The human eye is part of a complex visual system. Photosensitive nerve cells located at the back of the eye convert visible light into an electrical impulse that is directed through the optic nerve to the cerebral cortex. The sense of sight enables cognition of the world and navigation in it. For physicists and doctors, the eye is also a "window to the body" allowing for direct observation of, for example, blood vessels, fibers, and individual nerve cells. Observation of changes in these tissues allows to assess the patient's health condition and helps in diagnosing and in monitoring the progress of treatment of contemporary civilization diseases, such as diabetic retinopathy, arterial hypertension, or glaucoma. They lower the patient's standard of living, and at an advanced stage, they prevent normal functioning and professional work. The number of patients who require constant medical or social services care, and the help of their relatives is growing, which causes an increasing burden on the health care system and affects the economy of individual countries.

Doctors are ready to test new methods of diagnosis, monitoring, and treatment of civilization diseases that would be non-invasive and easy to implement in clinics. Optical coherence tomography (OCT) has become a diagnostic standard in ophthalmic examinations. The eye is an ideal object for diagnostic tests with the use of OCT because it is by nature transparent to light. Infrared or visible light can easily reach the deep layers of the eye, such as the retina or choroid. Part of the light is reflected from the anatomical layers of the eye, can be detected by a detector and processed into an image. In clinics and ophthalmology offices, OCT is mainly used for three-dimensional visualization of the anterior chamber of the eye (cornea, lens) or the retina.

The aim of the research proposed in this project is to develop methods of quantitative analysis of blood circulation in the eye fundus: the retinal and choroidal vascular systems. We will be developing methods that could be directly used in clinical diagnostics and in supporting the treatment of civilization diseases. We know from research conducted by scientists around the world that eye diseases, such as glaucoma or age-related macular degeneration, as well as systemic ones, such as diabetes or hypertension, are manifested by changes in the tissues and vascular systems of the eye fundus, also in the early stages of development of these diseases. Problems with the regulation of blood circulation in the eye are correlated with cardiological and vascular diseases causing damage to the vessels, changes in their flexibility, resistance, atrophy of vascular networks, or extravasation of blood within vascular sub-systems or the entire circulatory system of the body. Also in the case of eye diseases, e.g. glaucoma or age-related macular degeneration, the autoregulation of circulation in the vessels of the retina and the choroid of the eye can be disrupted. The development of methods for the quantitative analysis of the functioning of the blood vessels of the fundus may therefore allow for early diagnosis of diseases, at a stage when more effective medical procedures can be implemented.

In our research project, we will be imaging retinal and choroidal vessels in volunteers, using a swept-source OCT with a Fourier-domain mode-locked laser (FDML, SS-OCT), the speed of which allows for a significant reduction in artifacts related to eye movements. We will perform quantitative blood velocity measurements using the Doppler OCT technique. To date, our research enabled us to identify the shortcomings of this technique and data analysis methods that have inhibited the transfer of Doppler OCT methods from research laboratories to clinical practice, which is: the time required to process data and generate three-dimensional images with blood flow information, a limited range of measurable flow rates, direct access only to information about only one component of the blood flow velocity, depending on the inclination of the vessel in relation to the imaging light beam. We intend to solve these problems by applying and improving the methods developed in our preliminary research. We have suggested processing the data on graphic cards to accelerate computations and enable the generation of Doppler images in real-time. The range of measurable flow rates will be extended by using phase unwrapping methods in the OCT Doppler signal. We are going to use methods for determining the volumetric blood flow, making the measurement independent of the orientation of the blood vessels. We will apply our Doppler OCT methods and perform flow pulsatility experiments in 3-10 healthy volunteers. We will develop measurement protocols, and adapt data processing to the calculation of selected blood flow parameters in the choroidal vessels. Additionally, the interesting point of this project is checking the possibility of repeated measurements for selected vessels, which could enable the investigation of the reaction of the blood system to diagnostic tests and administered drugs in acute and long-term reactions. Obtaining reliable results could help to develop a physiological norm of blood flow parameters in the choroid and the retina of the eye.