INTERNSHIP PROPOSAL

Laboratory name: SYRTE
CNRS identification code: UMR 8630
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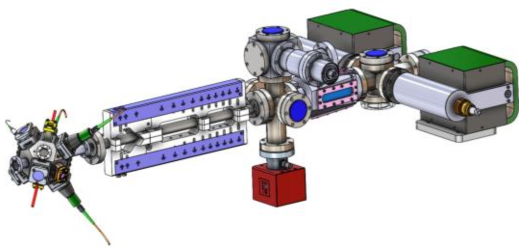
Internship location: SYRTE, Paris Observatory, 77, Avenue Denfert-Rochereau, 75014 Paris
Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: European

Ultrafast trapping of cold Yb atoms in a transportable optical lattice clock

The frequency of optical lattice clocks - based on the probing of the ultranarrow transition $^1S_0 \rightarrow {}^3P_0$ of ~ 10^4 neutral atoms trapped in a "magic" optical lattice - can now be controlled at the 18 digits level. This makes them the most accurate instruments ever built, which opens the possibility of applying this capacity to new fields of science: tests of General Relativity (Lorenz invariance, possible drift of fundamental constants), quest for dark matter, or sensing of the geopotential (chronometric geodesy). In this perspective, SYRTE (Observatoire de Paris) is developing the **transportable optical lattice clock** ROYMAGE, based on neutral Ytterbium, with the prospect of improving the cartography of the Earth gravitational potential, which is sensed by the atoms via gravitational time dilation.



Our team has built the core of a vacuum system aiming at ultrafast lattice trapping of Yb atoms (>10^4 atoms in a few 10 ms) in order to considerably increase the stability of the instrument. To this end, we built bricks making use of multiple atomic physics techniques: optical molasses (adapted to transverse speeds up to 18 m/s), Zeeman slower made of permanent magnets (able to slow atoms down to <20 m/s), and a multi-access aluminum science chamber to host a dual 399/556 nm 3D-MOT (Magneto-Optical Trap). The next step is the construction of the optical lattice and the design of ultrafast atom trapping strategies.

To this end, the **M2 applicant** will work on the different aspects of the lattice trapping:

• He/She will work on the **construction of the 'magic' optical lattice (759 nm)**, formed in a build-up Fabry-Perot cavity (finesse~200), and able to reach depths close to 1000 recoil energies. The work will consist in designing and mounting the optical bench to couple light into this cavity, to test the dynamics of the cavity under vacuum and to lock it to the 759 nm laser so as to remain at resonance. The total intracavity noise will be measured to assess the expected lifetime of trapped atoms.

• He/She will simulate and design an **original 2D-MOT at 399 nm in order to 'funnel' the atoms** towards the aforementioned lattice trap. The first step will consist in a theoretical study of the various possibilities to guide cold atoms in order to ensure that they can eventually reach the lattice. The second step will be based on numerical/Monte-Carlo simulations so as to derive atomic trajectories in the system given realistic initial conditions in terms of speed/position/divergence. Experimental implementation of the 2D-MOT resulting from this design is expected to take place by summer 2024.

Techniques: atomic spectroscopy, optics (@ 399 nm/556 nm/578 nm /759 nm), theoretical description of light-matter interaction, data analysis, numerical simulations, electronics, vacuum

Size of the team: 6 people (2 staff researchers, 1 Post-doc, 2 Phd Students and a M1 student)

Complete thesis description on the home page: **https://roymageanr.obspm.fr/**

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

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