Generating maximal entanglement between spectrally distinct solid-state emitters

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We show [1] how to create maximal entanglement between two spectrally distinct solid-state emitters embedded in a waveguide Mach-Zehnder interferometer. By tailoring the input to the interferometer, we optimise the concurrence of the emitter qubits states and show that a two-photon input state can generate deterministic maximal entanglement even for emitters with significantly different transition energies and line-widths. The optimal frequency is determined by two competing processes: which-path erasure and interaction strength. Smaller spectral overlap can be overcome with higher photon numbers, and quasi-monochromatic photons are optimal for entanglement generation. Our work reveals a rich underlying structure in multi-photon scattering from two non-identical emitters, and provides a new methodology for solid-state entanglement generation, where the requirement for perfectly matched emitters can be relaxed in favour of optical state optimisation.

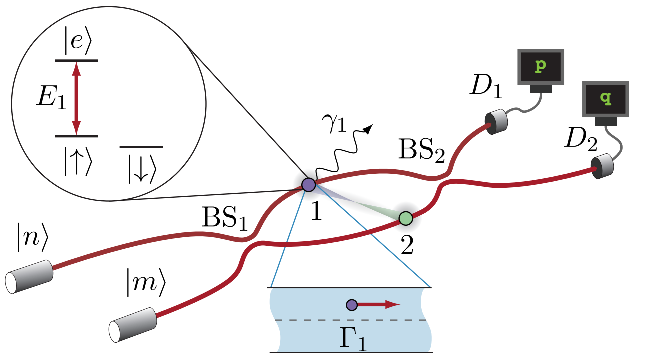

FIG. 1. Waveguide Mach-Zehnder interferometer with emitters embedded at positions 1 and 2, and with L-type level structures shown in the inset. The excited state $|e\rangle$ is coupled to a spin qubit state (e.g., $|\!\uparrow\rangle$) with transition energy E_α ($\alpha = 1, 2$), circular polarisation, and line-width Γ_α. The emitters are placed off-axis in the waveguide at c-points, such that circularly polarised light scatters only in the forward direction]2]. The loss rate from the guided mode is γ_α. Fock states $|n, m\rangle$ are injected into the interferometer, and detectors D_1 and D_2 record a photon number detector signature (p, q). Entangling techniques that use solid-state emitters are well-known to place very stringent requirements on the spectral identity of the emitters [3]. Our approach overcomes these restrictions by showing how to tailor multi-photon input states, mitigating a long considered weakness of solid-state emitters. We found that maximal deterministic entanglement between increasingly distinct emitters is possible using higher photon number input states $|n, m\rangle$, revealing a rich structure in multi-photon scattering from two emitters with different energies and line-widths (see Fig. 2).

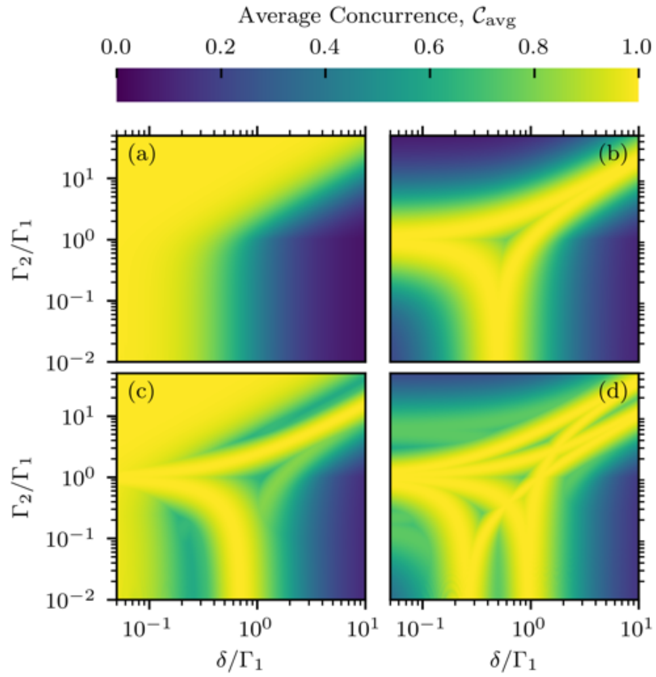

FIG. 2. Maximum average concurrence [4] for different photon input states injected into the interferometer. The emitter detuning δ and the line-width Γ_2 are both normalised to Γ_1, and we consider lossless waveguides. The input photons are identical and quasi-monochromatic in the configurations (a) $|n, m\rangle = |1, 0\rangle$; (b) $|1, 1\rangle$; (c) $|2, 1\rangle$; and (d) $|2, 2\rangle$. The characteristic shapes in (a) and (b) recur in (c) and (d), and are also found in higher photon number input states $|n, m\rangle$.

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