HL 4: Quantum dots and wires: Optical properties I

Time: Monday 9:30–13:00 Location: EW 201

HL 4.1 Mon 9:30 EW 201

Temperature-dependent investigations of the emission properties of InAs/InGaAs quantum dots in the telecom C-band

— •Cornelius Nawrath, Fabian Olbrich, Matthias Paul, Simone Luca Portalupi, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart

Over the last decades quantum dots (QDs) have proven to be promising candidates as single-photon emitters for applications like quantum computing and quantum communication. The prerequisites for this perspective, namely entangled photon generation and high indistinguishability have been shown to be feasible.

In the past, research has focused on QDs emitting around 900nm. For long-distance applications, however, emission around 1550nm (telecom C-band) is preferable, due to the global absorption minimum of the existing fiber network.

This talk presents recent progress for InAs QDs on a GaAs substrate using a metamorphic buffer. Their temperature stability is investigated by means of ensemble photoluminescence (PL) and μPL measurements. The thermal activation of charge carriers of the QD ensemble and the single dots is monitored. Furthermore, the individual behaviour of certain transitions is explored, pointing towards the presence of charge carrier traps in the vincinity of the QDs. Ultimately the single-photon nature of the emission is shown up to 77K and the different emission lines are identified.

HL 4.2 Mon 9:45 EW 201

InP-based coupled quantum well - quantum dot structures for 1.55 μm high speed laser applications

— •Sven Bauer[1], Vitalii Sichkovskyi[1], Wojciech Rudno-Rudziński[2], Grzegorz Sek[2], and Johann Peter Reithmaier[1] — [1]Technische Physik, Institute of Nanostructure Technologies and Analytics (INA), CINSaT, University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Institute of Physics, Wrocław University of Technology, Wybrzeze Wyspiańskiego 27, 50-370 Wrocław, Poland

The performance of directly modulated quantum dot (QD) lasers, used for 1.55 μm telecommunication, is limited by the intraband carrier relaxation time. To improve it, one might use a so called tunnel injection (TI) scheme. Carriers are captured and relax in a quantum well (QW) and tunnel through a thin barrier for recombination into the QDs. In order to get a better understanding of the involved mechanisms, coupled QW-QD structures have been grown on Fe-doped InP substrates. These consist of a InGaAs QW, a thin InAlGaAs barrier, both lattice matched to InP, and InAs QDs. Samples with varying QW and barrier thicknesses were grown, in order to determine the best TI structure candidate to implement into a high speed QD laser design. These were investigated with photoluminescence and photoreflectance spectroscopy. Atomic force microscopy was used to determine the influence of the QD morphology on their emission behavior. The influence of the band alignment and coupling strength on the emission behavior could be shown. An incorporation of the optimum TI structure into an actual laser design showed promising properties.

HL 4.3 Mon 10:00 EW 201

Determination of the two-photon interference visibility of remote quantum emitters: The influence of temporal correlations

— •J. H. Weber, J. Kettler, H. Vural, S. L. Portalupi, M. Jetter, and P. Michler — IHFG, IQ$^{\mathrm{ST}}$ Center and SCoPE, Universität Stuttgart

Two-photon interference (TPI) with photons from remote quantum emitters is of key importance for upscaling of photonic quantum information schemes. On this respect, the photon indistinguishability of the overall emission is the key property which is typically measured via photon correlation exploiting the Hong-Ou-Mandel effect. However, temporal dynamics in emitter brightness and blinking of the emission result in unexpected correlation statistics. Such temporal correlations are frequently observed in several solid state sources being then fundamental to understand their effect on the measured statistics. In this study, we perform TPI with two remote semiconductor quantum dots and fully reproduce the resulting Hong-Ou-Mandel measurement not only via a developed analytical approach but also via Monte Carlo simulation. We show how both blinking and dynamic changes in brightness affect the temporal correlation. As it is then possible to predict the outcome, we show how to securely extract the TPI contrast from a single measurement. Moreover, a novel setup scheme is shown, which allows for blinking- and brightness-independent extraction of the TPI contrast. Even though, this report is based on semiconductor quantum dots as single-photon emitter, all findings can be directly transferred to any kind of quantum emitter.

HL 4.4 Mon 10:15 EW 201

Single photons from a quantum dot interacting with an atomic vapor: model and simulation

— •Julian Maisch[1], Hüseyin Vural[1], Simone L. Portalupi[1], Simon Kern[1], Jonas Weber[1], Michael Jetter[1], Jörg Wrachtrup[2], Robert Löw[3], Ilja Gerhardt[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, IQST and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart — [2]3. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart — [3]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart

For future quantum network applications, hybrid quantum systems provide promising capabilities. One example for such a system is the interface between single photons from a quantum dot (QD) and an alkali vapor as storage medium. In any application, it is essential to know the properties of the investigated photons.

Therefore, a detailed investigation of the photon-atom interaction is necessary. Beyond experimental results, numerical simulations embody a powerful tool for this task. The presented framework adapts the description of particle diffusion to take the effects of spectral diffusion in a QD into account. Moreover, the influence of the vapor is considered via the complex refractive index. Altogether, all realized experimental observations (time-correlated single-photon measurements and two-photon interference measurements) can be understood on one basis. Additionally, the simulations can be possibly extended for the description of photon propagation in other media.

HL 4.5 Mon 10:30 EW 201

Unusual transitions in a QD induced by spatially structured laser beams

— •Matthias Holtkemper, Doris E. Reiter, and Tilmann Kuhn — Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster

The discrete states in semiconductor quantum dots (QDs) can be used to implement proposals from quantum information processing. We show in this contribution, that the optical control of QDs can profit from the excitation using spatially structured laser beams, such as Bessel or Hermite-Gaussian beams, by enabling the optical access to otherwise geometry-forbidden transitions. To be specific, we study selection rules induced by Bessel beams of a topological charge up to two within an analytical QD model. Next, we expand our model by including Coulomb interactions and valence band mixing within a configuration interaction approach. A weakening of the strict selection rules and thereby an increased number of addressable exciton states is found. We discuss the influence of the beam shape by a comparisons between Hermite-Gaussian and Bessel beams, the influence of a positioning of the beam axis away from the QD center and differences in absorption for differently charged QDs. In summary, we present an overview about the new possibilities that arise from QD excitations with spatially structured laser beams.

HL 4.6 Mon 10:45 EW 201

High-Q micropillars with a controlled number of deterministically grown quantum dots

— •Arsenty Kaganskiy, Fabian Gericke, Tobias Heuser, Tobias Heindel, Xavier Porte, and Stephan Reitzenstein — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623

We report on the realization of micropillars with site-controlled quantum dots (SCQDs) in the active layer. The SCQDs are grown via the buried stressor approach which allows for the positioned growth and device integration of a countable number of QDs with high optical quality. This concept is very powerful as the number and the position of SCQDs in the cavity can be simultaneously controlled by the design of the buried stressor. The fabricated micropillars exhibit high position control of the QD growth combined with Q-factors of up to 12000. The cavity Q-factor, Purcell factor and photon-extraction effciency are analyzed as a function of the aperture diameter demonstrating an additional oxid-aperture-induced mode confinement in the microcavity. Single-QD Purcell enhancement of the emission is investigated via temperature-induced resonance-tuning resulting in a Purcell factor of 4.3 ± 0.3. [1]

[1] A. Kaganskiy et al., arXiv:1711.09235 (2017)

15 min. break.

HL 4.7 Mon 11:15 EW 201

Spectroscopic Properties of Semiconductor 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

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. This effect results in potential variations, which in turn may influence the optical properties of these materials.[1] Here, we spectroscopically investigate phase-pure and polytypic cadmium telluride nanowires via confocal microscopy. The crystal phase distribution throughout single wires was analyzed by means of high resolution transmission electron microscopy (HRTEM). These single nanostructures revealed several distinct features and spectral shifts, when being spectroscopically analyzed at cryogenic temperatures. The fluorescence spectra were correlated to HRTEM images in order to get an insight into the effect of phase-alternations and domain sizes. We gratefully acknowledge financial support by the DFG via KI 1257/2 and ME 1380/16-3.

[1] D. Franz et al., Nano Lett., 2014, 14 (11), pp 6655-6659.

HL 4.8 Mon 11:30 EW 201

High Contrast Differential Reflection Measurements on a Single Quantum Dot — •Pia Eickelmann[1], Annika Kurzmann[1], Rüdiger Schott[2], Andreas D. Wieck[2], Arne Ludwig[2], Axel Lorke[1], and Martin Geller[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Lotharstraße 1, 47057 Duisburg — [2]Chair of Applied Solid State Physics, Ruhr-Universität Bochum, Universitätsstraße 150, 44780 Bochum, Germany

Excitons in semiconductor quantum dots (QDs) are promising candidates for the realization of quantum information technologies. Resonance fluorescence is a widely used possibility to address single excitons, where the laser background is suppressed by cross-polarization of two polarizers. Another possibility is differential reflection, where the ratio between the signal of a single QD and the reflected laser light is determined by lock-in technique. However, this technique was limited to low contrasts between QD photons and back-scattered laser light in the order of 10 % [A. N. Vamivakas, et al., Nano Lett. 7, 2892 (2007)].

In this talk we present an optimized sample structure which significantly increases the collection efficiency of the QD photons. A distributed Bragg reflector and an epitaxially grown gate allows us to measure contrasts up to more than 80 %, in confocal rejection even exceeding 800 %. It enables us to perform measurements on a single dot without the modulation of the lock-in technique. These findings open up the possibility to obtain optical measurements on single QDs without the need of suppressing the backscattered laser light.

HL 4.9 Mon 11:45 EW 201

Fully On-Chip Hanbury-Brown and Twiss Experiment with Semiconductor Quantum Dots — •Florian Hornung[1], Mario Schwartz[1], Ekkehart Schmidt[2], Stefan Hepp[1], Ulrich Rengstl[1], Simone Luca Portalupi[1], Michael Jetter[1], Konstantin Ilin[2], Michael Siegel[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Research Center SCoPE and IQST, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Institute of Micro- and Nanoelectronic Systems (IMS), Karlsruhe Institute of Technology (KIT), Hertzstrasse 16, 76131 Karlsruhe, Germany

The generation, manipulation and detection of single photons on-chip is currently under strong investigation due to their large potential in quantum information processing. Up to now, experiments using laser excitation of quantum dots and on-chip detectors suffer from a high laser background on the detectors, which makes a temporal filtering of the detected signal necessary. [1]

Here, we present a fully integrated circuit, consisting of an InGaAs/GaAs quantum dot which is resonantly pumped, two single mode GaAs/AlGaAs waveguides forming a 50/50 beamsplitter structure and two NbN superconducting nanowire single photon detectors. With this system we perform on-chip second order correlation measurements on a single photon level without temporal filtering.

[1] G. Reithmaier et al. *Nano Lett.*, **2015**, *15* (8), pp 5208-5213.

HL 4.10 Mon 12:00 EW 201

Strain-dependent optical spectra of carbon nanotubes — •Christian Wagner[1], Jörg Schuster[2], and André Schleife[3] — [1]Center for Microtechnologies, TU Chemnitz, Germany — [2]Fraunhofer Institute ENAS, Chemnitz, Germany — [3]Department for Materials Science, UIUC, USA

Optical transitions in carbon nanotubes (CNTs) show a strong strain sensitivity, which makes them suitable for optical strain sensing at the nano-scale and for strain-tunable emitters. The origin of this effect is the dependence of the CNT band-gap on strain and chirality, which is well explored. However, there is no quantitative model for the strain dependence of optical transitions — which are subject to strong excitonic effects due to the quasi one-dimensional structure of CNTs.

One approach towards such a model is a parametrized description of the quasiparticle gap as well as the scaling relation of the exciton binding energy in CNTs given by Perebeinos *et al* [1]. However, the description of screening in the scaling relation is insufficient, since for CNTs, a one-dimensional wave-vector dependent dielectric function $\epsilon(q)$ is required instead of an effective-medium dielectric constant ϵ_0.

We improve the approach by Perebeinos *et al* [1] by relating the screening physics in CNTs to the electronic transitions. The resulting model is fitted to electronic-structure calculations within many-body perturbation theory. This enables us to quantitatively predict the strain dependence of optical transitions for any CNT.

[1] V. Perebeinos et al., Phys. Rev. Lett. 92, 257402 (2004).

HL 4.11 Mon 12:15 EW 201

Theoretical evaluation of two-photon transitions in wurtzite III-nitride quantum dots — •Stefan Thomas Jagsch, Ludwig Albrecht Thorsten Greif, Stephan Reitzenstein, and Andrei Schliwa — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin

Experiencing both, strong carrier confinement and large exciton binding energies, nitride quantum dots (QDs) are predestined for single-photon emitter-based quantum optics at elevated temperatures. When grown along the (0001) crystallographic axis, wurtzite III-nitride systems exhibit strong internal pyro- and piezoelectric fields of the order of MV/cm. We explore the influence of these internal fields on two-photon transitions in wurtzite III-nitride quantum dots, via the mediation of parity selection rules, in the framework of 8-band k.p-theory [1]. We highlight possible routes to employ III-nitride QDs for frequency conversion on a single-emitter level. [1] Winkelnkemper, M., Schliwa, A. et al. PRB 74 (2006)

HL 4.12 Mon 12:30 EW 201

1550 nm wavelength emitting quantum dots, grown on a strain reduced InGaAs matrix — •Marcel Schmidt, Tim Bergmeier, Arne Ludwig, and Andreas D. Wieck — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum

An important milestone to quantum information transfer are single photon sources emitting at a wavelength of 1550 nm for low losses in optical fibres. To achieve an emission at 1550 nm, self assembled quantum dots (SAQDs) as nearly ideal single photon sources are very promising. With the tempting prospect to tune the energy levels of QDs to an emission wavelength of 1550 nm, we investigate molecular beam epitaxy grown InAs SAQDs on lattice mismatch reduced, relaxed InGaAs/InAlAs heterostructure layers with short period superlattices. We present first results of SAQDs already emitting at 1550 nm in photoluminescence spectroscopy at the temperature of T = 77 K.

HL 4.13 Mon 12:45 EW 201

Nonlinear Frequency Generation by Rabi Oscillations in Quantum-Dot Semiconductor Amplifiers — •Benjamin Lingnau and Kathy Lüdge — Institut für Theoretische Physik, TU Berlin

We investigate the nonlinear light propagation in InAs/InGaAs quantum-dot-in-a-well semiconductor optical amplifiers in the limit of strong optical excitation where Rabi oscillations are excited in the active medium. The amplifier is analyzed in a degenerate four-wave-mixing setup and characterized by its frequency conversion and creation performance. Our simulations show that the interplay between the nonlinear four-wave-mixing process and the coherent Rabi oscillations greatly influences the frequency conversion process. Rabi oscillations can be resonantly excited by the correct choice of the frequency detuning between pump and probe signals, which greatly enhances the nonlinear frequency conversion efficiency at frequencies up to several THz. We furthermore show that the coherent pulse shaping of ultrashort optical pulses in the quantum-dot medium can greatly enhance their spectral bandwidth, potentially allowing for ultra-broadband wavelength conversion and frequency comb generation.