PhD position on Interfacing molecular gases with silicon photonic platforms: Precision Casimir-Polder and cavity QED experiments – Laboratoire de Physique des Lasers, Université Sorbonne Paris Nord (USPN)

The PhD student will participate in QUEST, an international consortium funded by the EU Marie Skłodowska-Curie Doctoral Networks program. QUEST brings together six universities and five companies from seven European countries and will train a cohort of 15 PhD students. The individual PhD projects are united by a common scientific theme, **QUantum Electrodynamics with Silicon nanoTechnology**, with the overarching goal of exploring and developing silicon-based quantum electrodynamics at the deep nanoscale.

This PhD project will be carried out at the Laboratoire de Physique des Lasers (LPL), Université Sorbonne Paris Nord (USPN), in the Paris area. As part of the QUEST network, possible secondments at partner institutions include Humboldt-Universität zu Berlin (K. Busch and F. Intravaia) for QED theory and modeling of Casimir–Polder forces; LENS in Florence (C. Toninelli) to explore an alternative approach to molecular cavity-QED experiments; and the Technical University of Denmark (DTU, S. Stobbe) for silicon nanocell and high-Q cavity fabrication. The student will also interact regularly with the other 14 QUEST PhD students through consortium meetings, training schools, and workshops.

The PhD student will work within the SAI team at LPL. The team has strong expertise in experimental quantum electrodynamics and nanophotonics and has developed unique spectroscopic tools to probe atomic and molecular gases at the nanoscale, with applications to Casimir–Polder interaction measurements and near-field quantum sensing. The PhD project will benefit from strong synergies within the QUEST network, as well as from the team's extensive network of national and international collaborations. The PhD will be supervised by Assoc. Prof. Athanasios Laliotis.

Research project

Atomic gases (hot atoms) provide powerful and elegant tools for fundamental physics and for quantum sensing of electromagnetic fields. The SAI group at USPN has developed unique precision spectroscopic techniques to probe hot atomic vapors at nanometric distances from surfaces, enabling experimental tests of thermal effects in Casimir–Polder (CP) interactions, a long-elusive prediction of QED [1,2]. Extending these approaches to molecular physics is a fascinating prospect. Molecules possess a rich internal structure and ultra-narrow transitions, offering new opportunities for fundamental physics studies. The SAI group has recently extended its nanoscale spectroscopy techniques to molecular gases, pioneering precision spectroscopy in molecular thin cells [3,4].

The use of molecular rovibrational transitions opens new perspectives for photonic platforms that have traditionally relied on dielectric materials such as glass or silicon nitride. In particular, operation in the near- and mid-infrared enables the use of silicon for thin-cell (nanocell) fabrication and the development of more complex nanophotonic structures, particularly well suited for QED experiments. A major objective of this PhD project will be the fabrication of **nanocells** for precision measurements of **molecule–surface interactions**. Such interactions are of fundamental importance in physical chemistry and have attracted considerable theoretical interest because the complex geometry of molecules can give rise to anisotropic Casimir–Polder interactions. These interactions will be investigated through precision spectroscopy of acetylene or HF molecules confined in silicon nanocells. Our unique approach will directly probe differences in the surface interaction between molecular quantum states with different orientations of their rotational angular momentum relative to the surface. This platform could subsequently be extended by integrating more complex silicon nanostructures.

A further objective will be to interface acetylene, which exhibits rovibrational transitions at telecommunication wavelengths, with high-Q silicon nanocavities [5]. Coupling these two systems could provide access to molecular cavity-QED studies. Moreover, the strong confinement of electromagnetic fields within cavity gaps, on the scale of only a few nanometers, could enable molecular spectroscopy at unprecedented distances from surfaces, giving access to CP interactions in the extreme near field.

Objectives/tasks

1. Fabrication of nanocells filled with molecular gases (acetylene or HF).
2. Spectroscopic probing of molecular gases confined within 100 nm gaps, and precision measurements of the Casimir-Polder interaction.
3. Theoretical modeling of Casimir-Polder, molecule-surface interactions.
4. Coupling of acetylene gases with high-Q silicon nanocavities.

References

1. A. Laliotis, T. P. de Silans, I. Maurin, M. Ducloy, and D. Bloch, “Casimir–Polder interactions in the presence of thermally excited surface modes,” *Nat. Commun.* **5**, 4364 (2014).
2. J. C. de Aquino Carvalho, I. Maurin, P. Chaves de Souza Segundo, A. Laliotis, et al., “Revealing Some Disagreements between a Casimir-Polder Sensor and Predictions from Far-Field Emittance,” *Phys. Rev. Lett.* **131**, 143801 (2023).
3. J. Lukusa Mudiayi, I. Maurin, T. Mashimo, J. C. de Aquino Carvalho, D. Bloch, S. K. Tokunaga, B. Darquié, and A. Laliotis, “Linear Probing of Molecules at Micrometric Distances from a Surface with Sub-Doppler Frequency Resolution,” *Phys. Rev. Lett.* **127**, 043201 (2021).
4. G. G. Arellano, J. C. de Aquino Carvalho, H. Mouhanna, E. Butery, T. Billeton, F. Du-Burck, B. Darquié, I. Maurin, and A. Laliotis, “Probing molecules in gas cells of subwavelength thickness,” *Nat. Commun.* **15**, 1862 (2024).
5. A. N. Babar, T. A. S. Weis, K. Tsoukalas, S. Kadkhodazadeh, G. Arregui, B. Vosoughi Lahijani, and S. Stobbe, “Self-assembled photonic cavities with atomic-scale confinement,” *Nature* **624**, 57–62 (2023).

Qualifications

We are looking for a motivated physicist or engineer with a background in one of the following fields: quantum physics, atomic or molecular physics, photonics, laser physics, electrodynamics, or quantum optics, and with a strong interest in experimental work. Candidates must have a two-year Master’s degree (120 ECTS credits) or an equivalent degree at the same academic level. Due to the **mobility rules** of the Marie Skłodowska-Curie programme, candidates must not have resided or carried out their main activity (work, studies, etc.) in France for more than 12 months during the 36 months immediately preceding the recruitment date.

Approval and Enrolment

The scholarship for the PhD degree is subject to academic approval, and the candidate will be enrolled in one of the general PhD degree programs at USPN. For information about our enrolment requirements and the planning of the PhD study program, please https://ed-galilee.univ-spn.fr/.

We offer

LPL is a dynamic laser physics laboratory with more than 50 researchers, providing a stimulating and international environment for experimental research. The laboratory offers access to a broad range of experimental facilities and expertise, as well as the technical support required to develop ambitious experimental projects. Located less than 30 minutes from central Paris, LPL also benefits from close interactions with the exceptionally rich scientific environment of the Paris region.

Salary and appointment terms

The period of employment is 3 years, with possible extension depending on secondments. The **base gross salary** over 36 months is 4,735.81€ per month for living allowance, 710€ maximum per month for mobility allowance and 495€ maximum per month for family allowance.

Further information

Further information may be obtained from Athanasios Laliotis (laliotis@univ-paris13.fr).

You can also get more information about the LPL here https://www.lpl.univ-paris13.fr/en/ and for the SAI group (https://www.lpl.univ-paris13.fr/recherche/spectroscopie-atomique-aux-interfaces-sai/)