SCIENCES SORBONNE UNIVERSITÉ

Master thesis proposal

Laboratoire Kastler Brossel
Physique quantique et applications

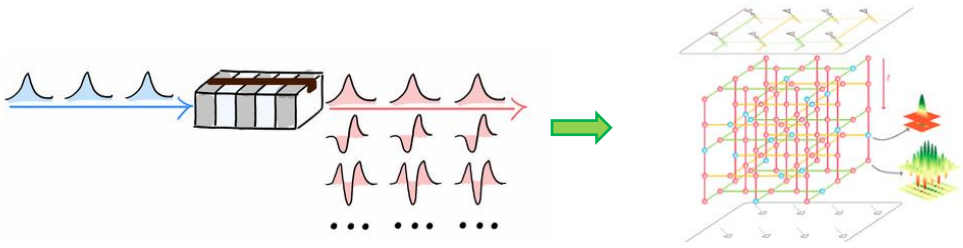
Campus Pierre et Marie Curie,
4 Place Jussieu, 75005 Paris

Director: Antoine Heidmann

Title: **Large Continuous Variable quantum networks for quantum information technologies**

Keywords: continuous variables, cluster states, optical quantum computing, quantum networks, quantum communication

Scientific description: Photonics quantum networks are essential resources for quantum communication and information protocols, they represent an essential part of the future quantum internet where quantum states of light will allow for the efficient distribution and manipulation of information. We explore continuous-variable (CV) entangled states, where entanglement correlations appear between quadratures of the electromagnetic field. Such states can be deterministically generated by mixing several squeezed optical modes via linear-optics operations or, more generally, via mode-basis changes. We recently demonstrated the generation of spectrally multimode squeeze states of light at telecommunication wavelengths involving more that 21 frequency modes [1]. For all transfer of information over appreciable distances, telecommunication wavelengths offer the most reliable solution. The generated resource can then be used for frequency multiplexed cryptographic protocols [2]. Moreover, the resource shows promise as a compact solution for scalable entangled states in quantum computing. The 21 squeezed modes are in fact generated in a the single-pass configuration based on non-linear waveguides and a femtosecond laser source: this allows for supplemental pulse-based multiplexing [3]. Large three-dimensional structures, necessary for fault tolerant quantum computing [4] can then be explored along with non-Gaussian operations [5] for quantum information protocols.



The internship may concern the test of the pulse-resolving homodyne detection, that will allow for the temporal multiplexing, or the design of non-Gaussian operations (like single-photon subtraction) via photon counting with nanowire detectors. The internship can be followed by a PhD project. The project fits with the purposes of ERC project COCQOoN, the national acceleration strategy PEPR OQULUS ('ordinateur quantique à base de lumière en variables discrètes et continues') and the EU projet veriqub.

[1] V. Roman-Rodriguez, D. Fainsin, G. L Zanin, N. Treps, E. Diamanti, V. Parigi *Spectrally multimode squeezed states generation at telecom wavelengths*, arXiv:2306.07267 (2023)

[2] O. Kovalenko, Y.-S. Ra, Y Cai, V. C. Usenko , C. Fabre N. Treps, and R. Filip, *Frequency-multiplexed entanglement for continuous-variable quantum key distribution* Photonics Research Vol. **9**, pp. 2351-2359 (2021)
[3] T. Kouadou, F. Sansavini, M. Ansquer, J. Henaff, N. Treps, V. Parigi, *Spectrally shaped and pulse-by-pulse multiplexed multimode squeezed states of light,* *APL Photonics* **8**, 086113 (2023)
[4] J. E., Bourassa, et al. Quantum **5**, 392 (2021).
[5] Ra, Y.-S., Dufour, A., Walschaers, M., Jacquard, C., Michel, T., Fabre, C., and Treps, N., *Non-Gaussian quantum states of a multimode light field*, Nat. Phys. **16**, 144–147 (2020)

Techniques/methods in use: femtosecond pulse shaping, homodyne detection, photon-counting, non-linear waveguides, continuous variables encoding /theory.

Industrial partnership: N

Internship supervisor(s) Valentina Parigi, valentina.parigi@lkb.upmc.fr

Internship location: Campus Pierre et Marie Curie, 4 Place Jussieu

Possibility for a Doctoral thesis: Y (EU fundings)