Contrat doctoral – ED Galilée

Titre du sujet : Atomic interferometry with nanostructures for a fifth force search and new quantum devises

- Unité de recherche : Laboratoire de Physique des Lasers
- Discipline : Physique
- Direction de thèse : Gabriel Dutier
- Contact : gabriel.dutier@univ-paris13.fr/quentin.bouton@univ-paris13.fr
- Domaine de recherche : Physique quantique
- Mots clés : propagation d'onde et simulation numérique, fluctuation quantique du vide, interférométrie atomique

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Every polarizable object in nature experiences the Casimir-Polder (C-P) forces, which becomes significant at the nanometer scale. To study such fundamental forces, our research group ("Optique et Interférométrie Atomique" at the Laboratoire de Physique des Lasers, Villetaneuse) uses laser-cooled atoms that diffract through a nanograting. As the atoms pass through the nanograting, they interact with the slits via the C-P interaction. The resulting phase shift induced by C-P interaction significantly alters the interference pattern, allowing to extract information related to the C-P potential from the diffraction picture [1].

The measured diffraction picture being an indirect signature of the C-P force, **strong theoretical support is necessary to exploit the data generated by the experiment**. In this context, we are collaborating with Pr. N. Gaaloul [2] (from University of Leibniz in Hanover, specialist in numerical methods for precision measurements for fundamental physics and inertial sensing), T. Emig [3] (from LPTMS, France, specialist in the C-P interaction interaction) and F. Impens [4] (from Federal University of Rio de Janeiro and specialist in Atom Interferometry).

The PhD project will be conducted in cotutelle with the group of N. Gaaloul, who is specialized in the numeric in order to produce efficient and robust code. **It will focus on the development of numerical and theoretical** tools to infer pertinent information about the experiment atomic diffraction signal. It will involve efficient solving of the time-dependent Schrödinger equation, employing multiple scattering expansion method to calculate the C-P interaction in complex geometries, conducting FDTD simulations in the sub-wavelength regime, and utilizing quantum Fisher information formalism, among other techniques. The prospective applicant will have the opportunity to work within both groups while closely collaborating with T. Emig and F. Impens. **This project is thus highly interdisciplinary, encompassing international research collaborations.** In particular, the project articulates around 2 research projects: the investigation of the fifth force and the development of innovative quantum sensors featuring nanograting, such as gravimeters or Rotation sensing with Sagnac effect.

[1] J. Lecoffre et al., *Measurement of Casimir-Polder interaction for slow atoms through a material grating*, Phys. Rev. Research **7**, 013232 (2025)
[2] C. Garcion et al., *Quantum description of atomic diffraction by material nanostructures*, Phys. Rev. Research **6**, 023165 (2024).
[3] T. Emig et al., *Surface scattering expansion for the Casimir-Polder interaction of a dielectric wedge*, Phys. Rev. A **110**, 062809 (2024).
[4] G. C. Matos et al., *Quantum Vacuum Sagnac Effect*, Phys. Rev. Lett. **127**, 270401 (2021).