An Investigation of Terahertz Near-Field Imaging

by

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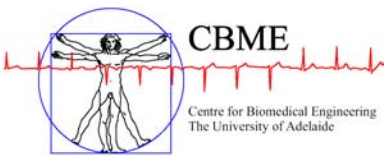

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Abstract

The spatial resolution of conventional terahertz (THz) images is limited by the wavelength of THz radiation (0.3 mm for 1 THz) and is therefore in the submillimetre range. The general motivation behind an increased spatial resolution is to distinguish objects separated by sub-wavelength distances and to cater for a smaller sample size. Owing to the infancy of the technology, much work has to be carried out to improve the system resolution. The focus of this Thesis is not to further improve the resolution, but rather, take a step back to elucidate further understanding THz near-field approach. This thesis, in the scope of engineering, investigates the focused beam near-field technique through experimentation and modelling with an aim to provide a better understanding in the far-field and near-field regime. The work aims to assist with the future implementation of THz near-field imaging systems. This body of work performs far-field studies of a sub-wavelength THz source (Chapter 5) and a near-field investigation for potential microscopic application (Chapter 6). In particular, this can be outlined into two categories:

Far-field studies of a sub-wavelength THz source focus on modelling the source as a radiating Gaussian aperture and illustrate the breakdown of the paraxial approximation at low THz frequencies. The findings show that the shape of the radiation pattern causes a reduction in detectable THz radiation and hence contribute significantly to low signal-to-noise ratio in THz radiation generation. The investigation can apply without a loss of generality to other types of sub-wavelength sources for THz generation, such as, in photoconduction and plasma generation. Simulation of the laser heating effects from prolonged intense exposure of a highly confined optical beam on the THz emitter is also conducted.

The near-field investigation of a sub-wavelength THz source in a THz emitter also models the source as a radiating Gaussian aperture. Based on realistic parameter values, the model allows for THz beam characterisation in the near-field region for potential microscopy applications. The proposed validated numerical model therefore aids in the quantitative understanding of the performance parameters. The work can

be applied to other focused beam THz techniques such as photoconductive antennas without a loss of generality. Thin THz emitters have been reported to generate THz radiation power enhancement. Empirical investigation of a reported unexpected thin crystal power enhancement is also conducted.

In addition to these parts of the original contributions, the Thesis offers an introductory background to THz-TDS and THz near-field imaging. Three side investigations are described in the appendices: (i) THz photoconductive antenna material characterisation, (ii) THz near-field material detection, and (iii) Gas recognition with THz-TDS.

Statement of Originality

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Hungyen Lin and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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December 12, 2011

Signed

Date

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I gratify this opportunity and glorify this Thesis to the Lord and His precious son Jesus Christ. He is truly the amazing rock in my life no matter what happens and the source of everything. I praise Him!

The fruition of this Thesis has come about because of many people and a few lines here are not sufficient to express my uttermost gratitude and appreciation.

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Conventions

Typesetting : This Thesis is typeset using the LaTeX2e software. Processed plots and images were generated using Matlab 7.6 (Mathworks Inc.), Ansoft HFSS 11.0 (Ansoft Corporation), CorelDRAW 11 (Corel Corporation), and Adobe Illustrator CS3 (Adobe Systems Incorporated) was used to produce schematic diagrams and other drawings.

Spelling : Australian English spelling has been adopted throughout, as defined by the Macquarie English Dictionary (Delbridge 2001). Where more than one spelling variant is permitted such as biassing or biasing and infra-red or infrared the option with the fewest characters has been chosen.

System of units : The units comply with the international system of units recommended in an Australian Standard: AS ISO 1000—1998 (Standards Australia committee ME/71, Quantities, Units, and Conversion 1998).

Physical constants : The physical constants comply with a recommendation by the Committee on Data for Science and Technology: CODATA (Mohr and Taylor 2005).

Frequency band definition : The terahertz spectrum from 0.1 to 10 THz is referred to as terahertz radiation as opposed to 'T-rays' in Abbott and Zhang (2007). This is because of the growing popularity of terms such as 'terahertz time-domain spectroscopy—THz-TDS' and 'terahertz gap' in the community.

Referencing : The Harvard style is used for referencing and citation in this Thesis.

Publications

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