Terahertz time-domain reflection spectroscopy for moisture tomography in gypsum

Christina Daskalaki[1*], Anastasios D. Koulouklidis[1], Christina Anastasia Alexandridi[2], Paraskevi Pouli[1], Vladimir Yu. Fedorov[3], Stelios Tzortzakis[1,3]

[1]*Institute of Electronic Structure and Laser (IESL), Foundation for Research and Technology - Hellas (FORTH), P.O. Box 1385, 711 10 Heraklion, Greece*
[2]*CEA-Saclay, IRAMIS, LIDyl, 91191 Gif-sur-Yvette,France*
[3]*Science Program, Texas A&M University at Qatar, P.O. Box 23874 Doha, Qatar*
*daskalak@iesl.forth.gr

Moisture and soluble salts are two of the major "enemies" of mural paintings, causing their gradual degradation [1]. High levels of moisture within depths of a few millimeters under the wall's surface can cause deterioration or detachment of the fresco painting due to diffusion and eventual evaporation from the surface. The efflorescence phenomenon is also driven by the moisture diffusion through the gypsum. Early detection and mapping of moisture layers under the wall surface is therefore essential in order to treat appropriately the problem in time.

Various methods [1–3] are currently used for moisture detection in walls, none of them though is a tomographic one, meaning that these techniques cannot locate the exact position of the moisture front inside a wall. On the other hand, terahertz time-domain reflection spectroscopy (THz-TDS) could be a natural fit for the in-depth moisture detection due to the unique properties of terahertz electromagnetic waves such as their non-invasive nature and their ability to penetrate through many materials, which are usually opaque in the other parts of the spectrum [4]. The fact that terahertz waves are strongly absorbed by water allows one to achieve high sensitivity detecting even small amounts of moisture, while the pulsed nature of our source enables the ability to acquire in-depth tomographic information.

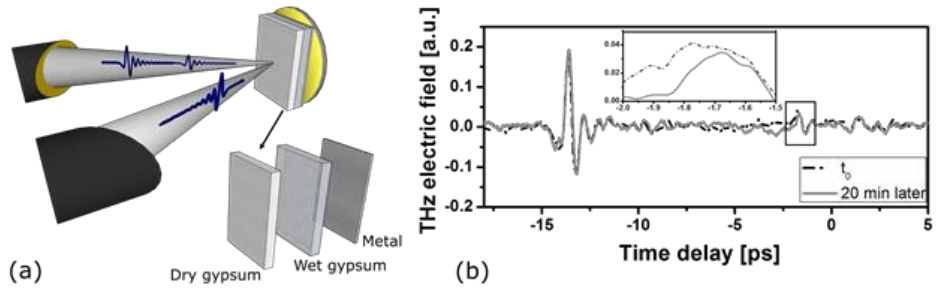

Figure 1: (a) Schematic representation of the studied structure. (b) The reflected THz electric fields.

Here we present our THz-TDS studies demonstrating the detection of the penetrant moisture front in gypsum samples. We observe that it is possible to identify the exact location of moisture in depth of a few millimeters, observing at the same time its temporal diffusion process. Our findings are also supported by theoretical simulations.

THz-TDS could, eventually be used as an early diagnostic technique allowing a targeted restoration procedure and contributing this way to an easier, faster and harmless treatment of mural paintings with high historic and artistic value.

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