INTERNSHIP PROPOSAL (M2)

Laboratory name: *PhLAM (Laboratoire de Physique des Lasers, Atomes et Molecules)*
CNRS identification code: *UMR 8523*
Internship director: *Radu Chicireanu*
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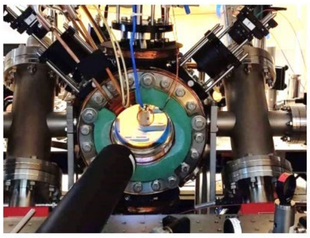
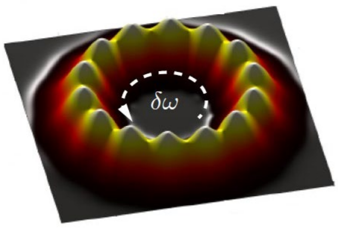
Web page:
https://phlam.univ-lille.fr/recherche/systemes-quantiques/recherches/i-condensat-bose-einstein
Internship location: *University of Lille, PhLAM Laboratory*

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

1D Superfluidity in Optical Ring Traps for Ultracold Quantum Gases





Superfluidity is a striking collective behavior of quantum fluids, characterized by a vanishing viscosity and frictionless flow, leading to features such as persistent currents, quantized vortices, and critical velocities for flow stability. In low dimensions however, and particularly in one-dimensional (1D) geometries, quantum fluctuations have an enhanced role, leading to significant differences compared to higher-dimensional ones, such as the predictions of a non-zero quantum friction force existing any flow velocity. The competition between this quantum friction force and the quasi long-range order in the system at low temperatures question the 'standard' definitions of superfluidity.

The M2 internship project is based on a potassium Bose-Einstein experiment developed at PhLAM laboratory (University of Lille). The central aspect of the internship is the development and implementation of optical traps designed to confine Bose-Einstein condensates in tightly focused ring-shaped potentials (see Fig. 1). These traps are obtained by conveniently shaping the phase profile of laser beams using 'spatial modulator devices'.

On a longer term, experimental protocols will include the precise calibration of optical barriers, dynamic modulations and rotating potentials, and detection methods such as time-of-flight imaging and phase-sensitive interference. This techniques will be aimed at characterizing critical speeds for superfluidity, excitation dynamics, and the role of quantum coherence. Ultimately, these developments will allow the investigation of the fate of 1D superfluidity beyond the mean-field framework, validate analytical predictions and guide future theoretical directions beyond the current state-of-the-art.

Pre-requisites: The candidate should have a good level in quantum and statistical physics. Although not compulsory, experimental background and attraction to numerical simulations are welcome.
Integration: This experimental M2 internship will take place in the PhLAM laboratory (University of Lille) and will utilize an existing potassium BEC experiment. The chosen candidate will join the "Quantum Systems" team (7 permanent members and 5 PhD students and 1 post-doc). The project is based on collaborations with researchers from Paris and Nice, and benefits from local theory support.
References:
[1] PRA 85, 053627(2012) - *Probing superfluidity of a mesoscopic Tonks-Girardeau gas*
[2] PRA 91, 063619 (2015) - *Dynamic structure factor and drag force in a one-dimensional strongly interacting Bose gas at finite temperature*
[3] RMP 94, 041001 (2022) - *Atomtronic circuits: From many-body physics to quantum technologies*

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Quantum Physics: YES