A Spin-Photon Interface in the Telecom C-Band with Long Hole Spin Dephasing Time

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Semiconductor quantum dots (QDs) are a highly investigated platform for interfacing solid-state spins with single photons which makes them promising building blocks for scalable quantum networks. Spin-dependent optical transitions connect the polarization of an emitted photon with the state of a confined spin. For a coherently evolving spin, multiple photons can be generated sequentially, creating a linear cluster state of entangled photons. Ultimately, the size of such multi-photon states is limited by the finite dephasing time of the spin, which is affected by its nuclear environment and fluctuations of external fields. Improvements in material quality have made it possible to extend spin dephasing times to > 70 ns for QDs in the near-infrared wavelength range below 1 micrometer [1]. In the telecom C-band on the other hand, coherence times exceeding entangling and gate operations by an order of magnitude have not been achieved until now.

We report on measurements performed on an $InAs/In_{0.53}Al_{0.23}Ga_{0.24}As$ quantum dot integrated in a deterministically placed circular Bragg-grating [2]. By analyzing the Zeeman splitting of the polarization-resolved spectral line of a positive trion in an increasing magnetic field, the in-plane g-factors for electrons and holes in the QD could be determined. By means of photoluminescence-excitation spectroscopy we identified a quasi-resonance that preserves the polarization selection rules for the studied charge complex. We probed the evolution of the electron and hole spin that govern the Larmor precession of the excited and ground state of the positive trion, respectively. Using the quasi-resonance with a ps-pulsed laser, the polarization-resolved lifetime trace of the trion exhibits oscillations. The frequency of these oscillation scales with an increasing magnetic field according to the electron g-factor.

We accessed the ground state by analyzing polarization-resolved two-photon correlations. Here, the spin state is heralded with the detection of the first photon, and its evolution is probed with the second photon. Continuous-wave laser excitation revealed that the ground-state Larmor frequency is determined by the hole g-factor, while the spin dephasing time – extracted from the damping of polarization oscillation visibility – decreases with increasing external fields such as laser power and magnetic field strength. Probing the degree of circular polarization of the spin after its free precession through two laser pulses with variable delay, a spin dephasing time of $T_2^* = (15.9 \pm 1.7)$ ns could be determined. To the best of our knowledge, this is the longest pure dephasing time measured for an electron or hole spin in telecom-emitting quantum dots so far.

[1] L. Huthmacher, R. Stockill et al., Physical Review B **97**, p. 241413 (2018).

[2] J.M. Michl, R. Hekmati et al., Preprint at https://doi.org/10.48550/arXiv.2512.19561 (2025).