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UMR 6082

Space-division multiplexing for quantum telecommunication networks

Starting date: October 2019
Funding: Contrat Doctoral Ordinaire (Université Rennes 1)

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Laboratory: Institut FOTON (CNRS UMR 6082)
Research team: Photonic Systems

Keywords: Photon pair sources – Space-division multiplexing – Nonlinear processes – Intermodal phase-matching – Quantum communication networks

Project description

Entanglement is a fundamental property on which rely the most remarkable quantum effects, and is the key resource for many applications in the fields of quantum communication and quantum information processing. It sets the stage for the development of quantum computers (with a huge increase of computational power compared to current devices) and for ultimate security of data sharing thanks to tamper-proof cryptography protocols. The ability to generate entangled photon pairs and to distribute entanglement through complex communication networks (and not only between two preset users through one independent transmission channel) is a prerequisite for industrial spreading and implementation of quantum communication networks. Until now, the only approach that has been studied (and experimentally demonstrated) for such a ***multipartite distribution of entanglement*** relies on wavelength-division multiplexing (from a broadband entangled photon pair source). This approach is particularly opportune since it allows to benefit from the resources developed for many years within the telecom community on wavelength-division multiplexing, which are both competitive and commercially available.

The project related to this PhD thesis proposes a new approach and new technological solutions for multipartite distribution of entanglement. By fully exploiting the benefits of the **new resources recently developed for classical telecom networks** (and their associated advantages in terms of data-carrying and distribution capacities), these solutions would be compatible with the next generation of telecom infrastructures and increase the potential number of users in the quantum network. Indeed, **the idea is to harness the spatial dimension as an additional degree of freedom (through several transverse propagation modes and/or several spatially distinct channels within the device generating the photon pairs), *i.e.* to develop a multipartite source of entangled photon pairs *based on space-division multiplexing***. Several source architectures can be considered, especially fibred architectures (which can be advantageously implemented within *fibred* networks since they allow to minimize the coupling losses between the source and other components in the network). We will mainly focus on the cases of **liquid- or gas-filled hollow-core microstructured fibres** (whose linear and nonlinear properties are particularly interesting in the framework of photon pair generation by spontaneous four-wave mixing – SFWM) and **nanofibres** (in which one can generate photon pairs by spontaneous parametric down-conversion (SPDC) by exploiting the surface second-order nonlinearities). In both of those architectures, the photon pair generation requires a phase-matching condition to be satisfied. This condition depends on the dispersive properties of the medium, and thus on the transverse propagation modes that are involved (as soon as the medium is multimode). Therefore, the idea is to exploit the **multiple allowed inter-modal phase-matching conditions** (thanks to space-division (de)multiplexers at the input and at the output of the source) to perform multipartite distribution of the generated photon pairs.

The PhD student will first have to characterize the linear and nonlinear properties on the fibered architectures under study. Then, she/he will have to implement, from these architectures, the generation of correlated photon pairs by exploiting intermodal spontaneous nonlinear processes (SFWM or SPDC). The generated pairs will be fully characterized (spectral and modal properties, generation rate, quantum purity, and ability of entanglement).

In a second stage, the PhD student will investigate the various entanglement schemes that can be implemented (polarization or time-bin entanglement scheme) in order to produce entangled photon pairs in multimodal regime from the fibered architectures under study. The produced pairs will also have to be characterized, and to do so she/he will build and implement a two-photon interference setup, for the measurement of fringe visibility and violation of Bell's inequalities.

This PhD work will thus involve an **important experimental work** as well as modelling work regarding the generation of correlated photon pairs through multiple modal phase-matching conditions. **The analytical part of this modelling work** will lean on a model that has been previously developed for the simplest case of single-mode generation of correlated photon pairs by SFWM in the fundamental Gaussian mode of an optical fibre. This model will be adapted to the multimode case. **A numerical modelling approach** will also be needed, in particular to evaluate the impact of crosstalk (due to inter-modal coupling) on the generation efficiency of the source and on its reliability in the prospect of a multipartite distribution by space-division multiplexing.

Qualifications

The applicant should hold a master degree in photonics, preferably including documented qualifications in the areas of optical fibers, nonlinear optics, telecom, and quantum optics. The ideal profile would combine experimental skills and interest for modelling and simulation work. Scientific rigor and scientific communication skills in English are required.

FOTON Institute

The FOTON Institute (centre of photonics for information technology) is a joint laboratory of CNRS, University of Rennes 1, and INSA Rennes. It gathers about 120 employees (including 75 permanents), in three teams and three research platforms addressing a wide range of topics in the area of photonics, for applications in the fields of optical communications, defence, life sciences, industry, and energy. FOTON is one of the first public research forces in France in its field, producing over 100 scientific papers a year. The Photonic Systems team is involved in research on photonic systems for laser architectures, sensors, and optical communications. Various technologies, based on standard or microstructured fibers, integrated waveguides, semiconductor components, or micro/nano-cavities are studied (design, fabrication, and implementation inside industrial devices for telecommunications, sensors, and laser sources).

More information about the FOTON Institute can be found at: http://foton.cnrs.fr.

Further information – Contact

Further information can be obtained by contacting margaux.barbier@univ-rennes1.fr.

Application procedure

Please submit your application at your earliest convenience by e-mail to margaux.barbier@univ-rennes1.fr. Your application should include:

- Cover letter + Detailed CV
- Copy of M.Sc. degree or equivalent + Grade transcripts
- List of publications, if applicable
- Contact details of two references

All qualified candidates are invited to apply.