MATRIX APPROACH OF FULL-FIELD OCT FOR VOLUMETRIC IMAGING OF AN OPAQUE HUMAN CORNEA

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Key Words: Microscopy, OCT, Matrix approach, Imaging through Turbid Media

Optical microscopy offers the possibility to image biological tissue with a diffraction limited resolution (~µm). However, the heterogeneity of biological tissues can strongly affect light propagation at large depths by distorting the initial wavefront. Large and short range fluctuations of the refractive index can induce aberration and multiple scattering, respectively. Inspired by a recent work [1], we have developed a matrix approach to Full-Field Optical Coherence Tomography (FF-OCT) to push back the fundamental limit of aberrations and multiple scattering. Here, we report on the application of this approach to the imaging of the human cornea and the quantitative measurement of the corneal transparency.

The matrix approach for FF-OCT is based on the measurement of a time-gated reflection matrix R. Each element of R corresponds to the impulse response between a point in a source and an image plane respectively, both conjugated to the sample plane. From R, we are able to recover a confocal image as well as an average focal spot. This reflection matrix can be used to measure the amount of aberration that the incident wavefront has undergone inside the medium.

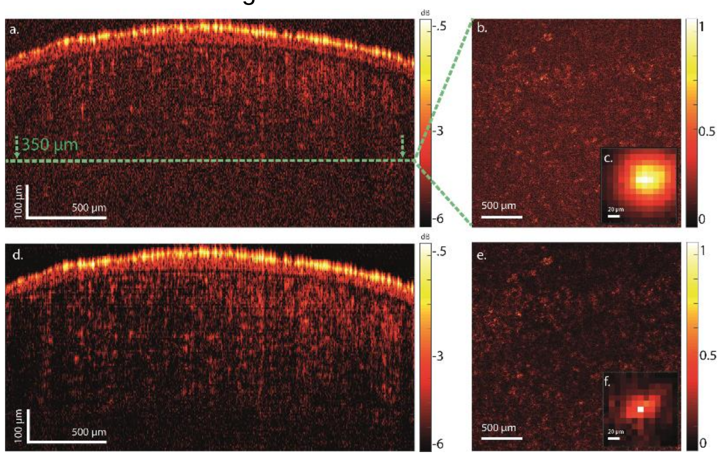

Figure 1 – Aberration correction for imaging of a human cornea. a. Axial section of the FF-OCT image (in dB) of the cornea without and d. with correction for aberration. b, f. En-face FF-OCT image of the cornea at a depth of 350 mm before and after correction, respectively. c, f. Average focal spot deduced from R at the depth of 350 mm before and after correction, respectively.

We measured R_z as a function of depth in an ex-vivo human cornea. As light propagates inside the cornea, it undergoes strong phase distorsion that severely degrades the quality of the FF-OCT image (Fig 1 a. and b.). This distorsion can be clearly observed on the spreading of the focal spot (Fig 1 c.). Conventional adaptive optics allows to correct for one part of the image but is not efficient over the whole FOV. Conversely, our matrix approach yields a high-quality image of the cornea over the whole FOV as if the inhomogeneities of the cornea had disappeared (Fig 1 d. and e.). Furthermore, the recovery of a diffraction limited PSF (Fig 1 f.) proves the success of the correction. This approach also allows a quantitative measurement of the scattering mean free path, l_s, inside the different layers of the cornea. This parameter is relevant to characterize corneal transparency, which can be impacted by several diseases such as keratoconus.

The perspective of this work is to go beyond cornea and apply our approach to retinal and choroidal imaging. In addition, as this matrix approach is not limited to the study of the eye, future work will be applied to in-depth imaging of biological tissues.

References

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