M1 internship : Large momentum transfer for ultrasensitive quantum gravimetry

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Key words: atom interferometry, inertial sensor, cold atoms, gradiometry, large momentum transfer (LMT)

Skills required: laser and atomic physics, instrumentation, data analysis

Summary: The Atom Interferometry and Inertial Sensors group (IACI) of SYRTE offers a M1 internship dedicated to development of habilitating technologies for quantum inertial sensors. The intern will implement a high-power laser system for large momentum transfer (LMT) atomic beam splitters, to demonstrate an enhanced sensitivity of atomic gravi-gradiometer.

Research project: A significant improvement in the performance of atomic inertial sensors is linked to the development of novel sensor architectures and enabling technologies. We are carrying on a new project of an *atomic gradiometer* sensing the gradient of the Earth gravity acceleration [1]. Differential signal is *free of common-mode vibrational and laser noise*, which provides a perfect platform for exploring cutting-edge techniques (atom chips, LMT beam splitting, hybridization with other sensors, etc.) to reach an unprecedented level of sensitivity, better than 1 Eötvös (=10^{-9} s^{-2}) at 1 s measurement time on the ground. Combined with an ability to discriminate the position and the mass of the gravitational source, allowed by a simultaneous access to g and ∇g, such sensors open intriguing perspectives for applications in geoscience both on the ground (natural resources exploration, $C0_2$ storage) and in space (Earth gravity field mapping), as well as for the tests of fundamental physics and inertial navigation [2].

Internship project: The gravi-gradiometer of SYRTE (see Figure, right) is operational close to the state-of-the-art, with validated key subsystems including dual cold atom source preparation, launching in the atomic fountain geometry, three-pulse (Mach-Zehnder like) interferometric sequence and atomic state detection. The ongoing work explores the benefits of low-order ($n \leq 3$, $2n\hbar k$ photon transfer) multi-photon Bragg diffraction pulses (see Figure, left) enhanced with quantum optimal control methods, for precision gravimetry.

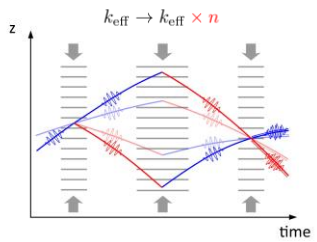
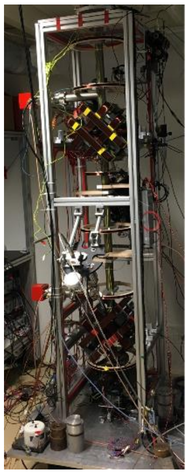


Figure: Scheme of the n-fold enhancement of interferometric area via LMT atomic beam splitter (left) and photo of laboratory atomic gravi-gradiometer of SYRTE (right)



The specific tasks of the internship will include:

- finalizing a new high-power laser system (fiber lasers, amplifiers, active and passive components, associated electronics for laser frequency and phase and power control) for LMT atom optics of $n \gg 3$
- validating the laser system via gravity gradient measurements in a Bragg interferometer with an optimized / improved sensitivity

The internship will consist of mainly experimental work and, optionally, physical simulation and modelling. An internal report and / or presentation of the results is expected at the end of the internship.

Application details: The intern will join a dynamic team consisting of three permanent researchers and three PhD students. The starting date is between February and April of 2025, and the internship duration can be up to 6 months (depending on specific Master program). Our group commits to the equal opportunities policy and, in particular, encourages the application of women candidates. To apply, the interested candidate should email indicated contact researchers.

[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)