# Ultrahigh Speed Imaging of the Rat Retina Using Ultrahigh Resolution Spectral/Fourier Domain OCT

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Ultrahigh Speed Imaging of the Rat Retina Using
Ultrahigh Resolution Spectral / Fourier Domain OCT

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ABSTRACT

We performed OCT imaging of the rat retina at 70,000 axial scans per second with ~3 μm axial resolution. Three-dimensional OCT (3D-OCT) data sets of the rat retina were acquired. The high speed and high density data sets enable improved en face visualization by reducing eye motion artifacts and improve Doppler OCT measurements. Minimal motion artifacts were visible and the OCT fundus images offer more precise registration of individual OCT images to retinal fundus features. Projection OCT fundus images show features such as the nerve fiber layer, retinal capillary networks and choroidal vasculature. Doppler OCT images and quantitative measurements show pulsatility in retinal blood vessels. Doppler OCT provides non-invasive in vivo quantitative measurements of retinal blood flow properties and may benefit studies of diseases such as glaucoma and diabetic retinopathy. Ultrahigh speed imaging using ultrahigh resolution spectral / Fourier domain OCT promises to enable novel protocols for measuring small animal retinal structure and retinal blood flow. This non-invasive imaging technology is a promising tool for monitoring disease progression in rat and mouse models to assess ocular disease pathogenesis and response to treatment.

Keywords: Ultrahigh resolution OCT, ultrahigh speed OCT, spectral/Fourier domain OCT, Doppler OCT, small animal imaging

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1. INTRODUCTION

The murine retina is structurally similar to the human retina. Rat and mouse models provide powerful tools for characterization of ocular disease pathogenesis and response to treatment. Therefore, non-invasive imaging technologies for measuring rat and mouse retinal structure and physiology at the micron scale could be useful tools for biomedical research on ocular disease. Spectral / Fourier domain OCT enables ultrahigh speed and ultrahigh resolution 3D imaging or volumetric imaging [1-3], offering a promising technique for rat and mouse retinal imaging [4].

2. MATERIALS AND METHODS

An ultrahigh resolution spectral / Fourier domain OCT prototype instrument has been developed for small animal imaging using new, high speed CMOS imaging technology [5]. This technology can achieve imaging speeds over 70,000 axial scans per second. Figure 1 shows the schematic of the OCT system for small animal imaging. To achieve ultrahigh-resolutions, we used a multiplexed two-superluminescent-diode light source (Superlum) with 145 nm bandwidth and 890 nm center wavelength. A microscope delivery system was used
for focusing and scanning the OCT beam in the animal eye. The power at the rat eye was 1.3 mW. The maximum sensitivity was ~94 dB. Three-dimensional OCT (3D-OCT) data sets of the rat retina were acquired. OCT fundus images were created from 3D-OCT data. Doppler OCT analysis [6-8] of blood flow in the rat retina was performed. The maximum measurable velocity before phase wrapping is 12 mm/s.

Figure 1. Schematic of high-speed ultrahigh resolution OCT system with a pre-objective scanning microscope design for small animal retina imaging. Spectral / Fourier domain detection is performed with a spectrometer and high speed CMOS camera.

3. RESULTS

OCT imaging of the rat retina was performed at 70,000 axial scans per second with ~3 µm resolution. A standard 3D-OCT data set containing 180 images, each consisting of 512 axial scans, is acquired in ~1.4 seconds. As shown in figure 2, minimal motion artifacts are visible and the OCT fundus images offer more precise registration of individual OCT images to retinal fundus features. Projection OCT fundus images[9] in figure 3 show features such as the nerve fiber layer, retinal capillary networks and choroidal vasculature. In figure 4, Doppler OCT images and quantitative measurements show pulsatility in retinal blood vessels.

Figure 2. A) Raster scan pattern shown on rat fundus photo. 3D-OCT data consisting of 512 axial scans per frame x 180 frames covering 2 mm x 2 mm area was acquired in ~1.4 seconds. B) Standard OCT fundus images are created by summing the signal in the axial direction, yielding an image similar to a fundus photograph. C-F) High definition OCT images with 2048 axial scans, each acquired in 29 µs, may be registered to the OCT fundus image.
Figure 3. OCT en face visualizations are created by summing layers sectioned at different levels in the axial direction, providing images of selected layers of the retina. This dataset consists of 300 axial scans per frame x 300 frames covering 1mm x 1mm area and was acquired in ~1.3 seconds.

Figure 4. A) Quantitative Doppler OCT measurement in the axial direction showing pulsatile blood flow. (A) Pulsatile blood flow showing a heart rate of ~300 beats per minute. B, C) Doppler OCT images over a 65 µm x 100 µm region of interest and blood flow measurements showing pulsatility during two cardiac cycles. Repeated Doppler OCT scans with 512 axial scans over a 250 µm cross section were continuously acquired for ~1.8 seconds.
4. CONCLUSIONS

In conclusion, ultrahigh speed retinal imaging was demonstrated in the rat retina using ultrahigh resolution spectral / Fourier domain OCT. 3D-OCT data sets obtained at high speed show reduced motion artifacts, enabling improved en face OCT fundus imaging. Doppler OCT provides non-invasive in vivo quantitative measurements of retinal blood flow properties and may benefit studies of diseases such as glaucoma and diabetic retinopathy. Ultrahigh resolution spectral / Fourier domain OCT promises to enable novel protocols for measuring small animal retinal structure and retinal blood flow. Furthermore, this non-invasive imaging technology is a promising tool for monitoring disease progression in rat and mouse models to characterize ocular disease pathogenesis and response to treatment.

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