“Mid-IR Ultra-fast Amplitude Modulators and applications”

We have an opening for a three-year PhD position at University Paris Saclay (France) within the Centre for Nanosciences and Nanotechnologies (C2N), in the framework of the project BIRD (Broadband mid-infrared semiconductor modulators) funded by the French agency 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. For instance MIR cameras have enabled thermal imaging and the invention of the quantum cascade laser (QCL) has enabled a vast range of applications in spectroscopy, metrology, medicine. 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 such as laser stabilization, coherent detection, spectroscopy and 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 proposed PhD project will evolve in this context, **aiming at the demonstration of 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. The potential of the developed modulators for spectroscopic/sensing applications is key element of this project and will be evaluated - through a collaboration - by setting up a dedicated high resolution-spectroscopy experiment.

The workflow will follow the following phases: (a) Design of the device’s 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 a transparent atmospheric window, therefore ideal for the spectroscopy experiments and free-space optical communications. (b) Cleanroom fabrication within the state-of-art facility hosted on C2N premises (training will be provided by the host team). (c) Opto-electronic characterizations of the fabricated devices in DC, using an optical set-up dedicated to integrated mid-IR devices, and subsequently in the RF domain using ultra-high speed detectors [2].

Consortium: The project will be done in collaboration with two other French laboratories IEMN (Lille) and LPL (Villetaneuse).

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 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.

Details: The position is available immediately with a starting date between October 2021 and March 2022. Applications, including a cover letter and a CV, should be sent to A. Bousseksou (adel.bousseksou@c2n.upsaclay.fr) and/or R.Colombelli (raffaele.colombelli@c2n.upsaclay.fr).

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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