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

MASTER INTERNSHIP POSITION

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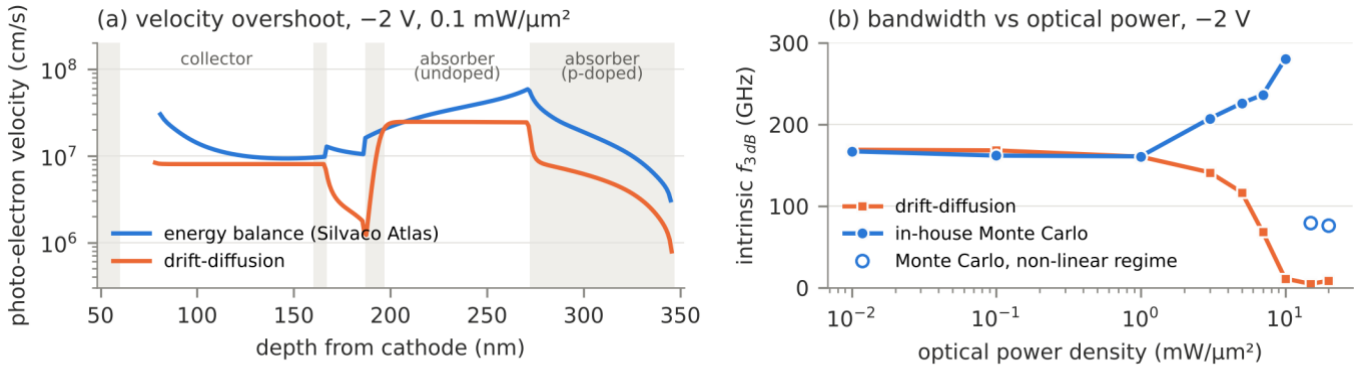
Groupe de Recherche : Photonique THz

Monte Carlo-Assisted Design of Ultra-Fast UTC Photodiodes for THz Generation



Reference UTC photodiode: (a) electron velocity, energy balance vs drift-diffusion; (b) bandwidth vs optical power.

Context : Uni-traveling-carrier (UTC) and modified UTC photodiodes are the key components of photonic THz sources and of photonics-assisted sub-THz wireless links[1,2]. Their bandwidth and saturation current are set by the transit of electrons through a thin collector (~100 nm), where transport is far from equilibrium: electrons reach several 10^7 cm/s (velocity overshoot) before scattering to the slower L valleys, and at high photocurrent the space charge and the self-induced field in the absorber reshape this dynamics[3,4]. Drift-diffusion TCAD misses velocity overshoot: it underestimates the bandwidth (≈ 120 GHz instead of ≈ 170 GHz on our reference structure) and misplaces the saturation current (figure). Energy-balance models capture it only through energy-relaxation times that are poorly known for InGaAs/InAlGaAs/InP heterostructures. The THz Photonics group has developed an in-house simulation chain: optical generation in resonant-cavity and grating photodiodes (RCWA), 1D/2D drift-diffusion and an ensemble Monte Carlo of the electrons (Γ, L, X valleys, CPU/GPU)[5]. The aim of this internship is to turn it into a reliable design method for next-generation ultra-fast photodiodes at 1550 nm and 1060 nm.

Mission: The intern will contribute to:

- Simulating reference UTC structures with the in-house Monte Carlo and Silvaco energy balance (Victory Device): velocity profiles, transit times, bandwidth and saturation versus bias and optical power.
- Calibrating the energy-balance relaxation times against the Monte Carlo, for a fast TCAD model that includes velocity overshoot.
- Extending the Monte Carlo model (Python/Numba): lattice self-heating, electron–hole scattering in the absorber.
- Designing optimized epitaxial structures for the bandwidth – responsivity – saturation trade-off, and taking part in their characterization.

This internship will provide hands-on experience in device physics, TCAD and Monte Carlo simulation.

Expected Profile: For this internship focused on semiconductor physics and device simulation, we are looking for a student who has followed an academic path in Physics or Electrical Engineering, with a solid background in Semiconductor Physics and an interest in numerical simulation (Python appreciated). It can follow the M2 research project proposed on the same topic.

Career Opportunities offered by this internship : The intern can then continue with a PhD or move towards the optoelectronics, 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 : March 2027**

APPLICATION DEADLINE : 31 DECEMBER 2026

1.Grzeslo, M. *et al.* High saturation photocurrent THz waveguide-type MUTC-photodiodes providing mW output power in the WR3 band. *Optics Express* **31**, 6484–6498 (2022).
2.Li, Z., Pan, H., Chen, H., Beling, A. & Campbell, J. C. High-saturation-current modified uni-traveling-carrier photodiode with cliff layer. *IEEE J Quantum Electron* **46**, 626–632 (2010).
3.Ishibashi, T. *et al.* InP/InGaAs uni-traveling-carrier photodiodes. *IEICE Trans. Electron.* **E83-C**, 938–949 (2000).
4.Shimizu, N. *et al.* Improved response of uni-traveling-carrier photodiodes by carrier injection. *Jpn. J. Appl. Phys.* **37**, 1424–1426 (1998).
5.Jacoboni, C. & Reggiani, L. The Monte Carlo method for the solution of charge transport in semiconductors with applications to covalent materials. *Rev. Mod. Phys.* **55**, 645–705 (1983).