Sensing with T-Ray Tomography

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Abstract: For the last two decades, THz imaging systems and their applications have developed a lot. In particular, the methodology of 3-D computed tomography (CT) has been applied to the THz range of frequencies. In this review article, applications of THz-CT have been discussed briefly. The methodology of X-Ray CT imaging using the Radon Transformation have mostly been used in 3-D THz tomography. THz-CT has been applied in medical sciences, security industry, cork industry to name a few.

THz imaging system: A THz-TDS system can be used to image objects by keeping the positions of the transmitter and receiver fixed while varying the position of the sample using motorized translational stages, which sits in between transmitter and receiver. A 2-D THz image is required a pixel at a time with each pixel corresponding to a different position of the sample. In fact, the first pulsed THz images of a leaf (Nuss, 1995) were acquired in this manner. The first THz images were reported by Hu and Nuss in 1995 (Nuss, 1995). Their work created a great deal of excitement among the scientific community for subsequent development of THz imaging systems and techniques. THz-TDS has been used in the majority of research work in the area of THz imaging for more than a decade. In addition to the development of THz-TDS systems, THz CW systems and imaging techniques were developed during this time. There has been significant development of THz transmitter and detection mechanisms.

T-Ray tomography imaging as a tool of inspection: There are many materials that are transparent in the THz range but there are substances, which are not. THz radiation is highly reflected by metals due to the high free charge carrier density. Living tissues and any living body is highly absorptive in THz radiation because of its water content. As water molecules as well as any polar molecules absorb THz radiation, transmission spectroscopy through a thick layer of those materials is highly improbable. For thick layers, one needs to study reflection spectroscopy. The first demonstration of 3D THz image reconstruction was described in 1997 by Mittleman *et all* (Mittleman et al., 1997). In that work, the authors studied a conventional 3.5-inch floppy disk by reflective T-Ray imaging and reconstructed 3D image of the disk (Figure 1)

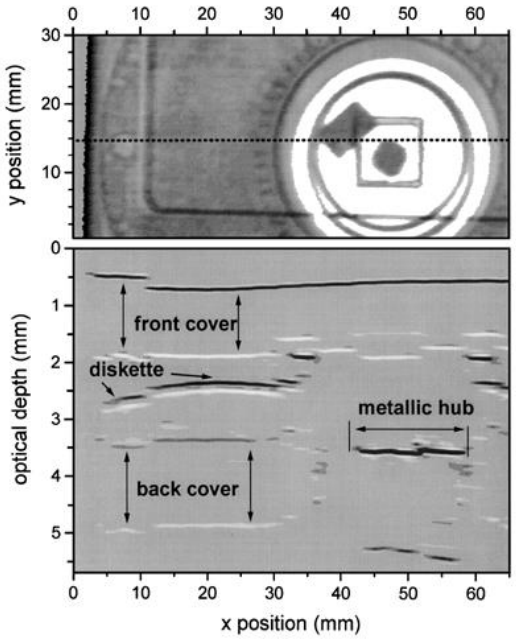

Figure 1: Conventional reflective T-Ray Image of a 3.5-inch floppy disk. (Mittleman et al., 1997)

As an example of alternative THz imaging hardware, Alan W.M.Lee *et all* demonstrated THz standoff (> 25m) imaging using terahertz QCL (aka THZ quantum cascade laser) and a room temperature micro bolometer array (Lee et al., 2006). Figure 2 shows the visible and terahertz image of the seed-pod respectively. Authors used real time imaging techniques using QCL.

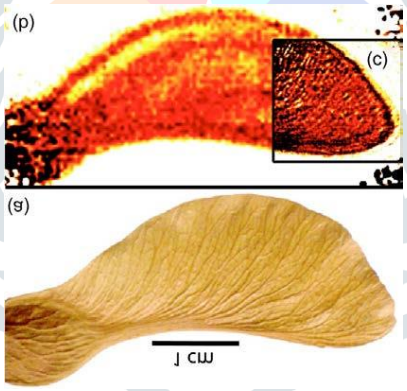

Figure 2: Dried seed-pod: (a) Image at visible range, (b)
THz image taken with configuration (1), and (c) terahertz image taken with configuration (2). Both (b) and (c) are taken with 1 S integration (average of 20 frames). (Lee et al., 2006)

At this time, a lot of attentions have been focused on 3D terahertz imaging (Mittleman, 1996, S. Wang and X.-C. Zhang, 2004). Because both THz-TDS and THz imaging are coherent measurement technologies, one can measure both phase and as well as amplitude of a THz pulse at a particular frequency. Since we can extract both phase and temporal information from THz waves, we can develop several 3D THz tomography modalities. There are several different types of three-dimensional Terahertz tomography imaging techniques. These are: Terahertz diffraction tomography (THz-DT), Terahertz computed tomography (THz-CT), THz binary lens tomography and THz digital holography (S. Wang and X.-C. Zhang, 2004, Mittleman et al., 1997). Whenever a coherent THz beam interacts with an object, it provides a lot of information about the object under study and consequently the 3D THz imaging techniques could be a very important tool for inspection and characterization of different types of object.

Conclusion: A brief discussion about the THz-CT imaging have been made in this article. T-Ray CT imaging is gaining attention of many scientists in several research areas. Although it is attracting attention but still a lot of improvements needs to be done before one can implement this technology in industry, especially in its detection mechanism.

References

LEE, A. W. M., QIN, Q., KUMAR, S., WILLIAMS, B. S., HU, Q. & RENO, J. L. 2006. Real-time terahertz imaging over a standoff distance. *Applied Physics Letters,* 89.

MITTLEMAN, D. 1996. T-Ray Imaging. *IEEE Journal of selected optics in quantum electronics,* 2**,** 679-692.

MITTLEMAN, D., HUNSCHE, S., BOIVIN, L. & NUSS, M. C. 1997. T-ray tomography. *Optics Letters,* 22**,** 904-906.

NUSS, B. B. H. A. M. C. 1995. Imaging with terahertz waves. *Optics Letters,* 20**,** 1716-1718.

S. WANG AND X.-C. ZHANG 2004. Pulsed terahertz tomography. *Journal of Physics D: Applied Physics,* 37**,** R1-R36.