



Title: Engineered resources for multimode Quantum Technologies

Keywords: Quantum Optics, Photonic quantum computing, Entanglement

Scientific description:

Photonic quantum information exploits quantum properties of light to achieve communication and computational tasks that are classically unfeasible. In this context, this work focuses on quantum correlation (entanglement) among optical modes. This represents a key resource due to the possibility of working with a high number of quantum information carriers that are linked together in highly correlated quantum state. In measurement-based quantum computing, for instance, multipartite entanglement enables quantum computation to proceed solely through local measurements on individual modes. At the same time, theoretical and experimental applications demand entanglement whose structure can vary depending on the specific quantum task. Such condition implies mastering the generation of quantum correlations as well as developing coherent manipulation and measurement techniques in the desired degrees of freedom.

The proposed work investigates the controlled generation and manipulation of highly multimode continuous variable entanglement among different frequency or temporal modes of light. Frequency- (temporal-) modes marry the advantage of achieving record numbers of entangled mode that can be separated thanks to multiplexing techniques. Entangled modes will be produced in non-linear waveguides: such a configuration marries the advantage of a high-dimensional quantum alphabet with that of cutting down the physical size of optical systems, both crucial conditions for realistic quantum applications.

Work plan and objectives:

The proposed work will investigate high-dimension frequency entanglement generated by spontaneous parametric down conversion (SPDC) in pulsed regimes. The multimode features of produced states are determined by acting on the working conditions of the SPDC process, by suitable shaping the SPDC optical pump frequency and temporal profile.

The student will join an ongoing experiment and will work during their stage in collaboration with a 3rd year PhD student. The proposed work will consist in validating the generation of engineered multipartite entanglement by homodyne measurement of the generated quantum state.

During the internship the candidate will contribute to:

- mount the interferometric setup for the state detection via homodyne technique
- take part in the data acquisition and interpretation of result, validating the level of entanglement obtained when engineering the source.

Within the frame of this project, the student will be asked to participate in the exchanges with the Quantum Optics group at Laboratoire Kastler Brossel of Sorbonne Université and with the theoretical group of Multimode Quantum Information of the University of Lille.

Developed competences:

From the practical point of view, the project will allow the candidate to develop competences in the domains of multimode quantum optics in continuous variable but also in discrete variables encodings, in guided optics, telecom and fibre components, data acquisition and processing, high level electronics. The endeavors on multipartite quantum optics are essential for the development of operational quantum network and measurement-based quantum computers. The results

demonstrated in this project are therefore expected to have major impacts at the international level in quantum information technologies.

This work is part of a bigger collaboration on photonic resources for on-fly quantum computing (projet OQulus <https://www.pepr-quantique.fr/en/projet/oqulus/>).

Techniques/methods in use: homodyne detection, optical interferences, guided non-linear optics

Applicant skills: Quantum Optics, Experimental Optics, Non-Linear Optics. We look for candidates with competences on continuous variable and/or discrete variables experimental quantum optics. The candidate should equally be able to collaborate with the theoretical partners to contribute to the development of original theoretical tools for entanglement development. Competences on non-linear optics, electronics and active control systems are welcome.

Industrial partnership: N

Internship supervisor(s) Virginia D'Auria, virginia.dauria@univ-cotedazur.fr ;

Internship location: Institut of Physics of Nice, Nice.

Possibility for a Doctoral thesis: Y. The project OQulus will provide a 6 month of M2 level internship plus a three-years PhD scholarship funding. Candidates can apply to both. The PhD thesis will be performed under the join guidance of Virginia D'Auria (INPHYNI) and Valentina Parigi (LKB, Paris valentina.parigi@lkb.upmc.fr). The candidate is thus expected to share their time between Nice and Paris.