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Measuring Pulsatile Motion in Ocular Structures with Swept-Source OCT

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1. Introduction

Swept-Source Optical Coherence Tomography (SS-OCT) stands at the forefront of advanced technologies, offering unparalleled depth-resolved and high-resolution imaging capabilities for studying eye structures. SS-OCT has a unique ability to assess pulsatile dynamics within intraocular distances. By precisely capturing dynamic changes in tissue movement and deformation throughout the cardiac cycle, SS-OCT emerges as a robust method for evaluating pulsatile motion. The fundamental strength of SS-OCT is its capacity to provide micron-scale resolution and real-time, non-invasive imaging.
In the context of pulsatile dynamics assessment, SS-OCT excels in detecting subtle movements and deformations caused by cardiac-induced changes in intraocular pressure and blood flow. These pulsatile motions are important indicators of ocular health and function, influencing illnesses like glaucoma, age-related macular degeneration (AMD), ocular hypertension, and other vascular diseases that affect the eye. By utilizing SS-OCT's ability to monitor these pulsatile shifts, researchers and clinicians can gain vital insights into the biomechanical features of ocular tissues and their responses to physiological circumstances. SS-OCT is a viable method for advancing our understanding of intraocular dynamics, potentially improving diagnostics and refining treatment regimens in ophthalmology.
In this work, we propose to demonstrate proof-of-concept experiments showing how long-range SS-OCT technology can identify and measure the pulsatile movements of different eye structures. We conducted full-eye-length OCT imaging to measure variations in intraocular distances.

2. Methods and results

Figure 1 illustrates a prototype Swept-Source Optical Coherence Tomography (SS-OCT) device, operating at a central wavelength of 1060 nm with a sweep rate of 60 KHz. This sophisticated imaging system was employed for in vivo ocular imaging, capturing detailed cross-sectional views of the eye's internal structures, including both the anterior and posterior segments. The high sweep rate of 60 kHz enables swift data acquisition, reducing motion artifacts and delivering clear, high-resolution images. The SS-OCT system prototype boasts a sensitivity of 102 dB, allowing it to detect subtle changes in ocular tissues by producing high-contrast images.
With an axial resolution of 11 µm, the system provides precise imaging of ocular structures. Additionally, it achieves a lateral resolution of 13 µm, ensuring high spatial resolution in the transverse plane, which enhances the clarity and detail of the captured images.
The experiments involved imaging healthy subjects using various scanning protocols: repeated B-scans (300 A-scans covering 15 mm) and central M-scans (repeated A-scans at the center of the pupil). This approach allowed for imaging eye dynamics with varying time resolutions. The cornea, crystalline lens, and retina were segmented, and the time evolution of intraocular distances was measured.

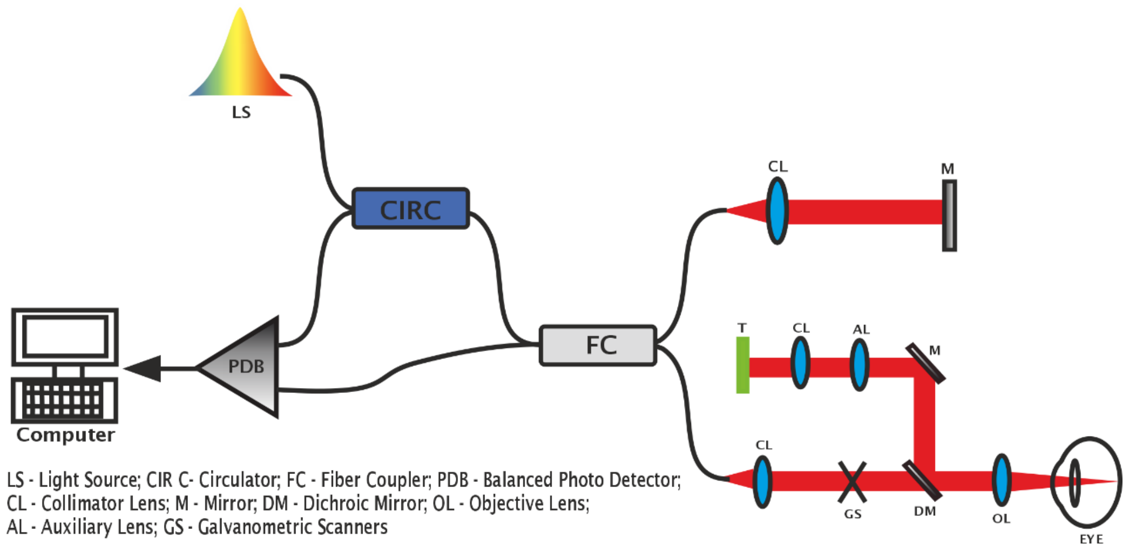

Figure1. SS-OCT experimental setup.

Figure 2 illustrates the concept behind the experiment, which is designed to perform in-vivo full-eye-length imaging. This advanced imaging system allows for comprehensive visualization of the entire eye, providing detailed insights into its structure and function. By utilizing rapidly repetitive scanning techniques, the system can capture high-resolution images that are crucial for both diagnostic and research purposes. The ability to obtain such detailed images in a non-invasive manner represents a significant advancement in ocular imaging technology.
The system employs two primary scanning methods: B-scans and M-scans. B-scans, which offer a time resolution of approximately 5 milliseconds, provide cross-sectional images of the eye, enabling the detailed analysis of various ocular layers and structures. On the other hand, M-scans, with an impressive time resolution of 16.7 microseconds, are used to capture real-time motion and dynamic changes within the eye. This dual approach ensures that both structural and functional information can be obtained with high temporal precision, making the system highly effective for a wide range of ophthalmic applications.

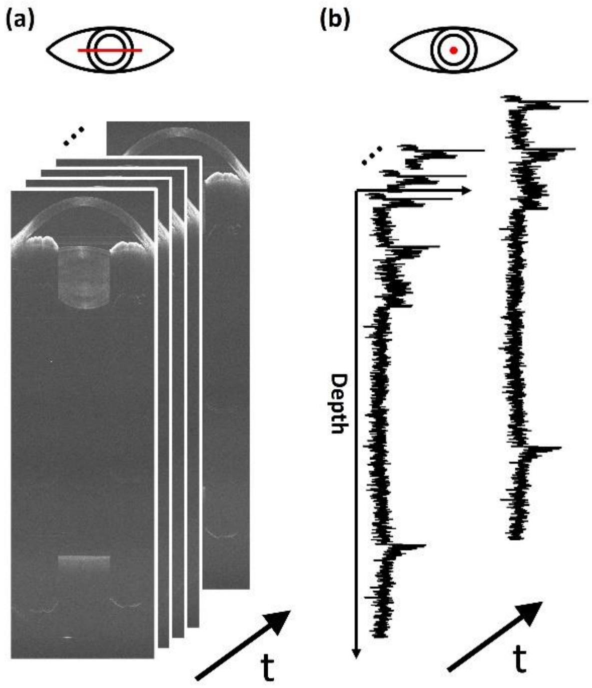

Figure 2. High-speed full-eye-length imaging of the natural motion of ocular structures: (a) repeated B-scan mode, (b) M-scan mode.

3. Conclusions

In summary, Swept-Source Optical Coherence Tomography (SS-OCT) represents an attractive approach for assessing ocular tissue vibrations caused by pulsatile excitation. This advanced imaging technique leverages its high-speed and high-resolution capabilities to accurately capture the minute vibrations and movements within the ocular tissues.
SS-OCT's ability to provide detailed, real-time imaging of these vibrations makes it an invaluable tool for both clinical diagnostics and research. By offering precise assessments of tissue dynamics, SS-OCT enhances our understanding of ocular biomechanics and helps in the early detection and monitoring of various eye conditions.

4. Funding

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5. References

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