INTERNSHIP PROPOSAL

(One page maximum)

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

A tunable optical lattice for ultra-cold quantum gases

The Helium lattice apparatus at Institut d'Optique exploits the specific properties of the Helium atomic species to probe lattice gases atom-by-atom in momentum space [1]. Over the past years, we have studied properties of interacting bosons in a 3D square lattice [2], including momentum Bogoliubov pairing [3] and a phase transition from a superfluid to an insulator – the Mott insulator – from the full counting statistics [4].

We are currently modifying the experimental setup to move towards new configurations of lattice gases which are expected to feature new phenomena. More specifically, we aim to study 2D systems of interacting bosons in a tunable lattice geometry. In this new configuration, the lattice will be made square, triangular or even more exotic, upon control.
The internship centered on the study of this tunable optical lattice is a crucial step in this direction, and it will lead to a PhD thesis (starting in Sept. 2026) that will pursue the scientific goals with 2D lattice bosons.

The Master 2 internship aims at conceiving, realizing and testing the tunable optical lattices. The conception of the optical system realizing the tunable lattice will carefully consider optimizing the lattice depth and homogeneity, as well as easing the tuning of the lattice configuration on the experiment. Numerical calculations of the physical parameters of the tunable lattice in the various configurations (e.g. tunnelling amplitude, on-site interaction energy) will be realized, to prepare the appropriate choice of parameters of the future studies. A substantial part of the internship will be dedicated the experimental characterization of the laser source used to create the tunable lattice. A self-heterodyne interferometer will be built on a test bench to precisely measure the phase noise of the laser, the latter being the most sensitive property affecting the lattice potential that results from interferences between retroflected laser beams.

References

[1] H. Cayla et al. - Phys. Rev. A **97**, 061609 (2018); M. Allemand et al. Phys. Rev. X Quantum **5**, 040324 (2024).
[2] C. Carcy et al. Phys. Rev. X **9**, 041028 (2019); C. Carcy et al. Phys. Rev. Lett. **126**, 045301 (2021); G. Hercé et al. Phys. Rev. Res. **5**, L012037 (2023).
[3] A. Tenart et al. Nature Physics **17**, 1364 (2021); J.-P. Bureik et al., Nature Physics **21**, 57-62 (2025).
[4] M. Allemand et al. arXiv:2508.21623 (2025).

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