Ultrafast Pulsed Terahertz Sensing for Process Monitoring and Industrial Imaging

*Pierre Jeunesse, Xavier Neiers, Uli Schmidhammer**

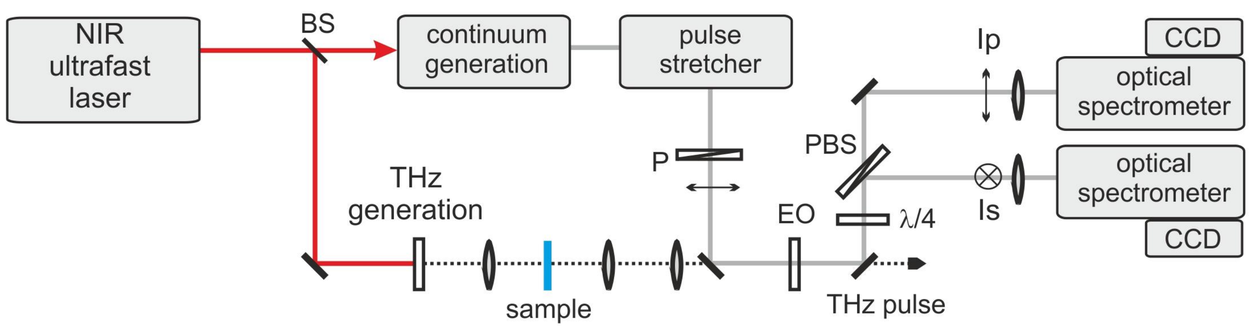
Laboratoire de Chimie Physique / ELYSE, CNRS / Université Paris-Sud
Orsay 91405, France

Introduction

We present a recently developed approach of **Terahertz Time Domain Spectroscopy** (THz-TDS) and its application on rapid and precise Non-Destructive Testing (NDT) of composites and concealed objects.

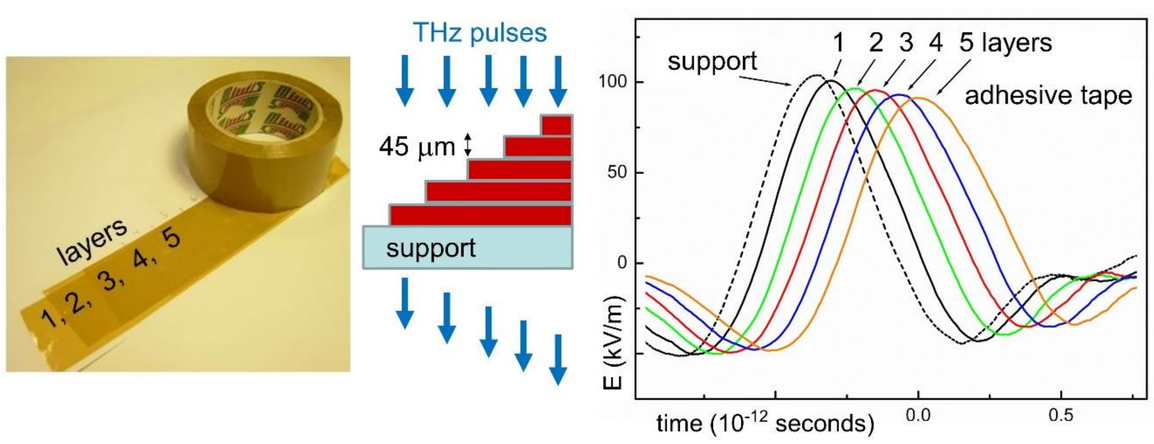
Electromagnetic radiation of THz frequencies has the ability to penetrate dielectric materials **without ionizing effect**; it allows the **contact-free testing** of dielectric volumes or buried metallic surfaces. Using ultrashort, spectrally large pulses, THz-TDS is a particular powerful tool for NDT as it provides a multitude of information for **imaging, material characterization and spectroscopic analysis**.

Single-Shot THz-TDS Sensor



Our technology **STRIPP** (**S**ingle Shot **T**Hz Sensing for **R**apid **I**ndustrial **P**roduct and **P**rocess Control) is based on an optical single-shot detection scheme. It provides the temporal information on the ultrashort THz electric field with variable window of several tens of picoseconds at kHz repetition rates. The spectrometer encodes the time domain signal on the temporally dispersed spectrum of a supercontinuum with the electro-optic (EO) effect; for each laser shot the polarization state of the supercontinuum is analyzed in polychromatic balanced detection. The concept and reliability of the SS-THz-TDS are described in reference 1, its here used configuration and performance in reference 2. This ultrafast acquisition method enables the analysis of moving objects and transient phenomena with high sensitivity.

Control of Coatings: Thickness Determination

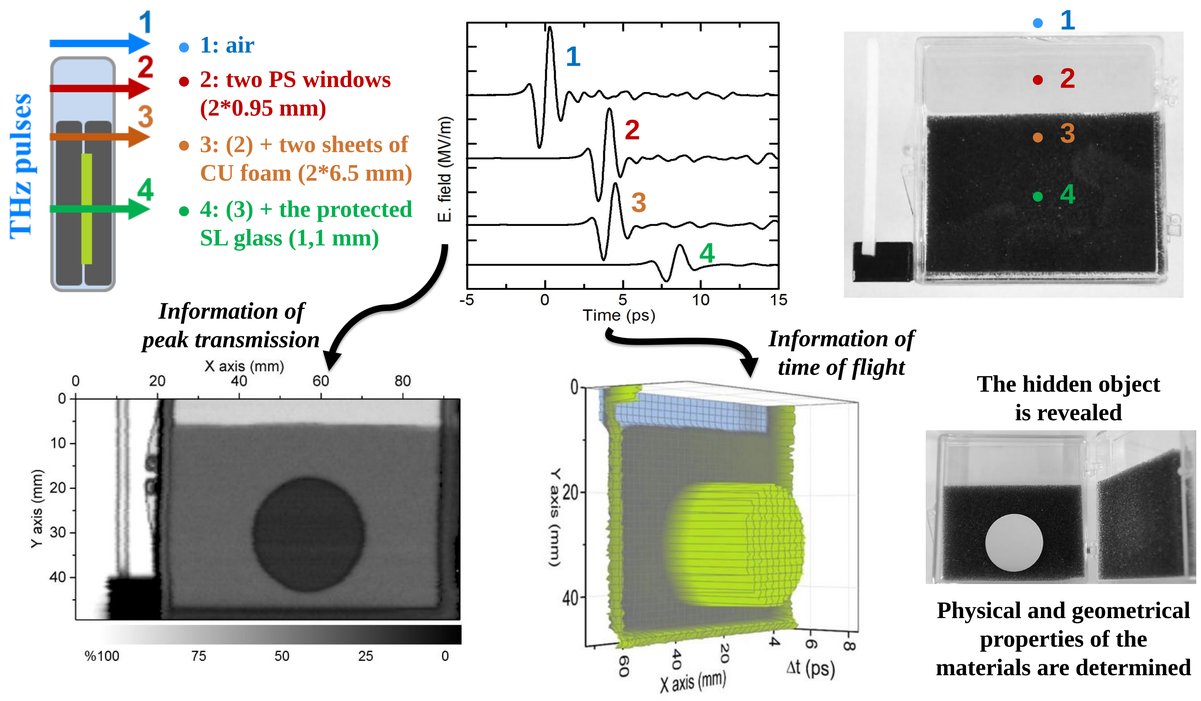


One advantage of ultrafast pulsed THz sensing is **its high depth resolution** that is directly connected to the information of time of flight Δt. For a variety of dielectric materials with known refractive index n, the **object thickness** d can be obtained in a very straightforward way from the time domain data with micrometer precision:

$$d = c \times \frac{\Delta t}{n - 1}$$

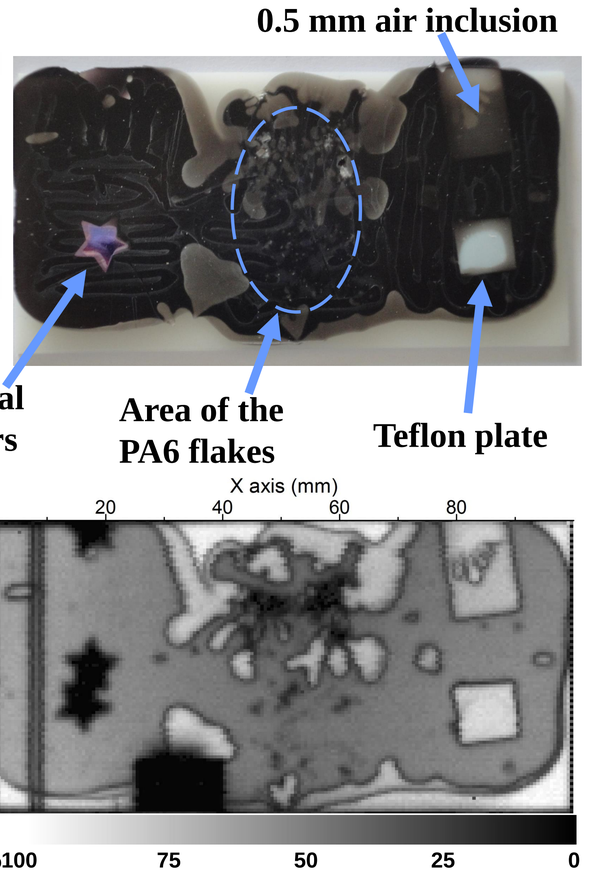
"On-the-Fly" Imaging

The ability of THz waves to penetrate dielectrics opens the way to **reveal the inner structures and dimensions** of objects that are opaque in the visible or infrared. **STRIPP** can image a packaged object "on-the-fly"; the raster scanning was performed during horizontal translation of the sample within tens of seconds.



Characterization of Adhesive Bonds and Defects

Backlighted sample (left) and sample disassembled after measurement (right). Two plates of high density polyethylene of 2 mm thickness are glued together with Araldite 2031. During the manufacturing we incorporated foreign bodies in the resin.



Different parameters of the THz data set obtained by the rapid raster scan are used to construct images of the optically opaque object (here on the right, peak amplitude transmission). they reveal its concealed substructures and the distribution of glue. The multitude of information of THz-TDS can be further applied to identify and characterize the substructures.

Conclusions

With the applied single shot spectrometer STRIPP, images of 50 cm² with transversal resolution on the scale of few 100 micrometers can rapidly be recorded in tens of seconds. Its ultrashort acquisition time allows imaging during translation without blurring over the object's substructures in spite of the displacement speed on the scale of meter per seconds. Inclusions of metal, air and dielectrics can be localized and identified without demanding data treatment. Foreign polymers buried in the polymerized adhesive are revealed thanks to their characteristics in the large spectral range accessible by the THz-TDS approach. In addition, the time of flight data allow mapping of thickness with accuracy on the micrometer scale.

See also our **presentation Friday at 09:00 in the Club A** (17. Terahertz Waves Testing)

References:

[1] U. Schmidhammer, V. De Waele, J.-R. Marques, N. Bourgeois and M. Mostafavi, "Single Shot Linear Detection of 0.01 - 10 THz Electromagnetic Fields," *Appl. Phys. B* vol. 94, 95-101, 2009.

[2] P. Jeunesse and U. Schmidhammer, ""On-the-Fly" Monitoring With a Single-Shot Terahertz Time-Domain Spectrometer," *IEEE Sensors Journal*, Special Issue on THz Sensing vol. 13, 44-49, 2013.

* **Contact: uli.schmidhammer@u-psud.fr**