THz Imaging System for Industrial Quality Control

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***Abstract* — THz imaging technology can complement quality controls in Agricultural and food industry due to the new point of view offered by THz. In this paper, an active THz imaging system based on a network analyzer with two frequency extender up to 0.22THz and a quasioptical system is presented. The resolution of the system is measured using metal squares placed on a leaf. This metal squares are used to show differences in power absorption levels. Defects are also placed in one sample, in order to check the possibilities offered by THz imaging to detect unwanted objects and defects in a leaf.**

***Index Terms* — THz Imaging, Terahertz, Active, Quality control.**

I. INTRODUCTION

Quality control systems in industry can benefit from the new possibilities offered by THz frequency range. THz imaging systems can complement actual quality control systems and at the same time offer new information about products, improving quality and reducing costs.

THz frequencies provide the capability of seeing inside some materials in a non-destructive way. This capability is due to the fact that some materials are transparent in this frequency range. At the same time, the variation in transmission and reflection parameters depending on the materials at THz range, can be used to obtain images.

In this paper, an implemented imaging system to control the quality of samples for the agricultural and food industry is presented. This system allows to detect defects or unwanted elements in the object under test. Firstly, the resolution of the system and a characterization of power levels are presented. Finally, some defects are measured like examples for the finally quality system.

II. IMAGING SYSTEM

The imaging setup used is based in two Vector Network Analyser (VNA) Extenders, a T/R module and a T module, working in the frequency range from 0.14 THz to 0.22 THz which have been connected to a E8361C PNA Network Analyzer (Fig. 1). The sample under study is placed in between these two VNA Extenders. Reflection and transmission parameters through the sample can be measured with this configuration. The sample is held by one slab of dielectric material which prevents its movement and gives rigidity to the setup. The assembly is placed in a three dimensional scanning system in a vertical position (Fig. 2).

The 3D scanning system is moved in the XZ plane, in order to map the whole sample. Each measurement point corresponds with a pixel in the final THz image. The movement of the 3D scan and the data acquisition is governed by an in house LabView interface.

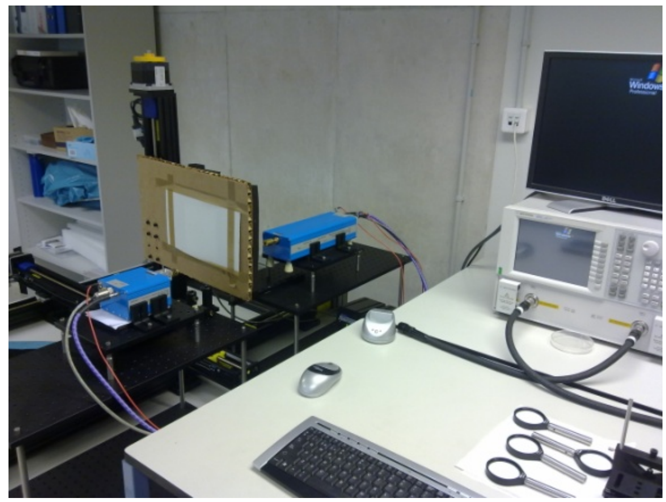

Fig. 1. Imaging System with the E8361C PNA Network Analyzer and 3D Scanning System.

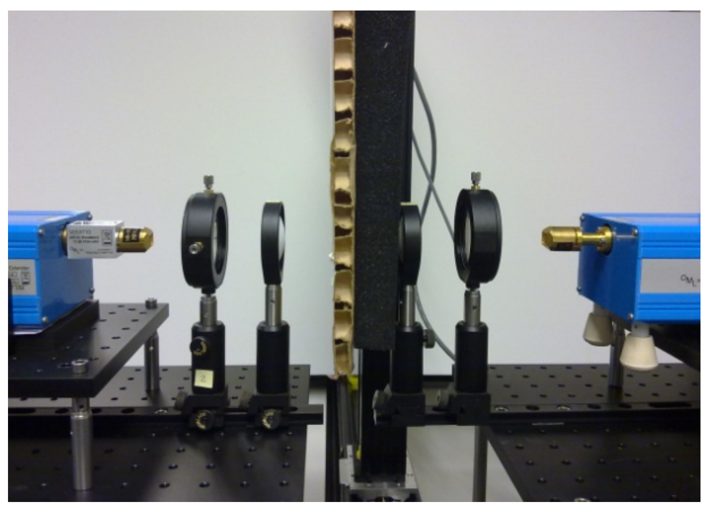

Fig. 2. Cuasi Optical system including the two pairs of lenses and two Vector Network Analyser (VNA) Extenders.

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The set-up uses two standard gain horn antennas in order to transmit and receive the THz signals.. A quasioptical set-up based on lenses has been designed in order to focus the beam. The lenses included were two pair of lenses with 50 mm and 100mm focal length. Two lenses have been placed in between the emitter and the leaf under test, and other two in between the leaf and the receiver (**Error! Reference source not found.** 2). The distance in between lenses has been optimised based in Gaussian beam theory [5].

III. EXPERIMENTAL RESULTS

A. Resolution Measurement

In a first step, in order to measure the resolution of the system in an experimental way, small metal squares from 2mm to 7mm side edge were placed on the surface of a leaf. . (Fig.3). A THz active image was taken using the imaging system at 0.2 THz.

Measured transmission values at 0.2 THz have been normalized with respect to the maximum transmission value at this frequency. Each value has been plotted in dB as a pixel of the image, obtaining the THz image at 0.2 THz presented in Fig. 4.

Squares from 3mm to 7mm side edge can be clearly distinguished and the smallest square (2mm side edge) can be identified with enough precision adjusting the image scale. Based on these results, it can be said that the resolution of the imaging system is, at least, of 2mm.

At the same time the central nerve of the leaf can be clearly distinguished in a blue color due to the high absorption experimented by the THz signal. The nerves contains higher water level, which is translated in a higher absorption in THz domain due to their sensibility to water presence.

B. Defect Detection

Different levels of absorption can be measured in the leaf. A slice of absorbent, a hole in one of the leaves and a metal square were placed in a leaf as can be seen in Fig. 5. Furthermore, some leaves were partially superposed to check the impact of the superposition in the power levels measured in the THz image.

As can be seen in Fig. 6, the system can detect level differences between the absorbent, the metal and the hole.

Fig. 3. Image in visible spectrum of the leaf with the metal squares. The triangle in top of the leaf is using for alignment.

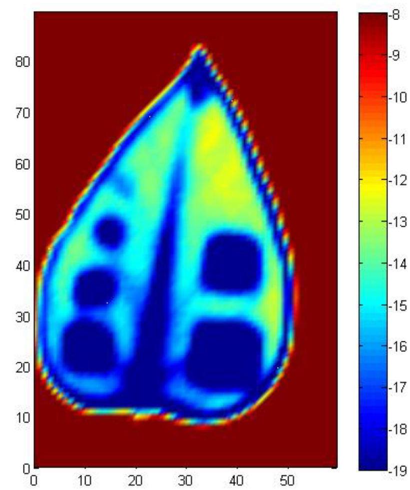

Fig. 4 0.2 THz active image of the leaf shown in Fig. 3. Dark blue shows very low level of received power.

Defects can be identified by their position in the leaf, but also by their levels of absorption, reflection and transmission. A metal piece, using electromagnetic theory is like a mirror. Due to this, a high level of reflection power can be expected for a metal square. A high reflection (for the same absorption level) is translated into a low transmission level. In Fig. 6, a very low transmission square can be distinguished in bottom-right part of the picture, where a metal square is seen in visible image (Fig. 5)

Using the same theory, absorbent can be identified, too. In this case, absorbent has a very high absorption parameter,. Transmission level has to be lower than free space case but higher than metal one. This region can be identified in the middle-top- position in Fig 6, where the absorbent slice is placed (Fig 5).

Finally, the hole in the leaf has to appear like a maximum in the transmission parameter. There is no reflection or absorption in this case, as can be seen in the right part of Fig. 6.

The leaf stack and the nerves can also be seen in Fig. 6 in green color due to the fact that they have a higher level of water, which is translated in a higher absorption in the THz image. In blue color it is possible to distinguish the superposition of the leaves due to the fact that the THz signal has to go through the double amount of water than in a single leaf. Quality control system can benefit from this superposition detection to control number of slices or thickness.

As can be seen in Fig. 6, the quasioptical set-up working with the network analyzer provides enough resolution (up to 2mm) to detect unwanted elements in the sample. Therefore the prove of concept of detecting unwanted objects, in this case in a leaf, in the THz frequency range has obtained satisfactory results. .

As a resume, it can be said that with a THz imaging system is possible to detect defects and unwanted objects and take a decision, if the final system required it. For this experiment only a single leaf has used although food industry can benefit from this detection in order to improve their quality and check their final products.

IV. CONCLUSIONS

Active THz Imaging can be used to improve the quality in food and agricultural industry. With a resolution of 2mm it is possible to detect and differentiate fragments inside the product (like metal or absorbent) or characteristics of the sample (like superposition of slices, high level water content or small parts).

This work is a first step in defect detection field for agricultural and food industry. Taking into account the requirements of the final system, the speed of the measuring system has to be adjusted. In the same way, it is necessary to determinate the minimum resolution of the final system, to configure the set-up.

ACKNOWLEDGEMENT

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Fig. 5. Leaf in visible spectrum with some defects: hole, metal square and a slide of absorbent.

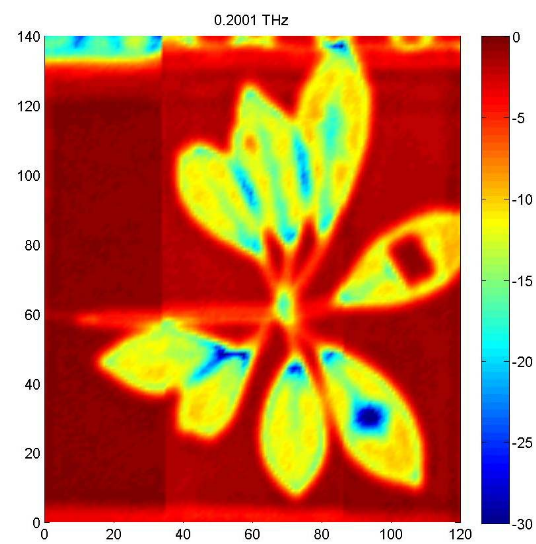

Fig. 6. 0.2 THz image of the leaf shown in Fig. 5

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