance regarding single-photon purity, photon indistinguishability and entanglement fidelity, making them promising sources for currently researched subjects such as quantum computation and quantum communication. The telecom C-band (1530-1565 nm) spectral regime is especially sought-after for fiber-based implementations of these applications due to the absorption minimum in the globally used silica fiber network. On the mature and promising GaAs material platform, the telecom C-band can be reached using a metamorphic buffer (MMB) layer and the recent progress on such QDs has attracted great interest.

While so far MMBs with a thickness of 1080nm have been employed resulting in a nominal 3-λ cavity, a 1-λ cavity would be greatly beneficial for more elaborate photonic structures regarding brightness and coherence. Here we report on the optical properties such as brightness, coherence and purity of In(Ga)As Quantum Dots emitting in the telecom C-band spectral regime on a novel metamorphic buffer layer compatible with 1-λ cavities.

HL 17.5 Wed 10:30 H32

Optical properties of semiconductor quantum dots embedded in an open, fiber-based cavity emitting in the telecom regime — •Julia Wecker[1], Thomas Herzog[1], Jonas Grammel[2], Ponraj Vijayan[1], Robert Sittig[1], Michael Jetter[1], Simone Luca Portalupi[1], David Hunger[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Stuttgart, Germany — [2]Physikalisches Institut, Karlsruher Institut für Technologie (KIT), Karlsruhe, Germany

Enhancing the brightness of quantum emitters can be achieved by coupling them to optical microcavities. Together with an enhanced light extraction, shortening of the spontaneous emission rate can be achieved via the Purcell effect. In this work, we investigate In(Ga)As quantum dots embedded in an open fiber-based Fabry-Pérot cavity. On the bottom distributed Bragg reflector, quantum dots operating at the telecom O- and telecom C-Band are grown, while the top mirror is deposited on a silica fiber which can be moved with nanometric precision across the sample. Therefore, the cavity mode can be tuned in order to achieve spatial and spectral matching with the investigated emitter. The emitted photons are then directly coupled into the telecom fiber, making this fiber-coupled single-photon source promising for quantum communication applications.

30 min. break

HL 17.6 Wed 11:15 H32

GaSb quantum dots surrounded by AlGaSb with indirect-direct bandgap crossover at telecom range — •Lucie Leguay and Andrei Schliwa — Institut für Festkörperphysik, Technische Universität Berlin

We report the modeling and theoretical characterization of a new type-I semiconductor material based on GaSb quantum dots embedded into AlGaSb with GaSb as substrate. The calculations are performed by the nextnano++ solver, using both the effective mass and the 8-band k·p method.

Experimental work shows the formation of nano-holes with a wide range of tunability in depth and density by the local droplet etching of a surface of AlGaSb by liquid gallium [1]. Then, optically active quantum dots are obtained by filling those nano-holes with GaSb and by the deposition of a GaSb quantum well on top [2].

Our calculations demonstrate an indirect-direct bandgap crossover as the thickness of the quantum well increases, which allows control of the system's luminescence. In the direct bandgap regime, the quantum dots emit narrow excitonic spectral lines in the telecom wavelength range. These properties, as well as the low density of the quantum dots, show a lot of promise for applications in the field of infrared quantum optics.

[1] J. Hilska, A. Chellu, T. Hakkarainen, Cryst. Growth Des. 2021, 21, 1917-1923

[2] A. Chellu, J. Hilska, J-P Penttinen, T. Hakkarainen, APL Mater. 9, 051116 (2021)

HL 17.7 Wed 11:30 H32

Coherent Spin Control in InAs Quantum Dots Emitting in the Telecom C-Band — •Johannes Michl[1], Łukasz Dusanowski[1,3], Cornelius Nawrath[2], Michael Jetter[2], Simone L. Portalupi[2], Tobias Huber[1], Peter Michler[2], and Sven Höfling[1] — [1]Technische Physik, Julius-Maximilians University of Würzburg — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen (IHFG), University of Stuttgart — [3]Princeton University

Semiconductor quantum dots can be used as spin-photon interfaces, enabling the preparation of photonic cluster states with a single spin in the quantum dot acting as the entangler. This leads the way towards memory-less quantum repeater protocols for quantum network applications. InAs quantum dots can be grown on metamorphic buffer layers, leading to strain relaxed growth and therefore light emission directly into the telecom C-band. Here we show magneto and polarization resolved photoluminescence experiments conducted to characterize the different charge complexes in a single quantum dot. Furthermore, we implement laser pulse sequences to gain full coherent control over a hole qubit.

HL 17.8 Wed 11:45 H32

Quantum Dot Localization Methodology based on Imaging — •Marc Sartison, Eva Schöll, Lukas Hanschke, Ioannis Caltzidis, Oscar Camacho Ibarra, and Klaus D. Jöns — PhoQS, CeOPP, and Department of Physics, Paderborn University, Germany

Since the discovery of the triggered generation of single photons in 2000, quantum dots have proven to be one of the most versatile quantum light sources for pure, indistinguishable, entangled photons while maintaining high brightness. Before developing deterministic integration techniques, high yield in device fabrication remained elusive due to the statistical growth properties in high-quality self-assembled growth modes. Several methods have been developed, providing the quantum dot location and its spectral information, namely in-situ optical lithography, in-situ electron beam lithography, and quantum dot localization using quantum dot imaging. Our work describes a methodological workflow using computational, and image processing approaches in python to precisely determine the quantum dot position concerning pre-deposited metal marker structures. Here, we investigate different hardware, marker geometries, and software methods. Furthermore, we quantify the expectable upper bound accuracy for device integration. Importantly, our presented methods are not developed for a fixed emitter wavelength or type. With the right choice of optical elements within the setup, it is possible to cover the wavelengths from the visible up to the telecom C-band. The presented technique can, in principle, be applied to any type of solid-state quantum emitters.

HL 17.9 Wed 12:00 H32

Fabrication and Electrical Characterisation of Junctionless Nanowire Transistors for Detection of Atmospheric Radicals and Other Gases — •Sayantan Ghosh[1], Muhammad Bilal Khan[1], Vaishali Vardhan[2], Ulrich Kentsch[1], Slawomir Prucnal[1], Subhajit Biswas[2], Justin Holmes[2], Artur Erbe[1], and Yordan M. Georgiev[1,3] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]School of Chemistry, University College Cork, Cork, Ireland — [3]Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria

Silicon junctionless nanowire transistors (JNTs) have shown excellent sensitivity to record-low concentrations of the protein streptavidin in liquid phase. However, JNTs have not yet been tested for sensing in gas phase. Here we present the fabrication and initial electrical characterisation of JNT-based electronic sensors for detection of atmospheric free radicals such as hydroxyl (*OH) and nitrate (*NO3), which are the main drivers of chemical processes in the atmosphere. The aim of this work is to develop small, low-cost JNT-based nanosensors for radical detection. Silicon-on-insulator wafers were doped by ion implantation and flash-lamp annealing. Device patterning was based on electron beam lithography, inductively-coupled reactive ion etching, metal deposition and lift-off. Initial electrical characterisation and gas sensing experiments on fabricated devices proved their good performance and potential suitability for detection of atmospheric free radicals.

HL 17.10 Wed 12:15 H32

Single photons from Semiconductor Quantum Dots in Circular Bragg Gratings for Quantum Cryptography — •Daniel Vajner, Lucas Rickert, Timm Gao, Koray Kaymazlar, Jan-Niklas Donges, Johannes Schall, Sven Rodt, Stpehan Reitzenstein, and Tobias Heindel — Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

Semiconductor quantum dots are an excellent source of single photons for future quantum networks [1]. In order to enhance their properties they are typically incorporated into photonic structures. Among these, circular bragg gratings (CBG) are a promising way to further enhance the outcoupling efficiency [2]. Additionally, they are especially suited for fiber-coupling to achieve more compact plug-and-play single photon sources [3]. In this work we deterministically integrate single InGaAs quantum dots in CBG structures, which have been numerically optimized beforehand. We characterize the properties of the CBGs and quantify the purity and indistinguishability of the emitted photons. Finally, we aim for the implementation of cryptographic primitives such as strong quantum coin flipping using single photons.

[1] D. Vajner et al., Adv. Quantum Technol. 2100116 (2022)
[2] L. Rickert et al., Optics Express 27.25 (2019)
[3] T. Gao et al., Applied Physics Reviews 9.1 (2022)