LABORATORY: CNR-ISPC

NAME OF THE INSTRUMENT

Terahertz Time-Domain Imaging Specrometer (THz-TDI):
TeraOSE Menlo Systems

GENERAL DESCRIPTION:

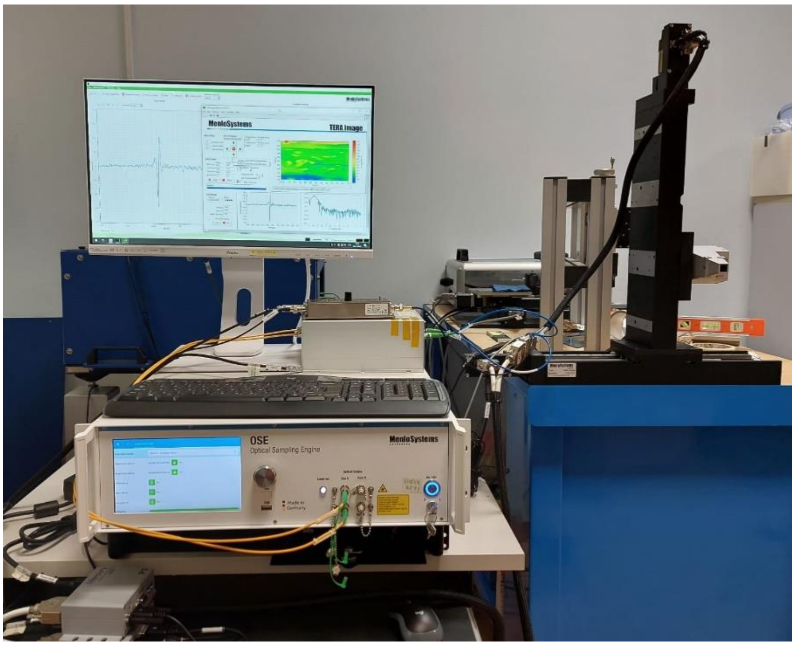
Time-domain spectroscopic imaging at Terahertz frequencies (THz-TDI) is a cutting-edge technique among those currently used for the study of Cultural Heritage and provides information on the layer structure and composition of a sample in a completely non-invasive way. THz radiation is indeed non-ionizing and capable of penetrating most non-metallic materials for depths of the order of a few millimetres. It can be used to carry out both transmission and reflection measurements.

THz-TDI measurements in reflection mode, carried out along several measurement lines, allow to acquire a data cube, which provides, after an adequate data processing, information on the surface and sub-surface of the sample along each of the three spatial sections, i.e. in the (x-y), (x-z) and (y-z) planes.

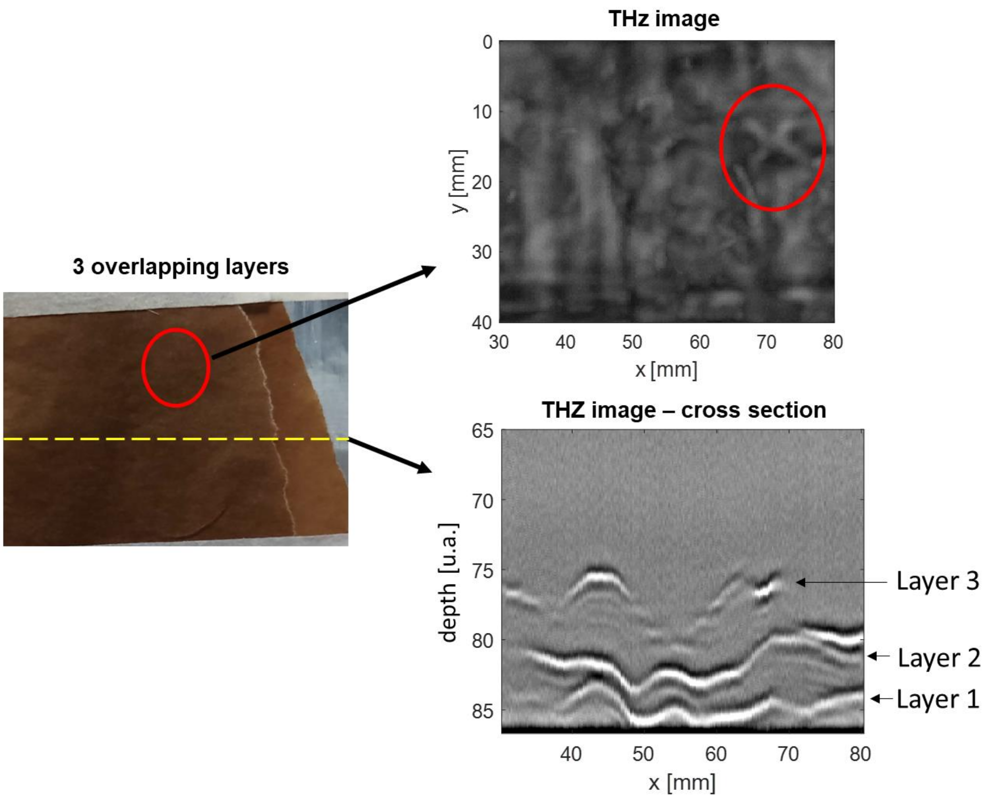
THz-TDI measurements in transmission mode allow both to generate two-dimensional images of the sample and to carry out spectroscopic analyses aimed at identifying the constituent materials. This kind of analysis can be carried out when the thickness and characteristics of the sample allow the transmission of the signal.
Possible applications of THz-TDI include the study of the stratigraphy of decorated artefacts (glazed ceramics, mortars, lacquers, paintings), the identification of preparatory drawings and re-paintings, and optically invisible detachments, cracks or defects, and the characterization of plastic and composite materials.

TECHNICAL DESCRIPTION:

The transportable spectrometer TeraOSE by Menlo Systems available through MOLAB allows to carry out both reflection and transmission measurements. This system exploits the principle of asynchronous optical sampling (ASOPS) thanks to the use of two ultra-fast femtosecond laser sources which are connected to the transmitting and receiving antennas via optical fibres.
The system of generation and acquisition of the THz signal (Optical Sampling Engine, OSE) is compact and integrated in a single unit. It is associated with a two-dimensional scanning system, whose maximum scanning area is 30 x 30 cm^2.
The spectrometer has a total weight of 36.5 kg (OSE = 24 kg, PC = 11 kg, splitter box = 1.5 kg), while the scanning system weighs 15 kg. The dimensions of the OSE are: 56 x 45 x 25 cm^3.
The nominal spectral window of the system is 4 THz and the scan interval in the time domain is 10 ns. The signal to noise ratio is > 70 dB (with frequency difference = -10 Hz, sampling rate = 10MHz, gain = 10^6, bandwidth = 1.8 MHz, 1000 averages).
The lateral resolution of the measurement is determined by the size of the THz pulse at the focal point, which is approximately 1.5 mm, and by the step of the scanning system, which cannot be less than 0.1 mm. The in-depth resolution depends on the usable bandwidth of the system and is about 0.5 ps, corresponding to 60 μm (in air).
The maximum depth of analysis is 7.5 mm (in air).



(a)



(b)

Figure: (a) THz-TD spectrometer TeraOSE, (b) sample prepared in the lab made of 3 overlapping layers of burnt parchment paper on which letters were drawn by pencil (figure on the left) and results of the THz investigation (figure on the right): an image in the plane parallel to the scanned area (top figure) and a cross-sectional image (bottom figure) are shown. The THz-TDI analysis allowed to identify the various layers of paper and to visualize one of the letters present under the first layer.

FURTHER INFORMATION:

- Catapano, I., Picollo, M. and Fukunaga, K. (2017) ‘Terahertz Waves and Cultural Heritage: State-of-the-Art and Perspectives’, in N. Masini and F. Soldovieri (eds) Sensing the Past. Cham: Springer International Publishing (Geotechnologies and the Environment), pp. 313–323. Available at: https://doi.org/10.1007/978-3-319-50518-3_14.
- Fukunaga, K. (2016) THz Technology Applied to Cultural Heritage in Practice. Tokyo: Springer Japan (Cultural Heritage Science). Available at: https://doi.org/10.1007/978-4-431-55885-9.
- Jackson, J.B. et al. (2011) ‘A Survey of Terahertz Applications in Cultural Heritage Conservation Science’, IEEE Transactions on Terahertz Science and Technology, 1(1), pp. 220–231. Available at: https://doi.org/10.1109/TTHZ.2011.2159538.

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