Sujet thèse / PhD subject 2025

Titre Thèse	**Mélangeurs opto-électroniques pour applications en gamme de fréquences millimétrique et THz**	
PhD Title	**Optoelectronic Heterodyne Mixers for Millimeter-Wave and Terahertz Applications**	
(Co)-Directeur	Emilien Peytavit	E-mail : emilien.peytavit@univ-lille.fr
(Co)-Directeur		E-mail :
(Co)-Encadrant (s)		E-mail :
Laboratoire	IEMN	Web : www.iemn.fr
Groupe(s)	Photonique THz	Web :THz Photonics group
Projet phare principal	Micro&nano devices	
Thèse fléchée Flagships IEMN ?	Oui ./ Non : Non Flagship concerné :	
Demande de labellisation Université de Lille (GREAL, labellisée)	Oui / Non :Non Label :	
Financement acquis Oui ☐ Non ☒ Partiel ☐	Si acquis (total ou partiel), préciser : (contrat, organisme, Université étrangère, , ….) :	
Financement demandé	Contrat Doctoral Etablissement	ULille ☒ Centrale Lille ☐ JUNIA ☐
	Région ou Autre ☐ Préciser :	Co financement (Préciser l'origine, demande en cours, et si acquis ou pas) :

Abstract

Heterodyne mixers are fundamental components in millimeter-wave and terahertz (THz) systems, enabling frequency conversion for applications such as high-resolution imaging, spectroscopy, and communication systems. Traditional electronic mixers, while effective, face challenges at higher frequencies due to increased losses and complex local oscillator (LO) distribution. Advancements in heterodyne mixer technology, including the development of waveguide-based hot electron bolometer mixers and tunable antenna-coupled intersubband terahertz mixers, have significantly enhanced receiver sensitivity and bandwidth in THz and millimeter-wave ranges. These innovations have been instrumental in fields such as radio astronomy, atmospheric science, and security screening, where precise detection and analysis of high-frequency signals are crucial.[1][2][3]. Optoelectronic mixers, utilizing optical local oscillators, offer significant advantages in this context. The optical LO can be easily distributed via optical fibers, providing a quasi-lossless method to deliver the LO signal to various points in the system. Additionally, the use of near-infrared lasers for the optical LO allows for a wide operational bandwidth. For instance, a telecom laser at 1550 nm has a central frequency of approximately 192 THz; shifting this frequency by 1 THz represents a minimal relative change, enabling flexible frequency tuning.

Moreover, optoelectronic mixers can simplify design considerations by eliminating potential crosstalk between the optical LO and the THz signal to be detected and down-converted. This isolation enhances system performance and reduces interference issues. At IEMN, we have developed, over the past fifteen years, ultrafast MSM photoconductors integrated into optical cavities, utilizing low-temperature-grown GaAs (suitable for 800 nm lasers) or Fe-doped InGaAs (suitable for 1550 nm lasers). These devices achieve photoconductance values approaching 10 mS (100 Ω), resulting in conversion losses of approximately 20 dB at 100 GHz and 30 dB up to 300 GHz without any impedance matching or filtering circuit, as presented in [4] and [5] (RD4 of the SOW). This impedance, around 100 Ω, makes them nearly compatible with 50 Ω source or intermediate frequency (IF) chains without additional matching. Furthermore, as these are optically controlled resistors operating at room temperature without dc bias, they function as attenuators with an attenuation coefficient equal to the conversion loss, which also corresponds to the noise figure. These advancements position our photoconductors as promising candidates for efficient THz signal detection in full-optoelectronic systems.

Thesis Objectives: The proposed research aims to explore the fundamental aspects of optoelectronic mixers and develop integrated mixers employing ultrafast photodetectors[5][4], which have been

advanced by our group in recent years. The focus will be on designing mixers integrated into waveguides for frequency bands of 140-220 GHz, 220-325 GHz, and 325-500 GHz.

Candidate Profile:

We are seeking a highly motivated candidate with a background in Electronics, Electrical Engineering, or Applied Physics. The ideal candidate should have a strong interest in high-frequency circuit design and optoelectronics, with a willingness to engage in both theoretical and experimental research.

Thes references below provide foundational knowledge and recent advancements relevant to the proposed research:

[1] G. Chattopadhyay, "Technology, Capabilities, and Performance of Low Power Terahertz Sources," *IEEE Trans. Terahertz Sci. Technol.*, vol. 1, no. 1, pp. 33–53, Sep. 2011, doi: 10.1109/TTHZ.2011.2159561.

[2] A. Maestrini *et al.*, "Terahertz Schottky Mixers for Atmospheric and Planetary Sciences," *Int. Conf. Infrared, Millimeter, Terahertz Waves, IRMMW-THz*, vol. 2019-September, Sep. 2019, doi: 10.1109/IRMMW-THZ.2019.8874320.

[3] E. Schlecht *et al.*, "Schottky diode based 1.2 THz receivers operating at room-temperature and below for planetary atmospheric sounding," *IEEE Trans. Terahertz Sci. Technol.*, vol. 4, no. 6, pp. 661–669, Nov. 2014, doi: 10.1109/TTHZ.2014.2361621.

[4] E. Peytavit, F. Pavanello, G. Ducournau, and J.-F. Lampin, "Highly efficient terahertz detection by optical mixing in a GaAs photoconductor," *Applied Physics Letters*, vol. 103, no. 20. American Institute of Physics, p. 201107, Nov. 12, 2013, doi: 10.1063/1.4830360.

[5] C. Tannoury *et al.*, "Photonic THz mixers based on iron-doped InGaAs embedded in a plasmonic microcavity," *APL Photonics*, vol. 8, no. 11, p. 116101, Nov. 2023, doi: 10.1063/5.0153046.