On-chip single photon transfer with site-controlled quantum dots coupled to photonic crystal waveguides

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The challenging goal of realizing on-chip quantum circuits in which spins are interfaced with photons that are then routed, processed and detected has triggered significant research efforts over the past decades [1]. InGaAs/GaAs quantum dots (QDs) integrated in photonic crystal (PhC) circuits are one of the most advanced technologies in this direction [2]. Most of the work has focused on Stranski-Krastanow QDs that nucleate at random positions, while achieving truly scalable quantum circuits requires a precise deterministic integration of an entire QD system in a photonic circuit. However, the inhomogeneous broadening inherent to QD systems makes the simultaneous efficient coupling of several QDs to a given photonic mode difficult to accomplish. On the contrary, the finite spectral bandwidth of photonic waveguides should facilitate the simultaneous optical coupling of QD systems. Such structures could be used, e.g., to increase the emission rate of single photon sources by efficiently coupling multiple QD single photon sources to the same optical channel.

In this work, we demonstrate the deterministic coupling of five site-controlled QDs placed at different positions within a W1 photonic-crystal semi-waveguide with a reflective termination and an out-coupler on its ends (Fig. 1a). The measured spectrally resolved near-field pattern of the structure (Fig. 1b-c) shows that light, emitted by a selectively excited QD positioned up to 20.5µm away from the out-coupler, propagates in the waveguide and is collected at the out-coupler. Photon correlation measurements show clear antibunching of light collected by the couplers (Fig. 1d), demonstrating single photon propagation along the waveguide. The impact of a small slow light zone to improve the efficiency of coupling of a QD to a waveguide mode is also explored and evidenced. Optimal coupling of QDs emitting at different wavelengths to the same waveguide is designed using modelling of the coupled modes. Perspectives for integration of these site-controlled QDs to functional on-chip photonic elements will be described.

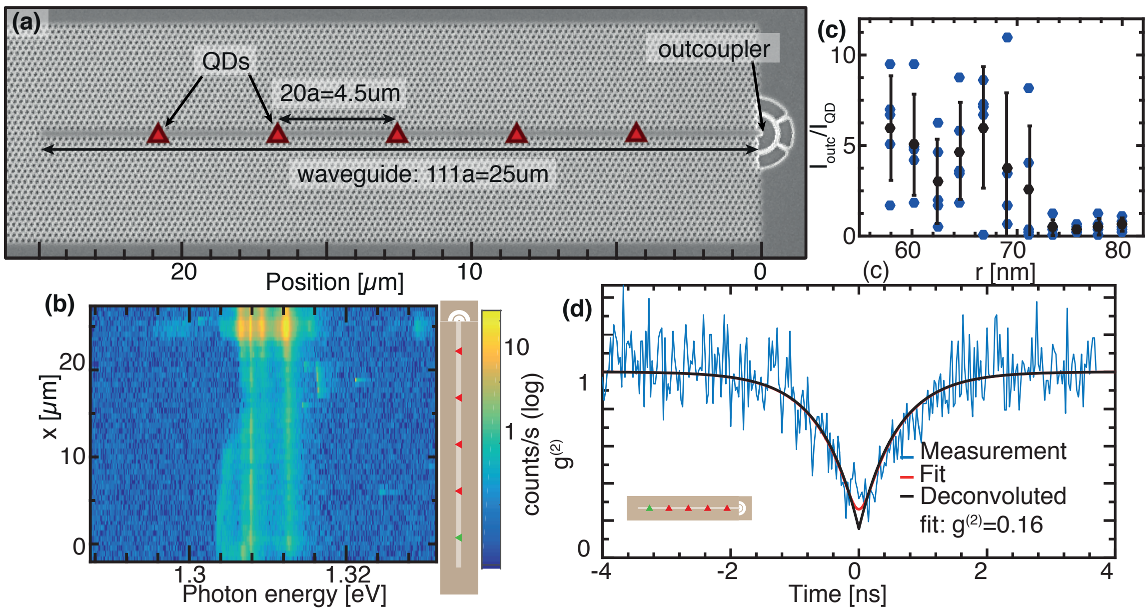

Fig. 1 (a) SEM picture of a 25µm long semi-waveguide with indications of QD positions, (b) Spectrally-resolved near field pattern of the structure in (a) (Excitation power: P=5µW, T=10K, r=61nm), only one QD (shown in green) is excited. (c) Effect of tuning the QD emission through the bandgap: fraction of the intensity extracted from the outcoupler divided by the intensity collected directly from the QD s-states as a function of the PhC hole radius (d) autocorrelation function of a QD excitonic line. (Excitation power: P=5µW, T=10K, for each PhC hole radius, each data point corresponds to the emission of only one of the five QDs).

References

[1] D. Loss and D. P. DiVincenzo, "Quantum computation with quantum dots," *Phys. Rev. A*, vol. 57, no. 1, pp. 120–126, Jan. 1998.

[2] P. Lodahl, S. Mahmoodian, and S. Stobbe, "Interfacing single photons and single quantum dots with photonic nanostructures," *Rev. Mod. Phys.*, vol. 87, no. 2, p. 347, 2015.