Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: LTCI
CNRS identification code: -
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Internship location: Telecom Paris, IPP, 19 place Marguerite Perey

Thesis possibility after internship: YES
Funding: NO If YES, which type of funding:

Title: Time-frequency quantum information processing

Summary:

The frequency degree of freedom of a single photon represents a continuous variable that serves as a powerful tool for encoding quantum information. It provides a high-dimensional encoding scheme, which in turn helps to reduce overall optical costs. Leveraging frequency as a continuous variable and subsequently discretizing it allows for the creation of qubits, which are essential for achieving fault-tolerance. These qubits demonstrate robustness against temporal or spectral broadening for the superposition of two frequency and time, and even small broadening in both the temporal and frequency domains, as for the time-frequency Gottesman–Kitaev–Preskill (GKP) states (Phys. Rev. A **102**, 012607). Errors can arise during the manipulation of single photons in logical operations and as they propagate through optical fibers. What we will explore in this internship is:

- **Studying the Propagation of Single Photons:** We will study the propagation of single photons with diverse spectral distributions through optical fibers. We will investigate the use of time-frequency GKP states and two-color (time-of-arrival) encoding schemes. We will then model and analyze noise that may affect these quantum states during their propagation, and will simulate light-matter interactions and implement computational methods using tools like Qutip. The purity and coherence of the resultant quantum states will be assessed for gaining valuable insights into their potential for quantum information processing.
- **Application in Quantum communication protocols:** Finally, the use of these time-frequency encodings for different quantum communication protocols will be investigated.

Keywords: Theoretical quantum optics, time-frequency quantum information processing, single photons, light-matter interaction

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:
Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: NO