A multi-lab intercomparison study of THz time-domain spectrometers

Mira Naftaly and John Molloy
National Physical Laboratory, Hampton Road, Teddignton, Middlesex TW11 0LW, UK

***Abstract*—This paper will present the first results of a multi-lab study comparing results obtained by THz time-domain spectroscopy on a set of standard materials. Measurements of refractive indices and absorption coefficients reported by participants will be collated and analyzed, and best practice guidelines recommended.**

I. INTRODUCTION

TERAHERTZ THz spectroscopy, and in particular time-domain spectroscopy (TDS), has become a widely used tool in the study of a broad range of materials and processes. However, conflicting results are often published [e.g. 1-4], and no agreed means exists to validate measurements or to compare results produced by different labs. There are no agreed measurement standards, and a variety of methods are employed in calculating derived parameters, whilst published papers seldom include the details of data analysis.

Developing measurement standards and agreed procedures is necessary in order to bring THz spectroscopy to the level of rigor and reliability common in other frequency bands, and to foster widespread acceptance and uptake. The field of THz science is currently undergoing the transition from a novel esoteric method to an accepted laboratory technique with many diverse applications. Standardisation of measurement practice is essential to underpin and facilitate this transition.

II. INTERCOMPARISON STUDY

This paper will present the first results of a multi-lab study comparing results obtained by THz time-domain spectroscopy (TDS) on a set of standard materials. An international group of THz practitioners have been recruited to participate, including national measurement institutes, academia, and THz system manufacturers. A set of standard material samples have been prepared, and measurements of their refractive indices and absorption coefficients reported by participants will be collated and analyzed. Uncertainties associated with various instrumental platforms and with different approaches to parameter extraction will be evaluated.

The set of material samples was chosen according to a number of criteria:

- The number of samples must be sufficient to represent different ranges of dielectric properties, but must not be too onerous; 5 samples were selected.
- The samples must exhibit a representative variety of features, as detailed below.
- The selected materials must be common, manufactured to a high standard, and be widely used in THz optics and measurements.

In the light of the above, a set of the following standard materials was chosen:

1. A high-resistivity (float-zone) silicon plate – high refractive index, low absorption, negligible dispersion.
2. A z-cut quartz plate – medium refractive index, low absorption rising to a phonon peak at 6 THz, significant dispersion.
3. A silica glass plate – medium refractive index, medium absorption strongly rising with frequency, significant dispersion.
4. High-density polyethylene (HDPE) plate – low refractive index, low absorption with a broad peak at 2.2 THz, significant dispersion.
5. A lactose monohydrate pressed-powder pellet – medium refractive index, strong absorption with several sharp peaks, strong dispersion.

The analysis of intercomparison data will take into account both system performance and the method of parameter extraction. The aim will be to quantify the effects on the obtained parameters of different aspects of system operation and of different algorithms for parameter calculations.

The results accumulated by the intercomparison study and their detailed analysis will be used to develop a best practice guide for THz TDS measurements and to design guidelines for common-usage instrument specifications. The study will also provide a basis for future standards for THz spectroscopy.

III. EXAMPLES OF INITIAL RESULTS

The study commenced in April 2015, and at the time of this submission several initial results have been collected. Some examples of these are shown in Figs. 1-4, presented anonymously with respect to participants. These results clearly indicate that standardization of measurement techniques is necessary and urgent.

A paper detailing the full compilation of all results and their analysis will be published at the completion of the study.

ACKNOWLEDGEMENT

Work at NPL was supported by the National Measurement Office of the UK.

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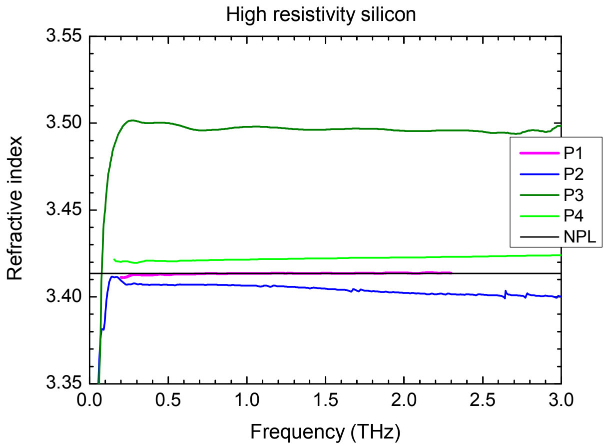

Fig 1. Refractive index of high resistivity silicon. Participants P1, P2, P3, P4 are anonymous; NPL data is denoted in black.

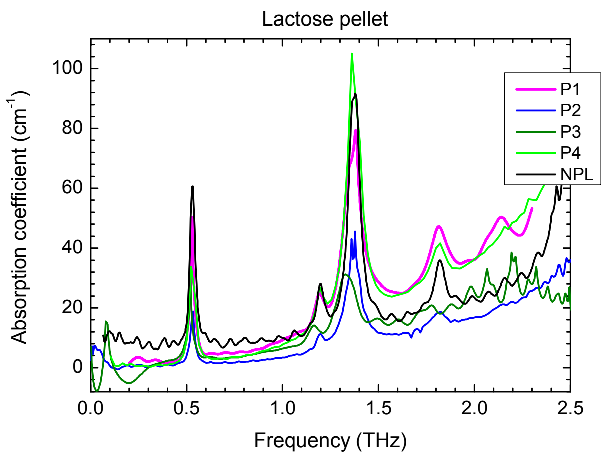

Fig 2. Absorption coefficient of a lactose pellet. Participants P1, P2, P3, P4 are anonymous; NPL data is denoted in black.

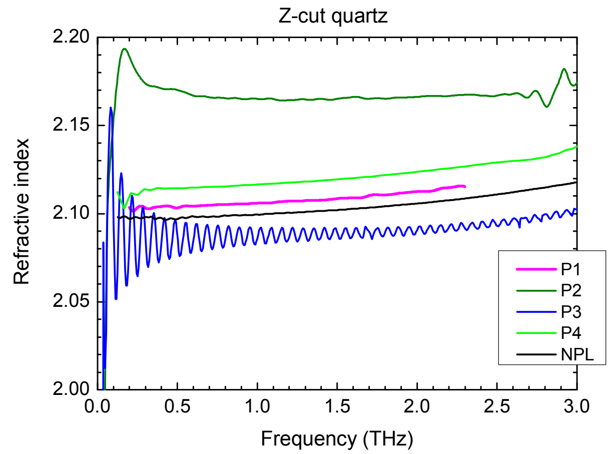

Fig 3. Refractive index of Z-cut quartz. Participants P1, P2, P3, P4 are anonymous; NPL data is denoted in black.

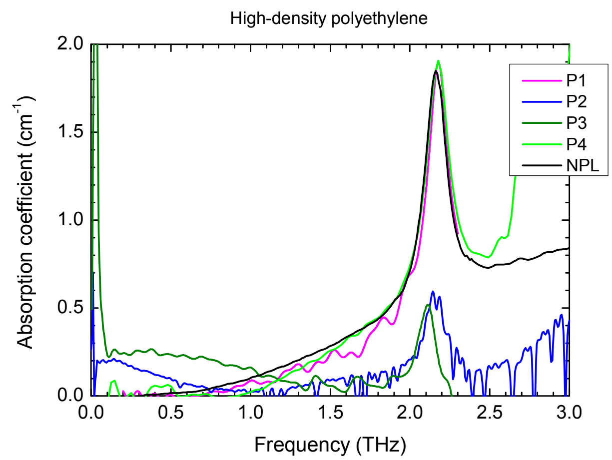

Fig 4. Absorption coefficient of high-density polyethylene (HDPE). Participants P1, P2, P3, P4 are anonymous; NPL data is denoted in black.