

**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](mailto:mathieu.manceau@univ-paris13.fr))  
**Contract:** 4-6 months, starting in Spring 2027

## 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 *Ultimos* project. These comparisons are directly motivated by **the search for potential variations of the proton-to-electron mass ratio  $\mu$ , 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  $\mu$ , making them powerful probes of possible temporal or spatial variations of fundamental constants. In *Ultimos*, 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  $\sim 3$  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](mailto:mathieu.manceau@univ-paris13.fr)).

There is a possibility of **pursuing a PhD** within the project.