Optimized SD-OCT spectrometer for selective retina therapy with real-time fundus tracking

Degree programme: BSc in Micro- and Medical Technology
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A new spectral-domain optical coherence tomography (SD-OCT) spectrometer has been developed and optimized for a specific OCT spectral range. This spectrometer is part of an OCT module that is combined in a device with a real-time fundus tracking system and a treatment laser for selective retina therapy (SRT) to precisely treat retinal pigment epithelium (RPE) related retinal diseases.

Introduction

Selective retina therapy (SRT) enables targeted treatment of RPE diseases without damaging surrounding tissue such as photoreceptors. The OCT module is essential for real-time dose control, as it enables the detection of characteristic signal washouts in the RPE during laser treatment. The spectrometer is particularly important in this context, as it splits the interference signal at a grating and scatters it over the detector, thereby enabling depth-resolved scans of the retina. Signal processing using k-linearization and dispersion compensation ensures optimized axial resolution, which improves image quality and, consequently, the detectability of small changes in the signal. Ultimately, this leads to more precise real-time dose control of the treatment laser, which reduces collateral damage to the retina.

Methods

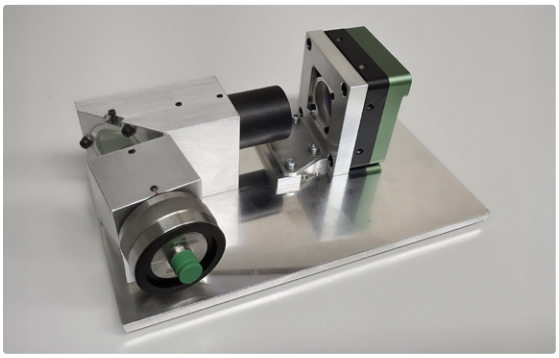
This project integrates a fundus camera with real-time tracking algorithms and an OCT-based dosimetry system for precise SRT delivery. Therefore, a new SD-OCT spectrometer was designed and characterized for a specific OCT spectral range using OpticStudio (ZEMAX). Multiple spectrometer configurations were evaluated through utility analysis, considering technical and economic factors. The system combines OCT monitoring in the near infrared (NIR) spectral range with SRT laser treatment at 532 nm and the fundus camera operating around 940 nm.

Results

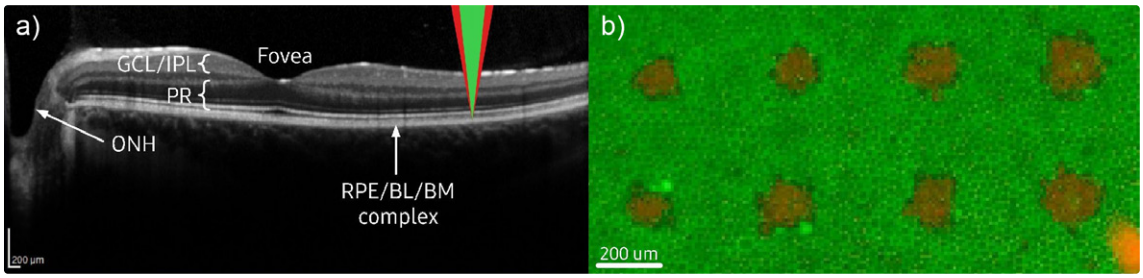
The optimized spectrometer achieved an axial scanning unit (ASU) of 5.1 µm. FallOff measurements have shown that the fiber end must be within ±35 µm of the collimator lens focus in order to be sufficiently collimated to achieve signal strengths of over 95%. It also achieves high sensitivity of over 100 dB with integration times of only 20 µs. In addition, the OCT beam path was combined with that of the fundus camera to demonstrate feasibility with the selected spectral ranges.

Conclusion

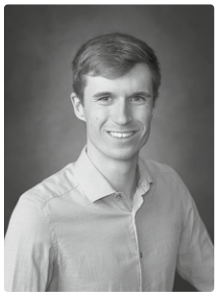
The redesigned spectrometer ensures uniform spectral resolution across the entire detector. This enables potentially better lesion detection, resulting in more precise dose control, which ensures laser damage is limited to the RPE and therefore enables SRT.



Custom-made OCT spectrometer with optimized optical design for real-time dose control of the treatment laser.



a) OCT cross-section showing the SRT and OCT laser targeting the RPE layer. b) Fluorescence microscope image showing an array of SRT lesions with controlled damage to the RPE and uniform lesion sizes.



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