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)
Supervisor: Pr Anne Amy-Klein (amy@univ-paris13.fr)
Co-supervisor: Dr Benoît Darquié (benoit.darquie@univ-paris13.fr),
Contract: Fixed Term, 36 months, starting in autumn 2022

Precision Measurements and tests of fundamental physics with cold molecules

A PhD student position is available to develop a new-generation molecular clock 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. The apparatus will be used in the first place for measuring the electroweak-interactions-induced tiny energy difference between enantiomers of a chiral molecule, a signature of parity (left-right symmetry) violation, and a sensitive probe of dark matter.

Compared to atoms, 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 also 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.

The successful applicant will take an active role in various aspects of the development of the experiment which constitute major steps in providing such techniques for molecules. She/he will participate in:
- the development of a novel cold molecule apparatus, an intense source of cold and slow polyatomic molecules, produced in a ~1 K cryogenic chamber, called a buffer-gas-cooled beam, one of the latest cold molecule technology, so far mostly implemented on simple species;
- the implementation of a high-sensitivity microwave detector, for the detection of individual internal quantum states populations of cold molecules;
- setting up mid-infrared systems based on high-purity quantum cascade lasers (QCLs) calibrated against primary frequency standards;
- developing advanced manipulation techniques combining ultra-stable RF, microwave and optical fields to obtain individual state addressing, high detection rates, long coherence times, cooling of various degrees of freedom…
- conducting precision spectroscopy on well-chosen promising species (chiral organo-metallics, polycyclic aromatic hydrocarbons…) produced in the cold molecule apparatus using saturated absorption spectroscopy and Ramsey interferometry, the same quantum optics method as used in the world's best atomic clocks.

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).

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 from the team: Fiechter *et al*, arXiv:2111.05036 (2021); 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 be doing its master in a relevant area of experimental physics or chemical physics: atomic, molecular and optical physics, spectroscopy, lasers, quantum optics. He/She will be expected to display the initiative and creativity, with the appropriate skills and knowledge, required to meet the project goals.

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).