Observation of Purcell effect with a site-controlled pyramidal quantum dot coupled to a photonic crystal cavity mode

C. Jarlov[1], L. Ferrier[1], M. Calic[1], P. Gallo[1], V. Belykh[2], A. Rudra[1], B. Dwir[1] , N.N. Sibeldin[2] and E. Kapon[1]

[1]*Laboratory of Physics of Nanostructures, Ecole Polytechnique Fédérale de Lausanne, CH1015 Lausanne*
[2]*P. N. Lebedev Physical Institute, Russian Academy of Sciences, Moscow, Russia*

Cavity quantum electrodynamics (cQED) experiments with quantum dots (QD) and micro-cavities have been used to study quantum effects that can be useful for the field of quantum information processing. Especially the development of high-efficiency single photon emitters requires the control of QD radiative properties. In cQED experiments, the spontaneous emission rate of QDs is modified when QDs couple to a cavity mode through the Purcell effect[1]. We demonstrate the increase of the emission rate of a single site-controlled QD located at the centre of an L3 cavity where the electric field of the fundamental mode is maximum (Fig 1 (a)), ensuring an optimal overlap between the field distribution and the QD. Precise positioning of our QDs during the fabrication process allows for a position error of less than 50nm[2]. We first performed polarization resolved photoluminescence (PL) and power dependence measurements of the ground state features of the single pyramidal QD coupled to the cavity mode (Q=2000) (Fig. 1-(d)) in the off-resonant and resonant configurations to identify the QD features and the coupling to the cavity mode. Figure 1-(b) and (c) show time-resolved PL measurements of the QD in the off-resonant and resonant cases. The biexciton's lifetime is drastically decreased when resonant with the cavity mode. A model based on a four-level rate equation model is used to fit the decay rates and retrieve the lifetime of the biexciton. An increase by a factor of 7 of the spontaneous emission rate of the biexciton is achieved.

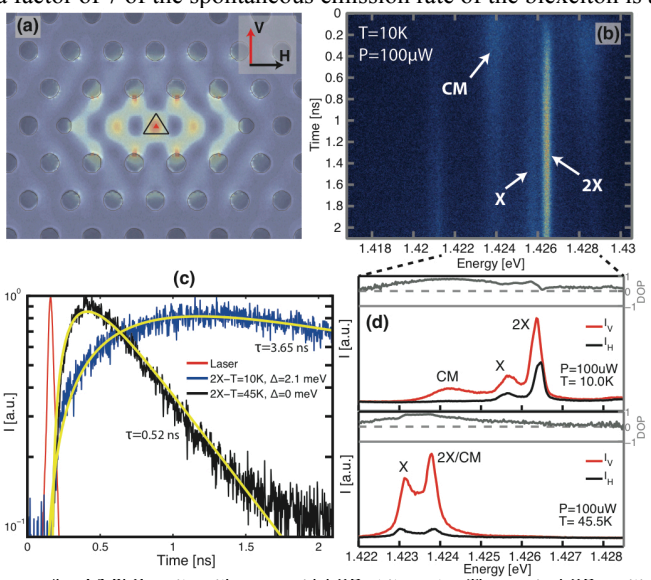

Fig. 1- (a) SEM image of an L3 PhC cavity with a pyramidal QD at its center. The nominal QD position is indicated by the red triangle. The field distribution of the fundamental mode of the cavity is superimposed on the image (FDTD simulations). (b) Time resolved image of the ground state feature of the QD coupled to the cavity. At T=10K, the 2X feature is detuned by 2.1meV from the cavity mode. (c) Temporal evolution of the 2X luminescence for an off-resonant (blue) and resonant cavity mode (black). (d) PL linearly resolved in polarization of the QD ground state features along the directions perpendicular (V) and parallel (H) to the cavity axis. Both the resonant case (bottom) and off-resonant case (top) are shown.

[1] D. G. Gevaux et al., Appl. Phys. Lett.. **88**, 13 131101 (2006).
[2] M. Calic et al., Phys. Rev Lett.. **106**, 22 7402 (2011).