INTERNSHIP PROPOSAL
Internship offer 2026-2027

Laboratory: C2N – Centre de Nanosciences et de Nanotechnologies (UMR 9001)
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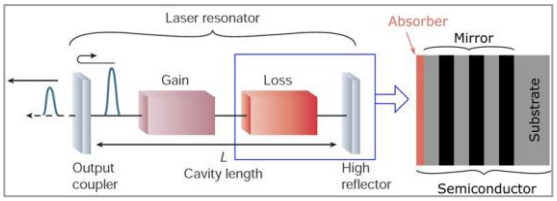
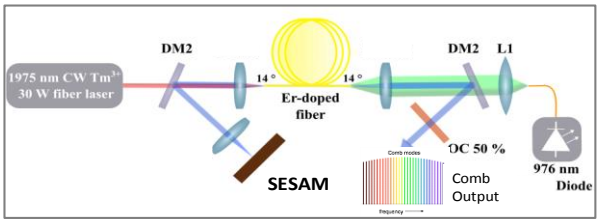
Mode-locked mid-IR fiber laser combs enabled by semiconductor saturable non-linear mirrors

Scientific project: Saturation of the light-matter interaction is a general nonlinear feature of material systems: atoms or semiconductors [1]. A saturable absorber exhibits an absorption coefficient that depends on the incident intensity. In semiconductors, a seminal example is the semiconductor saturable absorption mirror (SESAM) [2] based on interband transitions in quantum wells, that revolutionized the field of ultra-fast lasers in the vis/near-IR spectral range, allowing ultra-fast pulses (see picture on the right) that find applications in many domains.

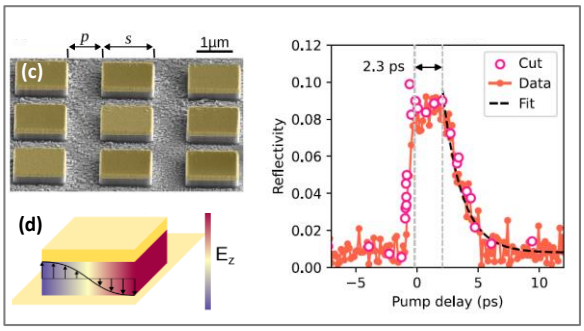


In the mid-IR (λ~3-30 μm), the intensity required to reach saturation is very high, ~1 MW/cm^2. This very high value **explains why saturable absorbers and SESAM mirrors are missing from the toolbox of mid-IR opto-electronic devices**: they could only be used with extremely high power laser sources.

The host team introduced a new concept for mid-IR SESAMs that solves the aforementioned road-block [3][4]. The solution is to operate in the so called *strong light-matter coupling regime,* where the system response is governed by coupled light-matter states called *polaritons.* The team demonstrated SESAMs with low saturation intensities**,** with the goal of **generating mid-IR frequency combs with tabletop fiber lasers, as sketched on the right** (the concept is also applicable to interband cascade or solid state lasers) [6].



The goal of the internship is to develop and optimize mid-IR nonlinear mirrors, supported by recent results [4][6], that **target comb operation of fiber lasers at λ=3.5 and 4.6 μm, and explore the mode locking regime.** Our collaborators at CORIA/CNRS have developed such novel sources ([5]), and our SESAMs will enable the mode-locking operation [6].



The work will proceed as follows. **First** characterizations consist in measuring the device reflectivity spectra with FTIR micro-reflectivity, to validate the design. **Second**: the devices are measured with a tunable CW laser at different incident powers to verify saturation and non-linear behavior. **Third:** time domain characterizations will be performed with a 1-ps-pulsed mid-IR pump/probe setup, to assess the device speed, a crucial figure of merit. An example is given in the figure on the side, showing the reflectivity as a function of the pump delay time. An ultra-fast decay time of 1.6 ps is measured. **Fourth and final:** devices will be coupled to fiber lasers (see figure in the center) to enable and explore frequency comb operation and pulse emission. The prospective intern will have the possibility to visit our collaborators' lab and work with them.

This project evolves in the context of a running ANR grant and of an ERC Advanced grand. Given recent results, exciting perspectives open for ultrafast, mode-locked mid-IR fiber and semiconductor lasers. The prospective intern will participate in this rapidly evolving dynamics.

[1] R. W. Boyd, Nonlinear Optics, 3rd ed. (Elsevier, Amsterdam, 2008).
[2]U.Keller et al, Opt. Lett. **17**, 505 ('92); U.Keller, Nature 424, 831 ('03)
[3] M. Jeannin, JM Manceau, R. Colombelli, Phys. Rev. Lett 127, 187401 (2021)
[4] M. Jeannin, E. Cosentino, et al., APL **122**, 241107 (2023).
[5] S. Normani et al., Optics Express **32**, 15106 (2024)
[6] S. Cassandra et al., *unpublished* (2006)

Methods and techniques: Modeling of the optical properties of the devices; quantum design of semiconductor heterostructures; use of lasers for optical pumping experiments; labview/python instrument control and data treatment; optoelectronic characterization techniques (mid-IR FTIR microscopy/spectroscopy…).

Possibility to go on with a PhD ? YES

Envisaged fellowship? Doctoral school or research grant (ANR / European ERC Advanced)