Stage de master de physique / Physics Master Internship

Proposition de stage/ Internship proposal (1 page max)

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Nom du Laboratoire / *laboratory name*: SYstèmes de Référence Temps-Espace			
Code d'identification : UMR8630	Organisme : Observatoire de Paris, CNRS, SU, LNE		
Site Internet / *web site*: https://syrte.obspm.fr/spip/science/iaci/			
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Lieu du stage / *internship place*: 77 avenue Denfert-Rochereau 75014 Paris			

Titre du stage / *internship title*: **Novel real-time control methods of the atomic phase for a cold-atom gyroscope**

Résumé / *summary*

Context: Inertial sensors with cold atoms offer many applications in fundamental physics (tests of the laws of gravitation, gravitational astronomy), geosciences (measurements of the gravity field or of Earth rotation) and inertial navigation. The operation of these sensors is based on atomic interferometry taking advantage of superpositions between quantum states of different momentum of an atom. These superposition states are obtained by means of optical transitions with two (or more) photons communicating momentum to the atom and acting as beam splitters and mirrors for the matter waves. SYRTE is a pioneer laboratory in the field, recognised worldwide for its expertise in the metrology of these quantum sensors, their use for different applications, and their technological transfer.

The objective of this project is to contribute to the **development of the cold atom gyroscope** currently operated at SYRTE, which represents the state of the art in terms of sensitivity and stability. In particular, it will focus on its development for applications aimed at **testing the predictions of the Standard Model Extension** (SME) on the one hand, i.e. the search for possibly new interactions beyond those of the Standard Model, and at opening up applications in **rotational seismology** on the other hand, an emerging field of study of rotational motions induced by earthquakes, ambient vibrations… The experiment also enables the implementation and testing of new atomic interferometry techniques that are of interest for future gravitational wave detectors based on cold atom technologies.

Master thesis work: One possibility for improving the sensitivity of cold-atom sensors is to increase their scaling factor related to the space-time area of the interferometer. This area can be increased by using so-called "multi-photon" splitters for atomic waves, where the momentum of several photons is transferred to the atom. A sensor architecture that allows this increase in area while minimising the introduction of spurious systematic effects is the atomic interferometer geometry using **double diffraction**. In addition, it should also improve our record performance and **target the standard quantum limit** by allowing a measurement setup with no dead time. In this geometry, an atom interacts symmetrically with two pairs of counter-propagating laser beams inducing stimulated Raman transitions in two opposite directions. The two arms of the interferometer are then associated with the same internal state of the atom, which **cancels out some systematic effects** (notably the effects of energy shifts of the atomic levels). Unfortunately, this makes it impossible to use the phase difference between the two Raman lasers to control the phase of the atomic interferometer. This project aims to overcome this problem by implementing a method for controlling the phase of a double diffraction interferometer. In particular, two methods will be implemented and compared: precisely varying the frequency of the Raman lasers and using a high-resolution piezoelectric mirror to scan the laser equi-phases.

In practice, the master thesis will involve

- Atomic physics calculation to estimate the Rabi frequencies, expected light shifts and optimise diffraction efficiencies;
- Laser physics and control electronics to upgrade the servo loop between two lasers;
- Test of the real-time control by frequency or phase jumps or by movements of the piezo-mirror;
- Data analysis.

Ce stage pourra-t-il se prolonger en thèse ? *Possibility of a PhD* **? : YES**	
Si oui, financement de thèse envisagé/ *financial support for the PhD***: Secured ANR**	