Chip-scale INtegrated Photonics for the mid-Infra REd

Results in Brief

Molecular ‘fingerprinting’ technology that fits on a fingertip

Table-top mid-infrared (IR) spectrometers are used ubiquitously in labs for identifying material structures in the biological, chemical and physical sciences. EU-funded research paves the way to a compact, portable and cost-effective system that will enable use in the field and potential applications from environmental monitoring to food safety to early medical diagnoses.

Technology for photonics integration within silicon chips has matured tremendously, with perhaps the greatest strides seen in the telecommunications and IT sectors. The INsPIRE project, funded by the European Research Council (ERC), took that technology in an entirely new direction with integration of mid-IR components onto a single chip for the efficient and portable identification of molecules such as pathogens in air, food and medical samples.

A unique set of wideband integrated optical functions

Spectroscopic methods exploit the absorption and reflection of light by matter, teasing out spectral patterns to identify the materials present according to their
characteristic spectra. The mid-IR range of wavelengths contains the so-called fingerprint region (around 2.5-10 µm) associated with the stretching, vibration and rotation of molecules. The spectral emission pattern, or ‘molecular fingerprint’, is unique to each specific molecule, so mid-IR spectroscopy can very accurately identify molecules in a sample.

INsPIRE set out to develop a new germanium-rich silicon integrated photonics platform for the detection of molecular fingerprints. As principal investigator Delphine Marris-Morini explains, “it exploits the advantages of silicon photonics technology, including maturity, large-scale fabrication and strong light confinement. It also takes advantage of the wide transparency window of germanium up to 15 µm. In comparison, silicon oxide is transparent up to 3.8 µm and silicon up to 8 µm.” This wide window of transparency means the optical materials used do not absorb and reflect light in this range so they do not impede its propagation. The monolithic integrated photonics design reduces the space required, resulting in a fingerprinting system-on-chip that fits on your fingertip.

You say you want a revolution

INsPIRE evaluated the optical properties of the envisioned platform and developed a new set of optical functions. Moving into uncharted territory, Marris-Morini recalls: “We realised the equipment we needed to test our mid-IR devices was much less developed than for near-IR wavelengths, where telecommunications applications have spurred innovation. We had to build our own wideband polarisation rotator and often bought prototypes or devices that were freshly commercialised.”

In the end, the team did in fact change the world of mid-IR spectroscopy, an evolution resulting in several world firsts with resonant structures operating in the 8 µm-wavelength range: integrated mid-IR Bragg grating-based Fabry-Perot resonators, broadband integrated racetrack ring resonators, and a high-resolution broadband mid-IR silicon-germanium Fourier-transform spectrometer. Although development of mid-IR optical modulators was not planned at the beginning of the project, the team achieved yet another record, the first optical modulation in a mid-IR photonic circuit operating in the 5.5-11 µm wavelength range.

Integrated mid-IR photonics for widespread application

Marris-Morini summarises: “By pushing the frontiers of what was possible, we have built high-resolution on-chip mid-IR spectrometers working in an ultra-wide frequency band (in principle 1.5-15 µm) on a circuit less than 1 square centimetre in surface area.” The technology paves the way to portable and low-cost sensors for applications from real-time environmental monitoring of pollutants to food safety to early medical diagnoses.
Keywords

INsPIRE, mid-IR, photonics, wavelength, molecule, optical, molecular, spectrometer, silicon, fingerprint, spectral, spectroscopy, platform, resonator, infrared, monolithic integration, germanium, system-on-chip, waveguide, refractive index

Project Information

INsPIRE

Grant agreement ID: 639107

Project website

Funded under
H2020-EU.1.1.

Overall budget
€ 1 498 125

EU contribution
€ 1 498 125

Hosted by
UNIVERSITE PARIS-SACLAY

France

This project is featured in...

RESULTS PACK

Light years ahead: EU research and innovation projects show how photonics will shape the future

26 February 2020

Discover other articles in the same domain of application
Network of artificial reefs provides valuable data for monitoring ocean ecosystems, including early detection of non-indigenous species

4 December 2020

Save-the-date for the online ASSEMBLE Plus Conference

30 September 2020

The evMANIFESTO released

24 February 2020

Last update: 24 February 2020
Record number: 413543


© European Union, 2020