Ophthalmic Imaging with Low-Cost Optical Coherence Tomography

Degree programme: BSc in Micro- and Medical Technology | Specialisation: Optics and Photonics
Thesis advisor: Dominik Inniger
Expert: Dr. Daniel Boss

Optical Coherence Tomography (OCT) is a non-invasive imaging technique used for depth resolved tissue analysis. In ophthalmology, this technique is used to detect the onset of eye diseases at an early stage. The objective of this thesis is the construction of a low-cost OCT capable of performing detailed anterior segment scans.

Mauro Settimo
msettimo99@gmail.com

Introduction

Optical coherence Tomography (OCT) is based on the principle of light interferometry, which allows high-resolution (1-15μm) depth scans of microstructures within biological tissues. Nowadays, OCT is one of the main diagnostic techniques used by ophthalmologists. This imaging method enables the diagnosis and follow-up of numerous corneal and retinal diseases such as age-related macular degeneration, diabetic retinopathy and glaucoma.
The cost of optical components used by companies to produce an OCT system is very remarkable. The aim of this project is to build an OCT scanner with low production cost, but still able to obtain high-resolution scans of the anterior segment and retina.

Materials and Methods

Frequency Domain Optical Coherence Tomography has evolved two different principles of operation, the less expensive one to produce is the Spectral Domain Optical Coherence Tomography (SD-OCT) [Figure 1]. A broadband light source is directed towards a beamsplitter which has the task of dividing the light beam into two different paths. One part is directed towards the reference arm, and the other towards the sample arm. The two arms reflect the signal back to the beamsplitter, which recombines the two beams into a single signal. A spectrometer is used to decompose the light beam into all its wavelengths, the intensities of which are measured by a line camera.
With the line camera, all the wavelengths dependent interference information between the light reflected from the sample arm and the reference is acquired simultaneously. Then, by digitally processing the signal, information on the axial scattering profile of the sample can be obtained.
By combining multiple individual axial scans (A-Scan), it is possible to obtain a 2D image (B-Scan) of the anterior segment of the eye.
In an attempt to improve the quality of the scan (sensitivity), different configurations of the focusing lens were simulated and tested.

Results

The goal of developing a Spectral Domain OCT with low-cost components, capable of imaging the cornea and anterior segment of pig and human eyes, was achieved.
From test measurements, first on pig's eyes and then on human eyes, it has been possible to calculate the thickness of the cornea and acquire good quality images of the anterior segment [Figure 2], in particular the anterior chamber, the lens, and the iris.
Due to the current sensitivity of the OCT system, weak signals such as the epithelium are difficult to be precisely detected.

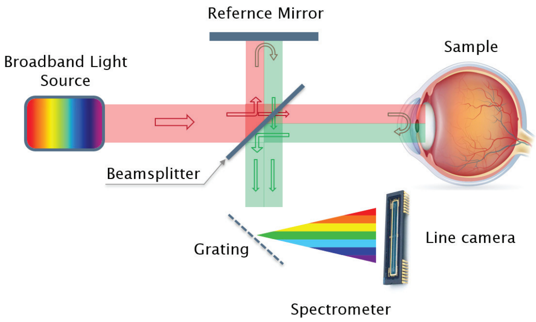

Figure 1: Working principle of a SD-OCT

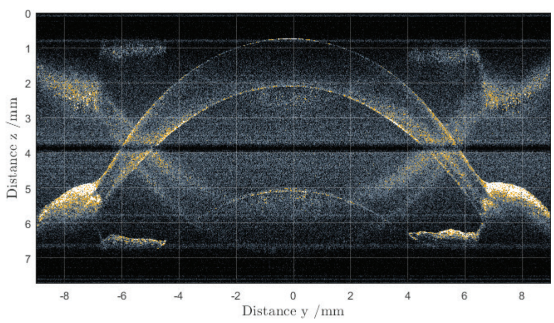

Figure 2: OCT B-Scan of a pig anterior segment, (central wavelength 880nm, 1000 A-Scans/s, average 5 B-Scans)