

## Terahertz Time-Domain Spectroscopy for artworks analysis

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In recent years, terahertz (THz) techniques have been used in many fields of applications, most of all in space, telecommunication and security industry. However, the number of projects connecting THz technologies with Science and Culture is constantly increasing and the conservation and restoration of art, e.g. paintings or sculptures, belongs to the most evolving areas in this domain.

The conventional spectroscopic and imaging techniques for the analysis of art pieces comprise: X-ray, Ultra-violet (UV), Infrared (IR) and laser spectroscopy, but even if well established, they may have negative impact on the objects under analysis due to high energies of photons. Only IR reflectography is considered as safe method, but in many cases it is simply not sufficient. THz imaging is a non-invasive and safe technique which extends spectral bands of X-ray and IR spectroscopies to lower and less invasive photon energies. Several years ago, it was proposed for the study of artworks and research in the Uffizi Gallery in Florence and recent developments in THz technology, in particular time domain techniques, enable easier and more effective usage of THz radiation in the field of art conservation.

The best established and most promising THz time domain technique is known as Terahertz Time Domain Spectroscopy (THz-TDS). It can be used to characterize and identify various materials in the THz wavelength range, basing on the intensity of the wave passing through the sample or the wave reflected from it. In addition, the measurement of the phase of the THz wave makes it possible to study the parameters characterizing macroscopic electromagnetic properties of materials, as extension to typical molecular absorption spectra.

Inspired by successful applications of THz techniques in the Uffizi Gallery in Florence, the Louvre in Paris or museums in Milan, we decided at CENTERA to prepare THz-TDS experiments, which provide new information about the internal physical structure of paintings or frescos such as canvases, paper and even dry plaster. THz waves have good penetration depths in all these materials (~1 cm) and with broad spectral bandwidth of ps THz pulses (0.1 - 10 THz), it is possible to identify the substances that the paint consists of basing on the registration of THz absorption spectra. As a result, one can learn about such properties of the analysed pieces of arts such as the depths of subsequent paint layers or pigments.

During investigations a specially prepared picture has been used. It was prepared using two types of paints: oil and acrylic, covering its selected areas with different amount of varnish (different layer thickness). Then the whole painting was painted over with white paint. Two dimensional (x-y) scans of the entire painting were made with THz-TDS spectrometer in both transmission and reflection modes with the resolution better than 1 mm. The obtained results will be presented on the poster.

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