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 \( V_{\text{mode}} \). 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 \( \sim 2,000 \) in the submicron diameter range for a standard microcavity design [1, 2]. To overcome the trade-off between high Q and low \( V_{\text{mode}} \), 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-\( \lambda \) microcavity structure (MC2) and MC1 for pillars with diameters ranging from 0.70 \( \mu \)m to 1.50 \( \mu \)m (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 \( \mu \)m and 1.00 \( \mu \)m 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 \( \mu \)m and 1.00 \( \mu \)m (indicated by the shaded box) (b; top)

References