Université de Toulouse

Bose-Einstein condensate interferometry

Macroscopic quantum separation for tests of fundamental physics

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Level	Master's (M2) student — PhD continuation possible

Background

Atom interferometry has become a central area of quantum metrology. Atom interferometers have enabled a new generation of instruments for gravimetry and inertial navigation, and are at the same time opening new frontiers in the exploration of fundamental physics. In the *Atom Interferometry and Quantum Metrology* team at LCAR, we develop interferometers based on the coherent manipulation of Bose-Einstein condensates in optical lattices. The distinctive feature of our approach is the ability to create superpositions of atomic trajectories separated by more than 10 cm. Beyond the remarkable nature of such a situation in quantum physics, this macroscopic separation provides an original handle for controlling the interaction between the atoms and their environment.

A recent advance of the team relies on a stroboscopic stabilisation method in accelerated optical lattices. This technique transfers very large momenta to the atoms with high efficiency, and establishes an original approach to large-momentum-transfer atom interferometry. We have demonstrated a separation of 600 photon recoils $\bar{}hk$ in only 2 ms. This performance opens the way to interferometers with metre-scale arm separation, and hence to considerable gains in sensitivity — a class of instruments that is particularly promising for gravitational-wave detection and for new tests of fundamental physics.

Scientific objectives

The team is currently building a next-generation atom interferometer, with the ambition of exploring so-far inaccessible regimes of the interplay between quantum mechanics and gravitation. A particularly original motivation concerns the gravitational Aharonov-Bohm effect, in which a matter wave evolves in a superposition of paths associated with different proper times. Recent theoretical studies show that our experimental architecture would make new tests of this effect conceivable and, more broadly, would allow gravitation to be probed experimentally in a regime lying at the boundary between quantum physics and general relativity.

Proposed workProposed work

The intern will participate in the development and optimization of the new experimental setup. The work may involve the following:

• Implementing new sequences in optical lattices based on optimal control for BEC manipulation and testing them experimentally;

• Developing and building a new Bose-Einstein condensate source;

• Modeling and simulating interferometric phases, and designing optimized configurations for gravitational tests.

The internship will take place in an experimental environment combining ultra-stable lasers, coldatom physics and numerical modelling.

Continuation as a PhD

The internship may be followed by a PhD devoted to the development of an atom interferometer with very large spatial separation and to its applications in fundamental physics. The objectives will include the demonstration of quantum gravitational phases, the study of the gravitational Aharonov-Bohm effect, tests of the neutrality of matter, and a measurement of the universal gravitational constant *G*.

Candidate profile and application

Master's-level student (M2 or final year of an engineering school) in physics; a specialisation in quantum physics, optics or cold-atom physics will be appreciated. We are looking for someone motivated by experimental work and interested in questions of fundamental physics. Programming skills (Python) and an appetite for modelling will be an asset.

Application. Please send a CV, and a cover letter to alexandre.gauguet@irsamc.ups-tlse.frandbaptiste.allard@irsamc.ups-tlse.fr.