INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de physique des lasers
CNRS identification code: UMR 7538
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Thesis possibility after internship: YES **Funding:** YES **type of funding**: ED

Widely tunable ultra-stable and SI-traceable quantum cascade lasers for frequency metrology and mid-infrared precise spectroscopy: application to space, atmospheric and fundamental physics

Ultra-high resolution molecular spectroscopy is an interdisciplinary field with fascinating applications ranging from fundamental physics to **astrophysics, earth sciences, remote sensing, metrology and quantum technologies**. Among recent instrumental advances, the stabilization of quantum cascade lasers (QCLs) on optical frequency combs with traceability to primary frequency standards, a method recently implemented in our team, is a breakthrough technology. It offers an **unprecedented level of precision in the mid-infrared,** an essential region known as the molecular fingerprint region, which hosts a considerable number of intense vibrational signatures of molecules of various interests. This opens up prospects for carrying out fundamental physics tests and exploring the limits of the Standard Model (testing fundamental symmetries, measuring fundamental constants or their variations, searching for dark matter, etc.), and for providing precise spectroscopic data on species of astrophysical or atmospheric interest.

We have for instance recently measured rovibrational frequencies in methanol with 11-digits accuracy by carrying out saturated absorption spectroscopy in a multi-pass cell and in a Fabry-Perot cavity enhanced spectroscopy, a more than 4 orders of magnitude improvement compared to previous measurements reported in the literature.

The master student will take an **active role in various aspects of the experiment in order to improve our setup and to allow us to target more complex molecules of atmospheric, astrophysics and fundamental interest**. She/he will:

- improve our current signal-to-noise ratio and spectroscopic resolution and assess the corresponding progress;
- perform sub-Doppler measurements on methanol (CH_3OH) at record precision and identify transitions relevant for testing the variation of fundamental constants such as the proton-to-electron mass ratio;
- perform precise spectroscopic measurements on increasingly complex molecular systems of interest for atmospheric sciences (dimethyl sulphide, CH_3SCH_3), astrophysics (trioxane, $C_3H_6O_3$), and for probing the violation of fundamental symmetries (chiral organo-metallic species).

The proposed technology is at the forefront of time-frequency metrology and bring increasingly complex polyatomic molecular systems within reach of precision measurement experiments and frequency metrology.

Keywords: ultra-high resolution vibrational spectroscopy, mid-infrared, frequency metrology, Doppler-free methods, precision measurements, optical frequency comb lasers, quantum cascade lasers, molecular physics, quantum physics, optics and lasers, vacuum techniques, electronics, programming and simulation

Relevant publications from the team: Cahuzac et al, European Frequency and Time Forum 2022, hal-03861460; Fiechter et al, J Phys Chem Lett 13, 42 (2022); Santagata et al, Optica 6, 411 (2019); Argence et al, Nature Photon. 9, 456 (2015).

Condensed Matter Physics: NO Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: NO