

# SPECIAL SECTION GUEST EDITORIAL

## Optical Coherence Tomography in Ophthalmology

Advances in photonics technology have enabled a significant improvement in the visualization capability of optical coherence tomography (OCT) in the last decade, thereby establishing OCT as a state-of-the-art, noninvasive, ophthalmic diagnostic imaging modality. OCT has now become a standard of care in ophthalmology, thus enabling advances such as the visualization of retinal pathology at resolutions not possible with other noninvasive imaging techniques, quantitative measurement of the nerve fiber layer for glaucoma diagnosis and monitoring, objective assessment of macular edema in diabetic retinopathy, and improved regulation of therapy in age-related macular degeneration.

As a consequence, there have been numerous developments of OCT technology and considerable interest in this topic—especially in the field of ophthalmology. Objectively this is demonstrated by the tremendous increase in publications, patents, and commercial ventures in the field of OCT in recent years. It is noteworthy that approximately 50% of all OCT publications have been in ophthalmic journals, thus demonstrating the technique's high impact in this field. Another 25% of OCT publications has been published in optics journals, thus reflecting the numerous technical advances that have been accomplished.

The purpose of this *Journal of Biomedical Optics* (JBO) special section is to highlight OCT advances in ophthalmology. The papers presented are grouped according to three themes: (1) OCT instrumentation and techniques involving the anterior eye (two papers), (2) image processing (six papers), and (3) morphological and functional retinal imaging (six papers).

(1) The anterior eye: Akiba et al. demonstrate ultrahigh-resolution full-field OCT for subcellular-level imaging of human donor corneas. By using ultrahigh-resolution *en face* images, epithelial cells, Bowman's layer, stromal keratocyte, nerve fiber, Descemet's membrane, and endothelial cells were clearly visualized. Keratocyte cytoplasm, including its nuclei and its processes, were also visualized, thus demonstrating the ability of full-field OCT to achieve subcellular resolution. Spöler et al. demonstrate the potential of OCT to dynamically detect chemical eye burns in the cornea by visualizing penetration kinetics during its initial phase. This work opens new possibilities in clinical evaluation of chemical eye burns, eye irritation testing, and product testing for chemical and pharmacological products.

(2) Image processing: Povazay et al. demonstrate a novel parameter for glaucoma diagnosis by using three-dimensional (3-D) ultrahigh-resolution OCT: the 3-D minimal distance as the optical correlate of true retinal nerve fiber layer thickness around the optic nerve head region. Studies in normal subjects and patients with characteristic optic nerve and retinal nerve fiber layer changes secondary to glaucoma are reported. Mujat et al. present an autocalibration method for wavelength assignment that does not require separate calibration measurements. Quantitative birefringence mapping of *in vivo* human

retinal nerve fiber layer is presented after removal of birefringence artifacts. Zawadzki et al. have combined methods from volume visualization and data analysis to enable better visualization and assessment of Fourier domain OCT retinal volumes. A support vector machine (SVM) used to perform semi-automatic segmentation of retinal layers has been tested successfully in clinical settings for its efficacy in assessing 3-D retinal structures in healthy as well as diseased cases. Szkulmowski et al. demonstrate a computationally efficient, semiautomated method for the analysis of posterior retinal layers in 3-D images obtained by spectral domain OCT. Thickness and distance maps from the segmented layers and their analysis are presented for healthy and pathological retinas. Jørgensen et al. demonstrate successful suppression of speckle noise by mutually aligning a series of *in vivo* OCT recordings obtained from the same retinal target by using the Stratus system from Humphrey Zeiss. The resulting image enhancement increases the contrast-to-noise ratio by a factor of three or more, and facilitates segmentation and quantitative characterization of pathologies. Somfai et al. demonstrate improved segmentation algorithms for more consistently accurate detection of retinal boundaries by modeling artifacts, including defocusing, depolarization, decentration, and a combination of defocusing and depolarization, in order to obtain a better quantitative analysis of clinically relevant features of retinal pathology.

(3) Morphological and functional retinal imaging: Pircher et al. demonstrate a software-based, corneal birefringence compensation method that uses the polarization state of the light backscattered at the retinal surface in order to measure the corneal birefringence. This information is used to numerically compensate the corneal birefringence for polarization-sensitive OCT of the human retina, and it has important implications for glaucoma diagnosis. Povazay et al. compare frequency-domain OCT operating at 1050 nm to conventional 3-D retinal imaging in the 800-nm wavelength region, thus demonstrating volumetric imaging of retinal pathologies with greater penetration into choroidal tissue and significantly improved imaging performance in cataract patients at 1050 nm. Kagemann et al. use Fourier-domain OCT to assess retinal blood oxygen saturation in 17 normal healthy subjects, thereby demonstrating that arterial optical density ratios are significantly greater than venous ones. Michaely et al. demonstrate resonant Doppler Fourier-domain OCT as a functional imaging tool for extracting tissue blood flow. This method scans the reference path in resonance with the Doppler frequency to suppress signals from stationary structures and to enhance signals from blood flow. Three-dimensional flow maps are demonstrated and preliminary reproducibility studies are presented. Bower et al. investigate the autoregulatory mechanism of human retinal perfusion with a real-time spectral-domain Doppler OCT system. Volumetric, time-sequential Doppler flow imaging was performed in normal healthy subjects in response to breathing normal room air ver-

sus 100% oxygen. Wang et al. present *in vivo* normal human volumetric retinal flow measurements by using Fourier-domain Doppler OCT with a dual-plane scanning pattern to determine the angle between the blood flow and the scanning beam. This method achieves quantitative measurement of total flow velocity.

All papers in this issue have undergone peer review. We wish to thank the numerous international research groups that have contributed to this special section, as well as the reviewers who generously gave their time and expertise for the review process. We are especially grateful to Bruce Tromberg (editor-in-chief) and the publication staff at the JBO for their hard efforts to make this special section possible: Rita Davis,

Karolyn Labes, Rebecca Saxton, and many others who contributed to the publication of this section. We hope you find the papers in this special section interesting and stimulating.

**Wolfgang Drexler**  
Cardiff University

**James G. Fujimoto**  
Massachusetts Institute of Technology

**Special Section Guest Editors**