Post-doc fellowship in Paris (LNE-SYRTE/Observatoire de Paris) on

Spectral Hole Burning for Quantum Metrology: from Ultra-stable Lasers to Quantum Correlations

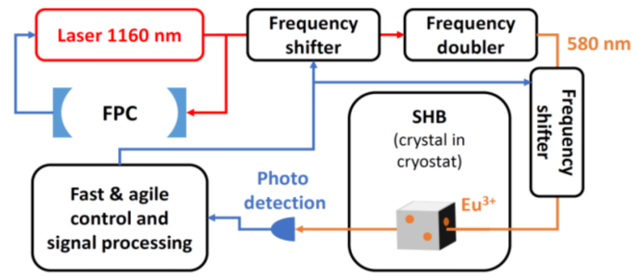
Background

Time and frequency metrology is one of the most successful fields of high accuracy measurement today. Microwave and optical frequency standards now realize accuracies in terms of fractional frequency in the 10^{-16} range, ensuring a vast variety of applications from practical day-to-day time keeping (realization of SI second, atomic international time, etc…) to the most demanding fundamental research experiments (measurement of the drift of fundamental constants, tests of relativity, detection of gravitational waves, …). The future of time and frequency metrology lies in the optical domain: the second, the unit of time will soon (~2026) be defined via an optical transition in atoms; optical clocks around the world have reported unprecedented performance in both stability and accuracy; and optical fiber networks provide means of comparing distant clocks and disseminating frequency and time.

Yet, as of today, the lack of ultra-stable lasers with sufficient performance to probe the atomic transitions without degradation hampers the search for ultimate performance. In short, the cold atom lattice clock devices could exhibit stability limited by their quantum projection noise if the interrogation lasers were to be substantially better than this limit. The lasers currently in use are based on stabilization to an ultra-stable Fabry-Perot Cavity (FPC) in extremely well controlled environment. Unfortunately, these systems are reaching their fundamental limits (due to thermodynamic noise at 300 K) at a few 10^{-16} stabilities, degrading the optical lattice clocks through noise aliasing. Although it is possible to fight against thermodynamic noise in Fabry-Perot cavities, the technological challenges are formidable, and we believe that a change of technological paradigm is more promising.

Project

Spectral hole burning in rare-earth ion doped crystals is a versatile system in quantum metrology. Narrow optical transitions of the dopant ions can serve as a frequency reference for laser stabilization. The presence of a large number of dopant ions not only ensures an excellent signal to noise ratio, but also provides a likely means to further reduce phase noise by exploiting classical and quantum correlations between them. The expected fractional frequency stability are thus orders of magnitude better than cavity-locked lasers at the state of the art.



At the SYRTE laboratory, an experimental setup using a $Eu^{3+}:Y_2SiO_5$ crystal has been constructed and the first demonstration of laser stabilization yields a fractional frequency stability at a few 10^{-15} around 1 s, limited by residual temperature fluctuations of the crystal [1]. Such a performance is compatible with that reported by NIST [2], whereas the technical noise floor is an order of magnitude lower. Sensitivities to environmental factors such as stress field [3] and electric field [4] have also been characterized metrologically.

This post-doc project aims to improve the techniques of laser frequency stabilization, possibly down to the range of a few 10^{-18} at 1 s, and will explore the fundamental limits of such techniques, unknown for the time being. On one hand, reduction of temperature fluctuations can be achieved by laser power lock and temperature control of the cryogenic environment, or going to dilution temperatures and dramatically reduce the temperature sensitivity. On the other hand, detection noise floor can be reduced by interrogating simultaneously multiple classes of ions at different frequencies; classical and possibly quantum correlations between these classes of ions should also be explored for even better frequency stabilities.

Scope and funding

The successful applicant will participate in all aspects of the project, including but not limited to working on the experimental setup, data acquisition and analysis, supervising PhD students on the project, and coordination with other experiments in the Optical Frequencies Group (e.g. frequency combs and optical clocks) for more involved measurements, etc. He/she is expected to collaborate with various technical services within the SYRTE laboratory and with our academic and industrial partners on the national and international scale.

The position will be open from June 1st 2021 onwards. Funding for salary and travel expenses (conferences, visits and meetings) is secured for 1 year, with the possibility of renewal.

The applicant

Serious, motivated and professional. Must hold a PhD in physics. Extensive experience in experimental physics (e.g. optics, electronics and programming) is required (typically from a PhD degree in relevant topics). Basic knowledge in quantum physics (quantum mechanics and atomic physics) is useful, but not a strict requirement. Given the collaborative nature and international context of the work, good technical English and capability of communication are a must.

Application

Interested candidates should apply online via the CNRS portal. This offer can be found at https://emploi.cnrs.fr/Offres/CDD/UMR8630-BESFAN-001/Default.aspx?lang=EN. A CV and a motivation letter are required in order to deposit a valid application. Interviews will be arranged once the documents are examined.

References

[1] N. Galland *et al*, *Optics Letters **45** 1930 (2020)*.
[2] S. Cook *et al*, *Phys. Rev. Lett. **114** 253902 (2015)*.
[3] N. Galland *et al*, *Phys. Rev. Applied **13** 044022 (2020)*; S. Zhang *et al*, *Phys. Rev. Research **2** 013306 (2020)*.
[4] S. Zhang *et al*, *Appl. Phys. Lett. **117** 221102 (2020)*.