# HL 49: Quantum Dots: Optical Properties III

Time: Wednesday 9:30–12:45 Location: POT 151

HL 49.1 Wed 9:30 POT 151

**A bright triggered twin-photon source in the solid state** — •Tobias Heindel[1], Alexander Thoma[1], Martin von Helversen[1], Marco Schmidt[1,2], Alexander Schlehahn[1], Manuel Gschrey[1], Peter Schnauber[1], Jan-Hindrik Schulze[1], André Strittmatter[1], Jörn Beyer[2], Sven Rodt[1], Alexander Carmele[3], Andreas Knorr[3], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany — [2]Physikalisch-Technische Bundesanstalt, Abbestraße 1, 10587 Berlin, Germany — [3]Institut für Theoretische Physik, Technische Universität Berlin, 10623 Berlin, Germany

We propose and experimentally demonstrate the efficient, triggered generation of photon twins using the energy-degenerate biexciton-exciton radiative cascade of a single semiconductor quantum dot (QD) [1]. For this purpose, we select a QD whose exciton's finestructure splitting equals the biexciton binding energy resulting in $E_X^H = E_{XX}^H$. Deterministically integrated within a microlens, this nanostructure emits highly-correlated photon pairs, degenerate in energy and polarization, at a rate of up to $(234 \pm 4)$ kHz. Furthermore, we directly observe the emitted twin-photon state by employing a photon-number-resolving detection system based on a transition edge sensor, which enables the reconstruction of the emitted photon number distribution.

[1] A. Thoma, T. Heindel et al., A bright triggered twin-photon source in the solid state, arXiv:1608.02768 (2016)

HL 49.2 Wed 9:45 POT 151

**Optical enhancement of quantum dot emission by surface nanowires** — •Sven Scholz, Rüdiger Schott, Carlo Sgroi, Yannick Raffel, Andreas D. Wieck, and Arne Ludwig — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

Molecular beam epitaxy (MBE) quantum dot (QD) structures are used as fundamental research structures to investigate quantum optical phenomena. To further enhance their optical properties we use nanowires as a subwavelength waveguide. While common photonic crystal structures work with holes or micro pillars, we use focused ion beam (FIB) to catalyze nanowire growth on QD structures. The LED-QD structure is optimized regarding the optical emission. Therefore we use a methode to remove the wetting layers (WL) PL signal. To access a wide emission spectrum we use rapid-thermal annealing (RTA) and a flushing technique coupled with the WL suppression. This results in tunable and good separated QD emission peaks. The NW growth is characterized and optimized with regards to crystalline quality and morphology. The samples are characterized by photoluminescence/electroluminescence, scanning electron microscope imaging and capacitance-voltage spectroscopy.

HL 49.3 Wed 10:00 POT 151

**Light holes in quantum dots** — •Vlastimil Křápek — Central European Institute of Technology, Brno University of Technology, Purkyňova 123, CZ-612 00 Brno, Czech Republic — Institute of Physical Engineering, Brno University of Technology, Technická 2, CZ-616 69 Brno, Czech Republic

The valence band edge of III-V zinc-blende semiconductors is formed by heavy and light holes. In quantum dots, the lowest confined valence state is usually contributed by the heavy holes with the weight above 90 % and by the light holes with the weight below 10 %. Thus, its properties are dominated by the heavy holes. However, there are phenomena in which the light holes play equally important or even decisive role.

In my contribution I review three such phenomena: excitonic fine structure splitting tuned by external strain field [1], quantum dot molecule with a tunable tunnel coupling [2], and brightened dark exciton [3]. I explain how the light holes couple to the heavy holes due to the quantum confinement and strain field stressing the differences between both effects.

[1] J. D. Plumhof, V. Křápek, F. Ding, K. D. Jöns, R. Hafenbrak, P. Klenovský, A. Herklotz, K. Dörr, P. Michler, A. Rastelli, and O. G. Schmidt, Phys. Rev. B **83**, 121302(R) (2011).
[2] E. Zallo, R. Trotta, V. Křápek, Y. H. Huo, P. Atkinson, F. Ding, T. Šikola, A. Rastelli, and O. G. Schmidt, Phys. Rev. B **89**, 241303(R) (2014).
[3] Y. H. Huo, V. Křápek, A. Rastelli, and O. G. Schmidt, submitted.

HL 49.4 Wed 10:15 POT 151

**Conductivity Spectroscopy Examination of Metastable Hole Storing** — •Carsten Ebler, Simon Schlombs, Arne Ludgwig, and Andreas D. Wieck — Ruhr-Universität Bochum, Germany

Approaching the goal of a memory, storing single charge quantum, especially quantum dots are interesting. Therefore, we used epitaxial grown self-Assembled InAs QDs (SAQD) as crystalline hosts and compatibility with coupling to photons in contrast to amorphous semiconductors used in today's flash memories.

We established SAQDs in tunnel contact with an inverted GaAs, AlGaAs HEMT structure, manipulated the system with electronical and optical pulses and time resolved conductivity measurements were performed.

The experimental interaction with the device consists of a pulse train of non-resonant optical excitation of electrons and holes in the QDs and the wetting layer. The structure is appropriately biased, that the Fermi level is in electronical resonance with the X0 state in the QD to store one single hole. This hole state is read out over changes in conductivity in the HEMT in relation to carrier density in the QDs and the 2DEG.

It was possible to capture the hole state for at least 10 s and to read it out afterward. Further experimentation and different voltage pulses will give information about tunneling processes of the hole and electron states, dynamic of non-equilibrium states and time resolved exciton behavior.

HL 49.5 Wed 10:30 POT 151

**Time reordering of paired photons in a dressed three-level cascade** — •Samir Bounouar, Max Strauss, Alexander Carmele, Peter Schnauber, Alexander Thoma, Manuel Gschrey, Jan-Hindrik Schulze, André Strittmatter, Sven Rodt, Andreas Knorr, and Stephan Reitzenstein — Technische Universität, Berlin, Deutschland

We present the two-photon coherent control over a ladder-type three level system (ground state, exciton, biexciton in a quantum dot) at the level of single photons and single photon pairs through photon correlation spectroscopy. By collecting the photons coming from the different dressed states and by correlating them, we show that strong coupling of the laser field to the radiative cascade allows for the manipulation of the paired photons time ordering. Such an operation is crucial for the on-demand production of entangled photons "across" generation [1]. Moreover, two-photon Rabi oscillations of the dressed states population, due to the non-linear coherent driving of the radiative cascade, are observed. We also show that the single dressed states emission can be operated as a widely tunable single photon source without need of additional piezo-tuning techniques [2].

[1] J. E. Avron, Phys. Rev. Lett. 100, 120501 (2008), [2] S. Bounouar et al., arXiv:1610.08268v1 (2016).

**Coffee Break**

HL 49.6 Wed 11:15 POT 151

**Optical and theoretical investigation of fluorescence spectral diffusion of CdSe/CdS dotrods** — •Sven-Hendrik Lohmann, Christian Strelow, Tobias Kipp, and Alf Mews — Institut für Physikalische Chemie, Universität Hamburg, Grindelallee 117, 20146 Hamburg, Deutschland

Here we investigate the photoluminescence properties of individual chemically-synthesized dotrods, which consist of a spherical CdSe core enclosed by an elongated CdS shell. Time- and wavelength-resolved data were collected at low temperature to analyze the spectral diffusion of the emission. We observe a correlation between the energy and the decay time of the emission. This trend was modelled by theoretical calculations, which include migrating surface charges to describe the fluorescence jittering. Our model calculations show good agreement with our experimental studies.

HL 49.7 Wed 11:30 POT 151

**Implementation of single quantum dots into photonic struc-**

**tures for enhanced light extraction efficiency** — •Marc Sartison[1], Simone Luca Portalupi[1], Timo Gissibl[2], Michael Jetter[1], Harald Giessen[2], and Peter Michler[1] — [1]IHFG, IQ$^{ST}$ Center and SCoPE, University of Stuttgart — [2]4$^{th}$ Physics Institute and Research Center SCoPE, University of Stuttgart

Semiconductor quantum dots (QDs) have demonstrated their strength in being ideal candidates for quantum information purposes. However, the amount of light extracted from the semiconductor matrix is severely limited by the refractive index contrast at the semiconductor-to-air interface. Several successful efforts were made to overcome this limitation by fabrication of light extraction enhancing structures, such as micro-pillars or micro-lenses. To enhance the fabrication yield of such devices, deterministic techniques of randomly grown Stranski-Krastanov QDs were established. We present a novel approach for the deterministic placement of single QDs into light extraction enhancing structures with a fabrication yield close to 100%. The QDs are spatially and spectrally pre-selected and characterized in micro-photoluminescence, followed by a low-temperature photolithography step to define precisely placed alignment markers which are then clearly visible under the optical microscope at room temperature and allow performing further fabrication steps. Based on these markers, a 3D direct laser writing machine is aligned and micrometric-sized broadband solid immersion lenses are printed to enhance the extraction efficiency.

HL 49.8 Wed 11:45 POT 151

**Far-field and quality factor optimized GaAs-based photonic crystal cavities with high collection efficiencies** — •Stefan Hepp, Simone L. Portalupi, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology IQ$^{ST}$ and Research Center SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

The optical properties of semiconductor quantum dots (QDs) integrated in photonic crystal cavities can be further improved via cavity quantum electrodynamic effects. Therefore the realization of cavities with both high quality factor $Q$ and small modal volume $V$ are from interest to achieve a large enhancement factor. Efforts have been made to optimize the $Q$-factor that in some cases turns out to be detrimental for the collection efficiency because the related strong light confinement can lead to an inferior directivity for the out-of-plane emission. Here we present theoretical and experimental studies on the simultaneous optimization of the $Q$-factor and the far-field emission profile of the frequently utilized L3-photonic crystal cavity. We fabricated, characterized and compared cavities with different degree of optimization via $\mu$-PL and back focal plane imaging and show that the out-of-plane radiation profile can be optimized to an almost Gaussian distribution making the light collection effective and the efficient coupling to fibers available. Despite the far-field optimization, the Q-factors still reach values as high as 6x10$^3$ showing that a good compromise between a high Q-factor and a near optimal emission profile can be achieved.

HL 49.9 Wed 12:00 POT 151

**Spectroscopic Properties of CdTe Quantum Wires at Cryogenic Temperatures** — •Svenja Patjens, Andreas Nielsen, Philip Harder, Tobias Kipp, and Alf Mews — Institut für Physikalische Chemie, Universität Hamburg, Grindelallee 117, 20146 Hamburg, Germany

One-dimensional semiconductor quantum wires grown by the solution-liquid-solid (SLS) mechanism or similar methods typically consist of alternating segments of zinc blende and wurtzite phases. [1] Here, we investigate the optical properties of near phase-pure and polytypic cadmium telluride nanowires via confocal microscopy. The wurtzite phase distribution in the wires, prepared by the solution-solid-solid (SSS) method [2], was analyzed by means of high resolution transmission electron microscopy (HRTEM). Photoluminescence spectroscopy of single specimens at cryogenic temperatures (T <9 K) revealed several distinct features and spectral shifts with respect to measurements at room temperature. Low-temperature fluorescence spectra of WZ-phase and polytypic wires were compared in order to get an insight into the effect of phase-alternations and domain sizes. We gratefully acknowledge financial support by the DFG vie KI 1257/2 and ME 1380/16-3.

[1] D. Franz et al., Nano Lett., 2014, 14 (11), pp 6655-6659
[2] F. Wang et al., Nano Lett., 2016, 16 (2), pp 889-894

HL 49.10 Wed 12:15 POT 151

**Analyzing solid-state single-photon sources utilizing photon-number-resolving detectors** — •Marco Schmidt[1,2], Alexander Thoma[2], Martin von Helversen[2], Manuel Gschrey[2], Peter Schnauber[2], Jan-Hindrik Schulze[2], André Strittmatter[2], Jörn Beyer[1], Sven Rodt[2], Tobias Heindel[2], and Stephan Reitzenstein[2] — [1]Physikalisch-Technische Bundesanstalt, Abbestraße 1, 10587 Berlin, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

Non-classical light sources are versatile resources for applications in various research fields ranging from quantum communication to quantum metrology. In this context, a comprehensive knowledge of the quantum optical properties of the utilized sources is highly desirable. In this work, we employ a photon-number-resolving detection system based on a transition edge sensor (TES) [1] to analyze the photon statistics emitted by deterministic solid-state single-photon source. Our measurements enable us to reconstruct the photon number distribution emitted by the single-photon sources. The obtained results are compared with standard coincidence measurements using Si-based click-detectors.

[1]Lita, Adriana E. et al., Counting near-infrared single-photons with 95% efficiency, Optics Express, vol. 16, issue 5, p. 3032 (2008)

HL 49.11 Wed 12:30 POT 151

**Temperature influence on the behaviour of 1D, 2D and 3D quantum confined system** — •Parva Chhantyal[1,3], Laszlo Sajti[1], Carsten Reinhardt[1,3], Suraj Naskar[2,3], Dirk Dorfs[2,3], Nadja Bigall[2,3], and Boris Chichkov[1] — [1]Nanotechnology Department, Hollerithallee 8, D-30419 Hannover, Germany — [2]Leibniz University Hannover, Physical Chemistry, Callinstrae 3a, 30167 Hannover, Germany — [3]Laboratory for Nano and Quantum Engineering, Schneiderberg 39, 30167 Hannover, Germany

Semiconductor nanoparticles with size less than 10 nm have an interesting property, called quantum confinement, which represents the introduction of new properties to the materials by tuning their size and composition. In this research, an influence of temperature change on the behaviour of CdSe/CdS semiconductor nanoparticles is investigated. Initially, a comparative study of amplified spontaneous emission of these nanoparticles based on different sizes, such as dots, rods and platelets at room temperature is performed. The study is compared with respect to their sizes that provoke different absorption and emission spectra. The nanoparticles are spin coated on glass slides to make continuous films and then optically pumped by a 355 nm nanosecond laser. The fluorescence and laser emission spectra are measured and compared. Afterwards, the sample is heated up to different temperatures and subsequently, the influence of temperature on their emission spectra is compared for all three nanoparticles. Upon the observation of temperature influence on these nanoparticles, this approach can be adopted in real-life application as a temperature sensor.