Terahertz imaging of carcinoma-affected colon tissues fixed in paraffin

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***Abstract*— A compact THz imaging system was developed for the adenocarcinoma-affected human colon tissues measurement simultaneously in transmission and reflection geometry. The contrast between the cancer and control tissues fixed in paraffin at 0.6 THz frequency was up to 23%.**

I. INTRODUCTION

RECENT achievements in the terahertz (THz) science and technology have triggered new applications in biology and biomedicine with particular attention to explore the specific spectroscopic fingerprints [1-2]. THz waves were demonstrated to be very useful for detection of the skin, colon, gastric cancer [3-5]. Generally cancer environment causes increased blood supply to affected tissues and increase content of water [6]. This fact acts as a natural contrast mechanism for THz imaging of cancer. Moreover, the structural changes occurring in affected tissues also contribute to contrast of the THz image [7-8].

In this work, the dehydrated human colon tissues were studied at 0.6 THz frequency. For this purpose compact THz imaging system with high numerical aperture optic components was developed and used for the adenocarcinoma affected human colon sections imaging simultaneously in transmission and reflection geometry.

Results demonstrated the contrast up to 23% between dehydrated neoplastic and control tissues fixed in paraffin. Found data corroborate with previous histologic findings and confirm that the contrast prevails even in dehydrated tissues.

II. RESULTS

Experiment setup for THz imaging in reflection and transmission geometry is shown in Fig. 1. Frequency multiplier chain was used as a THz source emitting monochromatic $f = 0.6$ THz radiation. Sensitive simultaneous detection of reflected and transmitted radiation was ensured by employing antenna-coupled micro-bolometer sensors operating at high speed suitable for real time operation [9]. Object under investigation was placed in the focal plane of two mirrors and raster scanned with a high speed motorized positioning stages. Position synchronized scanning with a constant speed of 20 mm/s was used to enable reasonable fast image acquisition for large area objects. A set of two 2” diameter off-axis parabolic mirrors (M4, M6) with a focal length of 5 cm was used to focus radiation to a spot size with a close to wavelength diameter. To confirm this spatial resolution was tested by THz imaging of high resolution target with pattern size being from 1.2 mm up to 0.15 mm. The results are shown in Fig. 2. It was demonstrated that patterns with size up to 0.5 mm can be distinguished with the developed system.

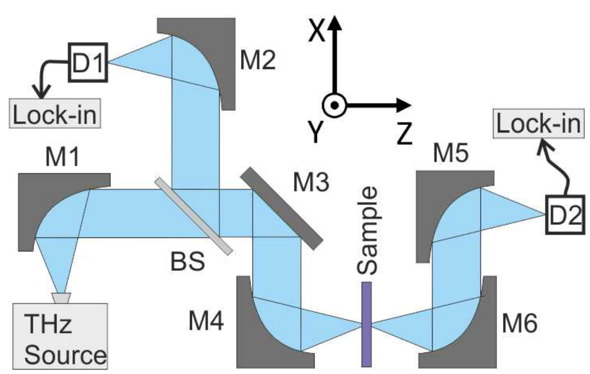

Fig. 1. Setup of compact terahertz imaging system working in the transmission and reflection geometries.

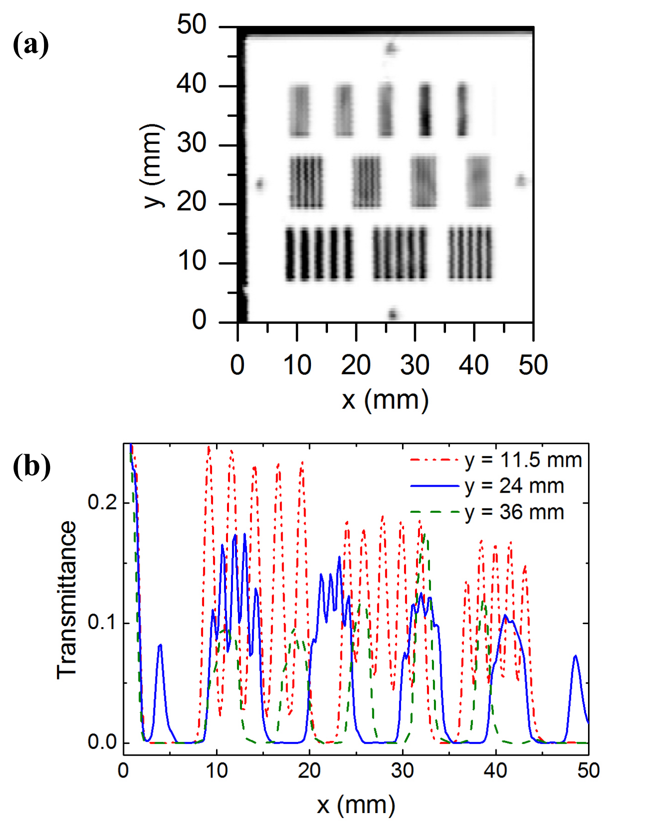

Fig. 2. (a) Transmittance image of high resolution spatial target at $f = 600$ GHz frequency. Black color corresponds to maximum transmittance. (b) Cross section profile along x axis of THz image (a) at position $y = 11.5$, 24.0, and 36.0 mm.

Histological samples with constant thickness of 2 mm were taken from partial distal and total gastrostomy. A set of 14 anonymous control and carcinoma-affected human colon tissue blocks was obtained from the archives of the Department of Pathologic Anatomy of São João Hospital under Authorization of Ethics Commission, CES 211-13 – Centro Hospitalar S. João – EPE, Porto, Portugal. Biological tissues with pT3 and pT4 adenocarcinoma types were selected for the experiment. The tissue samples were prepared according to the standard protocols. The tissue samples preparation and acquisition procedures were comprised in four steps: 1) specimens preparation and fixation; 2) selection of tissue from the specimens; 3) processing the tissue of the samples; and 4) paraffin-embedding and mounting in the paraffin blocks. In the steps 3 and 4 samples were submitted to a standardized fixation in formalin buffered at 10%, dehydrated with crescent concentrations of ethanol (75% - 90% - 100%), clarified with xylene. During experiment samples were kept at room temperature.

Biological samples were investigated via THz imaging in transmission and reflection geometries in the same measurement. The THz absorbance and reflectance images of the adenocarcinoma type pT4 blocks are shown in Fig. 3. We noted a high spatial resolution of the THz images obtained. Obvious contrast between tumor and control tissues can be seen in absorption images. Moreover noticeable differences between less developed and slightly more developed tumor stage was possible to distinguish. As for reflection images only minor differences can be observed with plain eye. Therefore deeper image analysis was carried out to numerically evaluate the differences between the control and the affected samples. For this purpose the range of interested was set to the THz images using the superposition of photo and THz images. After that, the average values of absorption and reflection was calculated for control and cancer affected samples. In average, control tissues exhibit absorption of 0.82 and reflection of 3.7%. As for diseased tissues average values of 1.15 and 4.7% was calculated. Such analysis revealed that the contrast between dehydrated neoplastic and control tissues fixed in paraffin was up to 23% via THz imaging.

Our experiment results showed that the dehydrated control and diseased tissues show contrast in THz absorption at 600 GHz frequency. This leads to a conclusion that other factors, like structural change of the tissue, have significant contribution to the imaging data. Further interdisciplinary studies may be required in the future to reveal exact physical contrast mechanisms. Despite that, this work shows that THz imaging with monochromatic waves is a promising tool for the diagnostic of biological tissues with the high spatial resolution.

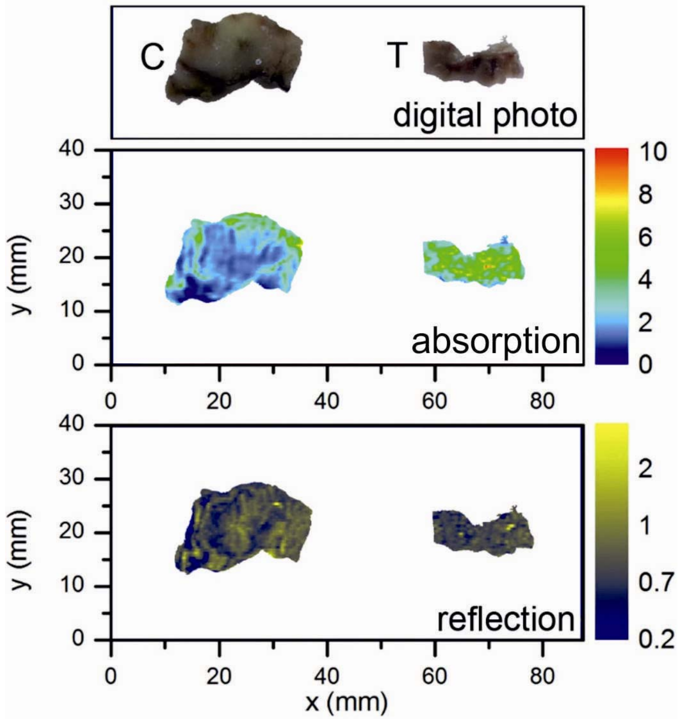

Fig. 3. Visible and the THz absorption and reflection images of the control (C) and adenocarcinoma tumor (T) tissues fixed in paraffin (ID number: #16481). Dark blue color in the THz image corresponds to lower absorption and reflection values, respectively.

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