Cleanroom Research Engineer
"Mid-IR ultra-fast amplitude modulators"

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Applications relying on mid-infrared radiation (MIR, 3-12 µm) have progressed at a very rapid pace in recent years. MIR cameras have propelled the field of thermal imaging; the invention of the quantum cascade laser (QCL) was a milestone that made compact MIR laser sources commercially available for a wide range of applications.
A crucial feature for most photonic systems is the ability to electrically modulate the amplitude of a beam at speeds of the order of GHz or higher. It is a valuable feature for a multitude of applications in MIR photonics, such as laser stabilization, coherent detection, spectroscopy. At present, ultra-fast modulation (1-40 GHz) of a MIR laser beam is a feature that does not have a definitive commercial solution and stand-alone, efficient and broadband modulators are lacking from the current mid-infrared photonics toolbox.

We develop meta-surfaces capable of applying ultra-fast RF modulation to a laser beam propagating in free space, whether in reflection or in transmission [1]. This approach does not require a specific integration of the source and can in principle be applied to laser sources other than QCL, i.e. any type of MIR laser (CO2 for example) opening the door to several scientific and industrial applications. These objects also exploit a fundamental phenomenon, the so called *strong coupling regime* between light and matter. The devices are one of few demonstrations of a practical device relying on the strong light-matter coupling regime [2] [3] [4].

The team developed a modulator demonstrator [1], following an idea that has been patented in France (Ref. FR 19 03211) and is now extended at the international level. The principle of operation is schematically represented in Figure 1. A quantum semiconductor heterostructure is incorporated into the resonator of Fig. 1a. The application of a voltage **modulates** the system reflectivity: an incoming laser beam will be amplitude modulated with high contrast. The normalized "beat-notes" obtained from the sample demonstrate the modulation of the incoming laser.

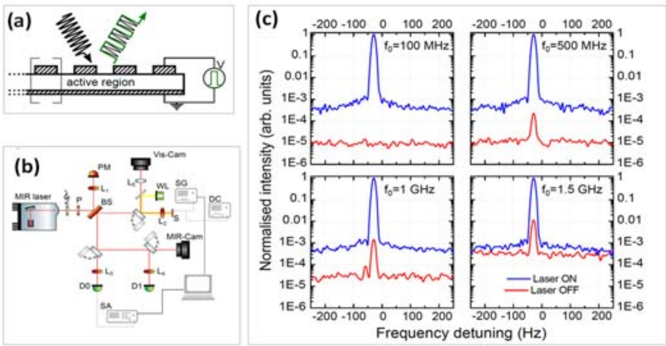

Figure 1 – (a) Sketch of the modulator geometry: the active region is embedded in a metal–metal structure. By applying an external bias, the amplitude of the reflected beam is modulated.
(b) Sketch of the experimental setup to measure the modulator bandwidth. The sample is pumped with a commercial tunable mid-infrared QC laser.
(c) Normalized beat-note spectra obtained when the sample undergoes modulation frequencies at 100 MHz, 500 MHz, 1 GHz, and 1.5 GHz from top left.

The activity

The goal of the project is to optimize the device modulation speed up to several GHz, integrating RF technology to the devices. **The activity focuses on the cleanroom fabrication. It implies processing of III-V semiconductor optoelectronic devices. The process flow includes e-beam lithography, hard mask deposition, metal evaporation, RIE/ICP etching, and – importantly – implementation of metallic air-bridges that are crucial to effectively enable RF capabilities (coplanar waveguide connections for instance).** In general, the full processing requires 7/8 processing steps.

This activity also implies judicious quantum design of the active region and optoelectronic and RF characterizations, that will be provided by the host team. The successful candidate of course will be able to participate to the characterizations of the fabricated devices. She/he will have the opportunity to learn advanced optical and RF characterization techniques (example setup Fig. 1b). The project benefits from collaborations with two French laboratories IEMN (Univ. Lille/CNRS) and LPL (Univ. Sorbonne Paris nord/CNRS), as the host team collaborates with them on a nearby topic [5].

Perspective candidate

The successful applicant will be an energetic individual with interest in semiconductor device physics, and **will have experience in processing of III-V semiconductor optoelectronic devices with multiple processing steps.** She/he will be able to autonomously solve issues that might emerge in the process flow of the devices and propose solutions.

The project is funded for 18 months (24 months negotiable), that covers the salary and epitaxy/cleanroom costs. The typical gross salary, that will be commensurate with experience, lies in the 3000/3800 Euros/month. The perspective candidate will be part of the host team (*Mid-IR and THz quantum devices team*) at C2N, and he/she will benefit from constant interactions with the team members, and of course full access to the existing process flows and experimental setups.

References

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