Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

Laboratory name: Laboratoire Kastler Brossel (LKB)
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Internship location: Sorbonne Université, Paris

Thesis possibility after internship: YES
Funding: YES, via EDPIF

Decoherence of collective light scattering in cold atomic clouds

When illuminated by an electromagnetic wave, a cold atomic cloud may response collectively to the field. A well known example of collective scattering of light is super-radiance, where the time decay of an atomic ensemble becomes faster than the response of a single atom. In atomic clouds heated to high enough temperature, a mean field description of light scattering by an atomic cloud is in general accurate. In the past, this approach was successfully used, e.g., to describe Lorentz-Lorenz collective Lamb shifts in the frequency line of the scattered field [1]. At low temperature, however, additional collective effects arise in light scattering, and escape the mean-field prediction [2,3]. They typically stem from a modification of the atomic cross-section due to the induced-dipole-dipole interactions with the surrounding atoms, and require a microscopic description of recurrent scattering beyond the mean field level [4].

The goal of this M2 internship is to theoretically describe how the collective induced-dipole-dipole interactions are impacted by temperature in an atomic cloud. Qualitatively, we expect their influence to progressively decrease as temperature increases, as a result of a decoherence mechanism destroying the collective interference of light scattering within atoms pairs. We will describe this mechanism using a microscopic theory of light scattering based on the impurity Green's function technique [4,5] taking Doppler shifts into account, to unveil how the mean-field regime is recovered at high enough temperature.

The internship project will be conducted at Laboratoire Kastler Brossel in Sorbonne Université within the "Quantum Theory, Atoms and Fields'' group, under the supervision of Nicolas Cherroret. A collaboration with Romain Pierrat at Institut Langevin will also be considered, in order to perform numerical calculations so to confirm the theoretical results.

[1] R. Friedberg, S. Hartmann, and J. Manassah, Phys. Rep. **7**, 101 (1973)
[2] S. D. Jenkins, J. Ruostekoski, J. Javanainen, R. Bourgain, S. Jennewein, Y. R. P. Sortais, and A. Browaeys, Phys. Rev. Lett. **116**, 183601 (2016).
[3] L. Corman, J. L. Ville, R. Saint-Jalm, M. Aidelsburger, T. Bienaimé, S. Nascimbène, J. Dalibard, and J. Beugnon, Phys. Rev. A **96**, 053629 (2017).
[4] N. Cherroret, S. Delande, B. A. Van Tiggelen, Phys. Rev. A **94**, 012702 (2016).
[5] C. C. Kwong, D. Wilkowski, D. Delande, and R. Pierrat, Phys. Rev. A. **99**, 043806 (2019)

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