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Waveguide-coupled Electrically-tunable Cavity-Emitter System

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In scalable quantum photonic integrated circuits it is imperative to spectrally tune both cavities and emitters independently, in order to overcome their intrinsic energy mismatch and generate indistinguishable single-photons on a chip. Here we present the first fully-controllable cavity-emitter system in the solid state and discuss its coupling to ridge waveguides.

Our device consists of a double-membrane photonic crystal (PC) where the wavelength of the resonant modes can be controlled by modulating the distance between the two slabs via electrostatic actuation [1,2]. A second p-i-n diode is realized across the upper membrane where a layer of self-assembled quantum dots (QDs) is located, in order to tune their emission spectrum by exploiting the quantum-confined Stark effect.

Fig.1(a,b) shows the micro-photoluminescence spectra of the device acquired when the cavity is electromechanically tuned, while two different biases are applied to the QDs. Harnessing this double-tuning mechanism, a single excitonic line is brought on resonance with the cavity mode (CM) at two distinct wavelengths (λ_1=1332.2nm, λ_2=1335nm). When the QD line is spectrally aligned with the resonant mode its emission is enhanced and a Purcell effect of $F_P(\lambda_1)=10.7 \pm 1.3$ and $F_P(\lambda_1)=7.5\pm0.6$ has been measured from time-resolved experiments.

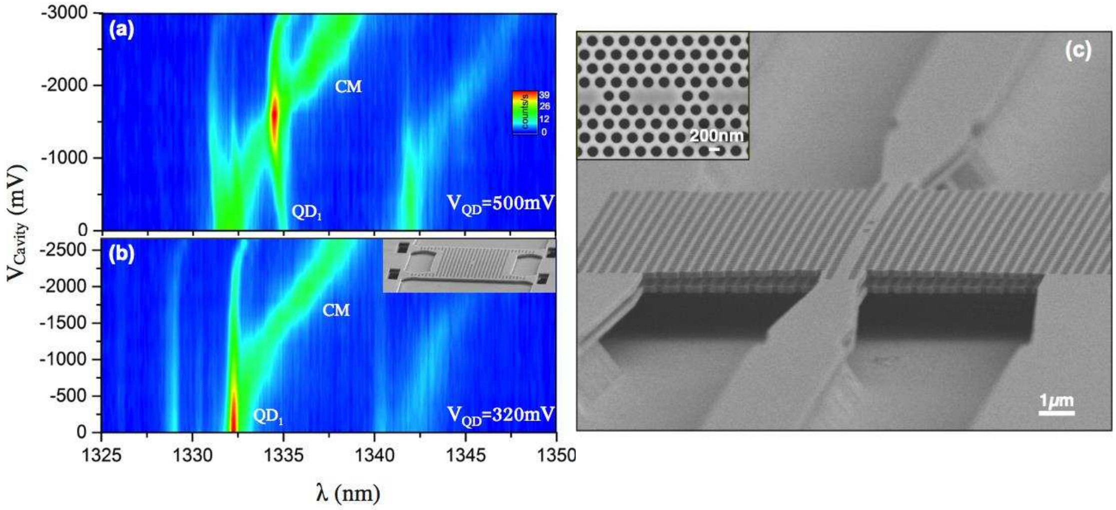

Fig. 1 (a,b) False-coloured micro photoluminescence spectra acquired varying the voltage across the two membranes (V_{cavity}) at two QD bias (V_{QD}=320mV and V_{QD}=500mV, respectively). (c) Tilted angled SEM picture of the double-membrane device integrated with ridge waveguides. The cavity is created by evanescently coupling an L3 defect with two W1 PC waveguides.

Furthermore, we focus on the integration of this architecture with supported ridge waveguides (RWs) required to funnel cavity-enhanced single photons with low loss across a planar circuit. We make use of two tapered suspended nano-beams to optically interconnect the free-standing crystal region to composite waveguides (Fig.1(c)). The efficient in-plane coupling is demonstrated by collecting the resonant modes of the cavity from both the top of the device and the cleaved facets of the RWs.

In conclusion, by exploiting the mechanical degree of freedom of a PC cavity and the electrical tunability of QDs, a fully-tunable cavity-emitter system is experimentally demonstrated, where the spontaneous emission of a single exciton is controlled at adjustable wavelengths. The integration of this platform with ridge waveguides will pave the way to novel reconfigurable quantum experiments where many single photon sources can interact on the same chip.

References

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