Novel T-ray Liquid Spectroscopy via Double Modulated Differential Time-Domain Spectroscopy

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***Abstract*— Liquid water absorption is one of the most enduring problems facing THz imaging and spectroscopy in biomedical applications. The absorption coefficient for liquid water shows a very high THz absorption, 200 cm^{-1} at 1 THz [1]. This strong absorption is a big hurdle for T-ray spectroscopy and imaging of liquid or even wet samples [2]. This paper proposes a novel method for parameter extraction of a liquid, using a double modulated differential time-domain spectroscopy (DTDS) technique with dual-thickness measurement. The proposed technique improves on the previous work by replacing the required sample dithering technique [3] with a rotating spinning wheel resulting in an improved noise performance up to two orders of magnitude.**

I. Introduction

Over the last decade, there has been a pronounced interest in THz spectroscopy of liquids. Liquid spectroscopy allows analysis of chemical composition and provides a better understanding of the solvation dynamics of various types of liquids [4], [5], [6], [7]. This leads to possible applications such as blood sample screening, urine test, contaminant detection in liquid, wet protein sample analysis, detection of inflammable liquids, sugar and salt level of content in water, fat or oil content in polar liquids and many more applications. This paper describes a promising novel liquid DTDS technique to extract the material parameters.

II. Approach

Although it has been shown that liquid spectroscopy using T-rays is feasible, there are still open questions that need to be addressed to improve the signal-to-noise ratio (SNR). Two major sources of noise that affect the SNR are the fluctuations in T-ray pulses caused by the fluctuations in the generating laser pulses and the accuracy of the material thicknesses. According to Mickan *et al* [3], the measurement of thickness d can be accurate by having closed-loop feedback for controlling the thickness of the liquid. The fluctuations of the laser are one of the main sources of noise in the T-ray pulses. These fluctuations are known to have a $1/f$ characteristic where the amplitude fluctuations of the laser are inversely proportional to frequency [3].

A fast measurement between the reference (thin) and the sample (thick) (dual-thickness) portion of the same liquid will be carried out using a spinning wheel (Figure 1). Reduction in the time measurement between the waveforms will be observed and hence minimize the effect of noise caused by laser fluctuations. Compared to the previous method [3], where the thickness depends on the variation of d of the dithering technique, this technique uses a fixed thickness. This removes the uncertainty caused by the error in thickness and thus further improves the SNR.

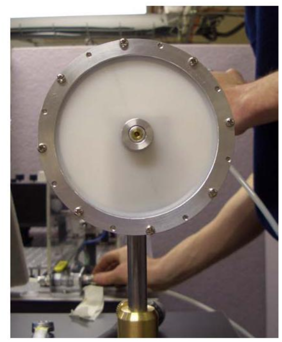

Fig. 1. An illustration of the prototype spinning wheel with dual-thickness. The thick and thin sample waveforms can be measured by spinning the wheel at a high frequencies to improves the signal-to-noise performance.

Preliminary results that demonstrate the potential of this technique for liquid spectroscopy will be presented.

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