

Volumetric image reconstruction with filtration of excessive phase information

To follow the progression and treatment of degenerative diseases, new *in vivo* imaging modalities are required. Building on the state of the art technology and recent advances in physical optics, we propose to develop new methods for repeatable and safe imaging to assess morphological and functional aspects of individual cells within human body. We will focus on methods derivative to Optical Coherence Tomography OCT, which is the most promising method for providing non-invasive, high-speed volumetric structural, and functional imaging at cellular-level.

Modern, dynamically developing optical imaging techniques using laser light can provide information on the morphology and function of the human body, offering high speed and better sensitivity than any other method. The advantage of using coherent laser radiation is high energy density, ease of control of the optical beam and access to phase. All these advantages allow for very high sensitivity, very accurate location and, most importantly, allow for three-dimensional reconstruction, which is unattainable for classical microscopy. However, the limitation is the deterioration of imaging quality: in the presence of strong scattering introduced by biological structures, coherent laser light generates a lot of useless information in the form of strong amplitude modulation. This is manifested by the presence of two effects - a speckle pattern and an optical crosstalk. Both of these effects make it impossible to clearly differentiate tissue structure at the level of individual cells (Fig. 1).

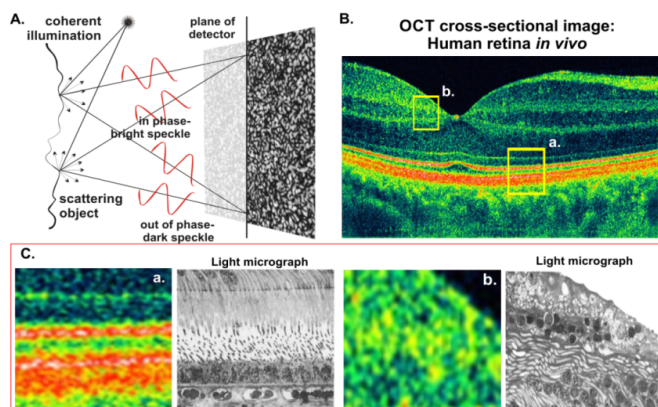


Figure 1. Speckle patterns prevent us from seeing retinal cells: A. Scheme showing the formation of a speckle pattern: back-scattered light waves reflected from a rough surface have random phases causing the intensity distribution in the imaging plane to vary randomly. B. Exemplary OCT cross-sectional retinal image. C. Zoomed details of panel B. compared to in-scale light micrographs; due to the presence of speckles the corresponding regions look different in OCT and light micrograph images even if the nominal resolutions of both techniques are comparable.

In the presented project we propose to use our developed technique of Spatio-Temporal Optical Coherence light phase modulation (STOC) for OCT imaging. As a result of applying this method we obtain an effect analogous to illumination with incoherent light - as in a normal microscope. However, we still have the possibility of three-dimensional reconstruction. This is because we first obtain 3-D reconstructions, as in the OCT methods, but for many different sample illumination implementations. Thanks to this we have a set of the same object reconstructions obtained for different spatial phase distributions. Then we are able to properly filter the images in post processing. The latter allows us to get rid of useless information inherent in the use of phase-sensitive technique.

However, it is not clear whether the image reconstruction obtained in such a process is identical to what we reproduce in classical methods such as microscopy or photography. We also do not know to what extent we are able to eliminate the disturbances of the wavefront appearing on the path of the illuminating light beam and to obtain a clean reconstruction from the internal layers of the object. The main task of this project is to answer these fundamental questions and to point out the physical and technical limitations of imaging methods that could use this knowledge in the future.