Integrated Mid-IR frequency comb generation

Master 2 internship; starting February/March 2025 (≥ 5 months)

Laboratoire : Institut des Nanotechnologies de Lyon, Ecole Centrale de Lyon

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Mots clefs: Nanophotonics, integrated photonics, nonlinear integrated optics, mid-infrared, hybrid integration, frequency comb, microcomb, supercontinuum generation

The aim of the internship is to realise a miniaturised, bright, broadband mid-infrared (MIR_region covering the wavelength range 3 μm to 15 μm) **nonlinear source, i.e supercontinuum or comb, integrated into a photonic circuit.** Supercontinuum/ frequency combs, are generated through nonlinear interactions in waveguides/optical cavities.

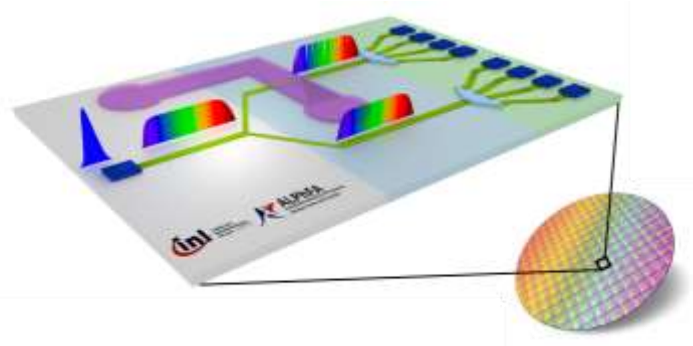
Background and context

The MIR is of considerable interest to the scientific and technological community. A notable feature of the MIR is that most chemical and biological compounds that are relevant to our health, safety and environment have a strong spectral signature in the mid-infrared. The MIR therefore offers unique opportunities for fundamental science (chemistry, biology, astrophysics, etc.) and the development of technologies with a strong societal impact (sensor applications, defence, industrial and environmental safety, etc.).

Numerous players in the nanophotonics scene are investing massively in this field in the USA (Air Force research lab, Harvard, UCLA, Princeton MIRTHE, IBM, Cornell, etc.), in Australia (ANU, RMIT, Macquarie, Adelaide, etc.), Asia, Europe (University of Surrey, University of St Andrews, Ghent/IMEC, EPFL…) and in France (CEA-LETI, INL, C2N, XLIM, FOTON Rennes, IES Montpellier, FEMTO, ICB etc.).

Challenges / objectives of the internship

Despite its recognized potential, MIR technologies are still limited in their range of applications, largely due to the size of MIR devices (optical components operating in this wavelength range have long been restricted to discrete components operating in free space, and to simple passive guides, generally based on multimode chalcogenide fibers) and to the prohibitive costs of the instruments used due to the lack of compact MIR optical devices. To address the limitations of MIR technologies, our strategy is based on the development of integrated MIR photonics, involving the miniaturisation of optical components and their integration on a planar substrate made of Ge, SiGe, and/or lithium Niobate materials that are transparent in the MIR range and highly nonlinear (see image).



On the way to the realisation of an actual MIR photonic circuit, the student's project will focus on one of the fundamental ingredient of integrated MIR, namely the sources and their integration in an optical circuit. In the framework of this internship, we will **exploit non-linear phenomena**. This approach will be based on the remarkable non-linear properties of silicon germanium (in partnership with CEA-LETI), Niobate lithium (in partnership with RMIT Melbourne and our industrial partner 3D oxides) at these high wavelengths and the exploitation of parametric processes to generate light over a very wide spectral band (covering the 2-10 m range). The aim is to develop i) sources that can be tuned over a wide spectral band (based on wavelength conversion) ii) "supercontinuums" and iii) multispectral sources or "COMBs".

The student will be able to participate in all stages of the project, from the design of the devices (FEMSIM, FDTD, nonlinear Schrodinger electromagnetic modelling tools), to the manufacturing of the devices using clean room processes via the INL's NANOLYON nanotechnology platform (nanolithography, etching, etc.) and their linear and nonlinear optical characterisations.

Scientific supervision and collaborations

The student will be hosted within the ILUM team of the INL ECL site and will benefit from the resources and expertise of the INL in silicon photonics, mid-infrared and non-linear optics (L. Ferhat, C. Grillet, C. Monat) and nanophotonics and heterogeneous integration both in terms of device design (the student will rely on the theoretical and numerical expertise of the INL as well as on the electromagnetic simulation tools available) and on the technology and clean room fabrication aspects for the realization of the first basic demonstrators.

The student will interact with our partners at CEA-LETI, our collaborators in the ANR projects MIRthFUL (XLIM) and OFCOC (FOTON, C2N, IES), our international collaborators in the LIA ALPhFA (International Associated Laboratory in Photonics between France and Australia) RMIT, Swinburne, ANU, Macquarie and the support of many industrial partners (3d oxides...).

Skills developed during this internship

The candidate should have a solid background in physics and optics with a strong taste for manufacturing, experimental and characterisation aspects.

The student will develop the full range of "nanophotonics/nanotechnology" skills, from the design of devices (simulation and design of optical microcomponents, dispersion engineering, split-step fourier method, LLE, FDTD) and their integration into a circuit, the fabrication of these components in clean room environments (electronic lithography, chemical etching and dry etching and their characterisation (within a complete optical bench - edge coupling, micro reflectivity, Fourier optics, nonlinear characterisation, pulsed laser, parametric processes)..

The internship may start in February 2025.

The internship may lead to a PhD funding.