Developments in Double-Modulated Terahertz Differential Time-Domain Spectroscopy

by

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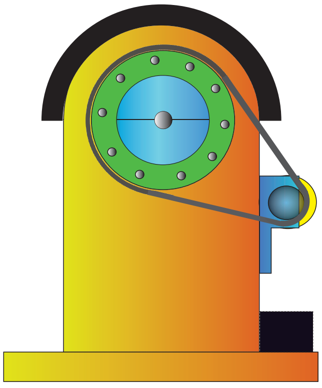

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Abstract

Recent years have seen a plethora of significant advances in terahertz (THz or T-ray) technology with the rapid development of the ultrafast femtosecond laser system. By definition, THz refers to an electromagnetic wave located between the microwave and infrared regions of the electromagnetic spectrum.

Over the last two decades, there has been an enormous interest in improving the sensitivity of spectroscopic measurements on liquids in the terahertz regime. Liquid studies at terahertz frequencies (0.1 - 10 THz) allow analysis of chemical composition and provides a better understanding of the solvation dynamics of various types of liquids. This Thesis focusses on developing a novel spinning wheel device using a double-modulated terahertz differential time-domain spectroscopy (double-modulated THz-DTDS) scheme coupled with a simultaneous dual-waveform acquisition technique for increasing the sensitivity and repeatability of liquid studies. The spinning wheel device promises a rapid succession of measurements, requiring one mechanical delay scan for the sample and reference signals.

The double-modulated THz-DTDS scheme with simultaneous dual-waveform acquisition was first introduced by Mickan *et al.* (2004). This Thesis builds upon this former work with a modification in the signal extraction technique. In this work, a step-by-step systematic engineering approach has been employed for the development of the spinning wheel device.

The Thesis is categorised into several parts leading to the development of the spinning wheel device. The first part provides a review on the historical development of the electromagnetic spectrum and a review of the state-of-the-art regarding THz generation and detection based on transient photoconductivity. Identifying an optimal polymer window material forms the second part of this Thesis. Here, a range of polymer materials are tested for low hygroscopicity and high transmission coefficient. The third part of the Thesis reviews various window cell geometries used in liquid spectroscopy measurements. A detailed data analysis technique is described for each geometry. The fourth part of the Thesis presents a prototype of the novel spinning wheel mechanism for THz material parameter extraction using the double-modulated THz-DTDS scheme. A proof-of-principle showing that the amplitude noise of a THz system decreases as a function of the spinning wheel modulation frequency is demonstrated. Preliminary experiments indicate the potential of this technique for achieving a better noise performance, which is of significance particularly for THz spectroscopy of polar liquids where the signal-to-noise ratios are typically low due to high absorption coefficient. The initial demonstration of the spinning wheel technique leads to THz spectroscopy of liquids based on a fixed dual-thickness window geometry. Here, a rapid switching between two fixed liquid sample thicknesses is introduced.

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 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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28 February, 2010

Signed

Date

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Thesis Conventions

The following conventions have been adopted in this Thesis:

1. **Definitions.** The T-ray band is defined in this Thesis to span from 0.1 to 10 THz (where 1 THz is 10^{12} cycles/s). This is an emerging definition in the literature (Abbott and Zhang 2007).

2. **Notation.** The acronyms and symbols used in this Thesis are defined in the Symbols and Glossary on page 207.

3. **Spelling.** Australian English spelling conventions have been used, as defined in the Macquarie English Dictionary (A. Delbridge (Ed.), Macquarie Library, North Ryde, NSW, Australia, 2001).

4. **Typesetting.** This document was compiled using LaTeX2e. TeXnicCenter was used as text editor interfaced to LaTeX2e. Adobe Illustrator CS2 was used to produce schematic diagrams and other drawings.

5. **Mathematics.** MATLAB code was written using MATLAB Version R2007b/R2008a; URL: http://www.mathworks.com.

6. **Referencing.** The Harvard style has been adopted for referencing.

7. **URLs.** Universal Resource Locators are provided in this Thesis for finding information on the world wide web using hypertext tranfer protocol (HTTP). The information at the locations listed was current on 17 December 2009.

Publications

Journal Articles

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