Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

Laboratory name: SYRTE (Systèmes de Référence Temps-Espace)
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Internship location: Observatoire de Paris, 77, avenue Denfert Rochereau, 75014 Paris

Thesis possibility after internship: YES
Funding: to be defined If YES, which type of funding:

Improved cold atom source for a Mercury optical lattice atomic clock

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.

[1] S. Bize, C. R. Physique, 20, 153 (2019).
[2] R. Tyumenev et al., New Journal of Physics, 18, 113002 (2016).
[3] Z. Burkley et al., Appl. Opt. 58, 1657-1661 (2019).

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: NO