Sciences Sorbonne Université
PSL Université Paris

# Master thesis proposal

SYRTE l'Observatoire de Paris | PSL
SYstèmes de Référence Temps-Espace

*SYRTE, Observatoire de Paris,*
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*75014 Paris*
*Director: Arnaud Landragin*

**Title**: Moving 399 nm molasses of cold Yb for a transportable optical lattice clock

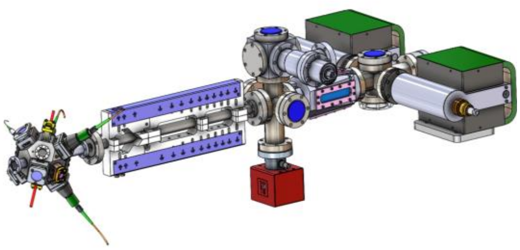
**Keywords**: Optical clocks, cold atoms, optical lattice trapping, gravitational time dilation

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

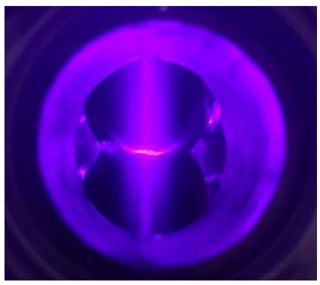
**Scientific description/Status**:

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 two apparatus aiming at ultrasfast atom loading so as to increase the stability of the clock. Yb-1 (ROYMAGE) is notably based on an optical molasses (adapted to transverse speeds up to 18 m/s), a permanent magnets-based Zeeman slower (able to slow atoms down to <20 m/s), an ongoing 2D-MOT (Magneto-Optical Trap) project and a Science chamber where 3D-MOT (399 nm and 556 nm) and magic trapping (759 nm) will be realized. Yb-2 (RAZPOUTYNE) is based on a very promising approach that lead to obtaining a high flux 2D-MOT in summer 2024.



*Heart of the ROYMAGE system at SYRTE*



*2D-MOT in the RAZPOUTYNE apparatus*

**Internship:**

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

- **Atomic Physics**: He/She will work on the simulation and the design of a **moving molasses** (MM) aiming at pushing a 399 nm 2D-MOT towards a 556 nm 3D-MOT, so as to capture as many cold atoms as possible (target: several $10^9$ atoms/s). The first step is to find a configuration enabling velocities as low as a few cm/s, while preventing the travelling cloud from expanding in the transverse directions. The second step will be the design of the mechanical system to implement this technique in the atomic loader RAZPOUTYNE. Experimental implementation of the MM resulting from this design is expected to take place in summer 2025.

- Laser Physics: He/She will build an enhancement cavity to **frequency-double 798 nm light into 399 nm light**, in order to equip the clock with a compact, reliable source of blue photons. The first step will be the calculation of the geometry necessary to form a butterfly cavity around an LBO non-linear crystal. The second step will be the mounting of the cavity itself, with the aim of making it suitable to continuous operation.

**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 5 people (2 staff researchers, 3 Phd Students). 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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Metro/RER: Denfert-Rochereau

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