Protecting a Quantum Dot Spin Qubit from its Environment

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Abstract

Spin carriers confined in self-assembled InAs quantum dots provide optically accessible qubit implementations, suitable for the construction of scalable quantum optical networks. Picosecond-timescale coherent manipulation has been realized [1], enabled by large oscillator strengths and the optical lambda scheme present for charged quantum dots.

The qubit coherence is principally affected by the hyperfine interaction with a bath of 10^5 nuclear spins, giving rise to ensemble dephasing times of 1-2 ns. Previous seminal research utilizing a Hahn spin-echo sequence has revealed single electron spin coherence times of a few microseconds [2]. With spin state lifetimes and nuclear coherence times having been found in the millisecond range [3,4], it is not yet clear what the limiting mechanism is for electron spin coherence, and indeed, what this limit is.

Here, we extend previous work on optical control of single quantum dot spins to demonstrate how the qubit coherence is modulated by the coherent evolution of the nuclear spin bath. Figure 1 displays an exemplary Hahn spin-echo pulse sequence and resulting echo visibilities. This technique allows us to observe environment noise at different timescales, the short time revivals evidencing the evolution of the nuclear environment. This fuller understanding of the environment dynamics allow for more effective protection of spin coherence.

Further, we implement dynamical decoupling with picosecond optical pulses and observe electron spin coherence extending beyond the Hahn spin-echo limit. Combining fast manipulation, long coherence times, and the ability to map the stationary electron spin qubit into a flying qubit [5], we aim to create a quantum optical network where remote spins are entangled by photonic interference.

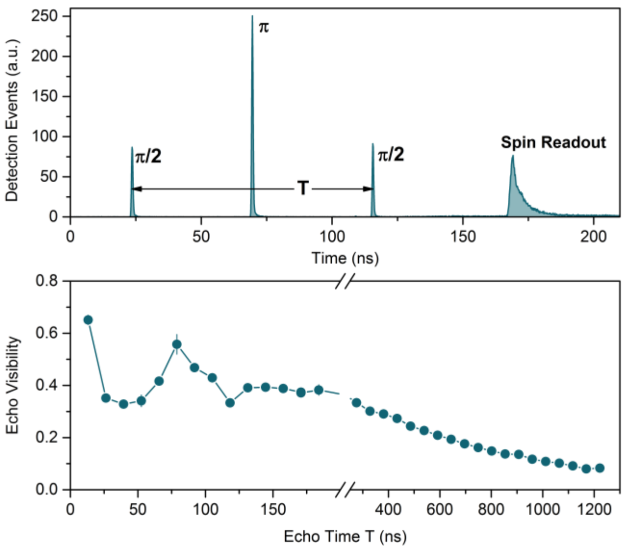

Figure 1 Top: *spin echo sequence with spin rotation and readout pulses. The π-pulse is translated in time, such that the Larmor precession of the spin is measured by the readout.* ***Bottom:*** *Visibilities for varying echo time T.*

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