A Coherent Spin-Photon Interface in a GaAs Quantum Dot

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The spin-photon interface is a promising building block for many areas of quantum information science, such as the creation of a quantum network or the creation of resource states for the photonic implementation of measurement-based quantum computing. Semiconductor quantum dots (QDs) represent one of the best quantum emitters due to the emission of highly indistinguishable single-photons and a high extraction efficiency. However, the low spin coherence due to the interaction with the nuclear-spin bath is a deficiency of the system and has limited the spin coherence time to several ns.

In this work, we present a semiconductor platform based on a on a new type of GaAs QDs that hosts a coherent spin and creates coherent single photons. We characterize the photon coherence with a Hong-Ou-Mandel experiment on a single QD and find a high two-photon visibility of $V = 98\%$. We find no reduction in photon visibility for photon delays up to 1 µs. Even in the case of photons interfered from remote emitters with uncorrelated environments we find an unprecedentedly high two-photon visibility of 93%, testifying the high degree of photon coherence (see Fig. 1a) [1]. For spin coherence, we implement all-optical nuclear-spin cooling [2,3] to tackle the problem of the short electron-spin coherence time T_2^*. Exploiting a resonance condition between the electron Rabi frequency and the Larmor frequency of the host nuclei, we increase the coherence time 155-fold from 3.9 ns to T_2^* =0.6 µs (see Fig. 1b). Additionally, we show that not only cooling of the nuclear-spin bath is possible using GaAs QDs but also that the dynamical decoupling of the electron spin from the noise environment is possible using the CPMG sequence [4,5].

Our work shows that a GaAs quantum dot produces coherent photons and hosts a coherent spin. The coherence is maintained for times much longer than the radiative decay time (~300 ps), all at a convenient wavelength (~780 nm). These are ideal properties for a coherent spin-photon interface.

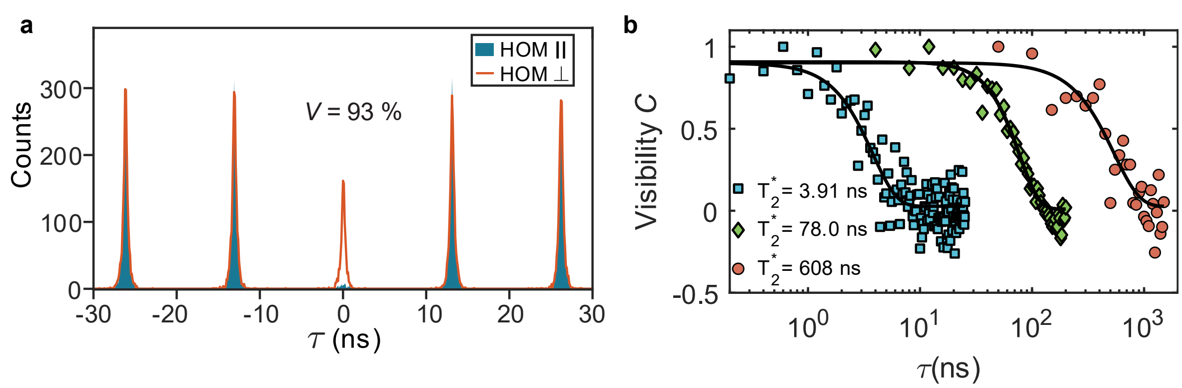

Fig.1. **a** Hong-Ou-Mandel interference between photons generated from two remote QDs. The vanishing central peak for co-polarized light shows a two-photon interference visibility of 93 %. **b** Ramsey interferometry on the electron spin showing the extension of the bare electron-spin coherence T_2^* (blue) via Rabi cooling (green) and quantum-sensing-based cooling (red).

References

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