Centre de Nanosciences et de Nanotechnologies

Soutenance de thèse

Mercredi 10 novembre
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Centre de Nanosciences et de Nanotechnologies
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Amphithéâtre

Miguel MONTESINOS- BALLESTER

"SiGe photonic circuits exploiting nonlinear optics and electro-optic effects in the mid-infrared"

Jury members :

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Abstract :

The mid-infrared (MIR) spectral range, commonly defined from 2 to 20 µm wavelengths, has attracted a great interest over the past two decades due to its unique characteristics for detection and security purposes. In particular, the fingerprint region (from 3 to 13 µm wavelength) allows a high sensitivity detection of most of molecules due to fundamental molecular vibrational modes that lead to specific absorption lines in this spectral range. During my PhD thesis, I have developed and optimized new fabrication processes in two cleanroom facilities, and also addressed the design, modeling and characterization of three missing functionalities based on thermal-tuning, nonlinear and electro-optic effects, showing a broadband operation in the MIR range.

First, I have demonstrated propagation losses lower than 4.6 dB/cm from 5 to 11 µm wavelength and in both optical polarizations, which are compatible with most of integrated MIR applications. Then, I proposed an integrated spectrometer approach based on a spatial-heterodyne configuration, in which I thermally tuned the path-delay unbalance of a MZI array to overcome the classical tradeoff between resolution, operational bandwidth, and number of interferometric structures required. These results facilitate the development of compact and robust spectrometers operating in the MIR fingerprint region. Next, I demonstrated a supercontinuum generation that spans from 3 to 13 µm wavelength in a 5.5 mm long graded-SiGe waveguide. This demonstration provides a broadband and coherent MIR light by mean of a single device, opening exciting perspectives for the simultaneous detection of multiple molecules. Finally, I experimentally evaluated the free-carrier plasma dispersion effect in a wide MIR range, to later demonstrate an integrated electro-optical modulator operating from 6.4 to 10.7 µm wavelength, showing up to 1.3 dB extinction ratio in current injection regime and 225 MHz modulation bandwidth in carrier depletion. This device is essential to implement synchronous detection and thus significantly improve the sensitivity of integrated detection systems.
In conclusion, this thesis has successfully addressed the development of integrated waveguides and three associated functionalities missing in the literature operating in a wide MIR spectral band. Therefore, this work opens exciting perspectives in a plethora of high-impact applications, paving the way towards the long-term development of compact multi-molecular sensor systems