Investigative Ophthalmology & Visual Science

Invest Ophthalmol Vis Sci 2006;47: E-Abstract 2924.

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Three–Dimensional Adaptive Optics Ultrahigh Resolution Optical Coherence Tomography: Towards Cellular Resolution Retinal Imaging

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Commercial Relationships: E.J. Fernandez, None; **B. Povazay**, None; **B. Hermann**, None; **A. Unterhuber**, None; **H. Sattmann**, None; **P. Artal**, None; **W. Drexler**, Carl Zeiss Meditec, C.

Support: FWF P14218–PSY, FWF Y159–PAT, the Christian Doppler Society, FEMTOLASERS, Inc, and CARL ZEISS Meditec, Inc.

Abstract

Purpose: To increase transverse and axial resolution in ophthalmic ultrahigh resolution three–dimensional optical coherence tomography (UHR OCT) by combining adaptive optics (AO) and chromatic ocular aberration correction, achieving unprecedented resolution in the living human retina.

Methods: A high speed frequency domain UHR OCT using an ultrabroad bandwidth spectral source, emitting a continuous and Gaussian shaped spectrum centered at 800nm and 160nm of full width at half maximum (FWHM), for imaging the living retina is developed. The experimental apparatus incorporates a lens specifically designed to correct ocular chromatic aberration, covering the entire spectral range of interest for OCT, from 700 to 900nm. A relatively compact AO system for measuring and correcting monochromatic aberrations is interfaced to the UHR OCT setup. The AO system uses a liquid crystal programmable phase modulator (PPM) as correcting device with XGA resolution, corresponding to ~ 570000 independent controllable pixels, and a Hartmann–Shack wavefront sensor for measuring aberrations.

Results: Three–dimensional images showing intraretinal structures, obtained in the living retina, are acquired with full aberration correction, ever to be able to record 30 B–scans/s, each one compounded by 1024x1024 pixels. Chromatic aberration correction allows the entire set of spectral components emitted

by the illuminating source to be focused on a same retinal plane, therefore increasing the signal–to–noise ratio of OCT images. The correcting device, PPM, corrects high order monochromatic aberrations with practically unlimited amplitude, due to its ability to perform phase wrapping. However, phase wrapping prevents perfect aberration correction at different wavelengths.

Conclusions: Intraretinal morphological features are resolved with this technique, making possible the detection of groups of photoreceptors' terminal bars. Correcting chromatic aberration by using the proposed achromatizing lens allows ultrabroad bandwidth spectral sources to be efficiently projected onto the retina, therefore increasing axial resolution of OCT retinal images. In addition, AO improves transverse resolution of the tomograms. The combination of UHR OCT with AO and chromatic aberration correction notably enhances resolution of retinal images.

Keywords: imaging methods (CT, FA, ICG, MRI, OCT, RTA, SLO, ultrasound) • retina • imaging/image analysis: non-clinical