Terahertz-Electronics with Particular Reference to Security Applications

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Electromagnetic signals at Terahertz frequencies have the advantage that their photon energies are in the low milli-electronvolt range and therefore not capable of breaking up organic molecules of living cells. Therefore they have been considered for many applications such as airport surveillance. These scanners can detect metals such as those of weapons hidden under clothing from a distance of several meters, without exposing the persons to harmful radiation. THz spectroscopy is used to characterize many materials, including packaging, explosives and drugs. A recent application has been to characterize single-wall nanotube thin film electrodes. In another approach, using a separate pump beam to excite charge carriers in a material shortly before the THz analysis is carried out, information about ultrafast carrier dynamics may be obtained. A recent example of such time-resolved THz measurement deals with poly (3-hexylthiophene) and methanofullerene blended films.

THz radiation can pass through clothing and packaging, but it is strongly absorbed by metals and many other inorganic substances. THz sources use a number of basic techniques, namely either harmonic extraction from the mm-waves or using various methods from the optical signals. The possibility of deep-infrared lasers by quantum-cascading reaches the low THz frequencies of interest only by cooling to liquid nitrogen or below.

Here then several approaches are described as developed by the research team of the author and his international research partners, together with an assessment of the capability for wide-spread applications, in particular in the biological field. Of course a decision is made here to not base the approach on such techniques as quantum cascade lasers, where low-temperature usage appears to be required for the generation of lower THz frequencies as needed for the security issues under consideration.

The development of THz power sources out of laser mixing is a primary interest. This concerns non-linearity effects with various types of materials or with semiconductor structures, which initially need to be simulated by using permissible approximations. An important issue is the handling of waste heat in electronic structures introducing new ideas of heat sinking.

The illumination of individual mixers of an array is undertaken by fibres from the output of two lasers operating at the difference frequency of the THz signal to be generated. The mixer array needs to be composed of mixers which are separated from each other by distances as required for good heat sinking. Such schemes are designed by us now on the basis of a heat-conducting thick metal grid. The THz antennas coupling out the electromagnetic waves are designed by us such that a narrow main lobe with only minimal side arms occurs.

Work was undertaken towards a photonic Vector Network Analyzer for THz heterodyne phase-coherent measurements. This is based on the combination of a continuous wave (CW) THz photonic transmitter and a CW THz photonic front-end receiver that serve as THz interface extensions for a radiofrequency Vector Network Analyzer (VNA). The proposed PVNA would be able to perform measurements in the THz range, where both magnitude and phase are directly measured, eliminating all the delays associated with typical time-domain schemes, by adding phase control and measurement to existing photonic THz heterodyne receivers. The proposed scheme makes use of commercial, low cost components to achieve a compact and cost-effective system. This approach is the first scheme for vectorial measurements of THz radiation using a photonic approach for both generation and detection, combining in a single scheme the RF, THz and optical frequency regions. This study was presented at the European Microwave Week in Amsterdam.

Imaging techniques are important issues towards the realization of a THz camera. To obtain Continuous Wave (CW) operation the main issue is power handling via suitable heat sinking strategies. Regarding a maximization of THz illumination, a new design structure and a first experimental approach is introduced by using Nitrogen implanted GaAs (N+i GaAs) material as a photoconductive material. The issue of CW operation requires careful heat transfer designs. Here a study is presented regarding multiple source interconnections in a matrix structure. This is aimed at broad illumination schemes.

The image detection is then based on an array of photoconductive antenna heterodyne receivers illuminated with two phase-locked optical wavelengths obtained from an Optical Frequency Comb Generation (OFCG) for CW operation. This architecture allows for an efficient, phase controlled, Local Oscillator (LO) distribution with low losses intrinsic to the use of optical fibers, as well as amplitude and phase recovery due to the coherence of the LO distributed. Tunable operation is achieved using the different lines of the OFCG and broadband design for the photoconductive antenna.

A design involvement concerns the opportunities of nanometric electronics. The assessment of the fabrication techniques are to be studied.

THz fingerprints of explosive gases and materials is under study worldwide. The absorption spectra of dangerous compositions are widely identified nowadays. Many of the studies are to be reviewed, particularly the efforts of the group of the speaker.