LPL Laboratoire de physique des lasers

UNIVERSITÉ SORBONNE PARIS NORD

Masters Internship (stage M2)

Title: Probing THz metamaterials with a quantum Rydberg-atom sensor

Keywords: Quantum technologies, Rydberg atoms, Casimir-Polder interactions, atomic physics and spectroscopy, sub-wavelength metamaterials.

Scientific description:

The SAI group has developed spectroscopic techniques for probing excited atoms near dielectric surfaces in the nanometric regime. The group has also used excited state atoms as quantum probed providing information on electromagnetic properties of solids, such as surface polariton resonances [J. C. de Aquino Carvalho, Phys Rev. Lett., 131, 1439801, (2023)]. We have also participated in studies probing atoms in the vicinity of metallic nanostructures [E. A. Chan et al., Science Advances, 4, eaao4223, (2018)] tuning Casimir-Polder, atom-surface interactions between a cesium atom and resonant metamaterials.

Metamaterial technology is particularly important for the realization of high-performance devices in the THz (~300µm wavelength) range, because materials available in nature rarely have electromagnetic responses in this frequency range. The characterization of THz metamaterials is carried out in the far field and remains limited by diffraction. For this reason, the development of near-field imaging with sub-wavelength resolution has recently become an important area of study.

The SAI group is setting up a new project to probe the near-field of THz micro-resonators using a gas of Rydberg atoms as a quantum sensor. The detection of far-field THz waves has already been demonstrated [L. A. Downes et al. *Phys. Rev. X*, 10, 011027 (2020)] using excited Rydberg atoms inside an atomic vapor cell that convert absorbed THz radiation into photons scattered in the visible range (THz to visible conversion). The same technique can provide near-field information, if the atomic vapor is brought into contact with metamaterials. Additionally, this experiment can also be used to demonstrate control the Casimir-Polder Rydberg-metamaterial interaction (by tuning the THz resonances).

We are therefore proposing a Master's internship to set up this new experiment. The student will be involved in the construction of a new atomic vapor cell with THz micro-resonators deposited at the internal interface of the windows and will perform Rydberg-atom spectroscopy in the vicinity (near-field) of the resonators. The student could also be involved in the fabrication and design of THz micro-resonators and their far-field characterization, in collaboration with J-M Manceau's group at C2N, specialists in THz devices. The project is supported by QuanTiP and CNRS funding.

Techniques/methods in use: Quantum electrodynamics, atomic and molecular physics, calculations of atomic and molecular spectra, high-resolution laser spectroscopy.
Applicant skills: Experimental skills, good theoretical background in physics and optics.
Duration: from March 2025 till July 2025 (exact dates flexible).
Internship supervisor(s) Athanasios Laliotis (laliotis@univ-paris13.fr)
Internship location : Laboratoire de Physique des Lasers, Université Sorbonne Paris Nord
Possibility for a Doctoral thesis: Yes (Ecole Doctorale Galilée)