

Title: A new source at 578 nm for clock interrogation and shelving of Yb atoms

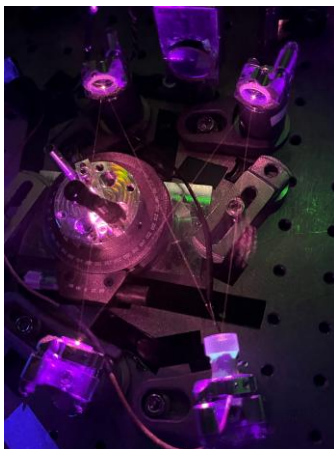
Keywords: Optical clocks, cold atoms, optical lattice trapping, gravitational time dilation

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

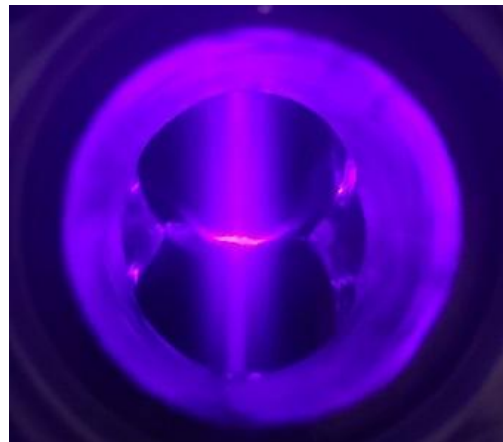
Scientific description/Status:

The frequency of optical lattice clocks - based on the probing of the ultranarrow transition $^1S_0 \rightarrow ^3P_0$ of $\sim 10^4$ 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 (Lorentz invariance, possible drift of fundamental constants), quest for dark matter, or sensing of the geopotential (chronometric geodesy). In this perspective, LTE (Laboratoire Temps-Espace) 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 probed by the atoms through gravitational time dilation.

Our team has designed and assembled two instruments 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), and 3D MOTs (Magneto-Optical Traps) at 399 nm and 556 nm. This architecture will be soon complemented by a 2D-MOT (399 nm) and a magic-wavelength optical lattice (759 nm). Yb-2 (RAZPOUTYNE) is based on a very promising approach that lead to obtaining a high flux 2D-MOT.



Butterfly cavity generating $\sim 1W$ at 399 nm



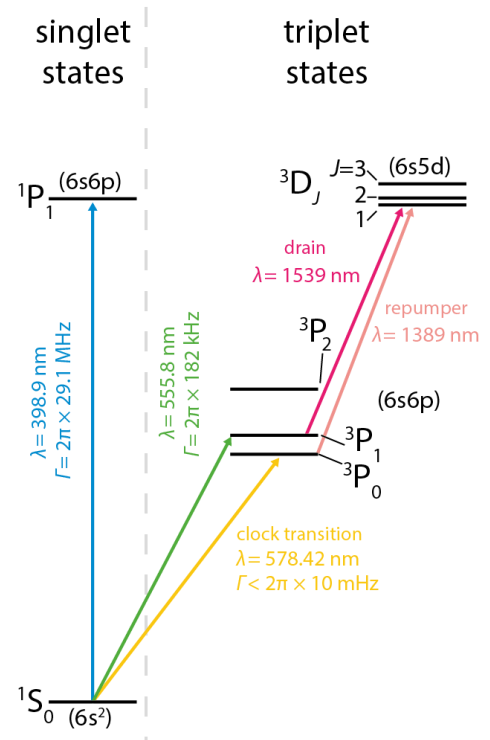
2D-MOT in the RAZPOUTYNE apparatus

Internship:

The applicant will have the opportunity to work on two aspects of the development of the project (to be discussed with the candidates):

- **Atomic Physics:** He/She will work on the simulation and the design of an atomic drain, a technique developed at LTE to shelve atoms in the metastable states in order to decouple the dynamics of the 3D-MOT from the loading of the optical lattice. The first step is a Monte Carlo simulation to evaluate the dynamics of the draining process. The second step aims at locking the two necessary lasers (556 nm and 1539 nm) to the correct frequencies, and at demonstrating the transfer towards the metastable states, either in a 399 nm MOT, or in a 759 nm lattice.

- **Laser Physics:** He/She will build an enhancement cavity to **frequency-double 1156 nm light into 578 nm light**, in order to equip the clock with a compact, reliable source of yellow photons to probe the clock transition. The first step will be the calculation of the geometry necessary to form a butterfly cavity around a PPLN non-linear crystal. The second step will be the mounting of the cavity itself, aiming at 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, 578 nm, 759 nm, 1539 nm),
- atomic spectroscopy,
- data analysis,
- theoretical description of the light-matter interactions,
- 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 ($<10^{-9}$ 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, 1 guest researcher and 2 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:

LTE (Laboratoire Temps-Espace), UMR 8255, Observatoire de Paris

77, Avenue Denfert-Rochereau, 75014 Paris

Metro/RER: Denfert-Rochereau

Possibility for a Doctoral thesis: Yes (the PhD thesis will be the extension of this Master thesis proposal), the funding is already partly secured.