Post: **Master internship 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
Dr Raphaël Hahn
Dr Mathieu Manceau (mathieu.manceau@univ-paris13.fr)
Contract: 4-6 months, starting in Spring 2026

High-Sensitivity Microwave Spectroscopy for Precision Measurements and Tests of Fundamental Physics

Internship description:

The master student will join the effort at LPL to develop a new-generation compact and versatile microwave (MW) spectrometer operating over the 2–20 GHz range. This instrument is conceived both as a high-sensitivity detector of internal quantum states in polyatomic molecules and as a precision tool for molecular frequency metrology. Proof-of-principle measurements have already demonstrated free induction decay (FID) signals on the $J = 0 \rightarrow 1$ rotational transition of OCS at 12.163 GHz with outstanding signal-to-noise ratios. The MW spectrometer is now being pushed towards unprecedented performance: thanks to SI-traceable and ultrastable frequency references disseminated by the REFIMEVE network, the goal is to pinpoint MW rotational lines of molecules at the **sub-Hz level**, enabling stringent tests of molecular models and fundamental physics.

In particular, the spectrometer will enable **cross-checks between** MW **rotational frequencies and mid-infrared (MIR) rovibrational data** planned to be measured at the 100 Hz level in the frame of the ANR *Ultiμos* project. These comparisons are directly motivated by **the search for potential variations of the proton-to-electron mass ratio μ, a fundamental constant** whose stability can be tested by **confronting laboratory data with MW astronomical spectra** of molecules such as methanol and ammonia. These species possess transitions with strong sensitivity coefficients to μ, making them powerful probes of possible temporal or spatial variations of fundamental constants. In *Ultiμos*, spectroscopy with ultrastable MIR quantum cascade lasers provide ultra-precise MIR frequencies with relative uncertainties of 10^{-12}. By using combination–difference schemes, these MIR data yield effective MW intervals that can be directly confronted with our SI-traceable MW measurements. Such dual determinations, based on entirely different experimental chains and affected by distinct systematic effects, are ideal for robust cross-validation of frequency values and uncertainty budgets.

The student will participate in further developments aiming at:

- Characterizing and optimizing the MW spectrometer performance waveguide configuration.
- Preparing for a MW cavity configuration.
- Performing precision spectroscopy of benchmark molecules (OCS, methanol, ammonia).
- Preparing for double-resonance MIR–MW schemes to improve SNR in rovibrational spectroscopy.
- Preparing for integration with a cryogenic buffer-gas cooling source of cold molecules at ~3 K.

The internship will thus combine experimental molecular spectroscopy, frequency metrology, fundamental physics and advanced detection methods.

Keywords: Microwave spectroscopy, free induction decay, double resonance MIR–MW, frequency metrology, cryogenic buffer gas cooling, precision measurements, optics, 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); Cournol *et al*, Quantum Electron. **49**, 288 (2019), arXiv:1912.06054; Tokunaga *et al*, New J. Phys. **19**, 053006 (2017), arXiv:1607.08741.

Requirements: The applicant should be doing its master studies 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 M. Manceau (mathieu.manceau@univ-paris13.fr).

There is a possibility **of pursuing a PhD** within the project, with **funding already secured.**