Coherent generation of Fock-encoded superposition states by QD-based emitters

E. Bargel [1,*], P. Steindl [1], I. Maillette de Buy Wenniger [2], S. Wein[3], L. Lanco[1,4], O. Krebs[1], D. Fioretto[1,3], P. Senellart[1],

[1]Université Paris-Saclay, Centre de Nanosciences et de Nanotechnologies, CNRS, 91120, Palaiseau, France
[2] Department of Physics, Imperial College London, SW7 2BX, London, UK
[3] Quandela SAS, 91300 Massy, France
[4] Université Paris Cité, 75013, Paris, France

Coherent control of a two-level system, as recently implemented on cavity-embedded semiconductor Quantum Dots (QDs) excited at resonance [1], enable the deterministic generation of not only single photons [2] but also coherent superpositions of quantum states. This effect was recently exploited to generate quantum superpositions of vacuum and single photons [3] with a high degree of Photon-Number Coherence (PNC). Such possibility opens exciting perspectives for both quantum communication (twin-field QKD) [4] and quantum computing [5].

In [3], high transfer of coherence to the Fock-basis was experimentally evidenced using self-homodyne interference visibility measurement, interfering two copies of the same quantum state successively generated by the emitter in an unbalanced Mach-Zehnder interferometer. This experimental technique allowed to access the PNC as confirmed by a theoretical description assuming a two-level system [3]. However, such description does not take into account the three- and four-energy levels structures of exciton and charged exciton (trion) QDs, nor can it explain for the systematically limited visibilities measured using trion sources (Fig. 1). This suggests the need to extend the two-level system approximation to more energy levels, depending on its excitonic state.

We report on an experimentalist-driven model to link the interference visibility and PNC. Our model, based on a time-averaged density matrix description, not only agrees with the two-level description of [3] but also reveals differences in measured visibilities between exciton and trion QD-based sources originating from the spin-photon entanglement. Moreover, it shows the intrinsic difference between single-photon interference visibility and PNC for more-than-two-energy-level structures. This paves the way for a wider understanding of the deterministic generation of coherent superposition of quantum states, and offers new possibilities in the generation of engineered Fock-encoded superposition states by tayloring the trion QD spin dynamics.

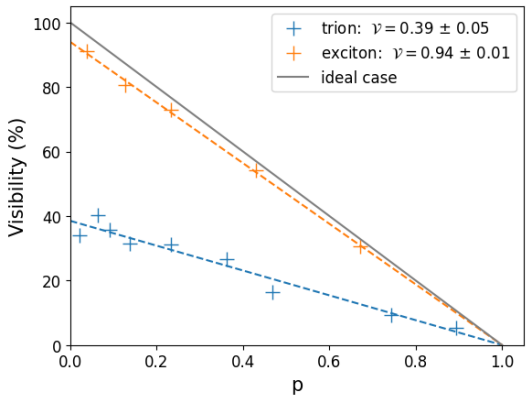

Figure 1: Interference visibility of Fock-encoded superposition states generated by exciton and trion QD-based sources: single-photon interference visibility is asymptotically accessed for small populations p.

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*E-mail: etienne.bargel@universite-paris-saclay.fr