Fibered semiconductor sources delivering highly indistinguishable photons beyond 4 MHz rate

H. Ollivier[1], *G. Coppola*[1], *P. Hilaire*[1], *A. Harouri*[1], *N. Somaschi*[2], *A. Lemaître*[1], *I. Sagnes*[1], *L. Lanco*[1,3], *J. Loredo*[1], *C. Anton*[1], *P. Senellart*[1]

[1] *Centre de Nanosciences et Nanotechnologies, CNRS, Université Paris-Saclay, 91460 Marcoussis, France*
[2] *Quandela, SAS, 86 Rue de Paris, 91400 Orsay, France*
[3] *Département de Physique, Université Paris Diderot, 4 rue Elsa Morante, 75013 Paris, France*

Single indistinguishable photons are the fundamental building blocks to develop quantum networks and photonic quantum computers. They are versatile flying qubits that allow carrying and manipulating quantum information efficiently. An ideal single photon source must provide light pulses with (i) no more than one photon (this being characterized by the single-photon purity, and measured through the standard Hanbury-Brown and Twiss measurement), (ii) with the highest efficiency, ideally one photon on demand (this property is characterized by the probability of having one photon per pulse) and (iii) being identical in all their degrees of freedom (indistinguishability measured by performing a Hong-Ou-Mandel interference).

Our sources are composed of quantum dots deterministically embedded in semiconductor micropillar cavities [1]. The quantum dot behaves as an artificial atom producing single photons that are efficiently collected by the cavity. The energy of the quantum dot is electrically tuned via the Stark effect: the application of a bias voltage onto the device helps to minimize the charge noise and obtain highly indistinguishable photons [2]. We recently reported the fabrication of bright single photon sources with a first-lens brightness of 15%. Here we show that we can fabricate several of such sources and demonstrate efficient coupling to a single mode fibre.

We report on several deterministically fabricated quantum dot single-photon sources, showing $g^{(}2)(0)$ below 3% and indistinguishability above 90% (without any spectral filtering) with a fibered brightness above 7%. This is obtained using either a neutral exciton or a charged exciton and with strictly pulsed resonant excitation. The detected count rate with pi-pulse excitation at the output of a single mode fibre is between 1,4 and 2 MHz, depending on the device. Considering the detector efficiency, this translates into a single photon rate at the fibre output of 4,2-6 MHz. Considering the losses in the optical setup, this corresponds to a first lens brightness between 12 and 15%.

Such sources are ready to implement multi-photon experiments using either time encoding or temporal-to-spatial demultiplexing. We also discuss the Hong-Ou-Mandel interference of remote sources for further scalability.

References

[1] A.K. Nowak et al., “Deterministic and electrically tunable bright single-photon source”, Nat. Commun. **5**, 3240 (2014).

[2] N. Somaschi et al., “Near-optimal single-photon sources in the solid state”, Nat. Photon. **10**, 340 (2016).