Centre de Nanosciences et Nanotechnologie

University Paris Saclay and CNRS (France)

"Mid-IR Ultra-fast Amplitude Modulators and applications"

Applications are invited for a three-year PhD position at University Paris Saclay (France), in the framework of project BIRD (Broadband mid-infrared semiconductor modulators), that is funded by the French ANR.

Applications relying on mid-infrared radiation (MIR, λ = 3-12 µm) have progressed at a rapid pace recently, stimulated by scientific and technological breakthroughs. We can name MIR cameras, that have enabled thermal imaging. And the invention of the quantum cascade laser (QCL), another milestone, that has enabled a vast range of applications in spectroscopy, metrology, medicine.

All the recent breakthrough advances **stemmed from the development of transformative optical components**. In addition to the generation and detection of light, a key functionality for most photonics systems is the possibility to electrically control the amplitude, phase, and polarization of a laser beam up to ultrashort time scales. Fast amplitude and phase modulation are in fact essential for a large number of applications. We can name laser stabilization, coherent detection, spectroscopy and sensing, optical communications.

Contrary to the visible and near-IR range, **in the MIR range broadband modulators with modulation bandwidth of several tens of GHz do not exist**, which hampers the progress of MIR photonics.

The PhD project we propose will evolve in this context, with the goal of demonstrating a power-efficient, broadband (up to 40 GHz bandwidth) and integrated MIR amplitude modulator, that is capable of addressing the needs of emerging MIR photonics applications/platforms. The potential of the developed modulators for spectroscopic/sensing applications is an important element and it will be validated - through a collaboration - by setting up a dedicated high resolution-spectroscopy experiment.

The workflow during the project will roughly follow the following phases. (a) Device design and conception, especially of the active region, that will rely on intersubband absorption in a system of coupled semiconductor quantum wells [1]. Operation will be optimized for the 9.5-10.5µm wavelength range, in the center of an atmospheric transparency region, therefore ideal for the spectroscopy experiments and free-space optical communications. (b) Cleanroom fabrication, relying on the state-of-art facility that is hosted on C2N premises (training will be provided by the host team). (c) Device opto-electronic characterizations in DC, using a setup that permits to characterize integrated mid-IR devices, and subsequently in the RF domain using ultra-high speed detectors [2].

Consortium: This project will be undertaken in collaboration with Laboratoire IEMN (Lille-France) and Laboratoire LPL (Villetaneuse-France).

Acquired know-how: quantum devices physics and technology; electromagnetic modeling; cleanroom fabrication; laser physics ; optoelectronic characterization techniques; quantum design; RF / microwave technology.

Applicant Profile: The thesis is experimental, but with an important part devoted to quantum/electromagnetic simulations towards device design and development. The successful applicant will be an energetic individual with interest in semiconductor physics. She/he will have completed an undergraduate program in Physics, Optics or Engineering with very good marks. The project will benefit from collaborations with two major French labs, being funded by a national ANR program.

Details: The position is available immediately, and the starting date must be between Octobre 2021/March 2022. Applications, including a cover letter and a CV, should be sent to Adel Bousseksou (adel.bousseksou@c2n.upsaclay.fr) and Raffaele Colombelli (Email: raffaele.colombelli@c2n.upsaclay.fr), preferably by e-mail.

Relevant References:

[1] *"Fast amplitude modulation up to 1.5 GHz of mid-IR free-space beams at room-temperature*", S. Pirotta, NL Tran, G. Biasiol, A. Jollivet, P. Crozat, JM Manceau, A. Bousseksou, R. Colombelli, Nat. Communications **12**, Article number: 799 (2021). https://www.nature.com/articles/s41467-020-20710-2

[2] "Ultrafast quantum well photodetectors operating at 10µm with flat frequency response up to 70GHz at room temperature", M. Hakl, et al., ACS Photonics **8,** 464 (2021). https://arxiv.org/abs/2007.00299

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