Master 2 "Photonics, Complex and Quantum Systems (PhoCQS)": Research Training 2025-2026
Master 2 "Matter Molecules and their Environment (MME)": Research Training 2025-2026

Appel à sujet de stage recherche / Call for research training subject

Laboratory: PhLAM

Supervisor: Radu CHICIREANU

Tél : 03 20 43 41 66, E-mail : radu.chicireanu@univ-lille.fr

Collaborator(s): Adam Rançon

Topic: Ultracold Atoms

Master 2: select the master and the most appropriate option

☑ Master 2 PhoCQS (GP-IKS)	□ Master 2 MME (GP-SCP)
☑ Option Complex and Quantum Systems	□ Option Condensed Matter
	□ Option Condensed Matter/Pharma
	□ Option Dilute Matter and Spectroscopy
	□ Option Atmospheric Sciences
	□ Option Modeling at the molecular & atomic scales
Return subject to : christophe.szwaj@univ-lille.fr	Return subject to : sebastien.merkel@univ-lille.fr

Development of 1D Optical Ring Traps for Ultracold Quantum Gases

Superfluidity is a striking collective behavior of quantum fluids, characterized by vanishing viscosity and frictionless flow. It manifests through features such as persistent currents, quantized vortices, and critical velocities for flow stability. In low dimensions, however –particularly in one-dimensional (1D) geometries–quantum fluctuations play an enhanced role, leading to significant differences compared to higher-dimensional systems. For instance, theoretical predictions suggest the existence of a non-zero quantum friction force at any flow velocity [1,2]. The competition between this quantum friction and the quasi-long-range order that emerges at low temperatures challenges the "standard" definitions of superfluidity in the 1D regime.

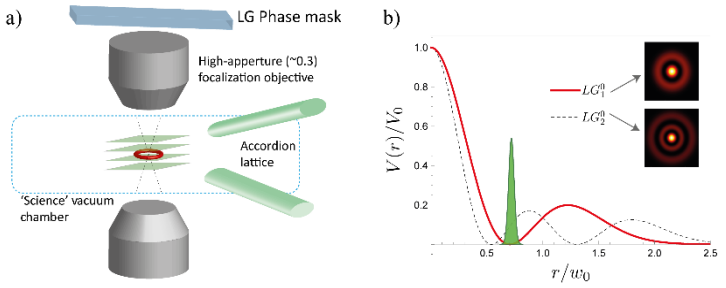

Figure 1 (a) Implementation of the 1D ring trap in the potassium BEC setup. (b) optical dipole trap potential using

Optical ring traps provide strong 1D confinement and support rotating persistent currents [3], making them ideal experimental tools to investigate superfluidity in the strongly 1D regime.

The aim of this M2 internship is to design and implement optical traps capable of confining Bose-Einstein condensates (BECs) in tightly focused ring-shaped potentials (see Fig. 1). These traps are created by shaping the transverse phase profile of laser beams using spatial light modulators –programmable phase masks that

can imprint arbitrary phase and/or intensity profiles onto the beams. In addition, an "accordion lattice" [4] – an optical standing wave with a dynamically tunable spatial period– will be designed and constructed. This lattice will allow confinement of atoms along the longitudinal direction in one or several parallel planes (see Fig. 1a). The combination of the ring potential and the accordion lattice will enable tight confinement of the BEC in a 1D ring geometry.

In the longer term, the 1D ring traps developed here will be employed to study exotic superfluid behavior in reduced 1D geometries. Using tunable interactions in potassium BECs, the project will explore these effects across a wide range of regimes, from mean-field to strongly correlated.

The internship will lead to a PhD project, funded by an ongoing PEPR "Quantum Technologies" project.

Key words: Ultracold quantum gases, Superfluidity, Quantum simulations