HL 95: Quantum Dots and Wires: Optical Properties III (mainly Cavities and Ultrafast Response)

Time: Friday 9:30–11:30 Location: EW 201

HL 95.1 Fri 9:30 EW 201

Directional whispering gallery mode lasing in limaçon shaped electrically driven quantum dot micropillars — •Caspar Hopfmann[1,2], Ferdinand Albert[1], Christian Schneider[1], Alfred Forchel[1], Martin Kamp[1], and Stephan Reitzenstein[1] — [1]Technische Physik, Universität Würzburg, D-97074 Würzburg, Germany — [2]Present address: Institute of Solid State Physics, Technische Universität Berlin, D-10623 Berlin, Germany

High quality factor and low mode volume microresonators featuring pronounced cavity quantum electrodynamics (cQED) effects are attracting considerable scientific attention with respect to efficient light sources. In this respect, electrically driven quantum dot based micropillar lasers are of particular interest because of straightforward current injection by a top contact. While standard micropillar lasers show highly directional emission normal to the sample surface, we report on directional lasing of whispering gallery modes (WGMs) confined in the central cavity layer of the micropillar. The in-plane directionality of emission is achieved by a controlled deformation of the pillar's cross-section using the limaçon-geometry. We present distinct directional WGM high β lasing with Q-factors up to 15.000 and laser threshold currents below 40 μA at 20 K, where the directionality of emission depends sensitively on the limaçon-parameter ε, i.e. the strength of deformation. Our devices provide a significantly better heat sinking compared to standard WGM lasers based on microdisks and have high potential to act as integrated light sources in planar photonic networks.

HL 95.2 Fri 9:45 EW 201

Single Quantum Dot Photocurrent Spectroscopy in high-Q Micropillar Cavities — •Manuel Gschrey[1], Peter Gold[1], Andreas Löffler[1], Sven Höfling[1], Alfred Forchel[1], Martin Kamp[1], and Stephan Reitzenstein[1,2] — [1]Universität Würzburg, Technische Physik, Am Hubland, 97074 Würzburg — [2]Present address: Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstraße 36, 10623 Berlin, Germany

We report on single quantum dot controlled photocurrent (PC) measurements in electrically contacted high-Q micropillar cavities in the cavity quantum electrodynamics (cQED) regime. The micropillars consist of single layer of InGaAs QD in a one λ cavity that is sandwiched between two distributed Bragg reflectors (DBR). The devices are contacted via a ring-shaped gold contact on the upper facet of the pillar. This enables the control of the emission properties of the coupled QD-cavity system via the quantum confined Stark effect. As such, PC-spectroscopy opens up the possibility of investigating and controlling the transmission properties of the coupled QD-microcavity system on a single QD level. To address the influence of cQED effects on the PC, the structure is probed under non-resonant as well as strictly resonant conditions using either sidewall excitation or excitation through the top facet of the micropillar. Single QD effects are identified via high-resolution PC spectroscopy under variation of temperature, bias voltage and excitation power. We observe pronounced changes of the photocurrent response when single QD emission lines are tuned in and of resonance with the fundamental cavity mode of a micropillar cavity.

HL 95.3 Fri 10:00 EW 201

Strong Quantum Dot - Cavity coupling in submicron diameter AlAs/GaAs micropillar cavities — •Matthias Lermer[1], Niels Gregersen[2], Florian Dunzer[1], Jesper Mørk[2], Stephan Reitzenstein[1], Alfred Forchel[1], Sven Höfling[1], and Martin Kamp[1] — [1]Technische Physik and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]DTU Fotonik, Department of Photonics Engineering, Technical University of Denmark, Building 343, DK-2800 Kongens Lyngby, Denmark

Micropillar (MP) cavities with embedded quantum dots (QD) are a promising semiconductor based platform for the investigation and application of cavity quantum electrodynamic (cQED) effects, e.g. the strong QD - cavity coupling. A figure of merit for this regime is the ratio Q/sqrt(Vmode), expressing that it is preferable to realize MPs providing not only high Q factors but also small mode volumes Vmode. This puts stringent requirements to the design and the processing of the MPs, which show a drastic decrease of the Q factor in the low diameter limit due to sidewall scattering losses and mode mismatch. These effects limit Q to about 2,000 in the submicron diameter range. To overcome this problem, we have designed and implemented a novel AlAs/GaAs cavity design showing Q factors exceeding 10,000 for MPs with submicron diameters. A record-high vacuum Rabi splitting (VRS = 85 micro eV) of the strong coupling in MPs with modest oscillator strength QDs has been observed for a MP with Q = 13,600 and a diameter of 850 nm.

HL 95.4 Fri 10:15 EW 201

Optimization of InGaN quantum dots for single line emission at elevated temperatures — •Elahe Zakizadeh, Heiko Dartsch, Timo Aschenbrenner, Stephan Figge, Carsten Kruse, and Detlef Hommel — Institute of Solid State Physics, University of Bremen, Germany

Due to the large bandgap and high exciton binding energy of the nitrides, InGaN quantum dots (QDs) are promising candidates for single photon emission at room temperature. In this presentation we show results of micro photoluminescence measurements on InGaN quantum dots formed by a spinodal decomposition process in MOVPE [1]. The samples show quantum dot related photoluminescence in the blue-green spectral region. Simple GaN layers containing InGaN QDs have been investigated as well as a fully monolithically grown cavity structure with InGaN QDs at the antinode position of a cavity between two GaN/AlInN Bragg reflectors. Single line QD emission could be observed up to a temperature of 100 K. In order to achieve single line emission at higher temperatures a novel concept of introducing AlGaN or AlInN barriers for larger carrier confinement will be discussed and first results will be shown.

[1] C.Tessarek, et al., Phys. Rev. B 83, 115316 (2011)

HL 95.5 Fri 10:30 EW 201

Ultrafast switching of a semiconductor quantum dot exciton — •Christian Dicken[1,2], Christian Wolpert[1,2], Klas Lindfors[1,2], Harald Giessen[1,2], and Markus Lippitz[2] — [1]Max Planck Institute for Solid State Research, Ultrafast Nanooptics — [2]University of Stuttgart, 4th Physics Institute

We report on ultrafast switching of the neutral exciton transition of a single GaAs quantum dot on the 50 ps timescale. In our experiment, an electron-hole plasma is created in the vicinity of the quantum dot by a strong 150 fs off-resonant laser pulse. As a consequence we observe in transient reflection a reduction of the transition dipole moment by typically 50 % and a redshift of the absorption line of up to 100 μeV. Both effects follow the dynamics of the electron-hole plasma and are strongly power dependent. We discuss the control and enhancement of the switching by confining the electron-hole plasma spatially.

HL 95.6 Fri 10:45 EW 201

Role of Coulomb correlations and carrier relaxation for pump-probe signals obtained from a single quantum dot — •Jan Huneke[1,2], Irene D'Amico[3], Pawel Machnikowski[4], and Tilmann Kuhn[2] — [1]Instituto de Ciencia de Materiales de Madrid, Sor Juana Inés de la Cruz 3, 28049 Madrid, Spain — [2]Institut für Festkörpertheorie, WWU Münster, Wilhelm-Klemm-Straße 10, 48149 Münster, Germany — [3]Department of Physics, University of York, Heslington York YO10 5DD, United Kingdom — [4]Institute of Physics, Wroclaw University of Technology, PL-50 370 Wroclaw, Poland

We present a theoretical modeling of femtosecond pump-probe experiments performed on a single negatively charged quantum dot. The influence of Coulomb-correlation effects as well as carrier relaxation is investigated. In particular, we study their influence on the fundamental trion absorption line. Our model describes the ultrafast disappearance of the fundamental trion absorption due to instantaneous Coulomb renormalizations and a delayed onset of gain at the same frequency, as found in the measurements[1]. As a result of spin- conserving carrier relaxation, our model predicts the emergence of new optical transitions exhibiting either gain or absorption. The time dependence of these new transitions provides insight into details of the carrier relaxation processes.

[1] F Sotier, T Thomay, T Hanke, J Korger, S Mahapatra, A Frey, K Brunner, R Bratschitsch and A Leitenstorfer, 2009 Nature Physics

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HL 95.7 Fri 11:00 EW 201

On the treatment of carrier scattering in quantum dots beyond the Boltzmann equation — •Alexander Steinhoff[1], Matthias Florian[1], Paul Gartner[1,2], and Frank Jahnke[1] — [1]Institute for Theoretical Physics, University of Bremen, Germany — [2]National Institute of Materials Physics, Bucharest-Magurele, Romania

As quantum dots (QD) can confine a small number of carriers in localized states with discrete energies, it is clearly questionable to neglect correlations between the carriers when describing their dynamics. We discuss the effects of carrier correlations in a single QD in contact with a wetting layer (WL) by comparing the carrier dynamics without correlations between the QD-carriers, as given by a Boltzmann equation, with the correlated dynamics governed by a Liouville-von Neumann equation. In a first step, we take into account correlations generated by the exact treatment of Pauli blocking. Subsequently, we include correlations generated by energy renormalizations due to Coulomb interaction between the QD-carriers. It is shown that at low WL-carrier densities, neither Pauli correlations nor Coulomb correlations can be safely neglected, if the dynamics of single-particle states in the QD are to be predicted qualitatively and quantitatively. In the high-density regime, both types of correlations play a lesser role and thus an uncorrelated description of carrier dynamics by a Boltzmann equation becomes reliable. Furthermore, the efficiency of WL-assisted scattering processes as well as scattering-induced dephasing rates depending on the WL-carrier density are discussed.

HL 95.8 Fri 11:15 EW 201

Low lasing threshold of CdS nanowires — •Robert Röder, Sebastian Geburt, and Carsten Ronning — Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

Semiconductor nanowires mark the physical size limit for photonic lasers: a further miniaturization can only be achieved by combination of photonic with plasmonic structures. High quality cadmium sulfide nanowires (CdS NW) were synthesized via vapor-liquid-solid (VLS) mechanism. The intense near band edge emission and the minor defect emission at low excitation power indicate the marginal defect concentration. Sharp peaks evolving at moderate excitation powers dominate the luminescence spectrum at higher laser power. The evaluated power dependency clearly shows all characteristics of lasing action in the NW cavity. The low threshold of 10 kW/cm^2 at room temperature was observed as well as its relation to the Q factor of the cavity. The length of the NW resonator was examined as one determining factor for the high Q values of up to 1800. Polarization and angular distribution of the emission from one end of the optically pumped NW can be studied using a "head on" experimental configuration. The lower length and diameter limits for photonic NW lasing were evaluated, but the CdS nanolaser can generate highly localized intense monochromatic light ideally suited for coupling plasmonic structures such as metallic nanoparticles, plasmonic substrates and quantum dots.