

Accelerating optical quantum technologies with quantum-dot based devices

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In the growing development of quantum technologies, optical based systems are yet to achieve such levels of efficiency and fidelity to allow for the realization of complex structures dedicated to quantum simulations, as in the case of superconducting circuits, trapped ions and cold atoms. Nevertheless, flying qubits (photons) represent the preferable mean to interconnect quantum nodes and develop secure quantum networks on the large scale, as recently achieved in large cities and even between earth and a low-orbit satellite.

The strong limiting factors which are holding back a large-scale implementation of optical quantum technologies are related to the low generation efficiency of heralded single-photon sources and by the probabilistic operation of two-photon gates. Deterministic operation of these two elements can in principle be obtained by making use of single-photon sensitivity proper of atomic transitions.

In this context, artificial atoms in the form of semiconductor quantum dots, have emerged as a promising system to scale up optical quantum technologies, offering the potential of integration and scalability.

In this talk I will present our recent progresses along this research line.

I will discuss how a single quantum dot can be positioned in an optical cavity in a controlled way [1, 2] thanks to a fully deterministic technique which permits to locate with nanometric precision the position of the quantum emitter, and couple it to an ad-hoc photonic structure, in-situ.

This unique fabrication technique permits to obtain micropillar cavities with quality factor of about 10000, with state-of-the-art single-photon extraction efficiency.

Combined with a unique design, which permits the electrical control of the quantum-dot system, we could obtain single-photon sources with single-photon purity and indistinguishability over 99% and brightness exceeding by a factor 20 the one of currently used sources based on parametric down conversion [3]. High visibility values (88%) are also maintained over multiple pulses, on a time scale (above 450 ns) which permits to store and use hundreds of single-photons for highly complex operations [4].

Altogether, the performances of these devices guarantee a considerable speed-up of quantum protocols, such as boson sampling [5], paving the way for the experimental realization of quantum operations with unprecedented number of photonic qubits.

Furthermore, in a contest where fabrication scale up becomes a crucial parameter to allow for a solid realization and commercialization of quantum technologies, the presented technology guarantees incomparable fabrication efficiencies of top-performances single-photon source devices in a scalable architecture (Fig. 1a).

In the last part I will also present our latest progresses

towards the development of deterministic two-photon gates with devices performing as nonlinear switches at the single-photon level, converting a coherent pulse into a highly non-classical light wave-packet [6] (Fig. 1b).

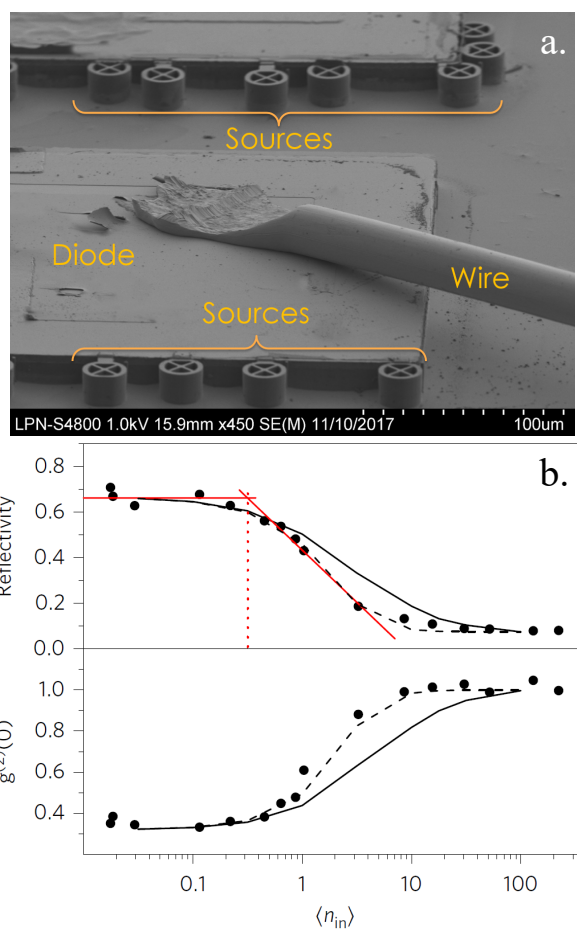


Figure 1: **a.** Scanning electron microscope (SEM) image of the single-photon sources, showing micropillar devices and electrical contact. (Credits: C2N-CNRS laboratory). **b.** Reflectivity (top) and second order intensity correlation function $g^{(2)}(0)$ (bottom) of the reflected light, as a function of the incident photon number (pulsed excitation).

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