Adaptive Optics Overview

Austin Roorda, PhD
Braff Chair in Clinical Optometric Science
School of Optometry
University of California, Berkeley

commercial interest disclosure:
patent: Univ of Rochester, Univ of Houston
consultant: OPTOS (patent licensee)
Summary

• By providing microscopic views of the living human retina, AO imaging is driving a paradigm shift in how we use retinal imaging for basic and clinical science
Current Progress in AO Imaging
Direct & Autofluorescence Imaging of RPE cells

RPE cells in Cone-rod dystrophy patient with AOSLO (Berkeley)
Roorda, Duncan, Zhang, IOVS in press

Monkey RPE cells with autofluorescence (Rochester)
Gray et al, Optics Express 14, 7144-7158 (2006)
AOSLO Fluorescein Angiography

AOSLO movie

Registered frame

University of Rochester
Gray et al, Optics Express 14, 7144-7158 (2006)
Overcoming Eye Movements in AOSLO
Hardware-based tracking makes it possible to maintain the raster at a fixed retinal location (within 20 microns).

Hammer et al. Optics Express, 14(8): 3354-3367 (April 2006)
Software-based Eye Tracking

Software-based tracking makes it possible to maintain a stimulus on a spot as small as a single cone (<5 microns)

Montana State University & UC Berkeley  Roorda et al, ARVO, 2007
Improving Resolution: AO and OCT

Resolution Volumes

- choroid
- photoreceptors
- outer nuclear layer
- outer synaptic layer
- inner nuclear layer
- inner synaptic layer
- ganglion cell layer
- optic fiber layer

100 µm

commercial OCT
AOSLO
commercial cSLO
AO OCT

Courtesy Donald Miller, Indiana University
AO-OCT

B-scans at 2° retinal eccentricity

1.25 degrees
(375 microns)

NFL

cones

Focus at photoreceptors
Focus at nerve fibers

Courtesy of Donald Miller, Indiana University
Zhang et al. Optics Express, 14(10): 4380-4394 (May 2006)
AO-OCT Volume Image of Retina

images courtesy of Robert Zawadzki, UC Davis
What’s the Latest in AO Technology?
Deformable Mirrors

Xinetics, Inc.
49 mm aperture
37-97 actuators
4 \( \mu \)m stroke

OKOTech
37-109 actuators

Imagine Eyes
50 \( \mu \)m of stroke

BMC MEMS
4mm aperture
12X12 actuators
3.5 \( \mu \)m stroke
Dual Mirror Systems

**Bimorph Mirror**
Corrects low order aberrations, (ie defocus and astigmatism) up to +/- 3D

**MEMS Mirror**
Corrects remaining high order aberrations
Dual-mirror AOSLO
LLNL and Doheney Eye Institute

Dual Mirror AOOCT - UC Davis and LLNL

Images courtesy of Robert Zawadzki, UC Davis
Dual Frame Imaging

Frame 1: red laser
Frame 2: IR laser

Where is AO ophthalmoscopy headed?

Genotype-Phenotype relationships
Dynamic imaging
Functional imaging
Genotype-Phenotype comparisons

NC - M cones absent

MM - all M cones

Has “normal” gene array

Missing all L gene(s)

Carroll, Neitz, Hofer, Neitz, Williams, PNAS, 2004
Genotype-Phenotype comparisons

Retinitis pigmentosa #1
Retinitis pigmentosa #2
Early cone dystrophy

genetic mutations identified

Duncan et al, IOVS in press
Dynamic Imaging: Leukocyte Velocity Measurement

- 532 nm laser
  - No fluorescent dyes required (safe, long term)
  - Identify ghost vessels (non-perfused capillaries)
  - 95% confident of velocity changes as small as 0.076 mm/sec

Dynamic Imaging: Eye Movement Tracking

- Original video
- Stabilized video

960 Hz eye trace, accurate to one image pixel (0.14 minutes of arc)

Scott Stevenson, Houston; David Arathorn, Curt Vogel, Al Parker, Qiang Yang, MSU
Functional Imaging: Delivery of AO-corrected Stimuli

All stimuli seen  Some stimuli not seen
AO-Microperimetry confirms cone drop-out

Proportion of Detected Flashes

Log Luminance

normals: open symbols

University of Rochester

Functional Imaging: Vision testing

Allows for simultaneous measurement of optical and retinal limits to vision

Also Rossi talk this afternoon
The fixation point is displaced about 10’ of arc from the point of maximum cone density.
Functional Imaging: Intrinsic scattering changes

\[ \frac{\sum I_B}{\sum I_A(t)} \]
Optophysiology: Depth-resolved probing of retinal physiology with functional ultrahigh-resolution optical coherence tomography


*Center for Biomedical Engineering and Physics/Christian Doppler Laboratory and †Department of Physiology, Medical University of Vienna, A-1090 Vienna, Austria; and ‡Femtosecond Optics Group, Physics Department, Imperial College, London SW7 2BW, England