1.9.10. TERAHERTZ SPECTRAL IMAGING TECHNIQUES IN NDT: TOPOGRAPHY AND COMPUTED TOMOGRAPHY

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The emerging technology of generation and detection of Terahertz waves (1 THz = = 10^{12} Hz) offers diverse potentials in non-destructive testing (NDT) regarding security as well as safety aspects. Herein, we focus on the latter with emphasis on imaging techniques.

The THz range (0.1 – 10 THz, 3 mm – 30 μm) closes the technological gap between ultra high frequency electronics and FIR optics in the electro-magnetic (EM) spectrum. Electro-optical sampling provides straight access to the EM wave (rather than intensity) including its phase. THz waves are well suited to characterize non-metallic materials since they penetrate paper, plastics, ceramics and certain composits (e.g. GFC).

We employ a commercial fibre-coupled THz time domain spectrometer (TDS) for scanning the samples laterally through a focal spot. At each position the entire temporal pulse train is recorded, which offers the opportunity to use various parameters derivable for imaging. Topographic measurements are performed as reflection set-up.

The achievable spatial resolution is diffraction limited at about 100 – 300 μm (which allows for perception of single defects on a sub-mm scale). In contrast to typical pulse echoed ultrasound testing THz topography is a non-contact inspection tool without coupling agents. Several reflections of subsequent concealed layers are detected instead of just the first encountered one. Comparing to X-ray (radiology) the non-ionizing THz-waves generate images of similar contrast regarding metal and plastic (organic) components, while conventional radiography emphasizes one type of material depending on the energy pre-selected. Moreover, the full temporal information is exploited to derive spectra in certain selected time windows, i.e. separated spectral properties of each layer in multilayered structures.

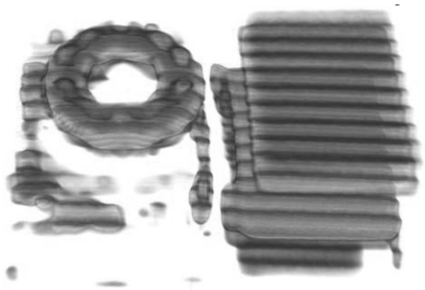

Fig. 1. THz time-of-flight topograph of a mobile music player. The vertical direction stands for the optical depth information (direction of incidence). Different structures such as ICs, plastic clippings, resistors and cables can be recognized

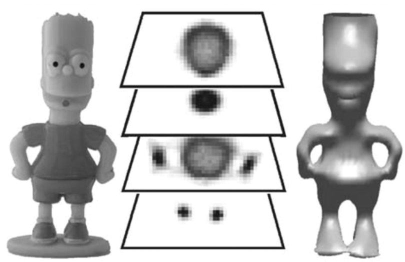

Fig. 2. THz CT of a small plastic figure. From left to right: photography, four different reconstructed transversal layers, and a full 3D reconstruction of the outer surface

Tomographic measurements are performed in transmission mode. The sample is mounted on a rotation stage in order to allow for lateral scanning under the different projection angles. The reconstruction is typically performed by filtered backprojection, which is widely used for X-ray CT. The adaption of this technique to the THz range comes along with several experimental drawbacks such as considerable refraction and scattering. According to these difficulties we investigate the occurring artefacts. The THz-TDS provides the opportunity to calculate a separate backprojection of each frequency interval as obtained by the Fourier transformation of the recorded time resolved amplitude. This results in a spectrally resolved reconstruction of each voxel, which is unique in computed tomography technology.