Deterministic assembly of a spin-photon interface based on a semiconductor quantum dot

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The development of future quantum networks requires an efficient interface between stationary and flying qubits. A promising approach is to use micropillars (fig. 1.a) to deterministically couple a single photon with a single charge trapped in a semiconductor quantum dot (QD) whose spin acts as a memory qubit. Such device offers the possibility to produce high-rate spin-photon entanglement and to create photonic cluster states for measurement-based quantum computation. We have previously demonstrated high quality single-photon sources [1] by deterministically coupling a QD to an electrically contacted micropillar cavity, albeit without prior identification of the QD charge state [2].

Here we propose to go further and deterministically couple a micropillar cavity with a QD trion transition identified beforehand. We design a layer structure to allow optical trapping of the corresponding charge (a single hole) in order to control its occupation probability. In addition, we use in-plane magnetic field spectroscopy to identify the QD optical transitions. The devices are fabricated using the in-situ lithography (fig. 1.b) to define a cavity centred on a single quantum dot with nanometre accuracy [2]. The identification of the QD charge state during the in-situ lithography step allows us to tune the micropillar parameters so that the cavity is resonant with the targeted trion transition.

The device is characterized through resonant excitation, combined with weak non-resonant pumping. We demonstrate a probability of occupation of the hole state of 50%. The device, characterized as a single-photon source, shows a first lens brightness of 20% and 95% indistinguishability. Using quasi-resonant excitation, we reach occupation probabilities higher than 90%, giving a brightness of 30%.

With such a device, we aim at producing a Faraday rotation of the polarization of incident photons with an even greater efficiency than what was previously demonstrated [3]. This will bring us closer to an ideal spin-photon interface.

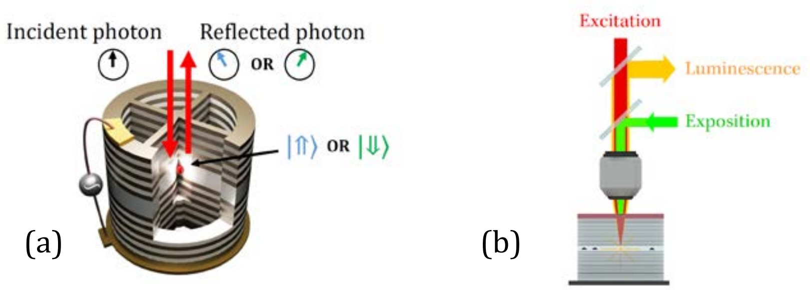

Figure 1 : (a) Micropillar coupled to a quantum dot trapping a hole spin. The photon polarization is rotated by spin-photon interaction. (b) In-situ lithography technique used to design micropillars.

References

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