Post: **PhD student position in Experimental Molecular Physics**
Location: Laboratoire de Physique des Lasers (LPL), CNRS-Univ Sorbonne Paris Nord, Villetaneuse, France
Team: Metrology, Molecules and Fundamental Tests (MMFT)
Advisors: Dr Benoît Darquié (benoit.darquie@univ-paris13.fr), Pr Anne Amy-Klein (amy@univ-paris13.fr)
Contract: Fixed Term, 36 months, **grant already secured**, starting: 01/10/2021

Frequency metrology and fundamental sciences with cold molecules

A PhD student position is available to develop new-generation molecular clocks specifically designed for precision vibrational spectroscopy of cold molecules in the gas phase. The proposed technology is at the forefront of cold molecule research and frequency metrology, and opens possibilities for using polyatomic molecules to perform tests of fundamental physics and explore the limits of the standard model, but also to address questions in astrophysics and atmospheric physics. This PhD is funded in the frame of the joint research project Infrared frequency metrology between LPL and the Centre of Cold Matter (CCM, Imperial College London) led by Mike Tarbutt.

Molecular systems, owing to their numerous degrees of freedom, offer promising perspectives for improving tests of fundamental physics and precision measurements in general. Molecules are increasingly being used internationally for instance to test fundamental symmetries[1], to measure fundamental constants[2] or their variation in time[3], to search for dark matter[4], … Many of these experiments can be cast as measurements of resonance frequencies of molecular transitions highlighting the importance of frequency metrology. They require advanced manipulation techniques already standard for atoms: individual states addressing, high detection rates, long coherence times, cooling of internal and external degrees of freedom.

Among recent instrumental advances, the stabilization of quantum cascade lasers (QCLs) on commercial optical frequency combs with traceability to some of the world's best atomic clocks, a method recently implemented in our team, is a breakthrough technology. It offers an unprecedented level of precision and resolution in the mid-infrared (~10µm). The successful applicant will be responsible for (i) extending the spectral coverage of the method to the 6-17µm window and improving its spectral resolution, tunability, detection sensitivity and flexibility; (ii) developing an intense source of cold and slow polyatomic molecules, produced in a cryogenic chamber, called a buffer-gas-cooled beam, one of the latest cold molecule technology, so far mostly implemented on simple species; and (iii) bringing these two technologies together for conducting precise mid-infrared frequency measurements on large molecules. The apparatus will be used in the first place for measuring the electroweak-interactions-induced tiny energy difference between enantiomers of well-chosen organo-metallic chiral molecules, a signature of parity (left-right symmetry) violation, and a sensitive probe of dark matter. It will also be used for spectroscopy at unprecedented levels of accuracy of increasingly complex species of interest for astrophysics and Earth sciences.

The PhD student will also participate in developing an SI traceable and ultra-stable 17µm QCL system for use at CCM for probing vibrational transitions in trapped, laser-cooled ultracold calcium monofluoride (CaF)[5]. She/he will have the opportunity to work there and participate in establishing the usefulness of this platform as a mid-infrared frequency standard and as tool to test the hypothesis that fundamental constants of nature may be drifting or oscillating in time.

The PhD will be carried out in the frame of Excellence French programs EquipEx REFIMEVE+ and LabEx FIRST-TF allowing the applicant to fully integrate with the time-frequency metrology community in France and beyond.

[1]Andreev *et al*, Nature **562**, 355 (2018). [2]Alighanbari *et al*, Nature **581**, 152 (2020). [3]Bagdonaite *et al*, Science **339**, 46 (2013). [4]Gaul et al, Phys. Rev. Lett. **125**, 123004 (2020). [5] Truppe *et al*, Nature Phys. **13**, 1173 (2017).

Keywords: frequency metrology, Ramsey interferometry, Doppler-free methods, precision measurements, parity violation, chiral molecules, molecular beams, buffer-gas cooling, cold molecules, frequency comb lasers, quantum cascade lasers, molecular physics, quantum physics, optics & lasers, vacuum, electronics, programming & simulation

Relevant publications:
Santagata *et al*, Optica **6**, 411 (2019); Cournol *et al*, Quantum Electron. **49**, 288 (2019) ; Tokunaga *et al*, New J. Phys. **19**, 053006 (2017), arXiv:1607.08741 ; Argence *et al*, Nature Photon. **9**, 456 (2015), arXiv:1412.2207

Requirements: The applicant should have an (almost) completed master degree in a relevant area of experimental physics or chemical physics: atomic, molecular and optical physics, spectroscopy, lasers, quantum optics.

Interested applicants should email a CV, a brief description of research interests and the contact details of 2 referents to B. Darquié (benoit.darquie@univ-paris13.fr).