HL 107: Microcavities, polaritons and condensates

Time: Friday 10:15–13:00 Location: EW 015

HL 107.1 Fri 10:15 EW 015

Optical bistability in electrically driven polariton condensates — •Matthias Amthor[1], Timothy Liew[2], Christian Metzger[1], Sebastian Brodbeck[1], Martin Kamp[1], Ivan Shelykh[2,3], Alexey Kavokin[4,5], Christian Schneider[1], and Sven Höfling[1,6] — [1]Technische Physik and Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, Universität Würzburg, D-97074 Würzburg, Am Hubland, Germany. — [2]Division of Physics and Applied Physics, Nanyang Technological University 637371, Singapore. — [3]Science Institute, University of Iceland, Dunhagi 3, IS-107, Reykjavik, Iceland. — [4]Spin Optics Laboratory, St-Petersburg State University, 1, Ulianovskaya, St.-Petersburg, 198504, Russia. — [5]Physics and Astronomy School, University of Southampton, Highfield, Southampton, SO171BJ, UK. — [6]School of Physics and Astronomy, University of St Andrews, St Andrews KY16 9SS, UK.

We observe a bistability in an electrically driven polariton condensate, which is manifested by a memory dependent threshold characteristic. In contrast to the polariton bistabilities previously observed, our effect occurs under non-resonant electric pumping and is triggered by the current injection scheme. We explain the origin of the bistability by a dependence of the electron-hole tunneling lifetime on the carrier density in the embedded QWs. The field screening effect creates a positive feedback loop, which yields the bistable behavior of the condensate. We develop a rate-equation based model which qualitatively explains the occurrence of the hysteresis, its reduction with increased magnetic field, and the absence of bistability under optical pumping.

HL 107.2 Fri 10:30 EW 015

Polariton condensates in textured microcavity potential landscapes — •Karol Winkler[1], Anne Schade[1], Julian Fischer[1], Robert Dall[3], Jonas Gessler[1], Elena A. Ostrovskaya[3], Martin Kamp[1], Christian Schneider[1], and Sven Höfling[1,2] — [1]Technische Physik and Wilhelm Conrad Röntgen Center for Complex Material Systems, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]SUPA, School of Physics and Astronomy, University of St. Andrews, St. Andrews KY16 9SS, United Kingdom — [3]Nonlinear Physics Centre and AMPL, Research School of Physics and Engineering, The Australian National University, Canberra, ACT 0200, Australia

Exciton-polaritons can be trapped in 0D quantum boxes by either trapping the excitonic or photonic part of these hybrid quasiparticles. Engineering the trapping potential then allows to tailor site-to-site evanescent coupling of the localised polariton mode wavefunctions in a periodic lattice. This leads to the formation of a tailorable polariton bandstructure which can be utilized to simulate complex many-body phenomena in the concept of quantum-simulators.

Here we report on recent measurements below and above bosonic condensation threshold on polariton lattices of different arrangement and dimensionality. The potential landscape in this structures is given by a versatile trapping technique that is based on local elongation of the $\lambda/2$-AlAs cavity layer in a high quality microcavity structure with embedded GaAs quantum wells.

HL 107.3 Fri 10:45 EW 015

The Structure of Polariton Macroscopic Quantum Phases in 2D Acoustic Lattices — •Jakov V. Buller[1], Edgar A. Cerda-Mendez[1], Raul E. Balderas-Navarro[1,2], Klaus Biermann[1], Dmitry N. Krizhanovskii[3], Maurice S. Skolnick[3], and Paulo V. Santos[1] — [1]Paul-Drude-Institut für Festkörperelektronik, 10117 Berlin, Germany — [2]Instituto de Investigación en Comunicación Óptica, 78000 San Luis Potosí, México — [3]University of Sheffield, Sheffield S37RH, United Kingdom

Exciton-polaritons are bosonic light-matter quasiparticles that result from the strong coupling of photon modes and quantum well excitons in a semiconductor microcavity. Due to their excitonic component, they show strong non-linear interactions, while their photonic component leads to very low effective masses and thus, formation of macroscopic quantum phases (MQPs) at kelvin temperatures. Also, their μm-long de Broglie wavelength allows modulation by micrometric acoustic potentials.

In this work, we present experimental results on the structure of polariton MQPs in tunable 2D acoustic lattices created by surface acoustic waves. The studies are carried out by a tomographic imaging technique, which gives energy-resolved information on the momentum- and real-space structure. The results show that MQPs with different symmetries, spatial distributions and coherence lengths coexist within the excitation laser spot. This work opens the way for the study of lattice vortex solitons and other polariton MQPs such as a Bose glass.

HL 107.4 Fri 11:00 EW 015

Analogy between optomechanical system and acoustic cavity — •Nicolas L. Naumann[1], Julia Kabuss[1], Andreas Knorr[1], and Weng W. Chow[2] — [1]Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Berlin, Germany — [2]Sandia National Laboratories, Albuquerque, NM, USA

Quantum optomechanics recently developed into an important research area. The system dynamics is driven by radiation pressure.

We propose an acoustic cavity for exploring analogies to optomechanics. A reason for this comparative study is that the electron–phonon coupling is stronger than the coupling due to radiation pressure, which may enable easier implementation of devices. We give two examples to illustrate the similarities in their stationary and dynamical behavior: Both systems exhibit the nonlinear effect of bistability. Furthermore, the effective damping of the respective low frequency component (mechanical mode or phonon mode) can be enhanced or diminished by choosing the detuning of the cavity to the pump laser appropriately.

HL 107.5 Fri 11:15 EW 015

Nonlinear spectroscopy of exciton-polaritons in a GaAs-based microcavity — •Johannes Schmutzler[1], Marc Assmann[1], Thomas Czerniuk[1], Martin Kamp[2], Christian Schneider[2], Sven Höfling[2,3], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Technische Physik, Physikalisches Institut, Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, D-97074 Würzburg, Germany — [3]SUPA, School of Physics and Astronomy, University of St Andrews, St Andrews, KY16 9SS, United Kingdom

We present a systematic investigation of two-photon excitation processes in a GaAs-based microcavity in the strong-coupling regime. Second harmonic generation resonant to the upper and lower polariton level is observed, which exhibits a strong dependence on the photonic fraction of the corresponding polariton. In addition we have performed two-photon excitation spectroscopy to identify $2p$ exciton states which are crucial for the operation as a terahertz lasing device, which was suggested recently [1]. However, no distinct signatures of a $2p$ exciton state could be identified, which indicates a low two-photon pumping efficiency [2].

[1] A. V. Kavokin et al., Phys. Rev. Lett. 108, 197401 (2012)
[2] J. Schmutzler et al., Phys. Rev. B 90, 075103 (2014)

Coffee break

HL 107.6 Fri 11:45 EW 015

Excition-polariton relaxation in a ZnO-based microresonator — •Oliver Herrfurth, Tom Michalsky, Helena Franke, Chris Sturm, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

We report on time-resolved photoluminescence (PL) measurements of the lower polariton branch (LPB) in a microresonator (MR) with a wedge-shaped cavity revealing the impact of longitudinal optical (LO) phonons on the polariton relaxation at low temperatures. The MR was fabricated by pulsed laser deposition. The wedge-shaped cavity enables access to different detunings between the uncoupled exciton and photon mode by probing different positions on the sample surface. If the LPB ground state is in the spectral vicinity of a LO phonon replica of the exciton-like polariton reservoir, then the polariton system can scatter efficiently with LO phonons. In particular, for such detuning PL spectra show maximal intensity and time-resolved PL measurements detect the slowest decay of the polariton ensemble. For these measurements only a small interval in k-space around the LPB ground state was chosen and resolved in time with a streak camera.

HL 107.7 Fri 12:00 EW 015

Strong light-matter interaction in ZnO nanowires concentrically coated with Bragg reflectors — •Tom Michalsky, Helena Franke, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

In this work we present the investigation of the optical and structural properties of ZnO nanowires concentrically coated with distributed Bragg reflectors. The whole structure was grown by pulsed laser deposition. Scanning electron microscope images reveal excellent structural and interface quality. Angularly and spatially resolved microphotoluminescence (PL) and reflectivity spectra prove lateral confinement and strong exciton-photon coupling even at room temperature. With increasing PL excitation density we observe a controlled transition from the strong to the weak coupling regime as evidenced by stimulated emission out of the uncoupled resonator modes.

HL 107.8 Fri 12:15 EW 015

Ultrafast all-optical switching of a single micropillar cavity — Henri Thyrrestrup[1], Emre Yüce[1], •Georgios Ctistis[1,2], Julien Claudon[3,4], Jean-Michel Gérard[3,4], and Willem L. Vos[1] — [1]Complex Photonic Systems (COPS), MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands — [2]Nano-Bio Interfaces, Saxion University of Applied Sciences, Enschede, The Netherlands — [3]CEA/INAC/SP2M, Nanophysics and Semiconductor Laboratory, Grenoble, France — [4]University Grenoble Alpes, INAC-SP2M, Nanophysics and Semiconductors Lab, F-38000 Grenoble, France

Micropillar cavities are versatile nanophotonic structures for locally enhancing light-matter interaction due to their high quality factors, low mode volumes, and clean free-space optical interface. These qualities have facilitated the successful application of micropillars as efficient single photon sources, for cavity QED strong coupling, and diode lasers. We present here frequency- and time-resolved pump-probe experiments of a single GaAs/AlAs micropillar cavity with a diameter of 6 μm studying the dynamics of the cavity resonance. All-optical switching is achieved by excitation of free carriers. We observe a simultaneous shift of two different transverse modes in the micropillar. The high-resolution frequency time traces of the resonances show a strongly non-exponential relaxation dynamics [1]. We interpret this with a second-order mechanism including the radiative recombination of electron and holes and a slow free carrier trapping time.

[1] H. Thyrrestrup et al, Appl. Phys. Lett. 105, 111115 (2014)

HL 107.9 Fri 12:30 EW 015

Dynamics of light and matter in ultrafast-switched semiconductor microcavities — •Georgios Ctistis[1,2], Emre Yüce[1], Henri Thyrrestrup[1], Julien Claudon[3,4], Allard P. Mosk[1], Jean-Michel Gérard[3,4], and Willem L. Vos[1] — [1]Complex Photonic Systems (COPS), MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands — [2]Nano-Bio Interfaces, Saxion University of Applied Sciences, Enschede, The Netherlands — [3]CEA/INAC/SP2M, Nanophysics and Semiconductor Laboratory, Grenoble, France — [4]University Grenoble Alpes, INAC-SP2M, Nanophysics and Semiconductors Lab, F-38000 Grenoble, France

The interest in all-optical switching of photonic nanostructures is rapidly increasing due to the inherent speed of the process. Achieving all-optical switching on ultrafast timescales promises both new developments in information technology and a novel control in cavity QED. A very popular switching mechnism is thereby the excitation of free carriers. The dynamics of this process is usually explained by the recombination dynamics of the excited carriers using a single population model. Here, we present time dependent differential reflectivity measurements of a GaAs/AlAs planar microcavity over a broad frequency range. We observe that the switching dynamics shows a spectral dependence. To accurately describe and understand this behavior we propose a model beyond the existing single population model.

HL 107.10 Fri 12:45 EW 015

The role of the local density of optical states in the frequency conversion of light in a microcavity — Emre Yüce[1], Henri Thyrrestrup[1], •Georgios Ctistis[1,2], Julien Claudon[3,4], Jean-Michel Gérard[3,4], and Willem L. Vos[1] — [1]Complex Photonic Systems (COPS), MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands — [2]Nano-Bio Interfaces, Saxion University of Applied Sciences, Enschede, The Netherlands — [3]CEA/INAC/SP2M, Nanophysics and Semiconductor Laboratory, Grenoble, France — [4]4 University Grenoble Alpes, INAC-SP2M, Nanophysics and Semiconductors Lab, F-38000 Grenoble, France

Converting light to a controllable frequency is well-known in traditional non-linear optics. In modern nanophotonics one frequency converts light which is trapped in a cavity or waveguide. Supposedly, the physics of frequency conversion differs between traditional non-linear optics and modern nanophotonics, regarding the rate of change and output spectrum. Here, we unify these disparate views. To this end, we consider a nanophotonic system, a planar microcavity, sustaining both a cavity resonance and a flat continuum of modes. We study the frequency conversion that occurs when the cavity is switched in an ultrafast way via the electronic Kerr effect [1]. We thereby observe either a red- or a blue-shift of the confined light, depending on the timing of the pulses in the pump-probe experiment. We study color-conversion for different quality factors, which allows us to identify the role of the local density of optical states available to the generated light.

[1] E. Yüce et al., arXiv:1406.3586 (2014)