Controlling the Biexciton-Exciton Cascade Kinetics in a Quantum Dot via Coupling to a Microcavity Optical Mode

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We have studied photoluminescence (PL) from a single micropillar cavity (Q = 4500 typically) with a set of single QDs in the active layer. The pillars with circular cross-section in the range of 1 - 2 μm have been processed by reactive ion-etching of GaAs/AlAs planar microcavity structure grown by molecular beam epitaxy. The Bragg reflectors were composed of 20 (23) repetitions of λ/4 GaAs/AlAs (69 nm/82 nm) layers in the top (bottom) mirrors. The single λ GaAs cavity contains an array of self-assembled $In_{0.6}Ga_{0.4}As$ QDs (density ~10^{10} cm^{-2}) placed at the antinode of the on-axis resonant fundamental mode of the cavity. The change of temperature in a range of 5 - 50 K was used to tune single QD emission lines on the resonance with the cavity mode – see Fig. 1 with an example of the spectra and the temperature tuning.

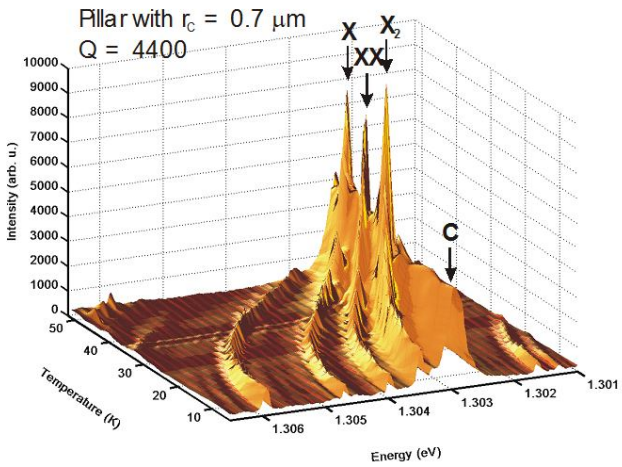

Figure 1. Micro-photoluminescence spectra showing exciton (X) and biexciton (XX) emission lines tuned consecutively through resonance with the cavity mode (C).

Depending on the excitation power density the QDs demonstrate the emission of exciton or biexciton with a difference in the transition energies of about 1 meV typically. The on- and off-resonance power dependence of the intensities has been found to be strongly different for the exciton and biexciton emission. However, both the QD exciton and biexciton transitions demonstrate strong and similar emission intensity enhancement by passing the cavity resonance due to Purcell effect. The experimental results are in good quantitative agreement with simulations based on a simple few level rate equations model. The variation of the exciton (biexciton) lifetime caused by Purcell effect has been shown to allow for controlling the ratio between the single and two exciton occupation and the emission rates in a single QD. This cavity-mode-assisted control of the biexciton-exciton cascade kinetics paves the way for further development of potential applications, which ranges from high speed and single photon sources to quantum information processing and cryptography.