Master 2: INTERNSHIP PROPOSAL

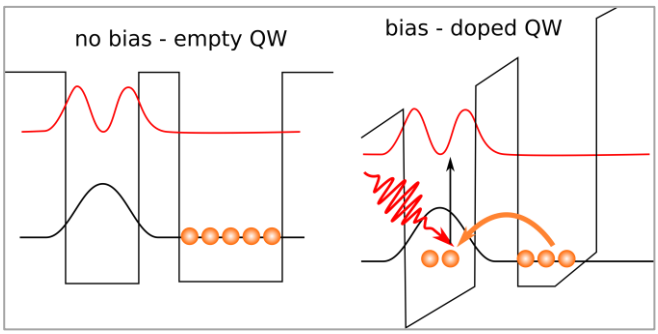
Laboratory name: **C2N – Centre de Nanosciences et de Nanotechnologies**
CNRS identification code: **UMR9001**
Internship director'surname: **Adel Bousseksou -** adel.bousseksou@c2n.upsaclay.fr - Tel: 01 70 27 06 29
Internship co-supervision: **Raffaele Colombelli –** raffaele.colombelli@c2n.upsaclay.fr
Web: https://odin.c2n.universite-paris-saclay.fr/en/activities/mir-thz-devices/
Internship location: C2N – Centre de Nanosciences et de Nanotechnologies / Palaiseau

Thesis possibility after internship: YES
Funding: YES / Doctoral school or research grant

Mid-IR ultra-fast amplitude modulators

Scientific project: 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. Unfortunately, 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. In this context, the host team has recently demonstrated a free-space MIR amplitude modulator operating up to 1.5 GHz [1], and identified the opportunity of greatly improving the modulation speed by operating the modulation in a waveguide instead of a free-space beam.

But du stage/internship objectives: The goal of the internship is to design a power-efficient, broadband (up to 40 GHz bandwidth) and integrated MIR amplitude modulator, based on an integrated waveguide geometry. The perspective student will perform the the design of the optical waveguide and of the quantum active region, that will rely on intersubband absorption in a system of coupled semiconductor quantum wells (see figure on the right) [1]. Operation will be optimized for the 9.5-10.5 µm wavelength range, in the center of an atmospheric transparency region, therefore ideal for the spectroscopy experiments and free-space optical communications. She/he will benefit from the experience of the host team (https://odin.c2n.universite-paris-saclay.fr/en/activities/mir-thz-devices/) in quantum and electromagnetic design of opto-electronic devices, of cleanroom fabrication, and device opto-electronic characterizations.



Qualités du candidat(e) requises/ required skills: Basic knowledge in optics and electromagnetics, semiconductor physics, optoelectronics, ability to work in groups, interest for experimental work.

Relevant References:

[1] *"Fast amplitude modulation up to 1.5 GHz of mid-IR free-space beams at room-temperature*", S. Pirotta *et al.,* Nat. Commun. 12, 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

Methods and techniques: Numerical modeling of the optical properties of waveguide and intersubband-transition in semiconductor heterostructure. Optical characterization, optoelectronic characterization techniques. During the internship student may follow cleanroom the first fabrication steps of amplitude modulators.