Institute: Laboratoire de Physique des Lasers (http://www-lpl.univ-paris13.fr/UK)

Head of Institute: Olivier Gorceix

Address: 99 avenue J.-B. Clément 93430 Villetaneuse

Internship supervisor: Benoît Darquié

Telephon: +33(0)1 49 40 33 92

e-mail: benoit.darquie@univ-paris13.fr

Internship Title

Precision Measurements and tests of fundamental physics with cold molecules

Summary:

An internship position is available to pursue experimental research in the field of precise spectroscopic measurements with cold molecules in the gas phase. The project is focused on the development of a new-generation molecular clock specifically designed for precision vibrational spectroscopy (around 10 µm) of complex polyatomic molecules. 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 the measurement of the tiny energy difference between enantiomers of a chiral molecule induced by electroweak interactions, a signature of parity (left-right symmetry) violation.

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 currently used to test fundamental symmetries, measure fundamental constants or their variation in time, test postulates of quantum mechanics. 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 hyperfine states addressing, high detection rates, long coherence times, cooling of both internal and external degrees of freedom. The instrumental developments to which the student will participate constitute major steps in providing such techniques for molecules.

The student will be expected to take an active role in the operation and development of this experimental activity, depending on his taste and on the status of the project: implementation a novel slow and intense source of cold polyatomic molecules, produced in a cryogenic chamber, so-called buffer-gas-cooled molecular beam; implementation of new laser sources emitting in the mid-infrared (3-25 µm) called quantum cascade lasers (QCLs) and development of a QCLs based Ramsey interferometer calibrated against primary frequency standards; implementation of a high-sensitivity microwave detector, for the detection of individual internal quantum states populations of cold molecules; development of advanced manipulation techniques to obtain individual state addressing, high detection rates, long coherence times, cooling of various degrees of freedom, …

Relevant publications:

Tokunaga *et al*, New J. Phys. **19**, 053006 (2017), arXiv:1607.08741
Argence *et al*, Nature Photon. **9**, 456 (2015), arXiv:1412.2207
Tokunaga *et al*, Mol. Phys. **111**, 2363 (2013), arXiv:1309.5630

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 and lasers, vacuum techniques, electronics, programming and simulation

Requirements: good knowledge of basic physics, a good expertise in experimental physics (in particular in experimental optics) and/or in programming and simulation would be welcome, curiosity and creativity.

Possibility of a PhD? yes

Financial support for a PhD? team's own contract (ANR)