Generation of single-photon and two-photon pulses from a self-assembled quantum dot

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Quantum two-level systems in the solid state are poised to serve the pivotal role of an on-demand single-photon source. More recently, multi-photon quantum state generators have nucleated additional interest for many quantum applications. Here, we investigate the dynamics of generating single photons from a resonantly-driven two-level system and demonstrate that it can surprisingly also operate in a two-photon bundling regime. Moreover, we demonstrate the generation of single-photons with ultra-low multi-photon error rates based on a three-level system.

Our two-level system of choice is a trion transition in a self-assembled quantum dot. For on demand single-photon generation, it is typically excited with a resonant laser pulse of area π. This prepares the two-level system in its excited state from where it spontaneously emits a single photon. However, emission that occurs already during the presence of the laser pulse allows for re-excitation of the system and, thus, multi-photon emission which degrades the single-photon purity [1,2].

In contrast, when exciting the system with a pulse of area 2π, the system is expected to be returned to the ground state. However, emission that occurs during the presence of the pulse is most likely to occur when the system is in its excited state – exactly after an area of π has been absorbed. This restarts the Rabi oscillation with a pulse area of π remaining in the pulse which leads to re-excitation with near-unity probability and the emission of a second photon within the excited state lifetime [2,3].

In addition, we investigate a two-photon excitation scheme based on a three-level system formed by the bi-exciton - exciton cascade in a self-assembled quantum dot and demonstrate that it improves the multi-photon error rate by several orders of magnitude while maintaining a simple implementation [4].

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