A quantum dot in an open microcavity as a high-rate source of polarization entangled photon pairs

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Quantum photonic technologies are a promising platform for quantum information processing, with applications ranging from secure communication to quantum computing and simulation [1]. At the heart of many quantum photonic protocols lies the entangled photon pair. Traditionally, spontaneous parametric down-conversion (SPDC) in nonlinear crystals has been the workhorse for generating such entangled photons. However, SPDC sources face fundamental trade-offs between brightness and fidelity [2]. Semiconductor quantum dots (QDs) present an attractive alternative, promising on-demand generation of highly indistinguishable single photons, and the creation of entangled pairs by interference at a beam-splitter. Here, we build on our previous work with InGaAs QDs embedded in a tunable open microcavity [3]. This platform serves as an ultra-bright single photon source operating at GHz rates while maintaining state-of-the-art coherence and purity. The combination of high end-to-end efficiency and Purcell enhancement enables the generation of polarization-entangled photon pairs at high rates with concurrence above 90 % and fidelity of 95 %. The polarization-entangled photon pairs are characterized with photonic quantum state tomography, complemented by purity and indistinguishability measurements. The results highlight the system's capacity for high-flux entangled-state generation, a critical requirement for quantum networks.

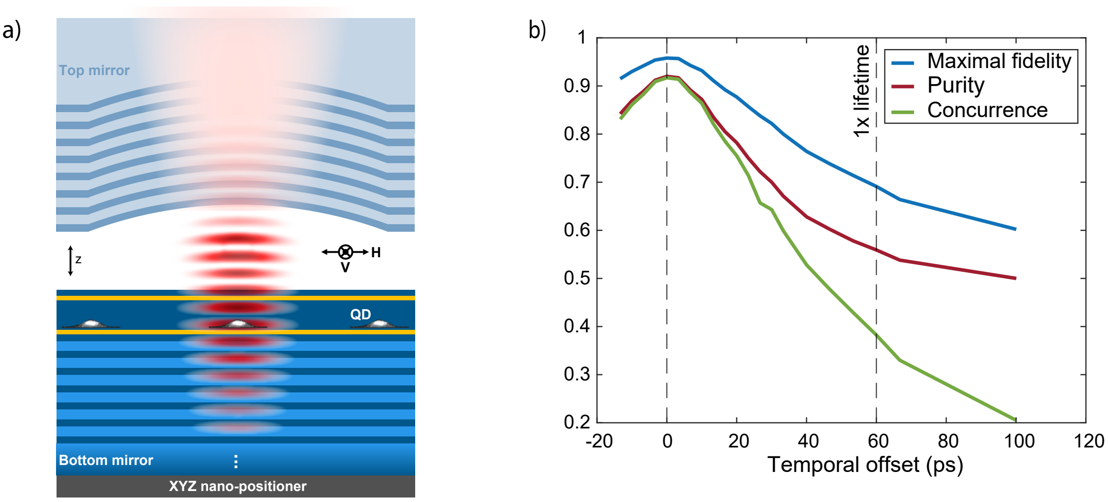

Figure 1: a) Sketch of the open microcavity. The semiconductor heterostructure consists of an AlAs/GaAs Bragg mirror (bottom mirror) and a p-i-n diode containing the QDs. The position can be adjusted with respect to the curved top-mirror via the xyz nano-positioner. The system operates at 4 K. Adapted from [3]. b) Behaviour of the fidelity (blue), purity (red) and concurrence (green) as a function of the temporal mismatch between the photons at the beam-splitter in the Mach-Zehnder interferometer.

References

[1] J. O'Brien, *et. al.*, *Nat. Photon* **3**, 687–695 (2009)
[2] H-S. Zhong, *et. al.*, *Phys. Rev. Lett.* **121**, (2018)
[3] N. Tomm, *et. al.*, *Nat. Nanotechnol* **16**, 399 (2021)

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