Software Implementation of THz Detection & Spectroscopy

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Abstract - Terahertz (THz) radiations have found importance in the various fields of science and technology. Its frequency band ranges from 100GHz to 10THz, and is often regarded as the most scientifically rich regime of the electromagnetic spectrum. The former limit of the THz frequency spectrum lies just above the microwave region, whereas the latter limit is located adjacent to the infrared frequencies. Thus, the THz regime is a fusion between microwaves (electronics) and infrared light (photonics). Imaging techniques based on THz radiations have gained a worldwide acceptance. The major barrier or limitation in achieving THz imaging is the expense of conducting experiments. A virtual platform will certainly help in this situation so that the expense in conducting experiments in THz regime can be reduced to a great extent. This paper presents a virtual platform; that is a software implementation of THz detection and spectroscopy. Previous works regarding this had proved that inexpensive THz detection can be achieved using miniature Neon lamps as detectors. Development of an FPA using such detectors is advantageous in cost and image quality. An attempt to demonstrate or simulate the detection mechanism in a suitable software platform has done. Also a terahertz imaging system was built from commercially available hardware whose functionality was integrated through home-made software. The core of the system is based on terahertz time domain spectroscopy; a technique in which terahertz radiation is generated and detected by optically gating an emitter and detector respectively. There is a need to design an interface board to connect the FPA board with a digital system. Image reconstruction has to be done through a software platform after the acquisition of pixel values.

Key Words**:** THz Radiation, Detectors, Focal Plane Array

1.INTRODUCTION

A THz is 1012 Hz, a measure of frequency; that means, each cycle is one picosecond, and the wavelength in free space is roughly 300µm.

Radiations sent at terahertz frequencies usually travel in line of sight. These wavesare in a waveband that is the overlap of what is normally regarded as microwave radiation and photonics waves. The earth's atmosphere is a strong absorber of terahertz waves, so the range of terahertz radiation is quite short. However, neoteric technologies using terahertz radiation have been developed, which are intended for prime applications such as medical imaging and surveillance.

The research in terahertz radiation is almost 15 years old and includes waves between 300 GHz to 10 THz. Hu and Nuss had developed the first imaging device based on terahertz radiation in 1995. Terahertz imaging has applications in security screening systems, genetic engineering, pharmaceutical quality control and medical imaging.

Imaging systems in the electromagnetic spectrum between 100 GHz and 10 THz are required for applications in medicine, communication, security, and space technology. This is because there is no known ionization hazard for biological tissue, and atmospheric attenuation of terahertz (THz) radiation. The absence of inexpensive room temperature detectors and focal plane arrays (FPAs) in this spectral region makes it difficult to develop detection and imaging systems, especially real-time ones. THz imaging has gained a worldwide acceptance. Here presents an inexpensive THz detection method using miniature Neon indicator lamps as detectors. This FPA facilitates high sensitivity and room temperature operation in a cost effective manner.

The Glow Discharge Detector (GDD) is a room temperature detector that is used in this study for direct THz radiation detection and imaging. There are several other room temperature THz detectors that are used for direct detection. The most popular detectors are Golay cells and microbolometers, which are too slow for video frame rates [1]. Furthermore, there are THz cooled detectors which are very expensive [1]. The advantages of GDD are its low cost, its high responsivity, room temperature operation, and its relatively fast response.

A candidate for FPA pixels is miniature neon indicator lamps, which were tested experimentally and found to be a very good THz detector [2]. The mechanism of detection in such a Glow Discharge Detector (GDD) involves both enhanced ionization and enhanced diffusion current [3–12] caused by the incident THz wave. The former increases lamp current, while the latter decreases it. The dominant detection mechanism in such devices was found to be the enhanced ionization process leading to increase of lamp current. Detection mechanism effects have been studied in such devices and, indeed, incident THz electric field polarity has a noticeable effect on GDD responsivity [11] according to these opposing effects.

In general, best response is obtained for the enhanced ionization. Light raysare emitted from the lamp because the high ionization and excitation collision rates between high kinetic energy free electrons and neutral gas atoms give rise to subsequent recombination and de-excitation. The GDD current is increased slightly by the incident THz electric field. The signal electrons thus generated are then accelerated too by the presence ofhigh dc field, so that they too ionize neutral gas atoms in subsequent collisions, thus amplifying the signal current considerably. GDD plasma properties have been studied in three electrode lamps in which the third electrode is used as a Langmuir probe, and such internal avalanche amplification has been calculated to be on the order of six orders of magnitude [8]. Response by such devices is linear with incident electromagnetic wave power [2], [8]. This is important in imaging process. For the separation of the detected THz signal from the large dc bias, it is desirable to modulate the intensity of the THz radiation. To separate the ac detected THz signal and the large dc bias, a capacitor is used.

2. THZ Imaging And Sensing

Sensing and imaging in the THz electromagnetic spectrum provides advantages for such security and defense applications as screening of personnel for hidden objects and detection of chemical and biological agents. As a consequence of optical diffraction, one can achieve higher-resolution imagery in the THz band with order-of- magnitude smaller imaging apertures. This makes THz imaging systems a practical option in the field of operations for many military platforms and missions.

THz imaging can achieve 10 times better depth of field than passive millimeter waves and phase information-imaging radar-can be extracted at THz frequencies. A THz imager could enable a tank traveling through dust and fog to see the vehicle ahead of it.

TDS, with its time coherence and extremely broad spectral bandwidth, will continue to expand its reach and range of applications, from spectroscopy of superconductors to subcutaneous imaging of skin cancer.

In the THz range, essentially two groups of near-field methods have been used till recently: one making use of sub-wavelength apertures and the other using sharp tips that scatter the THz rays. The size of imaging tool determines the resolution. Anyway, only a small fraction of the incident radiation contributes to the THz image.

One way to overcome the diffraction limit is to limit the detection area with an aperture. By using a detector with an integrated aperture, near-field images can be made with a spatial resolution determined by the aperture size and not the THz wavelength.

Generally, the near-field is an environment where the distance to an object of interest is 10-100 times larger than the physical size of the THz imaging array. Researchers have developed an aperture-less technique in which not the relation scattered into the far field, but the near field close to the tip is measured. The advantage of near field detection over the far-field detection is that one can directly measure the enhanced field around the tip, resulting in relatively strong signals.

The method to obtain a sub-wave length resolution has the following advantages:

1. The resolution is ultimately determined by the dimensions of the tip, not the incident THz beam size.

2. The measurements are background free.

3. The detection setup measures in the near field, where the electric field can be strong. This provides sufficiently large signals and thus reduces the measurement time.

4. The method has the more practical requirement of scanning a tip along the surface, instead of two surfaces parallel to each other.

In general, the THz radiation can be used to create images or to communicate information, just as visible light can create a photograph, audible radio wave can transmit music and speech, or invisible radiation can reveal broken bones.

3. Architecture

The system consists of a Terahertz source, GDD array, interface, lock-in amplifier and a PC. There are so many sources for THz radiations such as GaAs multipliers of Virginia diodes [14]. The radiations thus produced must be amplified to sufficient level and guided through a horn antenna. These waves will incident on the target material via an Off-axis Parabolic Mirror (OPM) and the reflected radiations are collected by the focal plane array that has been constructed with miniature neon indicator lamps as detectors with the aid of a spherical mirror. As soon as the terahertz waves incident on our GDD, glow discharge will occur [13, 14] corresponding to the illumination intensity.

The GDD is connected to the PC through an interface board.

From the tackled response of GDD array, it is possible to reconstruct the image. The pixel distortion can be corrected by applying a hybrid algorithm [14] under MATLAB platform. Due to the availability of one lock-in amplifier sequential read-out of pixels is employed in the previous works. For further improvement in resolution parallel read-out is implemented in this system.

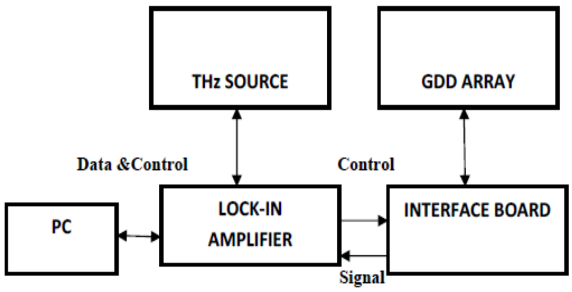


Fig. 1. Block Diagram of the System.

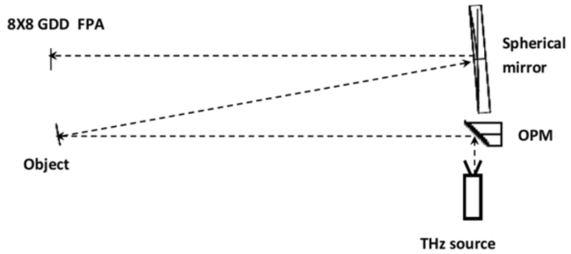


Fig. 2.Experimental setup of the Imaging System.

4. Hardware Implementation

An 8*8 FPA based on GDD pixel, operating in head-on configuration with parabolic reflector for each GDD has to be constructed[13].A custom programmable board was designed and fabricated for an 8*8 GDD array. The board is used to connect together and synchronize an integrated operation of all elements of the system. The board is computer operated and permits different regimes of system operation. The operation of the PCB board includes the following points.

• Interface to the GDD array.

• Amplification both in the pixel and in the column array levels.

• The signal recovery system.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 01 | Jan -2020 ISSN: 2582-3930

• Multiplexing of rows and columns in a sequential manner.

• Sampling and digitization of the analog signals.

• Generate all necessary control clocks, voltage, and current references for the array and image display.

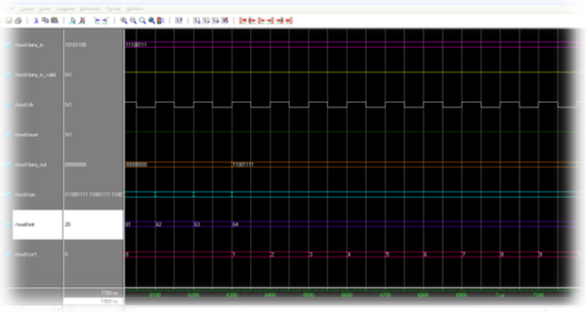
• Custom design software.

The type of hardware used reflects the cost of the experimental setup. For commercial implementations hardware cost is not a limiting constraint. But for academic level it becomes a major barrier; hence some compromises have to be done in case of sampling rate and number of pixels.

5. Results And Discussions

The coding for the software implementation of the receiving section in GDD focal plane array using neon lamps as detectors was done. The simulation results proved to be ideal for the detector array requirements. A graphical user interface is also developed in matlab for the various data processing according to the requirements and applications. THz imaging using the 8*8 GDD FPA is presented here, which suggests that use of very inexpensive miniature gas discharge indicator lamps as detectors can greatly reduce the cost of millimeter wave and THz imaging systems, while still obtaining good image quality. The quasi-optical design and components prove themselves and minimize the diffraction effects in the images. Reduction in illumination intensity makes pixelization and non-uniformities more apparent. The former can be dealt with by increasing the number of pixels. The non-uniformities can be dealt with computationally. The quality of the 32*32 pixel images obtained using the 8*8 pixel board encourages the development of higher resolution boards such as the 32*32 pixel system.

Dithering is planned for future systems. Although it has been shown recently that plasmas can be used for mm wave imaging by recording the spatial and temporal variations in glow intensity as in the positive column for example, the electronic technique shown here seems to be much more sensitive while still retaining similar speed of response. response. Future plans include investigating imaging via heterodyne detection. The sensitivity improvement should obviate the need for a lock-in-amplifier in many applications.



6. CONCLUSIONS

THz imaging using the 8*8 GDD FPA suggests that by using Neon indicator lamps as detectors, we can greatly reduce the cost of THz imaging systems . Future plan includes improvement in image quality and enhanced noise removal. Analytical survey of other terahertz detectors with better sensitivity is also under consideration.

ACKNOWLEDGEMENT

The authors would like to thank the University authorities and the head of the department for their kind cooperation and valuable suggestions for the completion of the work.

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