

INTERNSHIP PROPOSAL

(One page maximum)

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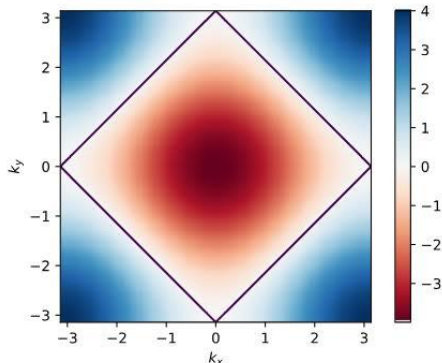
Thesis possibility after internship: YES
Funding: YES/NO If YES, which type of funding:

Probing the Fermi surface in a lattice with metastable helium atoms

The helium lattice team at Institut d'Optique exploits the specific properties of the helium species to probe lattice gases atom-by-atom in the momentum space [1]. The apparatus was built and operated with the bosonic species helium-4. Over the past years, we have studied interacting bosons in a 3D square lattice [2], revealing the Bogoliubov pairing through atom correlations [3,4], and probing the phase transition from a superfluid to the Mott insulator, exploiting the full counting statistics [5,6].

Interestingly, the detection method also applies to the fermionic species helium-3: it relies on the large internal energy stored in the metastable state, whether helium-3 or helium-4. Therefore, we have recently upgraded the experimental apparatus to add the fermionic species helium-3 and to produce a degenerate Fermi gas (DFG). The DFG is currently being characterized and optimized.

In a near future, we will load the fermionic gas into 3D square lattices to perform the first studies of lattice fermions with our single-atom-resolved detection in the momentum space.



The Master 2 internship will aim at characterizing the Fermi surface of non-interacting lattice fermions, and it is expected to lead to a PhD thesis (starting in Sept./Oct. 2027) with the goal of studying interacting lattice fermions (e.g. Fermi-Hubbard physics) through momentum-space correlations.

The M2 intern will join the experimental team to participate to the on-going efforts. The tasks mainly consist of (i) loading helium-3 gas into the optical lattices, ensuring an adiabatic loading, (ii) acquiring the experimental data with the single-atom detector, varying experimental parameters such

as temperature or filling of the lattice potential, and (iii) analyzing the single-atom-resolved distributions to characterize the Fermi surface.

References

- [1] Phys. Rev. A **97**, 061609 (2018); Phys. Rev. X Quantum **5**, 040324 (2024).
- [2] Phys. Rev. Lett. **126**, 045301 (2021).
- [3] Nature Physics **17**, 1364 (2021).
- [4] Nature Physics **21**, 57-62 (2025).
- [5] Nature **655**, 1148 (2026).
- [6] arXiv:2609.03433 (2026).

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