Application for a long-term internship (6 months or 1 year)

Realization of an optical cavity for atom interferometry

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Cold-atom inertial sensors offer several applications in fundamental physics (tests of gravitation, gravitational wave astronomy), geosciences (measurements of the Earth gravity field or rotation rate), inertial navigation, and metrology (measurement of fundamental constants). Better addressing these applications requires to constantly push further the performances of these sensors in terms of sensitivity, stability, accuracy, dynamic range, or robustness. A possible design for a compact, yet highly sensitive sensor is to interface a cold atom interferometer with an optical cavity. This internship project targets the realization and characterization of an optical cavity suited for high precision atom interferometry.

The principle of cold atomic sensors is based on the manipulation of matter waves in an interferometer, analogous to the manipulation of light waves in an optical interferometer. Beam splitters and mirrors for atomic waves are made from light pulses involving two counter-propagating lasers. During the pulses, an atom absorbs a photon of one of the two lasers and emits in a stimulated way a photon in the second laser (two-photon transition). This process is accompanied by a transfer of momentum from the light to the atom (velocities of the order of cm / s), which allows to create the arms of the atomic interferometer. The sensitivity of these devices is given by the momentum transfer between the laser fields and the atom, and increases with the number of photons exchanged. One way of improving the sensitivity therefore consists in producing so-called large momentum transfer beam splitters, which require a large coupling (i.e. large laser intensity) between the atom and the laser radiation. The sensitivity and accuracy of atomic interferometers are given by the level of homogeneity of the intensity and relative phase of the two lasers involved in the transition.

A resonant optical cavity could be used to meet the constraints of high laser intensity and good phase homogeneity, through enhancement of the intra-cavity light and interferometric control of the phase of the intracavity field. The gain brought by an optical cavity for atomic interferometry, however, requires reaching centimetric resonant beam sizes, in order to interrogate cold atomic clouds whose size are of the order of one centimeter. Obtaining such large resonant beams in a short cavity (50 cm) is a challenge.

A detailed study of an optical cavity geometry adapted to atomic interferometry has already been carried out at the SYRTE laboratory, and first experiments were conducted to validate the numerical simulations. This internship aims to continue this study. The work will be of experimental nature experimental (characterization of the optics, alignment of the cavity), with additional modeling of the cavity (notably optical simulations programmed in Python). Moreover, the stabilization scheme of the cavity will be characterized in order to assess the performance of the resonator for atom interferometry. This work will involve the stabilization and control of the length of the cavity, and the injection of two phase locked lasers in the resonator.

In the longer term, the optical cavity will be implemented on a gyroscope-accelerometer experiment of the SYRTE laboratory, which represents the state of the art of the sensitivity of inertial sensors with cold atoms.

Knowledge and skills acquired during the internship: physics of optical cavities, instrumentation in optics, simulations (Python based), optical metrology (phase lock loops, stabilization schemes, electronics).