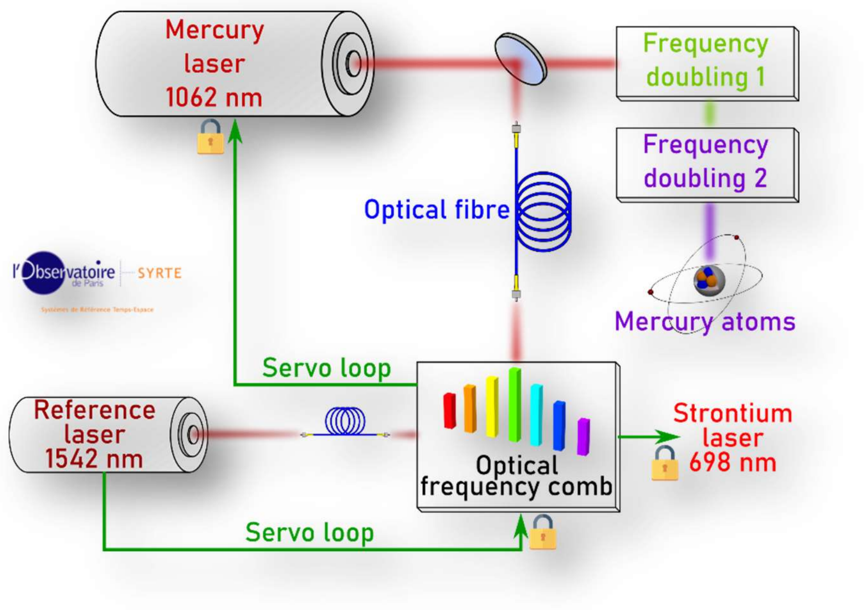
Masters 2 internship proposal

Spectral purity transfer between Mercury and Strontium optical lattice atomic clocks

Aim of the proposed internship

Establishing a stable and precise frequency (or time) reference is of paramount importance in several domains, for fundamental physics (tests of special or general relativity, physics beyond the standard model) but also for applications including maintaining the international coordinated time (UTC), realising navigation systems such as Galileo or GPS, or chronometric geodesy [1]. Within that context, our Mercury optical lattice clock [2] benefits from the well-controlled properties of light-atom interactions to allow for the realisation of ultra-precise frequency measurements (with relative uncertainties as low as a few 10^{-17} !).



These ultra-precise measurements rely on extremely stable oscillators to act as a reference, such as high-finesse Fabry-Perot cavities. Other techniques have also emerged to generate ultra-stable references, such as spectral hole burning [3]. However, most of these oscillators can only be used at a specific wavelength; therefore, there has been growing interest in realising "spectral purity transfer" [4] in order to transfer the exquisite stability properties of an oscillator to a different wavelength. In this context, the SYRTE laboratory organises spectral purity transfer tests between the Mercury and Strontium 87 optical lattice clocks [5], which operate at very different wavelengths (1062 nm and 698 nm, respectively), through an optical frequency comb.

The successful candidate will get acquainted with the spectral purity transfer technique, and notably the associated experimental setup which contains an intertwined chain of elements (optical and electronic), including servo systems – see Figure above. They will carefully consider and measure each possible source of noise or fluctuations, and implement them into a numerical model. This model will aim to evaluate the impact of the noise sources on the direct comparison between the Mercury and Strontium optical lattice clocks using the spectral purity transfer technique. Finally, the model will help optimise the impact of the new generation of ultra-stable laser systems on the experiment.

Candidate profile

The candidate should have a background in atomic physics and quantum physics. Previous experimental work in electronics and optics, as well as strong interest for numerical simulations and data analysis, will be highly appreciated.

Host institution

The internship will take place in the Optical Frequencies group at SYRTE, Observatoire de Paris (entrance located at 77 avenue Denfert-Rochereau, 75014 Paris).

Contact details

Please contact Dr Manuel Andia (manuel.andia@obspm.fr) for any enquiries.

References

[1] S. Bize, “The unit of time: Present and future directions,” Comptes Rendus Physique, 20, 153-168 (2019).

[2] R. Tyumenev et al., “Comparing a mercury optical lattice clock with microwave and optical frequency standards”, New Journal of Physics, 18, 113002 (2016).

[3] M. J. Thorpe et al., “Frequency stabilization to 6×10^{-16} via spectral-hole burning”, Nature Photonics, 5, 688-693 (2011).

[4] D. Nicolodi et al., “Spectral purity transfer between optical wavelengths at the 10^{-18} level”, Nature Photonics, 8, 219-223 (2014).

[5] G. Vallet et al., “A noise-immune cavity-assisted non-destructive detection for an optical lattice clock in the quantum regime”, New Journal of Physics, 19, 083002 (2017).