Spatially Encoded Frequency Domain Optical Coherence Tomography System for Volumetric In-Vivo Imaging at 1050 nm

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Abstract: Ophthalmic Frequency Domain OCT systems were limited to the 750-900 nm wavelength range due to limited response of silicon line array sensors. Although this wavelength range was extremely successful for obtaining ultra-high resolution tomograms and volumes in a wide group of patients, quite a few currently cannot profit from this diagnostic method, especially those with cataracts, where a pre-surgical assessment of the retinal structure is necessary. With the advent of broadband light sources at the water-window at 1050 nm time-domain OCT and its deeper penetration beneath the retinal pigment epithelium into the choroid for investigation of chorideo-vascular disorders like neovascularisation could be demonstrated. A spatially encoded, spectrometer based FD-OCT system was built for high speed, volume acquisition in patients. Preliminary results confirm the longer usable depth-range, different contrast and that lower scattering at 1050 nm significantly improves the transmission through opaque intraocular media, thereby widening the applicability of OCT.

Key words: optical coherence tomography, retinal imaging, choroid, penetration, scattering, infrared, cataract, near infrared, InGaAs-detectors, spectrometer

Biography: Boris Považay received his Masters degree in Technical Physics in 1998 at the Vienna University of Technology, Austria, in the field of laser physics. Until 2006 he was associated to the Medical University of Vienna, Austria to conclude his studies in the field of OCT in association with the Vienna University of Technology where he earned a PhD in Electrical Engineering. Currently, he holds a lecturer position at the School of Optometry and Vision Sciences at Cardiff University, Wales, United Kingdom.
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In the last years the method of high speed frequency domain optical coherence tomography (FD-OCT) became available for ophthalmic in vivo imaging, increasing the acquisition speed from several hundred depth-scans per second by two orders of magnitude, without sacrificing sensitivity. This increase was caused by the simultaneous measurement of the full depth scan with a line-array detector in an imaging spectrometer. The availability of high speed line-arrays however was limited to the wavelength range below 1000 nm, due to silicon based sensing equipment and high speed, high resolution OCT was restricted to the 750-900 nm range, where multiple light sources were available below the first strong water absorption band at 970 nm. Recently new light sources, centred at 1050 nm with bandwidths well above 50 nm full width at half maximum, just within the first water absorption band were introduced. With slowly scanning time-domain OCT systems it could be shown that this wavelength allows for signal extraction from layers beneath the retinal pigment epithelium (RPE), necessary for investigation of the choriocapillaris and choroidal vascular system.

With state-of-the-art high speed InGaAs, 512 pixel line array camera (Sensors Unlimited, Inc.) we were able to build a spatially encoded FD-OCT system, operating at 1050 nm at a bandwidth of ~70 nm driven by a compact light source emitting 18 mW centred at 1040 nm (NP-Photonics, Inc), which resulted in an axial resolution in tissue of about 7 µm. The imaging spectrometer geometry was set in a typical all-reflective Czerny-Turner design (fig. 2) for high light efficiency and limited geometric distortions to allow for a geometric spotsize of less than 18 nm across the whole spectrum used. The camera was connected by a CameraLink connection to an acquisition computer that Fourier-transformed a part of the data on-line for adjustment purposes.
Connected with an OCT-2 patient module (Zeiss Meditec), modified for operation at 1050 nm, this device was used to investigate the usability in case of cataracts or to monitor vascularisation and overall performance for imaging retinal and choroidal morphology.

In preliminary tests it could be shown that FD-OCT at 8 or 16 kHz line rate and 1050 nm central wavelength significantly improves penetration through scattering media that are usually intransparent for the commonly used 800 nm illumination (see fig. 1), additionally to the higher penetration into the choroid (compare fig. 3). As already seen in other 1050 nm systems the average signal in depth increases in respect to 800 nm. At this axial high resolution the major intraretinal layers can be separated, though the contrast, especially for the top layers of the neuro-retina is different due to the changed scattering potential at this wavelength.

1050 nm OCT technology improves clinical usability of OCT, especially for the wide range of patients with less transparent media where common 800 nm systems currently cannot be used. In this work the first spectrometer based high resolution system could be demonstrated and was successively applied to patients with subretinal irregularities and those with highly intransparent intraocular material like nuclear and other cataracts.

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References