INTERNSHIP PROPOSAL

Laboratory name: Laboratoire des solides irradiés-Ecole Polytechnique
CNRS identification code:
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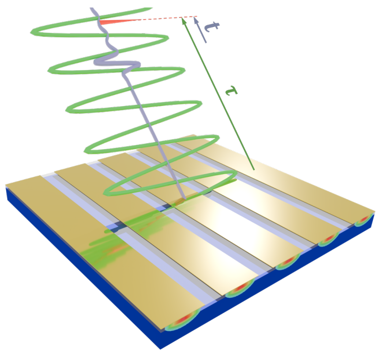
Internship location: Laboratoire des solides irradiés-Ecole Polytechnique

Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: Doctoral school/Research grant

Quantum plasmonic metamaterial time crystals

Photonic time crystals [1] -optical systems that are strongly and periodically modulated in time- have recently emerged as a novel paradigm for controlling light–matter interactions through temporal modulation, analogous to how conventional spatial photonic crystals manipulate light through spatial structuring. These systems have been theoretically predicted to enable novel mechanisms for light amplification, lasing and frequency conversion, as well as new forms of spontaneous emission control. Although their experimental realization remained elusive since they were first proposed, we have recently demonstrated the first optical realization of a photonic time crystal [2], achieved using a plasmonic cavity metamaterial operating at Terahertz (THz) frequencies [2,3,4].
Because photonic time crystals require a strong relative modulations of the optical properties on the order of unity to function, their operation so far relies on intense light fields and is limited to the classical regime of light–matter interaction. We now aim to go beyond this paradigm and extend experimentally the concept into the quantum regime. Our objective is to realize plasmonic time crystals that operate at the few-photon level, enabled by coupling quantum two-level systems to plasmonic cavities in the ultra-strong light–matter coupling regime.



During this internship, the student will lay the groundwork for this ambitious project by designing and studying plasmonic cavity metamaterials within a parameter range suitable for achieving these quantum effects. Specifically, this will involve extending the frequency coverage of our current THz spectroscopy setup to higher frequencies, within the 15–20 THz range, which will then be used to study and characterize the plasmonic metamaterials.

This project lies at the intersection of condensed matter physics and photonics. The student will gain hands-on experience with concepts and techniques such as: THz time-domain spectroscopy, plasmonics, metamaterials, nonlinear optics, quantum optics, ultra-strong light-matter interactions, cavity quantum electrodynamics.

[1] M. M. Asgari et al. *Advances in Optics and Photonics*, 16(4):958, 2024.
[2] T. Guo et al. arXiv 2510.02845
[3] I. Aupiais et al. *Nature Communications*, 14(1), 2023.
[4] I. Aupiais, et al. *ACS Photonics*, 11(10), 2024.

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: NO