Q 11: QuanTour I – Single Photons & Foundations

Inspired by QuanTour, the traveling quantum-dot light source, the sessions QuanTour I-V focus on the physics of quantum light generation in solid-state systems and applications in quantum networks.

Time: Monday 17:00–19:00 Location: P 7

Q 11.1 Mon 17:00 P 7

QuanTour - Combining excellence in Research and Science Communication — •Doris Reiter[1] and Tobias Heindel[2] — [1]Condensed Matter Theory, TU Dortmund University, Germany — [2]Department of Quantum Technology, University of Münster, Germany

QuanTour is the unique journey of a quantum emitter across Europe and the World. Since April 2024, this globe-trotting quantum emitter has been connecting researchers and the public through a collaborative scientific and outreach initiative. At each stop, the single-photon purity of the same emitter was characterized via Hanbury Brown and Twiss correlation measurements. We compare the results obtained in the European labs and discuss its relevance for the standardization of measurements in quantum technologies. In addition, we summarize the outreach activities associated with QuanTour, discussing their reach and impact. This collaborative effort demonstrates how scientific networks can be leveraged for effective and innovative science communication.

Q 11.2 Mon 17:15 P 7

QuanTour at PTB: a metrologist‘s perspective — •Hristina Georgieva[1], Lisa Quack[1], Marco López[1], Stefan Kück[1], Lucas Rickert[2], Doris Reiter[3], and Tobias Heindel[4] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Technische Universität Berlin, Berlin, Germany — [3]Technische Universität Dortmund, Dortmund, Germany — [4]Department für Quantentechnologie, Universität Münster, Münster, Germany

QuanTour is an outreach project in which a quantum emitter is sent to different universities and research institutions worldwide, enabling comparative measurements on the same chip. We present the results obtained at PTB. We measured the emission spectrum, the decay time and the excitation-power-dependent $g^{(2)}(0)$ value of the single-photon emitter based on a quantum dot in a circular Bragg grating. The core of our self-built confocal microscope is a set of high-transmission spectral filters. In contrast to the common use of a monochromator for the spectral filtering, this approach provides high count rates at the single-photon detector, while maintaining a low multiphoton probability. Moreover, consistent with observations from other project partners, we measured a tenfold improvement of the $g^{(2)}(0)$ under p-shell excitation compared with non-resonant excitation. This combination of high photon flux and low $g^{(2)}(0)$ is particularly relevant for the calibration of single-photon detectors. In addition, the demonstrated robustness and durability of the quantum emitter throughout the project is highly valuable for ensuring reliable and reproducible measurements in the field of quantum metrology.

Invited Talk Q 11.3 Mon 17:30 P 7

Quantum radiometry metrology for quantum photonics technologies — •Angela Gamouras[1], Malcolm White[2], Nathan Tomlin[3], Michelle Stephens[3], John Lehman[3], Philip Poole[1], Dan Dalacu[1], and Robin Williams[1] — [1]National Research Council Canada, Ottawa, Canada — [2]University of Colorado Boulder, Boulder, USA — [3]National Institute of Standards and Technology, Boulder, USA

Quantum photonics technologies are transitioning from research prototypes to widely adopted tools in laboratories and industry. Quantum photonic integrated circuits - devices that combine single-photon sources, detectors, and other components on a single chip - are now integral to quantum networking and computing hardware. Accurate characterization of single-photon sources and single-photon detector efficiencies are essential for verifying and validating system performance. However, these measurements remain a persistent challenge. Current characterization methods typically rely on standard optical power meters and attenuated laser sources to calibrate detector efficiency. In this presentation, we introduce quantum radiometry techniques designed to meet the demands of quantum photonics systems. We describe an ultra sensitive radiometer chip capable of measuring the optical power emitted by a quantum dot single-photon source. This approach enables direct source characterization, which can be extended to assess on chip components. Our measurement technique shows the feasibility of implementing optical power metrology for quantum dot emitters, enabling the validation and testing of quantum photonic technologies.

Q 11.4 Mon 18:00 P 7

Advances in Quantum Light Generation for Quantum Communication at Telecom Wavelengths — •Robert Behrends[1], Lucas Rickert[1], Pratim K. Saha[1], Mareike Lach[1], Martin v. Helversen[1], Nils D. Kewitz[1], David Becker[1], Jochen Kaupp[2], Yorick Reum[2], Tobias Huber-Loyola[2], Sven Höfling[2], Andreas Pfenning[2], and Tobias Heindel[3] — [1]Institute of Physics and Astronomy, Technical University Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Technische Physik, Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [3]Department for Quantum Technology, Univeristät Münster, Germany

We present an ultra-fast quantum dot (QD) single-photon source in the telecom C-band, based on InAs/InAlGaAs QD integrated in a circular Bragg grating cavitiy. We observe record-short biexciton decay time of T1=68 ps under resonant two-photon-excitation (TPE), which allows us to generate highly indistinguishable single photons at clock rates > 1 GHz. The two-photon interference visibility of photons emitted via the biexciton-exciton transition was measured in a Hong-Ou-Mandel-type experiment to be 92.4% and 82.6% at clock rates of 100 MHz and 2.5 GHz, respectively. Applying stimulated TPE in the telecom C-Band for the first time, we show that the photon indistinguishability can be further enhanced for exciton photons. Our results show promises to advance QD-based implementations of quantum cryptography to unprecedentedly high clock rates at wavelengths suitable for large-scale fiber-optic networks.

Q 11.5 Mon 18:15 P 7

Enhanced Exciton Dynamics in Free-Standing TMD Heterobilayers — •Marah Alqedra and Ibrahim Sarpkaya — National Nanotechnology Research Center, Bilkent University, Ankara, Turkey

Atomically thin transition-metal dichalcogenide (TMD) van der Waals heterobilayers enable the formation of spatially indirect interlayer excitons (IXs), with electrons and holes residing in different layers, offering long exciton lifetimes and a permanent electric dipole, promising for valley/spin physics and quantum-optical applications. Substrate-supported heterostructures, however, often experience substrate-induced disorder and environmental coupling that degrade IX photoluminescence (PL) emission and reduce optical quality. To overcome these limitations, we prepared suspended heterobilayers free from substrate interaction. Low-temperature PL and time-resolved PL measurements show a strong enhancement of IX emission in suspended heterobilayers compared to conventional supported samples. This indicates suppression of non-radiative losses and environmental dephasing, improving excitonic optical performance, a step toward realizing high-quality 2D-material emitters and quantum-optical devices.

Q 11.6 Mon 18:30 P 7

Wigner functions of pure photonic states emitted by quantum dot sources — •Hubert Lam[1], Petr Steindl[1], Yann Portella[1], Juan R. Álvarez[2], Kiarn Laverick[3], Anton Pishchagin[4], Thi Huong Au[4], Sébastian Boissier[4], Aristide Lemaître[1], Alexia Auffèves[3], Dario A. Fioretto[1,4], and Pascale Senellart-Mardon[1] — [1]Centre de nanosciences et de nanotechnologies, Palaiseau, France — [2]Télécom Paris, Palaiseau, France — [3]MajuLab, Singapore — [4]Quandela, Massy, France

Semiconductor quantum dots are excellent on-demand single-photon sources. Coupled to optical cavities, they emit pure, indistinguishable photons at high rates. While such sources have mainly been used for discrete-variable photonic quantum information processing, their ability to generate complex non-Gaussian states and provide strong single-photon nonlinearity positions them as promising resources for continuous-variable (CV) protocols as well.

We take a first step toward using cavity-coupled quantum dots as CV resources. We measure the Wigner functions of single-photon and photon-number superposition states from our emitter, achieving purities above 90 %. This is enabled by adapting homodyne-like displacement techniques to the high-brightness regime of our source.

These results demonstrate that quantum-dot sources can be harnessed for the generation and engineering of non-Gaussian states and pave the way for continuous-variable quantum information processing with optical solid-state emitters.

Q 11.7 Mon 18:45 P 7

Pulsed to continuous wave microcavity-quantum dot (in)coherent dynamics — •Mio Poortvliet and Wolfgang Löffler — Leiden Institute of Physics, Leiden University, Leiden, The Netherlands

Semiconductor quantum dots are a promising single photon source, when excited correctly. We focus on resonant excitation, this allows coherent control and is flexible to implement. The response from the quantum dot is well understood for continuous wave excitation, where a stream of single photons is produced without well-defined time-bins. Using pulsed excitation light with a pulse length shorter than relevant QD decoherence times is also well understood, population inversion above 50% can produce one photon per time bin deterministically.

In this experiment, we study a charged InGaAs quantum dot in a polarization-split monolithic micro-cavity and excite it using a custom pulse generator enabling pulse lengths from 20 ps to many times the QD lifetime. With this, we investigate how the cavity-quantum dot system behaves under various excitation conditions, from pulsed to continuous-wave, and for different quantum dot and laser detunings. We measure the characteristic chevron pattern of Rabi oscillations, modified by cavity field enhancement and cavity-QD hybridization. We are able to reproduce this data accurately by careful simulation. By simultaneously measuring the second order correlation function we observe how the photon statistics oscillate between anti-bunched and bunched, and by chaning the detuning we measure significant bunching likely from a single photon subtracted coherent state.