INTERNSHIP PROPOSAL

Laboratory name: Laboratoire Temps Espace (LTE)
CNRS identification code: UMR8255
Internship director' surname: Pereira dos Santos / Sidorenkov
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Internship location: Observatoire de Paris, 61 avenue de l'Observatoire 75014 Paris
Thesis possibility after internship: YES
Funding: NO

Large momentum transfer for differential quantum gravimetry

Context:

A significant improvement in the sensitivity of ***atomic inertial sensors*** is linked to the deployment of architectures based on differential measurements, such as atomic ***gradiometers*** sensing the gradient of the Earth's gravitational acceleration, that allow rejection the *common-mode vibrational and laser phase noise*. This feature enables the measurements at the quantum projection noise limit and provides an ideal testbed for exploring cutting-edge techniques (advanced atom sources, LMT beam splitting, hybridization with other sensors, etc.) to boost sensitivity and accuracy. Moreover, the ***simultaneous access to*** $\boldsymbol{g}$ ***and*** $\boldsymbol{\nabla g}$ values discriminates the position and the mass of the gravitational source, opening intriguing perspectives in geoscience (natural resource exploration, civil engineering) and navigation [1].

The gravi-gradiometer of LTE [2] employs dual cold-atom source and a sensitive three-pulse (Mach-Zehnder like) interferometric sequence. The atom-optics elements (beam-splitters and mirrors) are implemented using short pulses of counter-propagating laser beams that Bragg-diffract the atomic wave packets. Ongoing work explores methods of quantum optimal control to enhance the efficiency of low-order ($n \leq 3$, $2n\hbar k$ photon transfer) ***multi-photon Bragg diffraction*** in combination with advanced optical beam shaping.

Internship project:

To increase the separation of atomic wave packets - and thus interferometric area and sensitivity - we have recently developed a new higher-power laser system (fiber lasers and amplifiers, frequency-doubling stages, optical components and electronics for laser frequency, phase and power control) that should allow addressing $n > 3$ LMT transitions. The specific tasks of the internship will include:

- Improving the long-term stability of the new laser system and validating its performance via gravity gradient measurements in a conventional Bragg interferometer ($2\hbar k$ atom optics)
- Demonstrating LMT atom optics of $n > 3$ diffraction orders

The intern will perform experimental work requiring a good understanding of optics, laser physics, atom-light interaction and atomic physics, as well as scientific rigor and methodology. The skills in basic lab instrumentation, electronics, data analysis and physical modelling are a plus. The intern will join a team of three permanent researchers, postdoc and two PhD students, starting in spring 2026 for a period of up to 6 months, potentially followed by the PhD-thesis. The presentation of results at an internal group meeting is expected at the end of the internship.

[1] R. Caldani, et al., PRA **99**, 033601 (2019), R. Piccon, et al., PRA **106**, 013303 (2022)
[2] R. Geiger et al., AVS Quantum Sci. **2**, 024702 (2020)

Condensed Matter Physics: NO Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: NO