PhD subject

A continuous cold-atom interferometer to achieve quantum noise detection limit in inertial force measurements

Laboratory: Laboratoire Temps Espace - Observatoire de Paris, 77 avenue Denfert Rochereau, Paris 14, France

Supervisors: Arnaud Landragin, arnaud.landragin@obspm.fr

Website: https://syrte.obspm.fr/spip/science/iaci/

***Context**:* Cold atom inertial sensors have many applications in fundamental physics (testing the laws of gravitation, gravitational astronomy), geosciences (measuring the Earth's gravity field or rotation) and inertial navigation [1]. The operation of these sensors is based on atomic interferometry, taking advantage of superpositions between quantum states of different momentum in an atom, generated by optical transitions with two (or more) photons in order to realize accurate sensors. LTE (formerly SYRTE) is a pioneering laboratory in this field, recognized worldwide for its expertise in the **metrology of these quantum sensors** [2,3], their use in various applications, and their technological transfer, particularly for **geophysical applications** within the field of geodesy, hydrology, volcanos survey...

The objective of this thesis project is to develop **continuous measurements** using cold atom interferometers in order to **improve their sensitivity while maintaining their accuracy.** Ultimately, this method should enable the detection limit, which is intrinsically linked to **quantum projection noise**, to be reached. One of the limitations of cold atom inertial sensors is the inherently sequential nature of the measurement, which leads to a loss of information between successive measurements and aliasing effect of the inertial signal. The continuous measurement allows fast noise averaging such as $1/\tau$. The first developments in continuous operation have already demonstrated record performance for **rotation measurements** [4], but need to be modified to realize their full potential. The experiment will then be modified to target the subject of continuous measurement in **atomic interferometry more generally**. In particular, we aim in demonstrating **gravity measurements** sensitivity. This method is indeed very general in atomic quantum sensors and can also be applied to different others sensors (atomic clocks...).

Continuous measurements require a sequence whose cycle time is twice as short as the interrogation time (at least two atomic samples in the interferometer at any given time). To achieve this regime, certain modifications must be made to the existing experiment in order to simultaneously realize atomic beam splitters and mirror for three independent atomic samples. The first changes concern Raman lasers used to manipulate the atomic wave-packets. The preparation and detection of cold atomic samples must also be modified, as must the timing sequence, to ensure that the light emitted by the atoms during these stages does not disturb the atoms inside the interferometer. This last point is essential to guarantee accuracy. The studies will focus on both improvement of the sensitivity to achieve QPN and the systematic effects linked to the continuous measurements. This will be a real game changer in gravity field measurement as the sensor will be both accurate and have record sensitivity, thereby demonstrating the overall potential of this method.

References: [1] R. Geiger et al, AVS Quantum Sci. 2, 024702 (2020) ; [2] R. Gautier et al, Science Advances (2022) ; [3] L. Sidorenkov et al, Phys. Rev. Lett. 125, 213201 (2020) ; [4] D. Savoie et al, Science Advances, eaau7948 (2018);

Key words: atom interferometry, quantum sensor, cold atoms.

Required skills: optics and lasers, instrumentation, atomic physics, basis of Python programming for experimental control and data analysis; ability to work in a team.