HL 3: Quantum dots: Microcavities and photonic crystals

Time: Monday 11:15–13:00 Location: ER 270

HL 3.1 Mon 11:15 ER 270

Optical properties of ZnSe-based quantum dot pillar microcavities at elevated temperatures — •Joachim Kalden, Henning Lohmeyer, Kathrin Sebald, Thomas Meeser, Jürgen Gutowski, Carsten Kruse, Arne Gust, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, P.O. Box 330 440, D-28334 Bremen, Germany

II-IV quantum dots (QDs) are of high interest for emission in the green spectral region. CdSe QDs are embedded in monolithic ZnSe-based VCSEL structures grown by molecular beam epitaxy. In these structures the CdSe QDs are embedded inbetween MgS barriers which enhance the high temperature stability up to room temperature [1]. Pillar microcavities (MCs) with diameters down to 715 nm are prepared by focused-ion-beam (FIB) etching and optically characterized by micro-photoluminescence (μ-PL) measurements. Due to the three-dimensional optical confinement discrete mode spectra are detected and studied with regard to polarization and temperature, respectively. Experimental findings correspond to theoretical calculations [2]. Quality factors beyond 3000 are deduced from the spectral width of the fundamental MC mode (FM). Furthermore, the coupling between the single-QD emission and the FM is discussed. In this context we demonstrate how to tune the QD emission into resonance with the FM via temperature adjustment or post fabrication FIB etching. Thus, 5-fold PL intensity enhancement is achieved for individual QDs.

[1] R. Arians et al., Appl. Phys. Lett. **90**, 101114 (2007)
[2] H. Lohmeyer et al., Appl. Phys. Lett. **88**, 051101 (2006)

HL 3.2 Mon 11:30 ER 270

Electrically driven high–Q quantum dot–micropillar cavities — •Caroline Kistner[1], Carolin Böckler[1], Stephan Reitzenstein[1], Ralph Debusmann[1], Andreas Löffler[1], Takayuki Kida[1], Sven Höfling[1], Alfred Forchel[1], Laurent Grenouillet[2], Julien Claudon[2], and Jean-Michel Gérad[2] — [1]Technische Physik, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg — [2]CEA-CNRS-UJF Nanophysics and Semiconductors Laboratory, CEA/DRFMC/SP2M, 17 rue des Martyrs, 38054 Grenoble Cedex 9, France

In recent years generating non-classical light and exploring Cavity Quantum Electrodynamic (CQED) effects in semiconductor quantum dot microcavity systems has become an active field of research due to possible applications in the field of quantum computing and cryptography. Here, we report on electrically driven high-Q quantum-dot micropillar cavities which are attractive in order to realize, e.g. compact and efficient single photon sources. In particular, a special lateral current injection scheme is presented which ensures an efficient light outcoupling through the uncapped upper facet of the micropillar. Applying this approach, quality factors up to 16000 were achieved for a 4 μm diameter microcavity. Furthermore, the structures feature excellent single quantum dot CQED effects with a Purcell enhancement larger than 10 for a micropillar with 2.5 μm diameter.

HL 3.3 Mon 11:45 ER 270

Observation of Non-Resonant Dot-Cavity Coupling in Two-Dimensional Photonic Crystal Nanocavities — •Michael Kaniber, Arne Laucht, Andre Neumann, Max Bichler, and Jonathan J. Finley — Walter Schottky Institut, TU-München, Am Coulombwall 3, D-85748 Garching

We report the observation of non-resonant coupling between a single quantum dot (QD) and a photonic crystal (PC) nanocavity. Low density self-assembled $In_{0.50}Ga_{0.50}As$ QDs were grown by MBE at the midpoint of a GaAs slab. Nanocavities with $\omega_{cav}/\Delta\omega \sim 800 - 4000$ are formed by introducing point defects into the PC. Photon auto- and cross-correlation measurements were performed on different transitions from the same QD with a small spectral detuning ($|\Delta| < 2\omega$) from the cavity mode. These measurements were then repeated after Δ was increased up to $+10\Delta\omega$ by the adsorption of molecular nitrogen. For weak detuning different transitions from the same QD exhibit pronounced photon anti-bunching in both auto- and cross-correlation measurements, demonstrating that the different transitions arise from the same dot. The auto-correlation anti-bunching dip is shallower for transitions with smaller Δ due to the presence of an additional cavity mode background emission. Upon increasing the detuning to $\sim 10\Delta\omega$ the depth of the anti-bunching recovers. Most remarkably, cross-correlation measurements between the QD and the strongly detuned mode reveal correlated emission. This observation indicates the presence of a coupling mechanism between the spectrally detuned QD and the cavity. We discuss likely mechanisms mediating the remote coupling process.

HL 3.4 Mon 12:00 ER 270

Influence of the Spontaneous Emission Factor β on the Coherence Time of Semiconductor Microcavity Lasers — •Serkan Ateş[1], Christopher Gies[2], Sven M. Ulrich[1], Jan Wiersig[2], Stephan Reitzenstein[3], Andreas Loeffler[3], Alfred Forchel[3], Frank Jahnke[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Germany — [2]Institut für Theoretische Physik, Universität Bremen, Germany — [3]Technische Physik, Universität Würzburg, Germany

We present experimental and theoretical investigations on the coherence properties of (In,Ga)As/GaAs quantum dot (QD) based high-β ($\beta = 0.01$ to 0.05) semiconductor micropillar lasers. Power-dependent $g^{(1)}(\tau)$ first-order correlation function measurements have been performed by Michelson interferometry to investigate the coherence properties of the fundamental mode emission. A nonlinear increase of the coherence time (i.e., from $\tau_c \approx 30$ ps to ≈ 990 ps for a $\beta = 0.01$ micropillar) is found in the transition regime from spontaneous to dominantly stimulated emission. This increase is accompanied by a qualitative change in $g^{(1)}(\tau)$ measurements from a Gaussian-like profile to an exponential-type behavior. In addition, the emission coherence time of different diameter micropillars at comparable excitation conditions is found to be strongly influenced by the β factor. Devices with larger β exhibit shorter coherence times due to a stronger contribution of spontaneous processes coupled into the laser mode. The measurements are compared to results of a microscopic theory for coupled light-matter dynamics that describes the lasing properties of QD micropillars.

HL 3.5 Mon 12:15 ER 270

Realization of Electrically Tunable Single Quantum Dot - Cavity Systems — Felix Hofbauer, •Jakob Angele, Michael Kaniber, Gerhard Böhm, and Jonathan J. Finley — Walter Schottky Institut, TU München, 85748 Garching, Germany

We present studies of the radiative coupling of single $In_{0.4}Ga_{0.6}As$ self-assembled quantum dots to both extended and strongly localised optical modes in electrically contacted 2D photonic crystal (PhC) nanostructures. The samples investigated consist of a 180nm thick, free-standing GaAs membrane into which PhC are formed by etching a triangular lattice of air holes. Low mode-volume ($V < (\frac{\lambda}{n})^3$) and high $Q \sim 8000$ nanocavities are realised by introducing point defects into the PhC and the structures are electrically contacted via 30nm thick p- and n- doped contact layers in the membrane. These structures enable us to apply static electric field perturbations to the dots in the nanocavity and continuously vary the detuning (Δ) between the exciton and cavity using the quantum confined Stark effect.

The structures were studied using spatially resolved photoluminescence (PL) and photocurrent (PC) absorption spectroscopy. Our results show that Δ can be tuned in-situ by ~ 4 meV in the PL regime. Investigations of the PL intensity and spontaneous emission dynamics as a function of Δ reveal an increase in PL intensity by a factor of 1.5x and a twofold decrease of in spontaneous emission lifetime due to the Purcell effect. Using PC we observe enhanced optical in-coupling to the structures when exciting close to the cavity modes and can detect absorption from a single dot-cavity system.

HL 3.6 Mon 12:30 ER 270

Hybrid microcavities with embedded CdHgTe quantum dots — •David Zingelmann[1], Johannes Renner[1], Lukas Worschech[1], Andreas Löffler[1], Matthias Schäfer[2], Charles Becker[2], Laurens Molenkamp[2], and Alfred Forchel[1] — [1]Technische Physik, Universität Würzburg — [2]Experimentelle Physik III, Universität Würzburg

We have realized a hybrid optical microcavity for the near infrared spectral range. The cavity is based on three different material systems. The central cavity layers are made of II-VI semiconductors, namely CdTe with embedded CdHgTe quantum dots as active mate-

rial, formed by MBE growth and subsequent thermal annealing. The bottom mirror is implemented as high-quality III-V semiconductor distributed Bragg reflector (GaAs/AlAs), whereas the top mirror is built up by dielectric materials (SiO_2/Si). From this structure micropillars with diameters of a few μm have been fabricated by reactive ion etching. By means of photoluminescence and reflectivity measurements we demonstrated 1- and 3-dimensional optical confinement in planar structures and micropillar cavities, respectively.

HL 3.7 Mon 12:45 ER 270

Efficient single photon generation using single quantum dots in two-dimensional photonic crystals — •Arne Laucht, Michael Kaniber, Andre Neumann, Max Bichler, and Jonathan J. Finley — Walter Schottky Institut, TU-München, Am Coulombwall 3, D-85748 Garching

We present comparative investigations of single photon generation from self-assembled quantum dots (QDs) emitting into (i) a two-dimensional photonic bandgap (PBG) or (ii) a homogeneous photonic environment. The sample investigated consisted of a single layer of $In_{0.50}Ga_{0.50}As$ QDs embedded within a 180nm thick GaAs membrane. Specific regions of this air-GaAs-air waveguide were patterned using electron-beam lithography and reactive ion etching to form photonic crystal (PC) nanostructures with a PBG enclosing the QD emission. By probing QDs within, or next to, the PC nanostructures we examine the influence of the PBG on the single photon emission rate and external quantum efficiency. Optical measurements were performed using low temperature confocal microscopy. We observe strong photon antibunching with a low multi photon probability both for dots in the unpatterned membrane and the PC of less than 10%. Remarkably, the 2D PBG is shown to enhance the relative photon extraction efficiency by a factor of $\sim 16\times$. From measurements under pulsed excitation we estimate the absolute external quantum efficiency of $26 \pm 3\%$ for dots in the PC to be much larger than the one for dots in the unpatterned GaAs of $1.6 \pm 0.2\%$. Hence, we conclude that a 2D PBG may provide a simple route towards highly efficient QD based single photon sources.