Physics of Life
PHYS-468

OCT
Optical Coherence Tomography

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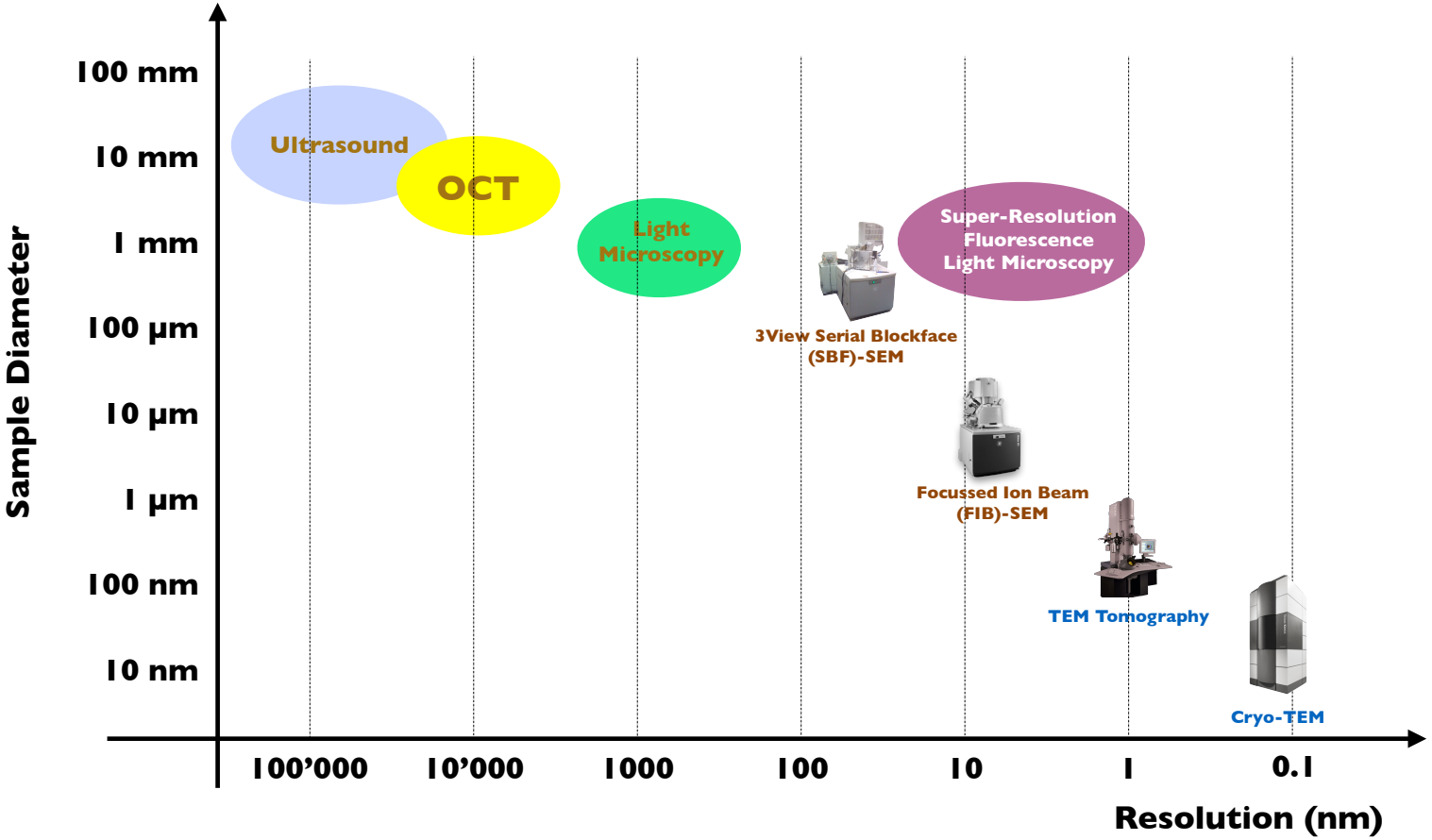
Techniques to probe samples in 3D with beams:

Technique	Beam	Sample	Resolution
SPECT (single photon emission)	(gamma emission)	Human	2 mm
PET (positron emission)	(pair of gamma emission)	Human	1 mm
CT	X-ray	Human	0.5 mm
Ultrasound	sound	tissue	0.3 mm
MRI	(magnetic field)	Human	0.1 mm
OCT	IR light	2 mm	10 µm
Synchrotron X-ray tomography	X-ray	2 mm	100 nm
Synchrotron X-ray ptychography	X-ray	2 mm	30 nm
Helium microscopy	He^{2+}	100 nm	1 nm
Electron microscopy: SBF-SEM	electron (3kV)	1 mm	3 nm
Electron microscopy: FIB-SEM	electron (3kV)	30 µm	2 nm
Electron microscopy: TEM	electron (300kV)	500 nm	0.1 nm

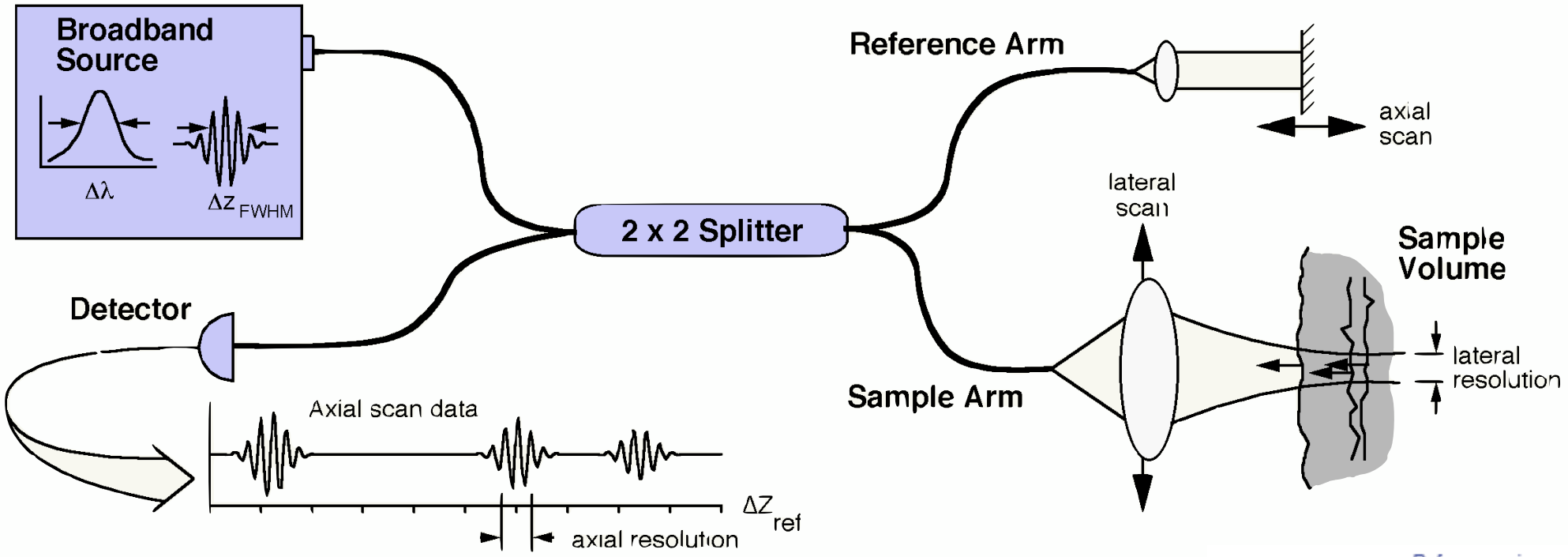
Multi-Resolution 3D Microscopy

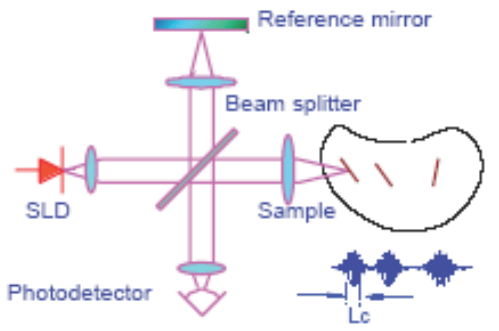


No single instrument can cover all scales.

Optical Coherence Tomography (OCT)

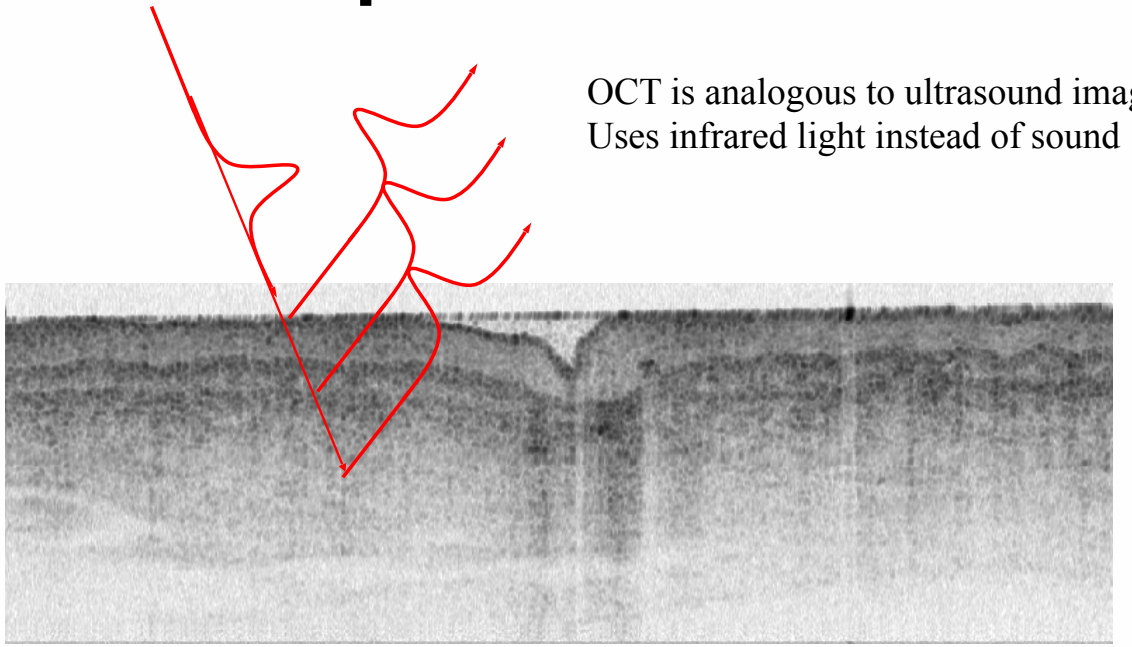
Michelson Interferometer with a broad-band partially coherent light source





Interferometry is used to measure small time delays of scattered photons

Optical Coherence Tomography (OCT)

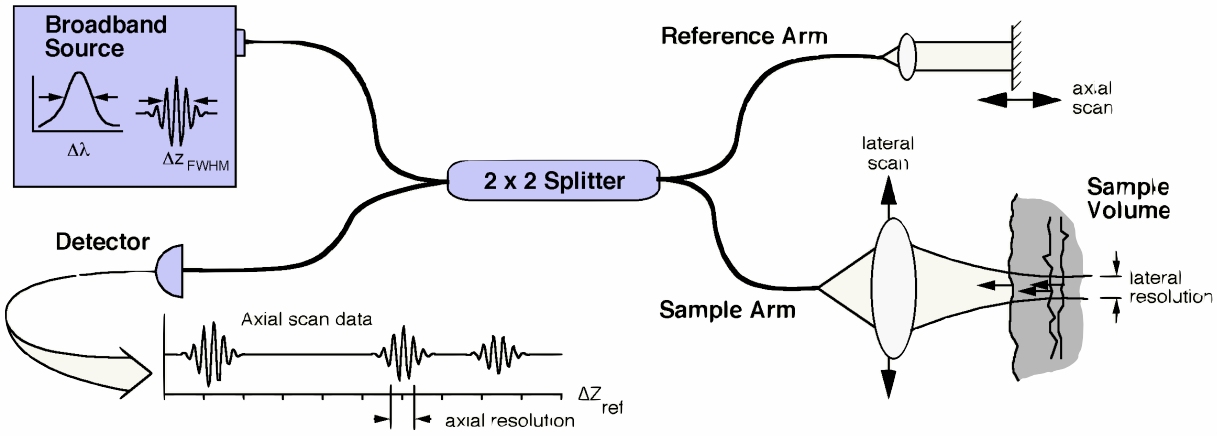


OCT is analogous to ultrasound imaging
Uses infrared light instead of sound

Speed of sound ~ 1480 m/sec (in water)
Speed of light – 3×10^8 m/sec

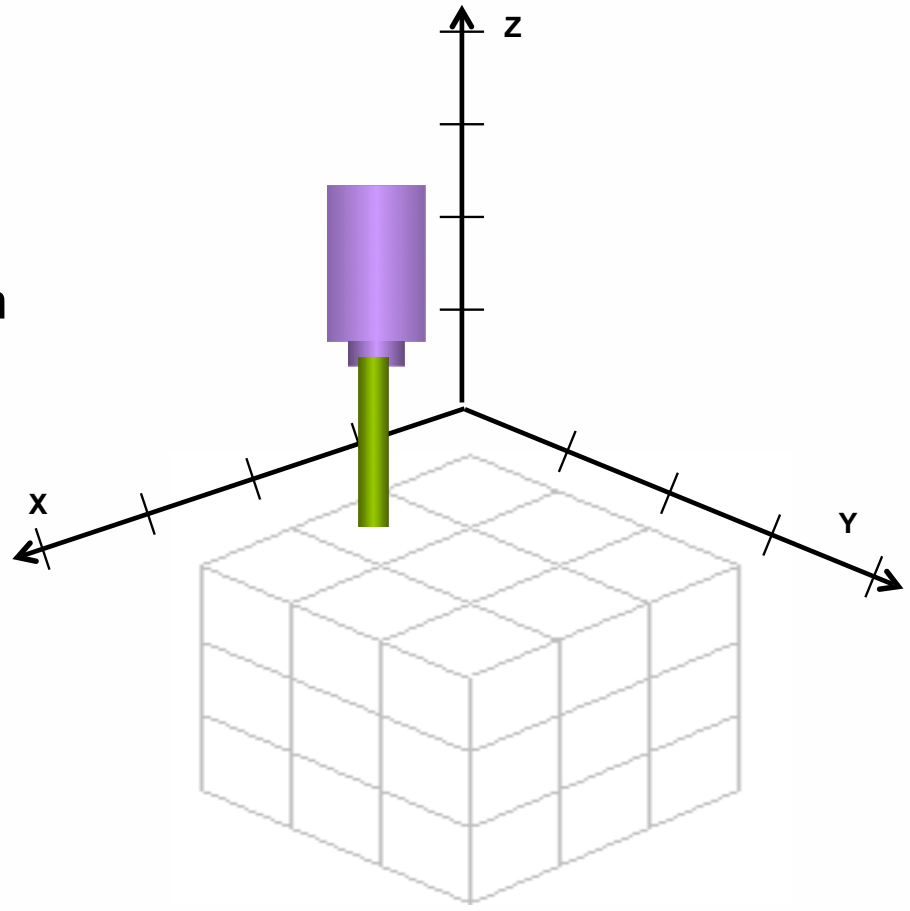
Human skin
5 mm wide x 1.6 mm deep
SpatialResolution: 10-30 µm

Interferometry
is used to measure
small time delays
of scattered photons



Optical Coherence Tomography (OCT)

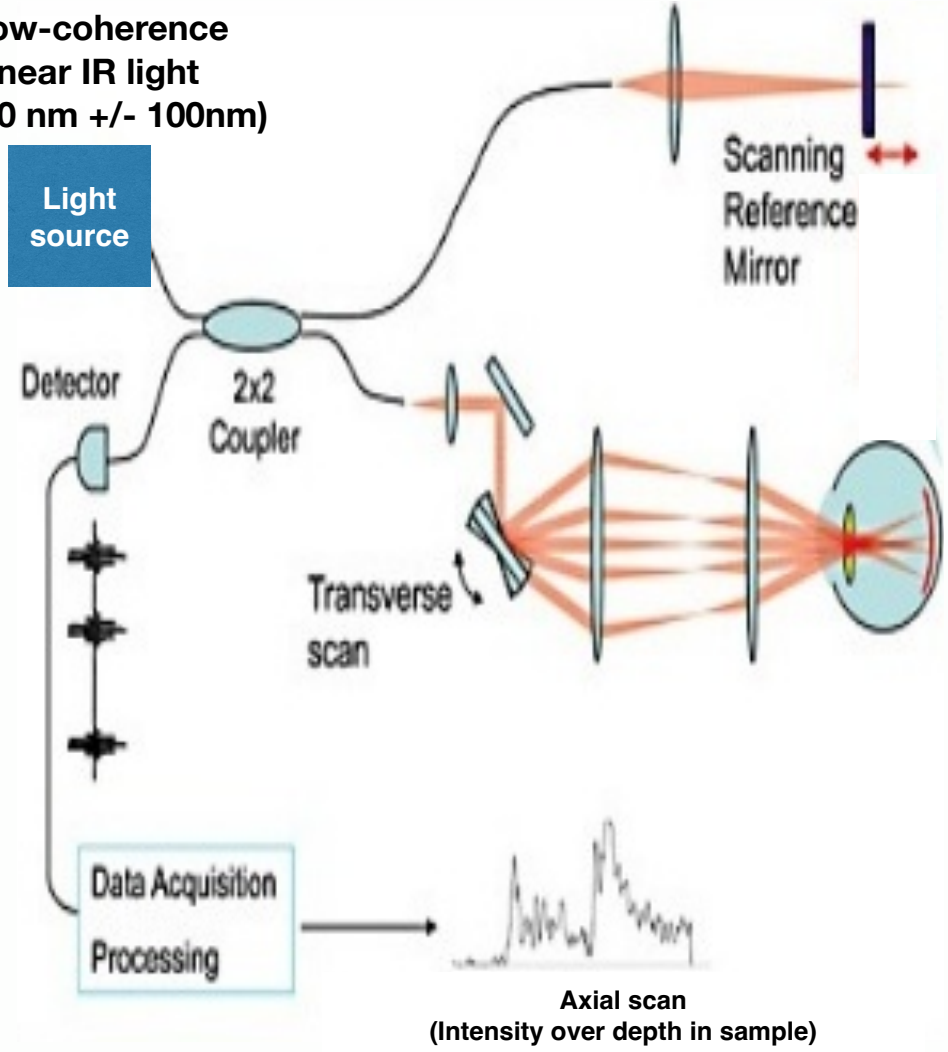
- Surface of sample is divided into imaginary grid of 10μm pixels
- The Z-profile is recorded at each pixel
- Scanning in X and Y direction gives the 3D volume



Optical Coherence Tomography (OCT)

Time Domain OCT

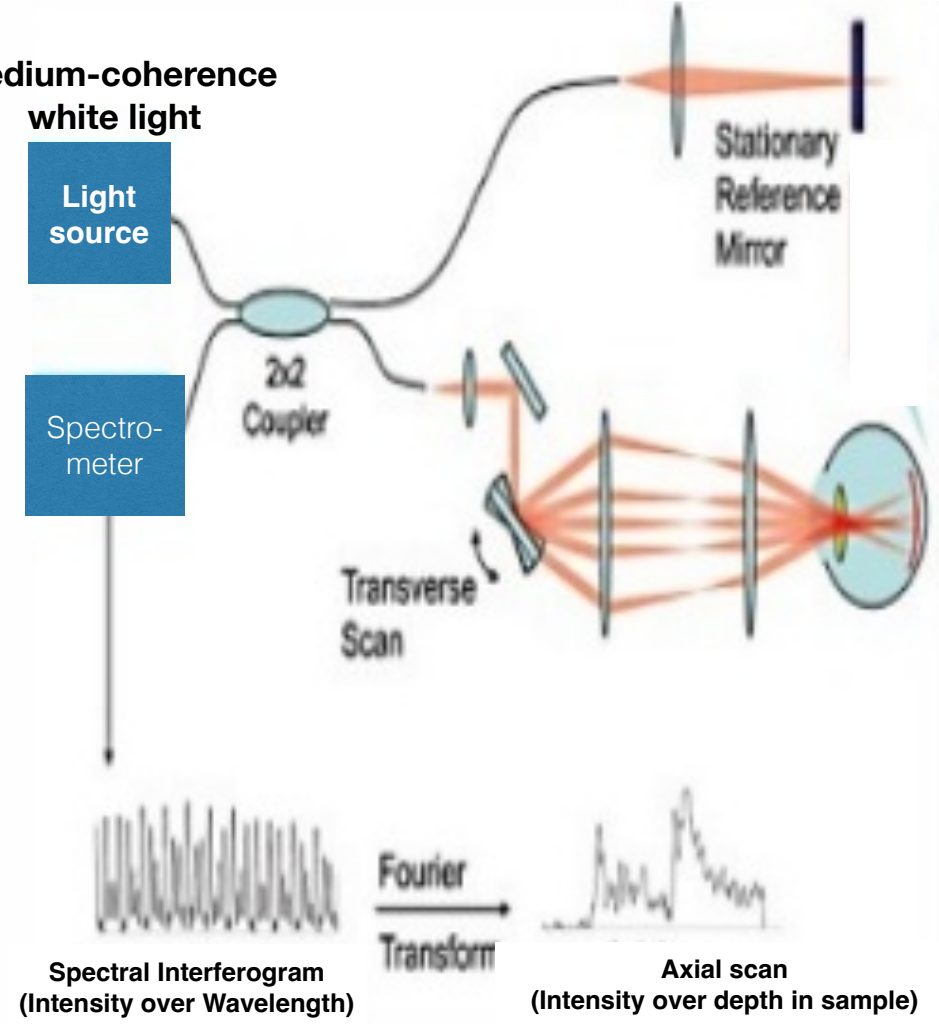
Low-coherence
near IR light
(1000 nm +/- 100nm)



Axial scan
(Intensity over depth in sample)

Fourier Domain OCT

Medium-coherence
white light

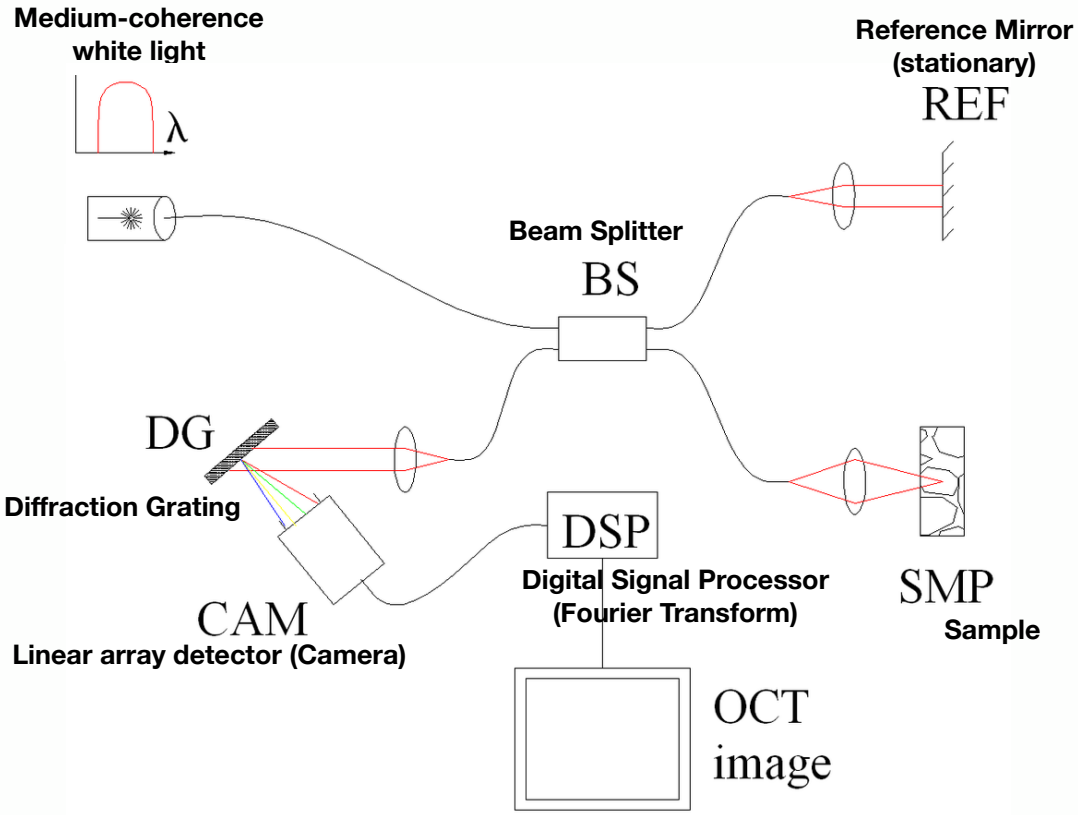


Spectral Interferogram
(Intensity over Wavelength)

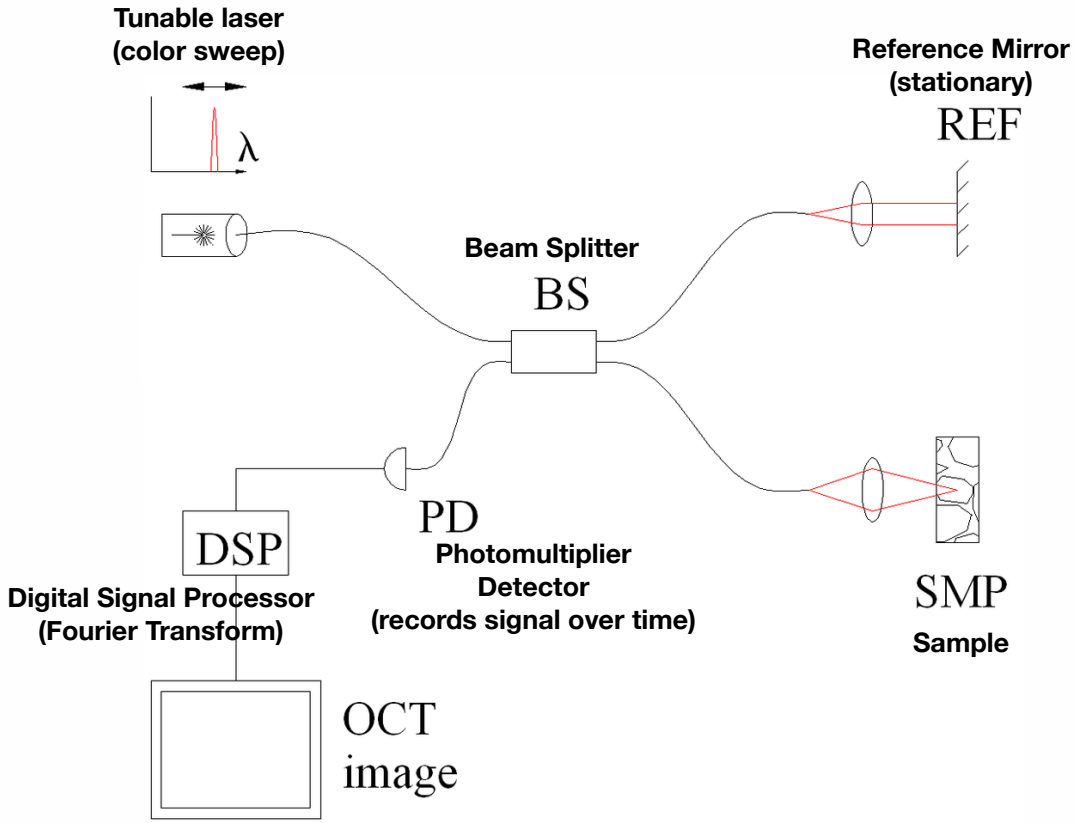
Axial scan
(Intensity over depth in sample)

Fourier-Domain Optical Coherence Tomography (OCT)

All colors on the same time => Faster, but lower resolution



One color at a time => Better resolution but slower



Optical Coherence Tomography (OCT)

TD – OCT (Time domain)

- Reference mirror moves
- 1 pixel of depth scan at a time
- Slow
- Motion artefacts present
- Less sharp images

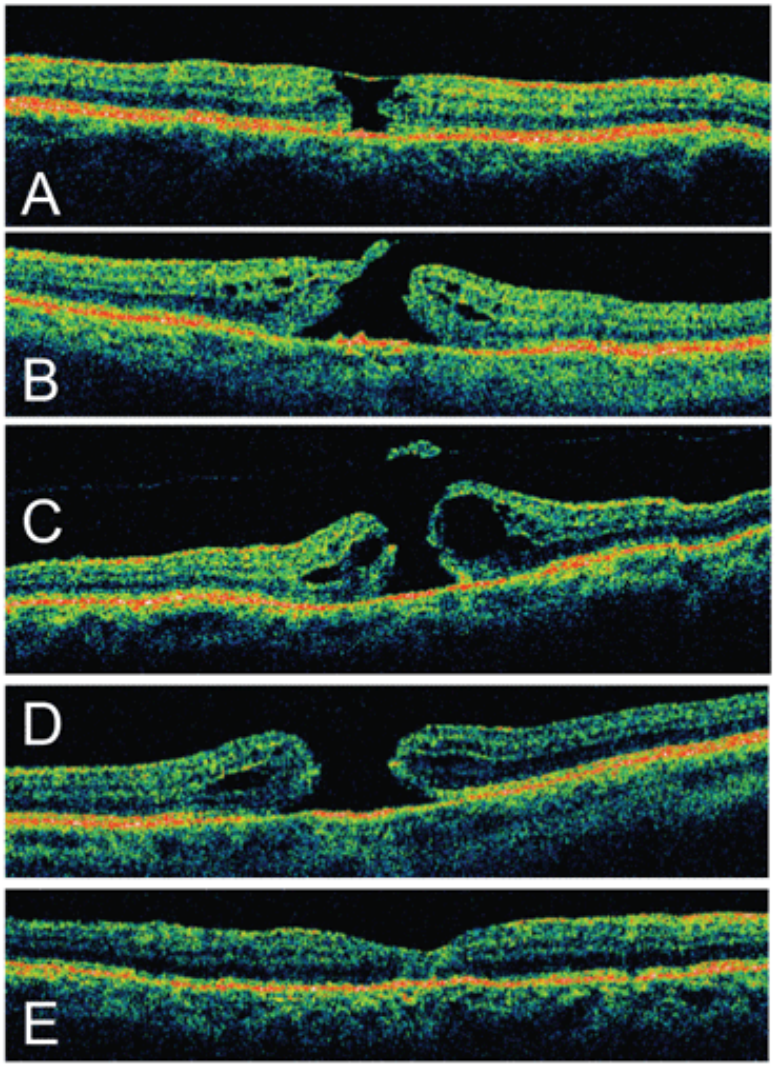
FD – OCT (Fourier domain)

- Reference mirror stationary
- Use white light and record entire spectrum at once
- Interference detected by spatial interferogram
- Interference pattern Fourier transformed
- 2048 pixels (full depth profile) at a time
- Rapid
- No motion artefacts
- Sharper and clear images

Optical Coherence Tomography (OCT)

- 3D analysis of retina. This patient had a hole in the retina.
- OCT can be used to monitor the course of the disease and the response to surgical intervention.

1. Macular Hole



Optical Coherence Tomography (OCT)

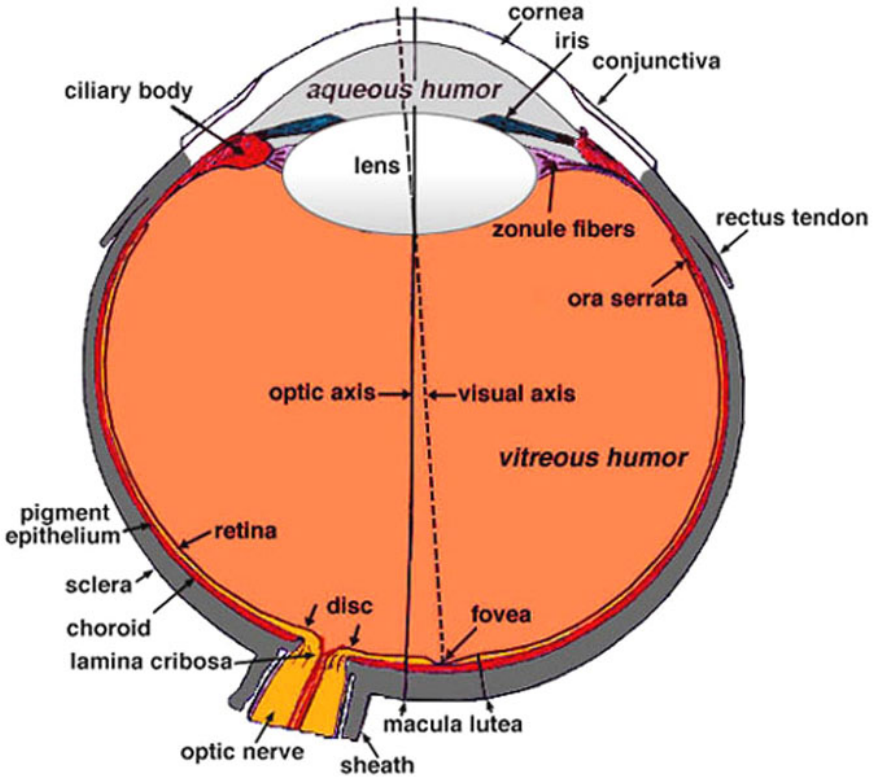
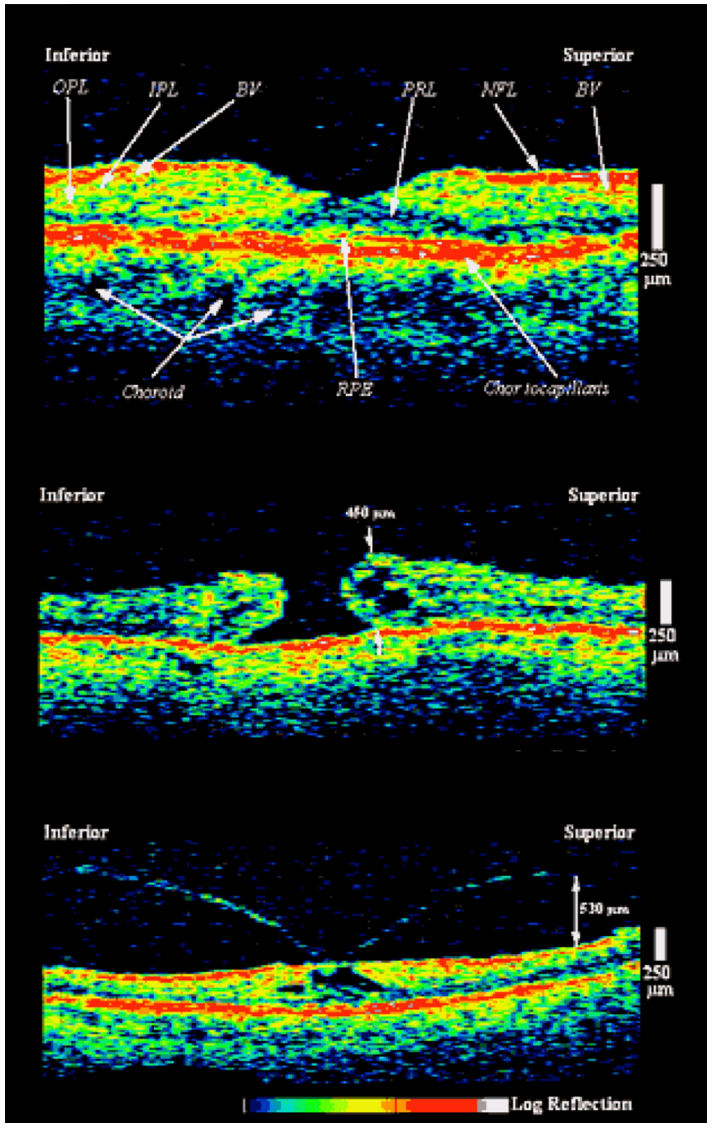


Fig. 2. Sagittal horizontal section of the adult human eye.

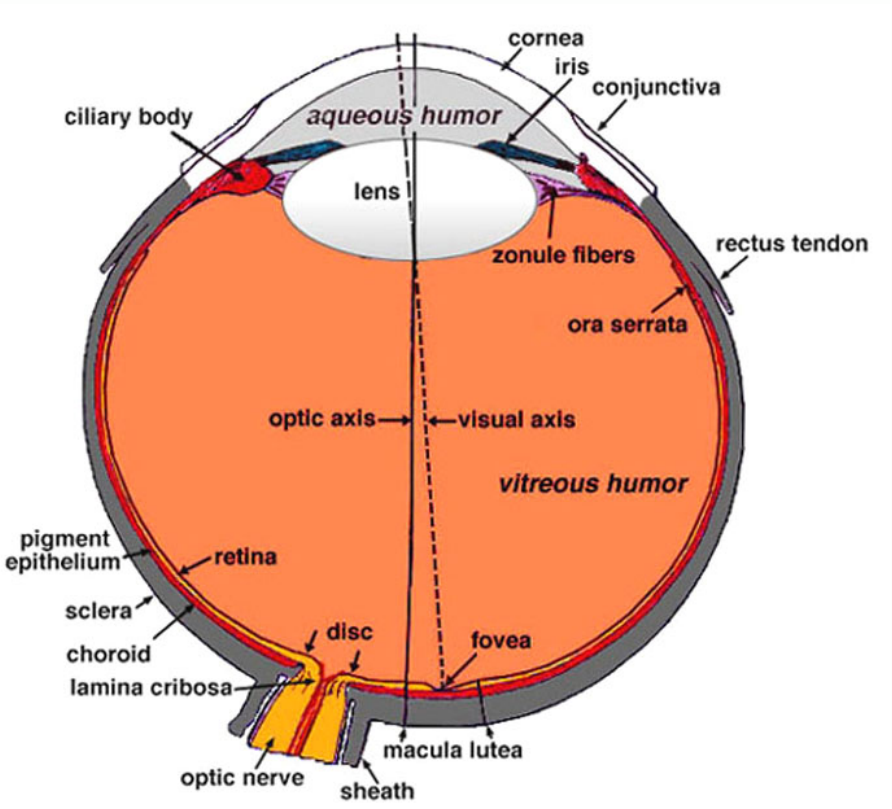


Normal patient

Patient with impaired vision (20/80): The cause is a macular hole

Patient's other eye (vision 20/25): Impending macular hole, which can be treated

Optical Coherence Tomography (OCT)



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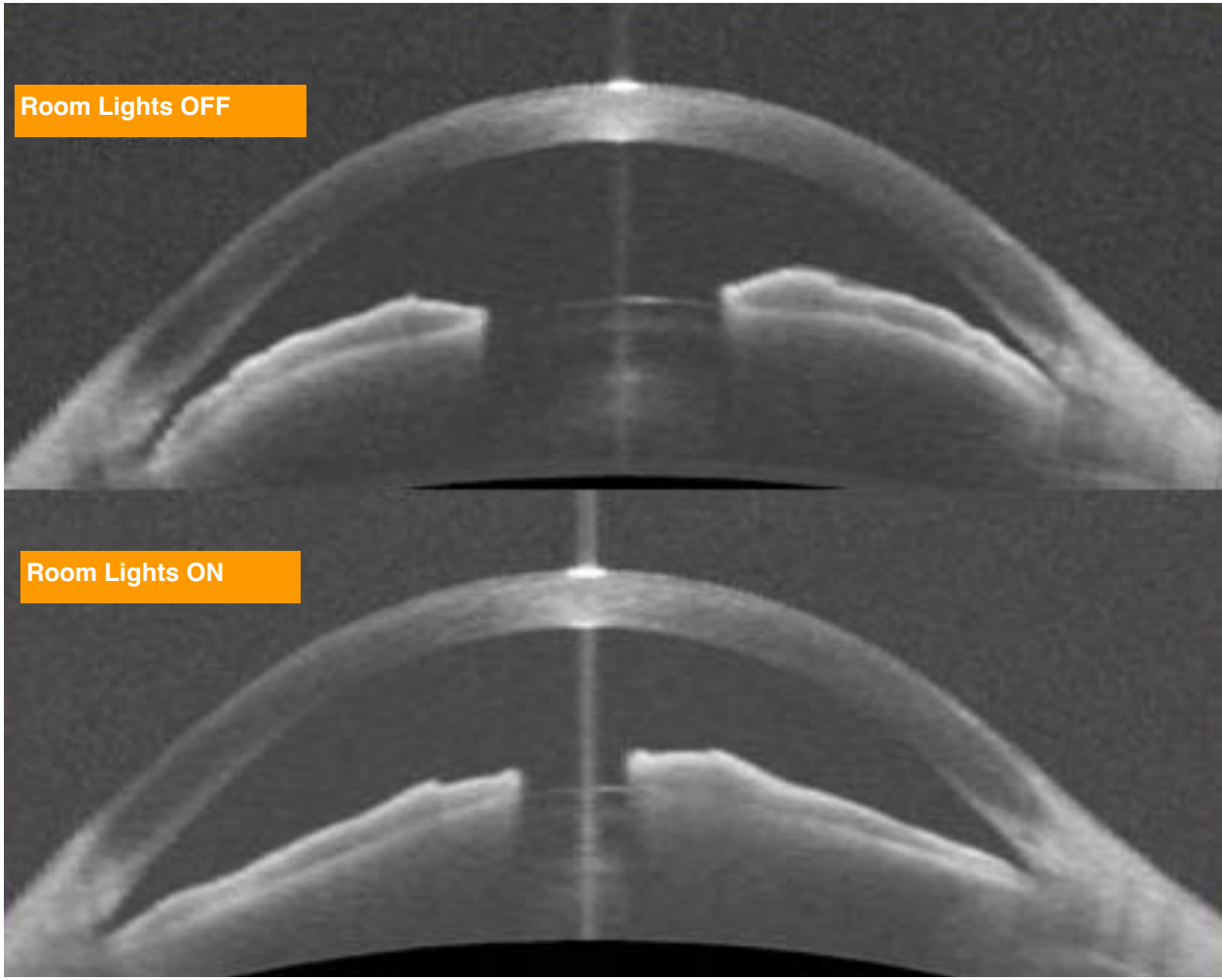

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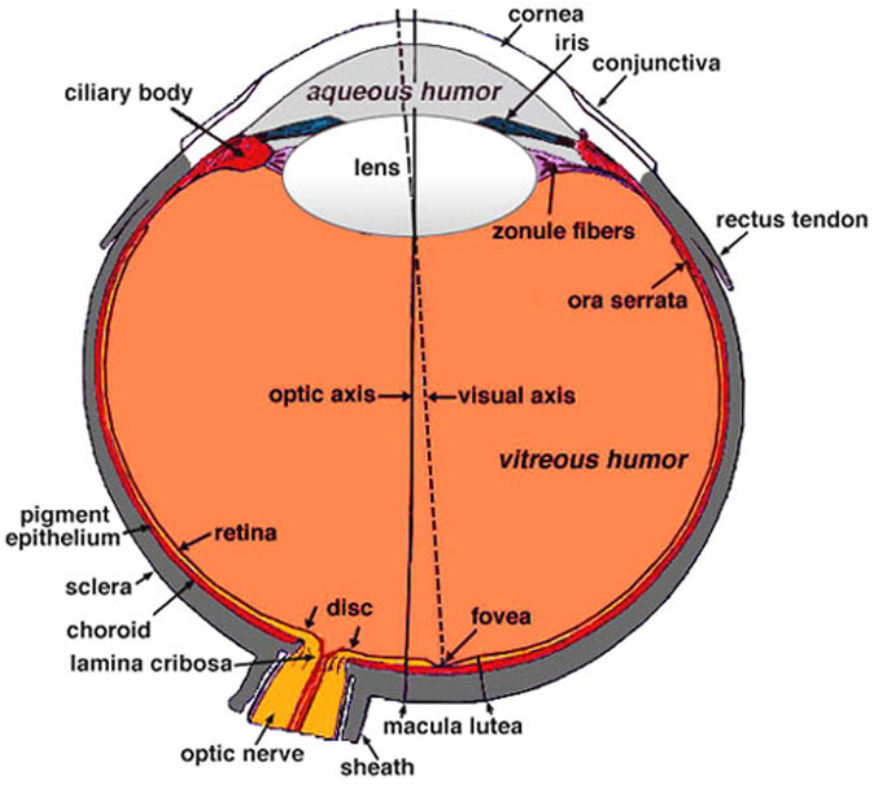

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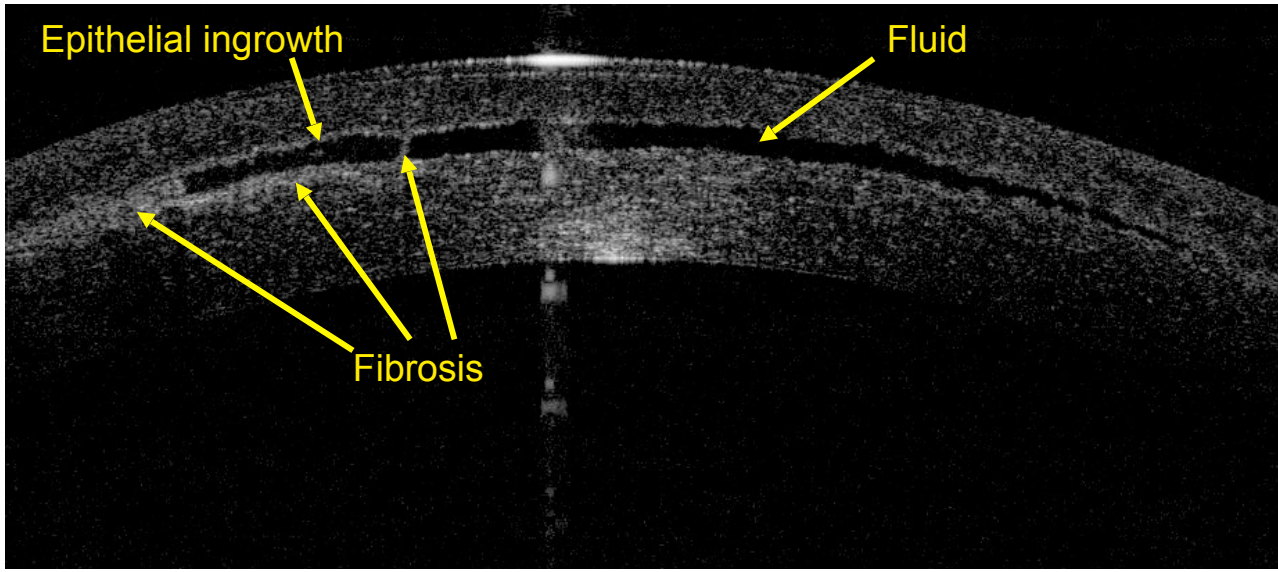
Post-LASIK interface fluid & epithelial ingrowth



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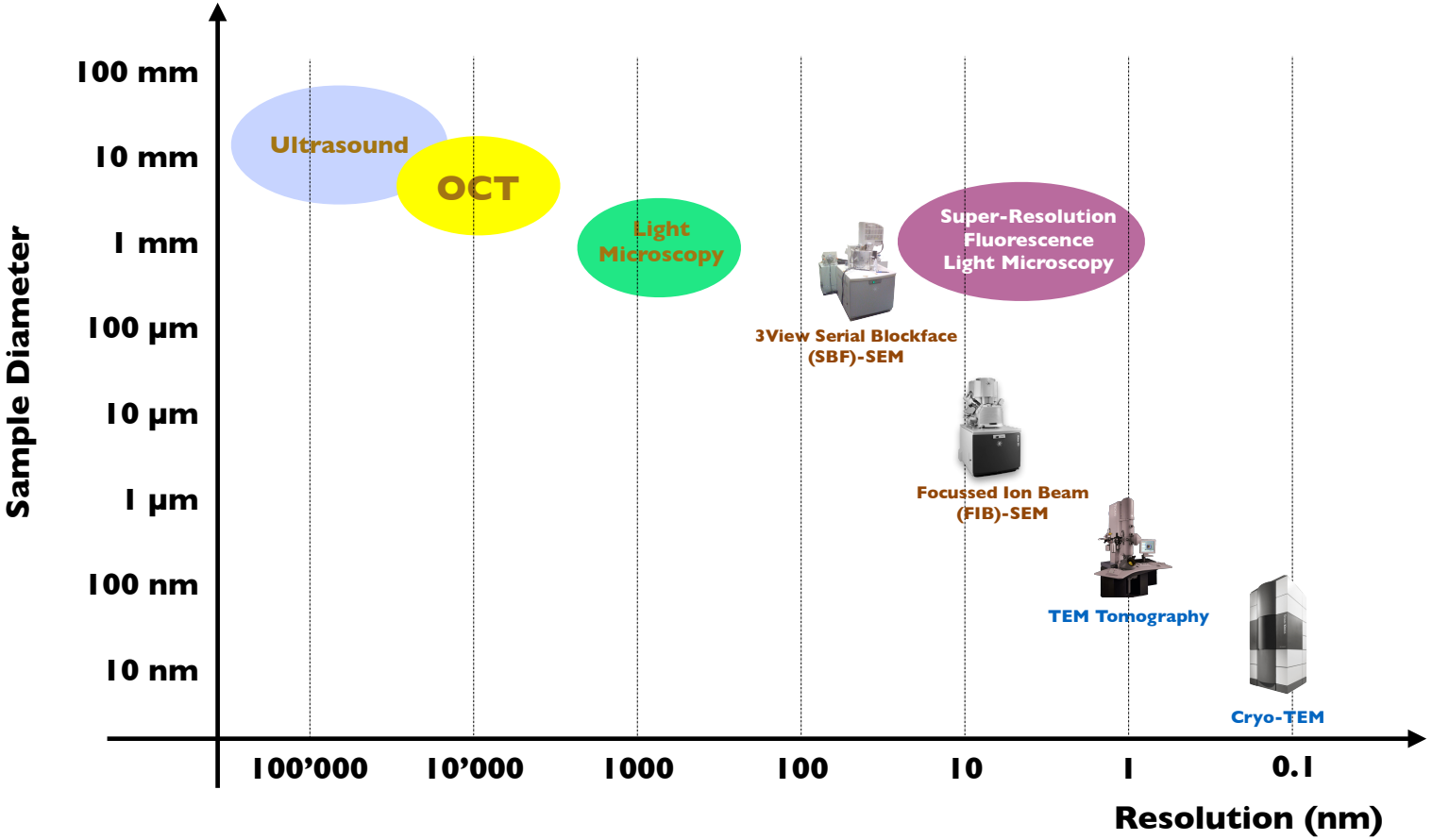

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