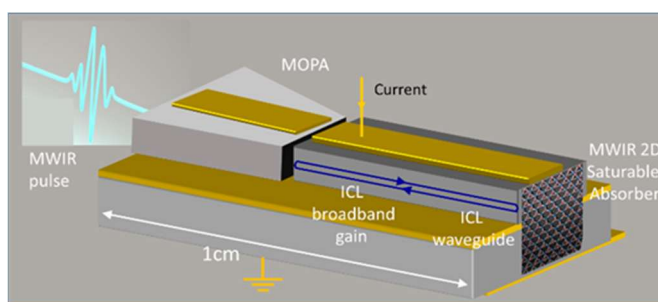


Title: 2D Quantum Materials coupled with mid-infrared Interband Cascade Lasers – Ultrafast pulse and Frequency Comb Generation

Keywords: Ultrafast and Frequency Comb Spectroscopy, band-structure and photonic engineering, Quantum materials

Scientific description: The generation of ultrafast and intense light pulses is an underpinning technology throughout the electromagnetic spectrum enabling industrial and academic exploitation in a plethora of applications across the sciences. A recent system has been semiconductor-based devices for pulse generation in the optical range. These benefit from inexpensive wafer scale production and low system costs and are an enabling technology in a range of applications.

However, in the mid-wave infrared (MWIR, 3 – 5 μm wavelength), a spectral range with countless molecular signatures and transparent atmospheric windows, a semiconductor technology platform for intense and short pulse generation has yet to be realised. Such sources would have an important impact in frequency comb spectroscopy as a vast number of molecular signatures exist in the MWIR. This project will breakthrough this technological gap to realise semiconductor-based MWIR ultrafast sources using the unique properties of Interband Cascade Lasers and new 2D materials for the MWIR.



Concept of ICL based modelocking with 2D materials, comprising zones for saturable absorption and amplification (MOA).

The project will innovate in several aspects that have not been previously brought together through new laser designs, engineering 2D materials for high nonlinearities and the realisation of entirely new approach for short pulse and frequency comb generation. This will be based on our recent work in the field [1,2], providing an important base for the project. The work will be in collaboration with the University of Montpellier, CEA Grenoble and the company mirSense.

[1] M. Mićica et al, "Determining Bandgaps in the Layered Group-10 2D Transition Metal Dichalcogenide PtSe₂". Adv. Funct. Mater. 2024, 2408982. <https://doi.org/10.1002/adfm.202408982>

[2] P. Abajyan et al; Mid-infrared frequency combs and pulse generation based on single section interband cascade lasers. Appl. Phys. Lett. 31 March 2025; 126 (13). <https://doi.org/10.1063/5.0245050>

Techniques/methods in use: Ultrafast spectroscopy, electromagnetic simulations

Applicant skills: Knowledge of condensed matter/quantum mechanics would be appreciated

Industrial partnership: YES – in collaboration with mirSense for the semiconductor lasers

Internship supervisor(s) : Sukhdeep DHILLON; dhillon@ens.fr; 01 44 32 35 07

Internship location: LPENS, 24 rue Lhomond, 75005 Paris

Possibility for a Doctoral thesis: YES – Already financed (start date ~ Sept/Oct 26)