SURVEY ON TERAHERTZ WAVE IMAGING AND

ITS APPLICATIONS

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Abstract— **The development of technology in the THz frequency band has seen rapid progress recently. THz frequency offers greater communications bandwidth than is available at microwave frequencies. The development of sources and detectors for this frequency range has been driven by applications such as spectroscopy, imaging, and impulse ranging. Recently Tera Hertz is becoming popular in security and medical applications such as THz radiation can detect concealed weapons since many non-metallic, non-polar materials are transparent to THz radiation and also this THz radiation possess no health risk for scanning of people. This paper briefly discusses an introduction to THz imaging and explores research possibilities and its possible applications in the security fields and medical fields.**

Keywords-TeraHertz Pulse Imaging(TPI), Concealed Weapon detection(CWD), X-Rays. .

I. INTRODUCTION

Terahertz waves are quickly gaining attention and research funding. Terahertz (THz) radiation, with a loose definition has the range between 0.3 THz to 30 THz (1 THz = 10^{12}Hz). It bridges microwave and infrared (IR) radiation known as "terahertz gap" as demonstrated in Figure 1. This gap exists because until recently effective methods of generating controlled THz waves, and methods for detection of THz waves, were not available. Today there are two basic methods by which terahertz waves are produced. The first method is to use solid-state electronics, but this proves difficult for many reasons. The second method is optical generation, in which high-speed lasers are pulsed as certain semi-conductor surfaces. It is this second method which is receiving the most research attention. Terahertz waves have found applications in many different fields, such as physics, material science, electrical engineering, chemistry, forensics, security and new research potential are being discovered in biology and medicine. The area of focus in this paper is terahertz pulse imaging and its security and medical applications. The properties of terahertz that make them the focus of current studies is also presented. Finally, some of the applications for terahertz waves, such as security and medical imaging, and also its advantages and disadvantages are discussed.

II. TERA HERTZ WAVES

The need for the study of TeraHertz is justified by the potential benefits these waves possess. It is the field that is currently receiving the most attention such as screening security, medical imaging and spectroscopy. THz waves have different absorption and reflective indices in different tissues. Using terahertz waves abnormalities could be detected sooner than currently possible. THz could also make it possible to distinguish between tissues more effectively. THz waves also provide an advantage over x-rays because they are less harmful to living tissue. This is because they carry less power than x-rays. Even in medical field RADITIONAL imaging techniques, based on X-ray, magnetic resonance, and ultrasound, are invaluable tools in medical diagnoses, and can provide detailed images inside human body. However, X-rays are harmful to living tissues, and have limited imaging contrast. Magnetic resonance imaging has high sensitivity, but is quite expensive. The major drawback of ultrasound imaging is a lack of chemical specificity although it is safe and inexpensive.

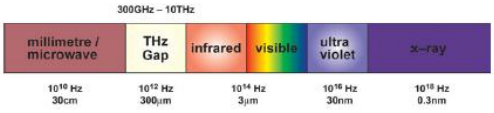


Figure 1. Electromagnetic spectrum showing the THz band gap.

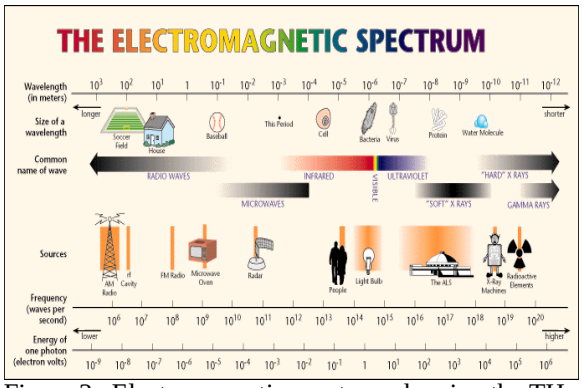


Figure 2. Electromagnetic spectrum showing the THz band gap unused.

Over the past several years, there has been an increased interest in the potential of terahertz (THz) detection for imaging of concealed weapons, explosives and chemical and biological agents.

There are three major factors contributing to this interest.

(a)Terahertz radiation is readily transmitted through most non-metallic and non-polar mediums, thus enabling THz systems to 'see through' concealing barriers such as packaging, corrugated cardboard, clothing, shoes, books, bags, etc. in order to probe the potentially dangerous materials contained within.

(b) Many materials of interest for security applications including explosives and chemical and biological agents have characteristics. THz spectra that can be used to finger print and thereby identify these concealed materials.

(c) Terahertz radiation possess either no or minimal health risk to either a suspect being scanned by a THz system or the system's operator. As plastic explosives, fertilizer bombs and chemical and biological agents increasingly become weapons of war and terrorism, and the trafficking of illegal drugs increasingly develops as a systemic threat, effective means for rapid detection and identification of these threats are required. Using THz spectroscopy it should be possible to detect explosives or drugs even if they are concealed, since the THz radiation is readily transmitted through plastics, clothing, luggage, paper products and other non-conductive (non-metallic) materials. By comparing measured reflectivity THz spectra with known calibration spectra, one may identify the presence of these agents and distinguish them from being objects.

III. THz Pulse Imaging

Just as other electromagnetic waves are used in imaging so can THz waves. This is the single most important application of THz waves and most other applications drawn from THz imaging. THz imaging has been demonstrated on leaves, semiconductors, IC packages, floppy disks, biological material, and teeth. THz imaging possibilities has been demonstrated on such a wide range of material because THz waves penetrate almost all non-metallic or polarizing substances. THz waves are more beneficial over X-rays. X-rays are capable of penetrating nearly all materials, and the technology is well developed. X-rays are limited however in what they can image. If the material as a low index materials x-rays cannot provide clear images. THz waves could be used to supplement x-rays in this case. There are other properties of THz waves that have clear benefits over other imaging techniques. One benefit of using THz time-domain spectroscopy (THz-TDI) is that THz-TDI provides a measurement of the electric field produced by THz waves, of the intensity of the wave. Through this phase information is maintained and a Fourier transform can reveal the imaginary and real components of the THz wave. When THz waves are applied to a sample the structure of the sample can be determined.

The Figure 3 shows the arrangement of the terahertz pulse imaging. Optical excitation was achieved using a ultrafast laser, centered at a wavelength of **800nm.** A beam splitter separated the pulses into two beams, an excitation beam and a detection beam. Generation of the THz was achieved by optical excitation of a gallium-arsenide antenna. This gave a usable range of 0.1 THz to 2.7 THz. The THz pulses were collimated and focused onto a Z-cut quartz window by a pair of off-axis parabolic (OAP) mirrors. The sample is placed onto the quartz window. The angle of reflection was *30*degrees to the normal. The THz pulses reflected from the tissue were re-collimated using another pair of OAP mirrors and focused onto a photoconductive receiver. By sweeping the optical delay through the entire THz pulse at a rate of 20Hz, the time-domain THz waveforms are obtained. The entire THz optics is scanned in the ***x-y*** plane to form an image. The TPI system records an entire waveform in 50 ms. Data acquired to a depth on the order of 1 mm into the samples, providing sufficient information for analysis. The spatial resolution is refractive index limited.

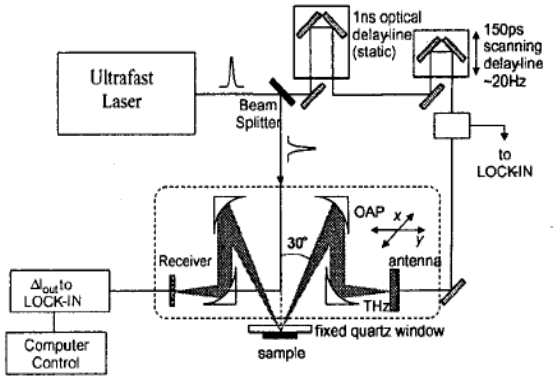


Figure 3. Components of Portable THz Pulse Imaging System[8]

IV. CRITICAL ISSUES IN SECURITY SCREENING

Recent events have demonstrated the need for ever more effective security screening, and for systems capable of detecting contraband. A wide variety of techniques are already available, for the detection of a variety of threats, such as weapons or explosives, or illicit items, ranging from drugs to illegal immigrants. Current methods of bag screening in the United States and elsewhere typically use X-ray inspection techniques with some use of further image analysis, manual search and chemical trace detection. Passenger screening relies heavily on archway and handheld metal detectors that are deployed throughout most airports. However, these techniques are not foolproof, and beneficial enhancements could be made in detecting the following:

- Weapons containing a small amount of metal
- Ceramic weapons
- Explosive materials
- Chemical and biological threats

Emerging technologies, such as X-ray backscatter and millimeter wave imaging might be employed to address some current deficiencies. However, the routine use of ionizing X-rays raises health concerns, whilst millimeter wave approaches have a limited spatial resolution. It is also unclear whether either technique can provide spectroscopic substance identification. Thus, X-ray and millimeter wave portals are likely to prompt frequent further searching whenever an image indicates a suspect item or area. False alarms can greatly increase the cost and reduce the throughput of screening systems; throughput is crucial in high volume situations such as in major airports. A further factor is the high dependence of current techniques on human operators. Any new technique that can enhance capability, and aid in the targeting of manual search operations to specific high-risk objects or areas, would be of major benefit.

V. SOME PROVEN EXPERIMENTS FOR APPLICATIONS OF THZ IMAGING

A. Concealed Weapon

THZ imaging can detect the metallic as well as non metallic objects concealed under the clothes for more challenging task the objects were concealed beneath multi-layered cloth and the objects were detected easily.

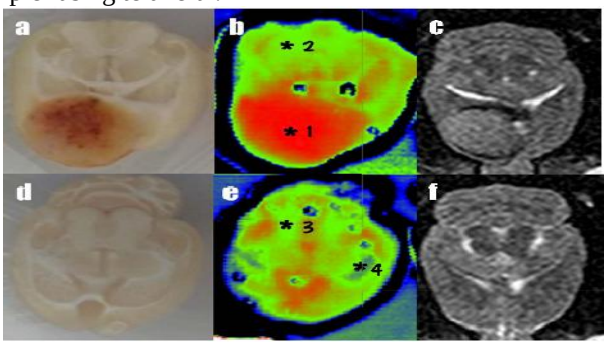
Figure 4. THz reflection image of a person carrying a gun[9]

B. 3-D imaging using TPI

TPI is an ideal solution for providing 3D imaging of the inside of an integrated circuit device. TPI yields significant advantages over existing techniques such as X-ray analysis, which provides only 2D images and can damage the semiconductor in the device, and other techniques such as ultrasound which provides limited resolution and can be difficult to implement.

C. Tumour detection

The Figure 5 shows the optic, terahertz imaging and MRI of the fresh brain and brain tumor. The terahertz imaging has relative good contrast compare to MRI. So detection is more simpler using terahertz.



. Figure 5. Optic,TeraHertz and MRI of fresh brain and brain tumour

D. 3 Layered Painted Image

Figure 6 shows 3 different layered paintings. The first layer has been detected earlier and has lower time delay. Middle layer has some more time delay and the bottom layer has highest time delay to detect the painting. The two THz peaks are achieved first. One from the painting surface and second one from the canvas reflection.

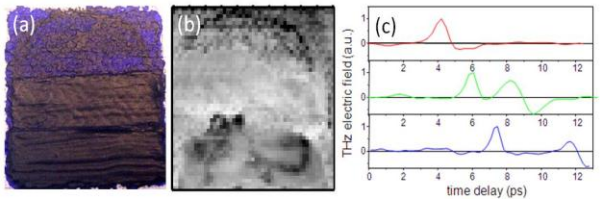


Figure 6. THz waveforms reflected by three paint layers (different thicknesses) and canvas [5].

VI. Advantages And Disadvantages Of THz Imaging

There are some advantages and disadvantages of this technique.

A. Advantages:

1. The spatial resolution of THz waves is excellent for CWD. THz waves can separate objects less than 1mm apart, which is more than enough to tell a weapon apart from its surroundings. This resolution is roughly 10 times better then that of Millimetre Waves (MMW), due to the smaller wavelength.
2. Many materials of interest for security applications including explosives, chemical agents and biological agents have characteristic THz spectra that can be used to fingerprint and thereby identify these concealed materials.
3. THz waves are non-dangerous. The penetrating ability of THz may seem harmful to health, similar to the x-rays but in actual fact it is totally harmless as T-rays are nonionizing. They do not alter molecules in the air or in human.

B. Disadvantages:

1. THz imaging is expensive because it requires special power sources.
2. Using close range imaging it is still difficult to develop video output because the scanning is still slow, leading to a poor frame rate.
3. Private invasion issue, because T-ray can penetrate clothes.

VII. Conclusion

Recently great progress has been made in the field of Terahertz imaging. Terahertz imaging could thus constitute a promising technique for the security and medical application. And these security applications will find number of areas where it can be used efficiently and causes no health risks. Thus terahertz properties make it different from the other existing technologies.

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