TT 50: Exciton Polaritons and their Condensates (jointly with HL)

Time: Thursday 9:30–12:15 Location: H2

TT 50.1 Thu 9:30 H2

Polariton lasing in III-nitride based microcavities: How far are we from the Mott-transition? — •Georg Rossbach, Jacques Levrat, Etienne Giraud, Eric Feltin, Jean-Francois Carlin, Raphael Butte, and Nicolas Grandjean — ICMP, Ecole Polytechnique Fd́érale de Lausanne, 1015 Lausanne, Switzerland

Non-equilibrium polariton condensates producing a coherent light source referred to as polariton laser have attracted a lot of interest as they should allow the realization of ultralow threshold coherent light-emitting devices due to the release of the population inversion condition. Polariton lasing under ambient conditions was demonstrated for the first time in a III-nitrid based microcavity, where the increased exciton stability and oscillator strength facilitate the strong coupling regime even for high carrier injection. Nevertheless, the generally observed emission energy blueshift toward the polariton lasing threshold indicates a significant altering of the light-matter coupling with increasing carrier density. Such non-linearities arise from the interacting excitonic fraction of cavity-polaritons.

Based on the investigation of the Mott-transition occurring in GaN/AlGaN single quantum wells and the microcavity bare active medium by means of non-resonant photoluminescence, the impact of the exciton renormalization on the polariton branch dispersion is discussed. Contrary to the usually assumed picture the exciton energy shift is shown to play a negligible role, while saturation effects emerging from phase space filling and exchange interaction govern the polariton renormalization already far below threshold.

TT 50.2 Thu 9:45 H2

Weak periodic modulation of exciton-polariton condensates — •Edgar Cerda-Mendez[1], Dipankar Sarkar[2], Klaus Biermann[1], Dmitry Krizhanovski[2], Maurice Skolnick[2], and Paulo Santos[1] — [1]Paul Drude Institut for Solid State Physics, Berlin, Germany — [2]Department of Physics and Astronomy, University of Sheffield, Sheffield, United Kingdom

Macroscopic quantum behavior manifest when bosonic particles undergo a phase transition to a condensate state described by a single quantum wavefunction. Such behavior also occurs in microcavities containing quantum wells (QWs), where quasiparticles called polaritons arise from the strong coupling of photons and the QW excitons. In this work, we study the properties of polariton condensates in a shallow square lattice created via acoustic modulation. We demonstrate the formation of an extended state with negative effective mass at the corners (i.e. M-points) of the square lattice mini-Brillouin Zone. Also, optical threshold intensities for condensation are reduced, which is attributed to the lower density of states at the M-points and to the negative effective mass which compensates polariton drift induced by repulsive interactions. Both effects may allow to reach the critical density for condensation more efficiently than at the center of the MBZ (i.e. the Γ point). Finally, the momentum spread of the M-point states is independent from the area covered by the MCP, showing that the wavefunction of the MCP has a self-induced intrinsic coherence length. This work opens the way for investigation of polariton quantum phases such as a Bose Glass, Mott insulator or bright gap solitons.

TT 50.3 Thu 10:00 H2

Coherent Propagation of blue Polaritons in Cu_2O — •Johannes Schmutzler, Dietmar Fröhlich, and Manfred Bayer — Experimentelle Physik 2, Technische Universität Dortmund, D-44221 Dortmund, Germany

The lowest excitons in Cu_2O are intensively studied as they are considered as candidates for Bose-Einstein Condensation. The excitons of the so-called yellow and green series are of even parity and thus only quadrupole allowed. There are, however, two other series of excitons (blue and violet series) which are dipole allowed and should thus exhibit a pronounced polariton structure.

Despite the fact that Cu_2O has inversion symmetry we report sum-frequency generation of blue exciton polaritons. This is possible since in our case the SFG is of quadrupole-dipole type. Typically the observation of non-linear effects requires power levels in the kW to MW range, necessitating pulsed laser sources. Here, we achieve strong sum-frequency (SF) signals far above the bandgap by spectrally narrow excitation of two exciton-polariton resonances in Cu_2O with two continuous wave lasers in the mW to W power range.

In the case of an antiparallel laser beam configuration pronounced oscillations of the SF-signal can be observed. We attribute these oscillations to a phase matching effect. This observation is rather surprising since the absorption length in one-photon absorption is in the range of 150 nm [1]. The occurrence of oscillations clearly indicates the creation of coherent exciton-polaritons, the damping of which is suppressed.

[1] S. Brahms et al., Physics Letters. 21, 31 (1966)

TT 50.4 Thu 10:15 H2

Polariton condensates in GaAs-based microcavities: influence of the spot size — •Matthias Salewski[1], Marc Assmann[1], Jean-Sebastian Tempel[1], Franziska Veit[1], Sven Höfling[2], Martin Kamp[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

Microcavity-polaritons consist of excitons strongly coupled to the photon field of the cavity. Photons leaking out of the cavity show the same energy-momentum dispersion as the polariton, which allows for easy experimental accessibility of the polariton states. It has been shown, that microcavity polaritons are able to undergo Bose-Einstein condensation.

Here, we investigated the influence of the excitation-spot size on the threshold carrier density necessary to create polariton condensates in a GaAs-based quantum-well microcavity. Different cavity-exciton detunings were examined.

By measuring the far-field emission of the cavity, we mapped the polariton dispersion relation as a function of the excitation power. Carriers were created by two excitation spots of different sizes. First, the intensity of the larger spot was varied. Second, while keeping the intensity of the larger spot fixed, the intensity of the second, much smaller spot was increased in the sub-milliwatt range. This way, we could measure the excitation efficiency of different spot sizes. Different results are observed for various detunings.

TT 50.5 Thu 10:30 H2

Optically and structurally trapped exciton-polariton systems — •Tom Michalsky, Helena Franke, Chris Sturm, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

The formation and properties of exciton-polaritons in microcavities (MCs) have been intensively investigated in the last years, since they can undergo a Bose-Einstein condensation (BEC). In this work we present the investigation of the momentum and spatial distribution of polaritons in the uncondensed as well as in the condensed phase for planar ZnO-based MCs with a wedge-shaped cavity layer and also in mesa structures. In the mesa structures we found an enhancement of the trapping as a result of the reduced potential energy therein. For MCs without mesa structures we demonstrate the manipulation of propagation of condensed polaritons. It turns out that for small negative detuning values the condensate is trapped by the excitation laser spot whereas for larger negative detunings an acceleration of the polaritons out of the pumping region accompanied by ballistic propagation [1] is observed.

[1] M. Wouters, I. Carusotto and C. Ciuti, Phys. Rev. B **77**, 115340 (2008)

Coffee break

TT 50.6 Thu 11:00 H2

Influence of disorder on the propagation of polariton BEC — •Martin Thunert[1], Helena Franke[1], Chris Sturm[1], Rüdiger Schmidt-Grund[1], Alexander Janot[2], Bernd Rosenow[2], and Marius Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig — [2]Universität Leipzig, Institut für Theoretische Physik, Brüderstr. 16, 04103 Leipzig

We report on the influence of disorder effects on the propagation of exciton-polariton Bose-Einstein condensates (BEC) in a ZnO-based bulk planar microcavity (MC). Due to their composite nature, the spatial distribution is affected by electronic (inhomogeneous carrier distribution) as well as photonic (thickness fluctuations, rough interfaces)

disorder. The energy(E)-k-space emission patterns of the condensate show in dependence on temperature (T) and detuning (Δ) two different regimes: 1) ballistic polariton propagation for low (T,Δ) values and 2) disorder effects for increasing (T,Δ) values, which are reflected by a fragmentation of the (E,k) emission patterns. This can be explained by interference of localized condensates or by propagating condensates with different discrete velocities determined by scattering events at the disorder potential. For each (T,Δ) parameter set increasing pump power causes an increase of the fragmentation parameter which is deduced quantitatively from the (E,k) emission patterns. A theoretical investigation shows that a non-equilibrium exciton-polariton condensate remains stiff at finite length scales only. This indeed suggests a scenario of fragmentation caused by the interplay of disorder and gain-loss of the condensate.

TT 50.7 Thu 11:15 H2

Exciton-polariton pseudospin polarization in a planar microcavity — •Steffen Richter, Chris Sturm, Helena Franke, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

Exciton-polaritons are composite quasi-particles which arise from strong coupling between excitons and photons. An interesting feature is their pseudospin. It expresses at the same time the average exciton spin orientation and the photonic light polarization of a polariton ensemble.

A planar ZnO-based microcavity of thickness $\lambda/2$ was investigated by angle-resolved photoluminescence experiments. A slight wedge shape of the cavity allows probing of different detunings. The Stokes vector of the emission from the lower polariton branch was determined under non-resonant excitation. The energetic splitting between the TE- and TM-polarized eigenmodes is found to increase with in-plane wavevector $k_{||}$ until the polariton becomes mostly exciton-like. It reaches about 20meV at most. Contrary to expectations, a circular polarization degree of up to 5% is found in the emission from these supposedly linear modes. The extent of this circular polarization reveals the same $k_{||}$-dependence as the TE-TM splitting.

The pseudospin model and the impact of related effective magnetic fields are discussed in order to explain the observed polarization behavior. Influences by different detunings, crystal quality and local anisotropic effects are considered.

TT 50.8 Thu 11:30 H2

Magnetic field interaction of exciton-polariton-condensates in a GaAs-quantum-well microcavity — •Julian Fischer[1], Ingo Lederer[1], Alexander Chernenko[2], Sebastian Brodbeck[1], Arash Rahimi-Iman[1], Matthias Amthor[1], Alfred Forchel[1], Christian Schneider[1], Martin Kamp[1], and Sven Höfling[1] — [1]Technische Physik, Physikalisches Institut, Universität Würzburg and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka, 142432 Russia

In this work we investigate the interaction of exciton-polaritons with an external magnetic field in a GaAs-quantum-well-microcavity. The magnetic field up to B=5T is applied in Faraday configuration. We focus on measurements of the Zeeman-splitting for the three regimes of our quantum-well microcavity: uncondensed exciton-polariton at low excitation power, exciton-polariton-condensate and a photon dominated regime above the mott density of excitons. For the uncondensed polaritons we measure the expected linear dependence of the Zeeman-splitting on the magnetic field, while we observed a quenching of the Zeeman-splitting for the condensate case, referred to as "Spin-Meissner-effect". Above the mott-density the Zeeman-splitting is not measurable anymore due to the negligible excitonic content. Hence, the Zeeman-splitting is a reliable tool to distinguish a polaritonic system from a photonic one.

TT 50.9 Thu 11:45 H2

Electroluminescence from spatially confined exciton polaritons in a textured microcavity — •Karol Winkler[1], Christian Schneider[1], Julian Fischer[1], Arash Rahimi-Iman[1], Matthias Amthor[1], Alfred Forchel[1], Stephan Reitzenstein[1,2], Sven Höfling[1], and Martin Kamp[1] — [1]Wilhelm Conrad Röntgen Center for Complex Material Systems, Technische Physik, Universität Würzburg — [2]Institut für Festkörperphysik, Technische Universität Berlin

Strong coupling between microcavity photons and quantum well excitons results in the formation of exciton polaritons. Spatial trapping of these quasi-particles in three dimensions allows for the observation of long-range coherence phenomena and could be exploited for new kind of coherent or non-classical light sources.

While electrical injection of quasi-2D-polaritons has been already archived, we report on electrically pumped formation of spatially confined polaritons. The trapping scheme is based on an elongated textured cavity which results in a three-dimensional confinement potential for the photonic part of the polaritons. An external bias can be used for fast manipulation of the exciton energy through the quantum confined stark effect with a simultaneous read out via resonant photocurrent measurements.

TT 50.10 Thu 12:00 H2

Zeeman split nonlinear emission from electrically injected exciton-polaritons — •Matthias Amthor[1], Christian Schneider[1], Arash Rahimi-Iman[1], Na Young Kim[2,3], Julian Fischer[1], Matthias Lermer[1], Martin Kamp[1], Stephan Reitzenstein[1,4], Alfred Forchel[1], Yoshihisa Yamamoto[2,5], and Sven Höfling[1] — [1]Technische Physik and Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, Universität Würzburg, D-97074 Würzburg, Am Hubland, Germany. — [2]E.L. Ginzton Laboratory, Stanford University, Stanford CA, 94305, USA. — [3]Institute of Industrial Science, University of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan. — [4]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, D-10623 Berlin, Germany. — [5]National Institute of Informatics, Hitotsubashi, Chiyoda-ku, Tokyo 101-8430, Japan.

We report on magneto-optical measurements of an electrically driven GaAs based exciton-polariton light-emitting diode. The system under investigation is a p-i-n GaAs microcavity with a stack of four InGaAs quantum wells in the center of a one-lambda cavity, etched into circular pillars with diameters of 20 μm. Three different regimes occur in the energy-momentum dispersion characteristics. Subject to an applied magnetic field in Faraday configuration, we observe two distinct nonlinearities in the excitation power dependent output characteristics. Additionally, we prove the conservation of the strong coupling regime above the first threshold by investigating the Zeeman splitting of the cavity resonance in the non-linear regime.