Accessing the dynamics of a single spin with a polarization-dependent projective measurement

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Key challenges to harness charged semiconductor quantum dots (QD) as qubits are to measure and control the dynamic properties of the resident charge [1]. Indeed, the spin coherence time is one of the limiting factors on the generation of cluster states [2]. Current approaches rely on controlled sequences of pulses and repeated strong measurements of the spin state to measure either lifetime or coherence.

Here, exploiting giant Kerr rotations [3], we introduce a time-dependent tomography protocol to probe the complete dynamics of a single spin in a micropillar cavity. This procedure is based on the interference between the reflected light from the cavity and the single photons from an electron confined in an InGaAs QD when applying a transverse magnetic field (Fig. 1). The information of the electronic spin state is encoded on the polarization degree of freedom of the reflected light.

By performing a polarization dependent measurement on a first photon, we access the conditional density matrix of the spin state. We track its evolution back to the stationary regime through the polarisation state measurement of the successive photons (Fig. 2). With this time-dependent polarization tomography protocol, both the coherence (~2 ns) and the lifetime (~5 ns) of the electron spin can be inferred.

References

[1] N. Coste et al., *Quantum Sci. Technol.* ***8*** (2023) 025021
[2] N. Coste et al., Nature Photonics **17** 582-587 (2023)
[3] E. Mehdi et al., Nat. Commun. **15**, 598 (2024)

Figures

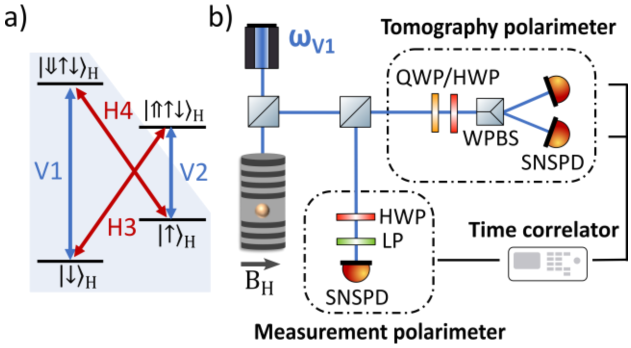

Figure 1: **a)** Energy levels of the QD system. We drive transition V1 at ω_{V1} with a cw laser and the photons emitted by transitions 1 and 4 are collected. H and V refer to linear polarization states. **b)** Experimental setup with two polarimeters: the measurement polarimeter performs a projective measurement along a given polarization state; the tomography polarimeter measures the polarization state of the reflected photons and track the evolution of the spin state.

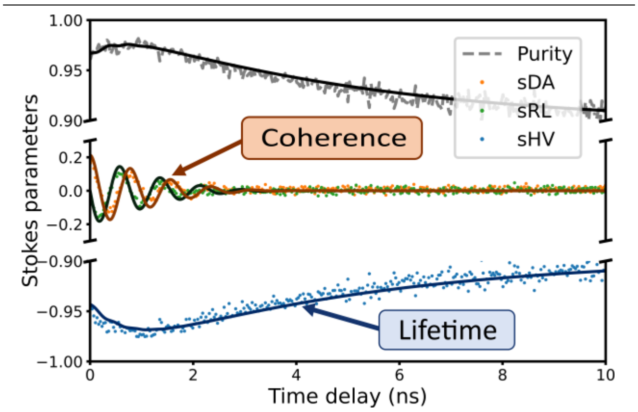

Figure 2: Time-evolution of the polarization state of the reflected photons after performing a measurement on the electronic spin at t=0. The Stokes parameters sHV, sDA and sRL describe the polarization state of the reflected light in the Poincaré sphere and measures both the coherence and lifetime of the free-evolving spin state.