Tytuł projektu

Optyka adaptacyjna i techniki modulacji fazy światła w obrazowaniu siatkówki i błony naczyniowej oka ludzkiego z wykorzystaniem koherencyjnej tomografii optycznej.

Project title

Adaptive optics and optical phase modulation techniques for OCT imaging of the retina and choroid of the human eye.

Dyscyplina /Area of science

Nauki fizyczne / Physical sciences

PROJECT DESCRIPTION

Project goals

- ➔ To develop computational adaptive optics methods for OCT imaging of the retina and choroid of the human eye.
- ➔ To research the methods for cellular-level imaging through highly scattering layers of the eye fundus: the retinal pigment epithelium and choriocapillaris.
- ➔ To design, construct and test a OCT setup for cellular-level imaging of the human retina and choroid.

Outline

Adaptive optics (AO) is a set of techniques and methods used for modification of optical fields in imaging systems in order to improve resolution of the images by correcting aberrations. In Optical Coherence Tomography (OCT), adaptive optics has been used to achieve cellular-level imaging resolution in imaging of the retina of the human eye *in vivo* [1] and to detect dynamic processes occurring within certain types of cells [2, 3]. There are a few groups of adaptive optics techniques suitable for the application in OCT [4]. The all-hardware approach uses Shack-Hartman wavefront sensors and deformable mirrors to detect and correct optical aberrations in the imaged object in real-time [1]. In a sensor-less AO approach only deformable mirrors are used to modulate the optical field while the images are analyzed numerically in real-time. The goal is not to detect aberrations but to improve the imaging resolution by searching for the best correcting shape of the deformable mirror [5,6]. The third possibility are fully computational methods which correct the OCT images in the post-processing, that is, in the acquired OCT data [7].

The goal of this PhD project is to study and research the methods for the cellular-level resolution in the OCT imaging of the human retina and choroid. While the methods for imaging of the retina are a subject of intensive research in many research groups around the world, adaptive optics methods for imaging of the choroid remain an unexplored area. There are two reasons for that. First, up to recently [8, 9], there were

no methods which would enable *in vivo* imaging of the choroid down to capillary vessels. Secondly, which is more interesting from the scientific point of view, high-resolution imaging of the choroid will require researching the topic of imaging through a layer of photoreceptor cells with wave-guiding properties, a layer of highly scattering retinal pigment epithelium, and a layer of choriocapillaris which not only scatters light but also the scattering changes dynamically as the blood circulates in this vascular network. The techniques of adaptive optics will therefore have to be combined with the methods of imaging through turbid media.

With the development of OCT techniques enabling imaging of the choroid, search for techniques of cellular-level imaging resolution for not only retina but also the choroid became possible. The PhD candidate will have an opportunity to participate in the development of the project from the very initial stages and gradually gain expertise starting with the study of basics in AO imaging and imaging through scattering media.

Work plan

- ➔ the PhD candidate will learn the theoretical and experimental basics of the OCT and adaptive optics techniques. The goal is to identify and understand advantages and limitation of the existing AO OCT methods and search for solutions which can be implemented for imaging of patients in the ophthalmology clinics.
- ➔ The PhD candidate will study the topics of tissue optics, with the focus on light scattering by tissues and cells, and will research the existing techniques of imaging through turbid media. The goal is to understand the challenges of imaging through scattering media and search for methods possible for implementation in OCT systems.
- ➔ The PhD candidate will design, construct and tests of the OCT imaging systems with the capability of cellular-level imaging resolution of the retina and the choroid.

Literature

1. R. Zawadzki, et al., Opt Express ;13:8532–8546, (2005).
2. O. P. Kocaoglu, et al., Biomed. Opt. Express 7, 4554-4568 (2016).
3. Liu Z, at al., Opthalmic Technologies XXVII, 10045:1004515 (2017).
4. Marcos S, et al., Vision Research, 132, 3-33, (2017).
5. Y. Jian, et al., Scientific Reports 6, 27620 (2016).
6. F. A. South, et al., Biomed. Opt. Express 9, 2562-2574 (2018).
7. L. Ginner, et al., Optica 4, 924-931 (2017).
8. K. Kurokawa, et al., Biomed. Opt. Express 8, 1803-1822 (2017).
9. J. V. Migacz, et al., Biomed. Opt. Express 10, 50-65 (2019).

Required initial knowledge and skills of the PhD candidate

The candidate will develop all necessary skills during the work on the project. However, basic knowledge in at least one the following areas are expected:

- ➔ imaging optics and physical optics,
- ➔ basic skills in computer programming (familiarity with at least one of the programming enviroments: C/C++, Matlab, Python, LabView),
- ➔ familiarity with computer control of electronic devices.

➔ basic knowledge in electronics, circuits and mechanical design.	
Zgłaszający projekt/ Author of the project	
dr hab. Iwona Gorczyńska stopień/tytuł, imię, nazwisko	e-mail: iwona.gorczynska@fizyka.umk.pl
	Instytut Fizyki UMK jednostka organizacyjna
Proponowani promotorzy i mentorzy/prospective supervisors	
1) promotor główny/ main supervisior	
dr hab. Iwona Gorczyńska stopień/tytuł, imię, nazwisko	e-mail: iwona.gorczynska@fizyka.umk.pl
	Instytut Fizyki UMK jednostka organizacyjna