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La photonique quantique fibrée et intégrée pour mettre en forme ou au pas beaucoup de modes ou de photons indiscernables

Taming many modes or photons with integrated and fibered optics

Nadia Belabas *

Centre de Nanosciences et de Nanotechnologies C2N, CNRS, Université Paris-Saclay,
10 boulevard Thomas Gobert, Palaiseau France nadia.belabas@c2n.upsaclay.fr

Integrated quantum photonics, multimode entanglement generation and manipulation, n-indistinguishability

Résumé/Abstract

Multimode entangled states and n-indistinguishable photon states are important resources for quantum information. We demonstrate how a selected set of promising sources and integrated and fibered circuits can achieve versatile entanglement, frequency qudits manipulation and n-indistinguishability measurement.

Les états intriqués multimodes et les états à n de photons indiscernables sont des ressources importantes pour l'information quantique. Nous démontrons comment un ensemble choisi de sources prometteuses et de composants intégrés et fibrés peut permettre la mise en forme de l'intrication, une manipulation de qudits fréquentiels et une mesure d'indiscernabilité à n photons.

1 Scaling up optical modes for quantum information

Many recent efforts for quantum technology applications harness photons pairs, single photons and other non-classical states of light. Photons indeed do not need to be trapped or cooled, their interaction with the environment is weak, and hence the lifetime and robustness of the states are high. Photons in the near infrared regime are especially appealing for quantum information because of the wealth of building blocks and off-the-shelf cheap devices in the telecom toolbox. The brightest single photon sources are, as of now, single emitters closer to the visible spectral domain. In addition, photons have several degrees of freedom to encode information: frequency, polarization, time, path, angular momentum and fluctuations of quadratures. Scaling up protocols harnessing an increasing number of photons or modes to reach meaningful quantum advantage or non-classical operation requires stable, compact, scalable circuits and schemes.

2 Taming multitude: Versatile entangler on chip, frequency gates and n-indistinguishability

We shall discuss sources and schemes for i) multimode quantum state generation on chip in the telecom wavelength regime, ii) frequency bins and iii) indistinguishable single photons manipulation in fibered circuits or on chip (see Figure). In the continuous variable encoding framework, we theoretically demonstrate that various cluster states, appropriate for quantum networks and measurement-based quantum computing, can be generated in realistic arrays of nonlinear waveguides with a single optical setup, using pump and measurement shaping only (i). Our findings are platform independent, thus compatible with the next generation of thin film waveguides, and they are supported by a comprehensive framework. In the discrete variable regime, we are implementing quantum gates and interferences in the frequency domain (ii) and directly quantify n-indistinguishability of path encoded photons (iii) with two promising platforms: SOI microring resonators emitting photon pairs around at 1540 nm and quantum-dot-based sources emitting 925 nm single photons respectively. All these schemes harness integrated and fibered optics for compact, multimode and (towards) scalable demonstrations.

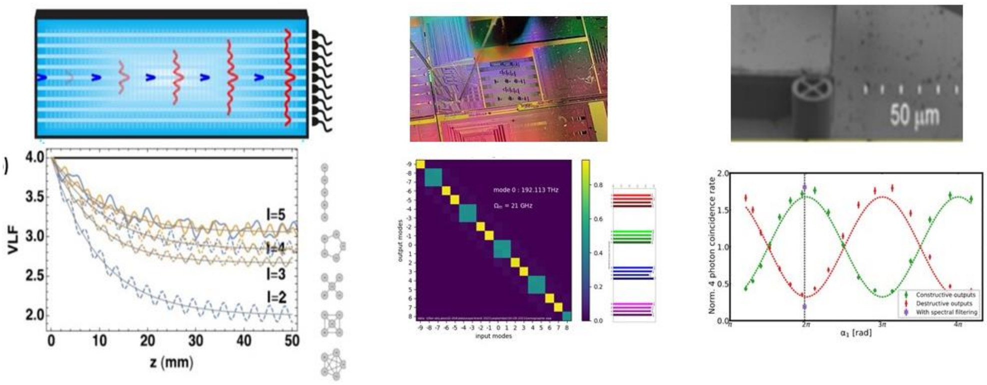

Figure: Left (i) – Top: Array of nonlinear waveguides in a spontaneous parametric down conversion configuration yielding (bottom) versatile multimode entanglement [1]. Middle (ii) – Top: Fiber injected SOI microring to build (bottom) parallelized Hadamard gates in the frequency domain. Right (iii) – Top: Single-emitter in a micropilar to achieve (bottom) direct measurement of 4 photon indistinguishability [2]

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