Post-doc / Research Engineer position

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Development of ultra-fast mid-IR modulators towards commercialization

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. All recent advances have resulted from the development of revolutionary optical components.

A crucial feature for most photonic systems is the ability to electrically modulate the amplitude and / or phase of a beam at speeds of the order of GHz or higher. This is a valuable feature for a multitude of applications in MIR photonics.

At present, ultra-fast modulation (1-40 GHz) of a MIR laser beam is a feature that does not have an adequate commercial solution. The fastest modulation rates, 20-30 GHz, have been obtained with direct modulation of quantum cascade lasers [1], [2], [3], but this requires specially designed devices and elevated RF (radio frequency) injected powers. In fact, in the visible / near-IR spectral ranges, the solution that proved successful consists in separating the functionalities: independent modulators, filters, interferometers that are physically separated from the source. For modulators, this has advantages in terms of RF power, laser linewidth, and flatness of the modulation bandwidth. However, to date, stand-alone, efficient and broadband amplitude / phase modulators are lacking from the current mid-infrared photonics toolbox.

In this respect our approach consists in developing modulators capable of applying ultra-fast RF modulation to a laser beam propagating in free space, whether in reflection or in transmission. **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.** The development of this technology is important because it can capture a significant fraction of the market.

We have developed a first modulator demonstrator [4], following an idea that we have patented in France (Ref. FR 19 03211) and that is now being extended at the international level. The principle of operation is schematically represented in Figure 1. A doped multiple quantum well structure is incorporated into the resonator of Fig. 1a, operating in strong light-matter coupling. The application of a voltage modulates the light-matter coupling strength and thus the system reflectivity: an incoming laser beam will be amplitude modulated with high contrast. The normalized "beat-notes" obtained from the sample with the setup in Fig. 1b, demonstrate the modulation of the incoming laser at least up to a modulation frequency of 1.5 GHz as shown in Fig.1c.

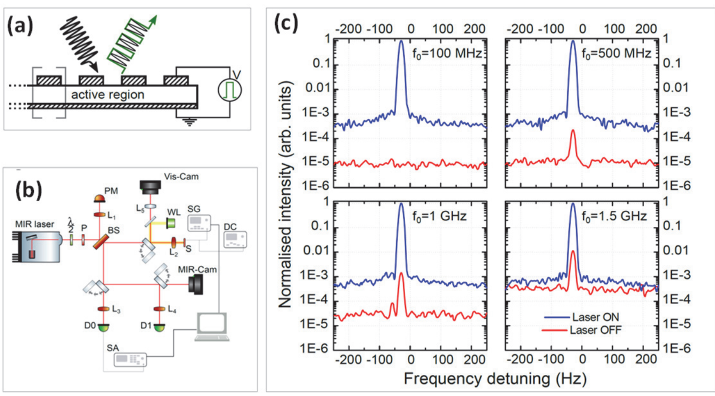

Figure 1 – (a) Sketch of the modulator geometry: the active region is embedded in a metal–metal structure. By applying an external bias, the amplitude of the reflected beam is modulated.
(b) Sketch of the experimental setup to measure the modulator bandwidth. The sample is pumped with a commercial tunable 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 modulator performs up to at least 1.5 GHz.

The project

The next step, **that is also the goal of the project,** is to improve the performance of these recently demonstrated/patented infrared modulators and to develop appropriate packaging for the possible "*valorization*" of the invention. These include:

- **Device level**: *optimize the device modulation speed. The minimum target is a 3dB cut-off at a modulation frequency of 15 GHz. These performances are achievable with careful RF design and open the door to several applications.*

- **"Product" level**: *develop a compact package (device, pre-aligned focusing micro-lenses, SMA cabling for high frequencies, possibly Peltier cooling) that can be easily adapted to a laser and evaluated by industrial/academic actors.*

Perspectives

A study of the opportunities and potential of these ultra-fast infrared beam modulators – that has been performed in the context of a possible business plan - anticipated the following applications: (i) Free space communications on a MIR carrier; (ii) High resolution *fast* spectroscopy by sideband generation; and (iii) Generation of MIR Frequency combs electronically.
During the project this "preliminary" study will be expanded to clearly weigh the impact of the possible applications, with a full market analysis and testing of the higher-TRL devices by industrial/academic actors. The objective is to wisely chose between a technology transfer or a start-up creation, that are the two probable outcomes of this action.

The perspective candidate

From the description, it is evident that this research project is closely connected to a vision of tech-transfer, start-up and commercialization. The perspective candidate should therefore have a strong interest towards that type of career path and applicative goals.

In terms of research, the activity is quite varied: it will include device RF design and fabrication, optical/RF testing, use of ultra-fast detectors [5], optical setup building and integration of optical components. The perspective candidate should be fluent in nanotechnology and nanofabrication, have experience with RF components and be able to program in Labview and/or python to upgrade the existing experimental setup.

Funding environment

This project is funded for 18 months by a CNRS PREMATURATION action, 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. Additional costs for running the action (consumables) are covered by the host team on other funding sources. The perspective candidate will be part of the host team (*Mid-IR and THz quantum devices team*) at C2N, and she/he will benefit from constant interactions with the team members, and of course full access to the existing experimental setups.

References

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