HL 46: Quantum dots and wires: Optical properties III

Time: Thursday 15:00–17:45 Location: A 151

HL 46.1 Thu 15:00 A 151

Ultrasensitive, high spectral resolution photocurrent spectroscopy of single QDs — •Sebastian Krehs[1], Alex Widhalm[1], Amlan Mukherjee[1,2], Björn Jonas[1], Nand Lal Sharma[1], Peter Kölling[2], Andreas Thiede[2], Jens Förstner[2], Dirk Reuter[1], and Artur Zrenner[1] — [1]Physics Department, University of Paderborn — [2]Department of Electrical Engineering, University of Paderborn, Paderborn 33098, Germany

Single InGaAs QDs embedded in electric field tunable structures allow for the realization of new coherent optoelectronic functionalities [1, 2]. In optical experiments on single QD photodiodes the exciton ground state transition appears as a two-level system with an almost lifetime limited linewidth of a few μeV. The measurement of the ground state occupancy can be performed quantitatively via photocurrent (PC) detection. Refinements of this method enabled us to improve its sensitivity down to the fA range. Resonant cw laser spectroscopy with high spectral resolution allows us to investigate the linewidth of QDs at very low excitation powers and at exceptionally low tunneling rates. Combined with PC detection we are able to demonstrate exciton linewidth down to 1.62 μeV. This result is close to the Fourier transform limit of the QD linewidth [3]. Ultrasensitive PC measurements at extremely low tunneling rates may be used in the future to perform the frequency stabilization of single photon emitters.

Ref:[1] A. Zrenner et al., Nature 418, 612 (2002). [2] S. de Vasconcellos et al., Nature Photonics 4, 545 (2010). [3] A.V. Kuhlmann et al. Nature Physics 9, 570-575 (2013).

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White light coherent 2D-spectroscopy on electrically pumped semiconductor nanostructures — Mirco Kolarczik, •Kevin Thommes, Bastian Herzog, Sophia Helmrich, Nina Owschimikow, and Ulrike Woggon — Institut für Optik und Atomare Physik, Technische Universität Berlin, Germany

InAs/GaAs nanostructures are an established material system for the fabrication of opto-electronic devices. Coherent and incoherent coupling mechanisms between the subsystems of different dimensionality (3D, 2D, and 0D) are the backbone of their functionality. We developed a setup for collinear two-dimensional coherent spectroscopy based on broadband laser pulses from a fiber laser system to address the complexity of such active media under operating conditions. We investigate Stranski-Krastanov grown InAs quantum dots in an InGaAs quantum well forming the active medium in the waveguide structure of a semiconductor optical amplifier. This device allows to control the inversion state of the optical transitions by electrical carrier injection. We observe the evolution of the homogeneous linewidth of the optical transitions in the inhomogeneously broadened quantum dot ensemble under variation of the initial inversion. Additionally, our broadband laser pulses allow us to observe coherent coupling of the quantum dot ground state and excited state separated by 70 meV.

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Exciton dynamics in InAs(Sb)/GaAs submonolayer stacks — •Bastian Herzog[1], Fuad Alhussein[1], Benjamin Lingnau[2], Mirco Kolarczik[1], Sophia Helmrich[1], David Quandt[3], Udo Pohl[3], André Strittmatter[4], Olaf Brox[5], Markus Weyers[5], Ulrike Woggon[1], Kathy Lüdge[2], and Nina Owschimikow[1] — [1]Institut für Optik und atomare Physik, Technische Universität Berlin — [2]Institut für theoretische Physik, Technische Universität Berlin — [3]Institut für Festkörperphysik, Technische Universität Berlin — [4]Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg — [5]Ferdinand Braun Institut, Leibniz Institut für Höchstfrequenztechnik Berlin

The deposition of InAs as a submonolayer (SML) superlattice into a GaAs matrix creates an electronic potential landscape with hetero-dimensionally confined charge carriers. While holes are fully trapped inside the In-rich agglomerations, electrons are freely moving within an effective two-dimensional reservoir leading to ultrafast carrier relaxation time scales and a strong coupling of occupation and absorption dynamics. The emission lines of these structures are relatively narrow. Via the doping of antimony (Sb) atoms into these In-agglomerations the emission linewidth is strongly enhanced. In photoluminescence experiments, we show that while the recombination dynamics in the Sb-doped SML stacks is altogether slowed down compared to undoped SMLs, general SML-specific features like lateral mobility of carriers and large amplitude-phase coupling are maintained.

HL 46.4 Thu 15:45 A 151

Nonlinear modulation of PbS/CdS quantum dots observed by sideband pump-probe technique — •Mirco Kolarczik[1], Christian Ulbrich[1], Pieter Geiregat[2], Yunpeng Zhu[2], Laxmi Kishore Sagar[2], Akshay Singh[3], Bastian Herzog[1], Alexander W. Achtstein[1], Xiaoqin Li[3], Dries van Thourhout[2], Zeger Hens[2], Nina Owschimikow[1], and Ulrike Woggon[1] — [1]Technische Universität Berlin, Germany — [2]Ghent University, Belgium — [3]University of Texas, Austin, Texas, United States

Optimizing active materials for GBit/s and Tbit/s rates in optical telecommunications demands a characterization of the material on ultrafast timescales. Colloidal PbS/CdS quantum dots (QDs) are a promising system for nanophotonic applications in the near infrared. For characterization purposes, spin-coating of quantum dots onto silicon nitride waveguides is an easy way to integrate nanocrystals into optical fiber networks. However, the overlap of the QDs and the waveguide mode is comparatively small, posing challenges to ultrafast spectroscopy. Douple-chop pump-probe setups provide high sensitivity, but usually lack the phase-sensitivity of heterodyne detection setups. Our hybrid setup provides both: Two parallel lock-in units detect the main heterodyne band and a pump-dependent sideband. Analog signal pre-conditioning allows for the detection of amplitude modulations in the range of 10^{-5} and corresponding phase-shifts of few arcseconds. While the ground state lifetime of PbS/CdS QDs is on the microsecond timescale, we observe fast sub-nanosecond modulation due to Auger effects and biexciton decay for high laser repetition rates (75 MHz).

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The Influence of the Individual Particles on the Ensemble Quantum Yield of Elongated CdSe/CdS Core/Shell Nanoparticles — •Alexandra Hinsch[1], Christian Strelow[1], Tobias Kipp[1], Christian Würth[2], Daniel Geissler[2], Ute Resch-Genger[2], and Alf Mews[1] — [1]Universität Hamburg, Grindelallee 117, 20146 Hamburg, Deutschland — [2]Bundesanstalt für Materialforschung und -prüfung, Richard-Willstätter-Straße 11, 12489 Berlin, Deutschland

Colloidal semiconductor nanoparticles with a spherical core and an elongated shell form bright emitters with a high absorption cross section. They show great potential for a multitude of opto-electronic applications such as LEDs or photovoltaic cells and can be used as gain material or as markers for bio imaging. For most of these applications high fluorescence quantum yields are a figure of merit for the emitter quality. Our previous work showed that the ensemble quantum yields depend strongly on the shell size and the excitation wavelength [1]. In this work we investigate how the ensemble quantum yield is affected by the properties of the individual particles. In particular, we prove the role of non-emitting particles as well as the role of blinking. Using a combination of AFM and spatially resolved photoluminescence spectroscopy we measured hundreds of individual CdSe/CdS dot/rod particles of different shell lengths exciting with two different excitation wavelengths for shell or core excitation, respectively.

[1] D. Geißler, C. Würth, C. Wolter, H. Weller, U. Resch-Genger, Physical Chemistry Chemical Physics 2017, 19, 12509-12516.

15 min. break.

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Frequency Feedback for Two-photon Interference from Separate Quantum Dots — •Michael Zopf[1], Tobias Macha[2], Robert Keil[1], Eduardo Uruñuela[2], Yan Chen[1], Wolfgang Alt[2], Lothar Ratschbacher[2], Fei Ding[1,3], Dieter Meschede[2], and Oliver G. Schmidt[1,4] — [1]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany — [2]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn, Germany — [3]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [4]Merge Technologies for Multifunctional Lightweight Structures, Technische Universität Chemnitz, 09107 Chemnitz, Germany

We employ frequency feedback to stabilize the single-photon emission of two separate, strain-tunable quantum dots to an atomic standard. Their transmission through a single rubidium-based Faraday filter serves as an error signal for frequency stabilization to less than 1.5 % of the emission linewidth. The long-term stability is demonstrated by two-photon interference between two quantum dots. The observed visibility of $V_{\text{lock}} = (41 \pm 5)$ % agrees with theoretical predictions. Our approach facilitates the way towards quantum networks with indistinguishable photons from different emitters.

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Quantum dots for silicon photonics: A new approach of telecom light for sensing applications — •Norbert Witz, Fabian Olbrich, Sascha Kolatschek, Simone Luca Portalupi, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und funktionelle Grenzflächen (IHFG), Research Centers SCoPE and IQST, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Almost 100 years after the formulation of quantum mechanics, physicists face the challenge of finding possible utilizations of the theory. Beside the most prominent applications, quantum-cryptography and quantum-computing, a different class has emerged in the recent years, which employs quantum mechanical states for sensing. As shown in theory and first experiments, quantum sensing can beat the classical counterpart in terms of sensitivity and facilitate precise measurements of various physical quantities beyond the shot noise limit. The highly developed silicon platform, which has been utilised extensively for classical sensing on biological and chemical systems is also a promising candidate for quantum sensing. Therefore, non-classical light from semiconductor quantum dots grown by metal organic vapour phase epitaxy (MOVPE) with emission wavelength in the telecom bands will be sent by direct fiber-chip coupling to a photonic integrated circuit, implemented on the silicon platform. Single photons from a quantum dot will be funneled into different waveguide-based structures, with the perspective of realizing quantum sensing on chip.

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Pure single-photon emission from InGaAs QDs in a tunable fiber-based external mirror microcavity — •Thomas Herzog[1], Marc Sartison[1], Sascha Kolatschek[1], Stefan Hepp[1], Alexander Bommer[2], Christoph Pauly[3], Frank Mücklich[3], Christoph Becher[2], Simone Luca Portalupi[1], Michael Jetter[1], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Universität des Saarlandes, Fachrichtung 7.2 (Experimentalphysik), Campus E2.6, 66123 Saarbrücken, Germany — [3]Lehrstuhl für Funktionswerkstoffe, Materialwissenschaft und Werkstofftechnik, 66123 Saarbrücken Germany

Cavity QED is extensively used in many solid-state systems in order to improve the quantum-emitter performances and accessing interesting physical regimes. It is essential that the cavity mode matches the emitter wavelength perfectly. In this work, we present an open fiber-based Fabry-Pérot cavity with a finesse of 140 coupled to single-photon emission by In(Ga)As quantum dots. We are able to match every emitter inside the cavity spatially and spectrally by precisely tuning the cavity in subnanometric resolution. Additionally, by using state-of-the-art photolithography we are able to deterministically relocate selected emitters. This allows comparing their behavior in resonance to the cavity and without any cavity effects. We find Purcell enhancement up to a factor of 4.5, while still having single-photon emission with a second-order correlation function limited only by the detector noise.

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Back-Focal-Plane Imaging on ZnO-Nanowires — •Christian Zietlow[1], Robert Röder[1], Maximilian Zapf[1], Robert Buschlinger[2], Ulf Peschel[2], and Carsten Ronning[1] — [1]Institute of Solid State Physics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Institute for Solid State Theory and -Optics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Semiconductor nanowires (NW) are one of the smallest lasing sources and thus gained a lot of attention in order to achieve the required future miniaturization of optoelectronic devices. Light-matter interaction in NWs and their angular emission distribution are determined by the operating transverse laser mode and thus to the polarization of the propagating light. Since single ZnO NWs provide gain material combined with a Fabry-Pérot-Cavity, coherent laser emission can be achieved by optical pumping. The laser emission is most pronounced at the end-facets such that both interfere similar to Young*s double-slit experiment. The emerging pattern is used to characterize the transverse NW lasing modes via Fourier optics in angular-resolved Microphotoluminescence. In addition to this back-focal-plane imaging, the Stokes parameters for individual modes can be determined giving an insight into the field distribution in the NW. These results are compared to measurements performed in head-on geometry [NanoLett.2016, 16, 2878-2884] that measure the field distribution of the emission emerging out of one end-facet in direction of the NW axis. Combining both techniques provides a broader understanding of transversal mode properties

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Deterministic implementation of a bright, on-demand single-photon source with near-unity indistinguishability via quantum dot imaging — •Stefan Gerhardt[1], Yu-Ming He[2], Jin Liu[3,4,5], Sebastian Maier[1], Monika Emmerling[1], Marcelo Davanço[3], Kartik Srinivasan[3], Christian Schneider[1], and Sven Höfling[1,2,6] — [1]Technische Physik, Physikalisches Institut and Wilhelm Conrad Röntgen-Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]University of Science and Technology of China, Hefei, Anhui 230026, China — [3]Center for Nanoscale Science and Technology, National Institute of Standards and Technology, Gaithersburg, Maryland 20899, USA — [4]Maryland NanoCenter, University of Maryland, College Park, Maryland 20742, USA — [5]School of Physics, Sun-Yat Sen University, Guangzhou 510275, China — [6]SUPA, School of Physics and Astronomy, University of St Andrews, St Andrews, KY16 9SS, United Kingdom

We report on the observation of bright emission of single photons generated via pulsed, resonance fluorescence conditions from a quantum dot deterministically centered in a micropillar cavity device via nanoscale quantum dot imaging. The brightness of the QD fluorescence is greatly enhanced on resonance with the fundamental mode of the pillar, leading to an extraction efficiency of $\nu = (49 \pm 4)\,\%$ for a single photon emission as pure as $g^(2)(0) = 0.015 \pm 0.009$ with a two-photon wave packet overlap up to $\nu = (94 \pm 3)\,\%$.