Tomography of the optical polarization rotation induced by a single quantum dot in a cavity

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The development of future quantum networks requires an efficient interface between stationary and flying qubits. A promising approach is a single semiconductor quantum dot (QD) deterministically coupled to a micropillar cavity: such a device performs as a bright single photon emitter [1] and the QD state can be coherently manipulated with a few incoming photons [2]. Here we focus on another exciting perspective: the development of polarization-based photonic gates, whereby the polarization state of a single incoming photon is manipulated through its interaction with the artificial atom.

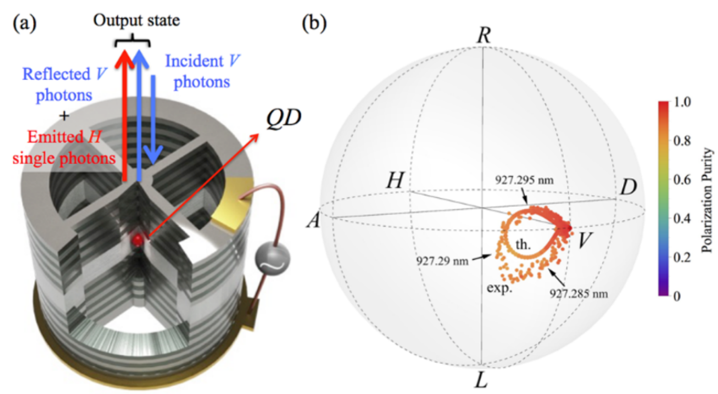

Figure 1: (a) Scheme of the electrically-controlled QD-cavity device and the input-output fields. (b) Representation of the polarization state in the Poincaré sphere for varying excitation laser wavelengths. The colorscale represents the purity of the polarization density matrix, kept above 84% at all wavelengths.

In this framework, we first investigate the polarization rotation of coherent light interacting with a neutral QD-cavity system, by analyzing the polarization density matrix of the reflected photons in the Poincaré sphere. The superposition of emitted single photons (H-polarized) with reflected photons (V-polarized) leads to a rotation of the output polarization by 20° both in latitude and longitude [3]. The evolution of the output state is illustrated in the Poincaré sphere as a function of the excitation laser wavelength, scanned across the QD transition wavelength (see Fig.1(b)). We demonstrate that the coherent part of the QD emission contributes to polarization rotation, whereas its incoherent part contributes to degrading the polarization purity. Besides, this technique is sensitive to the noise mechanism and provides a promising tool to study decoherence processes in cavity-QED devices.

In addition, we show that this polarization-based approach is particularly interesting for the development of an efficient spin-photon interface, using a resident hole in a charged QD as a stationary qubit. Indeed, we have recently demonstrated a large rotation of photon polarization induced by a single hole spin qubit [4]. We will discuss ongoing developments aiming at perfect spin-photon mapping: a situation where a single spin qubit, described in the Bloch sphere, is mapped into a single polarization qubit described in the Poincaré sphere.

References

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