

INTERNSHIP PROPOSAL

Laboratory name: **Laboratoire Kastler Brossel – Quantum Networks Team**

CNRS identification code: UMR 8552

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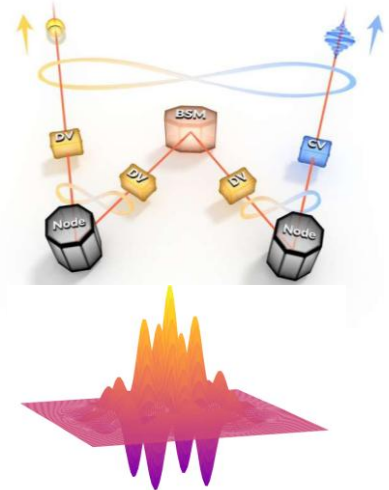
Internship location: Sorbonne Université, Campus P. et M. Curie, 4 Place Jussieu, Paris

Thesis possibility after internship: YES

Funding: YES, Doctoral school/group funding

Hybrid and non-Gaussian optical quantum state engineering

The use of light in quantum information processing and networks has historically been split between two communities depending on the degree of freedom favored for encoding. On one side is the continuous-variable (CV) approach, which treats optical fields as waves. On the other side is the discrete-variable (DV) approach, harnessing the properties of individual photons. These two strategies have been studied extensively and led to a variety of seminal demonstrations for quantum technologies with complementary advantages. By considering a hybrid approach bridging the two, one could envision quantum architectures where the two encodings can be for instance interchanged fittingly to the task at hand.



Several experiments have spearheaded the development of the so-called hybrid quantum optics paradigm. These advances spurred intense experimental and theoretical efforts towards novel protocols, including deterministic teleportation of photonic qubits or witnesses for single-photon entanglement based on CV homodyne measurements. In this context, the LKB team demonstrated the first engineering of **hybrid entanglement of light, i.e. entanglement between particle- and wave-like optical qubits**. This novel resource enabled then to demonstrate the remote state preparation of cat-state qubits and recently the teleportation between different encodings, realizing thereby a first **quantum-bit encoding converter**.

The research of the group is now focusing into two directions. The first one aims at harnessing further the unique benefits of the hybrid optical approach for quantum connections. The challenge is **to develop optical quantum connections** versatile enough to connect different physical quantum platforms and faithfully carry a broad range of quantum states. The second direction builds on the multiple high-fidelity non-gaussian resources available on the experimental setup and aims at the **realization of complex optical non-gaussian states** that can find applications in **bosonic error correcting codes**.

This research involves non-linear optics, superconducting single-photon detectors, non-Gaussian state generation, decoherence study and protection. The LKB team is a partner of the national consortium on optical quantum computing, under the French Quantum Initiative.

A few references

*Hierarchical Verification of Non-Gaussian Coherence in Bosonic Quantum States, PRL **134**, 233604 (2025)*

*Hierarchies of quantum non-Gaussian coherences for bosonic systems: theoretical study, PRA **III**, 063704 (2025)*

*Hybrid Approach to Mitigate Errors in Linear Photonic Bell-State Measurement for Quantum Interconnects, PRX Quantum **5**, 030331 (2024)*

*A quantum-bit encoding converter, Nature Photonics **17**, 165 (2023), See also the story about this work:*

[*Quantum data conversion offers a path to scale up quantum technology architectures*](#)

*Experimental Fock-state bunching capability of non-ideal single-photon states, Optica **8**, 743 (2020)*

Condensed Matter Physics: YES

Soft Matter and Biological Physics: NO

Quantum Physics: YES

Theoretical Physics:

YES