Stimulated Generation of Indistinguishable Single Photons from a Quantum Ladder System

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Abstract: Single photons play a key role for applications in photonic quantum technologies. Here we propose, model and demonstrate a scheme that enables the generation of high purity indistinguishable single photons from a quantum ladder system. © 2023 The Author(s)

1. Introduction

Semiconductor quantum dots are one of the most promising platforms for the on-demand generation of single photons. This stems from their excellent optical properties, such as almost exclusive emission into the zero-phonon line, near transform-limited linewidth, high emission rates and their integrability into nanophotonic structures [1].

A wealth of different excitation schemes for the generation of single photons have been developed, each with their specific advantages and disadvantages. Both resonant and phonon-assisted excitation allow for the generation of highly indistinguishable photons, while the single-photon purity is limited by reexcitation [2,3]. In contrast, two-photon excitation of the biexciton suppresses reexcitation, resulting in ultra-low multi-photon errors [4,5]. However, the indistinguishability of emitted photons is inherently limited by the timing jitter of the cascaded decay [6].

2. Stimulated generation of indistinguishable single photons

Here, we propose, model and demonstrate a scheme that combines the advantages of all previously established excitation methods [7]. The scheme is based on the resonant two-photon excitation of a biexciton (green arrows), followed by the stimulation of the biexciton-exciton transition (orange arrow) to selectively prepare an exciton (Fig. 1a).

![Fig. 1](image-url) Stimulated generation of indistinguishable single photons from a quantum ladder system: (a) Four-level system of the Biexciton-exciton cascade with applied laser fields (green and orange) and decay paths (red and blue). (b) Second-order intensity correlation histogram of the exciton emission after the stimulated preparation. (c) HOM visibility as a function of the relative pulse delay of the stimulation laser in units of the exciton lifetime exhibits a clear restoration of the indistinguishability for short time delays.
For short relative time delays between the two laser pulses, the subsequently emitted photon from the exciton recombination inherits the excellent purity from the two-photon excitation (Fig. 1b), while the precisely timed stimulation laser removes the timing jitter of the cascaded decay, thus restoring high indistinguishability (Fig. 1c). In contrast, increasing the relative time delay of the stimulation laser artificially increases the effective timing jitter of the cascaded decay, resulting in the observed decrease of the indistinguishability below the inherent limit of the cascaded decay (dashed line) for subsequently emitted photons, while for large time delays the indistinguishability approaches this limit. In addition, the emission energy is spectrally detuned from both driving laser fields, removing the necessity for polarization filtering, which enables high brightness. Via the polarization of the stimulation laser field, one of the two fine structure split branches of the cascaded decay can be selectively coupled, thus deterministically programming the polarization of the emitted photons (H/V).

3. References

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