INTERNSHIP PROPOSAL

(One page maximum)

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

Producing optical potentials for ultracold atoms with a DMD

The Helium lattice apparatus at Institut d'Optique is running with the bosonic species Helium-4. Exploiting the single-atom-resolved detection in momentum space [1], we have studied and characterized interacting lattice Bose gases in three-dimension (3D) (see for instance [2]). A fascinating feature of interacting lattice bosons is that they undergo a quantum phase transition from a superfluid state to an insulator state, called a Mott insulator.
A main drawback of the configuration used so far in our experiment lies in the presence of a harmonic trap: it implies that we probe gases with non-homogeneous atomic density and couplings in the lattice. Since the physics of the Mott transition strongly depends on the spatial homogeneity of these parameters, the study of the critical regime of the Mott phase transition is strongly impaired. Our plan is to upgrade the apparatus to realize homogeneous samples and probe the physics of the critical regime of the Mott transition.

An established technique to realize homogeneous samples consists in working with 2D gases whose trap and lattice geometry are controlled by optical potentials [3]. More precisely, we propose to combine the use of a high numerical aperture (NA) microscope - to shine optical potentials with high resolution - with the use of a digital mirror device (DMD) to create arbitrary patterns of optical potentials (see picture).

The aim of the internship consists in (i) characterizing the optical potentials created by the DMD, (ii) conceiving the optical setup to address the atoms with the light potential reflected from the DMD and, (iii) verifying the properties of the optical potentials on a test optical bench.

The internship paves the way to a PhD thesis where 2D gases of ultracold metastable Helium will be realized, the high-NA microscope and optical potentials created by the DMD will be shone onto the atoms and the characterization of the critical regime of the Mott transition with our single-atom-resolved detector will be performed.

References

[1] H. Cayla, C. Carcy, Q. Bouton, R. Chang, G. Carleo, M. Mancini and D. Clément - Phys. Rev. A **97**, 061609 (2018).
[2] C. Carcy et al. Phys. Rev. X **9**, 041028 (2019); A. Tenart et al. Nature Physics **17**, 1364 (2021); C. Carcy et al. Phys. Rev. Lett. **126**, 045301 (2021); G. Hercé et al. Phys. Rev. Research **5**, L012037 (2023); J.-P. Bureik et al., arxiv:2401.15340 (2024).
[3] N. Navon, R. P. Smith and Z. Hadzibabic Nature Physics **17**, 1334–1341 (2021)

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