T-Ray Tomographic Imaging

B. Ferguson, S.H. Wang, D. Abbott, and X.-C. Zhang

Abstract—**We present three terahertz wave (T-ray) tomographic imaging modalities: T-ray computed tomography (T-ray CT), T-ray diffractive tomography (T-ray DT), and tomographic imaging with a Fresnel binary lens. T-ray CT provides 3-dimensional (3D) images and reveals information about the target for functional imaging. T-ray DT achieves sub-mm spatial resolution, and a Binary lens leads a novel imaging modality with the use of a broadband T-ray pulse.**

Index Terms—**Terahertz, T-ray, Tomography, Imaging**

I. Introduction

We have demonstrated transmission mode 3D tomography with THz radiation. This has a number of potential advantages compared to competing techniques including: (1) The potential for sub-millimeter resolution, (2) Broadband terahertz (THz) spectral information, which yields the possibility of identifying materials based on their molecular resonance in the far-infrared, and (3) A number of materials including cloth, paper, plastics and cardboard are relatively non-absorbing in this frequency band.

II. Imaging Principle

T-ray CT is based on the same basic principle as X-ray CT. T-rays are focused, transmitted through the target and detected. The target is then raster scanned and rotated. The hardware is a simple extension of the chirped probe beam THz imaging system. This system is used to measure the full THz temporal profile simultaneously. The THz pulse is generated using a femtosecond laser and a wide aperture biased antenna. Parabolic mirrors are used to focus the THz to a 1 mm spot at the target. The probe laser pulse is chirped to 20-30 ps using the grating pair. Then the THz pulse is encoded onto the probe pulse via the electro-optic effect in the ZnTe crystal. Finally, a spectrometer and CCD are used to recover the THz information.

This paper was submitted to THz 2002 Conference August 2, 2002. This work was supported in part by the U.S. Army Research Office and the U.S. Air Force Office of Scientific Research.

Bradley Ferguson is a visiting scholar at the Center for Terahertz Research, Rensselaer Polytechnic Institute, NY 12180 USA. He is a graduate student at the University of Adelaide, SA 5005 Australia (email: fergub@rpi.edu).

Shaohong Wang is a graduate student at the Center for Terahertz Research, Rensselaer Polytechnic Institute, NY 12180 USA (email: wangs3@rpi.edu).

Derek Abbott is an Associate Professor of Electrical and Electronic Engineering at the University of Adelaide, SA 5005 Australia (email: derek.abbott@adelaide.edu.au).

Xi-Cheng Zhang is the Director for Terahertz Research, Rensselaer Polytechnic Institute, NY 12180 USA (email: zhangxc@rpi.edu).

III. Potential Application

Applications of this 3D biological tomographic imaging include functional imaging of cancerous tumors, mapping blood flow and oxidation, or fat content of tissues. Other applications are non-destructive signature detection of biological materials such as anthrax and TNT. High water absorption of THz limits deep-level imaging in water-rich tissue, however, the far-infrared dielectric difference between bound and free water molecules in biological materials may provide important information concerning biological cells, tissues and organs.

IV. Examples

A piece of turkey bone was imaged using T-ray CT. The bone has a fine internal structure with a size comparable to the wavelength. These features were not reconstructed accurately. This highlights one of the current challenges with T-ray CT. Multiple targets were topographically imaged by using a Fresnel lens and a broadband T-ray pulse.

V. Conclusion

We have developed and demonstrated several T-ray tomography systems. Using the filtered backprojection algorithm, we have been able to reconstruct simple target objects. This technique extends the potential of THz time-domain spectroscopy to several exciting new application areas. It is capable of reconstructing the 3D structure and the far-infrared optical properties of an object. The images may be obtained relatively quickly using two-dimensional CCD THz imaging. Importantly, using the frequency dependent complex refractive index, different materials may be uniquely identified despite being hidden within other opaque structures. We demonstrate 3D tomography images by using a Fresnel lens with broadband THz pulses. Objects at various positions along the beam propagation path can be uniquely imaged on the same imaging plane using a Fresnel lens with different frequencies of the imaging beam. This procedure allows the reconstruction of an object's tomographic contrast image by assembling the frequency-dependent images.

0-7803-7630-7/02/$17.00©2002 IEEE