ARVO 2013
# 5548

# Evaluation of a Dual-Conjugate Adaptive Optics Clinical Prototype for Retinal Imaging

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

[1] Department of Ophthalmology, Institute of Neuroscience and Physiology at the Sahlgrenska Academy, University of Gothenburg, Mölndal, Sweden. [2] Exomed AB, Sollentuna, Sweden.

For additional information please contact Zoran Popovic (zoran@oft.gu.se)

## Disclosure

Zoran Popovic - Patent: US7639369, Patent applications: PCT/EP2012/069620, EP12165365
Jörgen Thaung - Patent: US7639369, Patent applications: PCT/EP2012/069620 and EP12165365
Bengt Svensson - Employment: Exomed, Patent applications: PCT/EP2012/069620 and EP12165365
Mette Owner-Petersen - Patent: US7639369, Patent applications: PCT/EP2012/069620 and EP12165365

## Purpose

To evaluate a new dual-conjugate adaptive optics clinical prototype for wide-field high-resolution adaptive optics retinal imaging.

## Methods

A compact adaptive optics clinical prototype (Figure 1), based on the concept of dual-conjugate adaptive optics[1-3], employs five spatially separated retinal probe beacons, two magnetic deformable mirrors (DM) (ALPAO, Grenoble, France), and a multi-channel Shack-Hartmann wavefront sensor with spatial filtering.

Monochromatic aberrations are measured and corrected over a 6 mm pupil using five probe beacons (Figure 2). The beacons are generated using 830±10 nm light from a superluminescent diode (Superlum, Cork, Ireland). A 52 actuator DM positioned in a plane conjugated to the pupil of the eye will apply an identical correction for all field-points in the field of view (FOV). A 97 actuator DM positioned in a plane conjugated to a plane inside the eye will contribute with partially individual corrections for the five angular directions and thus compensate for non-uniform (anisoplanatic) or field-dependent aberrations. DM footprints are shown in Figure 3. Imaging is performed using a spectrally filtered Xenon flash at wavelengths of 575±10 nm.

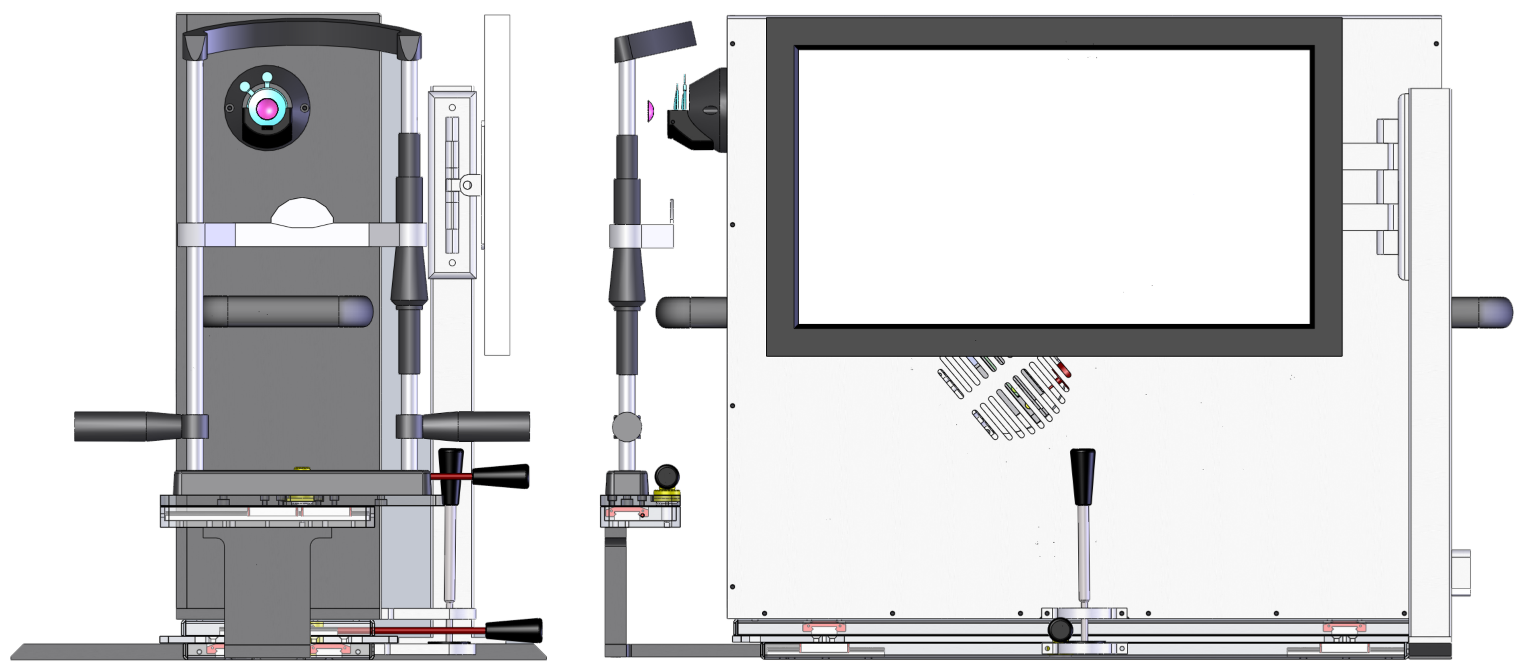

**Figure 1** CAD drawing of the dual-conjugate adaptive optics clinical prototype.

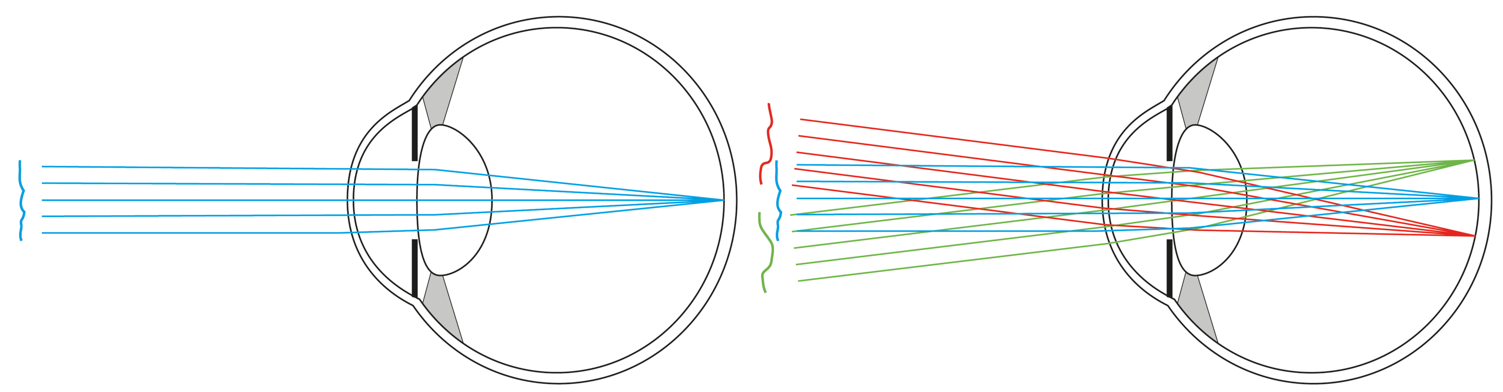

**Figure 2** Measuring aberrations using A) a single probe beacon, and B) multiple beacons. The side view in B) only shows three of five ray bundles. Retinal separation is exaggerated for clarity.

## Results

A 2048x2048 pixel region of interest on the science camera corresponds to approximately a 7x7 deg corrected retinal FOV (Figure 4). Custom made optics in the common path were optimized to deliver diffraction limited performance at both both wavefront sensing (830 nm) and imaging (575 nm) wavelengths (Figure 5). The pixel resolution is 0.059 mrad, corresponding to approximately 1 µm on the retina, allows retinal features down to 2 µm to be resolved. A narrow depth of field of approximately 10 µm in the retina enables tomographic imaging of separate retinal layers. Focusing on deeper retinal layers allows for imaging of cone photoreceptors (Figure 6), and focusing on upper retinal layers allows for imaging of retinal capillaries (Figure 7) with corresponding high resolution and contrast.

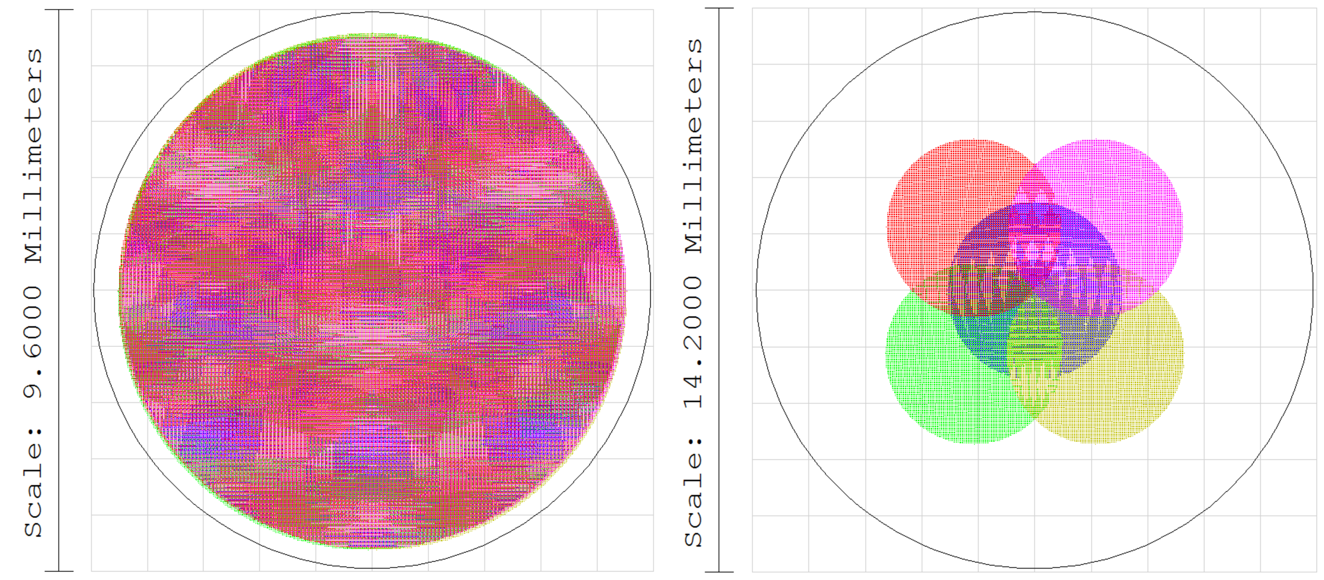


**Figure 3** DM footprints for the case of five beacons and two DMs. A) Overlapping footprints on the pupil conjugate DM (DMP). The DMP will apply an identical correction for all field-points in the FOV. B) Spatially displaced footprints on the DM positioned in a plane conjugated to a plane inside the eye (DMF). The DMF will contribute with partially individual corrections for the five angular directions and thus compensate for non-uniform (anisoplanatic) or field-dependent aberrations.

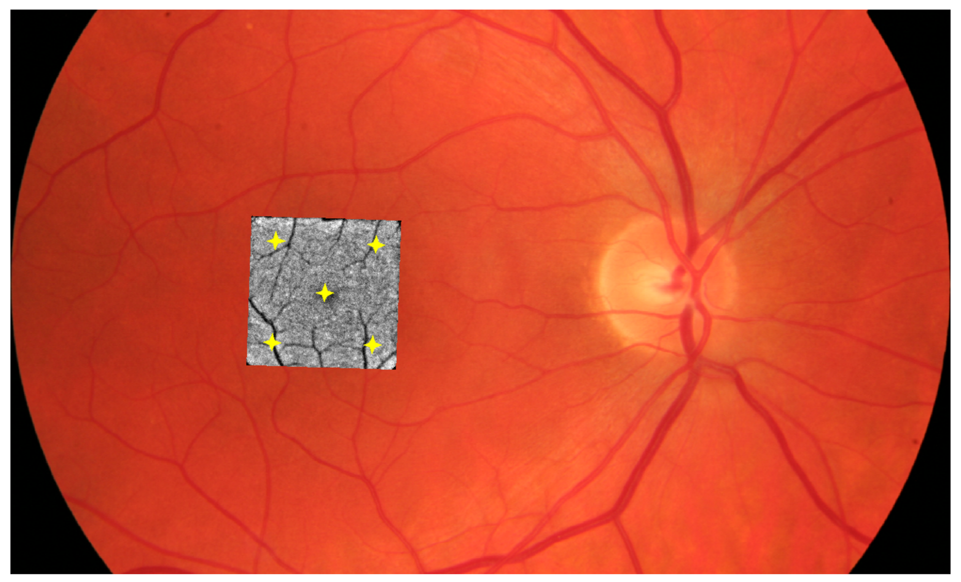

**Figure 4** Colour fundus image with 40° FOV. The grayscale inset and stars represents the 7x7 deg FOV and probe beacon positions. The FOV is large enough to cover the central part of the retina responsible for acute vision.

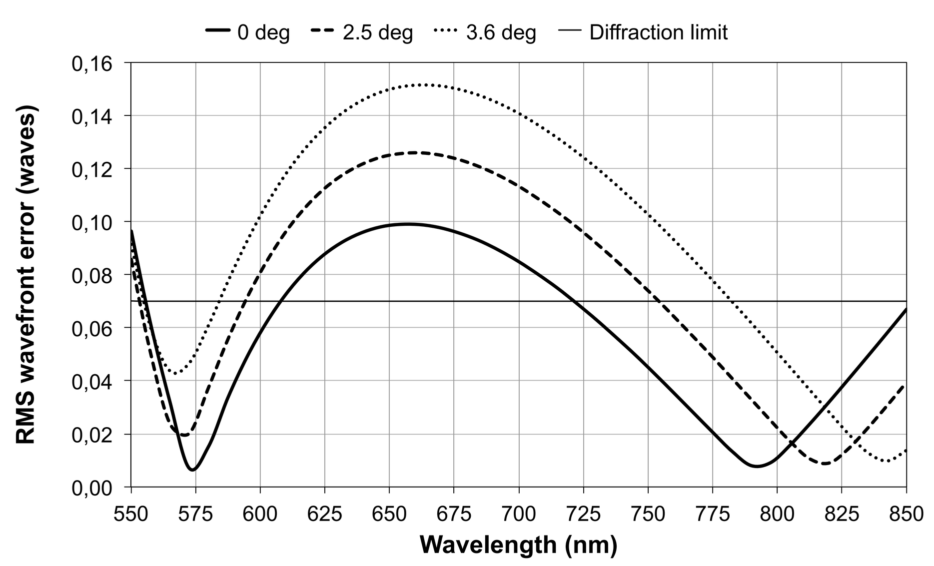


**Figure 5** RMS wavefront error at the exit pupil of the common path custom relay optics for three retinal field positions (0, 2.5, and 3.6 deg).

## Conclusions

High resolution adaptive optics retinal imaging has enabled the vision research community to gain deeper insight into the development and progression of retinal diseases. The dual-conjugate adaptive optics clinical prototype has a future potential for clinical imaging with an impact particularly important for early diagnosis of retinal diseases, follow-up of treatment effects, and follow-up of disease progression, at currently sub-clinical levels.

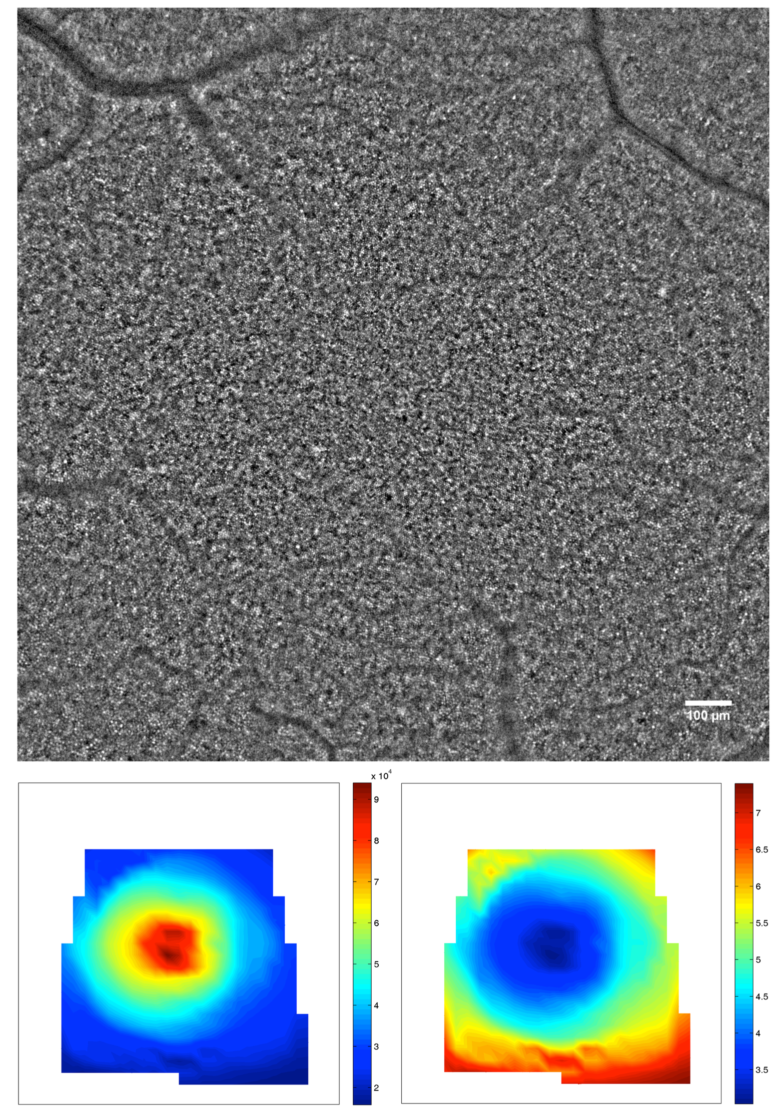

**Figure 6** A) Sum of two registered photoreceptor layer images. B) Color surface map of cone density (cells/mm$^2$) in A. C) Color surface map of cone separation (µm) in A.

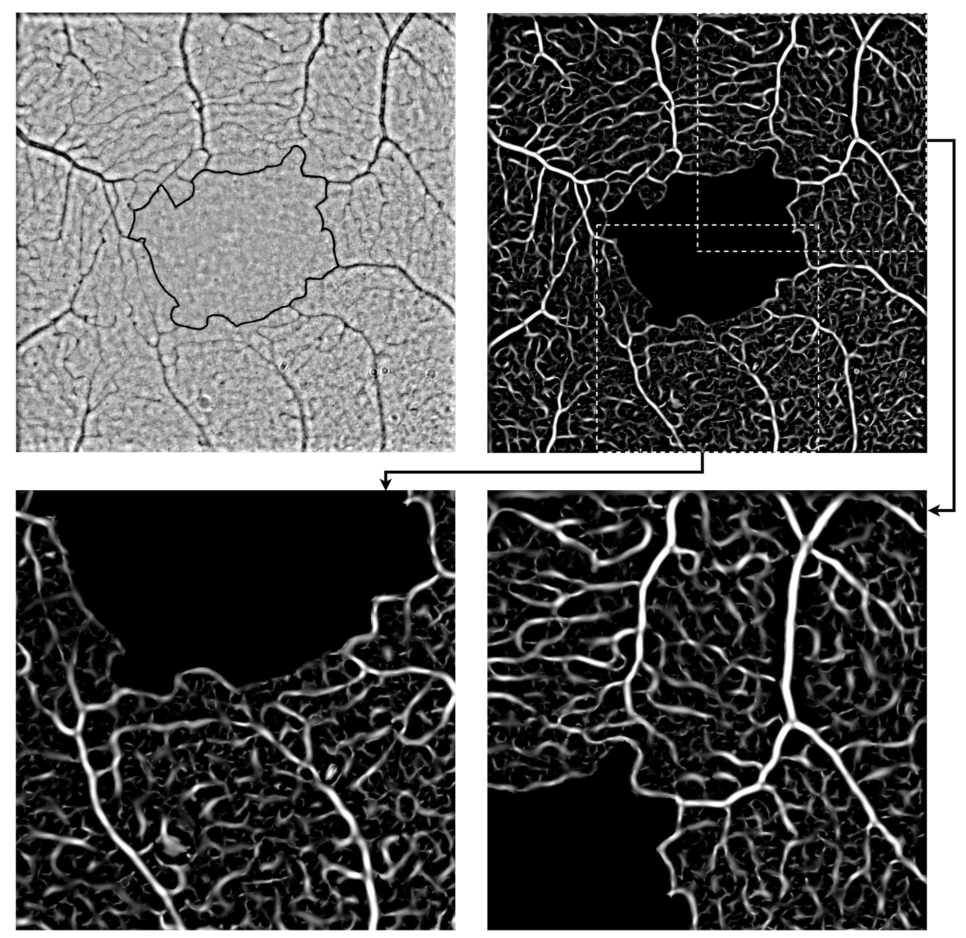

**Figure 7** Upper left image shows vessel image with an outlined foveal avascular zone. Upper right image shows identified capillaries. Two regions, indicated by dashed lines, are magnified and shown below the full field images.

## References

1. J. Thaung, P. Knutsson, Z. Popovic, M. Owner-Petersen (2009) *Opt. Express*, 17(6), 4454-4467.
2. Z. Popovic, P. Knutsson, J. Thaung, M. Owner-Petersen, J. Sjöstrand (2011) *Invest. Ophthalmol. Vis. Sci.*, 52(5), 2649-2655.
3. Z. Popovic, J. Thaung, P. Knutsson, M. Owner-Petersen (2012). Dual Conjugate Adaptive Optics Prototype for Wide Field High Resolution Retinal Imaging, Adaptive Optics Progress, Dr. Robert Tyson (Ed.), ISBN: 978-953-51-0894-8

The Sahlgrenska Academy