

Sujet thèse / PhD subject 2026

Titre Thèse	Photonics-Based RF and THz Instrumentation for Ultra-Broadband Device Characterization	
PhD Title		
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Laboratoire	IEMN	Web : www.iemn.fr
Groupe(s)	Photonique THz	Web : THz Photonics group
Projet phare principal	Micro&nano devices	
Financement acquis Oui <input type="checkbox"/> Non <input checked="" type="checkbox"/> Partiel <input type="checkbox"/>	Si acquis (total ou partiel), préciser : (contrat, organisme, Université étrangère, ,) :	
Financement demandé	Contrat Doctoral Etablissement	ULille <input checked="" type="checkbox"/> Centrale Lille <input type="checkbox"/> JUNIA <input type="checkbox"/>
	Région ou Autre <input type="checkbox"/> Préciser :	Co financement (Préciser l'origine, demande en cours, et si acquis ou pas) :

Context The continuous increase in operating frequencies of electronic and photonic devices used in telecommunications, sensing, and imaging systems requires the development of characterization tools capable of covering extremely wide frequency ranges. Modern millimeter-wave and terahertz (THz) components may operate from a few tens of GHz up to several hundreds of GHz, and in some cases approaching the THz domain. However, conventional electronic instrumentation such as electrical spectrum analyzers or vector network analyzers (VNAs) is typically limited to frequencies below about 100 GHz. Accessing higher frequencies generally requires multiple frequency-extension modules that are costly and operate in a band-by-band manner, which significantly complicates measurements and prevents continuous ultra-broadband characterization from microwave frequencies up to the THz range. Photonics-based approaches offer a promising alternative to overcome these limitations. In these techniques, optoelectronic devices are used to convert high-frequency signals into lower-frequency signals that can be processed using standard electronic instrumentation. Among the key enabling technologies are ultrafast photoconductive devices, which can operate at very high frequencies thanks to their high-speed optoelectronic response. Over the past fifteen years, the THz Photonics group at IEMN has developed ultrafast MSM photoconductors integrated into optical microcavities based on low-temperature-grown GaAs (LT-GaAs) and iron-doped InGaAs (Fe:InGaAs)[1-4]. These ultrafast photoconductors can operate in two complementary regimes that are particularly attractive for instrumentation. When illuminated by an optical beat signal, the time-varying photoconductance enables optoelectronic heterodyne mixing, allowing RF or THz signals to be down-converted to an intermediate frequency that can be analyzed with conventional electronic instruments. In this configuration, the device operates as an optoelectronic mixer suitable for broadband spectrum analysis. When the same photoconductor is biased with a DC voltage while being excited by an optical beat signal, the time-varying photoconductance generates an electrical current oscillating at the beat frequency. In this regime, the device operates as a photomixing source. The ability of the same device technology to operate both as a receiver (mixer) and as a transmitter (source) opens the way toward a new generation of photonics-based RF and THz measurement systems, including ultra-broadband spectrum analyzers and potentially photonics-assisted vector network analyzers capable of characterizing devices over extremely wide frequency ranges.

Mission : The objective of this PhD research is to develop key building blocks for photonics-based RF and THz instrumentation using ultrafast photoconductive devices. The work will focus on the modeling, design, and experimental validation of optoelectronic devices and circuits enabling ultra-wideband frequency conversion and signal generation. In particular, the research will address the optimization of photoconductive devices integrated into optical cavities, the design of optoelectronic mixers for broadband heterodyne detection, and the development of photomixing sources for tunable millimeter-wave and THz signal generation. Another objective will be to explore instrumentation concepts based on these devices, such as ultra-wideband spectrum analyzers or photonics-assisted vector network analyzers capable of operating from a few GHz up to several hundreds of GHz. The PhD work will include device modeling, circuit design, microfabrication in cleanroom facilities, and experimental characterization of RF and THz systems. The research will be carried out within the THz Photonics group at IEMN, which has strong expertise in ultrafast optoelectronic devices and high-frequency measurement techniques.

Expected Profile: We are seeking a highly motivated candidate with a background in electronics, electrical engineering, applied physics, or photonics. The candidate should have a strong interest in high-frequency electronics (RF, millimeter-wave, or THz) and optoelectronic devices. The project involves both theoretical and experimental aspects, including device modeling, circuit design, and laboratory measurements, so the candidate should be willing to work at the interface between electronics and photonics. Knowledge of microwave engineering, semiconductor devices, or photonics would be an advantage, although it is not strictly required. Curiosity, autonomy, and motivation to work in an interdisciplinary research environment are essential qualities for successfully carrying out the PhD project.

References

- [1] E. Peytavit *et al.*, "Milliwatt-level output power in the sub-terahertz range generated by photomixing in a GaAs photoconductor," *Appl. Phys. Lett.*, vol. 99, no. 22, p. 223508, 2011, doi: 10.1063/1.3664635.
- [2] E. Peytavit, F. Pavanello, G. Ducournau, and J.-F. Lampin, "Highly efficient terahertz detection by optical mixing in a GaAs photoconductor," Nov. 12, 2013, *American Institute of Physics*. doi: 10.1063/1.4830360.
- [3] E. Peytavit, P. Latzel, F. Pavanello, G. Ducournau, and J.-F. Lampin, "CW Source Based on Photomixing With Output Power Reaching 1.8 mW at 250 GHz," *IEEE Electron Device Letters*, vol. 34, no. 10, pp. 1277–1279, Oct. 2013, doi: 10.1109/LED.2013.2277574.
- [4] 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.