Contrat doctoral – ED Galilée

Titre du sujet : Precision spectroscopy of Casimir-Polder molecule-surface interactions

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- Discipline : Physique
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- Domaine de recherche : Physique quantique expérimentale et spectroscopie laser.
- Mots clés : Interactions Casimir-Polder molécule-surface, physique atomique et moléculaire, tests expérimentaux de l'électrodynamique quantique, spectroscopie moléculaire, optique et lasers.

Thin cells of nanometric thickness filled with atomic vapors represent simple platforms that interface atoms with the solid state and can easily be integrated with photonic devices. These platforms can be used for fundamental measurements but are also promising in the emerging field of quantum technologies. In particular, thin cells have been used as single photon sources, exploiting collective effects between Rydberg atoms and as efficient magnetic field or electric field sensors. Nevertheless, placing quantum emitters in proximity to solid surfaces requires good knowledge of the fundamental Casimir-Polder (CP) interactions, due to the existence of quantum fluctuations of the electromagnetic field in the vacuum. CP interactions become significant at nanometric distances, with an energy that depends on the inverse cube of the distance.

The SAI group specializes in the spectroscopy of atoms confined inside nanocells (typical thickness between 50-1000 nm) and has already developed thin cell spectroscopy as a major technique for probing CP interactions with excited or even highly excited atoms. Since 2017 the group has turned its attention to molecules demonstrating thin-cell rovibrational spectroscopy of confined gases in the near and mid infrared [G. Garcia Arellano et al. Nat. Commun. (2024)]. However, these experiments probed molecules in the micrometric regime, where CP interactions are small.

To explore Casimir-Polder interactions with molecules the group has fabricated nanocells (with nanometric thickness) that can be filled with molecular gases. We now propose to use these platforms to perform thin cell spectroscopy of HF in order to measure the Casimir-Polder molecule-surface interaction and study its anisotropic component. HF is an excellent candidate for these experiments, as it provides a large spectroscopic signal. The study of HF requires building an experimental machine operating at 2.5μm to probe the R(0) transition. Although this is a challenging and unusual region of the electromagnetic spectrum, the group has already assured the necessary funding to obtain a DFB laser emitting at this wavelength and dedicated optics. These experiments could provide the first measurements of CP interaction with molecules and could constitute a stepping stone towards hybridization of gas molecules with photonic devices.

We also plan to perform precise theoretical calculations of molecule-surface interactions with emphasis on the effects of Casimir-Polder anisotropy. This objective will be pursued in collaboration with S. Scheel's group in the University of Rostock (Germany).

We are looking for a PhD student with good background in quantum physics, atomic or molecular physics and light-matter interactions to work on both experimental and theoretical aspects of this project and participate in the exchanges with the German group of theorists.