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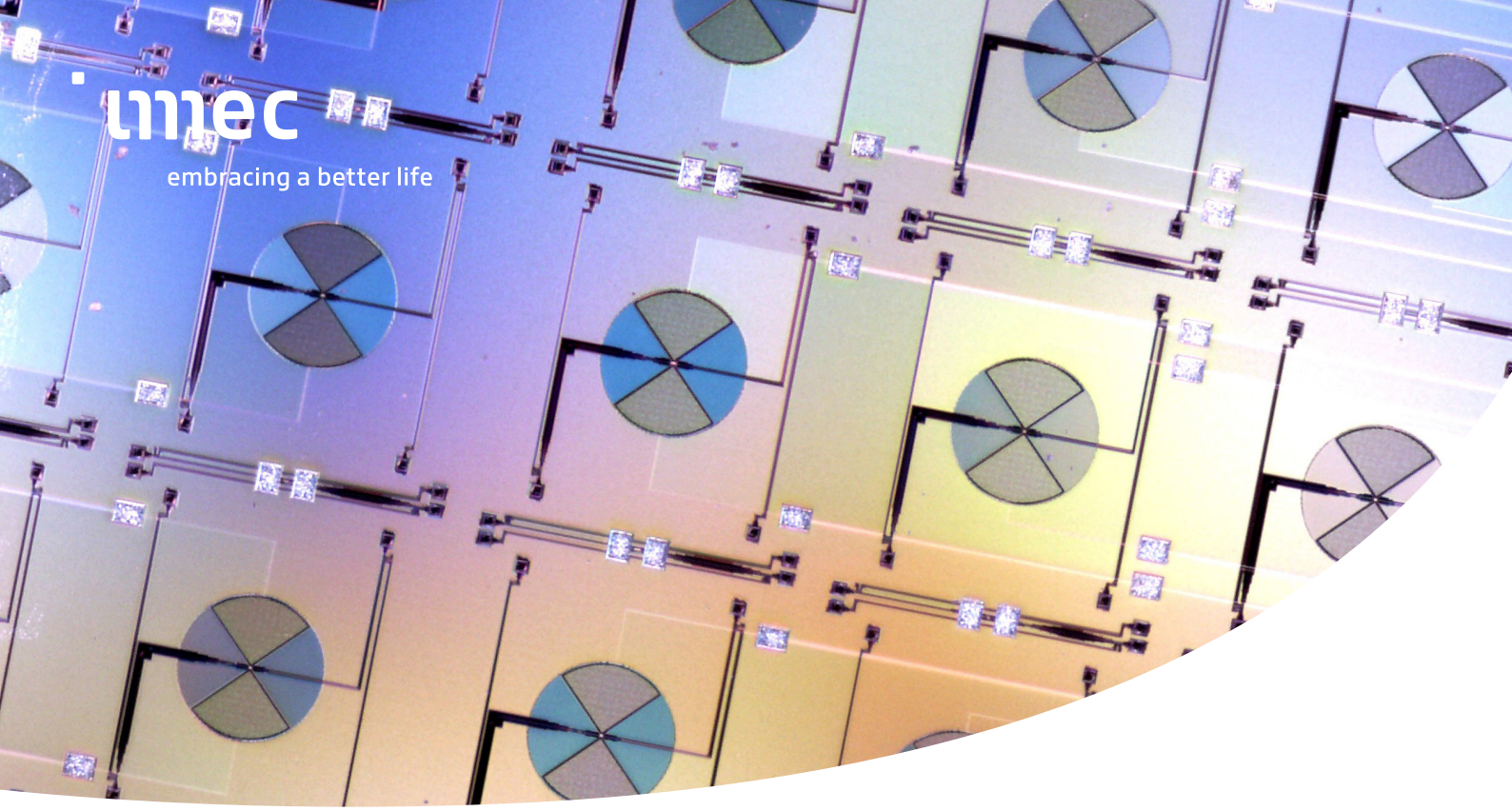
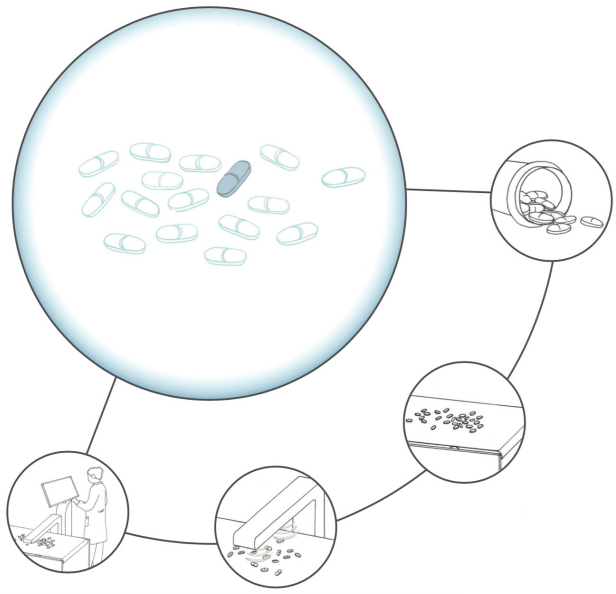


SILICON PHOTONICS-BASED COHERENT HYPERSPECTRAL TERAHERTZ IMAGING

Low cost and a high level of integration are imperative for the breakthrough of THz technology into new application domains. To bridge the so-called THz gap, i.e. the frequency range between 300 GHz and 3 THz, systems based on photomixing are of special interest. These systems make use of laser(s) to generate and detect frequencies that span the entire THz gap, enabling for example high resolution THz spectroscopy or in depth-probing of opaque materials down to the micrometer scale using ultra-short THz pulses.



TERAHERTZ IMAGING ON CHIP

Current state-of-the-art spectroscopic THz systems are based on III/V devices and typically comprise single-pixel systems that offer active THz imaging only by raster-scanning. Such systems have already found niche applications in industry, for example in the pharmaceutical industry where they are used for drug quality control and chemical identification.

For the breakthrough of THz technologies in other application domains, such as stand-off detection or non-destructive industrial imaging, however, the realization of dense emitter and detector arrays is needed, which is currently impeded by the high cost of integration of III/V devices.

Imec offers a silicon photonics-based solution that entails the low-cost integration of photonic components developed for telecommunications to achieve the needed functionality in the THz domain. Specifically, dense arrays of THz emitters and detectors can be realized by coupling germanium photodiodes and photoconductors to antennas and waveguides integrated within the SiPho platform. Moreover, by employing photonic circuits, advanced features such as THz beam steering and phase contrast imaging can be realized on-chip.

ACHIEVEMENTS AND OUTLOOK

- Imec has successfully demonstrated continuous wave THz generation up to 2.2 THz using antenna-coupled silicon-integrated germanium photodiodes.
- Very recently we have also shown THz detection up to 600 GHz using integrated germanium photoconductors, and are working towards increasing the detection range.
- Furthermore, we have extended our THz emitters with on-chip phase modulators that allow coherent (phase sensitive) imaging without the need for expensive and bulky external components.
- Using these integrated phase modulators we are currently characterizing our first phased THz arrays for THz beam-steering.
- Finally, we are working on the integration of low-cost CW 1550 nm laser diodes and amplifiers on-chip. We aim to demonstrate these external cavity lasers as low-cost sources for THz photomixing.

KEY BENEFITS

- Coherent detection with high signal-to-noise ratio (SNR)
- Both amplitude and phase information
- Spectrally selective imaging
- Tunable THz source through beam-forming
- High frame-rate imaging
- Portable and low-cost.

APPLICATION DOMAINS

1. Industrial applications

The non-ionizing features of THz waves allow to penetrate many materials, making the technology suitable for non-destructive testing in a number of industries:

- Concrete inspection (defects, corrosion on reinforcing bars, water diffusion, cracks)
- Surface corrosion in shielded copper conductors
- Ceramic tile adhesion detection
- Mechanical deformation of polymers
- Insulation in buildings and space stations
- Building inspection

2. Medical applications

The non-ionizing nature of THz waves also makes it a much safer alternative to the use of X-rays for medical imaging applications; and it comes with some additional benefits:

- Cancer imaging: the distinct absorption and refraction lines within the 0.5 – 1.5 THz range of cancer tissue makes THz technology ideal for cancer imaging.
- Dental imaging: the non-ionizing features of THz technology enable a regular, fast, non-invasive scanning of the teeth with the use of a portable dentist probe, allowing for early detection of tooth decay during regular medical appointments.
- Multi-spectral THz colonoscopy: THz technology can be combined with the traditional camera approach for both a visual and multispectral THz examination, enabling the inner layers of the large intestine to be visualized as well.

3. Cosmetic applications

THz imaging can be used to measure tissue hydration, melanin content, hemoglobin levels.

4. Agriculture and food

The distinct absorption lines within different ranges of the THz spectrum of different pesticides and other organic materials make THz technology ideal to detect their presence in soils and food. The fact that water is opaque to THz radiation also allows for detection of their hydration levels.

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