"Post-doc: Conception and fabrication of ultrafast mid-infrared photodetectors"

Position

24 months
Start date : January 1st, 2024
Level sought: PhD
Net salary: from ~2300€ to ~3300€ /month depending on experience.

General context

The THz Photonics group at the Institute of Electronics, Microelectronics and Nanotechnologies (IEMN) wishes to recruit a Post-Doctoral student on a fixed-term contract (24 months). The objective of the work will be the design and fabrication of photodetectors operating in the mid-infrared range (5-15m, 20-60THz).

The Mid Infrared (MIR) spectrum calls for a wide variety of technologies in the fields of optics and optoelectronics. In this context, the "THz Photonics" team (THz-Photonics-Group publications) – which is proposing this contract - has been developing for several years ultrafast MIR detectors based on III-V semiconductor heterostructures [1,2]. Nowadays these detectors have reached 3dB radiofrequency (RF) bandwidths of ~100 GHz, an unsurpassed performance to date. They consist of arrays of quantum-well photo-detectors coupled to plasmonic antennas [3]. In particular, we were able to demonstrate that their electrical bandwidth is limited by the time needed by the electrons, photo-excited above the potential barriers, to return to the fundamental level of quantum wells. The latter, called *capture time*, is of the order of a few ps and depends in particular on parameters such as the width of the potential barriers or the energy of the excited state. The RF bandwidth can therefore potentially be modulated, and in particular extended, by modifying the quantum design of the photodetectors. This is one of the aspects that we wish to explore in this project. Another key point is given by the plasmonic antennas, which allow to obtain a collection area of the incident MIR radiation larger than the detectors physical area, thus allowing to reduce significantly the detection noise and therefore increase the sensitivity compared to traditional devices. Presently, our photodetectors exploit patch-type antennas, but we now wish to explore other types of antennas to increase further the radiation collection.

Ultimately, the objective of this post-doctoral project is to demonstrate a new generation of photo-detectors in the 8-12µm range. To this end novel devices with an improved performance will be designed, fabricated and characterized, thanks to the design of new types of antennas and quantum structures. In particular we aim for an increase in responsivity by a factor of 2-3 compared to the state of the art, and for an extension of the RF bandwidth up to 200 GHz.

The work will take place within the project COMPTERA funded by the French National Research Agency (ANR), in collaboration with Ecole Normale in Paris and CEA-LETI in Grenoble. The goal is to demonstrate the feasibility of MIR detectors with unrivalled performance, for a number of applications such as spectroscopy and gas detection, coherent imaging, telecommunications in space. free, and astrophysics [3-5].

[1] M. Hakl *et al.*, "Ultrafast Quantum-Well Photodetectors Operating at 10 µm with a Flat Frequency Response up to 70 GHz at Room Temperature," *ACS Photonics*, 2021, doi: 10.1021/acsphotonics.0c01299.
[2] Q. Lin *et al.*, "Real-time, chirped-pulse heterodyne detection at room-temperature with 100GHz 3dB-bandwidth mid-infrared quantum-well photodetectors," *Under review (September 2023)*
[3] N. A. Macleod, et al. "Broadband standoff detection of large molecules by mid-infrared active coherent laser spectrometry," Opt. Expr. **23,** 912 (2015)
[4] H. Dely *et al.*, "10 Gbit/s free space data transmission at 9 µm wavelength with unipolar quantum optoelectronics," Laser Photon. Rev., **16**, 2100414 (2022)
[5] D. D.S.Hale, et al. "The Berkeley infrared spatial interferometer: a heterodyne stellar interferometer for the mid-infrared," Astrophys. J. **537**, 998 (2000)

Job description

The candidate will be responsible of the design and fabrication of the photodetectors. To this end, he will be asked to:

-Design the photo-detector using RF/photonics (CST, Lumerical, etc.) and quantum (Nextnano) simulation codes
-Carry out all the processing steps in a clean room environment (CAD design of the lithography masks, spin coating, electronic/optical lithography, metallization, PVD deposition, plasma etching).
-Characterize the samples during fabrication (AFM, profilometer, optical and electronic microscopy, electrical characterization).

To carry out these tasks, the recruited post-doctoral fellow will rely on the expertise of the THz Photonics team and of all the clean room staff.

Required skills

- Motivated post-doctoral fellow, independent, and capable of bringing new ideas.
- Good attitude towards team-work.
- Solid knowledge of electromagnetics, quantum mechanics and optoelectronic devices.
- Know-how in electromagnetic simulation with simulation software such as CST Microwave Studio, HFSS or Lumerical.
- Good knowledge of clean-room fabrication techniques. Initial experience in the fabrication of semiconductor devices (MEMS, diodes, photodetectors, transistors, etc.) in a clean-room environment is essential.
- Experience in the characterization of optoelectronic devices would be a plus.
- Good level of English, spoken and written.
- Good writing skills (writing of papers and reports) are highly desired

To apply

Applications, together with a CV and a motivation letter should be sent to Stefano Barbieri and Emilien Peytavit

Contact: Stefano Barbieri - Emilien Peytavit - IEMN, UMR 8520 CNRS, University of Lille, France

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Stefano Barbieri – web page