Introduction and Motivation

Single-photon sources are an integral part of numerous proposals in the emerging fields of quantum information processing and nanotechnology, including quantum computing and quantum cryptography. These schemes typically require quantum light sources which can emit indistinguishable single-photon on-demand with high efficiency.

One promising candidate for single-photon sources is a quantum dot (QD) inside a photonic cavity. QDs are nanoscale semiconductor objects in which excited electron-hole pairs (excitons) mimic the excited states of an atom. QDs can be exploited to emit photons into a cavity after pulse triggering, allowing for them to be used as single-photon sources. However, the solid-state nature of the QD means that photons (most importantly longitudinal acoustic (LA) phonons) intrinsically couple to the exciton states, adding a rich and complex interaction to the source excitation dynamics. Notably, phonons cause decoherence, typically degrading the figures-of-merit for practical single-photon sources.

In this work, we extend a theoretical proposal by Pathak and Hughes (Ref. [3]) which uses stimulated adiabatic Raman passage (STIRAP) and the QD biexciton cascade as a QD-cavity single-photon source, by adding into the analysis a rigorous model of LA phonon interactions.

Bictronix Cascade and STIRAP

We model the QD energy levels as a four-level system (bictronix-cascade-bictronix) consisting of ground state |g⟩, X and Y linearly polarized excitons (|X⟩ and |Y⟩), and bictronix (two excitons) state with energy levels energies hωX = 0, hωY, hωXY, and hωXX, respectively. We treat a cavity mode at the system level with creation (destruction) operators $\hat{a} (\hat{a}^\dagger)$. The system is modeled using effective parameter sweep of laser and cavity detunings to optimize indistinguishability of emitted photons and perform parameter sweep of laser and cavity detunings to optimize indistinguishability of emitted photons.

Results

Theoretical results and experiments are shown in Fig. 5. The indistinguishability of emitted photons is shown as a function of temperature and constant dephasing, $\gamma = 1$ GHz, with a temperature-dependent dephasing $\gamma(T) = 1$ GHz, with experimental results in Ref. [9].

Conclusions

Over 90% efficiency and indistinguishability simultaneously achievable on-resistance for realistic experimental parameters.

References