Hybrid-Integrated Quantum-Dot Single-Photon Sources on SiN Platform

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Integrated quantum photonics is attracting a lot of attention as a platform for quantum technologies. Superior properties of silicon nitride (SiN) for passive elements, especially low loss and a wide transparency window, make it suitable as a backbone optical circuitry[1]. On the other hand, there is a lack of active functions, including efficient generation of single photons. InAs/GaAs quantum dots (QDs) are among the best deterministic single photon sources (SPSs) known so far. Although there have been reports of QD SPSs integrated on SiN, it is still difficult to scale up the system due to challenges in extraction efficiency into the waveguide and spectral inhomogeneity of the QDs.

In this workshop, we present two approaches to advancing hybrid-integrated QD SPSs: efficient coupling to a SiN waveguide and spectral tuning of QD emissions, both leveraging transfer printing techniques for hybrid integration. First, we employed a photonic crystal (PhC) nanobeam cavity to realize a QD SPS on a SiN waveguide[2]. We found that the second-order mode of a period-modulated PhC nanobeam cavity is located close to the waveguide mode in the momentum space and could present a way to efficiently couple photons from the QD SPS into the waveguide. The nanobeam was fabricated and transferred onto the SiN waveguide as shown in Fig. 1(a). A photoluminescence (PL) spectrum collected above the grating exhibits a broad cavity peak around 960 nm together with several sharp peaks from QDs. Second, we demonstrated electrical tuning of a QD with indium tin oxide (ITO) transparent electrodes[3]. A 2D PhC cavity containing QDs is cladded between top and bottom ITO electrodes with SiO_2 spacer layers as shown in Fig. 1(b). PL spectra at different voltages are plotted. The QD emission shifts with applied voltage and shows enhanced intensity at resonance with the cavity mode around the voltage of -51.2 V. These works represent fundamental steps toward scalable quantum photonic circuits with multiple QD SPSs on SiN. More details will be discussed in the workshop.

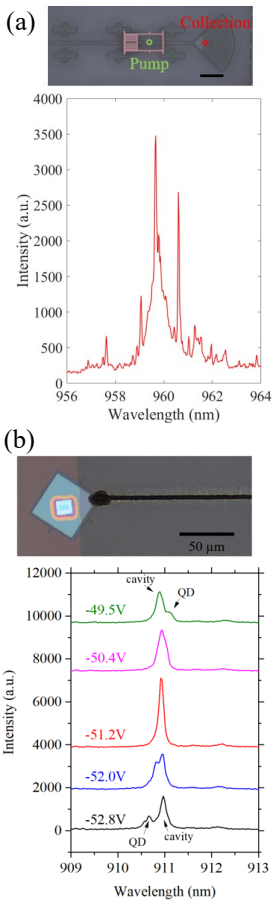

Fig. 1 (a) PL spectrum of a nanobeam cavity after transfer printing on a SiN waveguide as shown in the inset. The scale bar shows 10 μm. (b) PL spectra at different voltages of a 2D PhC cavity with ITO electrodes as shown in the inset. The scale bar shows 50 μm.

References [1] Xiang, C. *et al.*, *Photonics Res.* **10**, A82 (2022)
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[3] Pholsen, N. *et al., Opt. Mater. Express* **15**, 290–298 (2025).