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

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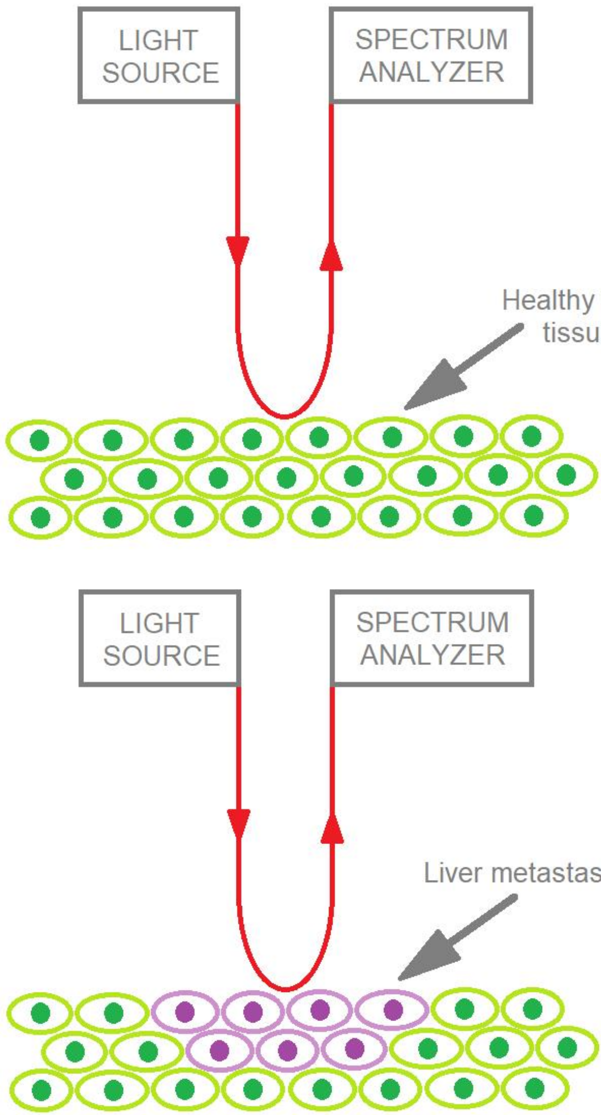
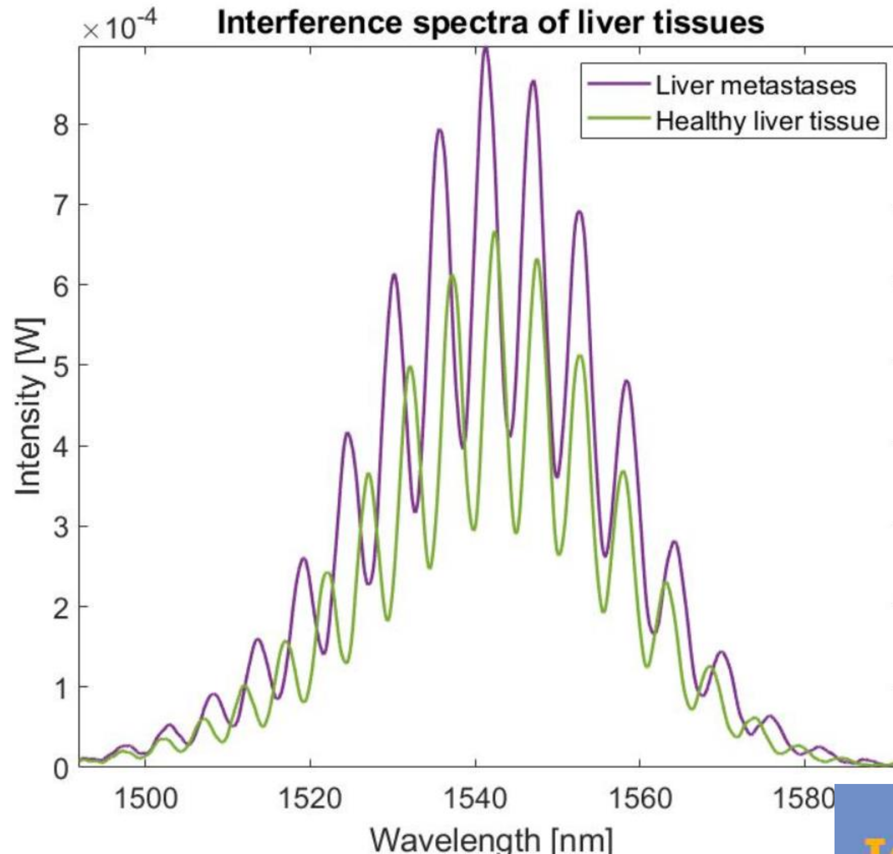
Graphical Abstract





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

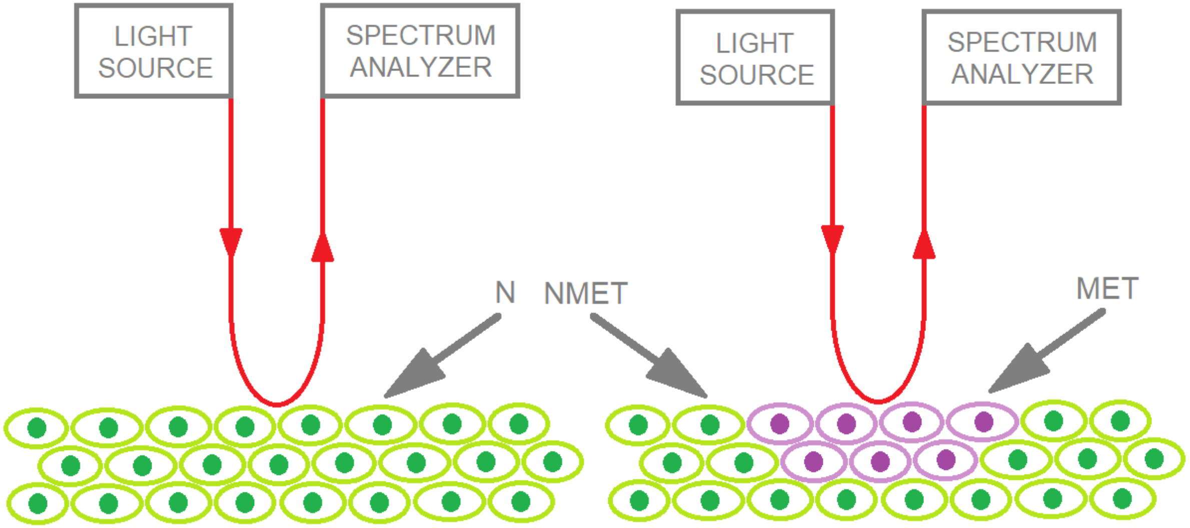
Introduction

- 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



Tissue	Mean real index ± SD	Mean imaginary index ± SD
N (reference group, healthy liver tissue)	1.362 ± 0.003	0.0024 ± 0.0009
MET (liver metastases)	1.343 ± 0.011	0.0038 ± 0.0016
NMET (non-cancerous liver tissue)	1.361 ± 0.010	0.0039 ± 0.0015

Giannios, P., Toutouzas, K., Matiatou, M. *et al.* Visible to near-infrared refractive properties of freshly-excised human-liver tissues: marking hepatic malignancies. *Sci Rep* **6,** 27910 (2016). https://doi.org/10.1038/srep27910

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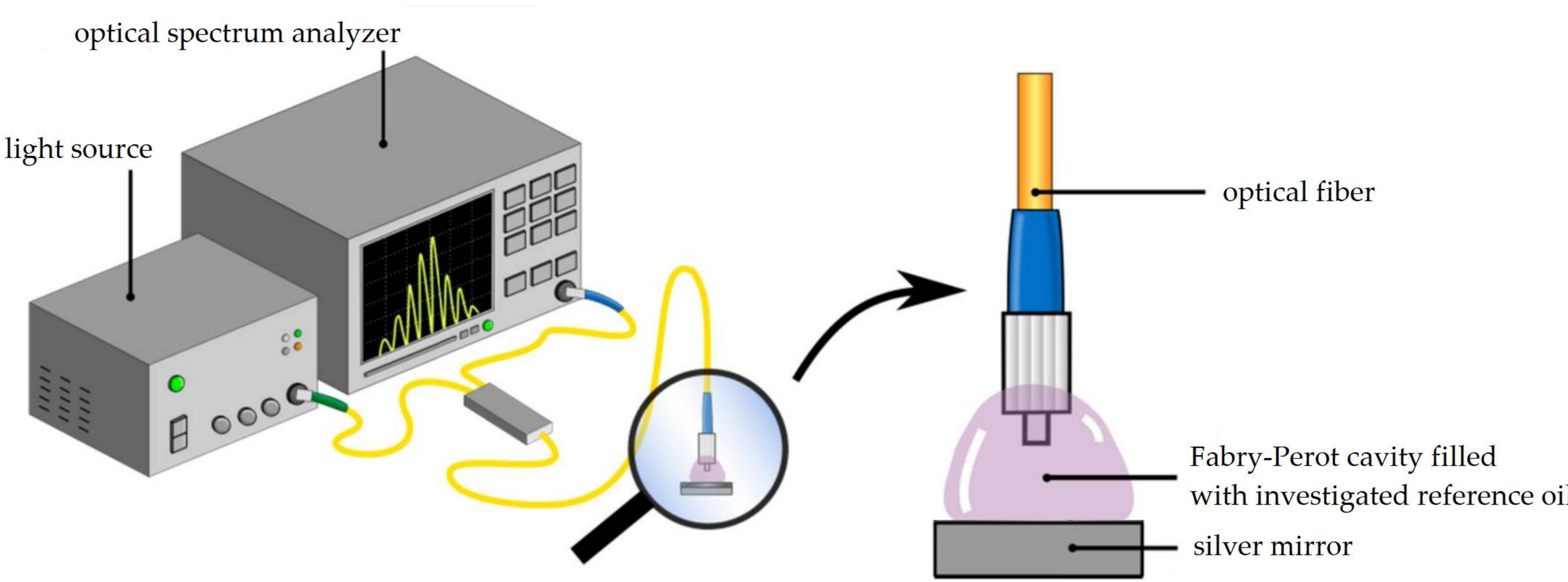
Methods – Measurement Setup

- 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: λ = 1550 nm, $\Delta\lambda_{FWHM}$ = 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

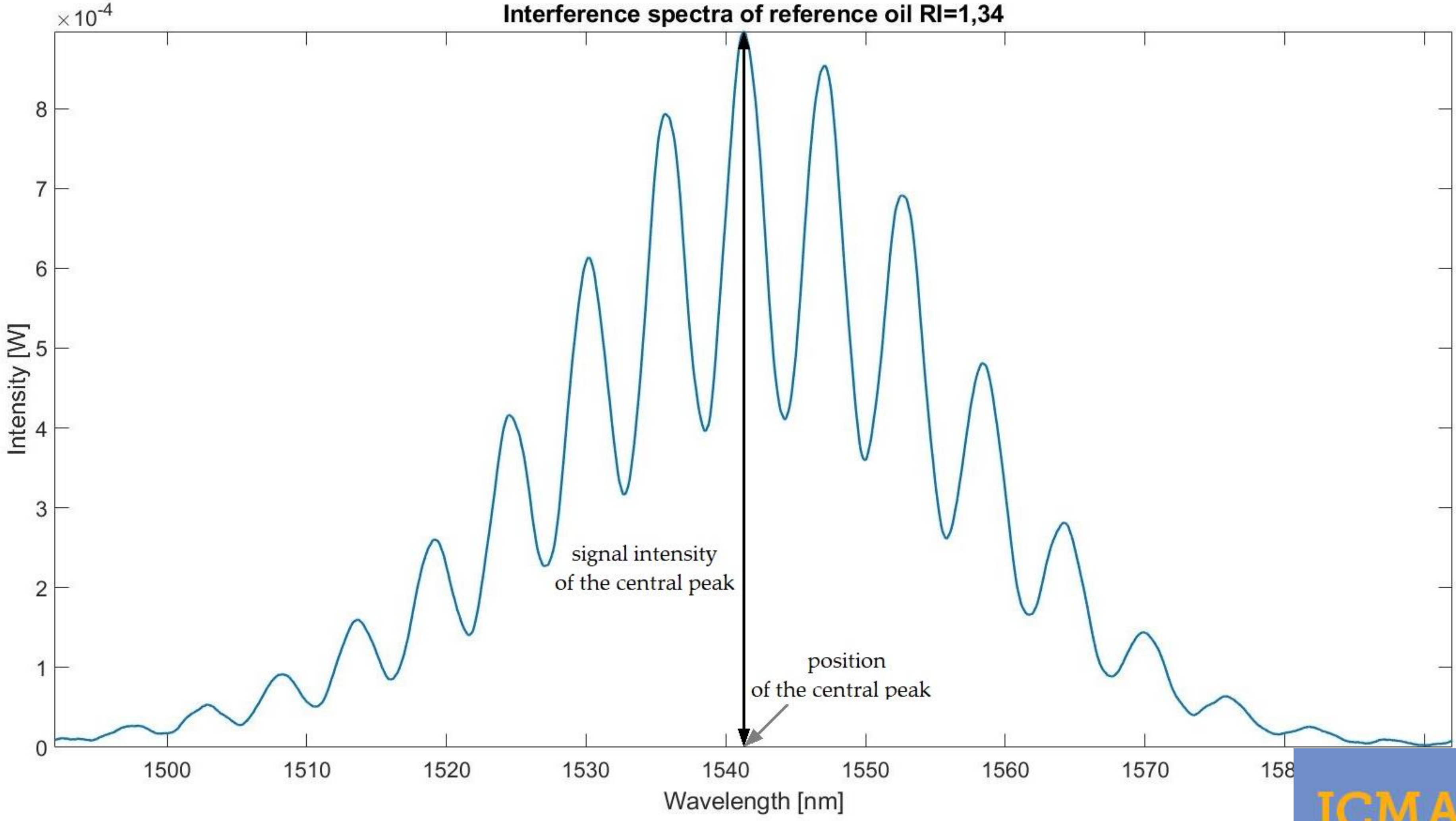


Kosowska M, Majchrowicz D, Sankaran KJ, Ficek M, Haenen K, Szczerska M. Doped Nanocrystalline Diamond Films as Reflective Layers for Fiber-Optic Sensors of Refractive Index of Liquids. *Materials*. 2019; 12(13):2124. https://doi.org/10.3390/ma12132124

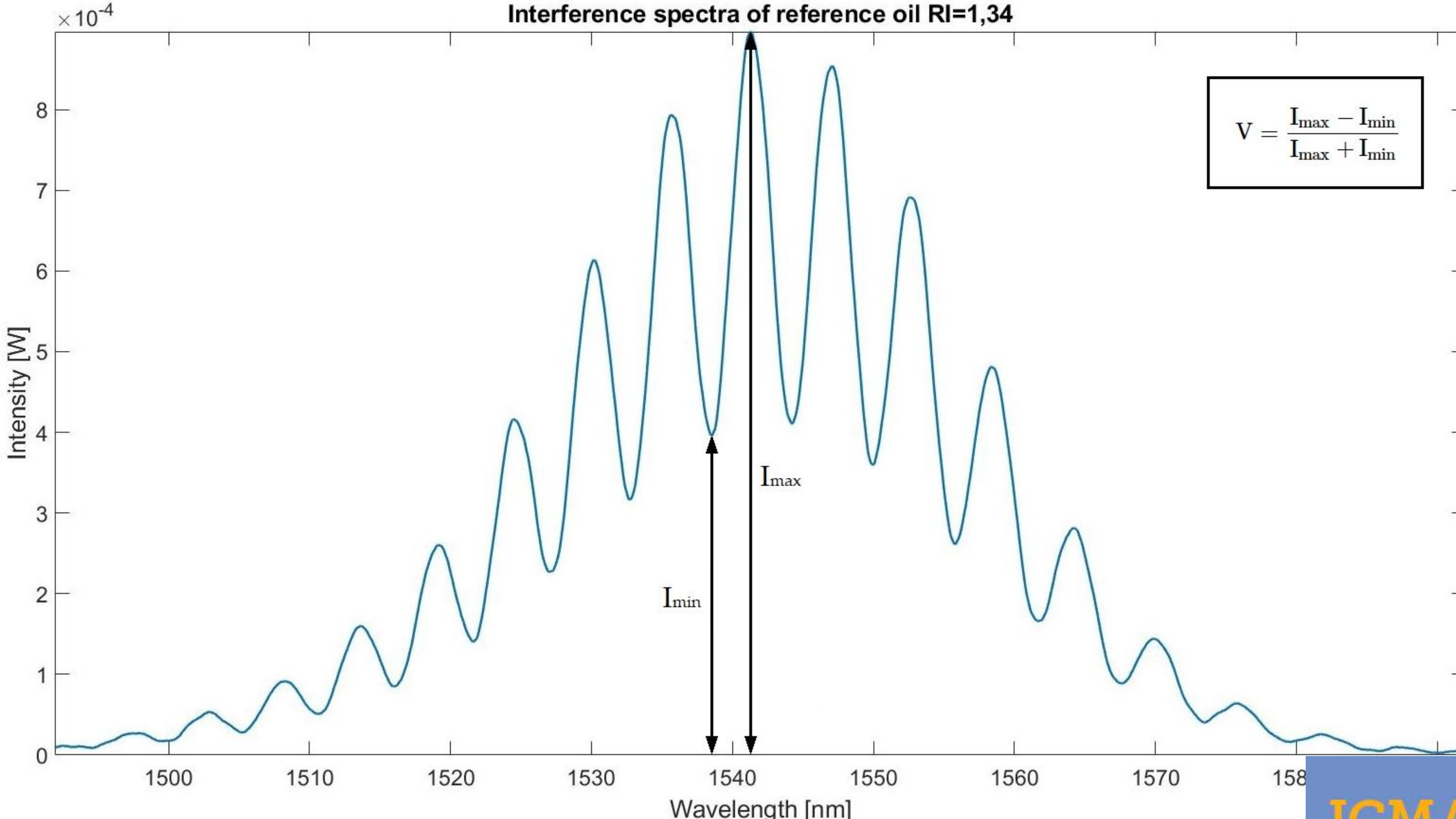
Methods – Examined parameters

- 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



Examined parameters – visibility (V) and absorption



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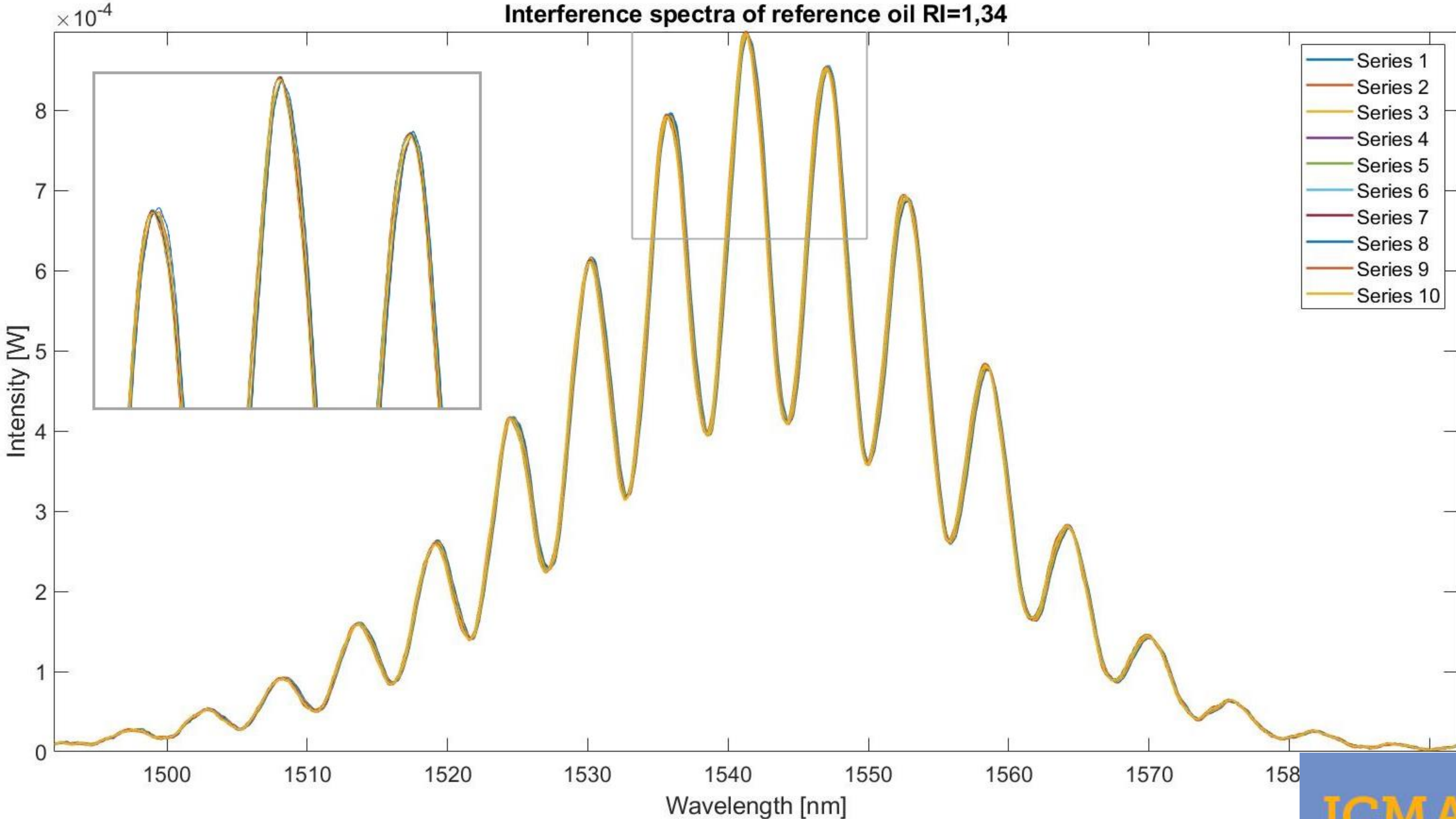
Results



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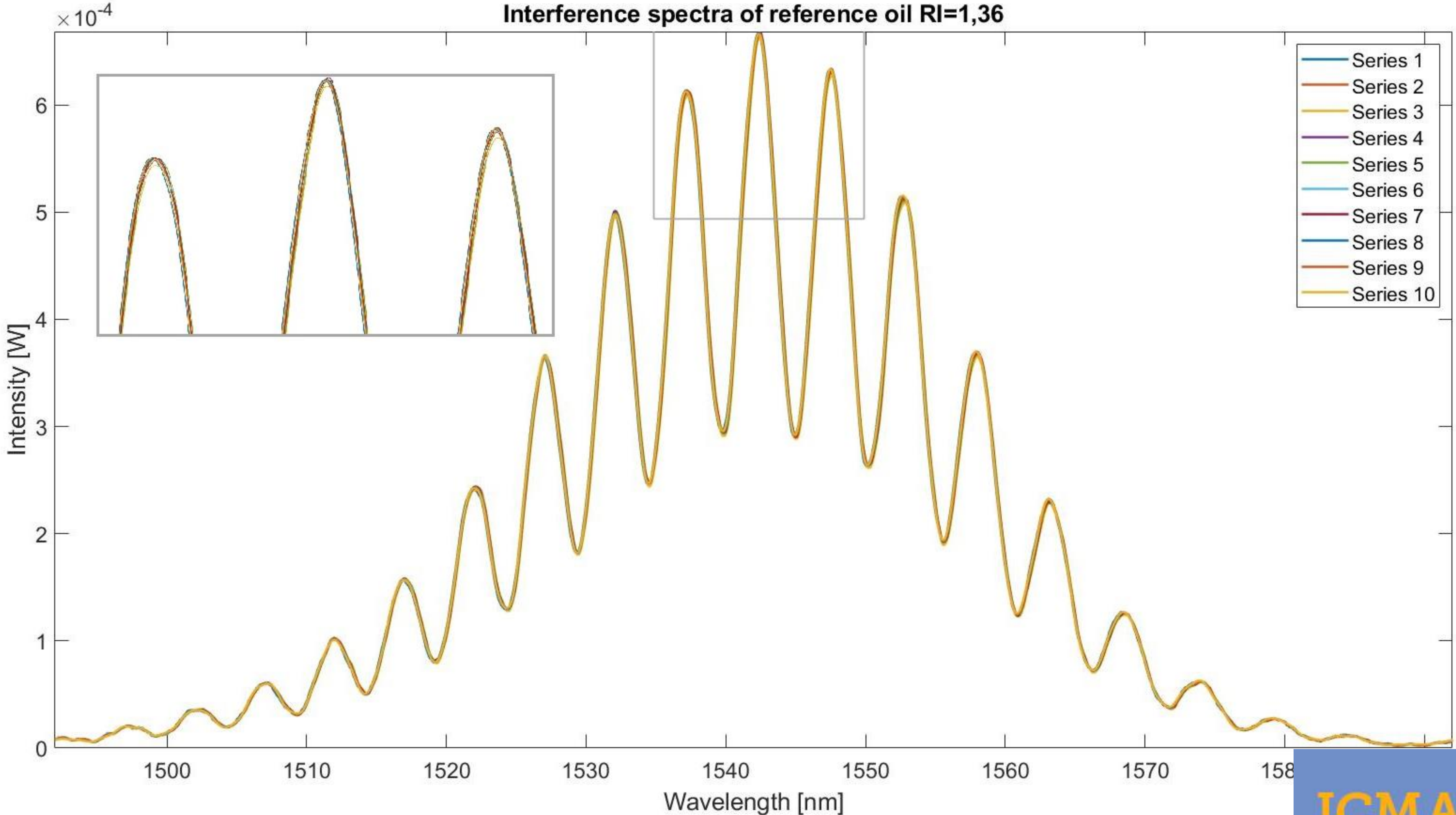
Results



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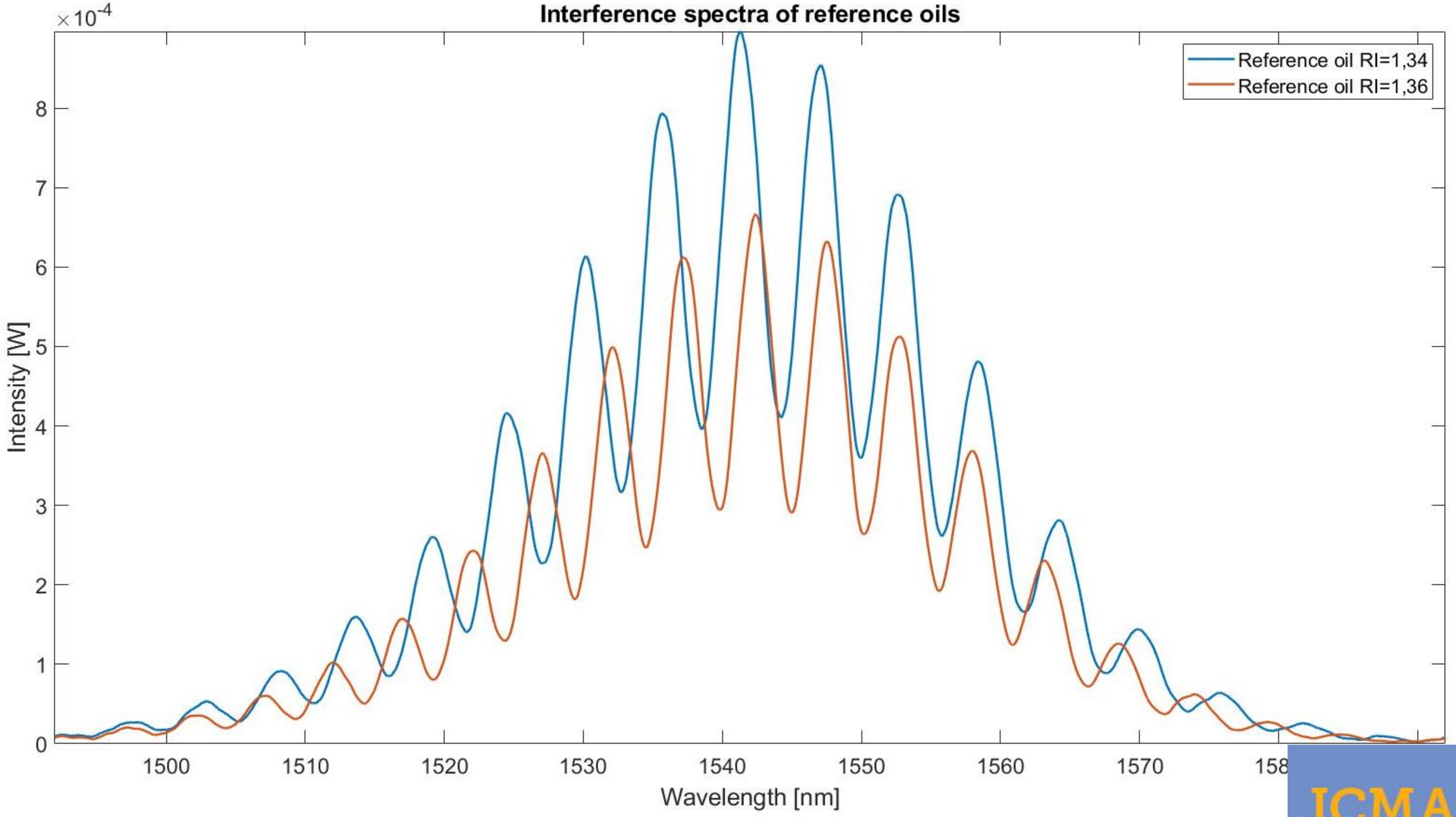
Results



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Discussion

Parameters	RI = 1,3400	RI = 1,3600
position of the central peak [nm]	1541,32 ± 0,04	1542,40 ± 0,04
signal intensity of the central peak [μW]	896,10 ± 1,61	666,52 ± 1,64
visibility (V) [a.u.]	0,38798 ± 0,00105	0,39295 ± 0,00169
absorption (signal intensity of I_{min}) [μW]	395,50 ± 1,14	290,47 ± 1,33

Discussion

- Visible differences between obtained interference spectra for examined reference oils.
- Developed setup is sensitive to the changes of:
  - refractive index,
  - absorption.

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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.

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Supplementary Materials

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Acknowledgments

Financial support of these studies from Gdańsk University of Technology by the DEC-034877 grant under the Technetium Talent Management Grants - ‘Excellence Initiative - Research University’ program is gratefully acknowledged.
Study title: ‚Examination of optical parameters of biological tissues and tissue phantoms as a function of temperature’.

UCZELNIA BADAWCZA
INICJATYWA DOSKONAŁOŚCI

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