



Terahertz Technology: An Introduction

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Abstract Terahertz technology is an exciting area of research for those interested in high frequency electromagnetic systems and related disciplines. This paper presents an introduction to terahertz technology and its applications. The goal of the paper is to acquaint engineers and scientists to this emerging field.

Keywords terahertz technology

Introduction

The new field of terahertz technology is attracting much attention. The terahertz region (from 100 GHz to 10 THz) of the spectrum lies on the border of where electronics and optics meet, i.e. between microwaves and infrared bands (light). Until about two decades ago, the terahertz region has been unexplored and unutilized [1]. The term “THz gap” was coined to indicate the underdevelopment of this portion of the electromagnetic spectrum; there were no efficient sources and detectors available, in contrast to the neighboring microwave and optical domains.

Terahertz radiation, also known as submillimeter radiation or T-rays, consists of electromagnetic waves in band of frequencies from 0.3 to 3 THz (1 THz = 10^{12} Hz). The corresponding wavelengths of radiation range from 1mm to 0.1mm in vacuum. The terahertz is growing rapidly into several independent fields: THz waves, THz electronics, and THz photonics.

Sources and Detectors

Although there are many ways of generating THz signals, THz sources can be classified as pulse and continuous-wave (CW) sources. The pulse sources generate THz signals using femtosecond lasers. Two common methods are used for broadband terahertz pulse generation: (1) transient photocurrent excitations, (2) optical rectification in a nonlinear crystal. Both methods utilize femtosecond lasers. A backward wave oscillator is used in generating CW waves. The aim is to generate a continuous wave having constant amplitude. A CW terahertz system can be developed by heterodyning two lasers in a photomixer. Compared with THz pulse imaging, CW THz imaging techniques allow fast scanning.

Field detectors respond to the THz electric field and usually generate an output voltage or current through a quadratic term in the current-voltage characteristic. A more recent THz detection mechanism is based on plasma-wave propagation and rectification [2]. All THz detectors can be described by two performance metrics: noise-equivalent power (NEP) and noise-equivalent temperature difference (NETD). Compact THz sources and detectors have been developed to generate, detect, and manipulate THz signals.

Applications

The terahertz technology is relatively new area both in research and applications. This is due to the fact that it provides unprecedented bandwidth and opportunities for completely new applications. Each time a new band in the electromagnetic spectrum opens up, a whole new set of applications and research opportunities develop around that band. Terahertz technology has applications in short-range communication, explosives detection, quality control of food and agricultural products, drug analysis, global environmental monitoring, medical diagnosis, security, sensors, etc. [1,3,4].

(1) *Space Applications:* Astronomy and remote sensing of the earth’s atmosphere have provided an incentive for the development of THz technology. Prior to the boom in communications, the major interest in



terahertz technology lay almost exclusively with radio astronomy. This mainly involves the detection of terahertz signals.

- (2) *Spectroscopy*: Terahertz technology has enabled the creation of specialist equipment such as the terahertz time-domain spectroscopy (THz-TDS), which has been shown to be able to obtain images of samples that are opaque in visible region of the spectrum. THz time-domain spectroscopy has been constructed with optical THz source and detector. This unique spectrometer utilizes powerful laser sources. It is a new powerful tool for measuring in the terahertz region. It can be used to investigate multilayer specimens [5]. An example of a THz-TDS is shown in Figure 1.

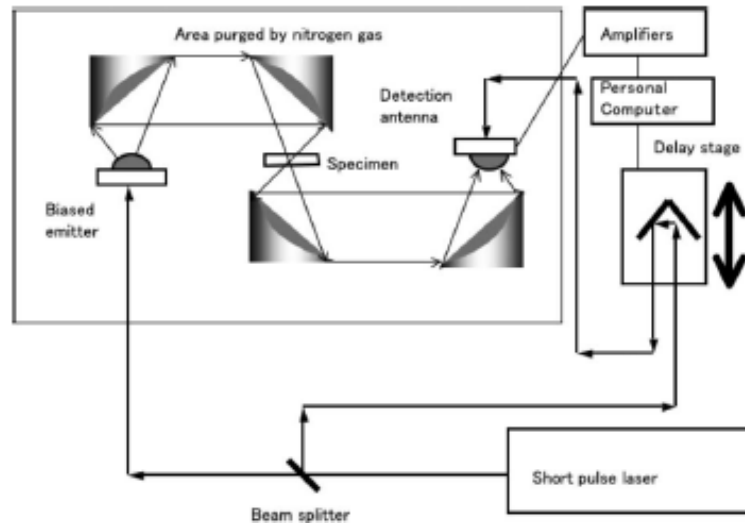


Figure 1: A typical example of terahertz time-domain spectroscopy (THz-TDS) [5].

- (3) *Biomedical Applications*: The fact that THz radiation does not damage materials makes THz imaging useful in the biology/medical field. In other words, THz radiation is non-ionizing and therefore safe for biomedical sensing and imaging. As a promising detection technology, THz technology provides a reliable means of diagnosing breast cancer and skin cancer. The attenuation of THz radiation for the human body and the signal-to-noise ratio of the radiation are important factors used in determining the penetration depths of THz radiation. It is hoped that THz medical equipment will be operated in hospitals in the near future.
- (4) *Semiconductor devices*: Terahertz technology has demonstrated viable device and circuit technology for communication applications. An interesting aspect of the terahertz research is the development of transistor technology for this region. Electrical properties of semiconductor devices, such as mobility, conductivity, and carrier density, can be precisely characterized by transmitting THz imaging configuration.
- (5) *Communication Systems*: The rapid demand for higher bandwidth and data rates in wireless communication. THz wireless communication involves using THz waves as the free-space carrier of data. The major advantage of THz communication systems compared to microwave systems is that of higher bandwidth [6]. THz radiation can penetrate dielectric materials, including plastics, ceramics, crystals, and colorants, allowing it to be applied in tomographic imaging.

Conclusion

Difficulty in generating and detecting terahertz radiation continues to plague most applications. This restricts terahertz applications to exploratory and scientific investigation. Efforts geared toward the implementation of terahertz applications are unbounded. Terahertz sources and detectors have been developed to generate and detect terahertz signals. Terahertz sensing and imaging systems are now commercially available.

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