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Giant Two-Mode Non-linearity Using a Single Quantum Dot Embedded in a Photonic Wire

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Optical logic down to the single photon level holds the promise of data processing with a better energy efficiency than electronic devices. In addition, preservation of quantum coherence in such logical components would enable optical quantum logical gates. Optical logic requires optical two-modes non-linearities to allow for photon-photon interactions. Non-linearities usually appear for large intensities, but discrete transitions in a well coupled single two-level system allow for giant non-linearities operating at the single photon level.

This is achieved by engineering what has been coined a "one-dimensional atom", wherein a light emitter is predominantly coupled to a single propagating spatial mode. Here we take advantage of the large coupling efficiency and the broadband operation of a photonic wire containing a semiconductor quantum dot (QD) to implement a two-mode non-linearity using two different optical QD transitions. Our system is made of a single InAs QD embedded in a GaAs tapered photonic wire (fig. 1a). This system, in which the QD is efficiently coupled to a single guided mode, has been exploited to realize ultrabright single-photon sources [1]. We exploit here its broad operation bandwidth (>100 nm around 950 nm) to efficiently address two different transitions of the QD with two different laser beams to implement a two-color giant non-linearity: a weak probe laser has its reflectivity controlled by a few photons of the control laser [2].

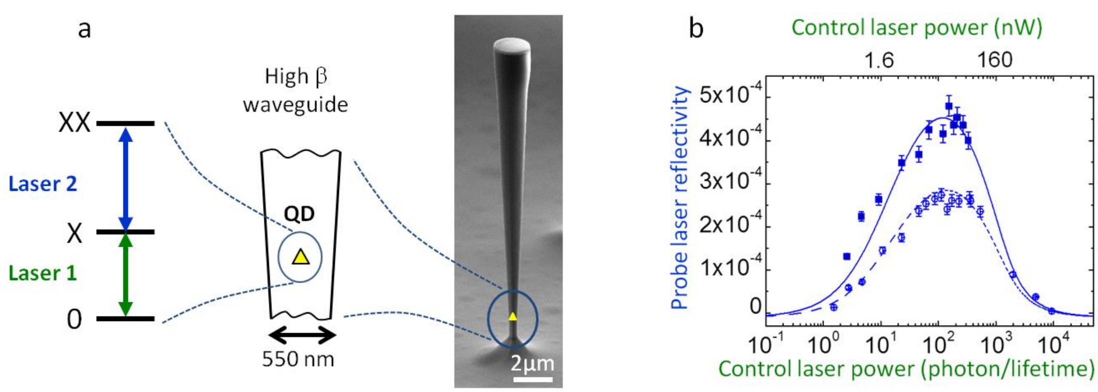

Fig. 1. a, A single InAs QD embedded in a GaAs waveguide. The thre-level system is made of the excitonic (X) and the biexcitonic (XX) transitions. The β parameter is the fraction of light emitted by the QD that is guided by the wire. **b**, The probe (upper transition) reflectivity is displayed as a function of the control (lower transition) power for a probe power of 0.5 nW (solid squares) and 2.6 nW (empty circles).

References
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[2] H.A. Nguyen et al, arXiv 1705.04056