Proposition de stage M2 / M2 Internship proposal

Responsable du stage / *internship supervisor*:

Nom / *name*:	Hugbart	Prénom/ *first name* :	Mathilde
Tél :	04 92 96 73 35	Fax :	04 93 65 25 17
Courriel / *mail*:	mathilde.hugbart@inphyni.cnrs.fr		

Nom du Laboratoire / *laboratory name*: Institut de PHYsique de NIce (INPHYNI)

Code d'identification : UMR 7010 Organisme : CNRS

Site Internet / *web site*: https://inphyni.univ-cotedazur.eu/sites/cold-atoms

Adresse / *address:* 1362 Route des Lucioles, Sophia Antipolis, 06 560 Valbonne

Lieu du stage / *internship place*: Valbonne Sophia-Antipolis et Campus Plaine du Var

Titre du stage / *internship title*: **Antibunching effect and squeezed light in a cold atom ensemble**

Résumé / *summary*

Cold atoms coupled to photons are a **promising platform for quantum information, computation and communication**: atoms are adequate systems to store and/or correlate photons, while the photons themselves can be efficient carriers of information over great distances. The light radiated by a quantum emitter, such as an atom, generally features **quantum correlations** and **squeezing**, which are at the heart of many applications in quantum technologies. While **antibunching** is the key ingredient for **single-photon sources**, squeezed light is an important tool for sub-shot-noise quantum sensing.

Antibunching naturally occurs in the light emitted by a single quantum emitter and vanishes for many emitters. Still, antibunched and squeezed light can be obtained using many atoms: instead of collecting the atoms fluorescence, one uses the light transmitted through the atomic cloud. This has been demonstrated recently by the group of Arno Rauschenbeutel in Germany in a 1D system with cold atoms trapped and optically interfaced with an optical nanofiber [1, 2]. This new scheme, which is based on the atoms' collectively enhanced non-linear response, is both of fundamental interest and favourable for applications. However, the nanofiber experiment requires a complex setup and is difficult to implement in practical applications.

The goal on our experiment is now to try to detect **antibunching and squeezed light with many quantum emitters in a 3D system**. This will be implemented and studied on our **cold-atom experiment**, taking advantage of our experience with generating clouds of cold atoms with **large optical thickness**, a prerequisite for this project. The experimental technique is based on intensity correlation measurement, an experimental tool largely used on our experiment to study the light scattered by a cold atomic cloud, from single to multiple scattering regime, and from classical to quantum regime [3, 4, 5, 6, 7]. The current collaboration with the group of Arno Rauschenbeutel will finally help to determine the experimental parameters needed to observe this antibunching effect.

This internship is **experimental** but will also include numerical studies in collaboration with Romain Bachelard (UFSCar, Brazil). An extension in a PhD is possible.

References:

[1] **Correlating photons using the collective nonlinear response of atoms weakly coupled to an optical mode**, A. S. Prasad *et al.*, Nat. Phot. **14**, 719 (2020).

[2] **Unraveling Two-Photon Entanglement via the Squeezing Spectrum of Light Traveling through Nanofiber-Coupled Atoms**, J. Hinney *et al.*, Phys. Rev. Lett. **127**, 123602 (2021).

[3] **Diffusing-wave spectroscopy of cold atoms in ballistic motion**, A. Eloy *et al.*, Phys. Rev. A **97** 013810 (2017).

[4] **Mollow triplet in cold atoms**, L. Ortiz-Gutiérrez *et al.*, New J. Phys. **21** 093019 (2019).

[5] **Connecting field and intensity correlations: the Siegert relation and how to test it,** D. Ferreira *et al.*, Am. J. Phys. 88, 831 (2020)

[6] **Field and intensity correlations: the Siegert relation from stars to quantum emitters**, P. Lassègues *et al*, to appear in EPJD (2022)

[7] **From classical to quantum loss of light coherence,** P. Lassègues, et al., preprint: physics/2210.01003

Ce stage pourra-t-il se prolonger en thèse ? *Possibility of a PhD* **? : OUI / YES**

Si oui, financement de thèse envisagé/ *financial support for the PhD***: Ecole doctorale ou ANR**