Positioning of InAs/InP quantum dots emitting at 1.55 µm and fabrication of circular Bragg gratings

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Single and entangled photon pairs generators for quantum communication and computation purposes require precise and deterministic structure processing that is indispensable for a high device yield. We challenge this issue, developing a few important technological steps which pave the way for the bright, highly-coherent quantum states generators compatible with the telecommunication C-band centered at 1.55 µm.

First, we optimize the growth of low-density InAs/InP quantum dots (QDs) utilizing the industry-compatible metal-organic vapour phase epitaxy [1]. Second, we develop a simple and cost-effective method for extracting QD emission from a semiconductor chip, reaching photon extraction efficiency ∼10 % in the C-band [2]. This step is crucial for 2D imaging of QD emission in our setup (2D µPL map is shown in Fig. 1a), allowing for pre-selection of QDs and their spatial positioning with <50 nm accuracy. This is needed for the following steps of shaping the QD photonic environment with, e. g., fabrication of circular Bragg gratings (CBG) directly at the position of a selected QD.

Following this issue, we model the CBGs and find a design reaching photon extraction efficiency up to 80 % (NA = 0.65) and the Purcell enhancement factor of $F_\mathrm{P} \sim 18$. Then, we fabricate (Fig. 1b) and characterize (Fig. 1c) the gratings, demonstrating the mode wavelength of 1.55 µm and width of ∼ 7 nm, translating into the quality factor of $Q = 230 \pm 35$ with high processing repeatability. These parameters allow for simultaneous coupling of QD-confined exciton and biexction states to the cavity field to reach highly-efficient emission of entangled photon pairs.

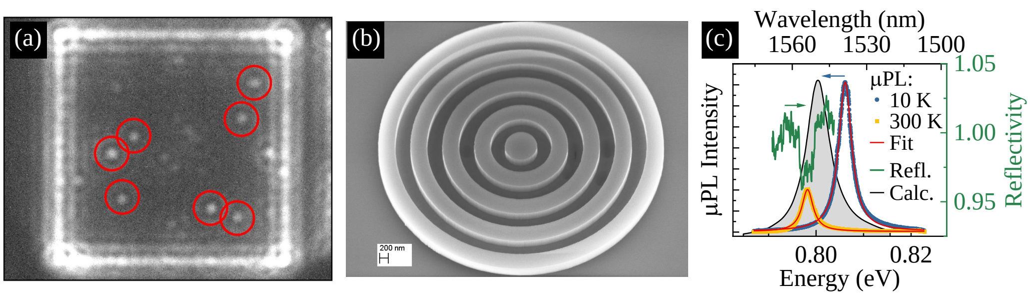

Figure 1: (a) An exemplary 2D µPL map of InP area with 7 QDs emitting at 1.55 µm and field edges serving as reference. (b) SEM image of a fabricated InP circular Bragg grating. (c) Comparison of the calculated and measured (µPL, reflection) mode profiles.

[1] P. Holewa et al., *Phys. Rev. B* **101**, 19, 195304 (2020).
[2] P. Holewa et al., *ACS Photonics* (in review).