Heralding of a single spin via giant polarization rotations in a QD-based spin-photon interface

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Charged InAs/GaAs quantum dots (QD) are promising candidates for quantum information processing. Entangling the spin degree of freedom of a charge confined in the QD and the polarization of single incoming photons would allow implementing deterministic spin-photon and photon-photon quantum gates. A promising strategy for this is to take advantage of the giant polarization rotations induced by a single spin, as in micropillar cavity-based spin-photon interfaces[1,2].

In our work, we use high-quality QD-based cavity devices (Fig. 1) to produce spin-dependent reflected polarization states $|\Psi_\uparrow\rangle$ and $|\Psi_\downarrow\rangle$. We demonstrate the orthogonality between these two states ($\langle\Psi_\uparrow|\Psi_\downarrow\rangle=0$), by showing that the detection of a single reflected photon with polarization $|\Psi_\uparrow\rangle$ projects the spin into the $|\uparrow\rangle$ state with 96% fidelity. We perform the polarization tomography of a second photon arriving at a later time before spin relaxation occurs. This allows visualizing the states $|\Psi_\uparrow\rangle$ and $|\Psi_\downarrow\rangle$ in the Poincaré sphere, where they are shown to be opposite (Fig. 2).

This orthogonality between $|\Psi_\uparrow\rangle$ and $|\Psi_\downarrow\rangle$ is crucial to allow producing novel maximally entangled states of the form $1/\sqrt{2}(|\Psi\uparrow,\uparrow\rangle+|\Psi\downarrow,\downarrow\rangle)$, between the electronic spin and an incoming photon.

References

[1] E. Mehdi et al, Nature Communications **15**, 598 (2024)
[2] M. Gundín et al, PRL **134**,036902 (2025)

Figures

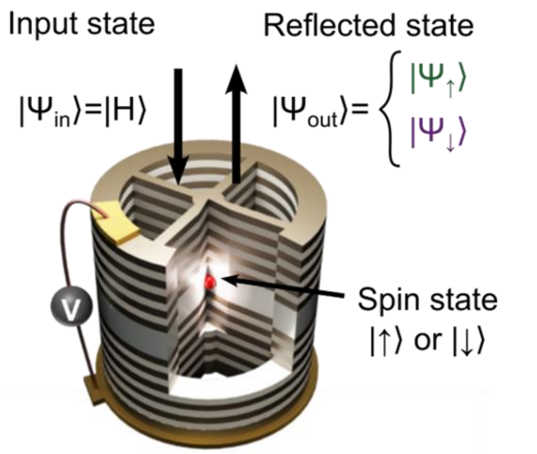

Figure 1: Device under study and principle of the spin-dependent polarization rotation.

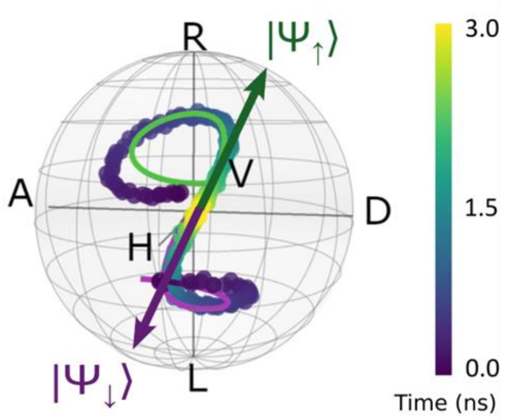

Figure 2: Experimentally measured $|\Psi_\uparrow\rangle$ and $|\Psi_\downarrow\rangle$ states in the Poincaré sphere, measured through the tomography of the second reflected photon, as a function of the time delay after the spin projection by a first photon.