Coherent nonlinear spectroscopy of an InAs quantum dot embedded in a photonic trumpet

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We investigate coherence dynamics of individual excitons in InAs quantum dots (QDs). Such a demanding measurement has been accomplished by fabricating photonic trumpets [1] (PTs) with embedded QDs, shown in Fig. 1, and retrieving their four-wave mixing (FWM) signal via heterodyne spectral interferometry [2].

During the last decade, this unique technique has proven to be a fruitful approach to measure [3] and control [4] the coherence, and investigate couplings [5] of individual quantum systems in solids; addressing relevant issues in quantum optics, nano-photonics, condensed matter physics and information science. Yet, measuring on strongly-confined excitons, like in InAs QDs, remains challenging. This is due to their rather small dipole moment and respectively high resonant intensity required to drive the FWM polarization.

Embedding QDs in PTs provides two key advantages in this context. Firstly, the coupling between the external beams inducing the FWM and the QD is drastically increased, owing to the tight lateral confinement of the guided mode in the PT. Secondly, the generated FWM is guided towards the detection optics, free from total internal reflection. As a result, FWM can be driven with a substantially reduced resonant intensity (here, $\pi/2$ pulse attained for $0.2\,\mu$W), and retrieved with the signal-to-background ratio improved by around three orders of magnitude (10^{-4}) with respect to bare QDs. We will discuss the measured exciton's coherence dynamics (shown in Fig. 1) and evaluation of its dephasing time T2 in a presence of inhomogenous broadening due to spectral wandering.

As a perspective, we will consider the mechanical degree of freedom of these structures [6], as an asset to achieve radiative coupling between distant QDs.

[1] M. Munsch et al. *Phys. Rev. Lett.* **110**, 177402 (2013) [2] W. Langbein et al. *Opt. Lett.* **31**, 1738 (2006) [3] J. Kasprzak et al. *Nat. Mater.* **9**, 304 (2010) [4] B. Patton et al. *Phys. Rev. Lett.* **95**, 266401 (2005) [5] J. Kasprzak et al. *Nat. Photon.* **5**, 57 (2011), F. Albert et al. *Nat. Commun.* **4**, 1747 (2013), [6] I. Yeo et al. *Nat. Nanotech.* **9**, 106 (2014)

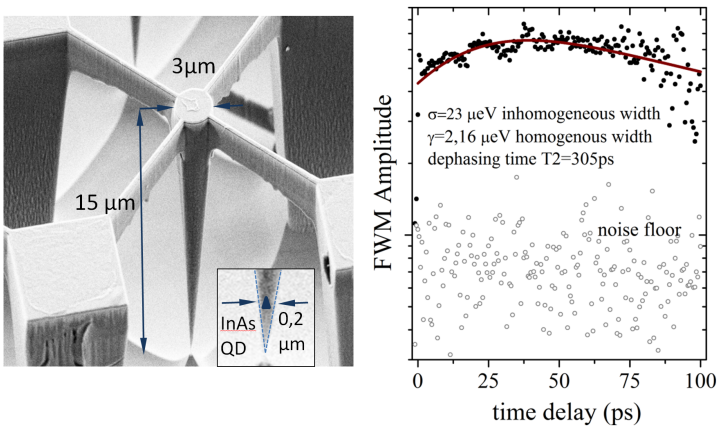

Figure 1: *Left: SEM image of a cone shaped GaAs-based PT, efficiently coupling (β-factor 0.4) the laser pulses with the QDs, located at the tip of the trumpet (inset). Right: Delay dependence of the FWM, yielding homogenous width* $\gamma = 2.16\,\mu eV$ *in a presence of inhomogenous broadening* $\sigma = 23\,\mu eV$.