Cavity Enhanced Two-Photon Interference with Remote Quantum Dot Sources

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Indistinguishable single-photons are fundamental building-blocks for conceiving long distance optical networks for quantum information. For example, the control of quantum interferences to implement efficient interactions between photons is a key-step for teleportation of quantum states.

Quantum dots (QDs) are promising candidates to realize solid-state sources of single-photons for quantum applications. A few years ago, quantum interferences between photons emitted by two distinct QDs were demonstrated [1,2]. More recently, a new generation of ultrabright sources of indistinguishable single-photons has been developed by deterministically coupling a single QD to a microcavity-pillar [3,4]. The next crucial step, addressed in this work, is to demonstrate quantum interferences between two of these ultrabright single-photon sources.

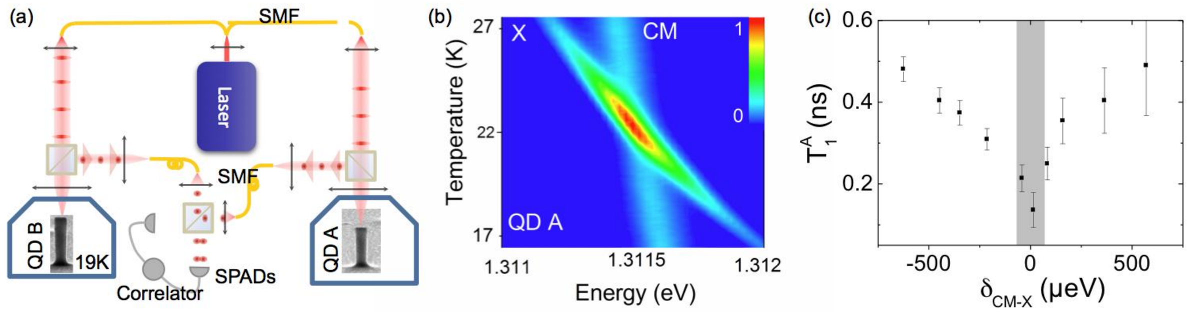

Fig. 1. (a) Scheme of experimental setup. (b) QD A emission as function of temperature and energy. The QD A exciton line (X) is resonant to the bare cavity mode (CM) at 22 K. (c) Decay time of QD A exciton line (T_1^A) deconvoluted from the temporal resolution of the setup vs. δ_{CM-X}. The spectral range of QD A emission used for the two-source interference is marked with a grey, vertical stripe.

In our experiments [see a sketch of the experimental setup in Fig. 1(a)], one of the two QD-sources (QD A) operates in a regime of strong Purcell effect [~10±2, Figs. 1(b,c)] and emits highly indistinguishable, single-photons ($g^{(2)}(0)_A$=10±3%, M_A=75±5%). Single-photons emitted by the second QD-source (QD B) are mostly distinguishable ($g^{(2)}(0)_B$=9±3%, M_B=19±15%). When the single-photons emitted from each source are sent to the two inputs of a beam-splitter [see Fig. 1(a)], a $M_{(A+B)}$=40±3% probability of two-photon coalescence is obtained [5]. The radiatively-enhanced homogeneous broadening of QD A allows obtaining a two-photon interference on a wide spectral range, see Fig. 2.

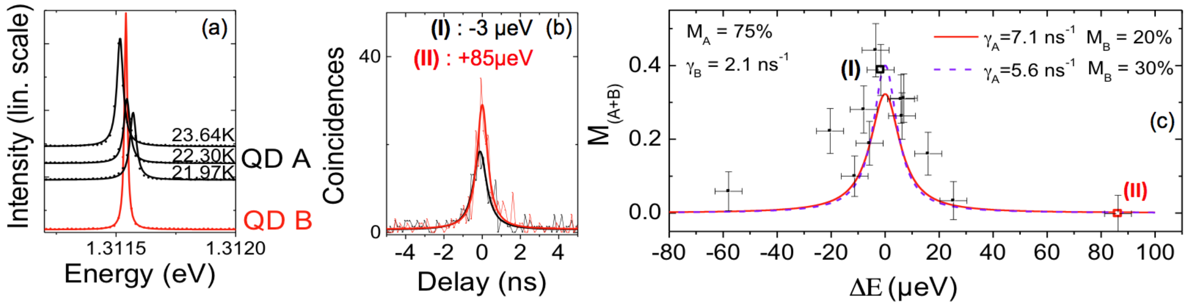

Fig. 2. (a) Emission spectra for QD B at 19 K (red bottom line) and QD A for various temperatures (black lines). (b) Measured correlation of the two-source interference at two values of ΔE (relative spectral detuning between QD sources): (I) -3 µeV (black) and (II) +85 µeV (red). Full lines are fits to the experimental data. (c) Measured $M_{(A+B)}$ as a function of ΔE. Lines are fits to the experimental data using the parameters indicated in the legend. The particular detunings (I) and (II) are labeled in the panel.

The Purcell effect, known to improve the indistinguishability of photons successively emitted by a single source, is shown to enhance the quantum interference of remote sources: accelerating the spontaneous emission on one device (QD A) can reduce the effect of dephasing on another one (QD B). This result is crucial for the scalability of QD-based quantum networks, where the imperfections of one device can be efficiently compensated by a highly indistinguishable single-photon source with a controlled lifetime.

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