In Vitro Bovine Retina Imaging by Digital Holographic Adaptive Optics

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Abstract A digital holographic adaptive optics system for retinal imaging is described. The experimental results on the in vitro retina are reported that demonstrate the feasibility of this imaging mode.

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The normal human eye suffers from many monochromatic aberrations that degrade the retinal image quality. The Shack–Hartmann sensor was first incorporated into an adaptive optics (AO) system for vision science in 1997 by Liang and colleagues [1, 2]. The cellular structure of the living retina was readily resolved by this system. Recently, we presented a new AO retinal imaging system that is based on the principles of digital holography (DH) [3]. Incorporation of DH in an ophthalmic imaging system can lead to versatile imaging capabilities at substantially reduced complexity and cost of the instrument. The presented digital holographic adaptive optics (DHAO) system replaces complex hardware components in conventional AO system with numerical processing through the principles of digital holography [4].

The schematic diagram of the apparatus of DHAO imaging system is shown in Fig. 1. The biological samples such as butterfly wing and bovine retina are placed at the retinal plane of the human eye (R), while a lens of a focal length 20mm serves as the eye lens (C). A phase aberrator is placed at the pupil plane (H) of the eye. A scientific grade CCD is placed in the conjugate plane of the pupil (H). First, phase aberration sensing is performed. A digital hologram is captured by the CCD, from which the complex amplitude of the optical field at plane H can be obtained. The phase map of this complex amplitude is the measured phase aberration. Then, full field retinal images are taken. The lens L1 is inserted into the beam. Likewise, the complex amplitude of the optical field at H can be obtained, from which the aberrated retinal images can be obtained. Finally, the aberration is removed from the distorted images to get improved ones.

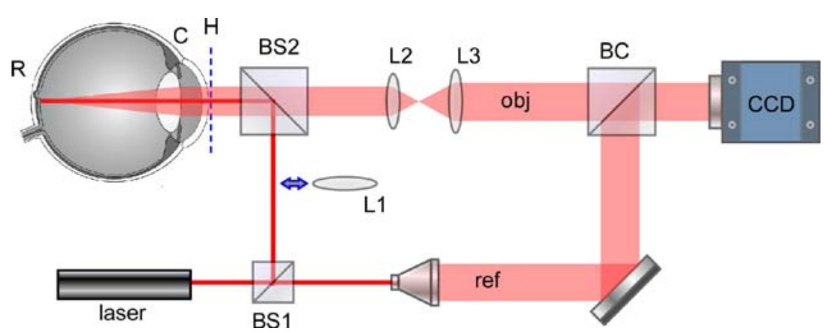

Fig. 1 The schematic diagram of the DHAO system. H: pupil plane, C: eye lens, R: retina.
BS1 and BS2: beamsplitters, BC: Beam combiner.

The experimental results on butterfly wing are shown in Fig. 2. The image in the absence of the phase aberrator is shown in Fig. 2(a). In the presence of the phase aberrator, the image is blurred and distorted as illustrated by Fig. 2(b). Fig. 2(c) shows the measured phase aberration introduced by the phase aberrator. Fig. 2(d) shows the corrected image. There is a significant improvement of quality in the corrected image, compared to the uncorrected one.

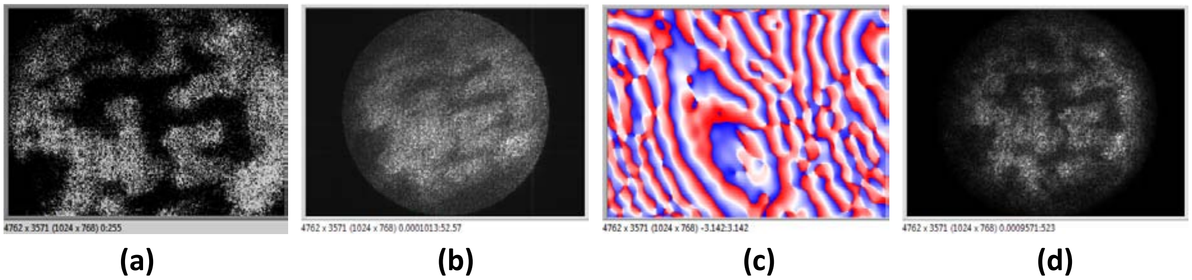

Fig.2 DHAO on butterfly wing. (a) the image without aberration, FOV: 99μm×720μm.; (b) distorted image; (c) phase aberration; (d) the corrected image.

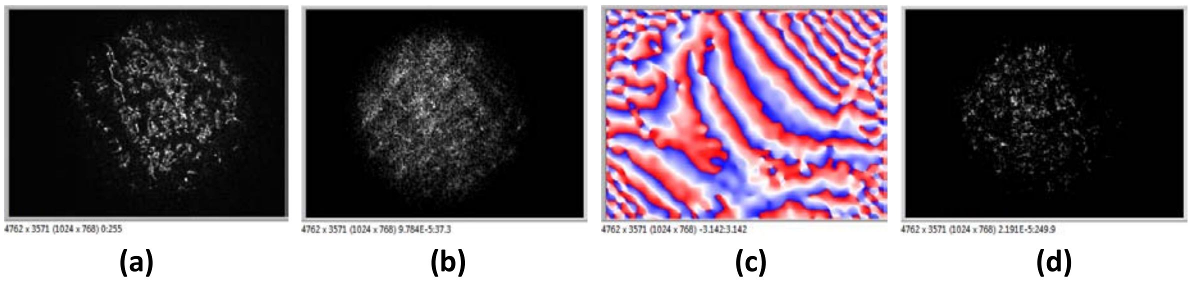

Fig.3 DHAO on bovine retina. (a) the image without aberration, FOV: 320μm×320μm.; (b) distorted image; (c) phase aberration; (d) the corrected image.

Then, DHAO is applied on the bovine retina. The retina is extracted from a preserved cow eye We put the retina on top of a glass slide. Fig. 3(a) shows the direct image of the bovine retina without aberrator in place. The distorted image due to the aberrator is given by Fig. 3(b), which is an inverted version of Fig. 3(b), because we use the image order of the hologram to reconstruct it. Both twin image and image orders of the hologram can be used to reconstruct the sample [4]. The aberration is shown by Fig. 3(c). Fig. 3(d) shows the improved image when the aberration is compensated for.

To apply the DHAO on the living retina, we have to resolve the mosaic cones that haven't been resolved by our current setup. To achieve this goal, we are going to investigate the cell size of the bovine retina under common microscope. Now, due to the thickness of the retina, we can not see a nice picture of the retina. Therefore we need prepare a much thinner retina sample to resolve the mosaic and measure the size under the common microscope. According to the cell size, we can modify parameters of the current setup so that it is able to resolve the cells without the aberrator in place. To simulate the real eye environment so that the data achieved from in vitro experiment can provide more reliable evidence of the feasibility of DHAO on living retina, we will make an eye model. The eye lens is still simulated by L1 in Fig.2. An iris will be added at the pupil plane to adjust the aperture according to requirement of the resolution. A cow eye will be cut in half. The rear part that contains the retina and the lens will be put into a glass cube. Solutions that can preserve the retina and have a similar refractive index as vitreous humor will be put into the cube. Then, we apply the DHAO on this eye model to simulate its application in the real eye. This work is still underway. The data will be collected in the near future.

In conclusion, we have demonstrated DHAO on the butterfly wing and bovine retina. The experiments on the eye model to collect more reliable evidence of its application on the living retina are underway.

References

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