HL 16: Microcavities

Time: Monday 14:30–17:15 Location: FOE Anorg

HL 16.1 Mon 14:30 FOE Anorg

Interdependence of first- and second-order coherence for quantum-dot micropillar lasers — •Jean-Sebastian Tempel[1], Ilya Akimov[1], Marc Assmann[1], Christian Schneider[2], Sven Höfling[2], Caroline Kistner[2], Stephan Reitzenstein[2], Lukas Worschech[2], Alfred Forchel[2], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund — [2]Technische Physik, Physikalisches Institut, Universität Würzburg, 97074 Würzburg

We present investigations on the coherence of the emission from the fundamental mode of a quantum-dot microcavity laser. We measured the first-order field-correlation function $g^{(1)}(\tau)$ with a Michelson interferometer, from which we directly determine the coherence time. To fully characterize the coherence properties of the cavity emission, we apply a model that connects first- and second-order coherence. Hereby it is possible to overcome the limited sensitivity of the streak camera used for photon correlation measurements, and thus to extend the accessible excitation power range for $g^{(2)}(\tau)$ down to the thermal regime.

HL 16.2 Mon 14:45 FOE Anorg

Emission characteristics of a highly correlated system of a quantum dot coupled to two distinct micropillar cavity modes — •Stefanie Weiler[1], Ata Ulhaq[1], Sven Marcus Ulrich[1], Stephan Reitzenstein[2], Andreas Löffler[2], Alfred Forchel[2], and Peter Michler[1] — [1]Universität Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Universität Würzburg, Am Hubland, 97074 Würzburg

Quantum dots (QDs) are promising candidates for quantum information technology. Even though they are referred to as artificial atoms, the interaction of QDs with the surrounding solid state medium has to be considered to explain the recently discovered and yet not fully theoretically explained effect of nonresonant dot-cavity coupling. In our work [S. Weiler et al., PRB 82, 205326 (2010)] we have investigated the emission characteristics of a system of one QD coupled to two distinct modes of a surrounding micropillar cavity. We have verified the anti-correlation among the QD and the two modes via auto- and cross-correlation measurements, revealing a highly correlated system. Systematic lifetime and coherence time measurements (p-shell excitation) gave important insight in the emission dynamics and coherence of the system. QD and modes show the lifetime behavior expected by Purcell enhancement, when controllably varying the emitter-mode detuning. The mode emission coherence stays at a constant low level for all detunings. When exciting the QD resonantly, we could demonstrate nonresonant coupling to the nearby mode and with increasing power also to the far detuned fundamental mode of the system.

HL 16.3 Mon 15:00 FOE Anorg

Spin mediated magneto-optical cavity quantum electrodynamics effects in quantum dot micropillar systems — •Peter Gold[1], Stephan Reitzenstein[1], Steffen Münch[1], Philipp Franeck[1], Andreas Löffler[1], Sven Höfling[1], Lukas Worschech[1], Alfred Forchel[1], Ilya Ponomarev[2], and Tom Reinecke[2] — [1]Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Naval Research Laboratory, Washington, D.C. 20735, USA

We report on magneto-optical studies of strongly coupled quantum dot - micropillar cavity systems. Laterally extended $In_{0.3}Ga_{0.7}As$ quantum dots (QDs) in the active layer of a micropillar cavity facilitate the observation of strong coupling. These QDs are characterized by large oscillator strength and they exhibit a large diamagnetic response, which is exploited to demonstrate magneto-optical resonance tuning. In addition, the coherent interaction between spin resolved states of the QDs and microcavity photon modes is studied. We access the spin degree of freedom by applying a non-zero magnetic field in Faraday configuration, so that the spin degeneracy of the QD exciton is lifted, while the resonance tuning of the Zeeman split exciton lines is achieved by temperature variation. A detailed oscillator model is used to extract coupling parameters of the individual spin and cavity modes. Our results demonstrate an effective coupling between photon modes that is mediated by the exciton spin states [1]. We further show simulations of the photon-photon coupling in dependence of the coupling parameters.

[1] S. Reitzenstein et al., Phys. Rev. B 82, 121306 (R) (2010)

HL 16.4 Mon 15:15 FOE Anorg

Site-controlled quantum dots in an electrically driven single-sided micropillar cavity — •Sebastian Maier, Christian Schneider, Alexander Huggenberger, Tobias Heindel, Stefan Heckelmann, Stephan Reitzenstein, Sven Höfling, Lukas Worschech, Martin Kamp, and Alfred Forchel — Technische Physik and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

Spatial control over the position of a single quantum dot is important for the realization of quantum optical and quantum electronic devices. We integrated site-controlled InAs quantum dots (SCQDs) in an electrically driven p-i-n diode by performing molecular beam epitaxial (MBE) growth on a pre-patterned substrate. The SCQDs are grown on a line of nanoholes fabricated with electron beam lithography and wet etching. We employed a low quality factor single-sided micropillar cavity design with diameters smaller than 2 μm that allows for directed and highly efficient light emission. The bottom (top) distributed Bragg reflector (DBR) consist of 24 p-doped (5 n-doped) pairs of quarter-wavelength thick layers of AlAs and GaAs. The SCQDs are centered in the intrinsic GaAs λ-cavity. Microelectroluminescence measurements of electrically driven SCQDs reveal emission from single SCQDs with narrow linewidths down to 170 μeV.

HL 16.5 Mon 15:30 FOE Anorg

Whispering gallery mode lasing in electrically driven quantum dot micropillars — •Ferdinand Albert, Tristan Braun, Tobias Heindel, Christian Schneider, Stephan Reitzenstein, Sven Höfling, Lukas Worschech, and Alfred Forchel — Technische Physik and Wilhelm Conrad Röntgen Research Center for Complex Materials, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

High quality factor and low mode volume nanophotonic devices featuring pronounced cavity quantum electrodynamics (cQED) effects are attracting considerable scientific attention with respect to efficient light sources. For instance they allow for the realization of efficient and compact microlasers. In this respect electrically driven quantum dot based micropillar lasers are of particular interest because of a straightforward current injection by a ring-shaped top contact. While standard micropillar lasers are characterized by a highly directional emission normal to the samples surface, we report on in-plane lasing emission under electrical pumping from whispering gallery modes (WGMs) confined in the central cavity layer of the micropillars. We present WGM lasing with Q-factors up to 40.000 and laser threshold currents below 10 μA. Our devices provide a significantly better heat sinking compared to standard WGM lasers based on microdisks and, thus, a better control of the emission wavelength. The latter is of particular importance for the realization of THz radiation from micropillar WGM lasers by means of difference frequency generation.

15 min. break

HL 16.6 Mon 16:00 FOE Anorg

In-plane manipulation of quantum dots by electric fields — •Johannes Beetz, Caroline Kistner, Stephan Reitzenstein, Christian Schneider, Sven Höfling, Martin Kamp, and Alfred Forchel — Universität Würzburg, Technische Physik, Am Hubland, 97074 Würzburg

Devices for applying vertical electric fields to quantum dots (QDs) are usually fabricated by conventional measures of lithography — e.g. electron beam lithography — using a pn-type heterostructure. The creation of lateral electrodes is even much more challenging, especially if they need to be applied to the active region of microcavites. This is of special interest since it is impossible to influence the in-plane electronic structure of self-assembled QDs with a vertical electric field. To generate the field inside the cavity layer of a micropillar, its sidewalls have to be provided with two diametrically opposed electric connections on the level of the cavity. In order to achieve this, we exploited focused ion beam induced deposition to define contacts on the micropillar's steep sidewalls. We optimized deposition parameters and contact architecture to preserve the cavity's Q-factor while achieving an effective coupling of the electric field into the cavity for minimized leakage

currents. To evaluate the effect of the lateral field we examined the spectral emission of QDs located inside the cavity. We demonstrate the manipulation of the emission energy by the quantum confined Stark-effect with tuning ranges up to 0.1 meV. Moreover, first studies show a reduction of the exciton fine structure splitting, which is interesting for the generation of entangled photons.

HL 16.7 Mon 16:15 FOE Anorg

Optical properties of monolithic InGaN quantum dot pillar microcavities — •Kathrin Sebald, Moritz Seyfried, Joachim Kalden, Heiko Dartsch, Christian Tessarek, Stephan Figge, Carsten Kruse, Detlef Hommel, and Jürgen Gutowski — Institute of Solid State Physics, University of Bremen, Germany

The realization of monolithic microcavities (MCs) with InGaN quantum dots (QDs) as active region can improve the performance of VCSELs as well as the single-mode emission of pillar structured MCs. In this contribution, we will present the successful implementation of InGaN QDs into fully epitaxial monolithic MCs showing discrete resonator modes for pillar structured samples and emission lines of single QDs. The complete structure, consisting of two DBRs surrounding the GaN λ cavity, was grown by MOVPE. A layer of InGaN QDs was embedded in the cavity at the antinode position of the electric field. Pillar shaped MCs with various diameters were prepared from the planar samples by FIB etching. Their three-dimensional optical confinement results in the clear occurrence of a transversal mode structure. Quality factors of up to 300 have been achieved. Furthermore, micro-photoluminescence spectra reveal distinct spectrally sharp emission lines around 2.73eV which can be attributed to the emission of single InGaN QDs. Their markedly enhanced intensities when compared to QD lines off resonance give clear evidence of these QDs to efficiently couple to the modes. Single emission lines can be traced up to 120K. These finding are very encouraging, and further optimization gives the opportunity for an efficient utilization of InGaN QD-based devices.

HL 16.8 Mon 16:30 FOE Anorg

Experimental realization of high-Q AlAs/GaAs micropillar cavities with submicrometer diameters — •Florian Dunzer[1], Matthias Lermer[1], Niels Gregersen[2], Jesper Mørk[2], Stephan Reitzenstein[1], Sven Höfling[1], Martin Kamp[1], and Alfred Forchel[1] — [1]Technische Physik and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]DTU Fotonik, Department of Photonics Engineering, Technical University of Denmark, Building 343, DK-2800 Kongens Lyngby, Denmark

Quantum Dots (QDs) integrated in micropillar cavities with both high quality factors (Q) and small mode volumes (Vmode) constitute a promising class of solid-state quantum light sources. For instance, pronounced cavity quantum electrodynamics effects in the weak and strong QD-cavity coupling regime can be observed in these systems. A figure of merit for the observation of pronounced effects in the two regimes are the ratios Q/Vmode and Q/(sqrt(Vmode)), respectively. Q factors as high as 165,000 have been demonstrated for micropillars with large mode volume (Vmode>50(λ/n)) [1]. To reduce Vmode one might simply decrease the diameter (dc) of the pillars, yet resulting in a significant reduction of Q due to side wall scattering losses and mode mismatch. These effects limit Q to about 2,000 for dc<1 micrometer [2]. To overcome this problem, we have designed and implemented a novel AlAs/GaAs cavity design showing Q factors higher than 10,000 for micropillars with submicron diameters (Vmode<3.5(λ/n)).

HL 16.9 Mon 16:45 FOE Anorg

Polarization properties of the exciton-polariton occupation in ZnO-based microresonators — •Chris Sturm, Helena Hilmer, Steve Linke, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

The possibility of the realization of a high temperature Bose-Einstein condensate (BEC), ultra-low threshold lasers and polariton based LEDs makes exciton-polaritons very interesting. Of special interest are ZnO-based microresonators since the formation of exciton-polaritons was observed up to 410 K and the predicted temperature for the formation of a BEC is 610 K [1,2]. Here we report on the influence of the polarization of cavity-photons, which are involved in the exciton-photon coupling, on the occupation of the lower polariton branch in ZnO-based microresonators. From photoluminescence spectra we deduce that scattering of the exciton-polaritons into the states at the bottleneck region is the largest contribution. At negative detuning, the scattering rates are larger for the TM-polarization than for the TE-polarization. This is caused by the TE-TM splitting of the involved cavity-photons. With increasing detuning the difference vanishes and the scattering into the ground state is enhanced (compared to that one into the bottleneck region). Furthermore, we obtained at $T = 10\,\mathrm{K}$ a superlinear dependence of the exciton-polariton occupation on the excitation density for an intermediate detuning regime ($|\Delta| \leq 20\,\mathrm{meV}$).

[1] C. Sturm *et al.*, New. J. Phys. **11**, 073044 (2009).
[2] S.F. Chichibu *et al.*, Semicond. Sci. Technol. **20**, S67 (2005).

HL 16.10 Mon 17:00 FOE Anorg

ZnO mesa-structures in planar microcavities — •Helena Hilmer, Chris Sturm, Steve Linke, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

The realization of Bose-Einstein Condensation (BEC) above room temperature in ZnO-based microresonators is still a topic of dedicated research. These systems offer both interesting physics as well as desirable applications. Until now we have observed our microresonators to be in the strong coupling regime up to 410 K [1].

Our microresonators have been grown on c-sapphire substrates by means of pulsed laser deposition. They consist of a ZnO-cavity as active medium, with an optical thickness of half a medium wavelength, that is sandwiched between two all-oxide Bragg reflectors (BR). Yttria stabilised zirconia and Al_2O_3 have been chosen as BR materials. In contrast to former samples, the cavity layer was structured with circular mesas of diameters ranging from 10...100 μm with a depth of only a few nanometers by photolithography and subsequent etching in highly diluted phosphoric acid. This leads to a blueshift of the uncoupled cavity-photon mode energy of about 20 meV in the etched area surrounding the mesa and therefore also to a shift of the lower polariton branch. The impact of such mesa as trap for polaritons and the effect on the polariton population is investigated.

[1] C. Sturm *et al.*, New. J. Phys. **11**, 073044 (2009).