HL 48: Quantum Dots and Wires: Microcavities

Time: Wednesday 9:30–12:00 Location: H15

HL 48.1 Wed 9:30 H15

Temperature-stable strong light-matter coupling in the solid state with quantum dot-micropillars — •Anna Musiał[1,2], Caspar Hopfmann[1], Maximillian Strauss[1], Andreas M. Barth[3], Martin Glässl[3], Alexei Vagov[3], Micha Strauss[4], Christian Schneider[4], Sven Höfling[4,5], Martin Kamp[4], Vollrath M. Axt[3], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [2]Faculty of Fundamental Problems of Technology, Wrocław University of Technology, Poland — [3]Institut für Theoretische Physik III, Universität Bayreuth, Germany — [4]Technische Physik, Universität Würzburg, Germany — [5]School of Physics and Astronomy, University of St. Andrews, UK

Strong coupling (SC) regime of cQED is important for implementation of quantum networks. We address experimentally and theoretically the crucial issue of its temperature stability. Experiments and statistical analysis of temperature influence on the vacuum Rabi splitting (VRS) performed for 89 cases of SC in a broad temperature range (10*50) K revealed behavior beyond the strong confinement approximation. The unprecedented temperature stability is attributed to compensation of phonon-induced renormalization of VRS in laterally-extended In0.4Ga0.6As QDs and their unique optical properties resulting from complex electronic structure. The calculations within path integral formalism reproduces observed behavior. Observed persistence of SC demonstrates appealing possibility to counteract detrimental phonon effects.

HL 48.2 Wed 9:45 H15

Experimental and theoretical investigation of a strong optical Stark effect in a semiconductor micropillar cavity — •Fabian Hargart[1], Kaushik Roy-Choudhury[2], Tilmann John[1], Simone Luca Portalupi[1], Christian Schneider[3], Sven Höfling[3], Martin Kamp[3], Stephen Hughes[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Department of Physics, Engineering Physics and Astronomy, Queen's University, Kingston, Ontario, Canada K7L 3N6 — [3]Technische Physik and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg

The energy shift of a two-level system by intense, oscillating electric fields—commonly known as AC Stark shift—is studied experimentally and theoretically for a cavity-driven, detuned quantum dot-cavity system. The electric field enhancement inside the cavity facilitates exceptionally strong line shifts of up to $4\,\mu eV/\mu W$. The effect is systematically investigated in dependence of the driving Rabi frequency Ω and the QD-cavity detuning δ. The fine structure splitting of exciton states $|X\rangle$ and $|Y\rangle$ can be increased by magnitudes of orders due to their unequal QD-cavity coupling strengths g_X and g_Y. By extending the system to four levels, including also the biexciton state, we explain the observation of an unexpected opposite Stark shift within a dressed-state picture. The experimental results are reproduced using a simple Hamiltonian for the QD-cavity system and the driving laser field.

HL 48.3 Wed 10:00 H15

Far-field and quality factor optimized GaAs-based photonic crystal cavities for high collection efficiencies in quantum optical applications — •Stefan Hepp, Ulrich Rengstl, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Research Center SCoPE and Center for Integrated Quantum Science and Technology IQ^{ST}, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Photonic crystal cavities in combination with integrated semiconductor quantum dots have become a fundamental element in present photonic research. High quality factors in combination with ultra-low mode volumes, below one cubic wavelength, make these photonic crystal structures interesting for a wide range of applications, such as the generation of non-classical light states or the investigation of cavity quantum electrodynamic (cQED) effects. However, a major issue is the off-plane radiation profile that features maxima at emission angles around 70° leading to very low collection efficiencies even with high numerical aperture (NA) objectives.

Here, we present a GaAs-based L3-photonic crystal cavity optimized for high quality factors with integrated InAs quantum dots. Additionally, we have modified the far-field emission properties for high collection efficiencies with low numerical aperture objectives that could be useful for quantum optical applications. Theoretical studies show, that the collection efficiency with a standard objective with NA=0.5 can be increased by a factor of 10 from around 7% up to almost 70%.

HL 48.4 Wed 10:15 H15

Deterministic generation of bright single resonance fluorescence photons from a Purcell-enhanced quantum dot-micropillar system — •Stefan Gerhardt[1], Sebastian Unsleber[1], Sebastian Maier[1], Yu-Ming He[1,3], Chao-Yang Lu[3], Jian-Wei Pan[3], Martin Kamp[1], Christian Schneider[1], and Sven Hoefling[1,2] — [1]Technische Physik, Physikalisches Institut and Wilhelm Conrad Roentgen-Research Center for Complex Material Systems, Universitaet Wuerzburg, Am Hubland, 97074 Wuerzburg — [2]SUPA, School of Physics and Astronomy, University of St Andrews, St Andrews, KY16 9SS, United Kingdom — [3]Hefei National Laboratory for Physical Sciences at the Microscale and Department of Modern Physics & CAS Center for Excellence and Synergetic Innovation Center in Quantum Information and Quantum Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

We report on the observation of bright emission of single photons under pulsed resonance fluorescence conditions from a single quantum dot (QD) in a micropillar cavity. The brightness of the QD fluorescence is greatly enhanced via the coupling to the fundamental mode of a micropillar with an extraction efficiency of (20.8 ± 0.8) % per linear polarization basis with a $g^{(2)}(0)$ of 0.072 ± 0.011 at a QD-cavity detuning of 75 μeV. We observe the first Rabi-oscillation in a weakly coupled quantum dot-micropillar system under coherent pulsed optical excitation, which enables us to deterministically populate the excited QD state.

30 min. Coffee Break

Invited Talk HL 48.5 Wed 11:00 H15

Exciton-polariton thermodynamics in ZnSe-based microcavities — •Sebastian Klembt[1,5], Emilien Durupt[1], Sanjoy Datta[2], Thorsten Klein[3], Yoan Léger[4], Augustin Baas[1], Charsten Kruse[3], Detlef Hommel[3], Anna Minguzzi[2], and Maxime Richard[1] — [1]Institut Néel, CNRS-CEA-Université Grenoble Alpes, France — [2]LPMMC, CNRS-Université Grenoble Alpes, France — [3]IFP, Universität Bremen, Germany — [4]CNRS, FOTON, Insa de Rennes, France — [5]Technische Physik, Universität Würzburg, Germany

Exciton-polaritons have attracted considerable interest since they allowed for fundamental understandings of light-matter interactions such as polariton Bose-Einstein condensation and superfluidity. At high density, polaritons constitute indeed a driven dissipative quantum fluid of half-light, half-matter integer spin quasi-particles, which is embeded in a solid-state crystalline environment. The thermodynamic properties of polariton fluids have been mostly overlooked so far. An intriguing specificity of polariton condensates is their contact with three different reservoirs: the thermal phonon bath, the exciton bath and the electromagnetic vacuum. We show experimentally and theoretically that phonons can be efficiently absorbed by inelastic scattering with polaritons. A Raman spectroscopy based technique is presented using anti-Stokes fluorescence (ASF) and we show that under suitable conditions a net cooling rate can be generated by polariton ASF. By using high-Q ZnSe-microcavities the interaction between polariton condensates at up to T=270 K with the respective phonon baths is also investigated.

HL 48.6 Wed 11:30 H15

cQED effects in resonantly excited quantum dot-micropillar cavities — •Caspar Hopfmann[1], Alexander Carmele[2], Anna Musiał[1,3], Micha Strauss[4], Christian Schneider[4], Sven Höfling[4,5], Martin Kamp[4], Andreas Knorr[2], and Stephan Reitzenstein[1] — [1]Institute of Solid State Physics, Technische Universität Berlin, Germany — [2]Institute of Theoretical Physics, Technische Universität Berlin, Germany — [3]Faculty of Fundamental Problems of Technology, Wrocław University of Technology, Poland — [4]Technische Physik, Universität Würzburg, Germany — [5]School of Physics and Astronomy, University of St. Andrews, UK

Resonant excitation of quantum systems offers the unprecedented possibility of coherent control important for both fundamental study and applications due to minimized dephasing and direct addressing of a chosen state, enabling observation of phenomena not accessible otherwise. We employed resonance fluorescence (RF) to study cavity quantum electrodynamics effects in strongly coupled quantum dot (QD) - micropillar system. An advanced 90 degree excitation/detection scheme as well as spatial filtering is employed to extract the signal. For large detunings between the exciton (X) and the cavity mode (CM) both direct RF and a cavity-mediated signal is monitored and provides direct insight into the X-CM coupling. Varying the excitation power on resonance enabled observation of co-existence of a strongly coupled X-CM system and a laser-driven uncoupled QD transition, this is supported by theory based on Fourier-transformed first-order autocorrelation functions including multi-photon scattering.

HL 48.7 Wed 11:45 H15

Auger-recombination in a single self-assembled quantum dot: Quenching and broadening of the charged exciton — •Annika Kurzmann[1], Arne Ludwig[2], Andreas D. Wieck[2], Axel Lorke[1], and Martin Geller[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, — [2]Chair for Applied Solid State Physics, Ruhr-Universität Bochum, Universitätsstraße 150, 44780 Bochum, Germany

The Auger-recombination is a non-radiative process, where the electron-hole recombination energy is transferred to a third charge carrier. While this process was extensively studied in colloidal quantum dots [1], it was considered, unimportant for self-assembled quantum dots (QDs). Here, we show that in a single self-assembled QD the Auger recombination rate can directly be determined using time-resolved resonance fluorescence (RF) measurements. Furthermore, the Auger recombination quenches and broadens the charged exciton transition (two electrons and one hole).

The QD is embedded in a field-effect transistor, and the tunneling rate from the charge reservoir into the dot is about $1/\mu$s. The measured Auger-recombination rate is of the same order of magnitude as this tunneling rate. This leads to an uncharged QD and a quenched RF signal. Our measurements show the relevance of the ratio between the Auger-recombination rate and the tunneling rate for the properties of the charged exciton transition. A model, based on rate equations, is in good agreement with our measurements.

[1] V. I. Klimov et al., Science **287**, 1011 (2000)