INTERNSHIP PROPOSAL

Laboratory name: Laboratoire Charles Fabry
CNRS identification code: UMR8501
Internship director'surname: CHENEAU
e-mail: marc.cheneau@institutoptique.fr Phone number: 01 64 53 33 39
Web page:
www.lcf.institutoptique.fr/groupes-de-recherche/gaz-quantiques/experiences/dynamique-quantique

Internship location: Institut d'Optique

Thesis possibility after internship: YES
Funding: NO

Propagation of correlations in a strongly-interacting quantum gas

Despite the formidable complexity of quantum relaxation dynamics, recent theoretical advances have put forward a very simple picture: the dynamics of quantum many-body systems would be essentially local, meaning that it would take a finite time for correlations between two distant regions of space to reach their equilibrium value, as happens in relativistic theory because of the limit imposed by the speed of light. This locality would be an emergent collective property, similar to spontaneous symmetry breaking, and have its origin in the propagation of quasiparticle excitations. The fact is, however, that only few observations directly confirm this scenario. In particular, the role played by the dimensionality and the range of the interaction potential between the particles is largely unknown.

The need for experimental insight has motivated the construction of a new apparatus at LCF to investigate the relaxation dynamics of ultracold atomic gases. The choice was made to study a gas of Strontium atoms (bosons and fermions) in a two-dimensional optical lattice, and to equip the apparatus with advanced measurement and manipulation tools, such as a fluorescence microscope for imaging the gas with single-atom sensitivity and sub-micron resolution. The construction of the experiment is now finished and we will attempt to record the first microscope images by the end of the year 2023. Once this is achieved, we will turn to the focus of our project, namely the experimental study of how correlations propagate in our system after a sudden variation of the lattice depth: Is the propagation ballistic or diffusive? How fast does it proceed? What is the link with the elementary excitations in the system?

In order to carry out this project, we are now looking for a master student willing to engage in a PhD thesis. By the start of the internship we will be preparing the very first measurements of the propagation of correlations. The intern will join a team of two PhD students, learn how to run the experiment, and directly participate in the measurements. There are also a couple of upgrades that we would like to prepare on the apparatus and the intern will have the possibility to work on one of them as a personal side project.

The ensuing PhD thesis will be devoted to the experimental study of the relaxation dynamics of the Strontium gas after a so-called quantum quench. In practice, the gas will initially be prepared in the ground state of the optical lattice and then put out at equilibrium by suddenly varying the lattice depth. The first experiment on the list is the search for a "light cone" in the space-time diagram with two dimensions of space. A recent experiment by a Japanese group suggests that such light cone exists but a definite proof is still lacking. We will then focus on the so-called critical region of the metal-to-Mott insulator transition. In this part of the phase diagram, the elementary excitations lose their quasiparticle nature and the fate of the light-cone-like propagation remains unknown.

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