Design of a defect-based photonic crystal nanobeam cavity robustly coupled to an underlying SiN waveguide

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A challenge to proceed from proof-of-concept quantum photonic integrated circuits (QPICs) to large-scale QPICs is the integration of single-photon sources (SPSs) with scalable performances. InAs/GaAs quantum dots (QDs) and SiN-based optical circuitry are among the most promising options for each part, but due to the difference in material platforms, a dedicated optical design suitable for hybrid integration is required. We recently demonstrated a GaAs photonic crystal (PhC) nanobeam cavity can efficiently couple QD emission into an underlying Si waveguide[1]. However, the design includes etched surfaces close to the QD, which will degrade the indistinguishability of generated single photons[2].

Here, we discuss a design of PhC nanobeam cavity with a defect region and its optical coupling to an underlying SiN waveguide buried in glass. As in Fig. 1(a), a 2.3-µm-wide defect region is formed in the 340-nm-wide and 130-nm-thick GaAs nanobeam cavity to address the surface proximity problem. The defect, however, increases the effective refractive index of the cavity mode, hindering phase-matching with a low-index SiN waveguide. The effective index of the guided mode can be increased by widening the waveguide to 900 nm, which however makes the waveguide multimode. According to finite difference time domain simulations, this design nevertheless allows the coupling of QD radiation selectively into the fundamental waveguide mode with a high efficiency of 90%. Even with lateral misalignment, no significant drop of coupling efficiency to the fundamental mode is observed up to 150 nm (Fig. 1(b)), which is well within the accuracy of many hybrid integration methods including transfer printing[1].

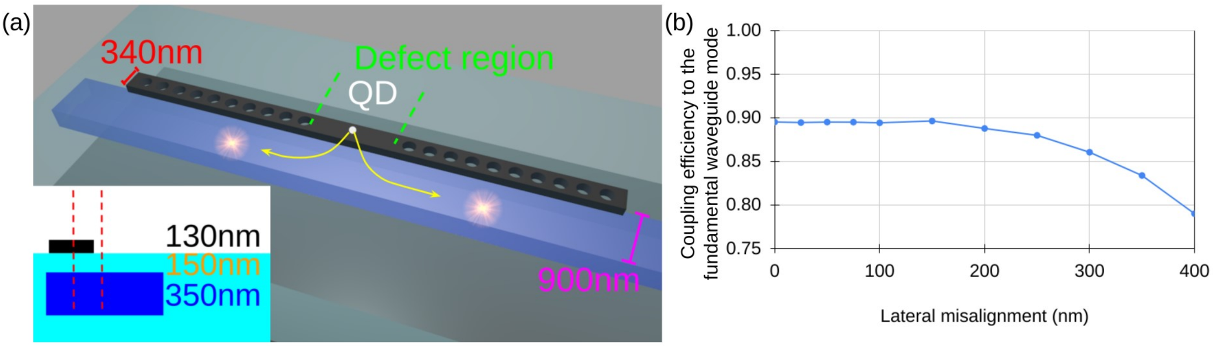

Fig. 1 (a) Schematic of the defect-based nanobeam cavity integrated on the SiN waveguide. The inset shows a vertical cross-section of the structure, showing the thicknesses of the nanobeam cavity, vertical separation, and the waveguide. The lateral distance between the red dash lines is the lateral misalignment. (b) Coupling efficiency into the fundamental guided mode as a function of lateral misalignment.

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