Novel hardware for terahertz time-domain spectroscopy (THz-TDS)

by

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Contents

Abstract

Terahertz time-domain spectroscopy (THz-TDS) systems have been generally limited to a single mode of operation, either in transmission or reflection geometries. The possibility of systems able to operate simultaneously in both geometries opens new possibilities for material characterisation. This Thesis designs and characterises a novel system able to simultaneously capture spectra from samples at normal incidence transmission and reflection. This enables materials that are opaque and/or partially reflective, as well as materials that exhibit non-unity values of permittivity and/or permeability to be thoroughly investigated.

In addition to a dual geometry system, this Thesis presents two novel beam-splitters useable in the terahertz (THz) range of frequencies from 0.1 to 10 THz. Optical components in the THz frequency range have been limited, with ongoing developments being made to fabricate and characterise lenses, polarizers and waveguides, with beam-splitters that are polarization dependent. The presented original contributions include a low-cost beam-splitter fabricated from an ultra-thin polymer substrate and silver paint, and a novel beam-splitter fabricated from conductive polymers. These beam-splitters provide a near frequency and polarization independent response.

An introductory background into THz-TDS along with generation and detection methods are also offered as part of this Thesis. Four auxiliary investigations are also described in the appendices: (i) a dual scanning THz-TDS system, to improve acquisition times, (ii) a mini investigation into food quality control using THz-TDS, (iii) an investigation into security applications for THz-TDS and (iv) second harmonic generation (SHG) using a β radiation damaged barium borate (BBO) crystal and a Ti:Sapphire laser.

Statement of Originality

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Benjamin Seam-Yu Ung 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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Date

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For Grandpa

Conventions

Typesetting : This Thesis is typeset using the LaTeX2e software. Processed plots and images were generated using Matlab 7.6 (Mathworks Inc.) and Adobe Illustrator CS6 (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 (Yallop and Delbridge 2005). 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 *et al.* 2012).

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.

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List of Figures

List of Tables