SYRTE l'Observatoire de Paris | PSL
SYstèmes de Référence Temps-Espace
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Director: Arnaud Landragin

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

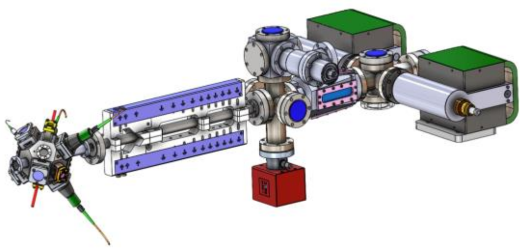
Keywords: Optical clocks, cold atoms, optical lattice trapping, gravitational time dilation

Website of the project: https://roymageanr.obspm.fr/

Scientific description:

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. The device will be connected to the large scale infrastructure REFIMEVE (optical fiber network disseminating an ultrastable reference at 1542 nm), in order to enable remote frequency comparisons with the ~ 12 stationary European optical clocks. This raises the prospect of improving the cartography of the Earth gravitational potential, which is sensed by the atoms via gravitational time dilation.

Our team has designed and assembled the core of the vacuum system Ytterbium-1 aiming at ultrafast lattice trapping of ytterbium atoms: we target >10^4 atoms in a few 10 ms. This will considerably increase the stability of the instrument and will allow us to reach unprecedented statistical resolutions. 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 aluminium science chamber to host a dual 399/556 nm 3D-MOT (Magneto-Optical Trap). The next step of the project is the construction of the optical lattice and the design of strategies to enable the ultrafast trapping of atoms.



Heart of the Ytterbium-1 system at SYRTE

Internship:

To reach this objective, the applicant will have the opportunity to work on several aspects of the development of the project.

- He/She will work on the construction of the optical lattice at 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 amplitude noise of the intracavity light will be measured, in order to assess the expected lifetime of atoms once they will be trapped.

- 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/methods in use:

The applicant will directly use the following techniques:

- optics (free space and fibers), manipulation of laser light at multiple wavelengths (399 nm, 556 nm, 759 nm, possibly 578 nm),
- atomic spectroscopy,
- data analysis,
- theoretical description of the light-matter interaction,
- numerical simulations

The applicant will also be familiarized (with support from specialists) to:

- the use of electronic modules to control the many laboratory instruments,
- ultra-high vacuum system assemblies (<10^{-10} mbars)

Applicant skills:

The candidate must have an advanced knowledge in quantum/atomic Physics, if possible with basis in atom cooling. A strong interest in experimental work, lasers, electronics and Python programming is absolutely necessary.

He/She will work in an international team of about 6 people (2 staff researchers, 1 Post-doc, 2 Phd Students and a M1 student). A good team spirit, as well as communication skills in English, are therefore mandatory.

Industrial partnership: No

Internship supervisor:

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Internship location:

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Possibility for a Doctoral thesis: Yes (the PhD thesis will be the extension of this Master thesis proposal)