INTERNSHIP PROPOSAL

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Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: 1/2 funding from ONERA is secured

RECONFIGURABLE PLASMONIC MATRIX ANTENNAS FOR THERMAL EMISSION CONTROL

The aim of this project is to create nanostructured infrared plasmonic antennas based on the repetition of a single sub-wavelength metal pattern (sub-λ) forming the basic building block of an NxN matrix structure. We will design reconfigurable infrared sources by addressing a subset of the sub-λ patterns making up the matrix antenna with visible laser heating forming specific patterns, in particular to control the polarization and spectral position of resonances with a view to creating smart reconfigurable infrared surfaces. We will describe the coupling between sub-λ patterns using simulations based on the quasi-normal mode method [Wu2023].

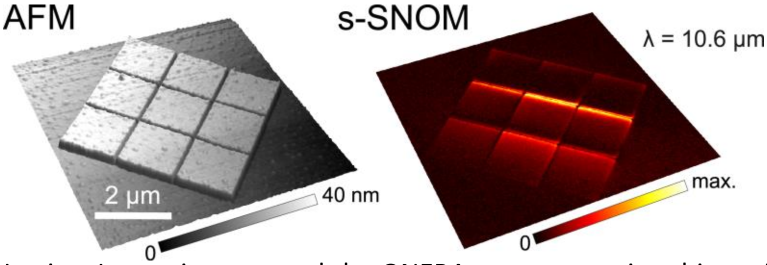

Figure 1: AFM and infrared SNOM (scanning near-field optical microscopy) images of a 3x3 matrix antenna.

The Institut Langevin team and the ONERA team proposing this project have been collaborating for several years on the theme of plasmonic antennas. The basic patterns of these antennas are metallic nanostructures of sub-λ size that possess resonance in the mid-infrared, at a wavelength that depends on both the size of the antenna and the materials that make it up. Observing the spectrum of individual plasmonic antennas is an experimental tour de force, as the signals to be detected are very weak due to the very small antenna size and the overwhelming infrared background. In previous work, we were able to measure the spectral resonance in the thermal radiation spectrum of individual metal-insulator-metal (MIM) antennas consisting of a square metal patch placed on a thin dielectric layer above a continuous metal film [Li2018]. We then combined this type of antenna to form MIM dimers, and demonstrated by spectroscopic measurements the hybridization of certain modes due to near-field coupling between the MIMs [Abou_Hamdan2021]. Finally, we have begun studying more complex systems consisting of arrays of 3x3 antennas [Abou_Hamdan_these]. Until now, the approach used to model the electromagnetic behavior of multi-element plasmonic antennas has been based solely on the use of commercial software (COMSOL, LUMERCIAL).

In this thesis, we will study matrix plasmonic antennas with mid-infrared resonances, whose radiative properties we will control using reconfigurable visible laser heating. The antennas will consist of gold (Au) nanostructures structured in an NxN matrix on a dielectric substrate, which we will heat by absorption of a visible laser beam in order to stimulate their thermal emission in the infrared or modify the dielectric medium to shift the resonance frequencies. The use of a spatial light modulator will enable us to modify the spatial configuration of this laser heating on the antenna array. The result will be a reconfigurable light converter from visible to infrared.

The experimental methods will combine infrared spatial modulation spectroscopy [Li2018,Abou_Hamdan2021], thermal radiation scanning tunneling microscopy [DeWilde2006] and TRSTM spectroscopy which has revealed non-planckian effects [Babuty2013].

[Li2018] C. Li et al, Phys. Rev. Lett. 121, 24, 243901 (2018).
[Abou_Hamdan2021] L. Abou-Hamdan et al., Opt. Lett. 46, 981 (2021).
[Abou_Hamdan_these] L. Abou-Hamdan, thèse de doctorat (2023).
[Makhsiyan2015] M. Makhsiyan et al., Appl. Phys. Lett. 107, 251103 (2015)
[Wu2023] T. Wu et al., Computer Phys. Comm., 284, 108627 (2023).
[Abou-Hamdan2023] L. Abou-Hamdan et al., arXiv preprint arXiv:2310.08351 (2023).
[DeWilde2006] Y. De Wilde et al, Nature 444, 740 (2006).
[Babuty2013] A. Babuty et al, Phys. Rev. Lett. 110, 146103 (2013).

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:
Condensed Matter Physics: YES Soft Matter and Biological Physics: YES
Quantum Physics: YES Theoretical Physics: YES