Optical Coherence Tomography OCT

3D Imaging in Medical Technology and Quality Control

SLN Seminar, EPMT Lausanne, 26. May. 2011

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www.OptoLab.ch

Outline

1. Introduction

2. OCT Basics
   Time Domain TD-OCT, Frequency Domain FD-OCT, Full Field OCT

3. OCT: Medical Applications

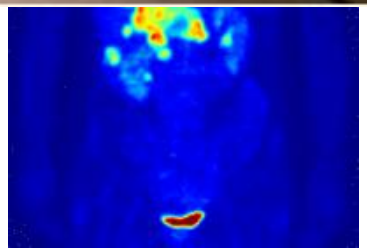
4. OCT: Industrial Applications

5. Some Projects @ OptoLab, BFH-TI, Biel-Bienne

Tomographic Methods in Medical Engineering

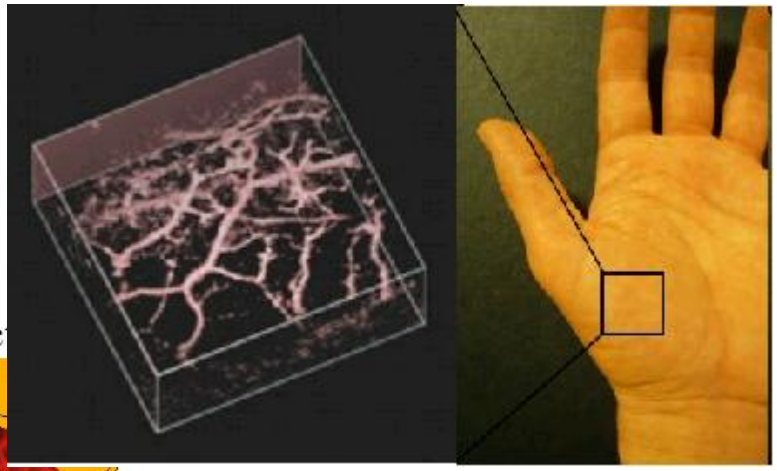
Tomography = 3D image by sections
Greek word tomos = slice, section

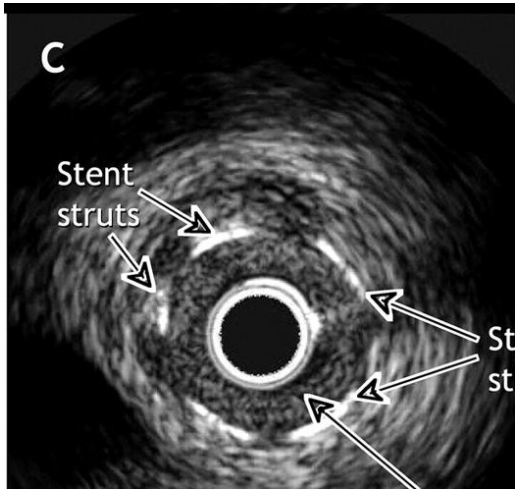
- CT X-ray
- MRI Magnetic Resonance Imaging
- PET Positron Emission Tomography

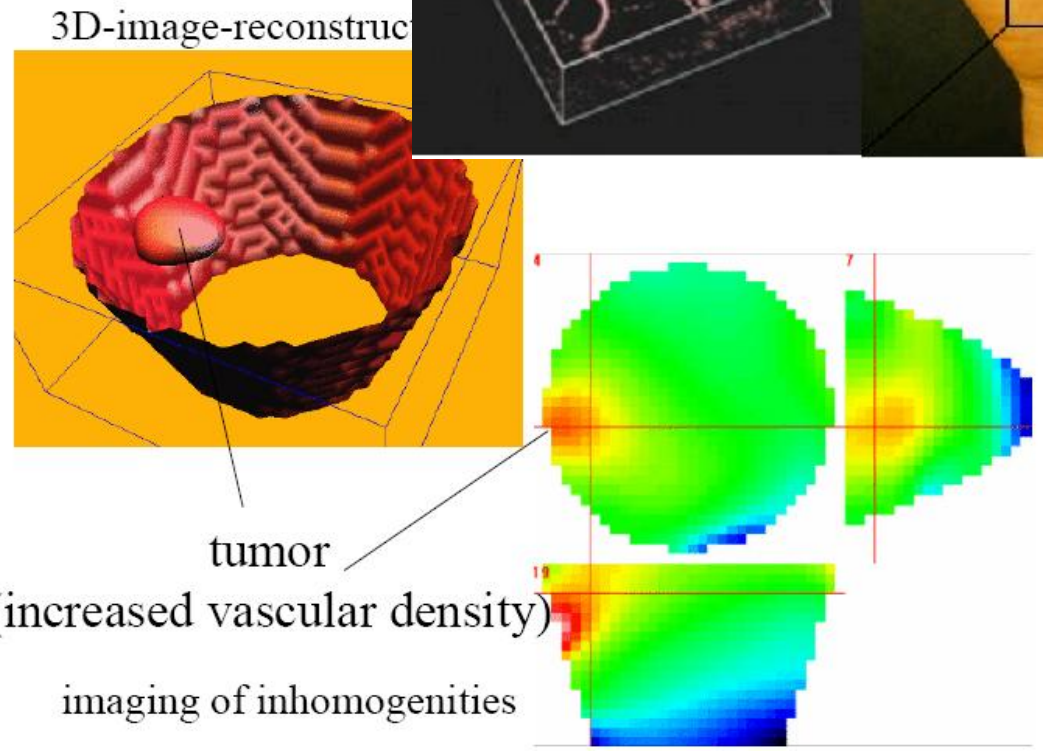


Tomographic Methods in Medical Engineering

- UST Ultra Sound Tomography
- ODT Optical Diffusion Tomography
- PAT Photoacoustic Tomography

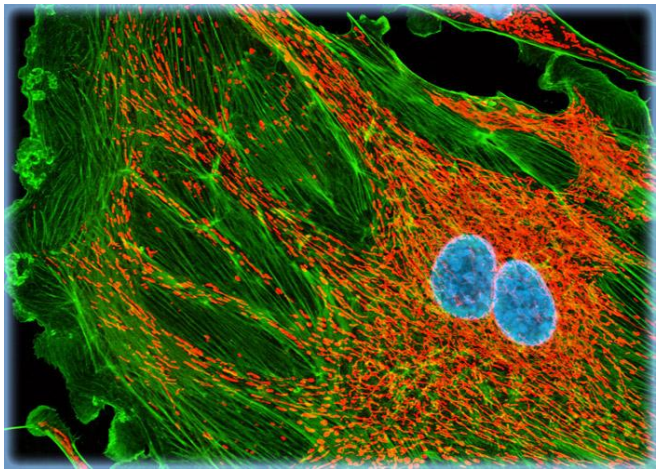






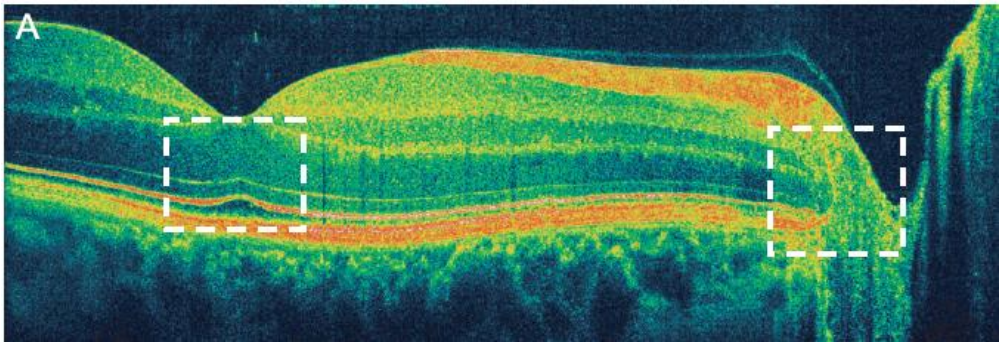
Tomographic Methods in Medical Engineering

- Confocal Microscopy



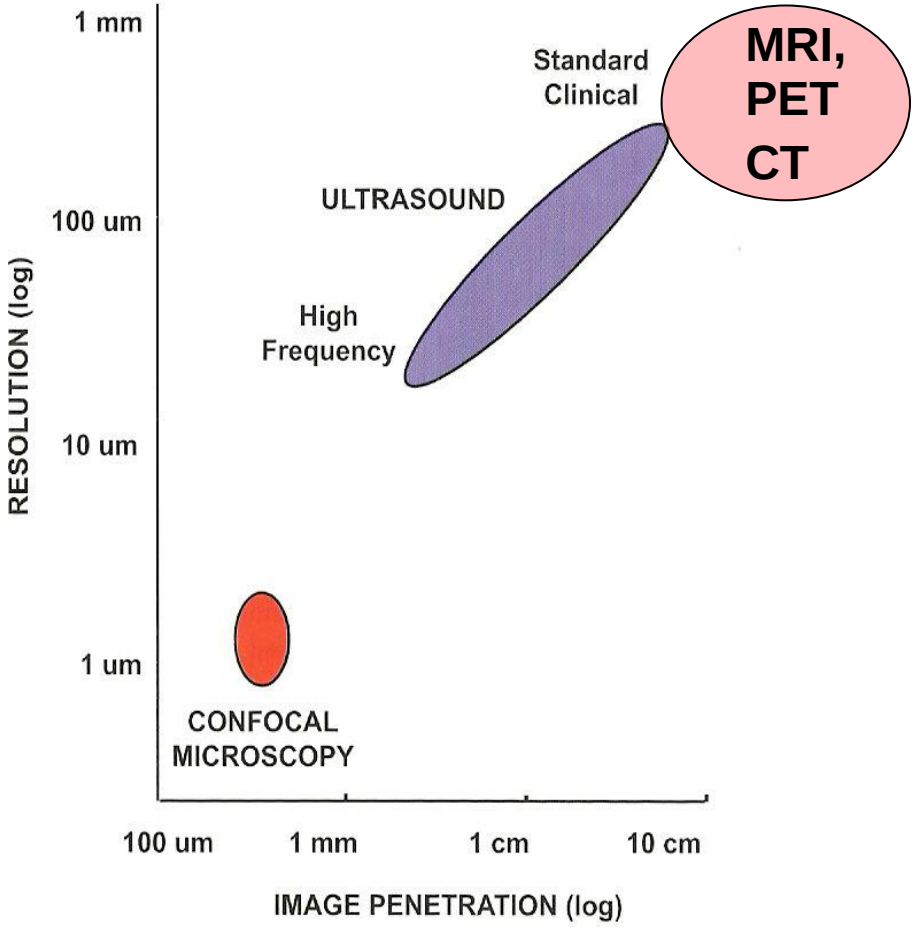
Stained mitochondrial network
Olypus Microscopy

- **OCT Optical Coherence Tomography**



Drexler W., Fujimoto J. Science Direct 2007

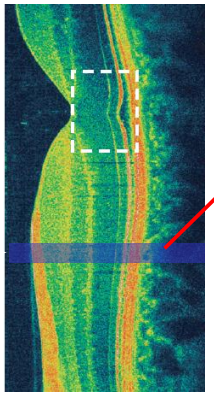
Tomographic Methods in Medical Engineering



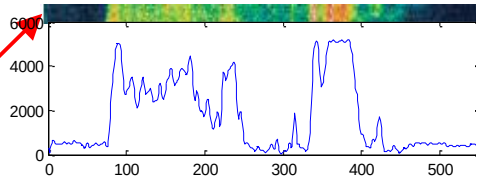
Name	Speed	Hazard
CT	-	+++
MRI	-	-
PET	-	+++
UST	++	-
DOT	-	-
PAT	+	-
OCT	+++	-

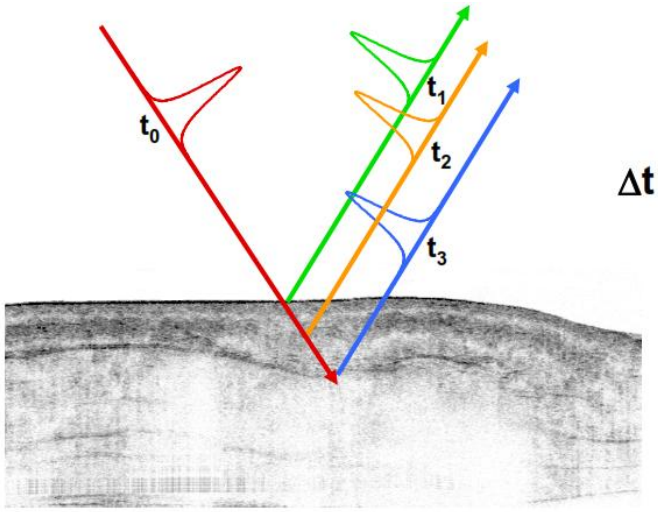
3D Imaging by scanning OCT

B-scan



A-scan, spatial domain

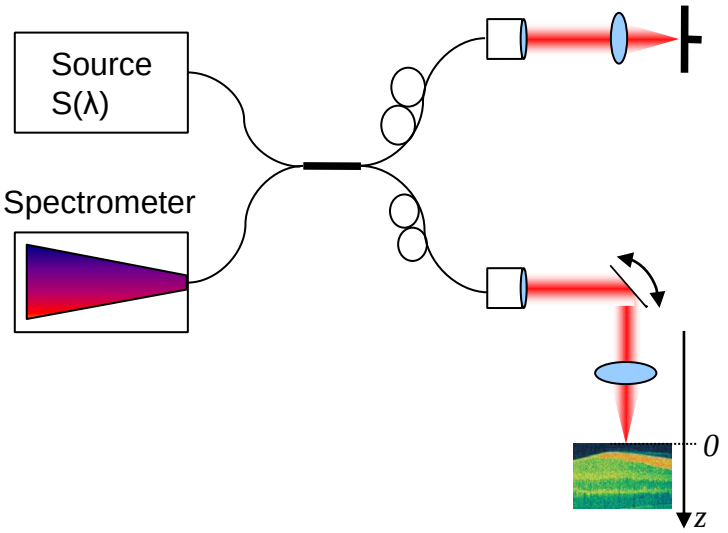




$$\Delta t = \frac{n_{sample} \cdot \Delta l}{c}$$

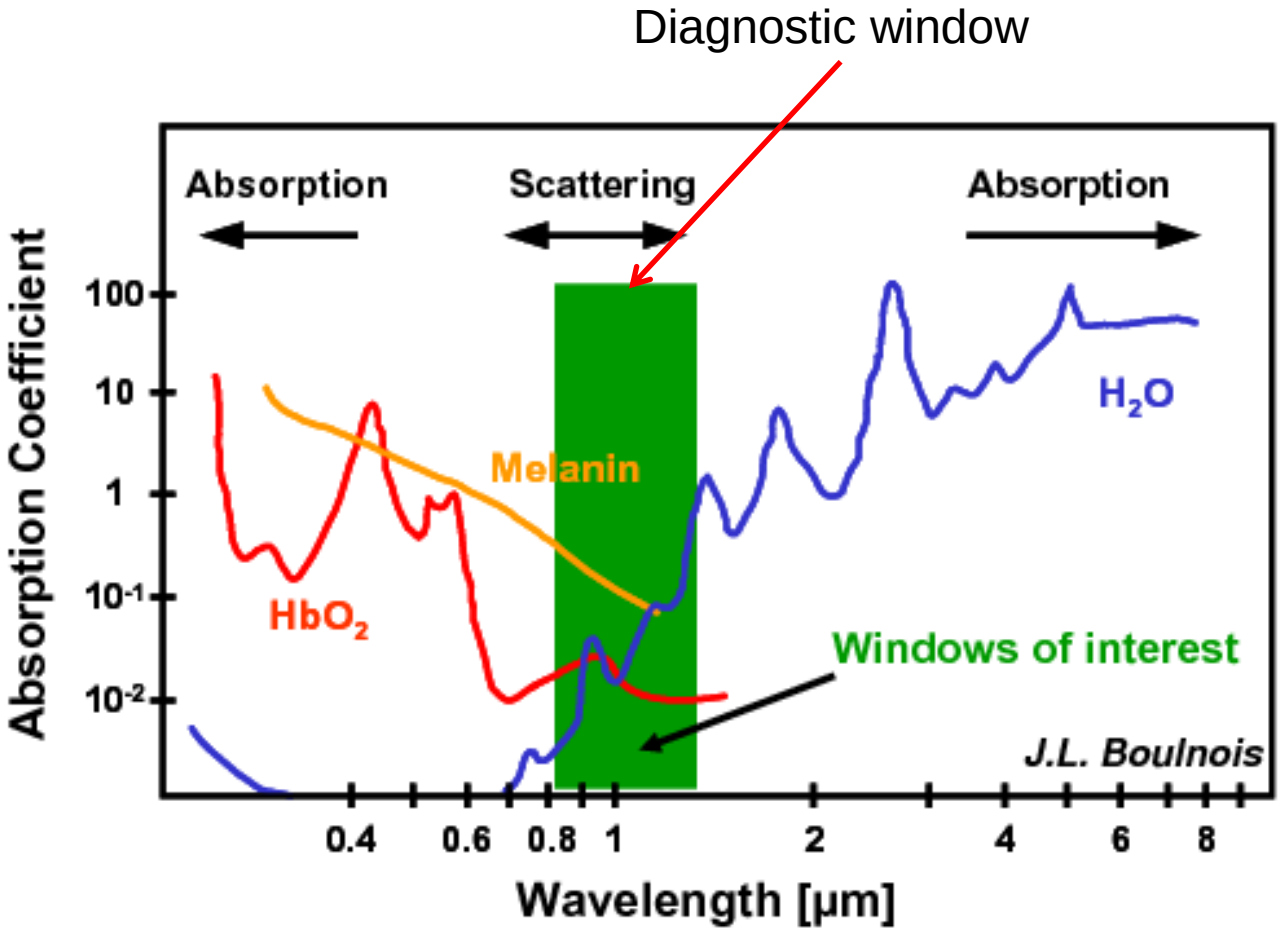
- A-scan: Depth profile of backscattered or back reflected light
- B-scan: Cross section obtained by scanning in x direction
- C-scan: 3D image.

- Similar to ultrasonic time of flight measurements
- Interferometric measurement technique



OCT: wavelength range

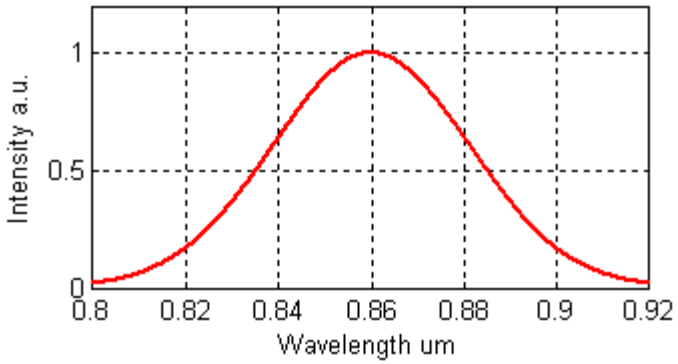
Hemoglobin and water have low absorption in near infrared

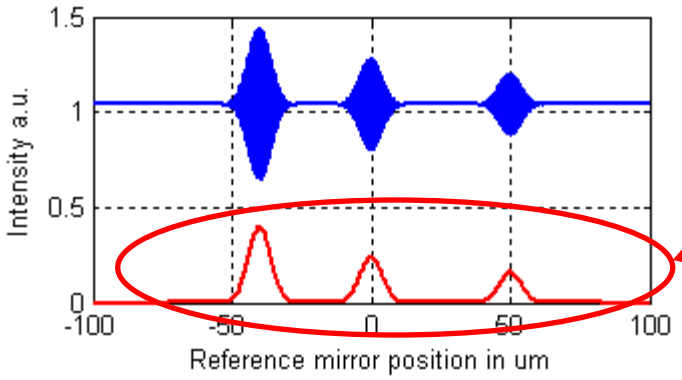


Commonly used wavelengths:

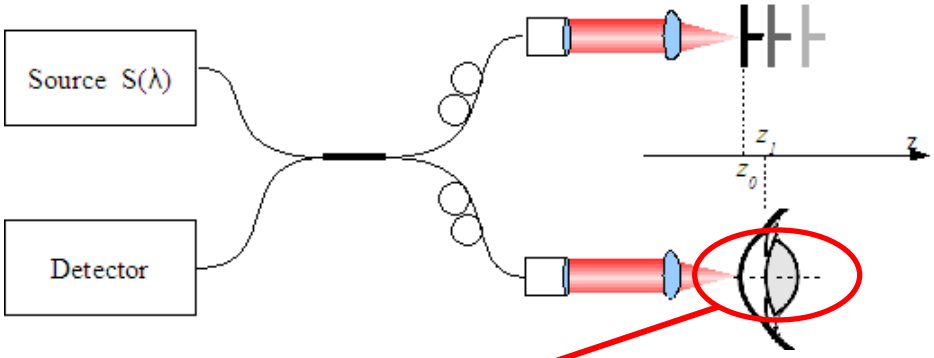
- 840nm
- 1060nm
- 1310 nm

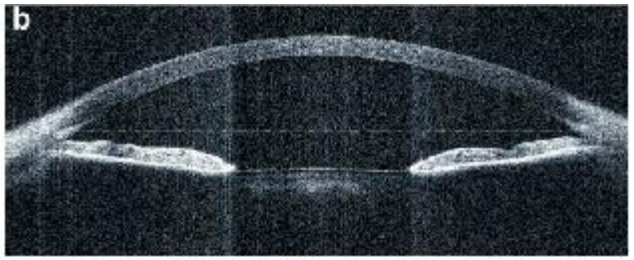
Basic principle: Time Domain OCT





Michelson Interferometer setup with moving reference mirror

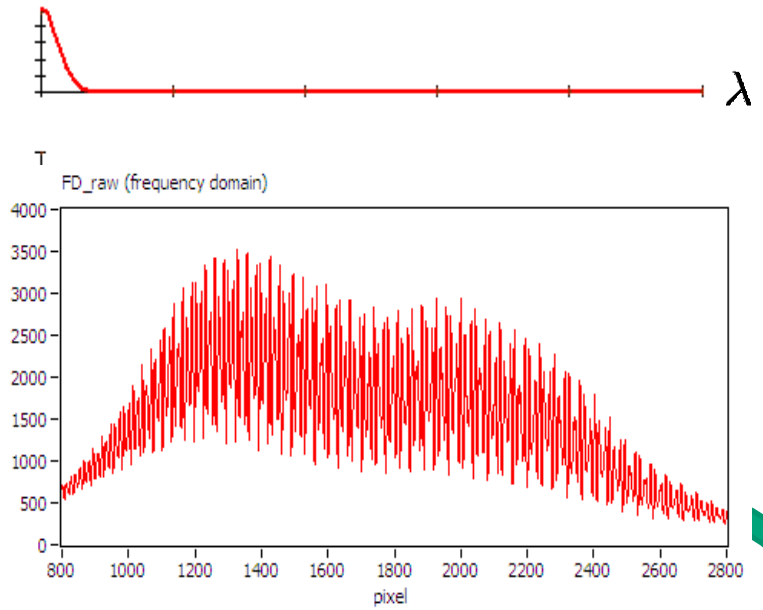




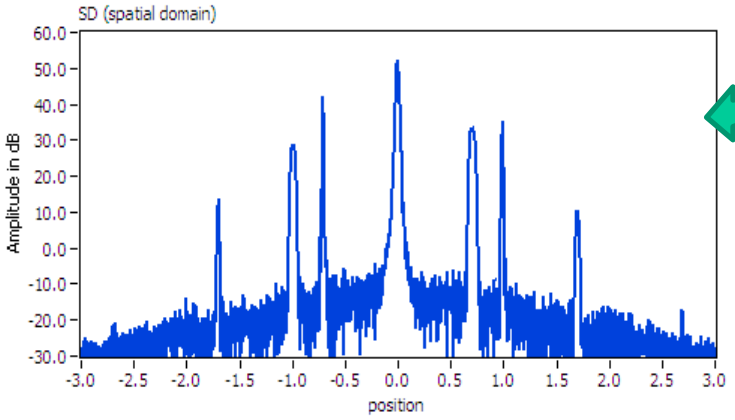
From: Sarunic, Optics Letter 2006

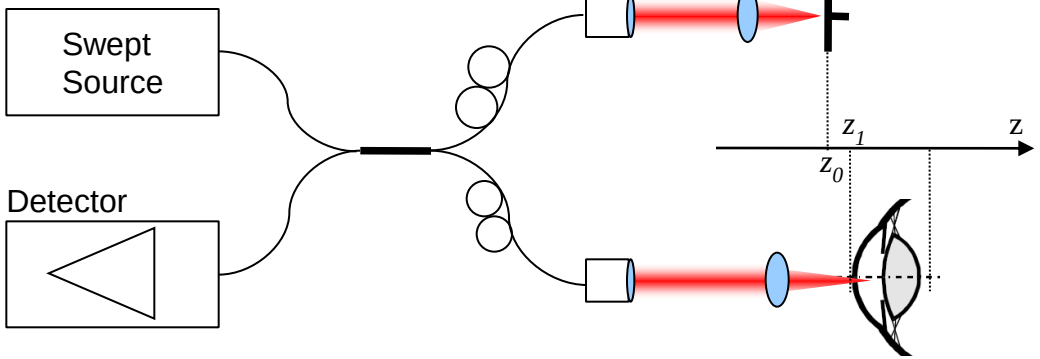
The signal envelope represent the reflectivity depth profile

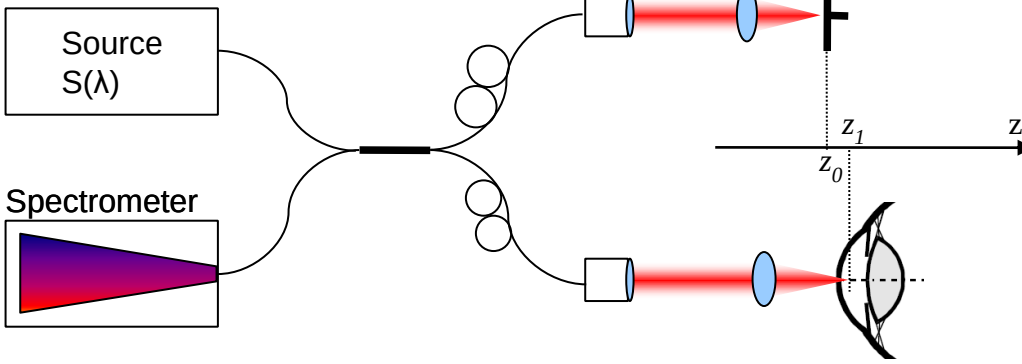
FD-OCT, basic principle



$\mathcal{F}^{-1}$



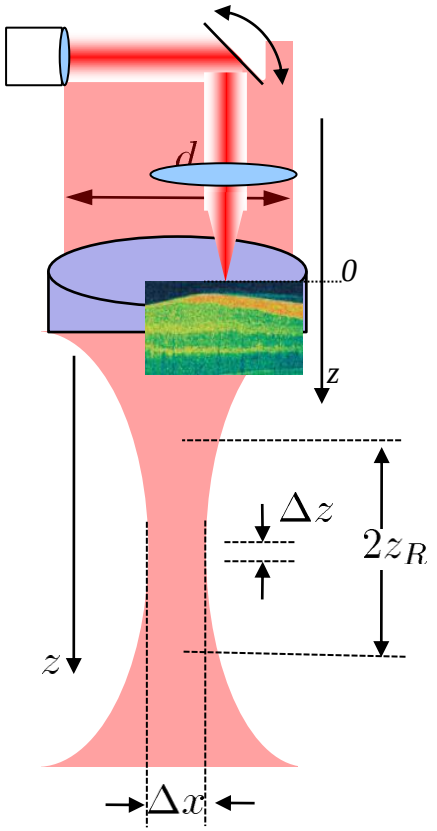




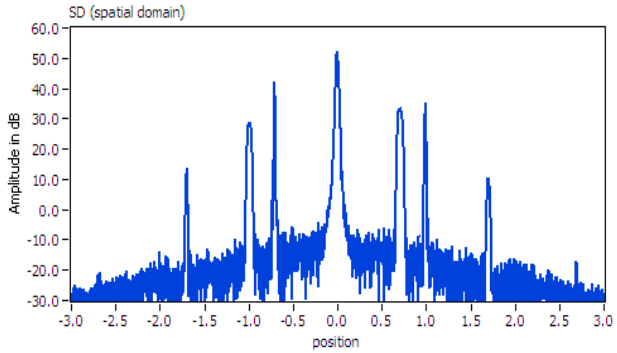
Resolution: OCT and Microscopy

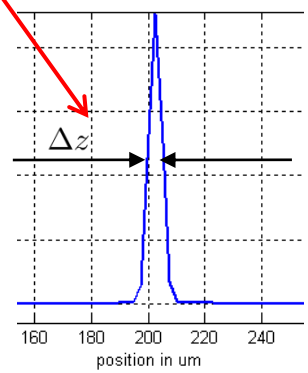
$$N_A = \frac{d}{2f}$$

	Lateral resolution	Axial resolution
Confocal Microscope	$\Delta x \sim \frac{1}{N_A}$	$\Delta z \sim \frac{1}{N_A^2}$
OCT	$\Delta x \sim \frac{1}{N_A}$	$\Delta z = \frac{4ln(2)}{\Delta k}$

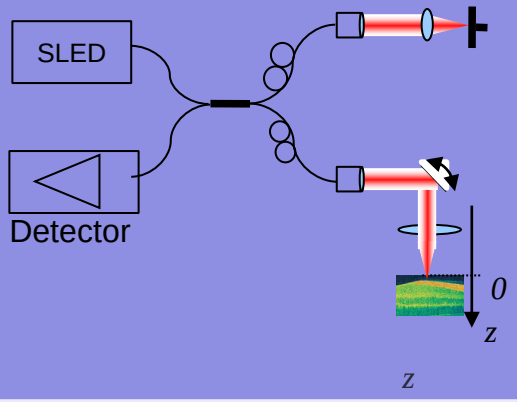


Coherence gate



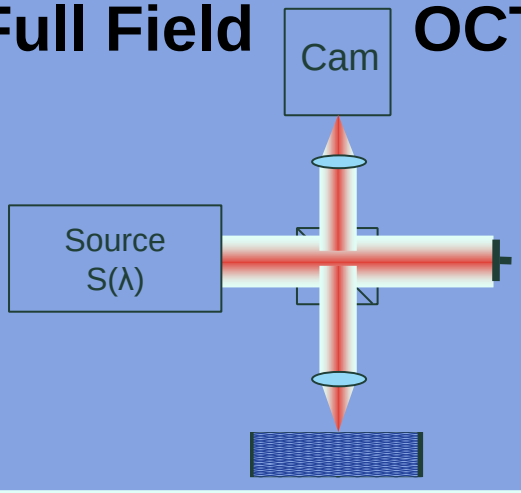


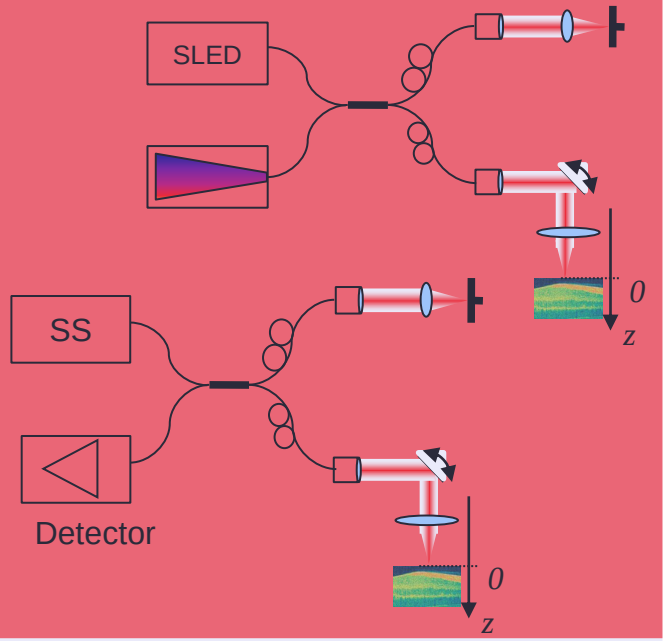
Scanning OCT



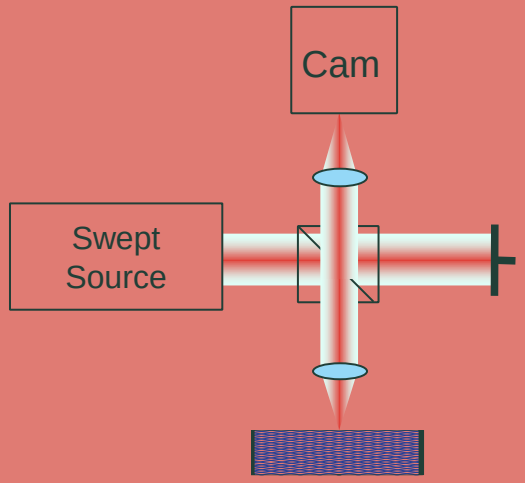
TD OCT

Full Field OCT

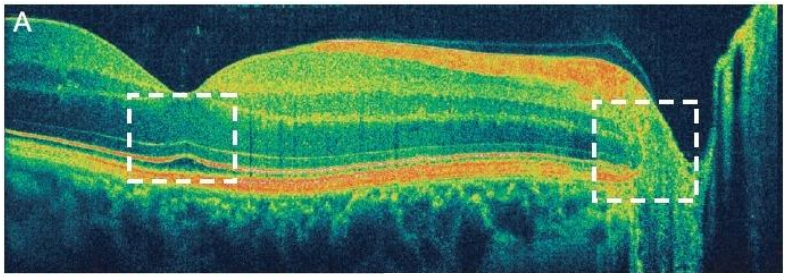


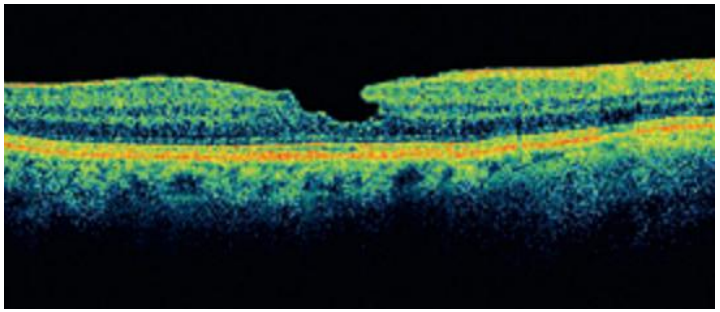


FD OCT

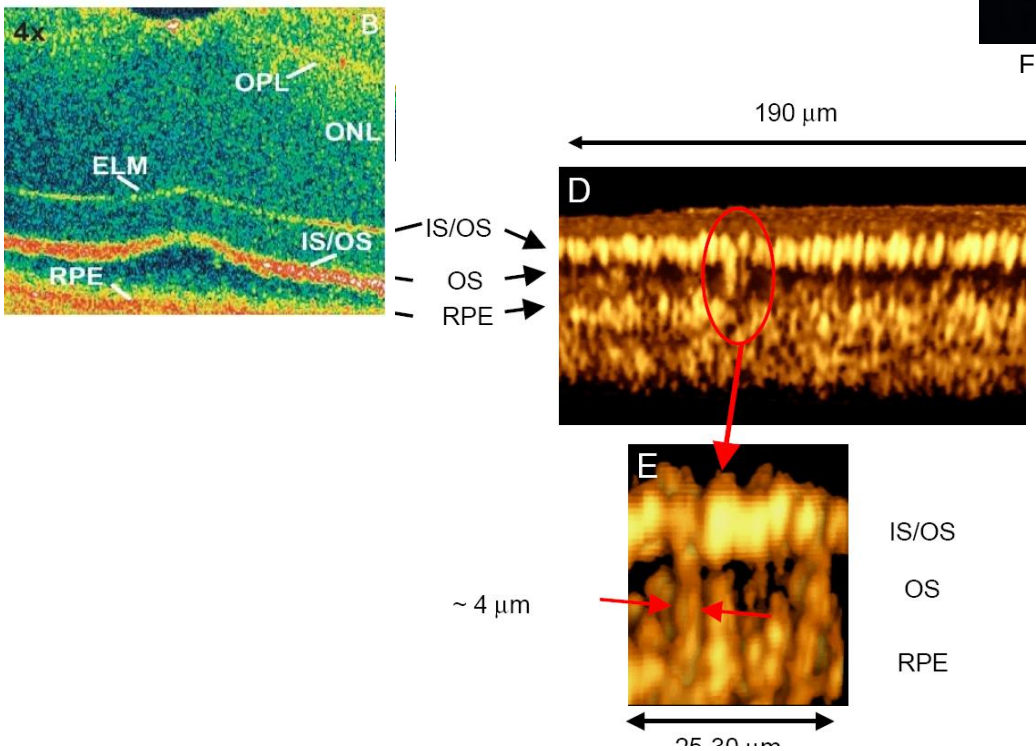


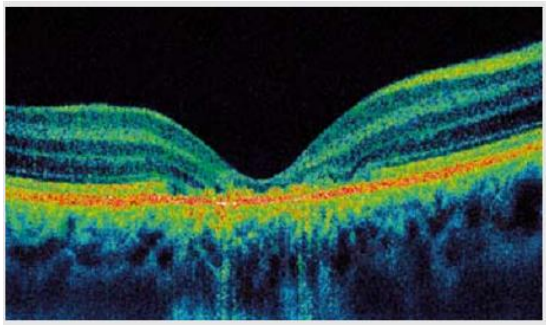
State of the art, retina imaging





From Zeiss cyrrus

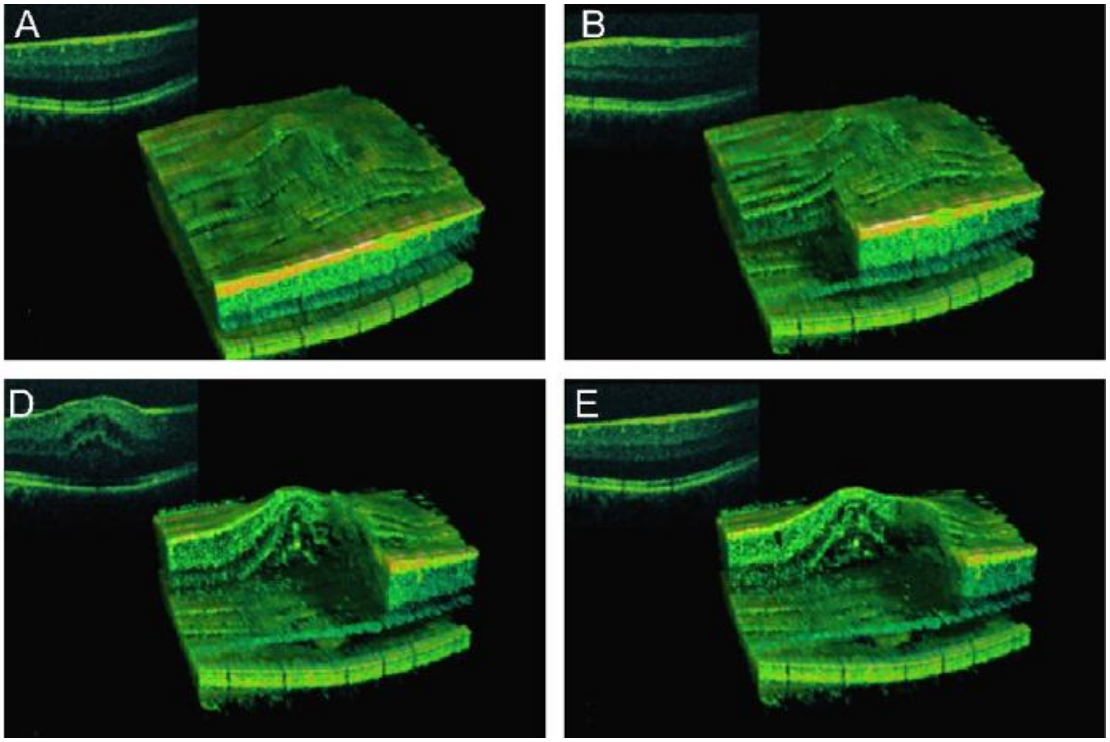




From OptoPol, soct_HR

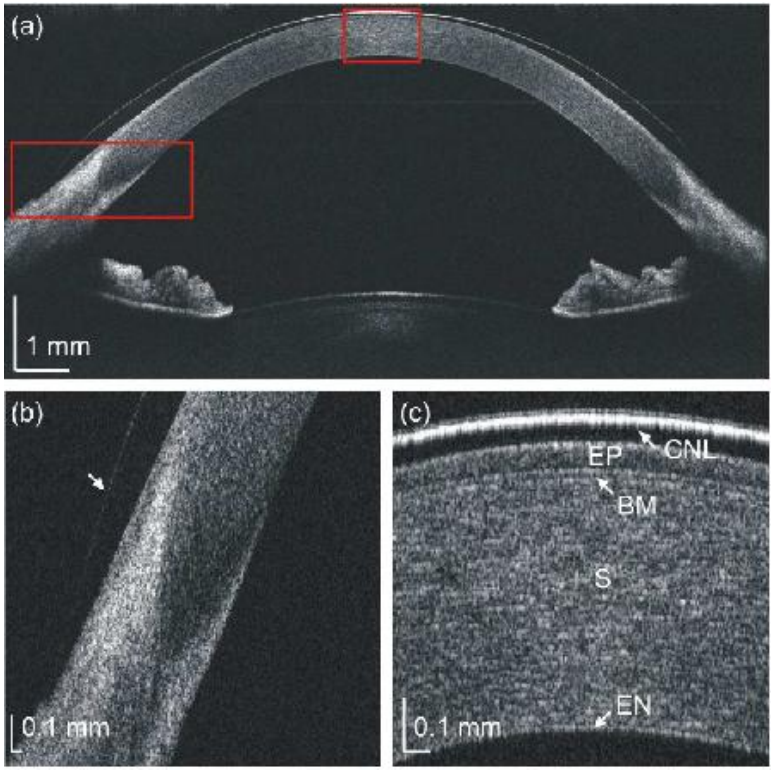
From: Drexler W., Fujimoto J. Science Direct 2007

State of the art, retina imaging

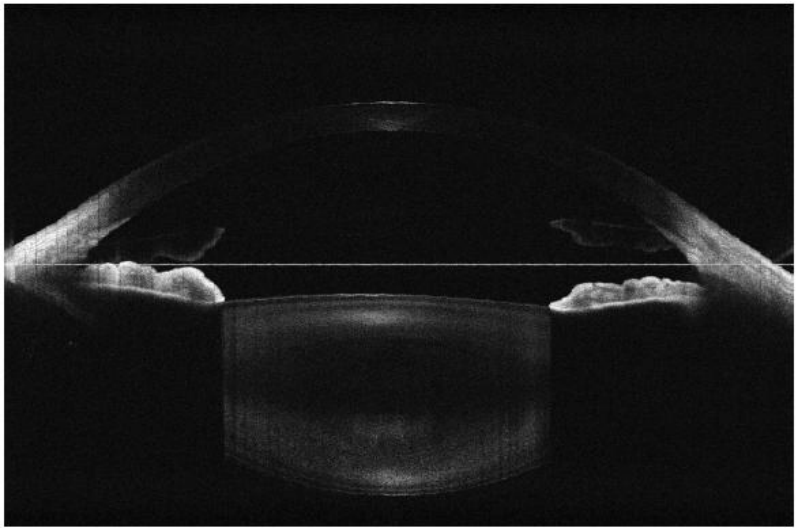


From: Drexler W., Fujimoto J. Science Direct 2007

Anterior segment of the eye

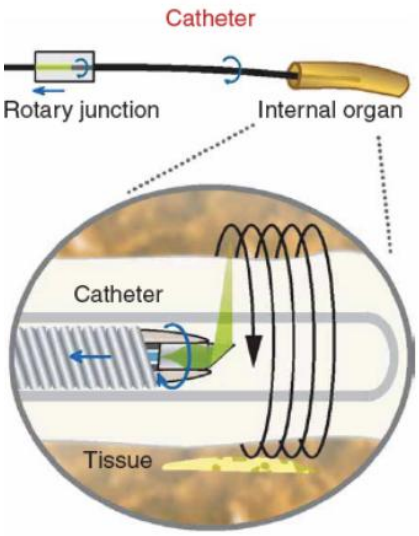


From: Grulkowski., Optic Express, march 2009

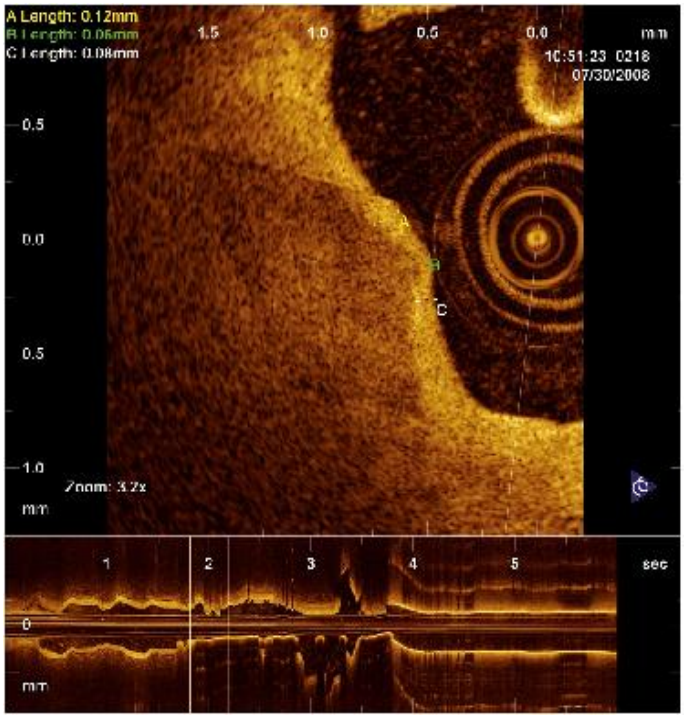


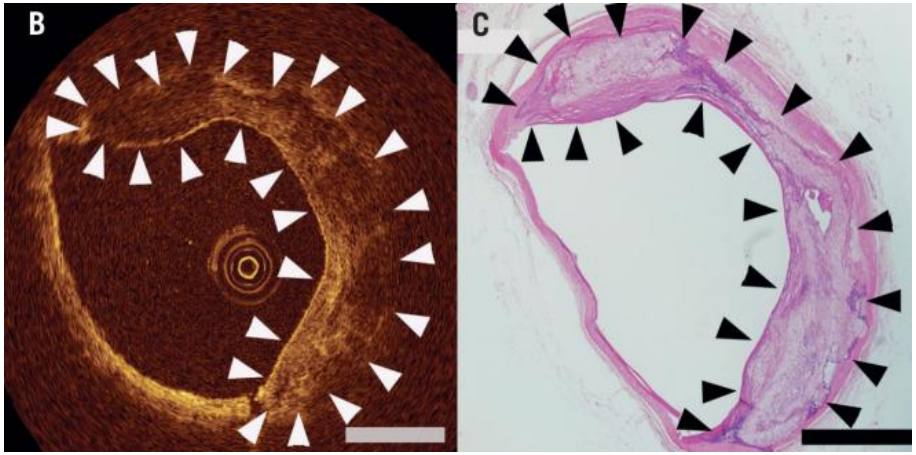
Woitkowsky, AVRO 2011

Endoscopic OCT and cardiology



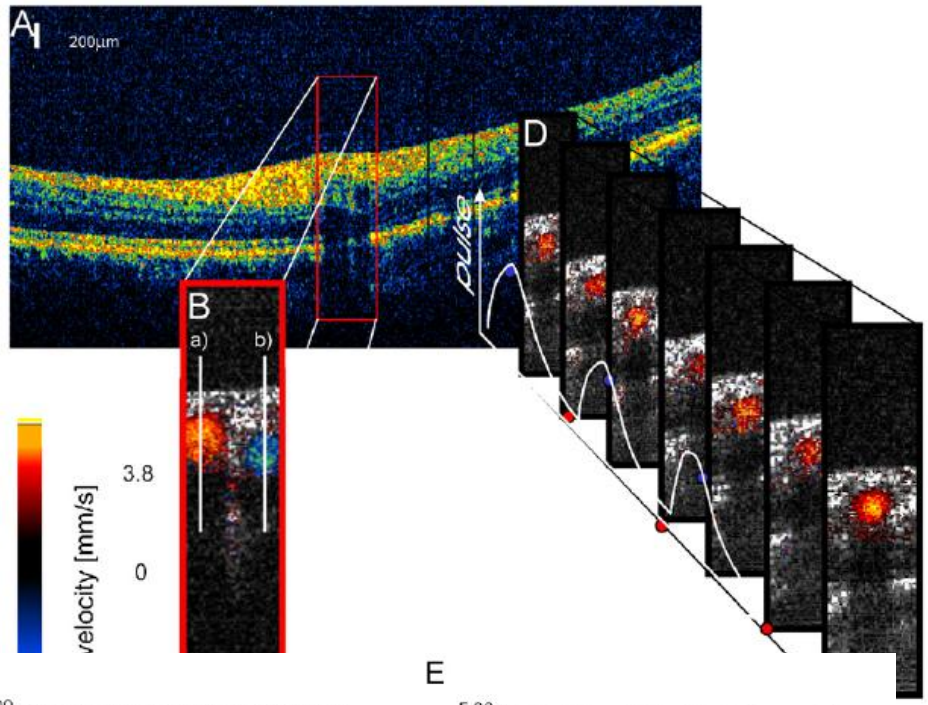
From LightLab

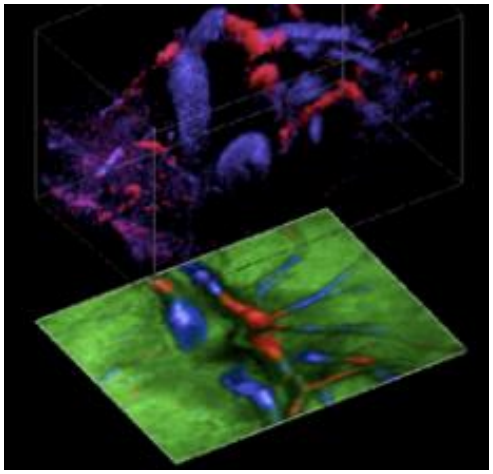


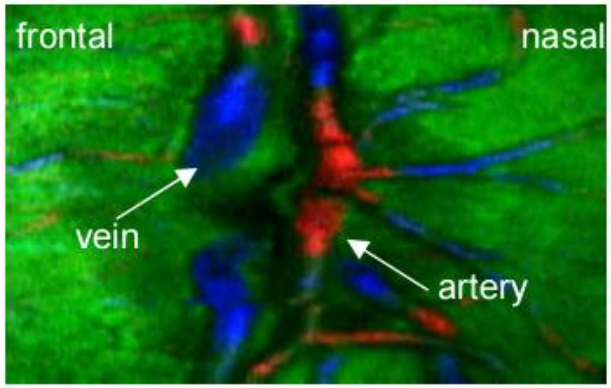


Kume, **Assessment of corocary calcification by OCT**, PCR online 2010

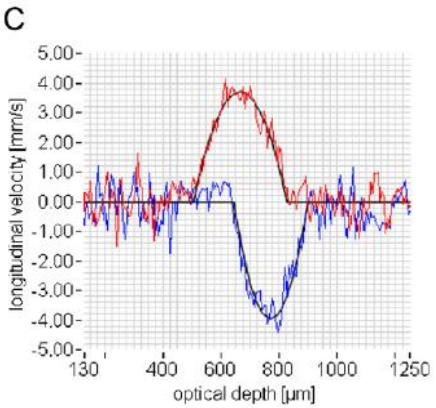
Functional OCT, Doppler

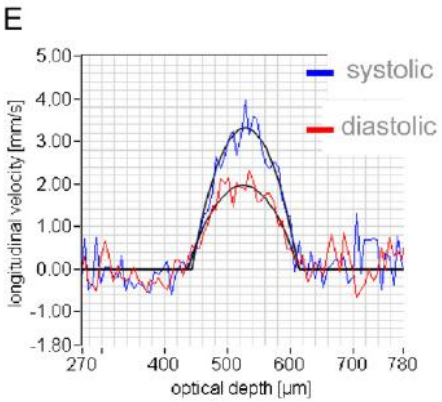






a)



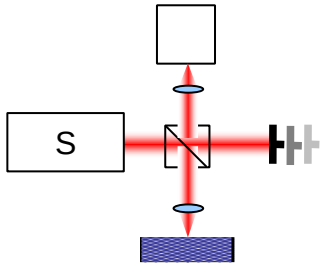


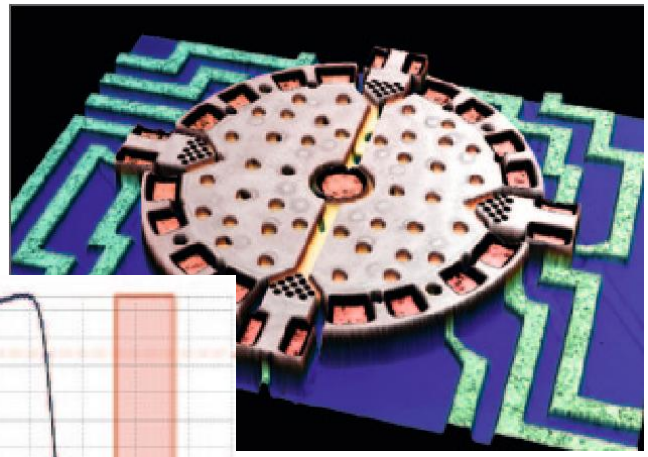
Bachmann,…Leitgeb. OpticExpress,. 2007

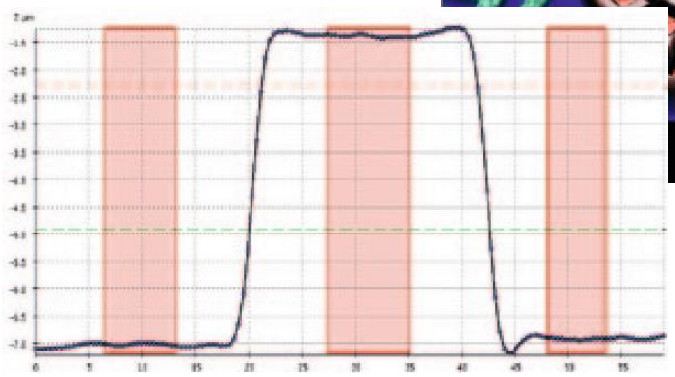
Leitgeb in Optical Cherence Tomography, Springer 2008

White Light Interferometry (Full Field time domain OCT)

- Different Microscope manufacterer provide such systems.
- Z-Resolution some nm
- Slow scanning motion
- Problem: mechanical vibration







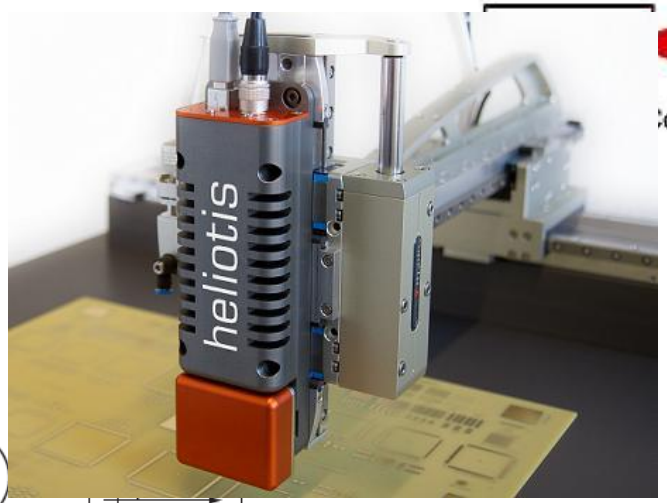
Full Field OCT: Smart Pixel Technology

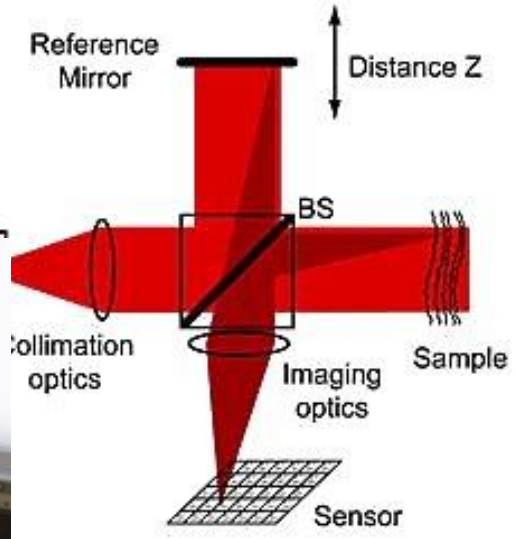
heliotis

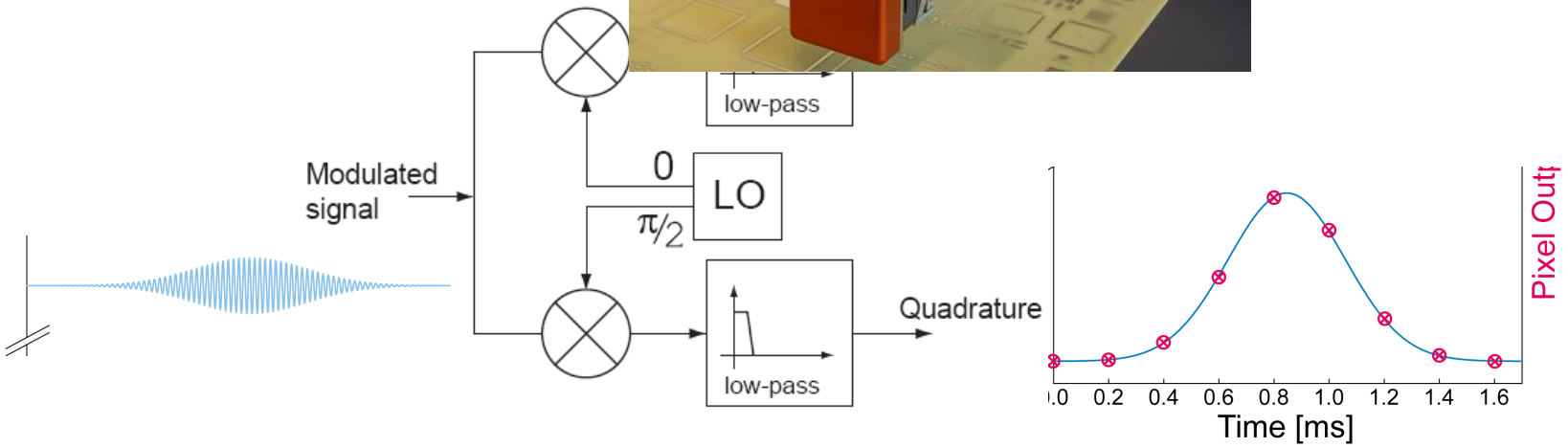
Phase–Sensitive Parallel Optical Coherence Tomography

Number of pixels 144 x 90
Vertical resolution 200nm
Lateral resolution 2 um

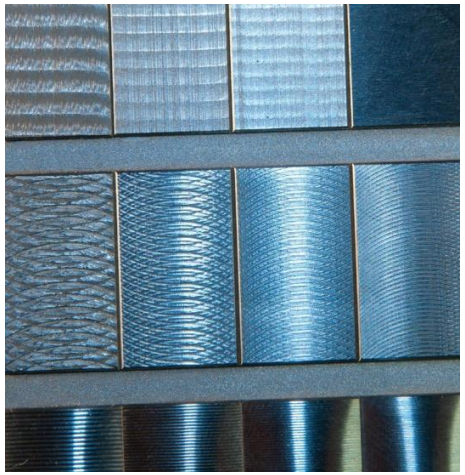
May 2011: 300x300



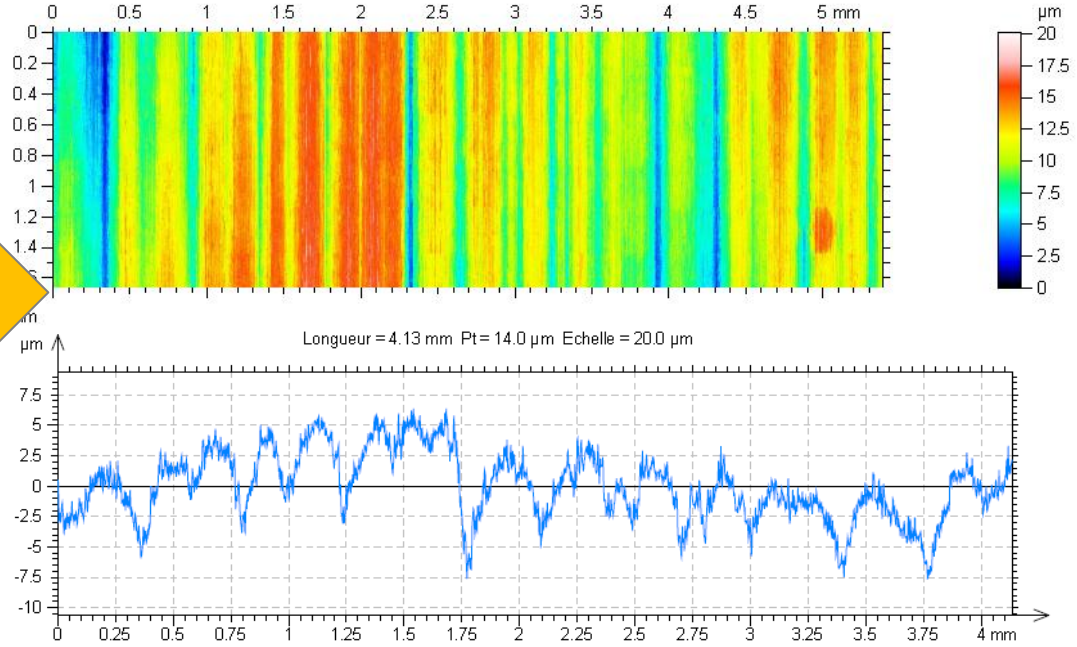


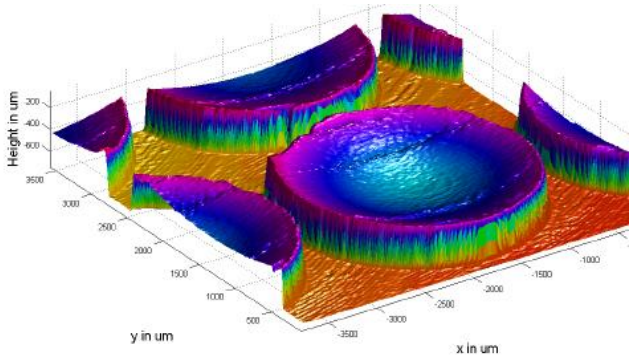


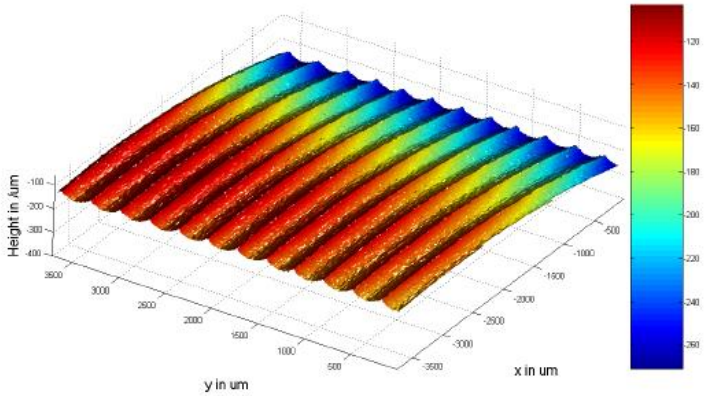
Surface Characterisation (ISO 4287)



3D

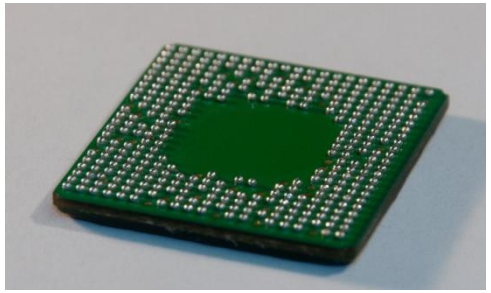




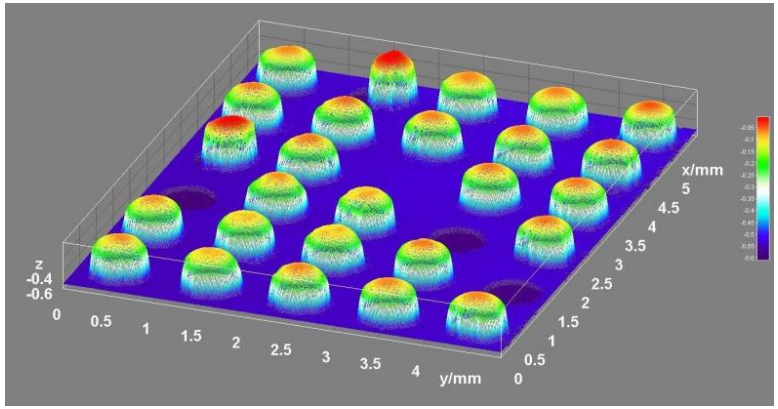


Electronic components

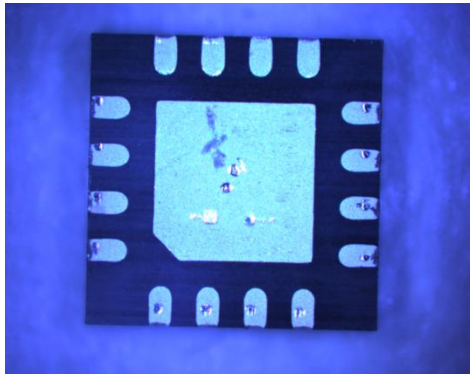
I) Solder bumps (BGAs)



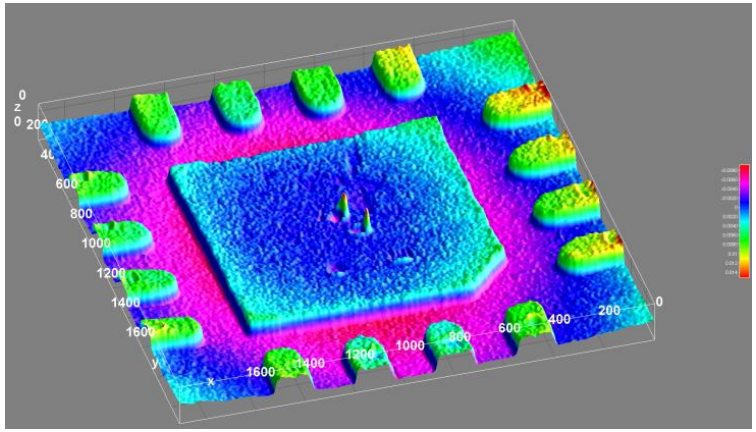
3D



II) Pads of an integrated circuit

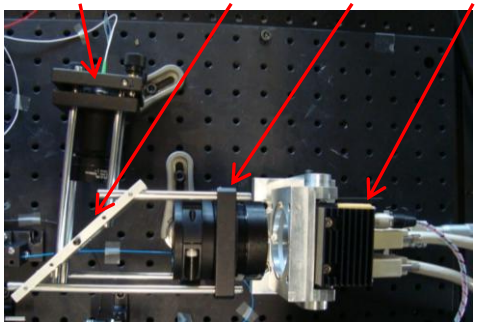


3D

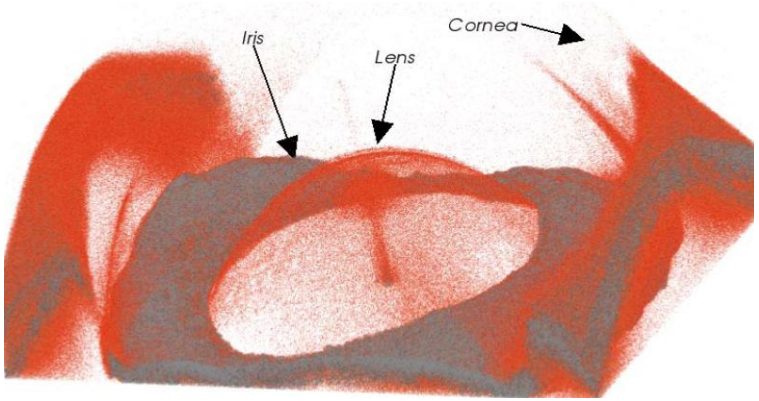


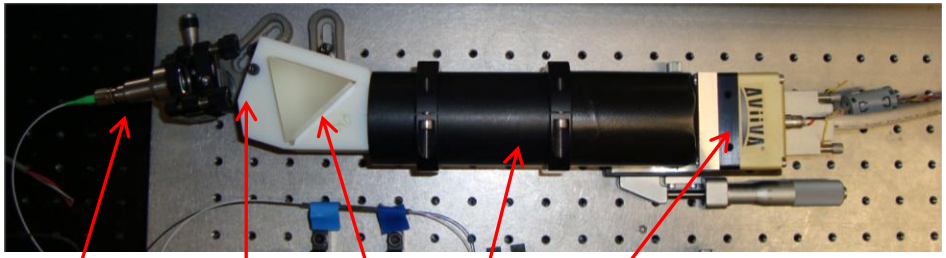
Spectrometer for OCT (fast and linear-k)

Collimator Grating Lens Camera

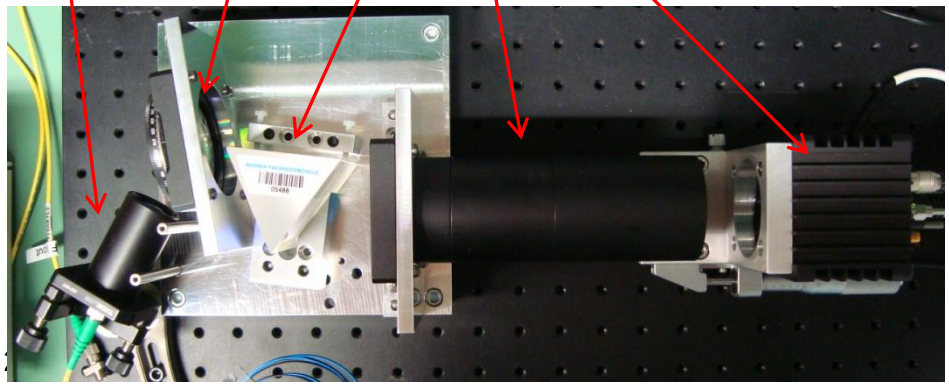


- λ=800nm ±60nm
- Sensitivity: 103dB [1]
- Camera speed: 72'000 A-scans/s
- Measuring range: 4.4 mm





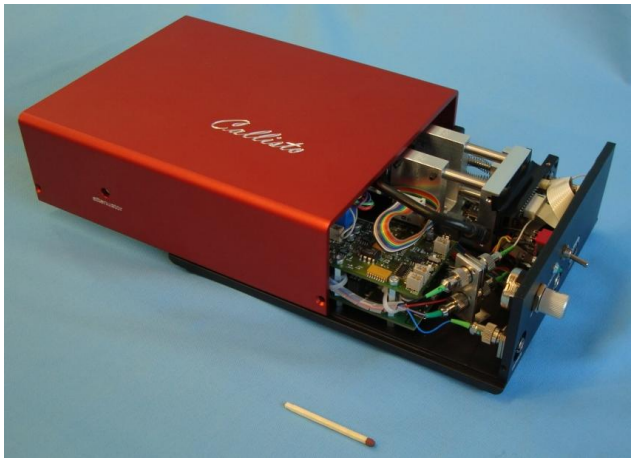
Collimator Grating Prism Lens Camera



- λ=835nm ±25nm
- Sensitivity: 93 dB [1]
- Camera speed: 28'700 A-scans/s
- Measuring range: 6 mm

- λ=1058nm ±30nm
- Sensitivity: in progress
- Camera speed: 92'000 A-scans/s
- Measuring range: 6 mm

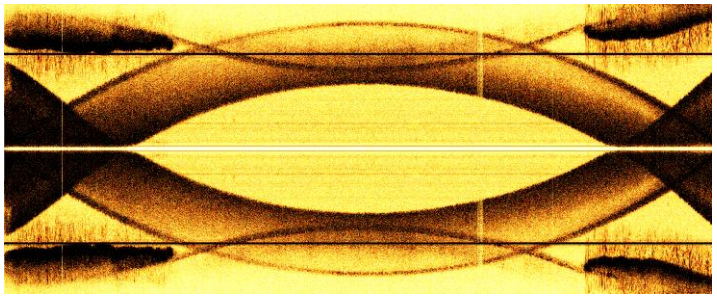
OCT Callisto

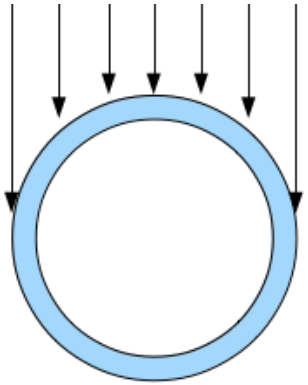


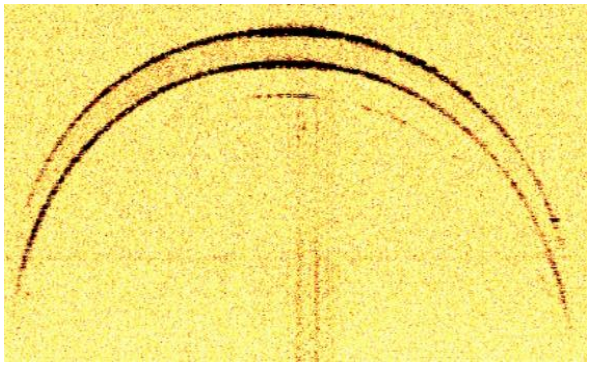
OCT Box Callisto

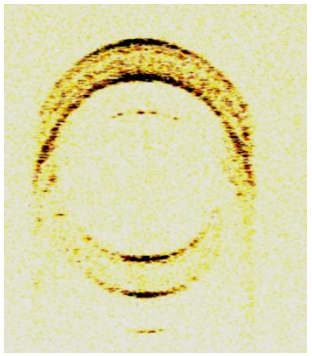
Includes: - Source
- Spectrometer
- Reference arm
- Interferomter

Dimensions:	200 x 150 x 70
Axial Scan Resolution:	6.5 µm
Measurement range	6.6 mm



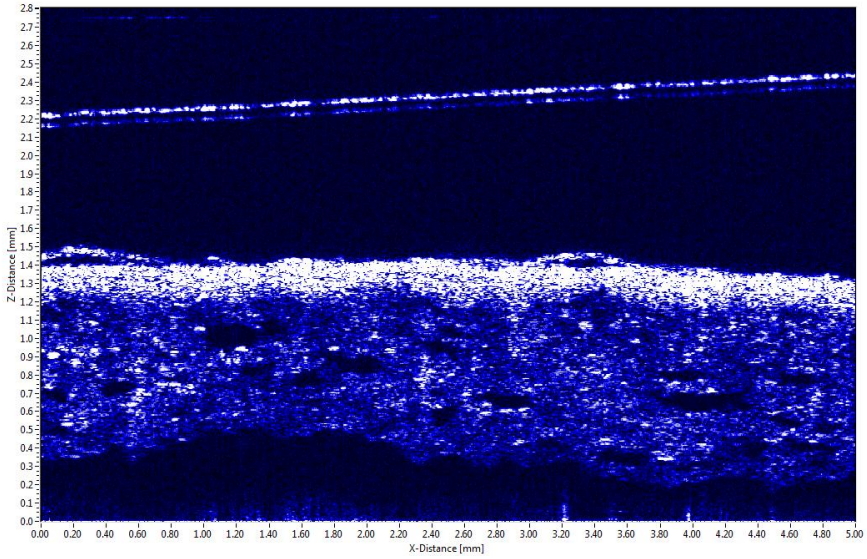






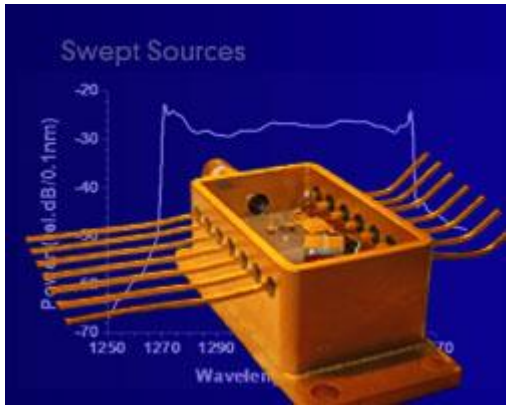
Optical control of bio-printed skin

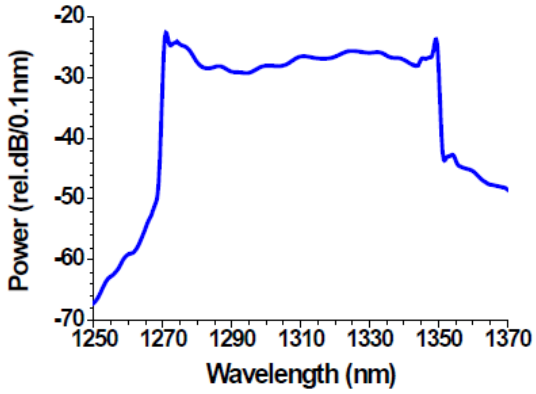
- KTI project in collaboration ZHAW and Delta Robotics (KTI 12148.1)
- Integration of OCT into the Delta Robotics engine
- Control of the quality and thickness homogeneity of the printed skin with OCT



Miniaturized Swept sources

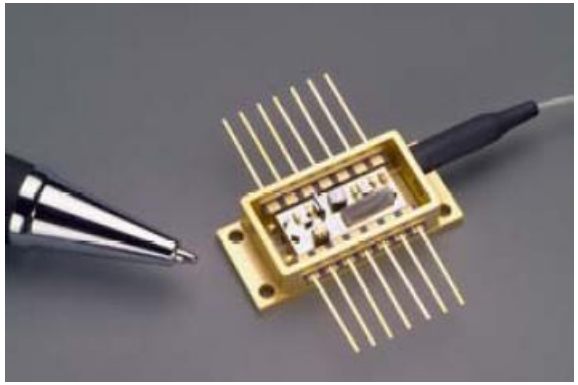
EXALOS
50 kHz sweep rate

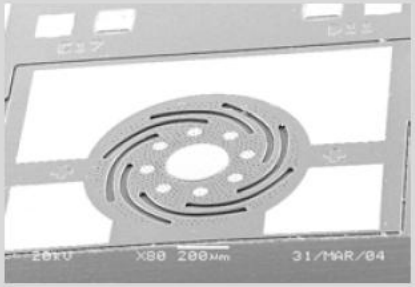




AXSUN

Parameter	*Value*
Wavelength Range	1250 – 1360 nm
Output Power	20 mW
Sweep Rate	50 kHz
Coherence Length	12 mm





Axsun MEMs Tunable Filter

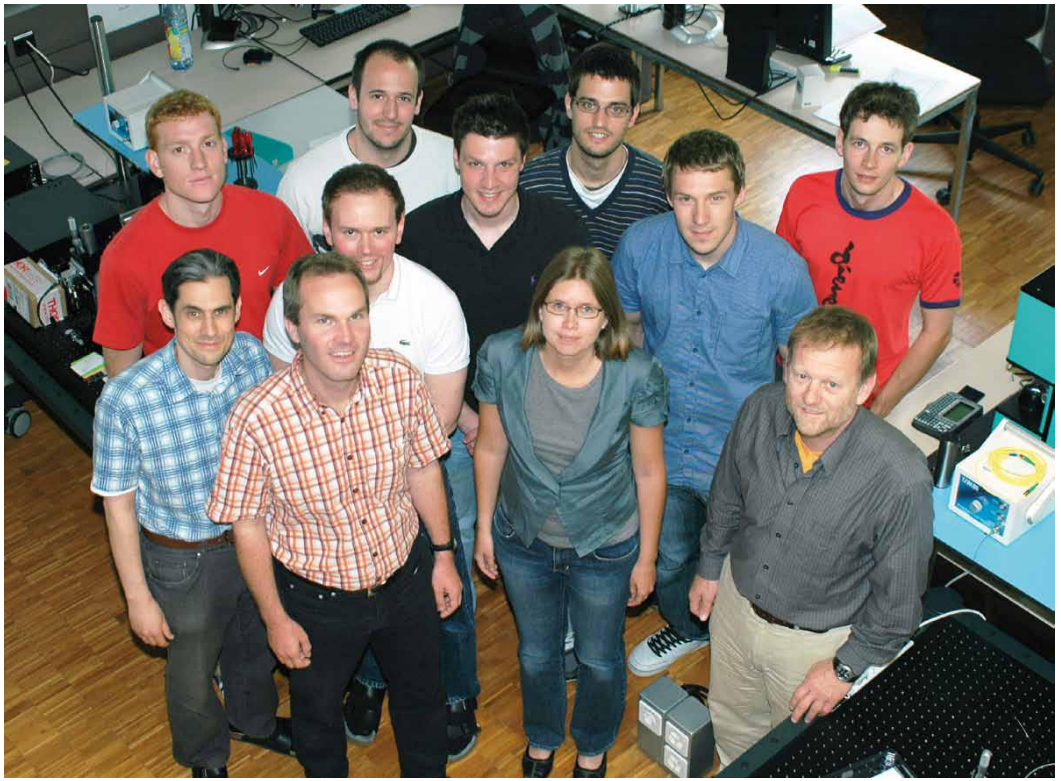
Sweeping due to tunable Fabry-Perrot filter

OptoLab
BFH TI Biel

www.ti.bfh.ch/OptoLab

Master Thesis available

Biomedical Master or
MSE Master Laser + Photonics



Thank you for your attention

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R. Lehmann, A. Bossen, Ch. Meier