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Institut d'Electronique, de Microélectronique et de Nanotechnologie
UMR CNRS 8520

MASTER INTERNSHIP POSITION

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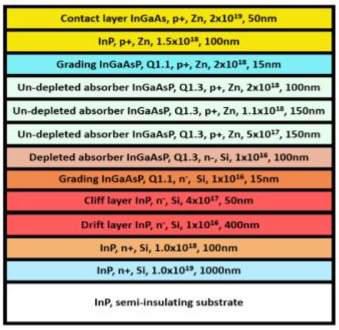
Groupe de Recherche : Photonique THz

Modeling of ultrafast unipolar transport photodiodes optimized for wavelengths near 1µm.



Epitaxial layer configuration of InGaAsP/InP photodiode. Drawn from Ref [1].

Context : Terahertz (THz) radiation, encompassing electromagnetic waves in the frequency range of 0.1 to 10 THz, plays a critical role in numerous advancements in fundamental research and engineering. It paves the way for a multitude of applications, including gas spectroscopy, THz imaging, and wireless telecommunications. The field of THz spectroscopy has seen significant progress in terms of pulse energy, tunability, and bandwidth. To generate THz pulses, one can utilize the conversion of ultrafast laser pulses through nonlinear interactions in liquids, gases, or crystals. Simultaneously, THz systems have been developed using ultrafast photoconductors (PCs), where a semiconductor (SC) is integrated with a THz metallic antenna. When the photon energy exceeds the SC bandgap, mobile electron-hole pairs are generated and accelerated by a static electric field applied to the SC via bias electrodes, producing an oscillating current at THz frequency responsible for radiation. Femtosecond lasers are typically used as an optical source to produce broadband, sub-picosecond THz pulses. It is also possible to generate continuous-wave (CW) THz radiation by producing an optical beat from two superimposed CW lasers, which is converted by the PC, known as a photomixer. In this regime, ultrafast photodiodes (PDs) outperform PCs as THz emitters. The PC/PD technology, which can be seamlessly integrated with optical fibers, offers substantial promise in terms of efficiency and integration into compact systems. The performance of THz systems is determined by the properties of the optoelectronic converter and the laser. Most THz PCs and PDs have been studied for operation at laser wavelengths around 800 nm and 1550 nm, compatible with advanced technologies such as fs Ti lasers and CW telecom lasers. In recent years, ytterbium-based fiber lasers have demonstrated impressive capabilities by significantly increasing the repetition rate and providing exceptionally high average power, reaching several kW in bulky systems or ~100 W in fibered setups. However, this substantial power available at the 1 µm wavelength has yet to be fully exploited for developing high-power THz emitters using optoelectronic devices that exhibit high optical-THz conversion efficiency and ease of integration.

Mission: In this internship, original structures of fast InP/InGaAs ultrafast photodiodes (PD) with high saturation current, compatible with ytterbium-doped fiber lasers emitting at 1020 nm, will be studied at IEMN. These structures will be based on modified unipolar transport PIN photodiodes, where the absorption region is partially doped to optimize the bandwidth-linearity trade-off at high optical regimes [2][3]. Additionally, resonant cavity structures [4] and waveguide structures will be studied. The electro-optical response modeling will be carried out using Silvaco, a semiconductor device transport property simulation software. For a detailed study of electron overshoot effects, advanced simulation tools such as the energy-balance (EB) model, which takes into account the nonequilibrium transport dynamics of electrons, will be used.

Expected Profile: For this internship focused on optoelectronics and semiconductor physics, we are looking for a student who has followed an academic path in Electrical Engineering or Physics with a solid background in Semiconductor Physics and who is motivated by research in applied physics.

Career Opportunities offered by this internship : The intern can then continue with a PhD or move towards the RF & microwave components and systems industry, which is currently highly promising.

NOTE: TWO MONTHS DELAY BETWEEN APPLICATION AND INTERNSHIP STARTING (ZRR CLEARANCE DELAY)

Salary : ~600€/month. **Duration : between 4 and 6 months** **Starting date : Mars 2026**

[1]Y. Peng, J. Zang, K. Sun, Z. Yang, and J. C. Campbell, “High-Speed and High-Power MUTC Photodiode Working at 1064 nm,” *IEEE Photonics Technol. Lett.*, vol. 31, no. 19, pp. 1584–1587, 2019, doi: 10.1109/LPT.2019.2938658.

[2]M. Grzeslo *et al.*, “High saturation photocurrent THz waveguide-type MUTC-photodiodes providing mW output power in the WR3 band,” *Opt. Express*, vol. 31, no. 4, pp. 6484–6498, 2022, doi: 10.1364/oe.475987.

[3]Z. Li, H. Pan, H. Chen, A. Beling, and J. C. Campbell, “High-saturation-current modified uni-traveling-carrier photodiode with cliff layer,” *IEEE J. Quantum Electron.*, vol. 46, no. 5, pp. 626–632, 2010, doi: 10.1109/JQE.2010.2046140.

[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.