Laboratoire: Laboratoire de Physique des Lasers (LPL), UMR 7538.
PhD Thesis: ***Spectroscopy of molecular gases confined in thin cells: Molecules interacting with surfaces***
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Group: The SAI (Spectroscopie Atomique aux Interfaces) group is widely recognized for optical measurements of the atom-surface interaction by vapor cell spectroscopy and has a wide network of collaborations, exchanging research visits with Germany, Uruguay, Singapore, Brazil and Japan. The group's work and collaborations are currently funded by an ANR-DFG projet ('SQUAT'), a French-German bilateral PROCOPE program and an International French-Uruguayan Laboratory (LIA).

Scientific Background:
Macroscopic surfaces modify the fluctuations of the electromagnetic field in vacuum giving rise to interactions between atoms or molecules and macroscopic objects. The interaction of atoms and molecules with dielectric surfaces, known as the Casimir-Polder interaction, is a fundamental problem of quantum electrodynamics and nanophotonics with implications in metrology, precision measurements and our understanding of the electromagnetic properties of matter and quantum vacuum.

The SAI group has developed selective reflection and thin vapor cell spectroscopy as techniques to probe Casimir-Polder interactions between dielectric surfaces and excited atoms in the nanometric range (typically ~100nm). The group has studied the coupling of atoms with surface polariton waves and demonstrated the near field temperature dependence of Casimir-Polder interactions. More recently, we have also demonstrated the possibility of using the above techniques (selective reflection and thin-cell spectroscopy) to probe molecular gases close to dielectric surfaces.

Research project:
Molecule-surface interactions are of fundamental interest due to the complex molecular geometry. Theoretical studies suggest that molecule-surface interactions depend on molecular orientation and chirality but experimental studies remain so far scarce. The goal of our project is to perform Casimir-Polder spectroscopy in thin-cells of nanometric thickness (~100nm) filled with molecular gas (NH_3, SF_6, OCS). In these extreme confinement conditions, the molecular energy levels will be significantly shifted due to the Casimir-Polder interaction with the cell windows. Using quantum cascade lasers we will perform rovibrational transmission spectroscopy of the confined molecular gases. Comparing the experimentally obtained spectra to a theoretical model will allow us to measure the Casimir-Polder, molecule-surface interaction.

Compact frequency references: Molecular rovibrational spectroscopy provides frequency standards based on molecular transitions that span from near to mid or far-infrared wavelengths, including the telecommunication window covered by C_2H_2 and HCN rovibrations. The goal of our project is to fabricate compact molecular frequency references using thin-cells of thickness smaller than the excitation wavelength λ (thickness of $\lambda/2$). The strong confinement of the molecular gas inside such cells leads to high-resolution (sub-Doppler) linear spectroscopy, a phenomenon known as the Dicke-narrowing effect. This will reduce the size and simplify frequency-reference set-ups that are currently based on nonlinear spectroscopy inside voluminous cells.

Group publications: J.C de Aquinho Carvalho et al. *J. Phys. B: At. Mol. Opt.* (2021), Laliotis et al., *Nat. Commun* (2014), E.A Chan et al., *Sci. Adv.*, 4: eaao4223 (2018), J. C de Aquino Carvalho et al., *Phys Rev A* (2018).