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Three–Dimensional Adaptive Optics Ultrahigh Resolution Optical Coherence Tomography

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Abstract

Purpose:

To combine high speed frequency domain optical coherence tomography (OCT) and adaptive optics (AO) to achieve both ultrahigh axial and transversal resolution for three–dimensional imaging in the living human retina.

Methods:

A second generation ultrahigh resolution frequency domain OCT (UHR FD OCT) system has been designed employing a compact ultrabroad bandwidth (160 nm) Titanium:shappire laser to achieve high axial resolution. A relatively compact AO system was interfaced to the UHR FD OCT system to correct the eye's aberrations that would degrade the minimum achievable retinal spot size and therefore transverse resolution. The AO system is composed of a real–time Hartmann–Shack wave–front sensor and a liquid–crystal programmable phase modulator (L–C PPM) as the correcting device. This device operates with VGA resolution, meaning ~ 200000 independent controllable pixels. The AO system enables the measurement and correction of the ocular aberrations up to an 8–mm diameter pupil.

Results:

Three–dimensional retinal in vivo imaging with video–rate, i.e. 25 B–scans/second, each tomogram consisting of 1024x1024 pixels, resulting in 25 Megavoxels/s could be accomplished. The merge of AO and UHR FD OCT significantly increased both the S/N ratio and the transverse resolution of the acquired tomograms. The L–C PPM may be a feasible alternative to the traditional deformable mirrors in the correction of the ocular aberrations. The available resolution of the L–C PPM, more than 3 orders of magnitude higher than typical deformable mirrors, permitted the accurate correction of large high order aberrations. However, a limitation of the L–C PPM for OCT is the wavelength dependence in the phase modulation, therefore preventing for perfect compensation in all the spectral components of the illumination beam.

Conclusions:

We demonstrated the benefits of using large pupil sizes in ophthalmic three–dimensional ultrahigh resolution OCT in combination with AO. Despite of some limitations, wavelength dependence and slow temporal response, L–C PPMs are an attractive alternative to the conventional deformable mirrors, especially in those situations where the eye suffer of large aberrations, as maybe the case in some pathologic eyes.

Keywords: imaging methods (CT, FA, ICG, MRI, OCT, RTA, SLO, ultrasound) • retina • macula/fovea