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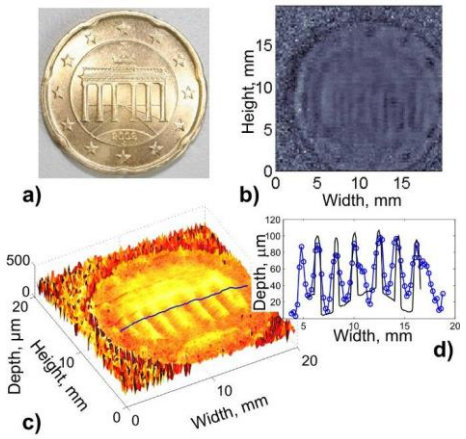
New developments in the terahertz Frequency Range

The terahertz (THz) frequency range is one of the last under-explored ranges of the electromagnetic spectrum. Nowadays the THz range is becoming more and more accessible due to the recent development of efficient detectors and mixers.

Interestingly, the THz frequency range has multiple advantages compared to other frequency ranges of the electromagnetic spectrum. For example, THz radiation can penetrate many optical non-transparent materials. This property is very intriguing in terms of applications for medical, safety or food technology (see page 2). Thus, the further development of THz technologies is very promising and can lead to a vast amount of future mass market devices.

Researchers of Goethe University Frankfurt am Main developed efficient and cost-effective detectors and a mixer for the THz frequency range. These components can be utilized to manufacture large area imagining sensors for the THz frequency range, based on the Silicon CMOS technology.



Elevation profile of a 20 cent Euro coin recorded with a CMOS-push broom scanner.

Silicon CMOS-push broom scanner with a subharmonic detector

A subharmonic detection concept involving CMOS field-effect transistors can used for 3D imaging. Utilizing the superheterodyne principle a feasible 3D imaging with 6 pixel detector arrays can be achieved. Compared to conventional detection devices the sensitivity is increased by 10 dB.
This camera marks the first use of THz technology in main stream process engineering of semiconductor electronics.
The camera offers a high reproducibility, small parameter variations and a low error rate within silicon process engineering. Read and evaluation strategies can be directly applied from established CMOS and CCD cameras. An additional advantage is the direct assembly of data reading and processing components on the detector chip. Due to the mass production of silicon chip technology it can be expected that the cost per detector unit will decrease enormously for larger quantities.

THz technology

In the following we present the key components, such as detectors and a subharmonic mixer, which underlie the technology of the CMOS push broom scanner.

Antenna I

A newly developed detector is based on an antenna structure which is arranged together with at least one field effect transistor on a single substrate. The detector serves in particular to capture the power and phase of THz waves.

The antenna structure and the field effect transistor are connected in such a way that an antenna-received signal in the range of THz frequency is fed into the field effect transistor via the gate-source contact.

Here, the integration of the antenna structure and of the field effect transistor provides a high integration density. Moreover the corresponding

short or non-existent distance between the field effect transistor and the antenna structure avoids transport-losses during the transmission of signals.

Patents have been granted in Germany (DE102007062562.8), the United States of America (US8,330,111), Canada (CA2,710,450) and Japan (JP5401469). A European patent application (EP08865626.9) is pending. Owner of the IP rights are the Goethe University Frankfurt am Main and the University Siegen.

Journal of Applied Physics - Antenna I

Antenna II

This new improved detector serves for the detection of electromagnetic radiation in THz frequency range. Thereby, the invention provides both increased detection efficiency and more flexibility in the circuit design. Moreover it provides an improved robustness.

Due to the novel arrangement of antenna and transistor additional components, like protection diodes are no longer necessary. Protection diodes are usually needed to prevent the generation of charge during the manufacturing process of similar circuits. Therefore, modulation and operating frequency are not limited.

Additionally, the arrangement leads to the possibility to utilize the antenna as a low pass filter. This makes additional transmission elements redundant and further reduces transmission loss.

Patents have been granted in Germany (DE102011076840.8), the United States of America (US9,508,764), and Japan (JP5930494). A European patent application (EP12726084.2) is pending. Owner of the IP rights is the Goethe University Frankfurt am Main.

Electronics Letters - Antenna II

Subharmonic mixer

The new subharmonic frequency mixer is based on standard semiconductor technology. It is used to generate a mixed signal from frequencies in the submillimeter and the THz range.

This new cost-effective mixing concept allows for an increased sensitivity compared with direct detection of high-frequency signals. Therefore, it is suitable for power measurements, distance sensors, cameras, tomography devices as well as in the high-frequency communication technology.

Patents have been granted in the United States of America (US9,190,956), and Japan (JP6084921). A European patent application (EP11721283.7) is pending. Owner of the IP rights is the Goethe University Frankfurt am Main.

IEEE Sensors Journal - Subharmonic mixer

Applications

The newly developed detectors and mixer are intriguing for a vast amount of applications.

Medical engineering

THz technology is opposed to x-ray technology non-hazardous for human tissue. With the aid of THz devices the water content of a human body can be measured. This is very useful for example to distinguish between a tumor and healthy tissue.

Non-destructive material testing

Spatial THz spectroscopy can be utilized to check a material for internal defects. Materials such as pottery and synthetics are penetrated by THz radiation. On the contrary THz radiation cannot penetrate water and metals. This property can be used to locate inclusions of water or paint within a material without destroying it.

Security technology

The same principles which are used for non-destructive material testing can be applied to security technology as well. THz technology is already deployed in body scanners in airports or the examination of mail.

Spectroscopy

THz radiation is an excellent tool to analyze materials and molecules. In many cases the THz spectrum yields in characteristic absorption bands. Additionally, it is possible to capture 2D and 3D images.

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The technologies can be licensed or assigned. Moreover, collaborations regarding further development are welcome.

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