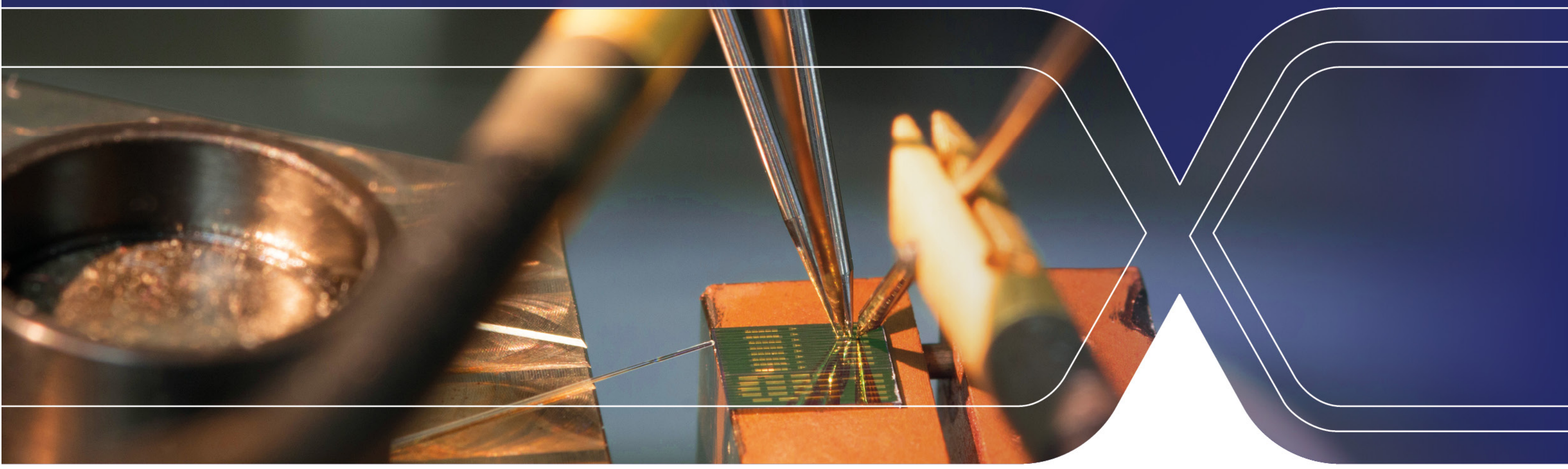
Application Note
THz Generation Using Integrated Photonics

JePPIX
Platform for Photonic Integration



THz Radiation

Terahertz (THz) technologies are attracting a great deal of interest, given the wide range of the THz radiation's applicability. Security screening and imaging at airports is just one of the better-known examples, taking advantage of the nondestructive testing capabilities of THz radiation. When referring to THz radiation, one commonly refers to the electromagnetic spectrum in the frequency range from 0.3 THz to 10 THz. These frequencies show unique characteristics, i.e., they are non-hazardous, allow high-contrast imaging of dielectrics (compared to X-ray imaging) and provide a higher resolution than microwaves[1]. Beyond the sensing, spectroscopy, non-destructive testing and medical diagnosis capabilities, THz radiation could revolutionize wireless communication, providing huge bandwidth for high speed wireless transmission. Estimated transmission speeds could lie in the tens to hundreds of Gb/s-range[2].

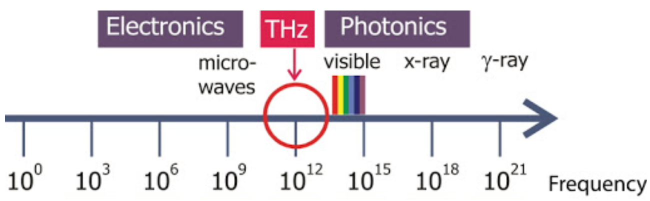


Figure 1: Electromagnetic spectrum with the THz radiation located between the visible light domain and the microwave domain, from [3].

InP Photonic Integrated Circuits (PICs)

Optical chips or PICs can contain tens to hundreds of optical components. While electronic integrated circuits (EICs) consist of transistors, capacitors, and resistors, a PIC consists of, for example, lasers, modulators, photodetectors, and filters, all integrated on a single substrate. Several application fields, such as data- and telecom, sensing, and lidar are already using or are considering the use of PICs for their products. This PIC technology is accessible to users without a cleanroom, through so-called multi-project wafer runs and open access foundries. InP based technology is commercially available through SMART Photonics and Fraunhofer Heinrich-Hertz-Institut. Access is individually coordinated by JePPIX.

In this context, photonic integration offers the attractive advantage of its compatibility with fiber-optic communication networks, promising seamless integration with this already existing infrastructure[4]. Full integration of THz systems will further enable reduced size, and low-cost manufacturing, overall providing a scalable and easily deployable solution for ubiquitous applications. THz photonic integrated sources use various different material platforms and integration strategies.

[1] https://doi.org/10.1007/s10762-019-00639-4
[2] https://doi.org/10.1109/JPHOT.2016.2580940
[3] http://www.thzscience.nl/THzFAQ.php
[4] https://doi.org/10.1038/s41566-019-0475-6

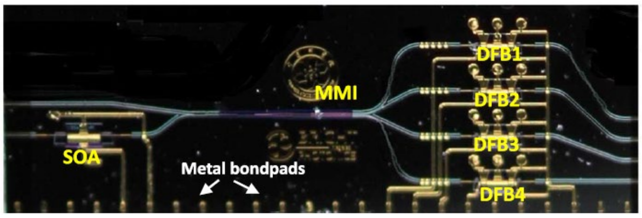


Figure 2 (a) Layout and (b) microscope view of the monolithically integrated THz PIC optical heterodyne[2].

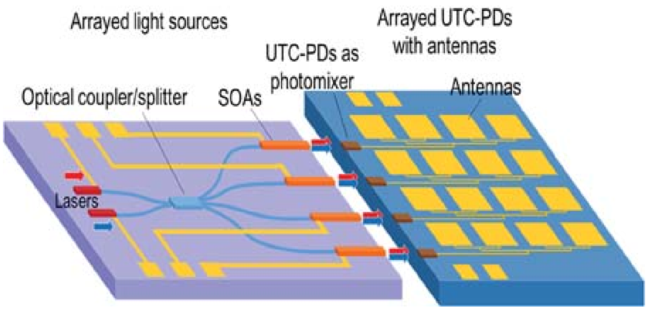


Figure 3 Schematic view of arrayed light sources and arrayed UTC-PDs[8].

THz Radiation Generation

Hybrid silicon photonic solutions often use mm-Wave generation schemes, pushing operation into the THz frequency regime[5]. More complex, heterogeneous material platforms have successfully demonstrated THz quantum cascade lasers showing the potential for high-power operation[6]. Yet, monolithic integration schemes using the Indium Phosphide (InP) photonic integration circuit (PIC) platform can reduce cost and size, while increasing system reliability and tuning range of the THz source. Additionally, the integration on the same substrate exposes the devices to the same environmental fluctuations reducing noise figures. Generic, open-access InP PIC technologies allow monolithic integration of the photonic building blocks required for on-chip THz generation, like distribute Bragg reflector (DBR) lasers, distributed feedback (DFB) laser diodes, optical amplifiers, multimode interference couplers, and even uni-traveling carrier photodiodes (UTC-PDs)[2].

Optical Heterodyning

Optical heterodyning is one promising method to realize monolithically integrated THz sources. It is attractive because of its compactness and operation at room temperature. This technique can use multiple integrated tuneable Distributed Feedback (DFB) lasers, which can be integrated side-by-side with on-chip light combining elements or in-line separated by a phase modulator[5], or dual-mode tunable lasers[2]. Mixing the two optical signals or modes, separated by a few nanometers in wavelength, on a photoconductive device, generates the THz signal at the difference frequency. DFB lasers are particularly suitable sources, providing large tuning ranges up to 200 GHz and narrow optical linewidth around 1 MHz[5]. The narrow linewidth of the generated THz signal in the MHz range allows high-resolution spectral imaging and highly resolved spectroscopy needed for, e.g., low-pressure gas detection[7].

THz beam forming

Especially for wireless communication and data transmission applications, targeted THz transmission is required between sender and receiver. Photonic integration offers optical beam forming without physically moving parts by using phased array antennas. One recent demonstration of arrayed photomixers, which are addressed by an array of integrated light sources, is shown in Figure 2, achieving generation and beam forming of 0.6 THz radiation[8].

Discuss your application with us

If you are interested in knowing more about the capabilities and use of InP PIC technology for THz applications, contact JePPIX. The JePPIX Pilot Line provides low entrance-threshold to mature-manufacturing, enabling high-TRL development in a scalable design kit driven process, taking open access InP PICs from proof of concept to industrial prototyping levels.

[5] https://doi.org/10.1109/JLT.2014.2321573
[6] https://doi.org/10.1088/2040-8986/abc312
[7] TOPTICA: Laser-based terahertz generation & applications
[8] Y. Kim, K. Kato, 600-GHz Wave Generator Consisting of Arrayed Light Sources in Combination with Arrayed Photomixers, ECOC 2020, Th2G-1