HL 55: Quantum Dots and Wires: (Single) Photonics

Time: Friday 9:30–12:30 Location: POT/0251

HL 55.1 Fri 9:30 POT/0251

Fabrication of a III/V SiO2/SiN hybrid cavity incorporating a single Stark tunable (In,Ga)As quantum dot for high rate single photon generation — •Imad Limame, Kartik Gaur, Sarthak Tripathi, Setthanat Wijitpatima, Aris Koulas-Simos, Chirag Chandrakant Palekar, and Stephan Reitzenstein — Institute for Physics and astronomy, Technical University of Berlin, Berlin, Germany

The advancement of quantum photonic technologies, particularly secure communication based on semiconductor quantum dots (QDs), relies on the on-demand generation of high-quality quantum light. Emission of single photons with high brightness, purity, and indistinguishability is essential for scalable quantum networks. However, the photon emission rate of QDs is fundamentally limited by their nanosecond-scale radiative lifetime. To overcome this, QDs are integrated into photonic nanostructures that enhance light-matter interaction via the Purcell effect, accelerating emission dynamics. Yet, such approaches often require complex bonding and alignment, hindering scalability.

We demonstrate a scalable hybrid cavity platform integrating a Stark-tunable QD within a p-i-n diode into a resonator composed of an epitaxially grown III-V bottom mirror and a PECVD-deposited dielectric top DBR. Deterministic QD positioning using marker-based EBL ensures precise spatial and spectral alignment, improving photon extraction and reducing the radiative lifetime. This approach enables scalable, high-brightness, coherent quantum light sources, providing a solid foundation for next-generation integrated quantum photonics.

HL 55.2 Fri 9:45 POT/0251

Deterministic single-photon source with on-chip GHz acoustic clock — •Alexander Kuznetsov[1], Meysam Saeedi[1], Zixuan Wang[2], Kevin Silverman[2], and Klaus Biermann[1] — [1]Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e. V., Hausvogteiplatz 5-7, 10117 Berlin, Germany — [2]National Institute of Standards and Technology, Boulder, Colorado 80305, USA

Solid state single-photon sources are a key component in quantum communication. Their efficiency depends strongly on the single-photon (SP) emission rates. Typically, the latter can be enhanced via Purcell effect by embedding quantum dots (QDs) in optical microcavities (MC), which requires the energy matching between MC optical mode and QD energies. Here, we demonstrate triggering of QD SP emission using dynamic Purcell effect induced by acoustic strain at a frequency of several GHz. To this end, InAs QDs are integrated in a hybrid photon-phonon AlGaAs microcavity, where the density of optical states is tailored by the lateral confinement of photons in um-sized traps defined lithographical patterning of the microcavity spacer. We demonstrate modulation of QD energy up to 14 GHz using quasi-monochromatic strain of a piezoelectrically excited bulk acoustic wave. The modulation periodically shifts the QD transition in resonance with a spectrally narrow confined optical mode, leading to an enhancement of emission, i.e., the dynamic Purcell effect. In combination with high-Q MCs this approach is promising for SP rates above 10 GHz under continuous wave optical excitation. [arXiv:2510.22826]

HL 55.3 Fri 10:00 POT/0251

Beyond-Dipole Radiative Lifetimes of Excitons and Biexcitons in GaAs/AlGaAs Quantum Dots — •Petr Klenovský — Masaryk University, Brno, Czech Republic — Czech Metrology Institute, Brno, Czech Republic

Semiconductor quantum dots are promising sources of on-demand single and entangled photons, but a quantitative microscopic description of their radiative lifetimes remains challenging. We theoretically investigate Coulomb-correlated multi-particle states (X^0, $X^{\pm}$, XX) in weakly confining GaAs/AlGaAs quantum dots using an 8-band $\mathbf{k}\cdot\mathbf{p}$ model combined with continuum elasticity and configuration interaction (CI). Polarization-resolved oscillator strengths and radiative rates are computed both in the dipole approximation and in a quasi-electrostatic beyond-dipole formulation based on a Poisson reformulation of the dyadic Green tensor. For the dots studied, the beyond-dipole treatment yields exciton and biexciton lifetimes in quantitative agreement with experiment. We further analyze electric-field tuning of the multi-particle spectrum and the resulting indistinguishability, characterized by $P = \tau^X/(\tau^X + \tau^{XX})$, and discuss the sensitivity to CI-basis size and to electron-electron and hole-hole exchange.

HL 55.4 Fri 10:15 POT/0251

High-quality single photons from cavity-enhanced biexciton-to-exciton transition — •Nils Heinisch[1], Francesco Salusti[1], Timon L. Baltisberger[2], Mark R. Hogg[2], Malwina A. Marczak[2], Rüdiger Schott[3], Sascha R. Valentin[3], Andreas D. Wieck[3], Arne Ludwig[3], Klaus D. Jöns[1], Richard J. Warburton[2], and Stefan Schumacher[1] — [1]Department of Physics, CeOPP, and PhoQS, Paderborn University, Germany — [2]Department of Physics, University of Basel, Switzerland — [3]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

Generating high-quality photons using the biexciton-exciton cascade benefits from the separability of the photons from the two-photon excitation laser pulse. However, the intrinsic lifetime ratio between biexciton (XX) and exciton (X) states leads to a fundamental limit for the achievable indistinguishability of the single photons [1]. Therefore, the XX must decay much faster than the X. We achieve this with an optical resonator that resonantly enhances the XX-X transition. By optimizing the cavity parameters and avoiding phonon-mediated cavity feeding, we show that high-quality cavity photons originating from XX can be generated. Furthermore, we show that spectral filtering restores single-photon quality in regimes of XX binding energies, where X emission into the cavity is not initially excluded. Our theoretical investigations are joined by key results from the experimental demonstration, which make this approach a major advance in the realization of practical quantum light sources. [1] E. Schöll et al., PRL 125, 233605 (2020). D. Bauch et al., Adv. Quantum Technol. 7, 2300142 (2024).

HL 55.5 Fri 10:30 POT/0251

Photon-mediated electron capture into a single quantum emitter — •Daniel Oppers[1], Hendrik Mannel[1], Luca Henrichs[1], Fabio Rimek[1], Arne Ludwig[2], Axel Lorke[1], and Martin Geller[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany — [2]Chair of Applied Solid State Physics, Ruhr-University Bochum, Germany

Single-photon emitters are one of the key components of quantum information technology. Especially single self-assembled quantum dots in a p-i-n diode structure for charge control are still a promising candidate. We use an InAs/GaAs quantum dot in a bias regime, where the dot is uncharged and drive the exciton transition optically resonant with a cw diode laser. A second off-resonant cw laser with a lower energy than any optical transition is used to induce an internal photoeffect [1], exiting electrons from the electron reservoir in the diode, that are captured into the quantum dot. Consequently, we observe a quenching of the exciton transition, which can no longer be driven resonantly. This electron capture by photo-excitation of electrons from the reservoir (see also [2]) is measured here in real-time, observing every quantum jump from an uncharged to a charged quantum dot in a random telegraph signal. Evaluating the telegraph signal using waiting time distributions we observe a linear increase in the electron capture rate scaling up with increasing excitation power of the off-resonant laser. Our findings reveal that photo-induced quenching is a possible source of exciton dephasing. [1] P. Lochner et. al., Phys. Rev. B **103**, 075426 (2021) [2] A. Kurzmann Appl. Phys. Lett. **108**, 263108 (2016)

HL 55.6 Fri 10:45 POT/0251

Influence of the internal photoelectric effect on the indistinguishability of single quantum dot photons — •Luca Henrichs[1], Fabio Rimek[1], Hendrik Mannel[1], Daniel Oppers[1], Arne Ludwig[2], Martin Geller[1], and Axel Lorke[1] — [1]Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg — [2]Chair of Applied Solid State Physics, Ruhr-University Bochum, Germany

A single self-assembled quantum dot (QD) is one of the promising candidates as a bright (high photon rate) and stable (Fourier-limited) linewidth single photon source [1]. For applications in photonic devices or in quantum communication networks the dephasing process is an important property, where besides spin- and charge noise, the Auger-Meitner [2] and the photoeffect [3] could play an important role.

Here, we investigate the impact of the internal photoelectric effect on the indistinguishability of single QD photons. We used pulsed Hong-

Ou-Mandel measurements at different excitation intensities of the exciton transition to determine the photon indistinguishability in various driving regimes, ranging from coherent scattering (the Heitler regime) to the incoherent regime above the saturation intensity. Above saturation, we observe the influence of the photoeffect, which reduces the indistinguishability. Our findings represent an important step toward understanding the decoherence of single photons in this important quantum system.

[1] N. Tomm et al., Nat. N. **16**, 399*403 (2021). [2] H. Mannel et al., AIP, **15**, 134 (2023). [3] P. Lochner et al, PR, **7**, 103, (2021).

15 min. break

HL 55.7 Fri 11:15 POT/0251

An ultra-compact deterministic source of maximally entangled photon pairs — Moritz Langer[1], Pavel Ruchka[2], Ahmad Rahimi[1], Sara Jakovljevic[2], Yared G. Zena[1], Sai Abhishikth Dhurjati[1], Alexey Danilov[1], Mandira Pal[1], Riccardo Bassoli[3], Frank H. P. Fitzek[3], Oliver G. Schmidt[4], Harald Giessen[2], and •Caspar Hopfmann[1,2] — [1]Institute for Emerging Electronic Technologies, IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany — [2]4th Physics Institute and Research Center SCoPE, University of Stuttgart, 70569 Stuttgart, Germany — [3]Deutsche Telekom Chair of Communication Networks, Technische Universität Dresden, Dresden, Germany — [4]Research Center for Materials, Architectures and Integration of Nanomembranes (MAIN), Chemnitz University of Technology, Chemnitz, Germany

We demonstrate an ultra-compact source of on-demand, maximally entangled photon pairs using single GaAs quantum dots in monolithic microlenses, efficiently fiber-coupled in a cryogenic environment. A 3D-printed micro-objective facilitates near-diffraction-limited performance at 3.8 K. The system achieves high single-photon emission rates (392(20) kHz) and purities (0.992(5)) via two-photon resonant excitation. Leveraging the exciton-biexciton cascade, it produces near-maximally entangled photon pairs (peak entanglement negativities of 2n=0.96(2)). This quantum light source combines state-of-the-art performance and stability with a dramatically reduced footprint, well-suited for seamless industrial integration.

HL 55.8 Fri 11:30 POT/0251

Spectral shadows of a single GaAs quantum dot — •Jens Hübner[1], Kai Hühn[1], Lena Klar[1], Fei Ding[1], Arne Ludwig[2], Andreas D. Wieck[2], and Michael Oestreich[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

Semiconductor quantum dots are today's leading candidates for generating single and entangled photons. However, even the most advanced devices face performance limitations due to charge state fluctuations within the quantum dot and its surrounding environment. We have carried out detailed time-resolved resonance fluorescence measurements on an individual charge-tunable GaAs quantum dot, providing new insight into the spectral signatures generated by the complex landscape of unintentional impurities. For the neutral exciton and the negatively charged trion transitions, we uncover multiple Stark-shifted resonances, linked to rare spectral jumps smaller than the homogeneous linewidth. In other experiments, these jumps are typically obscured by measurement noise. In contrast, the positively charged and doubly negatively charged trions exhibit distinctly different behaviors. We quantify the underlying impurity charge dynamics over timescales ranging from sub-milliseconds to several seconds, and demonstrate that the hole population of the positively charged trion is limited in our state-of-the-art pin-structure by fast hole loss combined with slow hole recapture.
[Hühn et al., arXiv:507.20290 (2025)]

HL 55.9 Fri 11:45 POT/0251

Adhesive bonding of In(Ga)As - QD membrane on Silicon for evanescent light coupling — •J. Unfried[1], R. Vijayan[1], U. Pfister[1], D. Wendland[2], S. Oberle[1], M. Weiss[1], M. Jetter[1], S. Portalupi[1], and P. Michler[1] — [1]IHFG, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]AG Pernice, Universität Münster, Heisenbergstraße 11, 48149 Münster, Germany

Hybrid integration of III-V materials with silicon photonics involves combining efficient III-V light emitters with low-loss, CMOS-compatible Si platforms. This allows high-performance PICs to be realised. Adhesive bonding is a scalable and flexible method for achieving this integration. It provides and enables lithography-defined alignment. However, this approach also presents significant challenges. Efficient coupling between the III-V active membrane and Si waveguides (WG) requires an extremely thin, optically transparent bonding layer to enable strong evanescent coupling. Such thin layers restrict the thermal budget available for post-bonding processes, and may result in delamination during subsequent fabrication steps. Reliable integration therefore necessitates an optimised bonding process and carefully controlled fabrication conditions. This work focuses on integrating an InGaAs membrane with C-band InAs QDs onto a Si photonic platform using an optimised adhesive bonding scheme. A simulation-guided design approach is employed to identify suitable waveguide and taper geometries, and a reproducible bonding process is used to fabricate uniform, thin bonding layers and tapered InGaAs waveguides that efficiently couple QD emission into Si waveguides.

HL 55.10 Fri 12:00 POT/0251

Revisiting Quantum Well Thickness Fluctuation Quantum Dots as a Source of Single Photons — •Tom Fandrich[1], Frederik Benthin[1], Yiteng Zhang[1], Benjamin Bohn[1], Maximilian Heller[1], Johan Hilbig[1], Tom Rakow[1], Arijit Chakraborty[1], Doaa Abdelbarey[1], Eddy P. Rugeramigabo[1], Michael Zopf[1,2], and Fei Ding[1,2] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover — [2]Laboratorium für Nano- und Quantenengineering, Leibniz Universität Hannover, Schneiderberg 39, 30167 Hannover

Semiconductor-based quantum dots (QDs) are promising candidates for quantum network applications due to their ability to generate single, entangled, and indistinguishable photons on demand. Modern epitaxial III-V quantum emitters based on local droplet etching with nanohole infilling or Stranski-Krastanov growth exhibit excellent properties from the near-infrared to the telecom bands. An alternative from the early days of QD research involved QDs formed by thickness fluctuations in quantum well (QW) heterostructures. These QW thickness fluctuation (QWTF) QDs can naturally display strong light-matter interaction due to giant oscillator strengths, yet have not been the focus of recent research as quantum emitters for single-photon applications. In this work, we investigate the optical properties of naturally formed QWTF QDs in GaAs QWs emitting near 780 nm. Our results demonstrate that their distinctive properties justify revisiting QWTF QDs with today's standard for single-photon sources competing against state-of-the-art epitaxial approaches.

HL 55.11 Fri 12:15 POT/0251

Single-Photon Emission with High Spectral Purity from Site-Controlled InGaN Quantum Dots — •Nima Hajizadeh[1,2], Nils Bernhardt[2], Richard Zimmermann[2], Felix Nippert[2], Luca Sung-Min Choi[2], Benjamin Damilano[3], Jean-michel Chauveau[4], and Markus Wagner[1,2] — [1]Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V. — [2]Technische Universität Berlin, Institute of Solid State Physics — [3]Université Côte d'Azur, CNRS, CRHEA — [4]Université Paris Saclay, Université Versailles Saint Quentin, CNRS, GEMaC

The development of high-quality Single-Photon Emitters (SPEs) based on Indium Gallium Nitride (InGaN) Quantum Dots (QDs) is essential for advancing quantum technologies. We present a comprehensive investigation of SPEs based on novel top-down fabricated, site- and size-controlled InGaN QDs. In this work, the optical and quantum optical properties of these isolated QDs are comprehensively investigated using high-resolution, time-correlated micro-photoluminescence (μ-PL) spectroscopy, including temperature-, power- and polarization-dependent measurements, as well as hyperspectral PL mapping of their excitonic emission. The purity of the single-photon emission is evaluated by measuring the second-order intensity autocorrelation function $g^{(2)}(\tau)$ in a Hanbury-Brown and Twiss (HBT) setup. We show that the emitter exhibits an exceptionally sharp emission bandwidth below 0.02 nm and pronounced antibunching with $g^{(2)}(0) < 0.36$. These results confirm the potential of our site-controlled growth methodology to deliver high-purity SPEs with narrow spectral lines.