Master's internship proposal (M1 and M2)

Title: Antibunching effect in a cold atom ensemble

Keywords: Cold atoms, quantum correlation, light scattering, intensity interferometry

Scientific description:

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**, 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]. 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 **antibunched 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 [2]. The current collaboration with the group of Arno Rauschenbeutel will finally help to determine the experimental parameters needed to observe this antibunching effect.

This master internship is experimental but can also include numerical studies in collaboration with Romain Bachelard (UFSCar, Brazil).

References:

[1] A. S. Prasad et al., Nat. Phot. **14**, 719 (2020). J. Hinney et al., Phys. Rev. Lett. **127**, 123602 (2021).

[2] A. Eloy et al., Phys. Rev. A **97**, 013810 (2017). L. Ortiz-Gutiérrez et al., New J. Phys. **21**, 093019 (2019). D. Ferreira et al., Am. J. Phys. **88**, 831 (2020). P. Lassègues et al, EPJD **76**, 246 (2022). P. Lassègues, et al, Phys. Rev. A **108**, 042214 (2023).

Techniques/methods in use: Lasers, cold atoms, intensity correlation
Applicant skills: Experiments in optics and laser physics, basic knowledge of atomic physics
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Internship location: Institut de Physique de Nice, Nice
Scholarship: Doctoral school scholarship or funding within the "cold atoms" research team