Titre Thèse	Generation of microwave and THz radiation through non-linear mixing and photomixing in metallic micro-cavities, loaded with mid-infrared quantum well heterostructures	
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Financement prévu	Contrat Doctoral Etablissement	ULille X☐ UPHF ☐ Centrale Lille ☐ Yncrea ☐
	Région – Autre ☐	Contrat de recherche ☐ Préciser :
Financement acquis ? ☐	Contrats de Recherche ☐ Préciser	Autre ☐ Préciser

Résumé du sujet: Multi-quantum well (MQW) hetereostructures have been shown to possess an intrinsic second-order non-linear susceptibility associated with electronic intersubband transitions that is several orders of magnitude larger than any other condensed matter system [1]. This fact makes them one of the most attractive nonlinear materials. However, the electronic intersubband nonlinearity couples only to an electric field polarized perpendicular to the MQW layers which hinders its excitation by radiation propagating perpendicularly to the surface. This issue can be elegantly solved by patterning the surface with subwavelength plasmonic metallic resonators specifically designed to resonate at the pump frequency of interest [2]. Such resonators convert a transversely polarized pump wave to a local electric field polarized orthogonally to the MQW layers. Moreover, they provide high local field intensities allowing the achievement of exceptionally high non-linear conversion efficiencies that can potentially be exploited for the generation of sub-mm and Terahertz (THz) radiation through difference frequency mixing [3]. Another efficient and well-known process for the generation of such frequencies is photomixing [4]. As for non-linear mixing this process can also benefit from the field enhancement provided by plasmonic microcavities. Recently we have demonstrated this concept by embedding a MQW heterostructure inside a 2D-array of patch-antenna resonators, connected to a microwave coplanar waveguide (see the figure). With this device we have shown microwave generation up to 70GHz by photomixing of two quantum cascade lasers emitting a 10um wavelength [5].

In the first part of this project we plan to exploit the same structure for microwave generation through non-linear mixing in asymmetric quantum wells, with a special focus on the so-called *optical rectification* process [1]. Indeed, coupling the array of patch resonators to a coplanar waveguide provides an ideal system to carry out a direct and straightforward comparison of the efficiencies of non-linear generation and photomixing in intersubband systems, which is still lacking in the literature. In the second part of the project we target the generation of radiation in the sub-mm and THz range. To this end we will couple the 2D-array of patch resonators with a properly tailored THz antenna that will radiate in free space. With this original system we target, for the first time, the demonstration of the generation of THz radiation through both photomixing and non-linear mixing of mid-infrared photons.

For this PhD project we look for a motivated student with a solid background in electromagnetism, optoelectronics, and quantum mechanics. The work will involve electromagnetic simulations using a finite-difference time-domain software, fabrication in a cleanroom environment and the optoelectronic testing of the realized devices using FTIR spectroscopy and optical mixing of mid-IR laser sources.

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[3] J. Lee et al. Nature, **511**, 65 (2014)
[4] S. Preu et al., J. Appl. Phys. **109**, 061301 (2011)
[5] M. Hakl, et al., “Ultrafast quantum well photodetectors operating at 10μm with flat frequency response up to 70GHz at room temperature”, ACS Photonics, *in press* (February 2021). https://dx.doi.org/10.1021/acsphotonics.0c01299