Development of the technique of terahertz pulse spectroscopy for diagnostic malignant tumors during gastrointestinal surgeries

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Abstract. Samples of fresh excised tissues obtained from patients who had undergone gastric cancer have been investigated. Samples were consisted of cancer zone, normal zone and zone mixed of normal and cancer tissues. Their optical properties and spectral features were investigated by terahertz time-domain spectroscopy (TDS) in reflection mode. It was found that waveforms of reflected signals from normal and cancer tissues were well distinguished so it can be concluded that it is easy to discriminate gastric cancer tissue from normal by using THz TDS.

1. Introduction
Terahertz (THz) reflectometry has been applied to a lot of biomedical research and cancer diagnosis has become the main course of this researches. As soon as endoscope was invented the potential of THz spectroscopy increased and during the past few years, the basic tissue characteristics of each digestive organ in THz regime have been investigated. Although advanced gastric cancers have shown poor prognosis, the early staged gastric cancers can be cured by surgery in patients with good operator-independent technique of cancer tissues diagnostics around tumors during surgeries.

The main advantage of the THz spectroscopy which is really important for biophotonics is that the characteristic energies of molecule’s rotational and vibrational motions lay in THz frequency region, so many chemical and biological molecules can be identified by their characteristic resonant peaks. In additional THz radiation is non-ionizing and might be applied in vivo diagnostics that is the big advantage for biological structures, because there are not appeared any destructions during the procedure.

The aim of the study was to evaluate the feasibility of THz time-domain reflectometry for the discrimination of gastrointestinal cancer tissues from normal tissues and searching of appropriate method for discrimination unique spectral features and optical properties of gastrointestinal tract cancer tumors for better it distinguishing during surgeries. In this study samples of fresh excised tissues obtained from five patients who had undergone gastric cancer have been investigated. Samples were consisted of cancer zone and normal zone.
Waveforms of signals reflected from the fresh tissues were obtained by the THz time-domain spectroscopy system in reflection mode. In addition, several optical properties extracted from the THz reflection signals were analyzed to quantitatively discriminate gastric cancer tissues from normal regions.

2. Description of the samples and experimental setup
Subject of study were fresh excised tissue specimens obtained from patients who had undergone gastric cancer. Samples were consisted of cancer zone, normal zone and zone mixed of normal and cancer tissues (figure 1).

All of the specimens were consisted of cancer zone, normal zone and zone mixed of normal and cancer tissues.

The specimens were investigated within 4 hours after their extraction by the THz time domain (TD) spectrometer in the reflection mode (figure 2). The characteristics of the spectrometer are following: the spectral resolution of 15GHz, the sensitivity of lock-in amplifier of 1mV, the lock-in amplifier time constant of 1s. The THz broadband pulsed radiation had the following parameters: the spectral range of 0.1–1.5THz, the pulse duration of 2.7ps, the average power of 30 mW. THz radiation was generated by femtosecond laser (Yb:KYW) irradiation of undoped indium arsenide crystal. The femtosecond laser parameters are following: the wavelength of 1040nm, the pulse duration of 120fs, the pulse repetition rate of 75MHz, the power of 1W.

The aim of the study was to evaluate the feasibility of THz time-domain reflectometry for the discrimination of gastrointestinal cancer tissues from normal tissues. The spectra in frequency domain were obtained by the Fourier transform of the measured time domain waveforms of signals reflected from the fresh tissues and then were analyzed to quantitatively discriminate gastric cancer tissues from normal regions by their optical properties.
Figure 2. Scheme of the THz pulsed spectrometer in the reflection mode. FL-1 — infrared laser; M — mirrors; 1 — beam splitter; 2 — optical delay line; 3 — THz radiation generator: crystal of InAs in a magnetic system; 4 — parabolic mirrors; 5 — chopper; 6 — biological object; 7 — THz radiation beam splitter on the basis of high-resistivity silicon wafer; 8 — TPX polymer lens; 9 — electro optical crystal of CdTe; 10 — achromatic quarter-wave plate; 11 — Wollaston prism; 12 — balanced photodiodes.

3. Results and Discussions
In our work the optical properties and spectral features of gastric cancer tissue and normal tissue were obtained. Averaging was made by five measurements. Due to the fact that THz radiation is strongly absorbed by water and oncological tissues have increased water content compared with normal tissues it is easy to discriminate these two tissues by intensity of the reflected signals. This study have shown such differentiation that you can see in figure 3.

Figure 3. Differentiating of reflected signals intensity of cancer and normal tissues occurred because of different water content in these tissues. Also the reflected signal of pure water is shown so it is clear that absorption coefficient of cancer tissue and water pretty similar.

For more accurate results it is necessary to calculate the optical properties of normal and oncological tissues and quantitatively discriminate these parameters. The basic optical properties such as refractive index and dielectric permittivity were calculated (figure 4 – 5). The dispersion of
refraction index is about 1.4 – 1.6 for normal tissues, 2.15 – 2.55 for cancer tissues and 2.2 – 2.7 for water in the frequency range of 0.25 – 0.6 THz. The comparison of refractive indices could be an additional approach in the diagnostics of gastrointestinal cancer.

**Figure 4.** The dispersion of real part of refractive indices of water, cancer and normal tissues in frequency range of 0.25 – 0.60 THz.

**Figure 5.** The dispersion of real part of dielectric permittivities of water, cancer and normal tissues in frequency range of 0.25 – 0.60 THz.

4. Conclusions

Thus, the possibility of THz reflectometry for discrimination of cancer tissues from normal tissues has been investigated. It was shown that it is easy to discriminate such tissues by using THz TDS because of their differences of water content. Due to this fact it is enough to get waveforms of reflected signals from different tissues for further its comparison. And to reach more accurate results the comparison of the optical properties might be used. Therefore, this method of investigation might be easily applied in clinical in vivo gastric cancer diagnostics.

Acknowledgments

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