Master thesis proposal

Laboratoire de Physique des Lasers
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Title: Near-field probing of THz metamaterials with Rydberg Atom sensors

Keywords: Quantum sensing, Quantum Electrodynamics and Casimir-Polder interactions, nanophotonics, atomic physics, light-matter interactions.

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)] allowing us to tune Casimir-Polder, atom-surface interactions.

Metamaterial technology, using microfabricated subwavelength resonators, is particularly important for the realization of high-performance devices in the THz (~300µm wavelength) range, because it allows us to shape the electromagnetic response around the active material. The characterization of THz metamaterials is mostly carried out in the far field and remains limited by diffraction thus preventing direct measurement of electromagnetic fields near THz resonators. 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 of THz micro-resonators and their far-field characterization, in collaboration with J-M Manceau's group at C2N, specialists in THz devices.

Techniques/methods in use: Laser physics and atomic spectroscopy, vacuum techniques and atomic vapor cell technology.
Applicant skills: Theoretical background in quantum and atomic physics
Industrial partnership: No
Internship supervisor(s) (name, email, phone, …): Athanasios LALIOTIS, laliotis@univ-paris13.fr
Internship location : Laboratoire de Physique des Lasers, 99 Avenue J-B Clément, 93430, Villetaneuse
Possibility for a Doctoral thesis: YES financed by the ANR project 'TERRA'