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Terahertz Emitters, Receivers, and Applications VIII

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Introduction

Why do we need THz and where are we now?

The terahertz (THz) spectral range (1–10 THz) is bridging the gap between the visible/infrared photonics and the high frequency electronics, where both disciplines are stuck by their marginal issues. The characteristic feature of THz waves is their ability to penetrate through dielectric materials, such as plastics, ceramics, wood or textiles, which gives a possibility for nondestructive examination highly demanded for security systems and other remote control equipment. Moreover, they can be used for identification of hidden substances because many materials exhibit specific absorption features at THz frequencies. The THz radiation is especially attractive for analysis of biological objects since, due to its small photon energy, it does not modify the inspected item and is therefore absolutely safe. Besides the unique features of THz imaging this technology offers new horizons in communications. Compared with existing standards, a much larger bandwidth, ranging from tens of GHz up to several THz depending on the transmission distance, can be achieved in this frequency region. Realization of the high potential of the THz technology requires adequate instrumentation: radiation sources, detectors, and relevant components such as lenses, mirrors, filters, coating, modulators, etc. This conference deals with a wide range of topics covering all the issues related to the THz waves, from theory to components and applications.

A source of radiation is the main component of any spectroscopic or communication system. THz sources can be organized as pulsed or continuous (as for the operation), narrowband or broadband (spectral coverage), coherent or incoherent (radiation properties), or the working principle. Sources generating THz (directly) via oscillation in electronic (solid-state based or vacuum-based) or in optical devices (e.g. lasers) are denoted as direct. On the other hand, sources generating THz via nonlinear mixing or conversion of electromagnetic pump waves in a nonlinear medium or in medium with accelerating electrons are called indirect.

Vacuum electron devices are the most ancient emitters of THz radiation. Such sources are still widely used in research laboratories due to the high power and room temperature operation. A backward oscillator emitting up to 1 W of THz optical power was presented at the conference. This paper (SPIE number 10383-2, Gamzina, et al) describes the outstanding technological effort to design and realize a backward wave oscillator with 0.346 GHz operating frequency to be employed in fusion plasma diagnostics. However, due mainly to the large footprint, the vacuum electron devices are not well suited for commercial use. Realization of on-chip, compact and mass producible THz sources will lead this technology to make a widespread social impact.

Quantum cascade lasers (QCLs) are partially filling the THz gap of coherent sources, although cryogenic cooling and very limited tunability have restricted the number of spectroscopic applications. Room temperature operation is one of the main characteristics required in semiconductor lasers for mass scale applications. Unfortunately, THz QCLs have not yielded the room temperature action yet. The maximum operating temperature reported till date is ~200 K for pulsed operation and 129 K for CW operation without using strong magnetic field. On the other hand, it is possible to fabricate RT THz emitters based on difference frequency generation (DFG) exploiting built-in nonlinear properties of mature high power mid-IR QCLs. This approach has been successfully employed by the Center for Quantum Devices directed by Prof. M. Razeghi in Northwestern University to demonstrate the best-to-date QCL-based THz sources operating at room temperature. These DFG-QCL THz emitters exhibit RT optical powers up to 2 mW in pulsed mode and 14 μW in the continuous wave regime. Such sources, as well as their application for frequency comb spectroscopy, have been reviewed in the keynote paper of Prof. Razeghi.

Compact solutions for spectroscopic solid-state based THz imaging systems are considered in several conference papers. To achieve compact and robust devices, a wide range of III-V semiconductors based materials for 1.55 μm THz photoconductive switches have been grown and optimized using various approaches by a research group from the University of Delaware. Relevant properties for the state-of-the-art materials for these devices including bandgap energy, dark resistance, carrier mobility, and carrier lifetime are discussed in this paper. Another paper on compact components for THz imaging is presented by the Center for Physical Sciences and Technology (Vilnius, Lithuania). Pulsed THz emitters based on a δ-doped p-i-n-i GaAs/AlxGa1−xAs heterostructure, on-chip integrated elements of diffractive optics and bow-tie-shaped InGaAs-based THz detectors were demonstrated and employed for direct and homodyne imaging of low absorbing objects.

Despite the fast advance in recent years, the potential of THz technology is still under-exploited due to the lack of practical devices for generation and detection of THz waves. We hope that the conference stimulates progress in this field and some new idea how to make THz technology as efficient and easy to use as near infrared one can be found in this volume.

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