INTERNSHIP PROPOSAL

Laboratory name: **Laboratoire Kastler Brossel – Quantum Networks Team**
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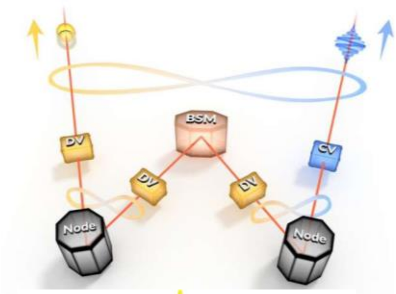
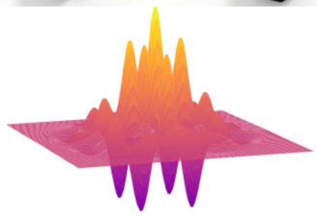
Internship location: Sorbonne Université, Campus P. et M. Curie, 4 Place Jussieu, Paris
Thesis possibility after internship: YES
Funding: YES, Doctoral school/group funding

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, quantum … The LKB team is a member of the ShoQC European consortium (Short range optical quantum connections) and of the Twinning project on "Non Gaussian Physics for Quantum Technology". It is also a partner of the starting French Quantum Initiative on Quantum Information.

A few references

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)
Connecting heterogeneous networks by hybrid entanglement swapping, Science Adv. 6, eaba4508 (2020)
See also the story about this work: Connecting the quantum internet

Condensed Matter Physics:	YES	Soft Matter and Biological Physics:	NO
Quantum Physics:	YES	Theoretical Physics:	YES