Fiber optic sensor for detecting neoplastic lesions in biological tissues - a preliminary study

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Graphical Abstract

Interference spectra of liver tissues

Intensity [W] vs. Wavelength [nm]

Healthy liver tissue vs. Liver metastases
Abstract:
Tissues affected by neoplastic lesions differ from healthy tissues in terms of functionality and anatomy. These changes affect light propagation in tissue, therefore modifying the refractive index, as well as scattering and absorption coefficients. The primary purpose of the research was to create a system to detect local changes in the refractive index using a fiber optic sensor. A prototype of a micromachine for biomedical applications has been developed. The measurements were performed using the low-coherence interferometry method, i.e. a measurement technique based on the phenomenon of interference of light waves from a broadband light source. The constructed optical system uses a light source with a central wavelength of 1550 nm, a spectrum analyser, a fiber optic sensor operating on the basis of a Fabry-Pérot interferometer and a silver mirror acting as a reflective layer. Measurements of the interference spectrum of reference oils, used for calibration due to the high stability of their parameters, were performed. It has been shown that the developed fiber optic sensor is able to detect changes in the refractive index based on the shift in the position of the central peak in the interference spectrum. It is also sensitive to changes of the absorption coefficient.

Keywords: fiber optic sensors; Fabry-Pérot interferometer; refractive index; neoplastic lesions
Introduction

- functional and anatomical differences between normal tissue and neoplastic lesions affect the light propagation in tissue
- significant changes of refractive index, scattering and absorption coefficients

**Thesis:** It is possible to differentiate normal tissues from neoplastic lesions based on the changes in interference spectra.

→ We have designed and developed a micromechanical system with a fiber optic sensor for detecting changes in the refractive index of biological tissues.
Introduction – RI of liver in 1550 nm

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Mean real index ± SD</th>
<th>Mean imaginary index ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (reference group, healthy liver tissue)</td>
<td>1.362 ± 0.003</td>
<td>0.0024 ± 0.0009</td>
</tr>
<tr>
<td>MET (liver metastases)</td>
<td>1.343 ± 0.011</td>
<td>0.0038 ± 0.0016</td>
</tr>
<tr>
<td>NMET (non-cancerous liver tissue)</td>
<td>1.361 ± 0.010</td>
<td>0.0039 ± 0.0015</td>
</tr>
</tbody>
</table>

Methods – Measurement Setup

• The constructed optical system consists of:
  • a Fabry-Pérot interferometer working in reflective mode,
    • cavity length: 150 μm
    • reflective layer: silver mirror
  • an optical spectrum analyzer (Ando AQ6319, Tokyo, Japan),
  • broadband NIR-radiation sources (S-1550-G-I-20: \( \lambda = 1550 \) nm,
    \( \Delta \lambda_{\text{FWHM}} = 45 \) nm Superlum),
  • a single-mode 1 × 2 coupler with 50: 50 power splitting ratio,
  • single-mode optical fibers (SMF-28, Thorlabs).
Methods – Measurement Setup

Methods – Examined parameters

- Examined parameters of the interference spectra:
  - position of the central peak [nm]
  - signal intensity of the central peak [μW]
  - visibility (V) [a.u.]
  - absorption (signal intensity of I_{min}) [μW]
Examined parameters

Interference spectra of reference oil RI=1.34

- Signal intensity of the central peak
- Position of the central peak

Intensity [W]

Wavelength [nm]
Examined parameters – visibility (V) and absorption

Interference spectra of reference oil RI=1.34

\[ V = \frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{max}} + I_{\text{min}}} \]
Results

Interference spectra of reference oil RI=1.34

- Intensity [W]
- Wavelength [nm]
Results

Interference spectra of reference oil RI=1.36

Intensity [W]

Wavelength [nm]
Results

Interference spectra of reference oils

- Blue line: Reference oil RI=1.34
- Orange line: Reference oil RI=1.36

Intensity [W] vs Wavelength [nm]
**Discussion**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>RI = 1,3400</th>
<th>RI = 1,3600</th>
</tr>
</thead>
<tbody>
<tr>
<td>position of the central peak [nm]</td>
<td>1541.32 ± 0.04</td>
<td>1542.40 ± 0.04</td>
</tr>
<tr>
<td>signal intensity of the central peak [μW]</td>
<td>896.10 ± 1.61</td>
<td>666.52 ± 1.64</td>
</tr>
<tr>
<td>visibility (V) [a.u.]</td>
<td>0.38798 ± 0.00105</td>
<td>0.39295 ± 0.00169</td>
</tr>
<tr>
<td>absorption (signal intensity of $I_{\text{min}}$) [μW]</td>
<td>395.50 ± 1.14</td>
<td>290.47 ± 1.33</td>
</tr>
</tbody>
</table>
Discussion

• Visible differences between obtained interference spectra for examined reference oils.

• Developed setup is sensitive to the changes of:
  • refractive index,
  • absorption.
Conclusions

• The interference spectra can be used as a source of information about changes in optical parameters of the tested material.

• The developed fiber optic sensor is able to detect changes in the refractive index based on the changes in the spectra.

• Developed measurement method will be used to distinguish between healthy and neoplastic tissues – need for further research on biological tissues.

• Developed method will be used to design and produce a micromachine for biomedical applications.
Supplementary Materials

References:


Acknowledgments

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Study title: ‘Examination of optical parameters of biological tissues and tissue phantoms as a function of temperature’. 
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