Post: **PhD position in Ultra-precise Mid-Infrared Molecular Spectroscopy**
Location: Laboratoire de Physique des Lasers, CNRS-Université Sorbonne Paris Nord Villetaneuse, France
Team: Metrology, Molecules and Fundamental Tests
Supervisors: Pr Anne Amy-Klein, amy@univ-paris13.fr
Co-supervisors: B Darquié, benoit.darquie@univ-paris13.fr - M Manceau, mathieu.manceau@univ-paris13.fr
Contract: Fixed Term, 36 months, starting in autumn 2025 - ***Funding already secured***

Looking for potential variations of the proton-to-electron mass ratio and other tests of fundamental physics via precision measurements with molecules

Internship Description:

The PhD student will participate in cutting-edge experiments aimed at ultra-precise measurements of rovibrational molecular transitions and dedicated to measuring/constraining the potential time variation of the proton-to-electron mass ratio (**μ**), a fundamental constant of the standard model (**SM**). Such variations, if detected, would be a signature of physics beyond the SM, providing insights into the nature of dark matter and dark energy. The idea here is to compare molecular spectra of cosmic objects with corresponding laboratory data. The experimental setup is based on quantum cascade lasers (**QCLs**) locked to optical frequency combs, with traceability to primary frequency standards, a breakthrough technology developed at Laboratoire de Physique des Lasers (**LPL**), allowing unprecedented spectroscopic precision in the mid-infrared range.

The PhD will focus on measuring mid-infrared transitions of **methanol** (**CH_3OH**), a molecule known for its enhanced sensitivity to changes in μ. The student will set up and stabilize a new QCL in a spectral region hosting particularly relevant transitions. The work will involve achieving sub-Doppler spectroscopic resolution to reach target laboratory frequency accuracies of ~100 Hz needed for **comparisons with astronomical observations**. This activity is part of the **ANR Ultiμos project**, a collaborative effort which seeks to refine current constraints on the possible variation of μ which involves leading research institutions, including **Laboratoire Kastler Brossel (LKB, L. Hilico)** and **MONARIS (C. Janssen)** at Sorbonne Université. The three partners of the Ultiμos consortium will collaborate to conduct measurements in methanol and other species such as ammonia (NH_3) in different spectral windows, to identify transitions as targets for future Earth/space comparison campaigns, which could further tighten constraints on variations of μ. Other collaborators, such as **Vrije Universiteit Amsterdam** and **Onsala Space Observatory**, will provide theoretical and observational/astronomical support to complement the experimental efforts.

The proposed laser technology is also crucial for the ongoing development at LPL of **a new-generation molecular clock** specifically designed for precision vibrational spectroscopy of **cold polyatomic molecules**. The student may therefore be involved in first precise spectroscopic measurements on cold molecules produced at ~1 K in a novel cold molecule apparatus. Combining frequency metrology and cold molecule research as the potential to bring even more stringent constraints on a drifting-μ, and opens possibilities for using polyatomic molecules to perform other fundamental tests, including the measurement of the energy difference between enantiomers of a chiral molecule, a signature of **parity (left-right symmetry) violation**, and a sensitive probe of dark matter.

Keywords: fundamental constants, standard model, precision measurements, ultra-high-resolution spectroscopy, frequency metrology, quantum cascade lasers, frequency comb lasers, cold molecules, molecular physics, quantum physics, astrophysics, optics & lasers, vacuum, electronics, programming & simulation

Relevant publications from the team: Tran *et al*, APL Photonics 9, 3, (2024); Fiechter *et al*, J Phys Chem Lett **13**, 42 (2022); Santagata *et al*, Optica **6**, 411 (2019); Cournol *et al*, Quantum Electron. **49**, 288 (2019), arXiv:1912.06054; Tokunaga *et al*, New J. Phys. **19**, 053006 (2017); Argence *et al*, Nature Photon. **9**, 456 (2015), arXiv:1412.2207.

Requirements: The ideal candidate should have a strong foundation in physics or chemical physics, particularly in areas such as spectroscopy, laser physics, molecular physics, and quantum optics. Proficiency in experimental techniques, data analysis, and computational modelling is highly desirable. Creativity, problem-solving skills, and the ability to work both independently and collaboratively in an interdisciplinary environment are also key. Interested applicants should email a CV, a brief description of research interests and the contact details of 2 referents to M. Manceau (mathieu.manceau@univ-paris13.fr) and/or B. Darquié (benoit.darquie@univ-paris13.fr).

Funding already secured. Potential applicants are also welcome to apply to a master internship position currently available in the same group on a similar subject that could constitute an ideal training for the PhD.