HL 25: Quantum dots: Microcavities and microlaser

Time: Tuesday 9:30–11:00 Location: EW 203

HL 25.1 Tue 9:30 EW 203

Towards a high-cooperativity strong coupling of a quantum-dot in a tunable microcavity — •Sebastian Starosielec, Lukas E. Greuter, Andreas V. Kuhlmann, and Richard J. Warburton — University of Basel, Departement of Physics, Switzerland

An enhanced interaction between photons and quantum emitters offers a rich field of quantum applications, including single photon transistors and emitter-emitter coupling. Tailoring the vacuum properties of high-Q, low mode-volume optical resonators facilitates this enhanced interaction and ultimately allows a coherent and reversal exchange of energy quanta, challenging to achieve at optical frequencies in solid-state system. We investigate this strong coupling regime of an InGaAs/GaAs quantum dot with a high-finesse tunable microcavity [1,2] by means of high resolution laser spectroscopy with a polarization-based dark-field detection [3] under weak resonant excitation. High signal-to-noise spectra show a clear anti-crossing feature with state-of-art exciton/cavity cooperativity ($C = 5.5$). Analyzing the resonance lineshapes, a spurious dispersive contribution to the exciton resonance is identified. In all likelihood a spectral fluctuation rather than a true decoherence process, the dephasing effect reduces the cooperativity from a bare value of $C = 9.1$. Aiming for the high-cooperativity regime, besides a high-Q cavity and low mode-volume, we stress the point that equal efforts need to be taken towards lifetime-limited emitter linewidths.

[1] R. J. Barbour *et al.*, J. Appl. Phys. **110**, 053107 (2011)
[2] L. Greuter *et al.*, Appl. Phys. Lett. **105**, 121105 (2014)
[3] A. V. Kuhlmann *et al.*, Rev. Sci. Instrum. **84**, 073905 (2013)

HL 25.2 Tue 9:45 EW 203

Photon statistics excitation spectroscopy of a quantum dot micropillar laser — •Marc Assmann[1], Tomasz Kazimierczuk[1], Johannes Schmutzler[1], Christian Schneider[2], Martin Kamp[2], Sven Höfling[2,3], and Manfred Bayer[1,4] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 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 — [4]A. F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, St Petersburg 194021, Russia

We propose photon-statistics excitation spectroscopy as an adequate tool to describe the optical response of a nonlinear system. To this end we suggest to use optical excitation with varying photon statistics as another spectroscopic degree of freedom. We apply photon-statistics excitation spectroscopy to a quantum dot micropillar laser. Both the intensity and the photon number statistics of the emission from the micropillar show a strong dependence on the photon statistics of the light used for excitation of the sample. The results under coherent and pseudothermal excitation reveal that a description of the laser properties in terms of mean input photon numbers is not sufficient. It is demonstrated that the micropillar acts as a superthermal light source when operated close to its threshold. Possible applications for important spectroscopic techniques like two-photon excited fluorescence in biological imaging are discussed.

HL 25.3 Tue 10:00 EW 203

CQED effects in resonantly excited quantum dot-micropillar cavities — •Caspar Hopfmann[1], Micha Strauss[2], Christian Schneider[2], Sven Höfling[2], Martin Kamp[2], and Stephan Reitzenstein[3] — [1]Institute of Solid State Physics, Technische Universität Berlin, D-10623 Berlin, Germany — [2]Technische Physik, Universität Würzburg, D-97074 Würzburg, Germany — [3]present address: University of St Andrews, North Haugh, KY16 9SS UK

Resonance fluorescence of single quantum dots (QDs) as well as cavity quantum electrodynamics (cQED) in high quality QD-microcavities have been subject of extensive research interest in recent years. We employ resonance fluorescence to study cQED effects in high-quality QD-micropillar cavities. An advanced 90 degree excitation/detection scheme as well as spatial filtering is employed to separate excitation and signal. This study of cQED phenomena includes investigation of fundamental cavity effects in the coupled QD-micropillar system in both weak and strong coupling regime as well as their application in non-classical light sources. We investigate strict resonant excitation in the strong coupling regime. In this regime with enhanced light-matter-coupling strength the off-resonant QD-cavity coupling is very efficient and allows us to use the cavity mode emission as a convenient monitor in resonance fluorescence experiments on single QD under variation of the spectral detuning with the cavity mode. Moreover, using resonance fluorescence, dephasing of QD transitions is reduced, which in turn enables the investigation of effects such as higher ranks of the Jaynes-Cummings ladder not accessible in non-resonant excitation schemes.

HL 25.4 Tue 10:15 EW 203

Boosting the photon outcoupling efficiency in deterministic all-epitaxial quantum dot microcavities — •Peter Schnauber, Manuel Gschrey, Arsenty Kaganskiy, Jan-Hindrik Schulze, Alexander Thoma, Sven Rodt, André Strittmatter, and Stephan Reitzenstein — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

Single semiconductor quantum dot (QD) based non-classical light sources have high potential to path the way for future quantum communication networks. In realistic scenarios key requirements are a high photon outcoupling efficiency, strong suppression of multiphoton emission events and a high degree of photon indistinguishability. These strict requirements can be met by integrating single QDs deterministically into microcavities showing acceleration of spontaneous emission and directional outcoupling of light. In this work we present numerical optimization of all-epitaxial QD-microcavities for which a Gaussian shaped photonic defect in the central cavity layer ensures 3D light confinement. Maximizing the outcoupling efficiency η_{ext} of spectrally resonant QDs placed in the center of the photonic defect yields η_{ext} as high as 81% and a Purcell-factor of 9 for such microcavities. The optimized layout is implemented by means of in-situ electron-beam lithography [1] which allows us to achieve spatial and spectral resonance of single pre-registered QDs and the confined mode of all-epitaxial microcavities. Preliminary experimental results show the feasibility and the great potential of this approach.

[1] M. Gschrey et al., APL 102 (25), 251113 (2013)

HL 25.5 Tue 10:30 EW 203

Unconventional Collective Normal-Mode Coupling in Quantum-Dot-based Bimodal Micro-Lasers — •A. Foerster[1], M. Khanbekyan[2], H.A.M. Leymann[1], C. Hopfmann[2], C. Schneider[3], S. Höfling[4], M. Kamp[3], J. Wiersig[1], and S. Reitzenstein[2] — [1]Institut für Theoretische Physik, Universität Magdeburg, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [3]Technische Physik, Universität Würzburg, Germany — [4]School of Physics and Astronomy, University of St Andrews, United Kingdom

Collective coupling of multiple emitters and the normal-mode splitting proportional to a generalized coupling strength has been observed in many experiments. We analyze the occurrence of a rather unconventional normal-mode coupling in bimodal micro-lasers. The effect is attributed to the collective interaction of the cavity field with a mesoscopic number of semiconductor quantum dots as the active medium. In contrast to the conventional normal-mode coupling appearing in various schemes in the context of the single-particle or collective strong coupling regime, here we observe a hybridization of the cavity modes that leads to a locking of the frequencies and to a splitting of the linewidths in the coherent regime. Vice versa in the incoherent regime splitting of the frequencies and locking of the linewidths is observed. Our investigations are based on microscopic calculations for a bimodal quantum-dot-laser[1] and experiments that confirm the predictions in the incoherent regime.

[1] H.A.M. Leymann, et al. Phys. Rev. A 87, 053819 (2013)

HL 25.6 Tue 10:45 EW 203

Influence of optical feedback on the characteristics of quantum dot micropillar lasers — •Steffen Holzinger[1], Elisabeth Schlottmann[1], Sören Kreinberg[1], Micha Strauss[2], Christian Schneider[2], Sven Höfling[2,3], Janik Wolters[1], Martin Kamp[2], and Stephan Reitzenstein[1] — [1]Technische Universität Berlin, Germany — [2]Universität Würzburg, Germany — [3]Present address: University of St Andrews, United Kingdom

The chaotic behavior of feedback-coupled semiconductor lasers has been so far mainly experimentally studied in the classical regime. Electrically pumped quantum dot micropillar lasers constitute an advantageous platform for the realization of feedback experiments in the quantum regime, when single photon and single emitter effects become prominent. In these structures two linear, orthogonally polarized lasing modes compete using a common gain medium, resulting in a significant difference between the output power characteristics, especially above the lasing threshold. Using an external cavity, we investigate the influence of the feedback strength and polarization on the output power, photon statistics and coherence times of the lasing modes.