

Quantum dot microcavities - status and challenges for investigations of physical properties and devices

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Semiconductor systems with three dimensional photonic confinement, like micropillar cavities with vertical optical confinement by distributed Bragg reflectors (DBRs) or semiconductor membrane based photonic crystal cavities have permitted to observe a number of fundamental phenomena of cavity quantum electrodynamics (cQED). By using low level optical excitation of semiconductor cavities with embedded quantum dots, both the weak and strong coupling regime between a single photon and a single quantum dot could be clearly observed. In order to study these phenomena the quantum dot and the cavity mode have to be shifted on resonance e.g. by adjusting the quantum dot emission energy via temperature tuning. In the case of weak coupling strong emission intensity enhancements of up to two orders of magnitude are observed on resonance as well as a shortening of the radiative lifetimes. For strong coupling vacuum Rabi splittings of up to 0.7 meV and 0.2 meV have been observed in II-V and III-V systems, respectively.

Using molecular beam epitaxy, high resolution lithography and dry etching we have fabricated quantum dot micropillar cavities with and without integrated p-i-n structures. By using up to 36 AlAs/GaAs quarter wavelength mirror pairs in the upper and lower DBRs surrounding the cavity, Q-factors up to 160.000 are obtained for undoped cavity structures. This Q-value corresponds to a photon lifetime of close to 90 ps.

Although investigations on optically pumped structures constitute a very active field permitting to study e.g. fundamental aspects of quantum information processing, applications of cQED will depend strongly on the availability of electrically driven devices which are operational at or near room temperature. In the talk low temperature studies on electrically driven quantum dot micropillar structures will be presented and compared to results from optically pumped structures. We will also discuss challenges ahead which have to be met in order to reach application grade devices.

Micropillar cavities using electrical carrier injection into the QDs have been fabricated using e.g. 27 mirror pairs in the n-doped bottom DBR and 23 mirror pairs in the p-doped top DBR. In order to minimize losses, the one wavelength thick cavity between the DBRs is undoped. The micropillars are embedded in BCB which acts as isolator and planarizer for the realization of the upper ring shaped p-contact. Most importantly for pillar diameters below 2 μm , which are particularly interesting for the observation of strong coupling effects, we observe no difference between the Q factors of doped and undoped structures, which indicates that sidewall losses are dominating the overall loss of these structures. For larger diameters damping by the doping reduces the Q factors compared to undoped cavities significantly. Using doped micropillars we have studied possibilities for field induced tuning of the quantum dot energies on resonance with the cavity mode in comparison to thermal tuning. Results on devices regarding weak and strong coupling effect as well as lasing will be reported.

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