Master 2: ***International Centre for Fundamental Physics***

<u>INTERNSHIP PROPOSAL</u>

(One page maximum)

Laboratory name: Matériaux et Phénomènes Quantiques
CNRS identification code: UMR
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Internship location: Laboratoire Matériaux et Phénomènes Quantiques

Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: PEPR

Quantum metrology using the collective degrees of freedom of single photons

The 2022 Nobel prize celebrated the confirmation of fundamental properties of quantum mechanics which are essentially different from classical ones, namely, the possibility of having non-local correlations inferred through local measurements at particles. Such experiments were conducted measuring a discrete degree of freedom of single photons, their polarization. However, polarization, as any other degree of freedom associated to the electromagnetic field is neither quantum nor classical. How come it is possible to reveal quantum properties by its measurement? In this case, the fact of dealing with single photons is essential, since their statistical properties are inherited by the measured degree of freedom. By pursuing these lines, we have recently unveiled how this field-mode non-separability leads to the definition of continuous variables associated to single photons. Examples of conjugated continuous variables for the single photon are its frequency and time delays. Surprisingly, these degrees of freedom, when associated to a collection of single photons in different propagation modes behave as position and momentum of massive particles and can be used in quantum information and communication protocols as quantum continuous variables. We have recently exploited this fact to provide a new way of looking at metrology protocols using time and frequency variables combining both theoretical and experimental results [1, 2, 3].

The goal of this internship is to adapt the theoretical tools developed in [1] to discrete modes of single photons of dimension higher than 2 in the context of quantum metrology and other applications. We'll try to define collective variables, as a total spin, associated to N single photons and identify how they provide different metrological advantage. The idea is to apply our results to experiments as the Hong-Ou-Mandel experiment. In this context, we work in close collaboration with the experimental photonics team of our lab led by Prof. Sara Ducci, where the frequency degrees of freedom of single photons can be manipulated both as continuous or discrete degrees of freedom.

[1] E. Descamps, N. Fabre, A. Keller and P. Milman, Phys. Rev. Lett. 131 (3), 030801 (2023).
[2] E. Descamps, A. Keller, P. Milman, Phys. Rev. A 108, 013707 (2023).
[3] O. Meskine et al. arXiv:2309.10633 (2023).

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

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