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QUANTUM-DOTS IN MICRO-PILLAR MICRO-CAVITIES: EXPERIMENT AND THEORY

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We are aiming to develop efficient single spatial and temporal mode single photon sources for quantum information applications. One promising route is to use micropillar microcavities containing single quantum dots. Here we model micro-pillar micro-cavities made of III-V semiconductor materials (AIAs/GaAs) with quarter-wavelength-period stacks resonant at wavelengths in the 900-1000nm region using the 3-D finite-difference time-domain (FDTD) method. We place a broadband dipole source in the centre of the cavity and input a short few-cycle excitation pulse to model quantum dot emission. The cavity then rings at its resonant frequency and we monitor the cavity ring down using a probe above the pillar. This allows us to determine the resonances of the various waveguide modes in the cavity (fig. 1).

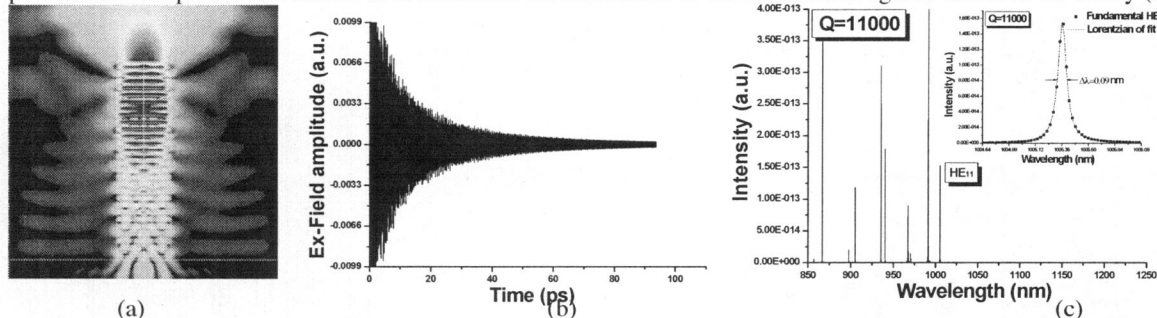


Figure 1. (a) Single frequency snapshot of the field in the cavity on-resonance, 15 mirror pairs on top and 30 mirror pairs below b) Time evolution of the field at the top of the cavity showing ring down. (c) Intensity spectrum obtained for the time evolution data showing resonant modes. The inset of (b) shows the fundamental resonance with Q -factor of 11000.

At large radii (3 μm) we see small blue shifts and high- Q (>11000) resonances in pillars with 30 bottom mirror pairs and 15 top mirror pairs. At small radii the fundamental mode Q -factor falls due to lower field confinement and scattering at the index discontinuity on the pillar edges. Experimentally we make micro-pillars by focussed ion beam etching of planar microcavities. The cavity region contains a layer of self organised quantum dots. At high dot density the photoluminescence spectra measure the narrow resonances associated with the cavity modes allowing us to estimate cavity Q -factors. In preliminary studies we see high Q -factors for large (10 μm pillars) but the fall in Q -factor begins at larger pillar diameter. This may be due to surface roughness of the pillars. At small diameters we begin to see single dot spectra and are able to tune individual dots in and out of resonance with the cavity by changing sample temperature. We hope to present evidence of single photon emission at the conference.

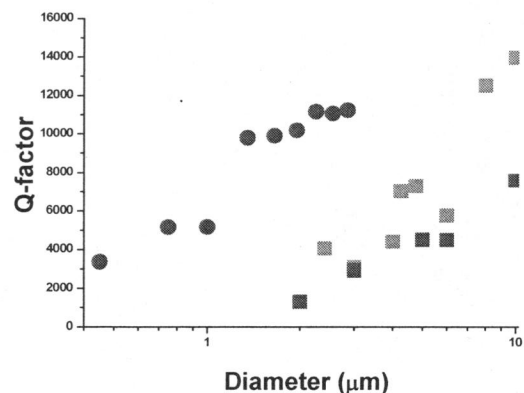


Figure 2 Reduction of Q -factor with reduced cavity diameter measured experimentally (squares) and by FDTD modeling (circles).

1. Y. -L. D. Ho, M. J. Cryan, I. J. Craddock, C. J. Railton, and J. G. Rarity. Modelling quantum dots in conventional and annular III-V micro-pillar micro-cavities for single-photon sources, Proceedings of the 4th IEEE Conference on Nanotechnology, Munich, Germany, Paper WE3_1_2 (2004).