Emission Characteristics of Quantum Dots in Photonic Crystal Nanocavities

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Semiconductor quantum dots in nanocavities provide a promising and exciting platform for the investigation of many fundamental effects in quantum optics.[1] An important property of a quantum dot is how closely it approximates a true two-level system. A prominent characteristic of truly quantum emitters is their antibunched photon statistics in $g^{(2)}(\tau)$ photon correlation experiments. In our experiments we investigate the emission characteristics, including photon statistics, of single quantum dots (SQDs) in photonic crystal nanocavities.

Our samples are grown by Molecular Beam Epitaxy (MBE) with a single layer of InAs quantum dots in GaAs. The photonic crystal nanocavities are fabricated by reactive ion etching (RIE) according to the design of Noda's group[2]. Our spectroscopy is performed by looking at photoluminescence (PL) from the dots excited above band by a continuous wave or by a pulsed Ti:Sapphire laser. We select dots of interest by considering spectral location relative to cavity modes, and signal intensity of individual quantum dots. One major source of interest for us is how closely the signal intensity of individual quantum dots corresponds to the Purcell enhancement of that dot. We have observed dramatic increases in PL signal levels for dots which are spatially and spectrally near a cavity mode, even for relatively low-Q modes. Figure 1 shows an example of a very bright single quantum dot near a low-Q cavity mode.

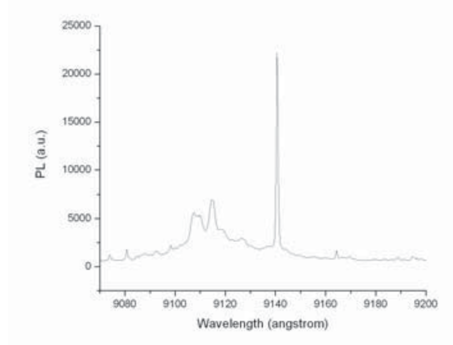

Fig. 1: *Photoluminescence spectra of a single quantum dot near the resonance of a low-Q cavity*.

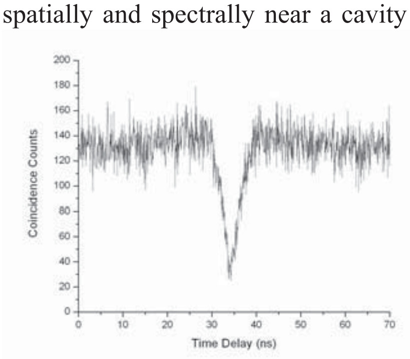

Fig. 2: *Coincidence counts from a SQD excited with cw excitation measured using a Hanbury Brown-Twiss interferometer*.

We use a Hanbury Brown-Twiss interferometer to observe $g^{(2)}(\tau)$ photon correlation statistics for both pulsed and continuous wave (cw) excitation. We have succeeded in observing antibunching in both cases. Figure 2 shows the results of one such measurement using a single quantum dot in a cavity. The experiments verify that the quantum dots we have grown are truly quantum emitters, suitable for quantum optics experiments and quantum information applications. Ongoing experiments include characterizing the cw $g^{(2)}(\tau)$ dip to observe the dependence of its width and depth on pump intensity and detuning from a cavity mode. The detuning between a cavity mode and a single dot can be changed by a technique we have developed of condensing xenon or nitrogen on the sample[3]. We hope to see if it is possible to measure the lifetime of the SQD, and hence the Purcell enhancement, using the cw $g^{(2)}(\tau)$ photon correlation experiment. Finally, we are interested in measuring the photon correlations for cavities which in prior work have exhibited gain and lasing[4]. Since such high-β devices do not exhibit a distinctive intensity threshold, a decisive criterion for lasing is the transition from bunched to coherent photon statistics, corresponding to the transition from a thermal to a coherent source. Our Hanbury Brown-Twiss interferometer should also allow us to perform these measurements.

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[4] Hendrickson, J., *et al.,* Phys. Rev. B, **72**, 193303 (2005).