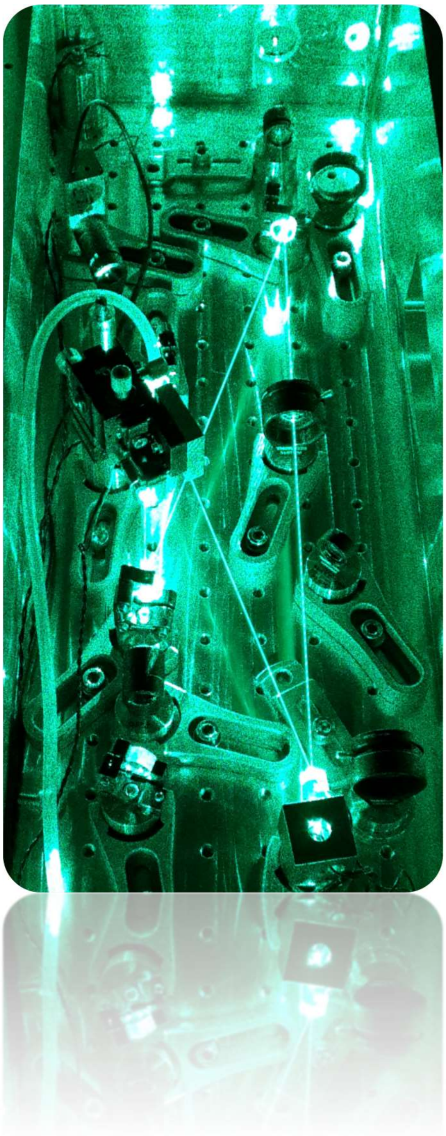
Masters 2 internship proposal

Improved cold atom source for a Mercury optical lattice atomic clock

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} !). However, one of the main experimental challenges for the Mercury atom stems from the deep-UV wavelengths required to manipulate the atom, notably for optical cooling (254 nm).

In order to increase the precision and reliability of our measurement, we wish to improve the 3D magneto-optical trapping (3D-MOT) stage that produces ultra-cold Mercury atoms. In particular, the Barium Borate (BBO) crystal currently used in the generation of light at 254 nm has limited efficiency, which results in poor levels of usable optical power for cooling the atoms. The Caesium Lithium Borate (CLBO) crystal has recently emerged as an efficient and reliable medium for the generation of UV at similar wavelengths [3], and should prove a good candidate for replacing the current BBO crystal in our setup. In addition, a more efficient and reliable source of cold atoms will enable the first-ever experimental interrogation of the clock transition of a bosonic Mercury isotope, which could represent a significant step towards the participation of the Mercury optical lattice clock in the upcoming redefinition of the SI second.

The successful candidate will join this effort by realising a new system for optical frequency doubling based on a CLBO crystal placed in an optical cavity. This will require getting acquainted with the intrinsic mechanisms of atom-light interactions to understand the implications of such a system on our experiment, but also realising numerical simulations to estimate the expected doubling efficiency, with considerations about the output beam intensity and profile. Finally, they will confront the resulting system to cold Mercury atoms in the actual conditions of the experiment, and assess the resulting gain in performance of the Mercury optical lattice clock.

Candidate profile

The candidate should have a background in atomic physics and quantum physics, and should be strongly interested in experimental physics. Previous experimental work in optics will be greatly 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] Z. Burkley et al., “Highly coherent, watt-level deep-UV radiation via a frequency-quadrupled Yb-fiber laser system,” Appl. Opt. 58, 1657-1661 (2019).