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Terahertz spectroscopy and imaging for cultural heritage management: state of art and perspectives

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Non-invasive diagnostic tools able to provide information on the materials and preservation state of artworks are crucial to help conservators, archaeologists and anthropologists to plan and carry out their tasks properly. In this frame, technological solutions exploiting Terahertz (THz) radiation, i.e. working at frequencies ranging from 0.1 to 10 THz, are currently deserving huge attention as complementary techniques to classical analysis methodologies based on electromagnetic radiations from X-rays to mid infrared [1].

The main advantage offered by THz spectroscopy and imaging systems is referred to their capability of providing information useful to determine the construction modality, the history life and the conservation state of artworks as well as to identify previous restoration actions [1,2]. In particular, unlike mid- and near-infrared spectroscopy, which provides fingerprint absorption spectra depending on the intramolecular behavior, THz spectroscopy is related to the structure of the molecules of the investigated object. Hence, it can discriminate, for instance, the different materials mixed in a paint [1,2]. Moreover, THz radiation is able to penetrate several materials which are opaque to both visible and infrared materials, such as varnish, paint, plaster, paper, wood, plastic, and so on. Accordingly, it is useful to detect hidden objects and characterize the inner structure of the artwork under test even in the direction of the depth, while avoiding core drillings. In this frame, THz systems allow us to discriminate different layers of materials present in artworks like paints, to obtain images providing information on the construction technique as well as to discover risk factors affecting the preservation state, such as non-visible cracks, hidden molds and air gaps between the paint layer and underlying structure.

Furthermore, adopting a no-ionizing radiation, THz systems offer the not trivial benefit of negligible long term risks to the molecular stability of the exposed objects and humans.

Recently, the interest on THz technology is also growing up thanks to the development of flexible and compact commercial systems having source and detector probes coupled by means of optical fiber cables and that do not require complex optical alignments. These features allow us to reconfigure the measurement configuration easily; thus transmission, normal reflection and oblique reflection data can be collected according to the constrains and objective of the survey to be performed. Moreover, they open the way to on field applications.

An example of last generation THz systems is the Fiber-Coupled Terahertz Time Domain System (FICO) marketed by Z-Omega and available at the Institute of Electromagnetic Sensing of the Environment. Such a system is designed to perform both transmission and reflection spectroscopy and imaging measurements in the range from 60GHz to 3THz; with a waveform acquisition speed up to 500Hz.

A review of the literature assessing potentialities and open challenges of THz spectroscopy and imaging in the frame of cultural heritage preservation will be provided at the conferences, with a specific focus on the diagnostic capabilities of last generation systems.

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