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

Q. Mermillod[1,3], T. Jakubczyk[1,3], V. Delmonte[1,3], A. Delga[2,3], E. Peinke[2,3], J-M. Gérard[2,3], J. Claudon[2,3] and J. Kasprzak[1,3]

[1] *CNRS, Institut Néel, "Nanophysique et semiconducteurs" group, F-38000 Grenoble, France*
[2] *CEA, INAC-SP2M, "Nanophysique et semiconducteurs" group, F-38000 Grenoble, France*
[3] *Univ. Grenoble Alpes, F-38000 Grenoble, France*

We investigate coherence dynamics of individual excitons in InAs quantum dots (QDs). Such a demanding measurement has been accomplished by fabricating photonic trumpets [1] 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 proved 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.

Here, by engineering wave-guiding in photonic trumpets, we amplify the coupling of an external laser field with a QD. Furthermore, the induced FWM is guided towards the detection optics, free from total internal reflection. Such a two-fold optimization enables to reach this third-order optical nonlinearity with a substantially reduced resonant background. As a result, the signal-to-background ratio is improved by around four orders of magnitude (10^{-4}) with respect to bare QDs (typically 10^{-8}). We will discuss the measured exciton's coherence dynamics (shown in Fig. 1) and retrieval 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 [1], as an asset to achieve radiative coupling between separated quantum dots.

[1] I. Yeo et al. *Nature Nanotechnology* **9**, 106 (2014) [2] W. Langbein and B. Patton *Optics Letters* **31**, 1738 (2006) [3] J. Kasprzak et al. *Nature Materials* **9**, 304 (2010) [4] B. Patton et al. *Physical Review Letters* **95**, 266401 (2005) [5] J. Kasprzak et al. *Nature Photonics* **5**, 57 (2011), F. Albert et al. *Nature Communications* **4**, 1747 (2013)

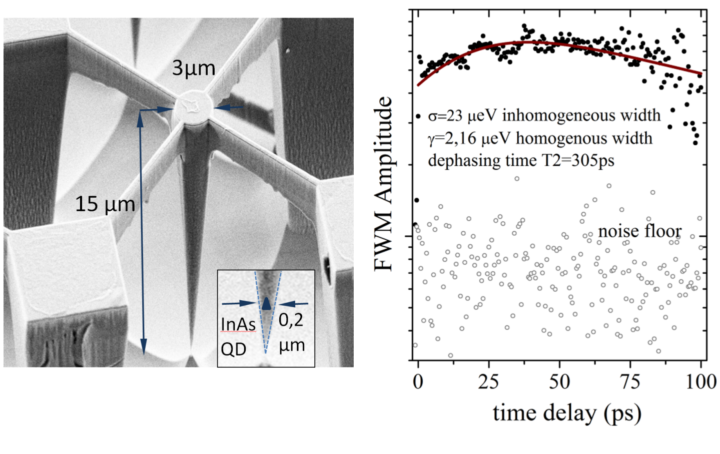

Figure 1: *Left: SEM image of a cone shaped GaAs-based photonic trumpet. Such a waveguide, efficiently couples (β-factor around 0.4) the laser pulses with the QDs, located at the tip of the trumpet (inset). Right: Delay dependence of the FWM, yielding homogenous width of $\gamma = 2.16\,\mu eV$ in a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