Filter-free quantum dot resonance fluorescence in an integrated cavity-waveguide device

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Semiconductor quantum dots embedded into micro-pillar cavities are excellent emitters of quantum light; for instance, single photons when pumped resonantly. These properties are achieved because of the inherently high quantum efficiency and high spontaneous emission rates of the optically allowed, lowest level exciton states, and their integration into optical cavities. Because of the large material index of refraction and the single mode cavities used, the resonant excitation pump and signal are often in the same spatial mode. Separating the two is most often achieved through special polarizers and orthogonal pump-probe polarization, leading to a 50 % signal reduction. Here, we demonstrate micro-pillar cavities connected orthogonally to waveguides, allowing us to resonantly excite single quantum-dot states. This approach eliminates the need for cross-polarization and, as shown here, can be measured without any filtering. This integrated device allows for vertical, off-chip, cavity-enhanced resonance fluorescence through on-chip waveguide coupling. Since several quantum-dot containing cavities are simultaneously waveguide coupled, we expect this design to be a prototype for larger chip-scale quantum photonics.

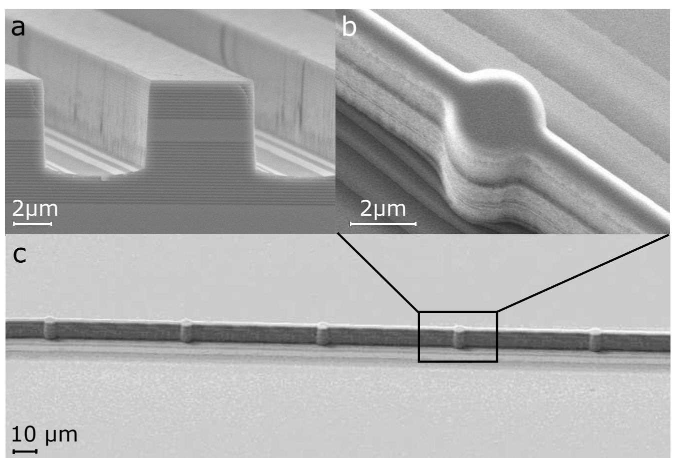

Figure 1: Scanning electrom microscopy images of the sample. **a** Cleaved edge of the sample which is used to couple the laser into the waveguide. **b** A single micro-pillar. **c** Micro-pillar cavities connected by a waveguide.

In Fig. 1 we show scanning-electron microscopy images of a waveguide coupled to several pillar optical cavities. The cavities (and waveguide) are formed from upper and lower distributive-Bragg reflector mirrors of GaAs and AlAs with a 4 wavelength cavity region resonant at 930 nm. The center region of the cavity contains a single layer of InAs QDs. Each waveguide contains 25 micropillar cavities and the embedded QDs are excited by free-space coupling of light into the waveguide through the cleaved facet of waveguide. We planarized the sample and applied a gold coating with openings at the micropillar positions to suppress the collection of scattered laser light from the waveguide-cavity interface. The measured quality factors of the cavities range from 3000 to 4000, for cavity diameters between 2.1 and 2.8 μm. The measured Purcell enhancement is 2.44(6), which is in the expected range for the measured quality factors and the 4λ cavity mode volume. Second-order autocorrelation measurements with cw-resonant pumping through the waveguide show deconvoluted $g^{(2)}(0)$ values of zero within the experimental error ($+0.054$), revealing good suppression of incoherently scattered pump light.