HL 58: Quantum Dots: Optical Properties IV

Time: Wednesday 14:45–18:15 Location: POT 151

Invited Talk HL 58.1 Wed 14:45 POT 151

Towards an ideal semiconductor source of polarization entangled photons — •Fei Ding — Institute for Solid State Physics, Leibniz Universität Hannover, Germany — Institute for Integrative Nanosciences, Leibniz Institute for Solid State and Materials Research Dresden, Germany

Sources of polarization entangled photons are important components for building optical quantum networks [1]. Semiconductor quantum dots (QDs) are among the most promising sources due to several undeniable advantages. However, they are far from being ideal and several critical challenges need to be solved for practical applications.

In this talk I will review our recent efforts in developing a high yield, high fidelity and wavelength-tunable entangled photon sources. A large ensemble of as-grown entangled photon emitters can be obtained with a yield close to 100% and high entanglement fidelity (up to 0.9) [2]. The wavelength mismatching between different source can be solved by using a unique strain tuning technique [3,5]. The superior properties of these sources, combined with the possibilities of electrical injection [5] and on-chip integration [6], will eventually lead to the development of an ideal semiconductor entangled photon source.

[1] J.W. Pan et al. Rev. Mod. Phys. 84, 777 (2012) [2] R. Keil, M. Zopf, F. Ding* et al. arXiv:1611.03717 (2016) [3] F. Ding* et al. Phys. Rev. Lett. 104, 067405 (2010) [4] Y. Chen, F. Ding* et al. Nature Commun. 7, 10387 (2016) [5] J. Zhang, F. Ding* et al. Nature Commun. 6, 10067 (2015) [6] Y. Zhang, F. Ding* et al. Nano Lett. 16, 5785 (2016)

HL 58.2 Wed 15:15 POT 151

Linear and nonlinear spectroscopy of excitonic complexes in single self-assembled quantum dots — •Jens Kerski[1], Annika Kurzmann[1], Amran Al-Ashouri[1], Patrick A. Labud[2], Arne Ludwig[2], Andreas D. Wieck[2], Martin Geller[1], and Axel Lorke[1] — [1]Faculty of Physics and CENIDE, Universität Duisburg-Essen, Germany — [2]Chair of Applied Solid State Physics, Ruhr-Universität Bochum, Germany

The maximum resolution of images taken with an optical setup is given by *Abbe's diffraction limit.* This can be overcome by using nonlinear processes as demonstrated by the semiconductor industry and in STED-microscopy.

In this work, we use linear and nonlinear photoluminescence spectroscopy to image a single self-assembled InAs/GaAs quantum dot (*QD*). In self-assembled QDs the recombination intensity of different excitonic radiative transitions depends nonlinearly on the excitation power. Due to this nonlinearity, we show here an increased spatial resolution of the optical imaging of a single QD. The experimental results are supported by empirical simulations, implemented for this work. This mechanism can easily be adapted to nanoparticles and other systems which exhibit a nonlinear dependence of their emitted radiation on the excitation power. Furthermore, an unexpected effect is observed indicating a specific angle dependence of the radiations of different excitonic states.

HL 58.3 Wed 15:30 POT 151

InGaAs quantum dots as light source for silicon photonics — •Norbert Witz, Matthias Paul, Jan Kettler, Michael Jetter, Simone L. Portalupi, and Peter Michler — IHFG, IQST Center and SCoPE, University of Stuttgart

One of the greatest needs of silicon photonics is an efficient light source, since many other functionalities have been already demonstrated and optimized. Indeed, being an indirect bandgap material, the photon emission in silicon is a three particle process thereby resulting in low efficient light emission. An attractive alternative is found in III/V semiconductor materials, which exhibit excellent optical properties. Especially semiconductor quantum dots (QDs) are promising candidates for this task. Adjusting the growth conditions, it is possible to tailor QD size and shape so that the emission wavelength shifts into the telecom O- or C-band at 1.3μm or 1.55μm. Because of the large lattice mismatch, monolithical growth of III/V materials on silicon substrate causes the formation of defects, which could prevent the efficient photon emission from the QDs. To evade this problem, III/V light sources grown by metal-organic vapour-phase epitaxy (MOVPE) have been directly glued onto a silicon chip. The emitted light is coupled into a single-mode waveguide by a diffractive Bragg grating, optimized for the spectral range of the glued sample. In order to fabricate a compact device, it is inevitable to excite the light source electrically. For this reason electrically pumped samples, with InGaAs QDs serving as an active medium have been developed.

HL 58.4 Wed 15:45 POT 151

Deterministic integration of quantum dots into on-chip waveguides and beamsplitters by in-situ electron beam lithography — •Peter Schnauber[1], Oliver Kirsch[1], Ronny Schmidt[1], Arsenty Kaganskiy[1], Andre Strittmatter[2], Sven Rodt[1], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany — [2]Abteilung für Halbleiterepitaxie, Otto-von-Guericke Universität, 39106 Magdeburg, Germany

On-chip waveguides and beamsplitters have proven to be suitable to realize basic quantum logic circuits. Moreover, quantum dots (QDs) can be integrated into such on-chip elements to act as quantum light sources. In order to efficiently couple the QD's emission into a waveguide, the QD's lateral position inside a thin waveguide must be precisely controlled. When integrating multiple QDs in complex waveguide circuits it is important to preselect and fine-adjust their emission wavelength to achieve for instance two-photon interference which is necessary for quantum gate operation. A spatially and spectrally deterministic integration of QDs into waveguides can be achieved by in-situ electron beam lithography (EBL)[1]. By applying our method, QDs are preselected by means of helium-temperature cathodoluminescence spectroscopy right before waveguides and beamsplitters are patterned in-situ with the naturally high resolution of EBL. Special care is taken to optimize the surface roughness of such low-temperature-patterned structures.

[1] M. Gschrey et al., Nat. Commun. 6, 7662 (2016)

HL 58.5 Wed 16:00 POT 151

Influence of morphology on InAlGaAs quantum dots emitting at telecom wavelength — •Christian Carmesin[1], Marco Schowalter[2], Vitalii Sichkovskyi[3], Mohamed Benyoucef[3], Daniel Mourad[1], Michael Lorke[1], Tim Grieb[2], Knut Müller-Caspary[2], Johann Peter Reithmaier[3], Andreas Rosenauer[2], and Frank Jahnke[1] — [1]Institute for Theoretical Physics, University of Bremen — [2]Institute of Solid State Physics, University of Bremen — [3]Institute of Nanostructure Technologies and Analytics, University of Kassel

Self-organized quantum dots are promising candidates for the realization of deterministic single photon sources with high repetition rate and tunable emission energy due to the advantage of integrability into electrical devices. We have characterized a new and promising material system of InAs/InAlGaAs/InP based quantum dots and identified dominant contributions to the connection between morphology and optical properties. For this purpose, experimentally determined photoluminescence spectra are compared to results of atomistic tight-binding calculations using a one hundred million atom supercell. Structure und composition characteristics of the system are obtained from high-resolution scanning transmission electron microscopy of a single representative quantum dot. We have identified concentration fluctuations among different quantum dots of the ensemble as the main source of inhomogeneous broadening.

Coffee Break

HL 58.6 Wed 16:45 POT 151

Inversion of permanent exciton dipole moment in self-assembled In(Ga)As quantum dots by nonlinear piezoelectricity — Johannes Aberl[1], •Petr Klenovsky[2,3], Johannes S. Wildmann[1], Javier Martin-Sanchez[1], Thomas Fromherz[1], Eugenio Zallo[4,5], Josef Humlicek[2,3], Armando Rastelli[1], and Rinaldo Trotta[1] — [1]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Altenbergerstraße 69, A-4040 Linz, Austria — [2]Department of Condensed Matter Physics, Masaryk University, Kotlářská, CZ-61137 Brno, Czech Republic — [3]Central European Institute of Technology, Masaryk University, Kamenice 753/5, CZ-62500 Brno, Czech Republic — [4]Institute for In-

tegrative Nanosciences, IFW Dresden, Helmholtzstraße 20, D-01069 Dresden, Germany — [5]Paul-Drude-Institut für Festkörperelektronik, Hausvogteilplatz 5-7, 10117 Berlin, Germany

We show tuning of the electric dipole moment of excitons confined in self-assembled In(Ga)As quantum dots by anisotropic biaxial stress up to complete erasure of its magnitude and inversion of its sign. We attribute this effect to the piezoelectricity due to applied stress, the magnitude of which we estimate using a simple model based on the piezotronic effect. Self-consistent $\vec{k}.\vec{p}$ calculations reveal that the strain-induced changes of the dipole moment in our QDs that we observe can be only accounted for by the nonlinear piezoelectric effect, the importance of which in QD-physics has been theoretically recognized but it proved to be difficult to single out experimentally.

HL 58.7 Wed 17:00 POT 151

Two-photon interference from deterministically fabricated remote quantum dot microlenses — •Peter Schnauber[1], Alexander Thoma[1], Jonas Boehm[1], Manuel Gschrey[1], Jan-Hindrik Schulze[1], Andre Strittmatter[2], Sven Rodt[1], Tobias Heindel[1], and Stephan Reitzenstein[1] — [1]Institut fuer Festkoerperphysik, Technische Universitaet Berlin, Hardenbergstrasse 36, 10623 Berlin, Germany — [2]Abteilung fuer Halbleiterepitaxie, Otto-von-Guericke Universitaet, 39106 Magdeburg, Germany

Two-photon interference (TPI) is of fundamental importance for the realization of quantum communication schemes such as the quantum repeater. Here, we report on TPI experiments in Hong-Ou-Mandel configuration using deterministically fabricated, remote single-photon sources [1]. By using 3D in-situ electron-beam lithography, we fabricate quantum-light sources at desired wavelengths by integrating preselected semiconductor quantum dots into monolithic microlenses. Exciting the quantum dot microlenses into their p-shell at 80 MHz, the individual "single photon" sources exhibit TPI visibilities of 49 % and 22 %, respectively. When examining the TPI of photons emitted by two remote sources, we measure an uncorrected TPI visibility of 29 %. This agrees with the visibility predicted from the dephasing of the individual emitters. Due to the broadband increase in photon extraction efficiency ($>$ 20 nm), quantum dot microlenses are a promising technology platform for future entanglement swapping experiments employing entangled photon pairs from remote biexciton-exciton radiative cascades.

[1] A. Thoma et al., arXiv:1611.06859, 2016

HL 58.8 Wed 17:15 POT 151

Coherent Control of a Photonic Crystal Microresonator with Electric Readout — Wadim Quiring[1], •Björn Jonas[1], Jens Förstner[1], Ashish K. Rai[2], Dirk Reuter[1], Andreas D. Wieck[2], and Artur Zrenner[1] — [1]Center for Optoelectronics and Photonics Paderborn (CeOPP), Universität Paderborn, Paderborn, Germany — [2]Ruhr-Universität Bochum, Bochum, Germany

We present coherent two pulse experiments on GaAs photonic crystal microresonators. The MBE-grown structures have a membrane, which is designed as a n-i layer with an embedded InGaAs quantum well. Metallic contacts with 50 nm dimensions have been processed by e-beam lithography in order to realize a local Schottky gate on the central part of the microresonator. The resulting structures allow for photocurrent detection of cavity excitations at Q-factors around 5000. [1] Resonant and detuned two-pulse ps-laser excitation is used for the coherent excitation and manipulation of the cavity, which is monitored by photocurrent detection via the built-in quantum well. We are able to measure the amplitude and phase of the cavity excitation as a function of the detuning. Our experimental findings are well described by an analytical theory, in which the cavity is treated as a dissipative two-level system. We further show, that our phase sensitive experiments can also be successfully performed at room temperature, which makes real-world applications of cavity based phase control and frequency discrimination feasible.

[1] W. Quiring et al., Appl. Phys. Lett. 107, 041113 (2015)
[2] W. Quiring et al., Optics Express 24, 20672 (2016)

HL 58.9 Wed 17:30 POT 151

Towards the optimization of photodetectors based on ZnO nanowires functionalized with Carbon Nanoparticles (C-Dots) — •Kseniia Zimmermann[1], Davide Cammi[1], Rene Gorny[1], Angelina Vogt[1], Frank Dissinger[2], Siegfried Waldvogel[2], and Tobias Voss[1] — [1]Braunschweig, Institut für Halbleitertechnik, Germany — [2]Johannes Gutenberg-Universität Mainz, Institut für Organische Chemie, Germany

Carbon nanoparticles (C-dots) have been first discovered in 2004 by Xu. et al. as a side product during the synthesis of single-wall carbon nanotubes. Since then, they have gained huge attention due to their tunable optical properties, low toxicity and the availability of a variety of relatively easy preparation methods. Today, C-dots are considered to be promising candidates for color conversion in LEDs, as well as further applications in pharmacy and photonic. In this work, the optical properties of different colloidal carbon dots have been investigated and it has been found, that the absorption and emission properties strongly depend on the stabilizing (ligand) molecules, the nature of the solvent and the pH-value of the solution. The C-Dots were subsequently attached to the surface of hydrothermally grown ZnO nanowires in order to study electron transfer processes in the hybrid system. Compared to unfunctionalized nanowires, we have observed enhanced photoconductivity in the hybrid devices under irradiation with photon energies below the band gap energy of the ZnO nanowires, down to 2.1 eV. Such hybrid organic/inorganic structures may be used for light-harvesting and in photodetectors.

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An electrically controlled single-photon source driven by an on-chip integrated quantum dot microlaser — •Pierce Munnelly[1], Tobias Heindel[1], Martin Kamp[2], Sven Höfling[2], Christian Schneider[2], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universtität Berlin, Germany — [2]Technische Physik, Universität Würzburg, Würzburg, Germany

Quantum dot micropillar cavities are of great interest with respect the realization of high-β microlaser and non-classical light sources. Beyond this, they can also act as active elements in integrated quantum optics schemes, in which they can be monolithically fabricated together with other electro-optical components to form, for instance, compact, resonantly driven single photon sources.

In the present work, we report on an electrically triggered, monolithically integrated whispering gallery mode (WGM) laser which drives a c-QED enhanced single photon source (SPS) on a chip. In our concept, lateral emission from the WGM laser excites a quantum dot in a laterally displaced (by 10 μm) micropillar cavity which acts as an efficient, vertically emitting SPS. Via an additional electrical contact applied to the displaced micropillar, we are able to eletro-optically control the SPS via the quantum-confined Stark effect. In this configuration we demonstrate fast spectral resonance tuning and triggered single photon emission of an on-chip driven quantum dot micropillar cavity.

HL 58.11 Wed 18:00 POT 151

Degradation of semiconductor nanowire lasers upon optical pumping — •Maximilian Zapf, Robert Roeder, and Carsten Ronning — Institute of Solid State Physics, Friedrich Schiller University Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Semiconductor nanowires (NWs) are promising candidates for nanoscale coherent light sources in future optoelectronic devices, as they inherently provide the necessary compounds of a laser system such as optical gain and a resonator-like structure. The optical output intensity of a semiconductor NW follows the pump power dependency of a multimode laser system upon moderate optical pumping [Geburt et al., Nanotechnology 23, 365204 (2012)]. However, for extremely high pump powers a material degradation of the laser gain material induces an unambiguous deviation from this dependence. Yet, experiments and future applications require a degradation-free lasing operation in order to retain reliable and durable devices. Thus, we developed a method for identifying the threshold value of any degradation process and its underlying physics. Furthermore, a critical temperature for a NWs' applicability as nano laser can be determined by evaluating the temperature dependence of both the lasing and the degradation threshold.