Göteborg University / Sahlgrenska Academy

Institute of Neuroscience and Physiology / Department of Ophthalmology

# Wide-field dual-conjugate adaptive optics instrument for retinal imaging

Zoran Popovic[1], Mette-Owner Petersen[2], Jörgen Thaung[1]

[1]Department of Ophthalmology, Göteborg University, Sweden; [2]Lund Observatory, Lund University, Sweden

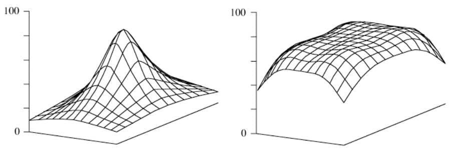


**Fig. 1** Comparison of simulated Strehl value over a corrected field of view using SCAO (left) and (MCAO (right) (http://gemini.conicyt.cl/sciops/instruments/adaptiveOptics/docs/MCAO4DUMMIES.ppt)

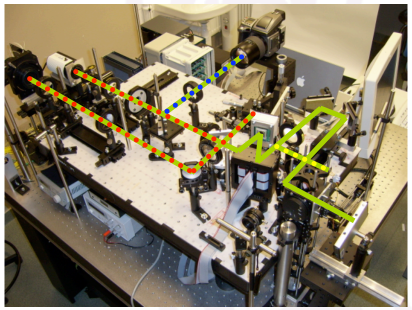

**Fig. 2** Wide-field dual-conjugate adaptive optics instrument for retinal imaging

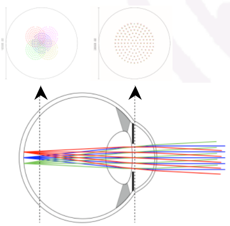

**Fig. 3** Conjugate planes in the eye and corresponding DM footprints (different footprint scales!)

To date only conventional single-conjugate adaptive optics (SCAO) systems are used to correct ocular aberrations. A major shortcoming of SCAO is the severely restricted corrected field of view (Fig. 1). This can be solved with multi-conjugate adaptive optics (MCAO), a solution that could be costly and result in bulky instruments. We present a 'compact' dual-conjugate adaptive optics (DCAO) system for ophthalmology (Fig. 2) that will enable wide field high resolution imaging of the retina *in vivo*, implementing five retinal guide stars and two OKO micromachined membrane deformable mirrors (DMs). One 15 mm 37 channel DM is conjugated to the pupil, and a 40 mm 79 channel DM is conjugated to a plane approximately 3 mm in front of the retina (Fig. 3). The system works with a closed loop correction frequency of approximately 4 Hz in DCAO mode, 7 Hz in ground layer mode (small DM and all five guide stars), and 12 Hz in SCAO mode.

Continuous relatively broadband near-infrared light (835±14 nm) from a super-luminescent diode (Superlum Ltd, St. Petersburg, Russia) is fed through five single mode fibers to form five separate collimated rays. A Badal system is used to correct for a subjects spherical refractive error, and passing the guide star (GS) light through the Badal system ensures the delivery of well-focussed spots on the retina. The five spots are arranged in a cross (c.f. Fig. 4) with a center-to-center displacement of 600 µm (2.2 deg) on the retina.

The setup (Fig. 4a) incorporates an array of collimator lenses in the wavefront sensor (WFS) arm to spatially filter the light from all guide stars using just one adjustable iris (Fig. 4b,c), thereby removing unwanted light from parasitic source reflections and light from unwanted object regions. The Hartmann patterns of the multiple reference sources (Fig. 4d) are imaged onto a Shack-Hartmann WFS made up of a lenslet array (pitch 300 µm, focal length 7.9 mm, 33 x 33 square lenslets, SÜSS MicroOptics SA, Neuchâtel, Switzerland), a relay lens, and a single monochromatic CCD camera (Retiga EXi Fast 1394, QImaging, Barnaby, BC, Canada). Optical simulations in ZEMAX indicate an increase of the retinal isoplanatic patch from a radius of approximately 0.5 degree using SCAO to approximately 5 degrees using our DCAO setup.

The imaging camera is a Hasselblad H2D digital camera. It has a 22 Mpix, 16 bit RGB CCD, 36.7 x 49.0 mm (4080 x 5440 pixels). This is equivalent to a 9 µm square pixel size yielding a resolution of 0.68 µm/pixel on the retina with a 10 deg visual field imaged on the short CCD side (0.52 µm/pixel long side). We will be testing the Hasselblad H2D-39 in the near future (39 Mpix, 6.7 µm pixel size, retinal resolution 0.5 µm/pixel short CCD side, 0.38 µm/pixel long CCD side).

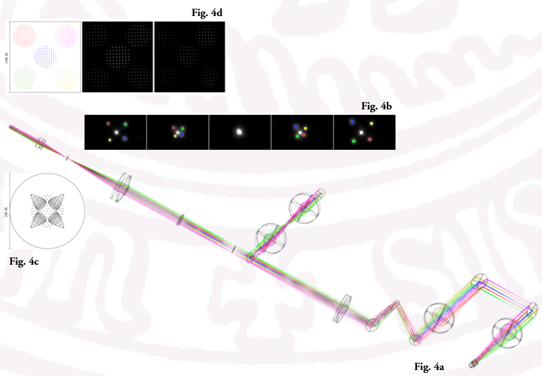


**Fig. 4** a) 3D rendering of ZEMAX model, b) collimated reference source rays passing through WFS spatial filter, c) ZEMAX simulation of WFS spatial filter, d) simulated and real WFS images of reference source Hartmann patterns

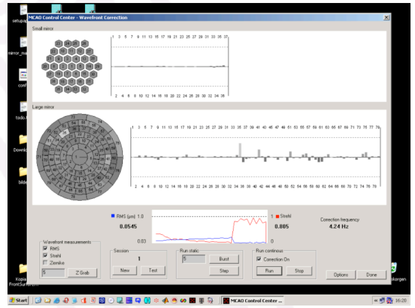

**Fig. 5** Screen shot of DCAO system GUI running in closed-loop mode, correcting internal system aberrations

Acknowledgement

Supported by Swedish Research Council Grant No. 2003-6254, Göteborgs Läkaresällskap, De Blindas Vänner i Göteborg, Kronprinsessan Margaretas Arbetsnämnd för synskadade.

Victor Hasselblad AB, Göteborg, Sweden, for the loan of the H2D digital camera.

Commercial interest: US patent pending.