Master in Photonics – "PHOTONICS BCN"
Master ERASMUS Mundus "EuroPhotonics"

MASTER THESIS PROPOSAL

Starting full time from April 2024
Presentation at the end of July or beginning of September 2024

Laboratory: Ultracold quantum gases group
Institution: ICFO - The Institute of Photonic Sciences
City, Country: Castelldefels (Barcelona), Spain

Title of the master thesis:
A laser system to address the clock transition of strontium atoms in an optical lattice

Name of the master thesis supervisor and co-supervisor:
Leticia Tarruell; Vasiliy Makhalov
Email address: leticia.tarruell@icfo.eu; vasiliy.makhalov@icfo.eu
Phone number: +34935542254
Mail address:
ICFO - The Institute of Photonic Sciences
Av. Carl Friedrich Gauss, 3
08860 Castelldefels (Barcelona)

Keywords: quantum simulation, ultracold atoms, optical lattices, atomic clocks, ultrastable cavities

Summary of the subject (maximum 1 page):

Ultracold atomic gases have emerged in the last two decades as a highly versatile platform for the study of quantum many-body physics. In particular, by trapping the atoms in crystals of light generated by interferring laser beams (so-called optical lattices), they allow for the realization of extremely controlled artificial materials. Moreover, using high-resolution imaging optics, it is possible to image every atom in a site-resolved manner, gaining full microscopic access to the system properties (see Fig. 1). This allows one to investigate cornerstone models of condensed-matter physics such as the Hubbard model or the Heisenberg model, and to investigate physical phenomena normally appearing in strongly correlated materials.

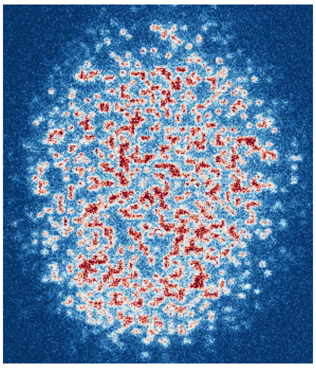

Fig. 1. Single-atom resolved fluorescence imaging of a Bose-Hubbard system in the ICFO strontium quantum gas microscope.

In our lab at ICFO, we have constructed a quantum gas apparatus which allows us to detect single atoms of quantum degenerate bosonic strontium in an optical lattice, see figure. However, a fermionic isotope, strontium-87, is also available. It has a nuclear spin I = 9/2, which gives access to Hubbard models with 10 different spin states, extending beyond the SU(2) magnetism of pure electrons in

solids. This isotope also possesses an optical transition with a linewidth of only a few mHz, which is used to operate the world's most precise atomic clocks. The clock transition constitutes as well a very useful resource for quantum many-body experiments. In our apparatus, we want to exploit it to add spin selectivity to our imaging system. To this end, an advanced laser system is however required.
In this project, a master student will design and construct the clock laser system of our strontium quantum gas experiment. At the end of the project, the performances of the clock laser will be characterized by addressing the clock transition of ultracold strontium atoms trapped in a deep optical lattice.

Objectives:

- Build an optical setup to couple the laser to a very high-finesse ultra-stable optical cavity (already present in our lab) in order to actively stabilize its frequency and reduce its linewidth.
- Provide a stable environment for the optical cavity, stabilizing its temperature and reducing vibrations with active and passive methods;
- Actively cancel the phase noise introduced by the optical fibers used to transfer the clock laser light to the atoms using an interferometric scheme.
- Characterize the performances of the clock laser by addressing the clock transition of ultracold strontium atoms trapped in a deep optical lattice.

Additional information (if needed):

* Required skills: We are looking for candidates with a good background in quantum optics and atomic physics, and a strong motivation for setting up and conducting challenging experiments in a team of three to four people. We offer training in a broad range of cutting-edge experimental techniques (from optics, electronics, ultra-high vacuum technology and computer control to laser cooling and trapping), as well as in theoretical atomic, quantum, statistical, and condensed matter physics.

* Miscellaneous: The Master project is funded. More details concerning the typical student research fellowships at ICFO can be found in jobs.icfo.eu

For further information on our group and our research, please consult:

- www.qge.icfo.eu
- https://www.icfo.eu/research-group/25/quantumgases/home/437/
- X (Twitter): @icfo_QGE