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Publication date:
2012

Citation (APA):
Lermer, M., Gregersen, N., Dunzer, F., Mørk, J., Reitzenstein, S., Höfling, S., Kamp, M., & Forchel, A. (2012). *High-Q AlAs/GaAs adiabatic micropillar cavities with submicron diameters for cQED experiments*. Abstract from 7th International Conference on Quantum Dots, QD 2012, Santa Fe, NM, United States.

High-Q AlAs/GaAs adiabatic micropillar cavities with submicron diameters for cQED experiments

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Quantum dot (QD) micropillar cavities represent an interesting class of microresonator systems aiming at the observation and application of cavity quantum electrodynamics (cQED) on a semiconductor platform. They combine valuable properties i.e. a highly directional and approximately Gaussian shaped emission pattern, efficient electrical operation, high quality (Q) factors up to 165.000 at large diameters [1].
In order to observe cQED effects such as weak or strong QD-cavity coupling it is necessary to realize micropillars providing not only high Q factors but also small mode volumes V_{mode}. This puts stringent requirements to the design and the processing of the micropillars which show a drastic decrease of the Q factor in the low diameter limit due to sidewall scattering losses and mode mismatch. Indeed, these effects limit the Q factor to ~2,000 in the submicron diameter range for a standard microcavity design [1, 2].
To overcome the trade-off between high Q and low V_{mode}, we designed and implemented a novel adiabatic AlAs/GaAs cavity design (MC1) with 3 taper segments (Fig. 1 (a)) as it was suggested by Zhang et al. for SiO_2/TiO_2 micropillar cavities [3]. Comparative measurements of the Q factor were performed between a standard one-λ microcavity structure (MC2) and MC1 for pillars with diameters ranging from 0.70 µm to 1.50 µm (Fig. 1 (b; bottom)). As can be seen in Fig. 1(b) MC1 shows significantly higher Q-factors exceeding 10.000 in the submicron diameter range due to the adiabatic cavity design. Purcell factors F_P between 225 and 325 can be expected in the diameter range between 0.70 µm and 1.00 µm as it is indicated by the shaded box in Fig. 1 (b; top). Moreover, strong coupling between a standard InGaAs QD and an 850 nm diameter adiabatic micropillar with quality factor of 13.600 has been achieved.

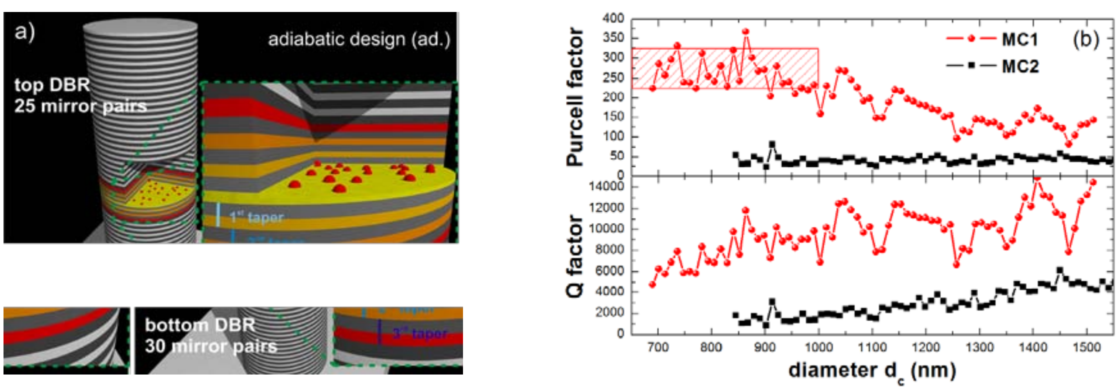

Figure 1: Schematic sketch of the adiabatic AlAs/GaAs micropillar cavity design with 25/30 mirror pairs in the top/bottom DBR. A zoom in picture in the cavity taper region is added (a). Comparative measurements of Q were performed between MC1 and MC2 (b; bottom). Purcell factors for MC1 between 225 and 325 can be expected for micropillars with d_c between 0.70 µm and 1.00 µm (indicated by the shaded box) (b; top)

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