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Innovating THz Detectors: Unmatched Sensitivity at Room Temperature, Infinite Possibilities

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Summary: We have developed monolithically integrated THz detectors that operate at room temperature, covering a frequency range from 100 GHz to 1500 GHz with exceptional sensitivity and speed. These detectors are scalable to larger arrays, enabling the realization of THz imaging systems that were previously unattainable. In this paper, we present the THz detectors and a prototype THz scanner developed as a technology demonstrator, showcasing the groundbreaking capabilities of this innovative technology.

Keywords: monolithically integrated THz detectors, THz direct detectors, TeraFeT, THz scanner, THz camera

Introduction

The frequency range from 100 GHz to 1.5 THz offers unique opportunities for a wide range of applications. THz waves in this frequency range can penetrate non-conductive materials such as plastics, fabrics, and ceramics while being non-ionizing and safe for biological tissues and in industrial environment. These properties make THz technology particularly promising for material inspection, medical diagnostics and security screening.

THz direct detectors, which convert THz waves directly into DC electrical signals, play a crucial role in enabling real-time, high-resolution imaging systems without the need for complex intermediary steps [1]. Unlike other approaches, direct detectors eliminate the necessity for local oscillators.

Current THz detector technologies primarily use Schottky diodes, though their scalability to large arrays remains limited and 2D arrays are yet to be realized. Transistor based THz detectors have also been widely explored using CMOS, GaN HEMT and InP HBT devices [2, 3, 4]. Existing focal plane arrays have been realized by the authors using GaN technology [5] and other groups relying on Silicon [6], but their limited sensitivities lead to long image acquisition times and time-integration, significantly reducing readout speeds. Passive THz imaging [7] shows limited potential due to extremely long acquisition times of several hours and mechanical scanning, which is undesirable for many applications.

Highly sensitive and monolithically integrated detector arrays are essential for improving image quality and achieving faster scanning of broader areas. Image resolution of such detector arrays is dictated by the distance between the individual detectors on the chip. Large-scale detector array chips allow real-time imaging of larger areas and hence avoid complicated mechanical scanning, making such THz imaging systems suitable for real-world applications.

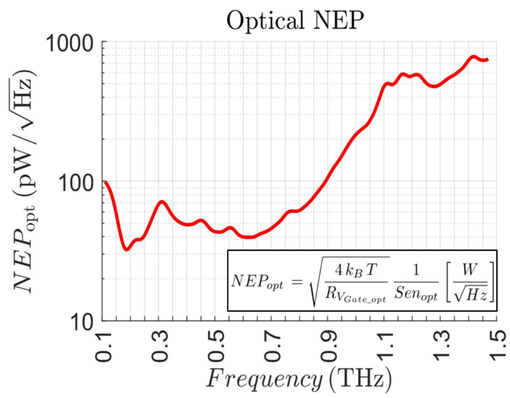

Fig. 1: Noise equivalent power (NEP) of a single detector

THz detector arrays

Figure 1 shows a single detector's outstanding noise equivalent power (NEP). The THz scanner line is made of up to 80 of these detectors. The line is 6 cm long and comprises 20 individual chips. Figure 2 shows the image of the line with the magnification of one chip. The distance from the center to the center point of the detectors is 640 µm. The patented array design of the detectors [8] avoids crosstalk to neighboring structures.

THz scanning system

The THz line scanner demonstrator operates at 300 GHz with a source power of 10 dBm illuminating an area larger than the THz detection array of 80 THz detectors each with a transimpedance amplifier providing a gain of 4 $M\Omega$

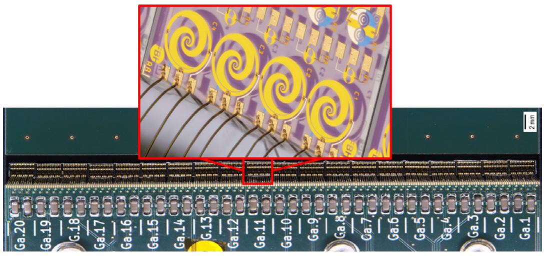

Fig. 2: THz scanner line; chip with 4 THz detectors per chip

and an analog-to-digital converter with 16-bit resolution and a sampling rate of up to 15,000 lines per second. The conveyor belt with a width of 27 cm is arranged between the signal source and the detectors with operating speeds of up to 1.5 m/s. The readout speed, determined by the electronics and system structure, can reach 2 GHz, with all detector pixels operating in parallel. This configuration enables efficient and high-speed data acquisition, making the setup ideal for real-time, high-resolution imaging. The figure shows a photo of 5 stacked Lego plates and the THz image generated by the THz scanner. The image presented in Figure 3 was captured in real-time on the conveyor belt. Each step of the stacked Lego plates can be identified due to increasing attenuation with plastic thickness. The small individual bumps, typical for Lego, can also be identified.

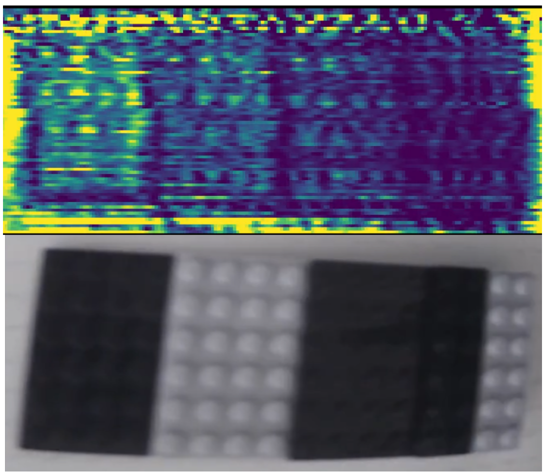

Fig. 3: Image of stacked Lego bricks and THz image, generation speed ¡ 1 s

Conclusions

The THz detectors and arrays presented here pave the way for the development of THz imaging systems that were previously unattainable, due to enhaced sensitivity and signal processing speed. To showcase these capabilities, we have constructed and demonstrated a real-time THz scanner. Videos of some scanning objects will be presented during the show.

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