HL 18: Focussed Session: Strong Light Matter Coupling I

Time: Tuesday 9:30–13:00 Location: H13

Invited Talk HL 18.1 Tue 9:30 H13

Strong light-matter interaction in quantum dot micropillar cavities — •Stephan Reizenstein, Caroline Kistner, Steffen Münch, Christian Schneider, Micha Strauss, Philipp Franeck, Arash Rahimi-Iman, Tobias Heindel, Sven Höfling, Lukas Worschech, and Alfred Forchel — Technische Physik, Universität Würzburg, Würzburg, Germany

Following the first demonstration of strongly coupled quantum dot (QD)-microcavity systems enormous effort has been devoted to this field of cavity quantum electrodynamics (cQED). For applications and for fundamental cQED studies it is crucial to control the light-matter coupling strength by external parameters. To date most experimental studies involving strong coupling in QD-microcavity systems have relied on temperature tuning while electric and magnetic fields are required to fully explore their potential in terms of switching speed, local tuning and in-situ control of the interaction strength.

In this contribution, we will address recent progress in the field of strongly coupled QD-micropillar systems controlled by external parameters. For instance, it will be demonstrated that electrically contacted high-Q micropillars with large, high oscillator strength $In_{0.3}Ga_{0.7}As$ QDs in the active layer allow for electro-optical resonance tuning in the strong coupling regime. Besides, we will show that external magnetic fields can induce a transition from the strong to the weak coupling regime and provide a means to access the spin degree of freedom in magneto-optical studies.

Invited Talk HL 18.2 Tue 10:00 H13

Strong light-matter coupling in GaN based semiconductors — •Nicolas Grandjean — EPFL, Switzerland

III-V nitride semiconductors are well suited for short-wavelength optoelectronic devices such as blue light emitting diodes and laser diodes. On the other hand, III-V nitrides are quite promising for the physics of cavity-polaritons. Indeed, GaN possesses intrinsic properties like oscillator strength 10x larger than that of GaAs and exciton binding energy as large as 50 meV in ultra-thin quantum wells (QWs). As a consequence, the light matter-interaction is enhanced allowing the strong coupling regime (SCR) to be sustained at room-temperature (RT). Such characteristics have led to the first demonstration of polariton lasing at 300K.

Optical pumping experiments performed on GaN bulk MCs have already shown the potential of III-V nitride semiconductors for polariton condensation. Recent results obtained on QW-MC indicate polariton condensation at 300K with a very low threshold. As expected, the threshold is dependent on both the temperature and the detuning of the cavity mode with respect to the exciton mode.

Another interesting feature is concerned with the polarization behaviour with increasing the pump power above threshold. A depinning of the polarization is observed resulting in a progressive decrease of the polarization degree of the emitted light.

Finally, we will discuss the perspectives of GaN cavity-polaritons for device applications.

HL 18.3 Tue 10:30 H13

Higher Order Photon Bunching in a Semiconductor Microcavity — •Franziska Veit[1], Marc Assmann[1], Manfred Bayer[1], Mike van der Poel[2], and Jorn M. Hvam[2] — [1]Experimentelle Physik II , TU Dortmund , D-44221 Dortmund, Germany — [2]DTU Fotonik, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark

We were able to show the statistical behaviour of photons in the single mode emission of a semiconductor microcavity by determining the correlation function $g^{(n)}$ (τ, t) of the emitted light up to fourth order. We studied the photon correlation in the weak as well as in the strong coupling regime. Our setup using a modified streak camera allowed us to directly record the photon counting statistics with picosecond time resolution. Therefore, we had the possibility to perform measurements of the photon bunching with a time resolution comparable to the coherence time of the light, allowing us to address $g^{(n)}$ (τ, t) inside the light pulses instead of just between them.

We can illustrate bunching behaviour in the strong coupling regime whereas in the weak coupling regime the cavity starts lasing and therefore the photon bunching vanishes leading to statistically independent photon emission. For the first time the n! prediction for the zero delay correlation function $g^{(n)}(\tau = 0)$ of n thermal light photons could be verified.

HL 18.4 Tue 10:45 H13

Multi-Quantum-Well Microcavity Structures for electrical excitation of Exciton-Polaritons — •Matthias Lermer[1], Arash Rahimi-Iman[1], Christian Schneider[1], Sven Höfling[1], Stephan Reitzenstein[1], Lukas Worschech[1], Alfred Forchel[1], Na Young Kim[2], and Yoshihisa Yamamoto[2] — [1]Technische Physik, Universität Würzburg, D-97074 Würzburg, Germany — [2]E. L. Ginzton Laboratory, Stanford University, Stanford, CA 94305, USA

In semiconductor microcavities strong coupling between quantum-well (QW) excitons and cavity-photons can be realized. In low excitation regime, bosonic quasiparticles, the so called exciton-polaritons, are formed, consisting of half-light/half-matter and exhibit unique properties like stimulated scattering, Bose-Einstein-Condensation and lasing, which have been intensively investigated so far by optical excitation.

We have studied planar AlGaAs/AlAs microcavities featuring 1, 4 and 12 GaAs/AlAs QWs and investigated the strong coupling in photoluminescence and reflection for varying temperatures. To amplify the process of stimulated scattering, it is important to enhance the density of polaritons, thus in the presented work we carefully increased the number of QWs in the device. At the same time homogenous pumping of the QWs has to be ensured as it is critical for the purpose of realization of an electrically driven polariton structure. In that way we could achieve a light emitting diode operation in the strong coupling regime, namely a polariton diode. Our results show that the number of GaAs/AlAs QWs in combination with a sophisticated cavity design is of key importance for studies in the field of polaritronics.

15 Min. Coffee Break

Invited Talk HL 18.5 Tue 11:15 H13

Spectroscopy and Thermodynamics of Ultracold Excitons in a Potential Trap — •Heinrich Stolz — Institut für Physik, Universität Rostock,18051 Rostock, Germany

The condensation of Bosons into the system ground state at sufficiently low temperature in thermal equilibrium is one of the most spectacular manifestations of the quantum nature of matter and was first realized for atoms in a potential trap. Due to the general nature of the arguments, this Bose-Einstein condensation should occur in any system of quasi-particles with integer spin, the most prominent example being excitons, bound electron-hole-pair excitations in semiconductors. Especially promising have been the yellow 1S exciton states in cuprous oxide, but, despite several experimental studies of dense exciton states in this material, none of these resulted in a clear demonstration of the existence of a Bose condensed state of excitons. Recently, we have developed a theory of the spatio-spectral luminescence of excitons in a confining potential that takes both the polariton nature of the excitons and the exciton-exciton interaction into account [1]. Experimental results from a new strategy for creating a dense exciton system at low temperatures in a potential trap will be discussed with respect to these predictions. [2] H. Stolz and D. Semkat, submitted to Phys. Rev. B, cond-mat. ArXiv:0912.2010(2009).

HL 18.6 Tue 11:45 H13

Resonantly probing micropillar cavity modes by photocurrent spectroscopy — •Caroline Kistner, Stephan Reitzenstein, Kai Morgener, Christian Schneider, Sven Höfling, Lukas Worschech, and Alfred Forchel — Universität Würzburg, Technische Physik, Am Hubland, 97074 Würzburg

Compared to simple optically excited structures electrically contacted high-quality (high-Q) quantum dot-micropillar cavities provide an additional degree of freedom to either control the emission properties of the system via the quantum confined Stark-effect or to read out its optical properties by means of photocurrent (PC) spectroscopy [1,2]. This has particular implications when probing the system under strict resonant optical excitation where stray light from the excitation laser is a critical issue in resonance fluorescence studies. Here, we demonstrate the feasibility of detecting the cavity mode patterns of high-Q micropillars via PC spectroscopy. In particular, we resonantly probe the cavity resonances of electrically contacted micropillars by scanning the wavelength of the light incident on the top facet of the device and simultaneously measure the PC through the p-i-n structure using lock-in technique. At the cavity mode resonances of the micropillar the incident photons can efficiently enter the stop-band of the distributed Bragg reflectors, thus leading to an enhanced absorption of the light in the quantum dot layer which is reflected in pronounced resonances in the PC. The PC spectrum is in very good agreement with the mode spectrum obtained from micro-photoluminescence measurements.

HL 18.7 Tue 12:00 H13

Growth and characterization of II-VI-based Bragg reflectors for the blue-violet spectral region — •Sebastian Klembt, Carsten Kruse, and Detlef Hommel — Institute of Solid State Physics, Semiconductor Epitaxy, University of Bremen, Otto-Hahn-Allee NW1, 28359 Bremen, Germany

The objective is to realize surface emitters for the blue to violet spectral range from 400 to 460 nm using II-VI materials. For this purpose, highly reflective distributed Bragg reflectors (DBRs) are necessary. Since the standard high index material ZnSSe is absorbing at 460 nm, it has to be alloyed to achieve a higher bandgap. The investigated structures consist of ZnMgSSe layers for the high refractive index material and MgS/ZnCdSe superlattices for the low index material. One main challenge is to achieve sharp DBR interfaces when the Mg content of the quaternary ZnMgSSe layers is higher than 20%. Furthermore, the requirement of lattice matching to the GaAs substrate needs precise control of deposition parameters during the DBR growth run. High-resolution X-ray diffraction (HRXRD) measurements were performed for calibration of the composition. In order to determine the exact quarterwave thickness of each layer, the use of in-situ reflectometry turned out to be crucial.

A 16 pairs DBR with a stopband centered at 460 nm reaches a reflectivity exceeding 98%, while the stopband width is about 35 nm. Vertical resonators formed by two DBR mirrors and a cavity containing binary ZnSe quantum wells will also be discussed.

HL 18.8 Tue 12:15 H13

Influence of growth imperfections on optical properties of nitride pillar VCSEL microcavities — •Matthias Florian[1], Frank Jahnke[1], Angelika Pretorius[2], Andreas Rosenauer[2], Heiko Dartsch[2], Carsten Kruse[2], and Detlef Hommel[2] — [1]Institute for Theoretical Physics, University of Bremen, Germany — [2]Institute for Solid State Physics, University of Bremen, Germany

The combination of distributed Bragg mirrors and pillar fabrication leads to photonic devices with efficient three-dimensional photon confinement for applications as low-threshold lasers and single-photon sources[1]. However, the quality of the optical mode confinement is reduced by fabrication imperfections of the underlying structure. For a Al(Ga)N/GaN micropillar system high resolution TEM investigations reveal layer-thickness gradients and fluctuations. The experimentally determined true layer profile as well as dispersion measurements for the low and high-index material are used as input for numerical calculations of the three-dimensional mode structure based on a vectorial transfer matrix approach[2]. We determine the influence of various types of structural imperfections on the reduction of the mode confinement in terms of the cavity quality factor. Furthermore, theoretical and experimental mode spectra are compared, that exhibit various confined transverse modes.

[1] H. Lohmeyer et al., Eur. Phys. J. B 48, 291–294 (2005)
[2] D. Burak and R. Binder, IEEE JQE 33, 1205–1215 (1997)

Invited Talk HL 18.9 Tue 12:30 H13

Novel polariton-based devices: Room temperature polariton laser and electrically controlled polariton parametric amplifier — •Gabriel Christmann, Stavros Christopoulos, Christopher Coulson, and Jeremy J. Baumberg — NanoPhotonics Centre, Department of Physics, University of Cambridge, CB3 0HE, UK

Semiconductor microcavities (MCs) offer a unique system for producing novel types of non linear devices. In such systems polariton parametric amplification as well as polariton lasers can be obtained. These properties combined with the recent demonstration of electrical injection of polaritons offer a great potential for device realization.

Room temperature polariton lasers will be first presented. Here such systems are fabricated from lattice-matched monolithic GaN-based multilayers, including both bulk and QW microcavities. Coherent emission with a threshold below exciton saturation density is demonstrated in both types of structures. These devices offer a new route to robust long-lived GaN lasers and also provide a new prototype system for the study of macroscopic coherent states.

Then, recent results on a biased GaAs polariton light emitting diode structure will be presented. Pump probe experiments in the parametric amplifier geometry have been performed exhibiting up to 100 fold gains. By varying the electric field across the cavity, a very strong (>90%) quenching of the optical gain is observed for a sharp resonance. This effect is ascribed to competition between the rate of Rabi-coupling and of electronic tunnelling between adjacent quantum wells and is of high potential for the realization of novel light modulators.