Controlling photon polarisation in the Poincaré sphere through giant single-spin Kerr rotation

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The development of a future quantum network requires an efficient interface between a flying qubit and a stationary qubit. Here we use the polarisation of a photon as the flying qubit and the spin of a charge as the stationary one. Our interface is built with a pillar microcavity in which there is an InAs quantum dot (QD), enabling the efficient coupling of incoming photons with the spin of a charge in the QD [1,2]. As shown in figure 1, the polarisation of reflected photons is rotated according to the spin state [3,4,5].

Here, we show a controlled π-phase shift rotation of the polarisation of the photon in the Poincaré sphere after its interaction with a single spin. We display in figure 2 the extrapolated Stokes vector associated to a QD in spin "up" state. The polarisation of the reflected photon depends on the detuning between the laser and the quantum dot, and on the applied magnetic field, in full agreement with the numerical simulations. In particular, the purity of the output polarisation is slightly diminished due to the effect of the hyperfine interaction between the electron and the surrounding nuclei.

This demonstration is a first step toward deterministic spin-photon and photon-photon quantum gates, exploiting the giant spin-induced polarisation rotation.

References

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[2] Hilaire et al, PRB 102, (2020) 195402
[3] Hu et al, PRB 78, (2008) 085307
[4] Arnold et al, Nature Commun. 6, (2015) 6236
[5] Androvitsaneas et al, ACS Photonics, 6 (2019) 429-435

Figures

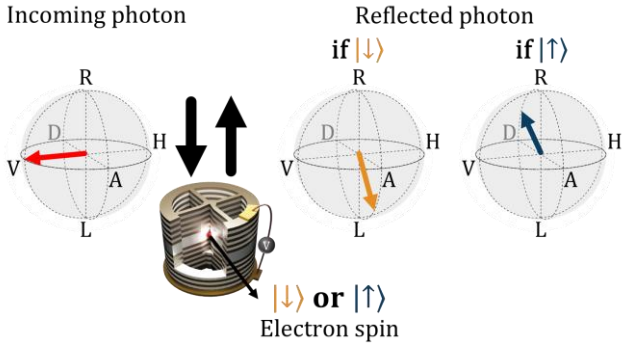

Figure 1: Scheme of an electrically contacted pillar microcavity coupled to a charged quantum dot. The polarisation of reflected photons is rotated through the interaction with the embedded spin qubit.

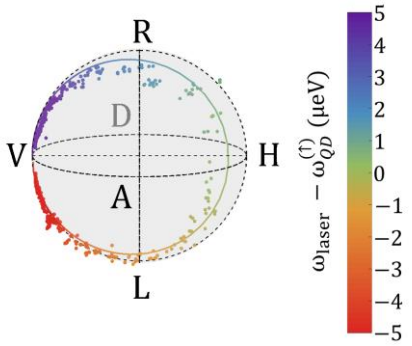

Figure 2: Extrapolated output polarisation measured in the Poincaré sphere as a function of the detuning between the laser and the QD energy, displaying a giant rotation.