

OCT mini-Symposium

Presenters

Donald Miller, Indiana Univ.

Joseph Izatt, Duke Univ.

Thomas Milner, Univ. of Texas at Austin

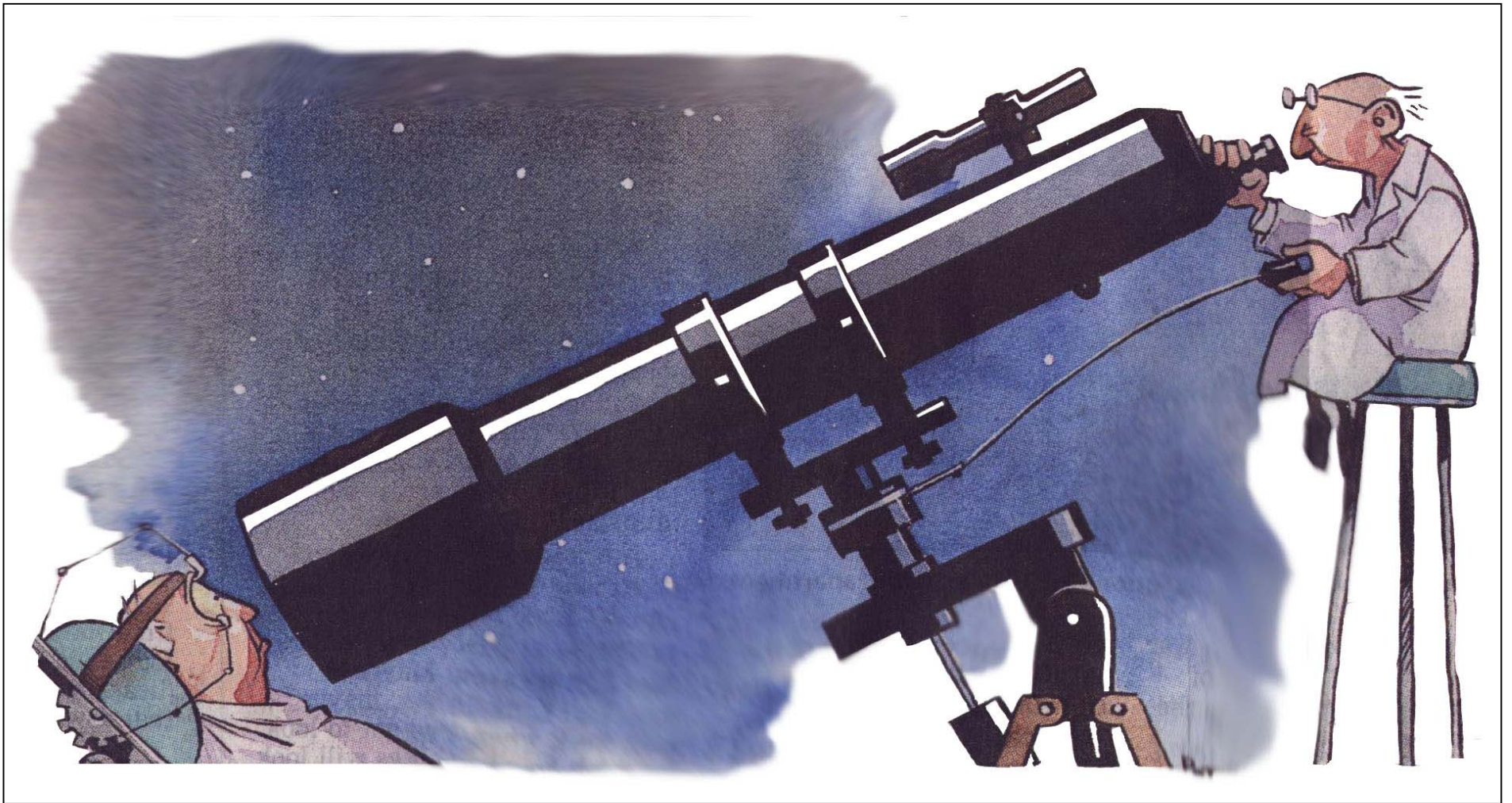
Jay Wei, Zeiss Meditec

**Indiana University
School of Optometry**



“Starlight, eyebright”

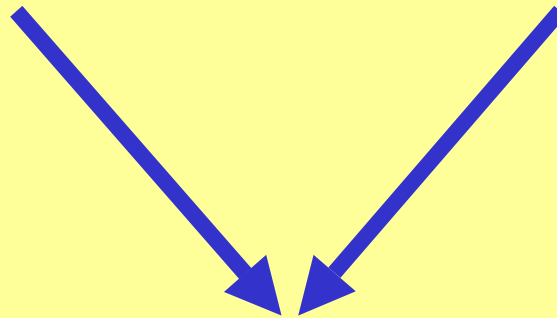
Canberra Times, Australia



Combining the strengths of adaptive optics and coherence gating

Adaptive Optics
(high transverse resolution)

Coherence Gating
(high axial resolution,
i.e. optical sectioning)



AO C-G Retina Camera
(high transverse & axial resolution)

OCT

Tomography
(x-z image, Wei)

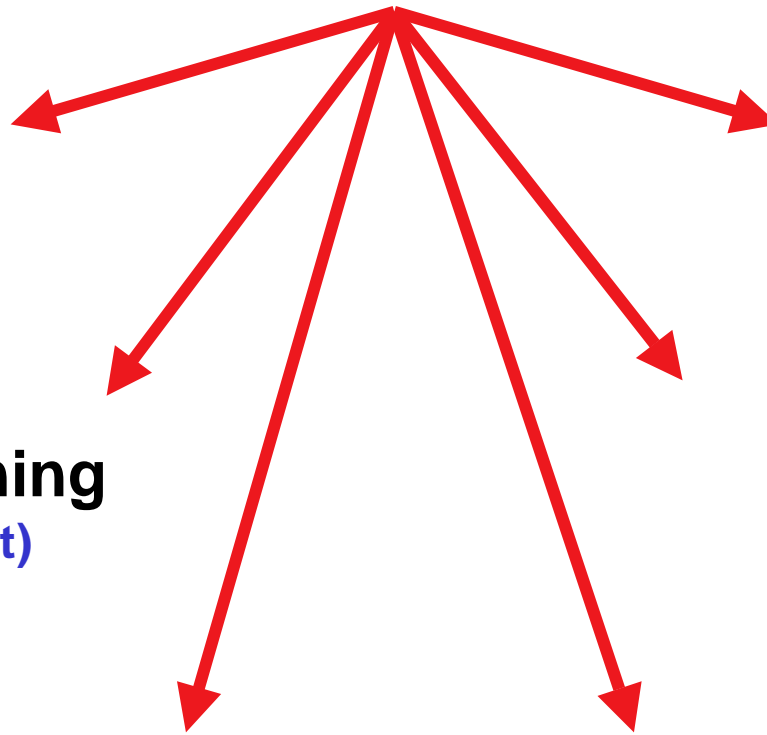
Color Doppler OCT
(flow detection, Izatt)

En face scanning
(x-y image, Izatt)

Polarization-sensitive OCT
(Milner)

Flood-illumination
(photodiode array, Milner
CCD, Miller)

Clinical OCT
(Wei)



High-Resolution Retinal Imaging Using AO and OCT

Junle Qu, Ravi Jonnal, and Karen Thorn

Donald Miller

Indiana University
School of Optometry

Adaptive optics is being integrated into three main architectures of retina cameras.

1. Flood-illumination

Chinese Acad. Of Sciences (China), Indiana, Lawrence Livermore, Moscow State Univ. (Russia), Murcia (Spain), Observatoire de Paris (France), Rochester, UC San Diego

2. Scanning laser ophthalmoscope

Houston, Imperial Col. (UK), Lawrence Livermore, Murcia (Spain), National Univ (Ireland), Rochester, Schepens, UC-Berkeley, UC-San Diego, Waterloo (Canada)

3. Coherence gating (OCT)

Indiana, Lawrence Livermore, National Univ (Ireland), Observatoire de Paris (France), Rochester, UC-Davis, Univ. College (UK), Univ of Kent (UK)

Adaptive optics coherence-gated retina camera

New medical imaging modality
(1991*)

Optical analogy of ultrasound

Axial resolution $\sim 1 / \text{coherence length of the light source}$

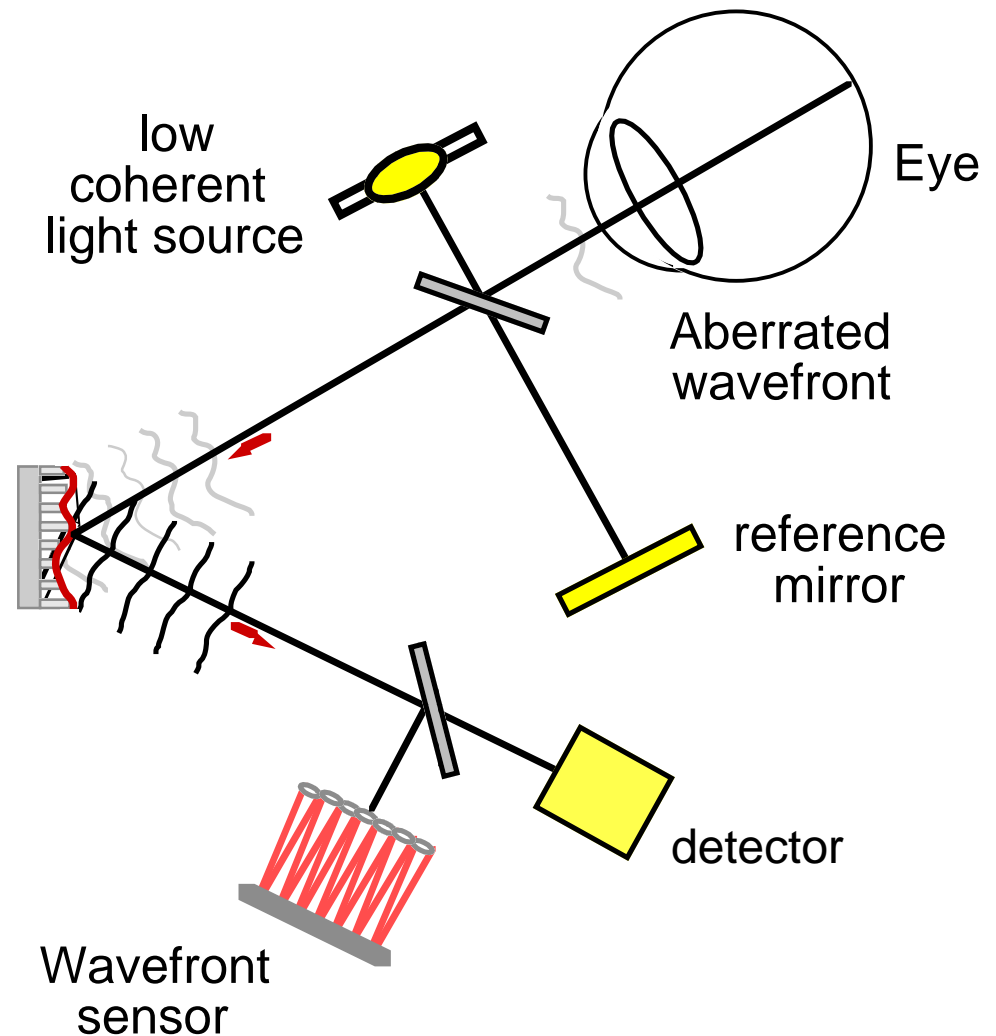
Detected signal

$$= |\Psi_{\text{ref}} + \Psi_{\text{retina}}|^2$$

$$= |\Psi_{\text{ref}}|^2 + |\Psi_{\text{retina}}|^2 +$$

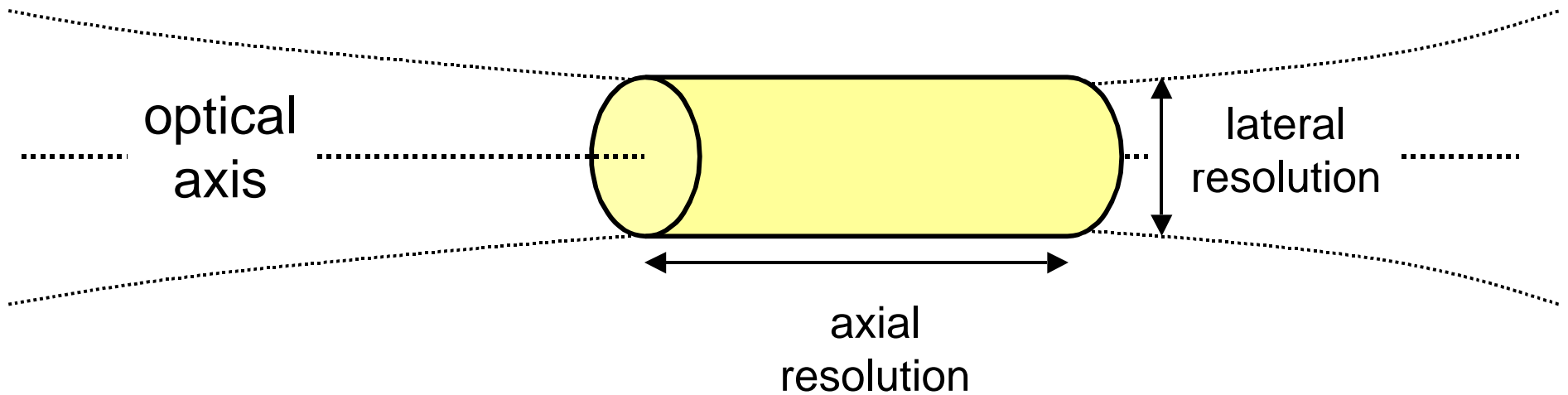
$$2 |\Psi_{\text{ref}}| |\Psi_{\text{retina}}| \cos(\phi_{\text{ref}} - \phi_{\text{retina}})$$

layer
1

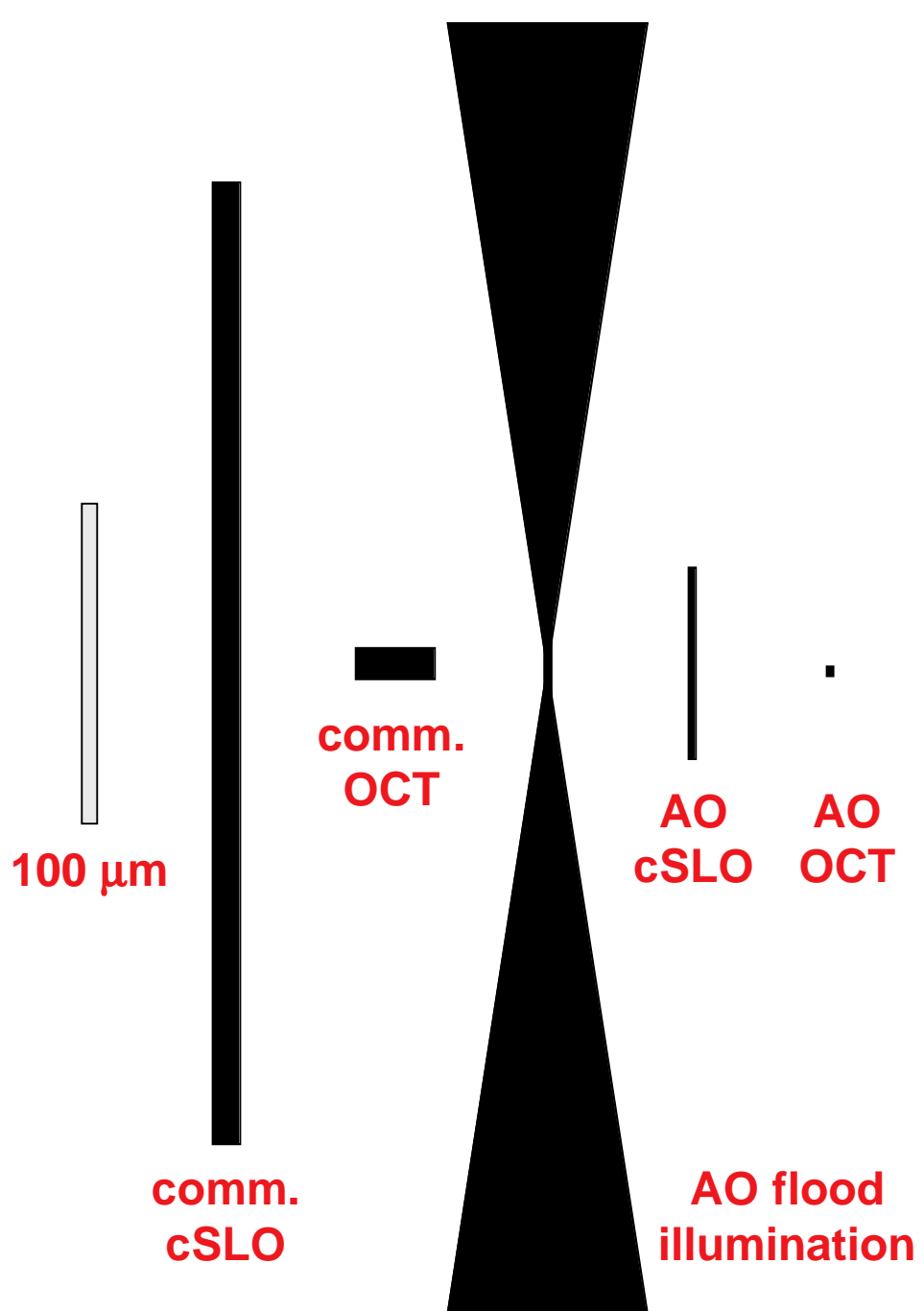
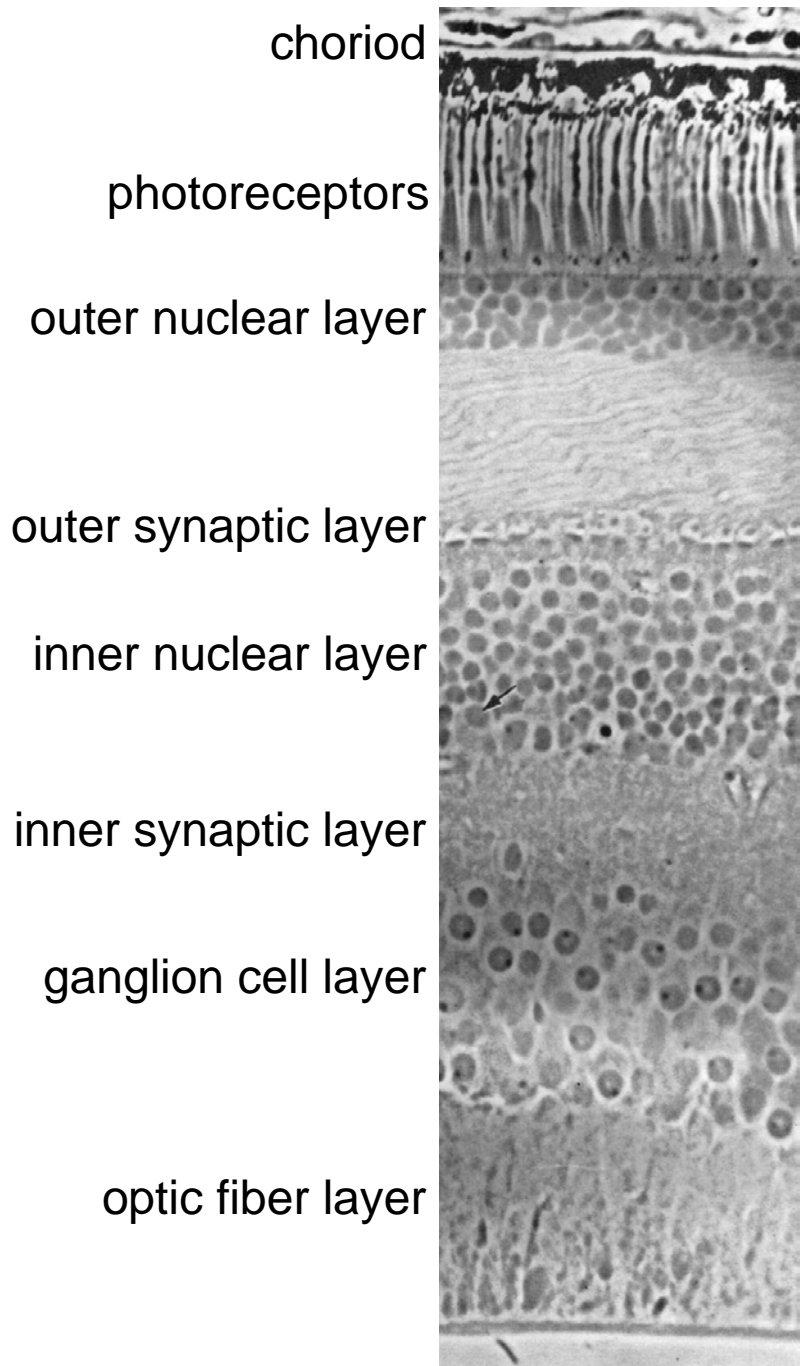


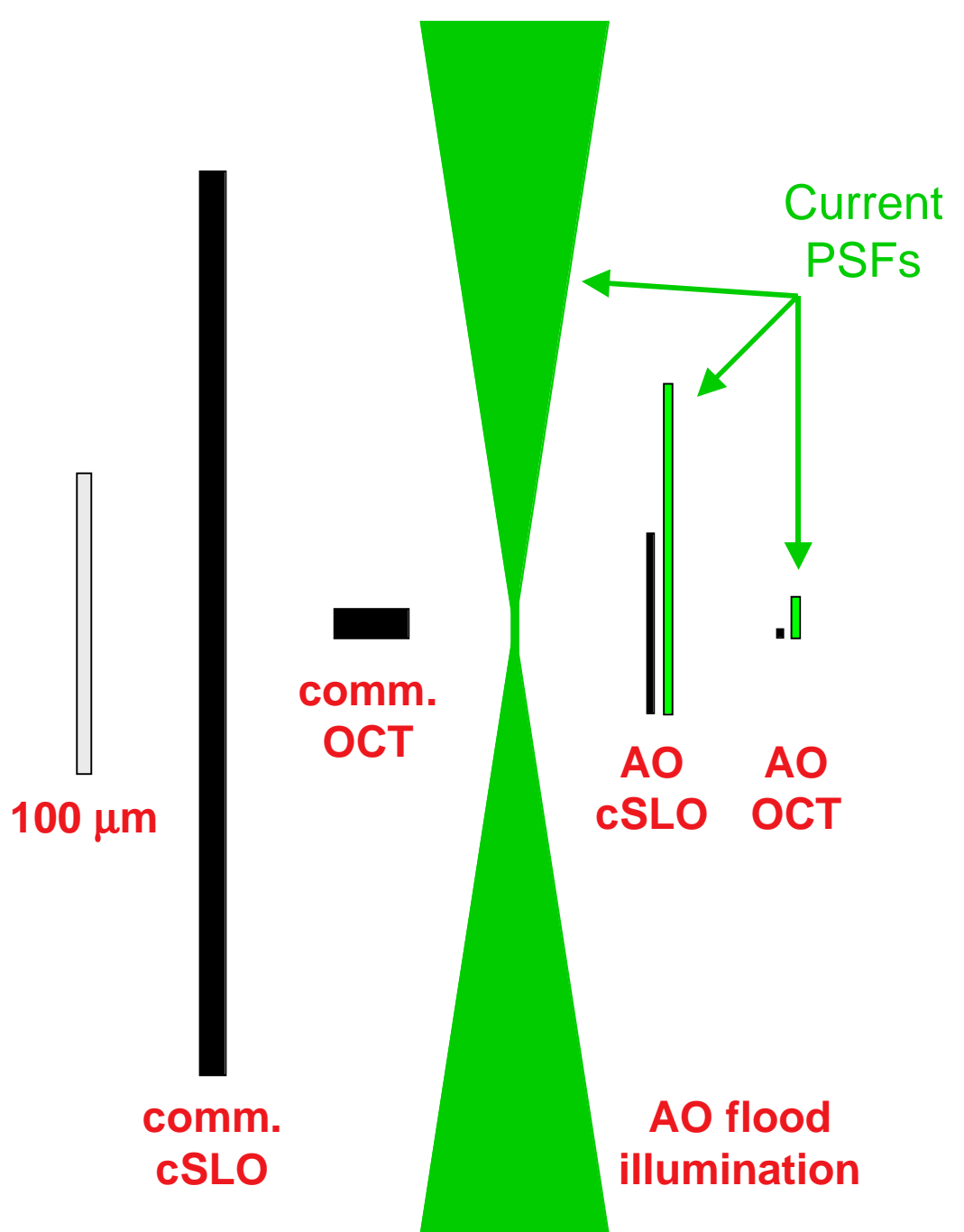
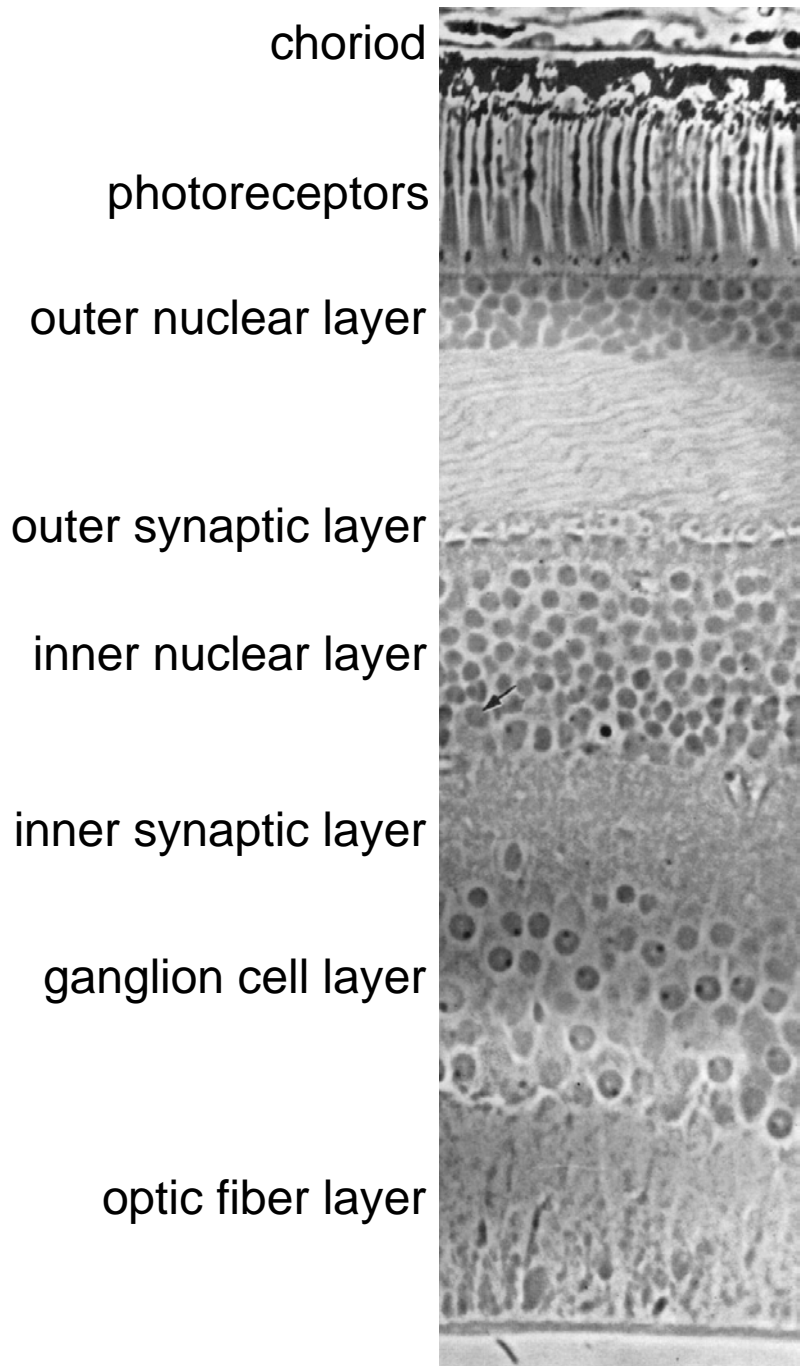
*Huang, Swanson, Lin, Schuman, Stinson, Chang, Hee, Flotte, Gregory, Puliafito, Fujimoto, Science **254**, 1178 (1991).

Volume of the 3-D point spread function for various combination of AO and camera architectures.



	Lateral	Depth	Voxel volume
Commercial cSLO	8.7 μm	300 μm	71,000 μm^3
Commercial OCT	25 μm	10 μm	15 X smaller
AO-Flood illumination	2.2 μm	very poor	-----
AO-cSLO	2.2 μm	60 μm	80 X smaller
AO-OCT	2.2 μm	3 μm	1,593 X smaller





En-face coherence-gating with a CCD

Replacing single point photodetector with a 2-D video sensor enables parallel detection without scanning.

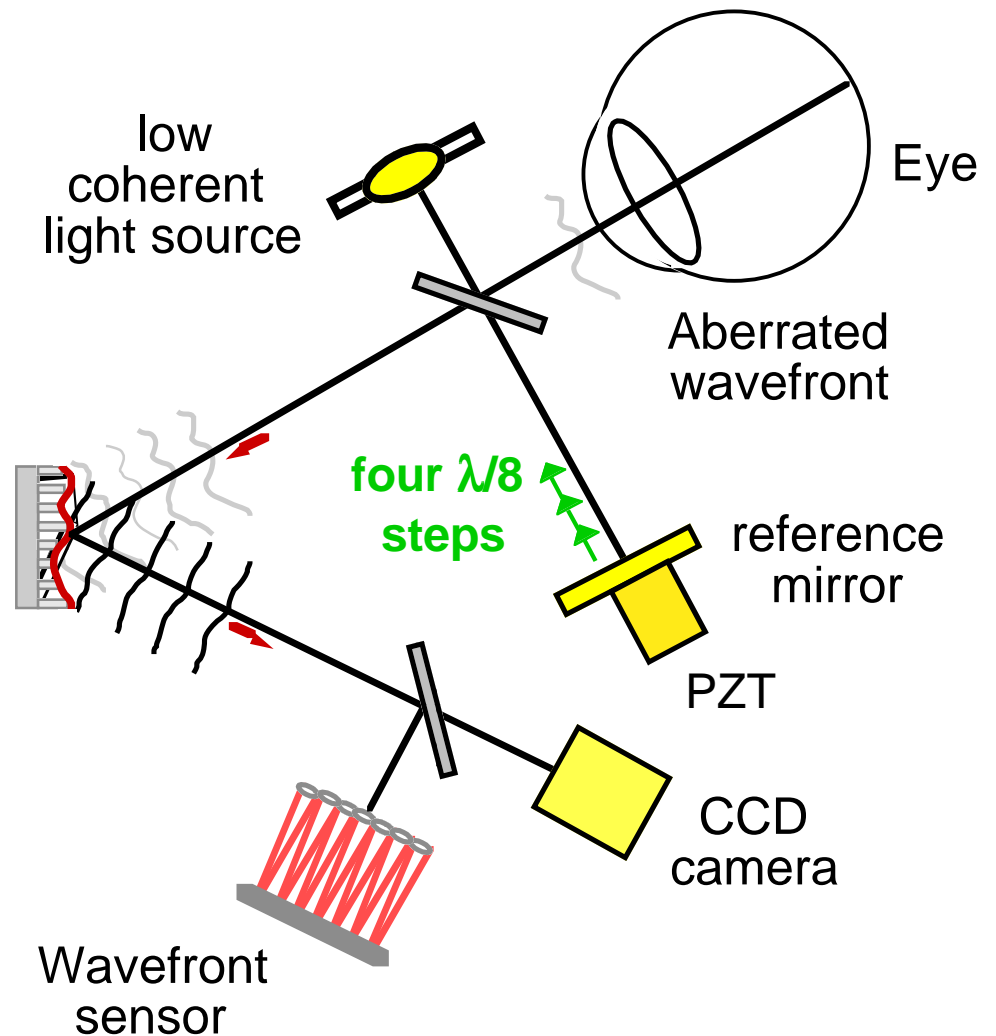
Detected signal

$$= |\Psi_{\text{ref}} + \Psi_{\text{retina}}|^2$$

$$= |\Psi_{\text{ref}}|^2 + |\Psi_{\text{retina}}|^2 +$$

$$2 |\Psi_{\text{ref}}| |\Psi_{\text{retina}}| \cos(\phi_{\text{ref}} - \phi_{\text{retina}})$$

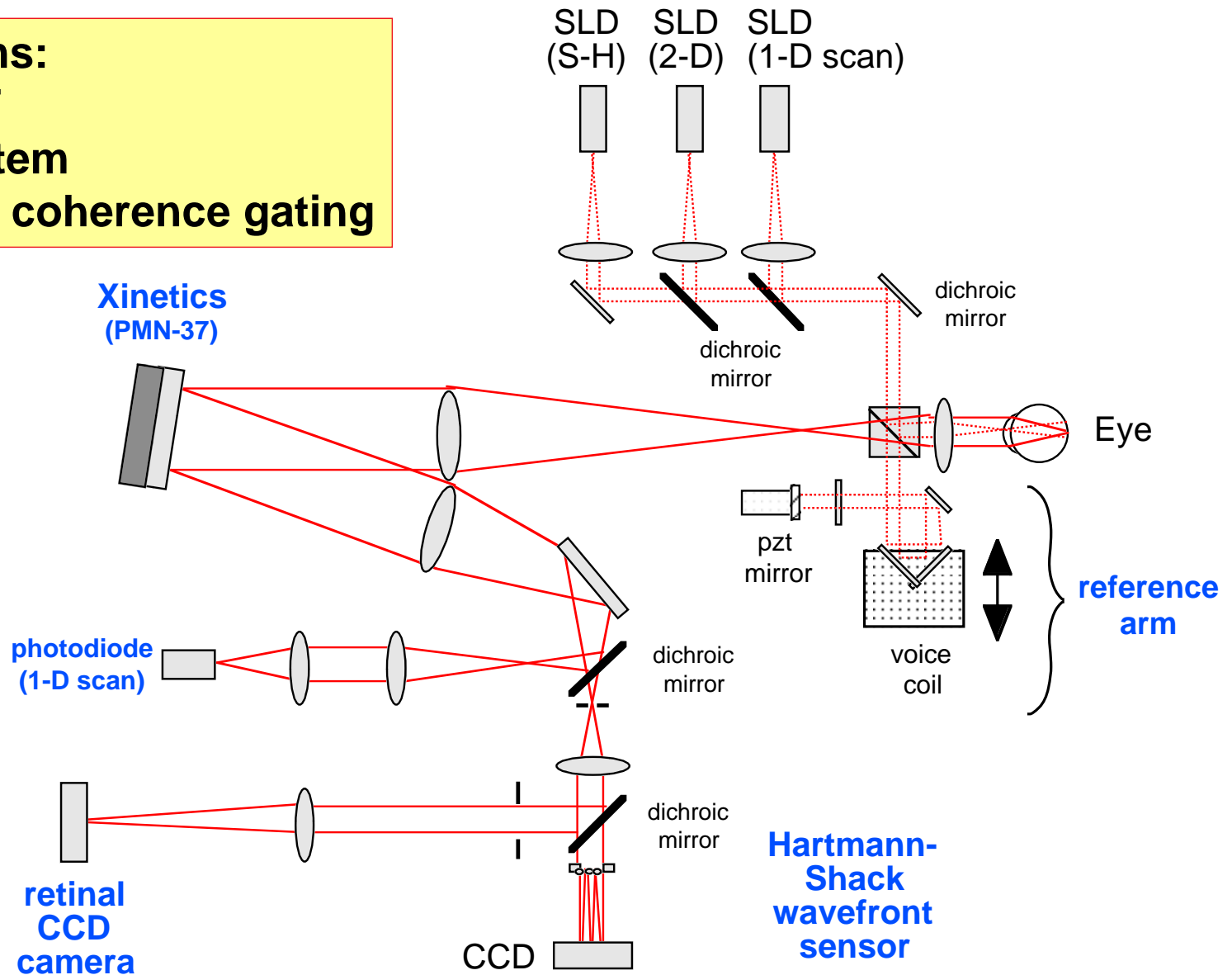
layer
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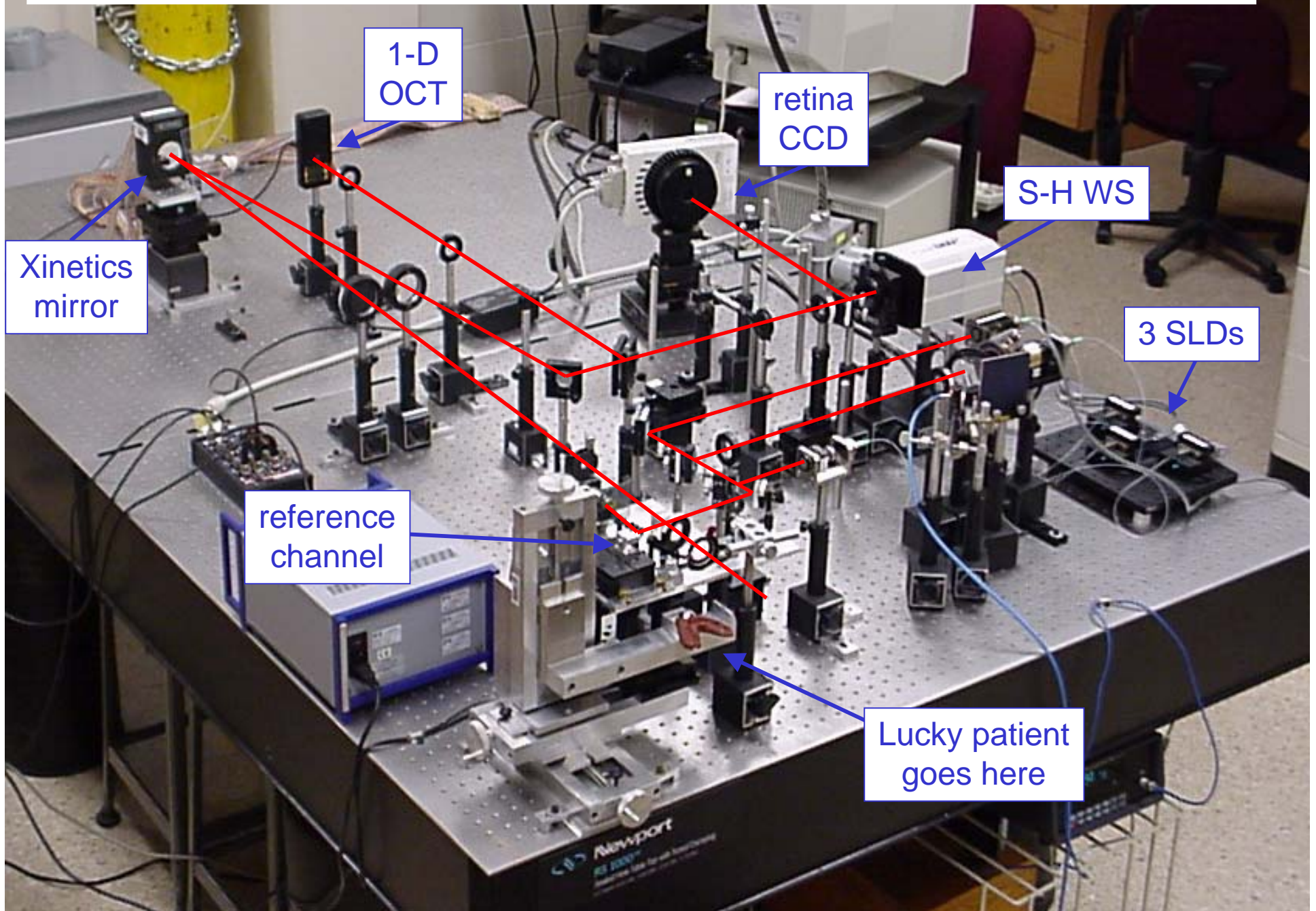
Optical layout of the coherence gated adaptive optics ophthalmoscope

Sub-systems:

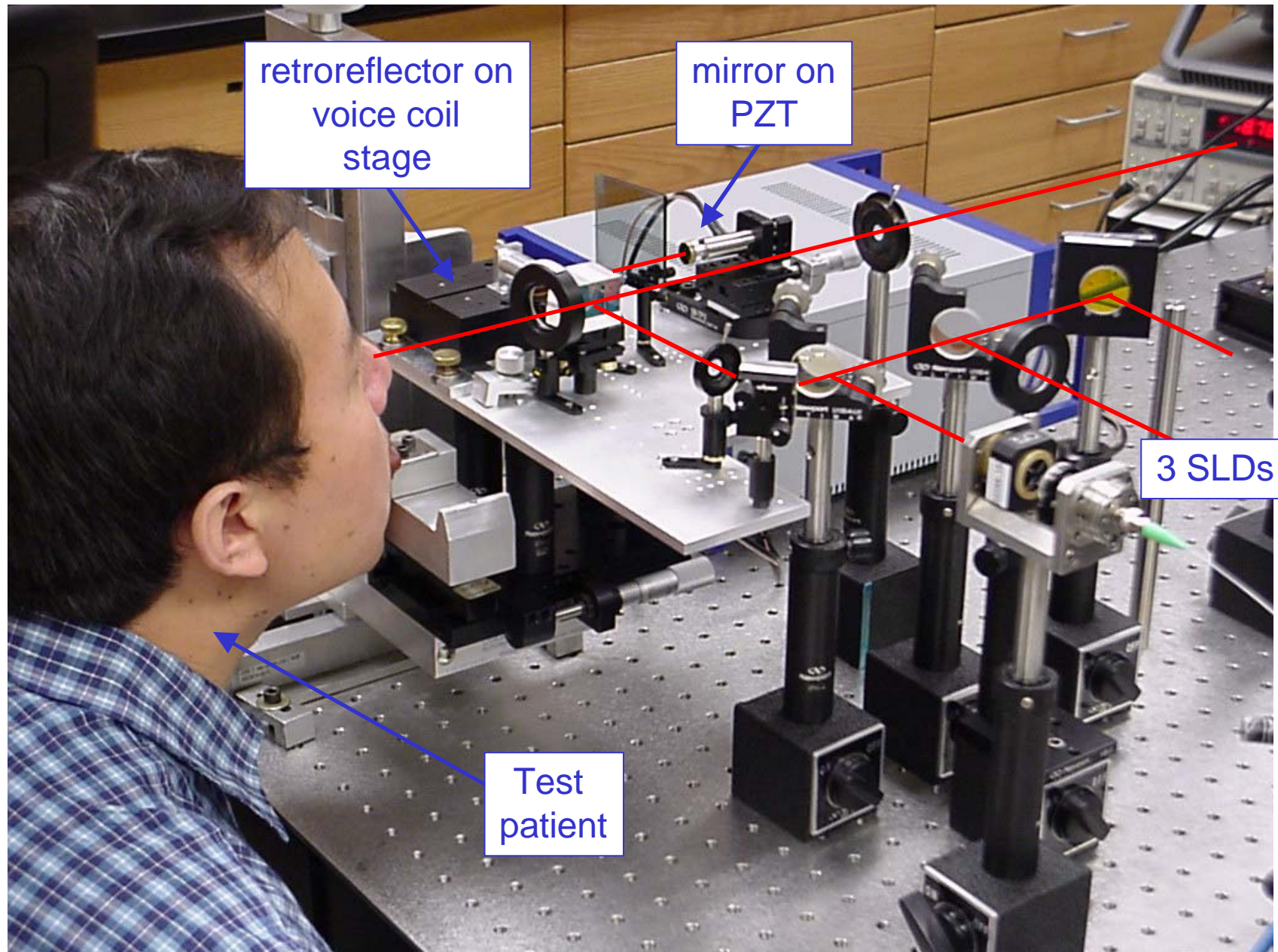
1. 1D OCT
2. AO system
3. En-face coherence gating



Photograph of the coherence gating AO retina camera

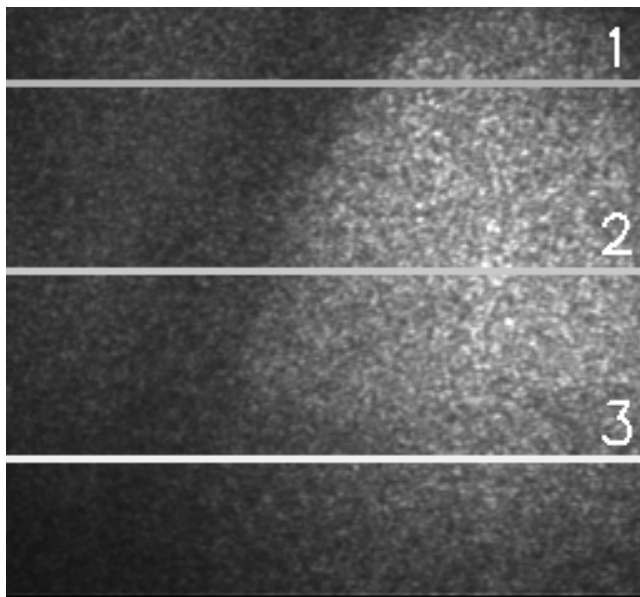


Close up view of the bite bar stage

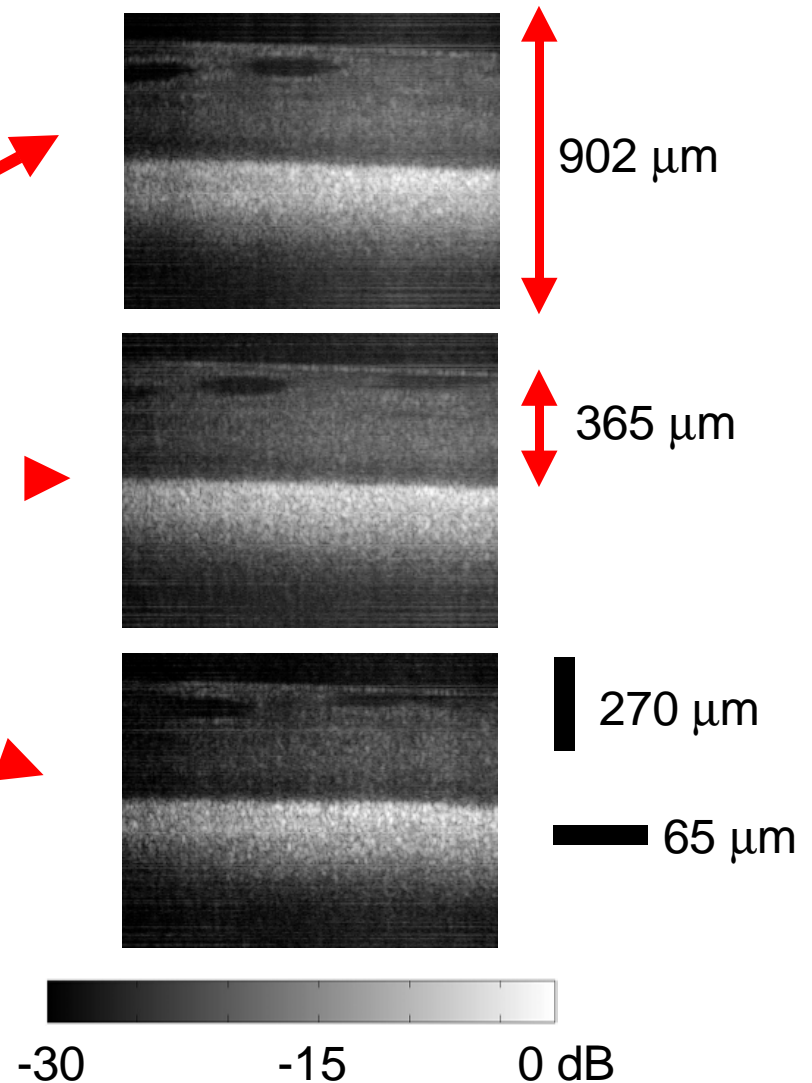


Axial Cross sections through the reconstructions reveals depth information of the bovine fundus

**Flood-illumination
of an in vitro bovine retina
(no coherence gating)**

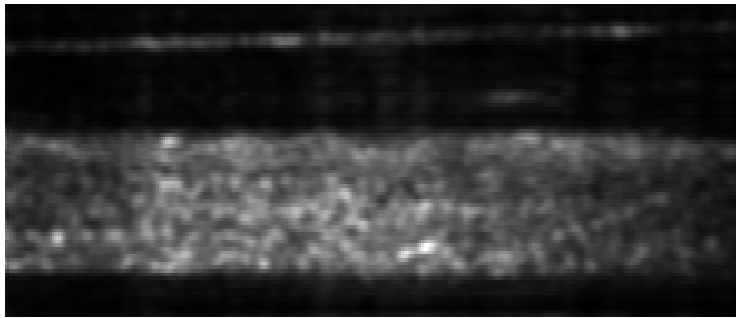


**Cross sectional slices
(coherence gating)**

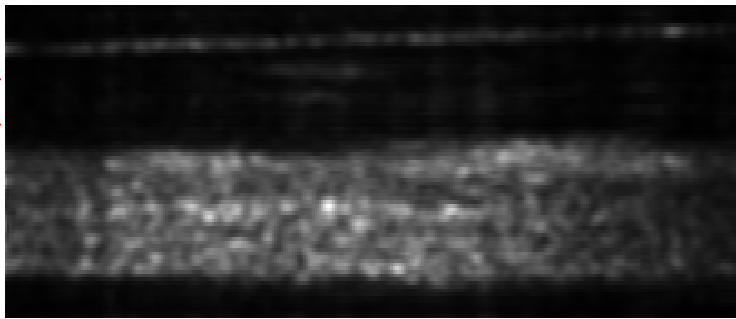


In vitro goldfish fundus

355
to
394
 μm

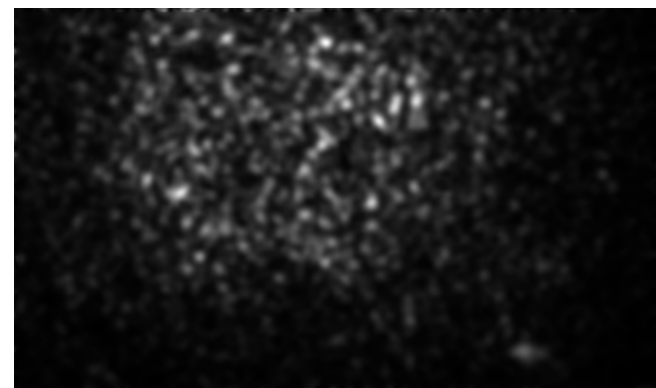
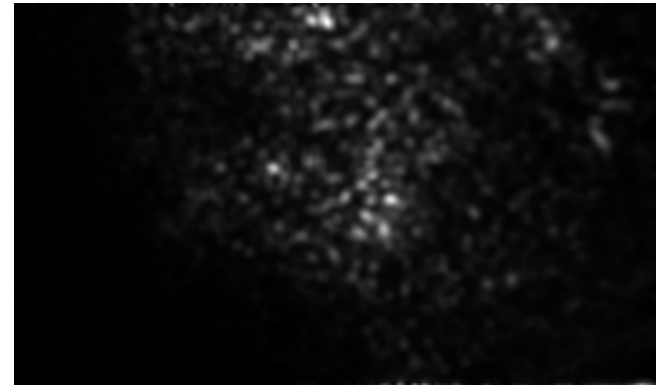


154
to
172
 μm



65 μm

270
 μm

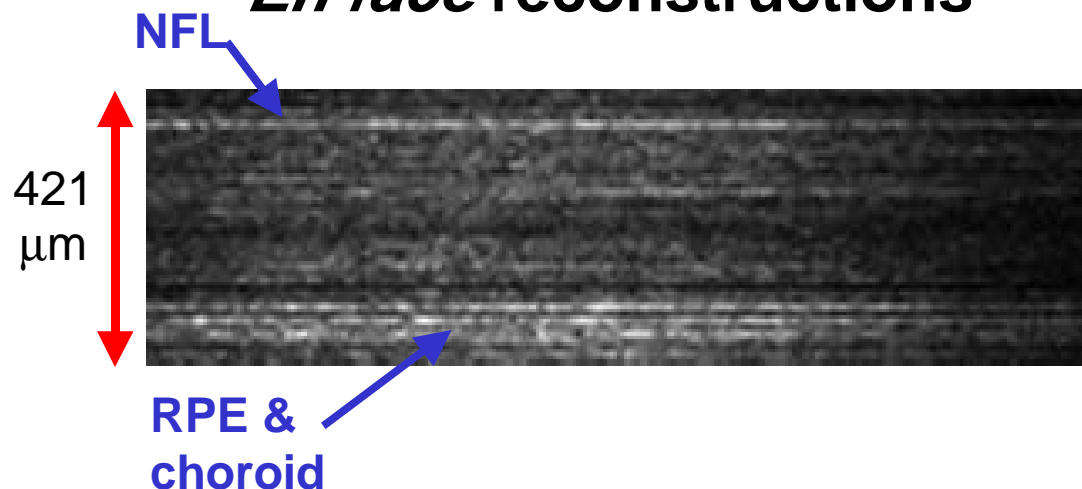


Tomographic (X-Z)

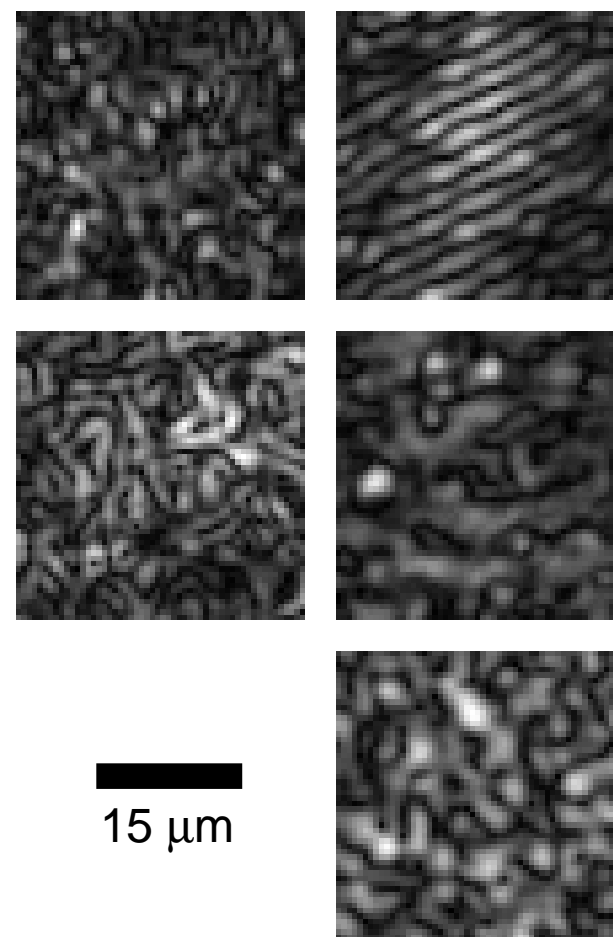
***En face* (X-Y)**

AO-OCT Retinal Images for One Subject

**X-Z slice through 41
En face reconstructions**



**Single *en face* (X-Y)
reconstructions**



Setup:

- 10 micron step size
- 42 reconstructions
- 6 deg eccentricity
- focus on photoreceptors
- AO correction
- track retinal position

Conclusion

- **AO-OCT retina camera has been developed.**
- ***En face* OCT images of *in vitro* bovine and goldfish retinas reveal clear stratification of the fundus.**
- **AO & *en face* OCT images of the living human retina suggest there is sufficient sensitivity to study the nerve fiber layer, photoreceptors, RPE, and choroid.**