

# Medical diagnostics using terahertz pulsed spectroscopy

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**Abstract.** The paper contains recent results of studying the ability of human body disease diagnosis with terahertz time-domain spectroscopy. *In vitro* skin cancer samples (squamous cell carcinoma, epithelioid cell melanoma, infiltrating carcinoma) were studied experimentally with terahertz pulsed spectrometer. The parametrical *in vitro* images of skin cancers are presented. The ability to make early tooth cariosity diagnosis with terahertz time-domain spectroscopy was also shown experimentally. The results of studying the *in vitro* tooth samples are presented and discussed.

## 1. Introduction and background

Terahertz (THz) technology could become an effective tool for medical diagnostics. THz rays are strongly absorbed by water molecules. Human body penetration depth of THz radiation is low due to high water concentration in tissues [1]. But penetration depth is high enough to make a diagnostics of human epithelial tissue diseases, human tooth diseases.

List of papers are dedicated to the medical applications of THz spectroscopy. The potentiality for THz time-domain spectroscopy (TDS) usage for diagnostics of basal cell carcinoma of skin was shown in works [2],[3]. The papers [4],[5] indicate that THz pulsed spectroscopy could become a powerful tool for intraoperative diagnosis of human breast cancer. TDS system would help to find the region of cancer disease during the operation of cancer excision. Also THz spectroscopy could be useful for diagnosis of colon tissue cancers [6], but the problem of THz beam delivery into human colon should be solved at first. The potential application of THz sensing to the field of ophthalmology was considered in paper [7].

## 2. Results

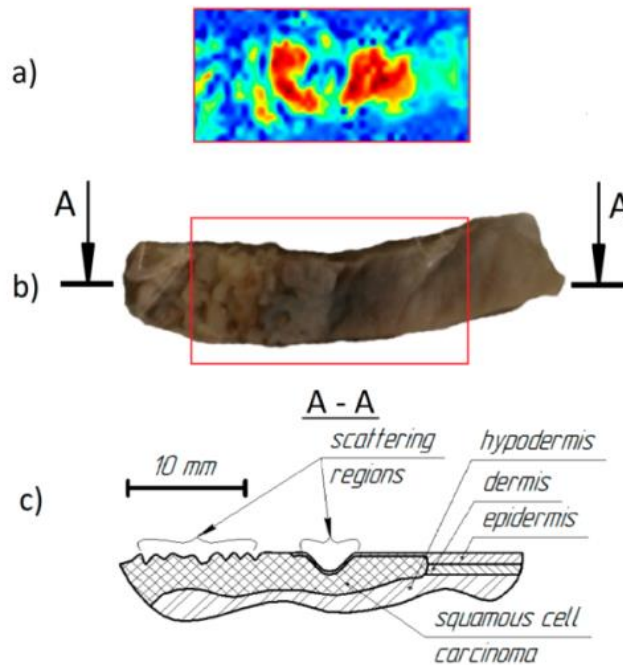
### 2.1. Screening diagnostics of skin cancers

There are differences between structure and chemical composition of healthy and diseased tissue which leads to differences in THz spectral reflectivity. Sensitivity of THz radiation to water concentration in tissue allows us to detect cancer on its initial stage.

In the figures 1, 2, 3 the results of different skin cancer studying are presented. The experiments were produced using THz TDS system equipped with the mechanical raster scanning system. The

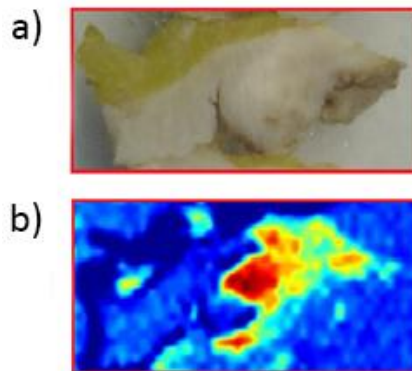


samples were studied *in vitro* in reflection geometry. Parametrical images of skin samples were obtained after processing of collected spectroscopic measurements of raster scan utilizing the method of spectra integration suggested in [8].

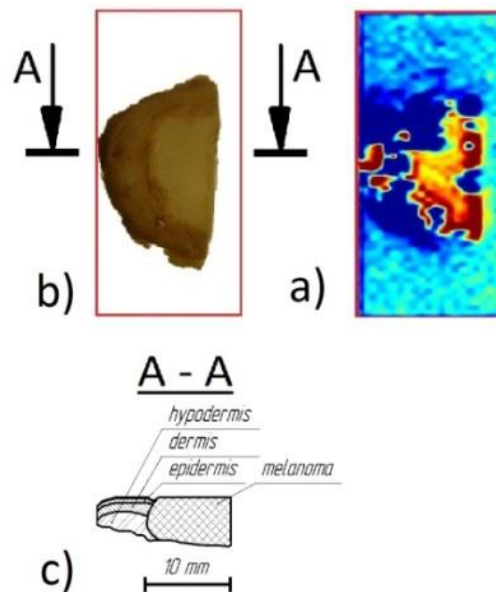


**Figure 1.** Squamous cell carcinoma:

(a) is a parametrical image, (b) is a photo of *in vitro* diseased skin, (c) is an illustration of the sample surface profile.



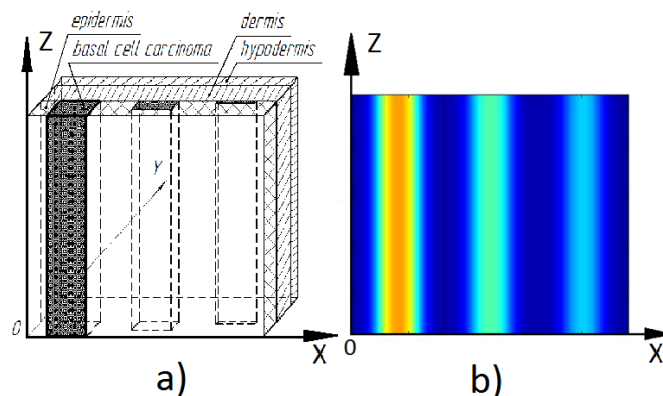
**Figure 2.** Infiltrating carcinoma: (a) is a photo of *in vitro* diseased skin, (b) is a parametrical image of the cancer.



**Figure 3.** Epithelioid cell melanoma: (a) is a parametrical image, (b) is a photo of *in vitro* diseased skin, (c) is an illustration of the sample surface profile.

Differences in THz spectra of healthy and diseased skin lead to appearance of contrast between healthy skin and sick tissues in parametrical images. High contrast in parametrical images was observed for all examined types of skin cancers. Contrast also presents at the regions of the samples where the cancer lies at a small depth under the layer of the healthy skin (about **0.5 mm**).

Figure 4 shows the results of mathematical modelling of parametrical image generation process with TDS system [10]. THz radiation interaction with a diseased skin (basal cell carcinoma) was modelled by means of numerical solving of Maxwell's equations with finite-difference time-domain (FDTD) method. Skin cancers located at a different depth under the healthy epidermis were considered. The modelling results allow us to conclude that the skin cancer diagnosis is possible if the depth of cancer is smaller than **1 mm**. Cancer regions with lateral size smaller than **0.5 mm** could be detected. Thus TDS systems and THz imaging systems seem to be a good instrument for the skin cancer screening diagnosis.

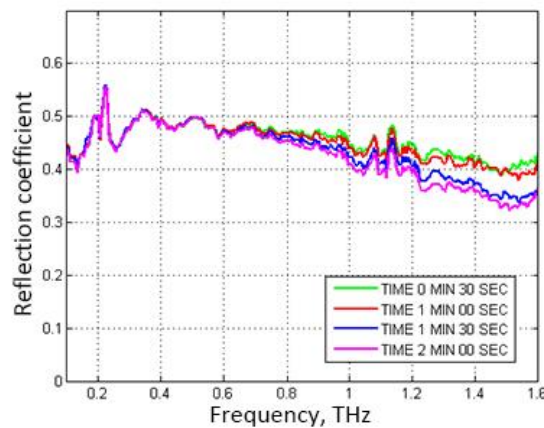


**Figure 4.** Modeling of the parametrical imaging: (a) is a model of skin diseased with basal cell carcinoma, (b) is a results of parametrical image generation.

## 2.2. Early diagnostics of tooth cariosity.

Low water content in tooth enamel and sensitivity of THz radiation to mineral content in dental tissue make it possible to use THz radiation for tooth demineralization diagnostics (diagnostics of early tooth cariosity) [9]. Mineral content in enamel tissue is strongly related with enamel reflectivity at THz frequencies.

In the figure 5 the result of experimental studying of tooth enamel reflectivity in different demineralization conditions are presented. The stages of demineralization were modelled by means of washing out tooth minerals with orthophosphoric acid (35%). At all stages of minerals leaching the tooth looked healthy and did not contain any white spots. But THz reflectivity of sample differs for all demineralization stages.



**Figure 5.** Reflectivity of tooth enamel *in vitro* after leaching of minerals with orthophosphoric acid (35%) for **30 sec., 1 min., 1 min. 30 sec., 2 min.**

Notice, the spectral reflectivity is decreasing during the enamel demineralization especially at high frequencies. It could help us to make early tooth cariosity diagnostics with TDS system [11].

## Conclusions

The present paper has gave the brief overview on biomedical applications of THz pulsed spectroscopy. Recent results of studying the ability to make early diagnosis of skin cancers and tooth enamel demineralization with THz radiation were presented and discussed.

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