The indistinguishable photons emitted by semiconductor quantum dots

O. Gazzano[1,3], S. Michaelis de Vasconcellos[1], M. P. Almeida[2], A.K. Nowak [1], C. Arnold[1], S.L. Portalupi[1], A. Lemaître[1], I. Sagnes[1], L. Lanco[1], A. White[2] and P. Senellart[1]

T. Thomay[3], E. Goldschmidt[3,4], S. Polyakov[4], V. Loo[3], and G. S. Solomon[3, 4,]

[1] Laboratoire de Photonique et de Nanostructures, CNRS, Marcoussis, France
[2] Quantum Technology Laboratory, University of Queensland, Brisbane, Australia
[3] Joint Quantum Institute, (NIST & University of Maryland), Gaithersburg, MD, USA.
[4] National Institute of Standards and Technology, Gaithersburg, MD. USA.

Semiconductor quantum dots are more and more seen as promising light sources for quantum information processing. The large purity and indistinguishability of the emitted photons, combined with a high emission brightness has recently allowed to implement quantum information experiments. [1,2]

Combining a highly bright source with a large photon purity and indistinguishability was not trivial to obtain. Indeed, quantum dots are embedded in semiconductor layers presenting high refractive indexes: less than 1% of emitted photons can be collected on the upper space in bulk structures. Moreover, the high brightness regime usually requires a strong excitation of the system, which in turn could introduce dephasings and therefore reduce the coherence properties of the source.

I will present the method we used to combine, for the first time, those three parameters on the same source. We inserted single quantum dots in pillar microcavities and we benefic on cavity quantum electrodynamics effects [3].

The single photon purity and indistinguishability measurements are usually performed at two different times. This requires the source parameters to remains constant over those two independent and sequential measurements. We propose and demonstrate a four detectors experiment that allows the simultaneous determination of the single photon purity and indistinguishability (Figure b).

The experiment can also be considered as an elementary block of boson-sampling circuit where multiple photons from a single quantum dot are sent to a 4x4 linear optical circuit. The experiment is a road step towards the implementation of linear optical quantum protocols that can fully process random input photon-number such as stand-alone metrology testbed or in experiments, such as quantum random walks and boson sampling.

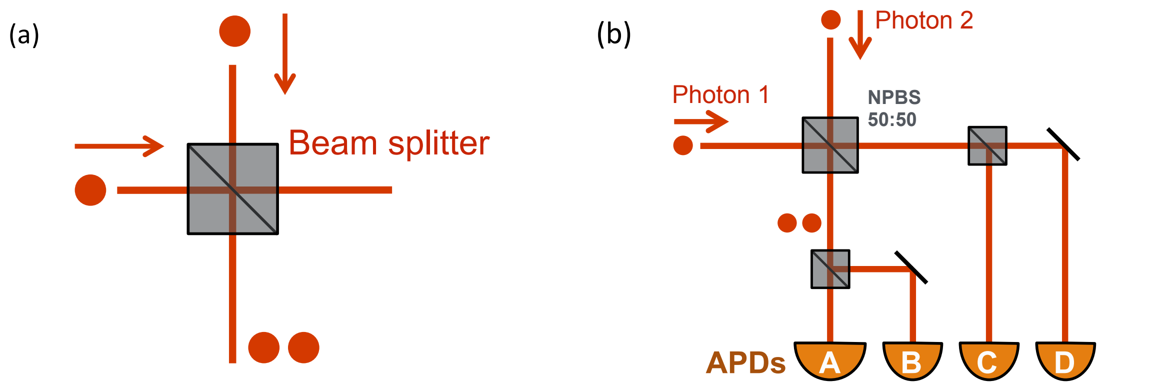

Figure: (a) When two indistinguishable photons arrive at a beam splitter, they coalesce. (a) Circuit that allows the simultaneous measurement of the photon purity and the photon indistinguishability.

[1] O. Gazzano et al., Physical Review Letters, **110**, 250501 (2013).
[2] Y.-M. He et al., Nature Nanotechnology, **8**, 213–7 (2013).
[3] O. Gazzano et al., Nature Communications, **4**, 1425 (2013).