Master 2: International Centre for Fundamental Physics

INTERNSHIP PROPOSAL

Laboratory name: Laboratoire Charles Fabry (LCF)
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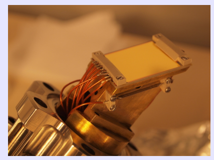
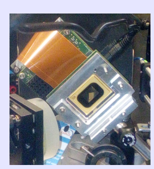
Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ANR

Investigating the quasi-particle distribution of 1D Bose gases



Atom-chip used to manipulate atoms. Undernetah the gold miror, micro-wires, deposited on the SiC substrate, produce the magnetic trap.

In the atom chip experiment of the quantum gases group at LCF, bosonic atoms are confined in magnetic traps produced by current-carrying micro-wires. This technology enables the realization of atomic guides with a strong enough transverse confinement to freeze the transverse degrees of freedom. We thus realize one-dimensional (1D) Bose gases.
Interactions between atoms in our system are very well described by local repulsive interactions. Then, our gases are modeled by the famous Lieb-Liniger model of 1D Bosons with contact repulsive interactions. The Lieb-Liniger model is a paradigm example of integrable many body quantum systems. Integrable systems are characterized by the fact they host quasi-particles of infinite lifetime. The existence of those quasi-particles renders the physics of integrable models, both at equilibrium and out-of-equilibrium, very different from that of chaotic systems. In particular, while chaotic systems, as long as local observables are concerned, do relax towards thermal states described by only a few parameters, integrable models do not relax to thermal states. Huge theoretical efforts have been devoted those last years to the physics of integrable systems. A breakthrough has been the development of the generalized hydrodynamic (GHD) theory, valid in the long wave-length approximation. In this theory, the gas is described, locally, by its quasi-particles distribution. On the experimental side, only a few results have been obtained. The atom-chip experiment at LCF has been a pioneer in this field with the first experimental test of the GHD theory [1].
As now established theoretically, the quasi-particle distribution is the key notion to describe integrable systems. Although first introduced as a mathematical concept, it has been recently realized that this quasi-particle distribution can be accessed experimentally, performing 1D expansions. The goal of the atom-chip team is to investigate the quasi-particle distribution, in a spatially resolved way and both in equilibrium and in out-of-equilibrium situations. Our atom-chip setup is an ideal playground for such studies since it offers unique opportunities compared to other experimental setups. One of the particularities of the experiment is that a *single* gas is investigated: our measurements are not ensemble-averaged measurements so that not only mean values but also fluctuations can be extracted [2]. This will permit us to study fluctuations of the quasi-particle distribution, which should reveal their fermionic nature.
A key point for our research goals is the capability to perform local measurement of the distribution of quasi-particles, which will avoid smearing due to average over the spatial density profile. This requieres the development of a new tool on the experiment. The idea is, prior to the measurement of the rapidity distribution, to select a small part of the cloud: the rest of the cloud will be pushed away by the radiation pressure produced by a laser beam spatially shaped using a micro-mirror device. During the internship, the student will implement the spatial selection of a zone of the cloud, and hopefully, measure the rapidity distribution of the selected zone.



The micro-mirror device that will be used to select a zone of the atomic cloud.

[1] Max Schemmer, Isabelle Bouchoule, Benjamin Doyon, Jerome Dubail, Phys. Rev. Lett. **122**, 090601 (2019)
[2] See for instance some of our previous works : Phys. Rev. Lett. **106**, 230405 (2011), Phys. Rev. Lett. **116** , 050402 (2016)

lease, 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:	YES