Polarization Sensitive Optical Coherence Tomography for In-Vivo Cornea Measurements

Degree programme: BSc in Mechatronics and Systems Engineering (Medical technology | Robotics)
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Optical coherence tomography (OCT) is a non-invasive imaging technique extensively used to image the human eye. Polarization sensitive OCT (PS-OCT) additionally allows visualizing the orientation of collagen fibrils in the cornea's stromal layer. However, fiber based PS-OCT systems are prone to disturbances like vibrations, producing inadequate results in-vivo. In order to prove the system stability, a PS-OCT based on free space optics is presented and tested.

Introduction

Anatomy of the Eye

The eye is a spherical organ where the cornea and pupil work together to focus incoming light onto the retina. The retina contains receptor cells that convert light into electrical signals, which are then transmitted to the brain via the optic nerve, enabling vision. The cornea accounts for most light focusing and is therefore ideal for refractive surgeries.

Problem

It has been shown that the cornea is birefringen due to collagen fibril distribution. To measure the polarization changing characteristics of the cornea, a PS-OCT system is well suited. However, fiber based PS-OCT systems are prone to disturbances due to vibrations and temperature changes. For clinical applications, a compact system is demanded. To solve this, a PS-OCT based on free space optics is elaborated.

Methods

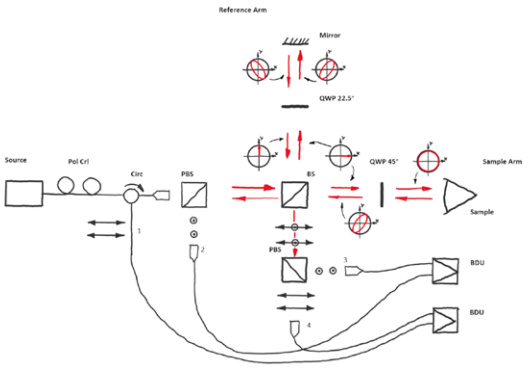
The core of a PS-OCT system is a Michelson interferometer. Light from a laser source is split into two equal parts by a beamsplitter. Reflected light from eye and reference arm interferes. Before reaching the detectors, the light is split again based on its polarization. This setup uses one balanced detection unit (BDU) per polarization for common mode rejection. Components for the OCT were designed, manufactured and ordered. After assembly, tests were conducted to evaluate the system's performance.

Results

Below, a PS-OCT image of a cornea is shown. The left image shows the intensity of reflected light. The middle image displays the optical axis direction. In a cornea this indicates the collagen fiber orientation. The right image shows the retardation, visualizing the cornea's birefringent properties.

Discussion

Designing a free space PS-OCT reduces the effects of disturbances and enables polarization sensitive measurements in-vivo in clinical environments. As shown in Figure 1, the systems sensitivity is not high enough for adequate cornea measurements. However, calculating optical axis and retardation leads to plausible results, providing a proof of concept for free space PS-OCT.



Schematic of a PS-OCT with one BDU per polarization.

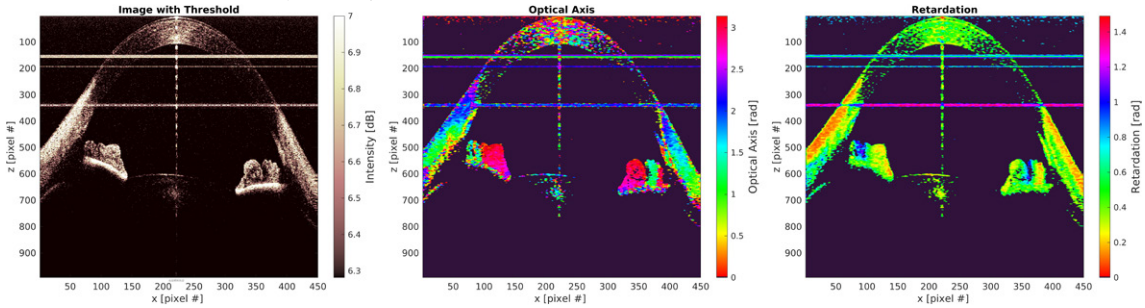


Image of a human cornea in-vivo. Left: measured intensity. Middle: optical axis. Right: retardation.

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