Integrated Quantum Optics with Electrically Driven Quantum Dot - Micropillars

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Abstract

We report on results in the field of integrated quantum optics using a novel integrated photonic device consisting of electrically contacted InGaAs quantum dot-micropillar cavities. Whispering gallery modes support single-mode lasing and radiate within the plane of the active material towards neighbouring, separately contacted micropillars, which are monolithically integrated and can be used for a range of purposes including on-demand single photon generation and investigating opto-electronic feedback.

Device Layout: The micropillars are fabricated on a GaAs substrate and their composition can be seen in Fig. 1 (a). A single micropillar 6-10 microns in diameter is surrounded by a group of five smaller micropillars (diameters ~ 2 microns, see Fig. 1 (b)). The peripheral pillars share one contact with apertures above each pillar for the vertical emission of single photons. The larger central micropillar supports single mode lasing of laterally emitting whispering gallery modes (WGMs); this laser light excites the quantum dots (QDs) in the peripheral pillars, whose spontaneous emission is enhanced by cQED effects. The lasers themselves have high β-factors on the order of 10% on account of their low mode volumes resulting in threshold currents as low as 8 μA [1].

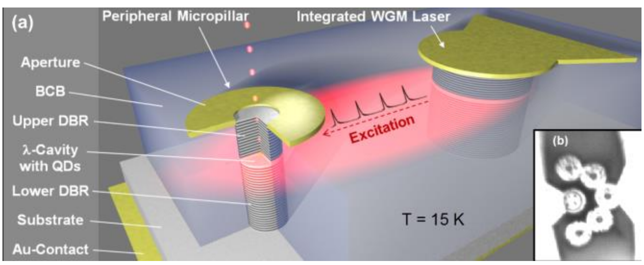

Fig. 1. Sample layout based on pin-doped semiconductor QD-micropillars. a) GaAs/AlAs distributed Bragg reflectors form the top and bottom parts of the micropillars. The central micropillar is an electrically pumped single mode WGM laser which excites the neighboring QD-micropillars. (b) A CMOS camera image of the sample. Pillar-laser separation is 15 μm.

Experimental Setup and Results: The sample is analyzed with a micro-photoluminescence spectroscopy setup at cryogenic temperatures. Purcell factors of between 2 and 4 have been observed in the external pillars [2] as well as single-photon purities of as low as $g^{(2)}(0) = 0.07$ during integrated microlaser excitation, as shown in Fig. 2(c). The emission of these single photons can be spectrally tuned by up to 1.1 meV via the Stark effect as demonstrated in Fig. 2(b). Alternatively, if the bias is negative, the micropillars serve as photodetectors, converting laser light into photocurrent which has been used to determine the laser threshold using a lock-in technique [3], and this photocurrent has been also used in a feedback experiment to generate self-sustained pulses in the laser output, opening possible routes to chaos in the laser emission (c.f. Fig. 2(d)). Further work will focus on on-chip resonant excitation to generate highly indistinguishable photons under pulsed electrical excitation.

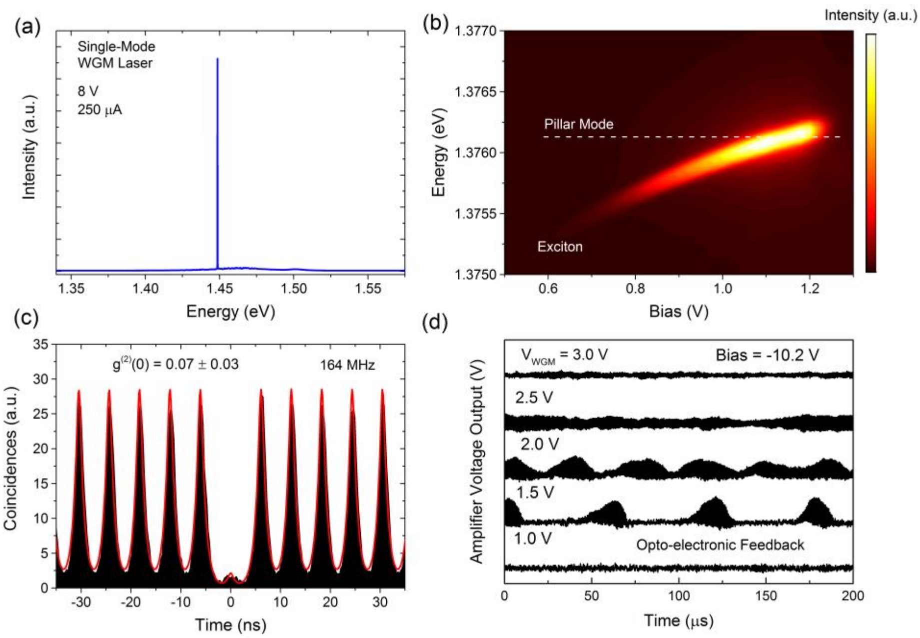

Fig. 2. Experimental results. (a) Single mode lasing from a central WGM microlaser. (b) Electro-optical tuning of a single QD exciton via the Stark effect. (c) Pulsed second order autocorrelation function measured on a QD pumped via the integrated microlaser. (d) Opto-electronic feedback between a microlaser and surrounding micropillars acting as photodetectors, with increasing laser bias V_{WGM}.

References

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