Laser Sources for Frequency-Domain Optical Coherence Tomography FD-OCT

Photonic Sensing
Workshop SWISSLaser.Net

Biel, 17. 9. 2009

Ch. Meier

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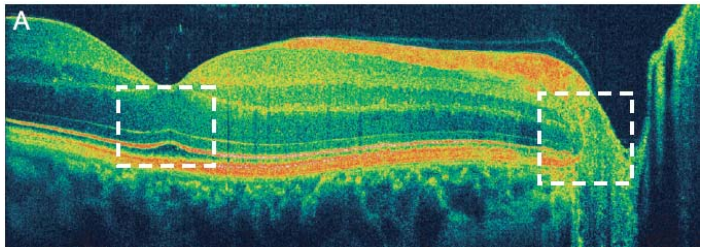
Some application

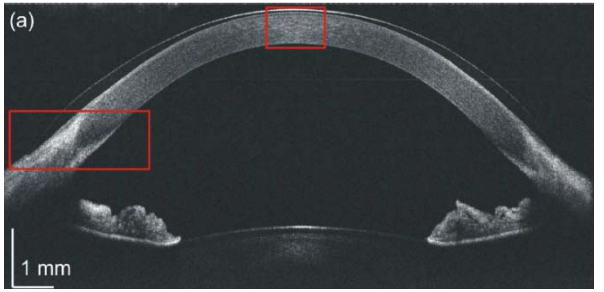
Ophthalmology

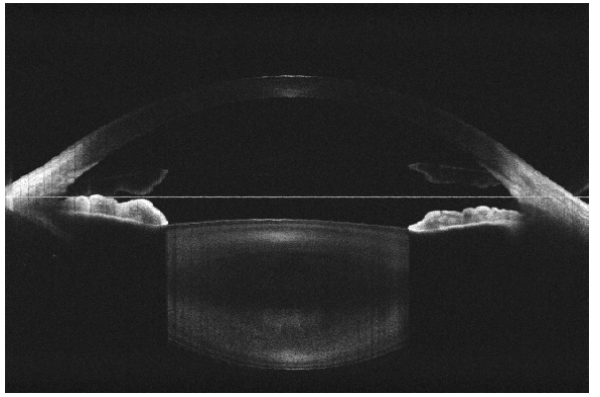
Anterior segment

Retina imaging



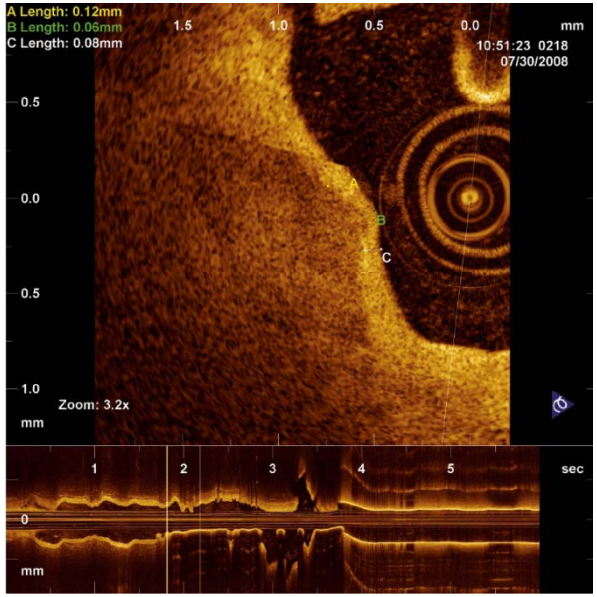
Drexler W., Fujimoto J. Science Direct 2007





Grulkowski., Optic Express, march 2009

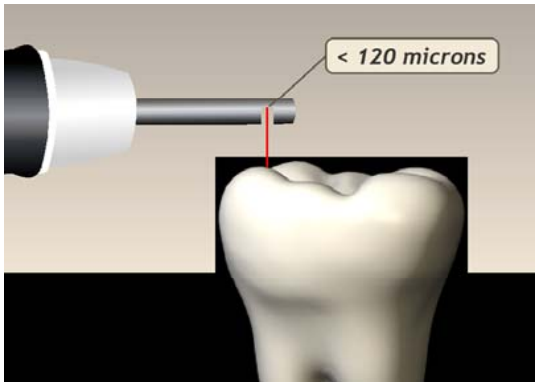
Cardio-vascular application



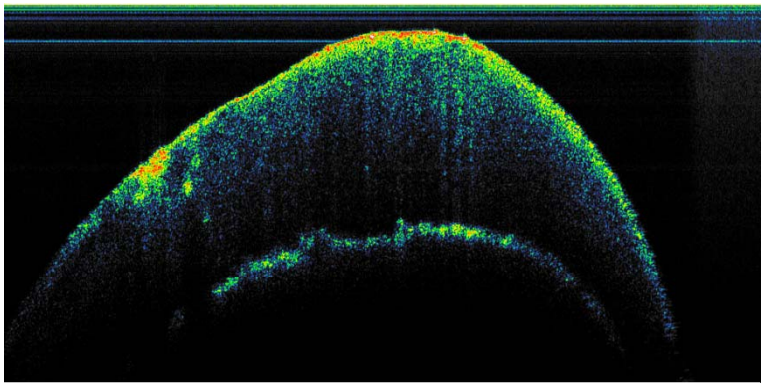
LightLab 2008

Some application

Dentistry

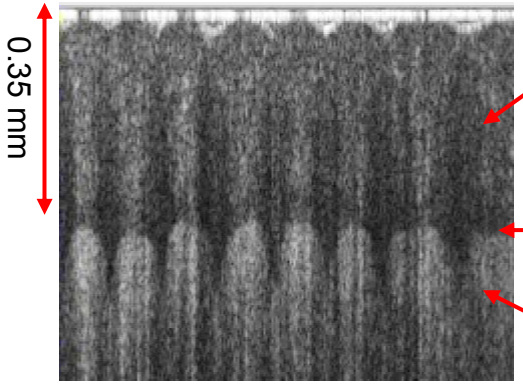


From Lantis

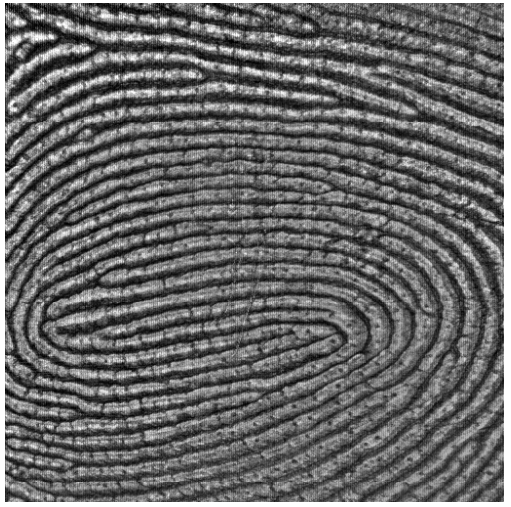


Tooth, Enamel - Dentin, BFH OptoLab, 2009

Security and Identification



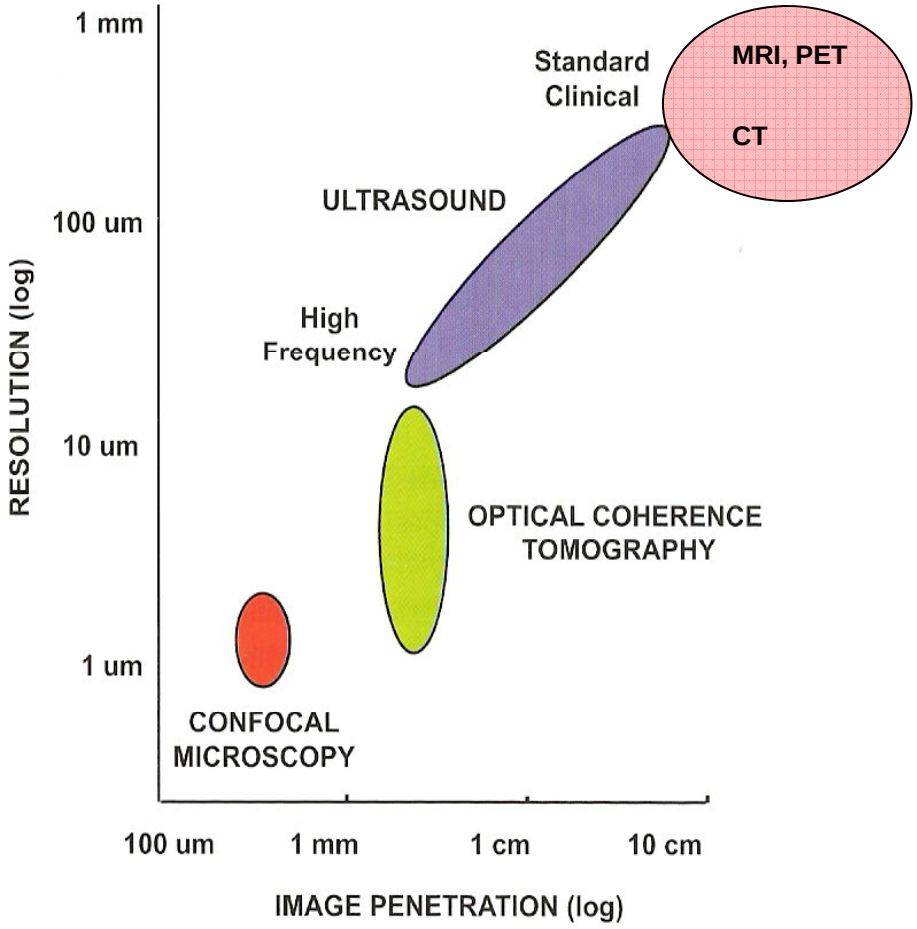
B-scan of Fingerprint,
BFH OptoLab, 2009



Internal Fingerprint

BFH OptoLab, 2009

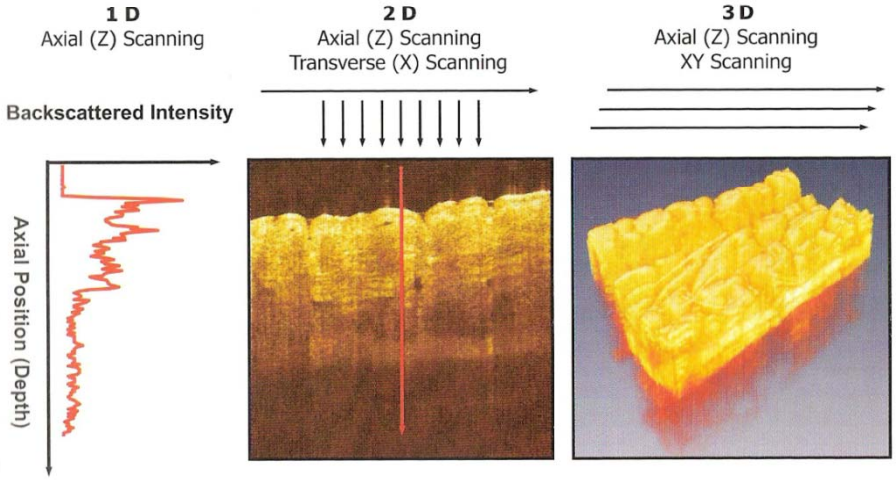
Tomographic Methods in Medicine



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

OCT Basics

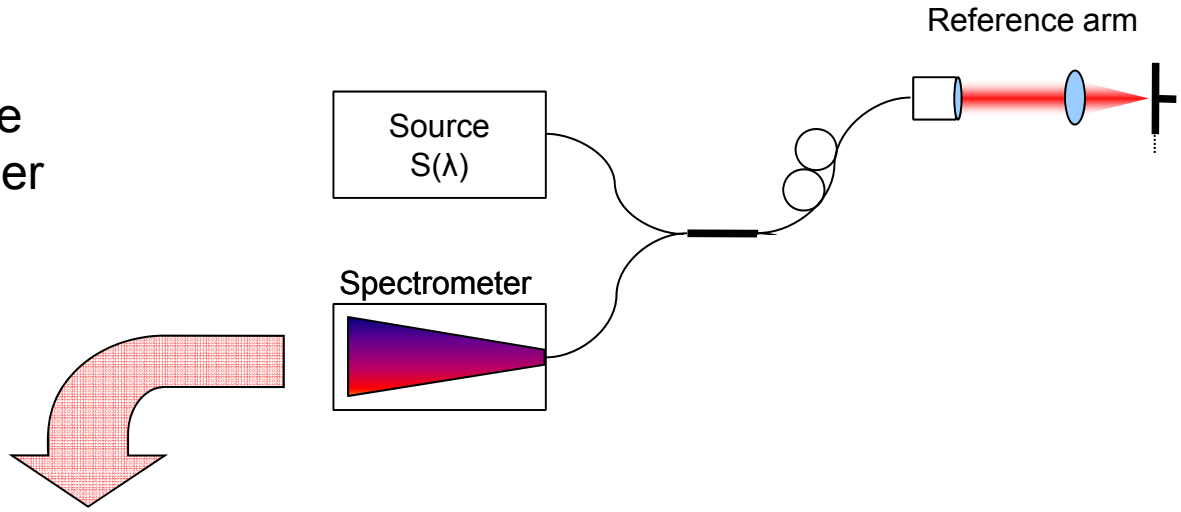
- Similar to ultrasonic tomography
- Depth profiles are constructed by measuring the time delay of backscattered or backreflected light
- Cross sectional images are obtained by scanning in x and y direction

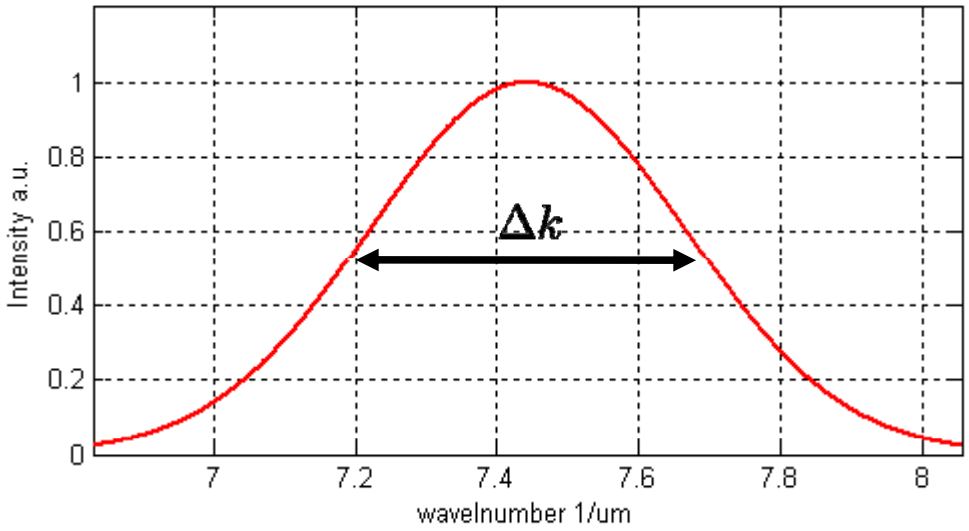


From: W. Drexler, J.Fujimoto, Springer 2008

FD-OCT, basic principles

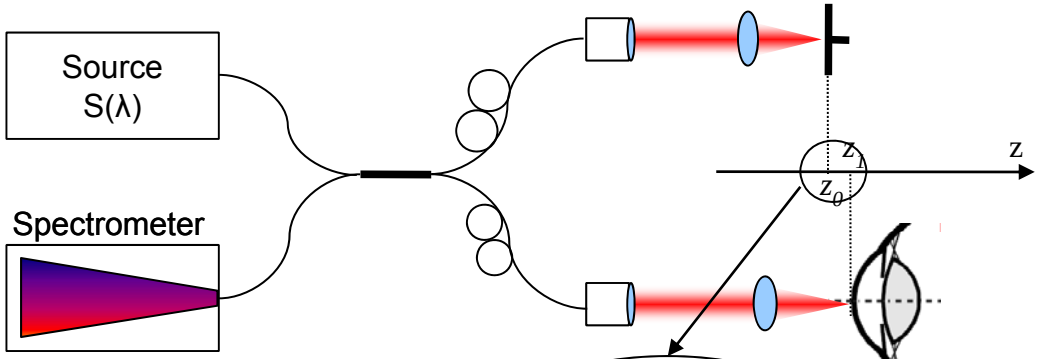
Broadband source
coupled to SM fiber

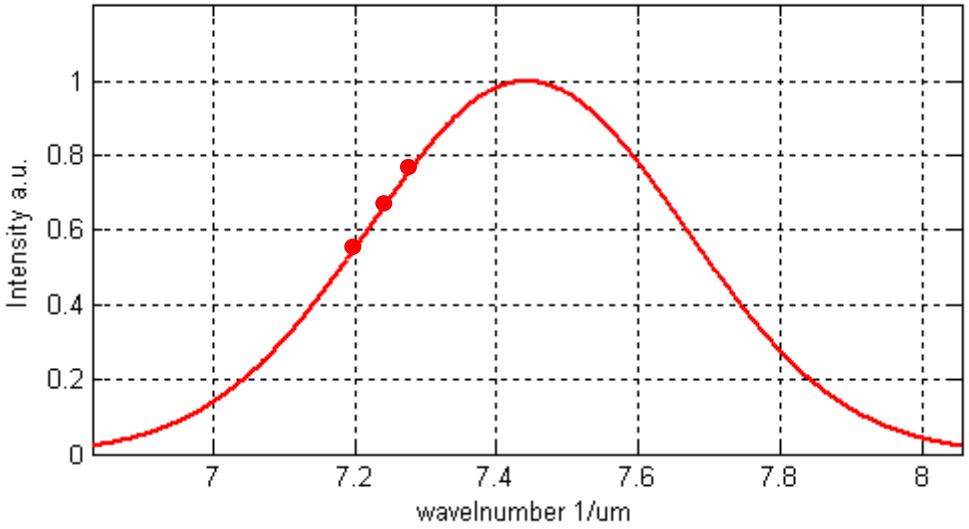


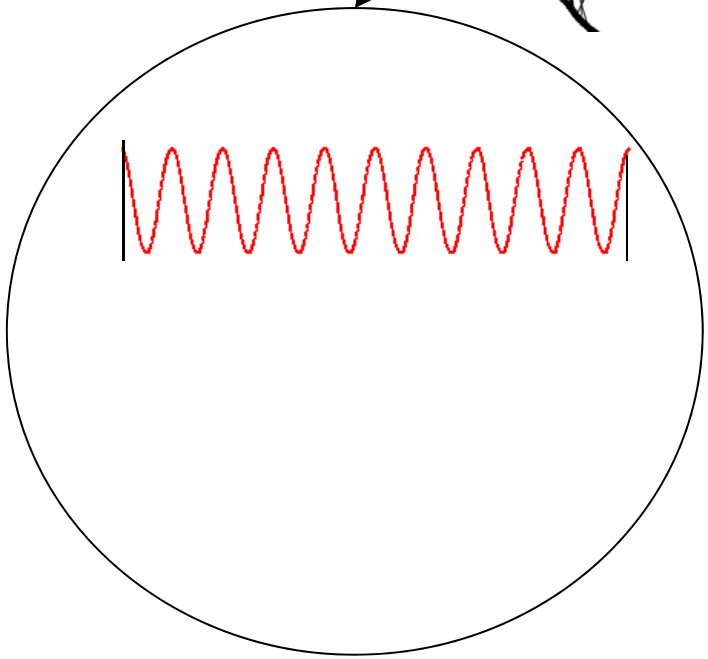


$$k = \frac{2\pi}{\lambda} \qquad \Delta k = 2\pi \frac{\Delta\lambda}{\lambda_m^2}$$

FD-OCT, basic principles

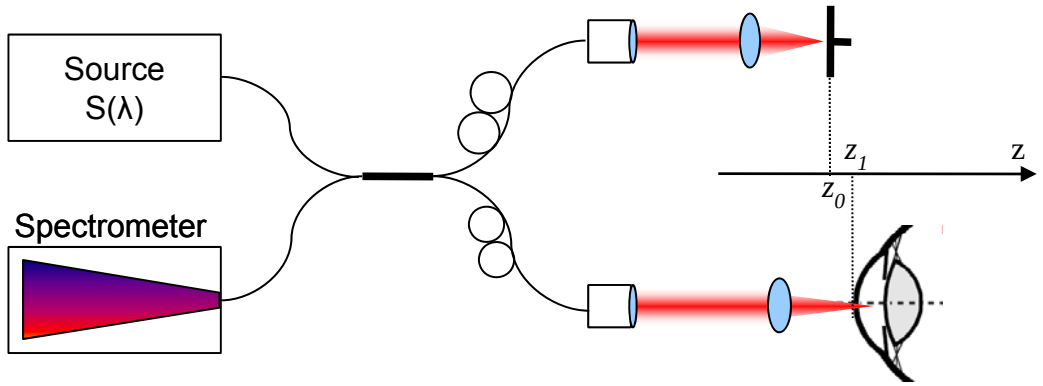


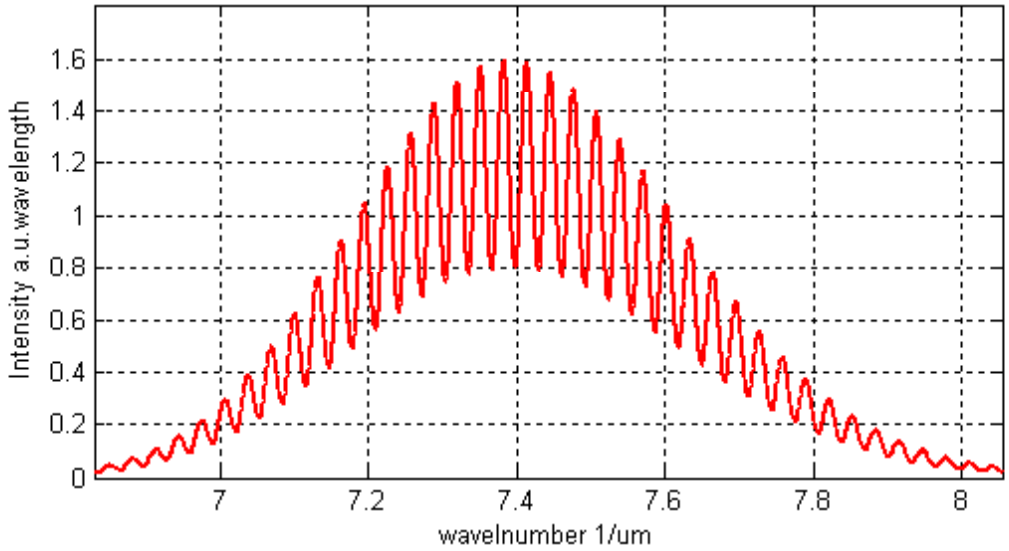




FD-OCT, basic principles

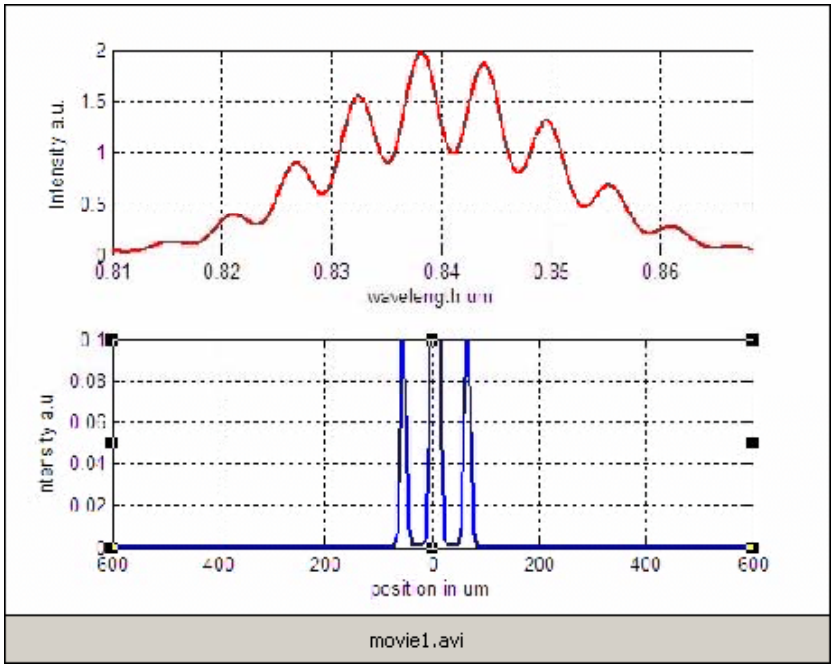
Interferences due to optical path difference

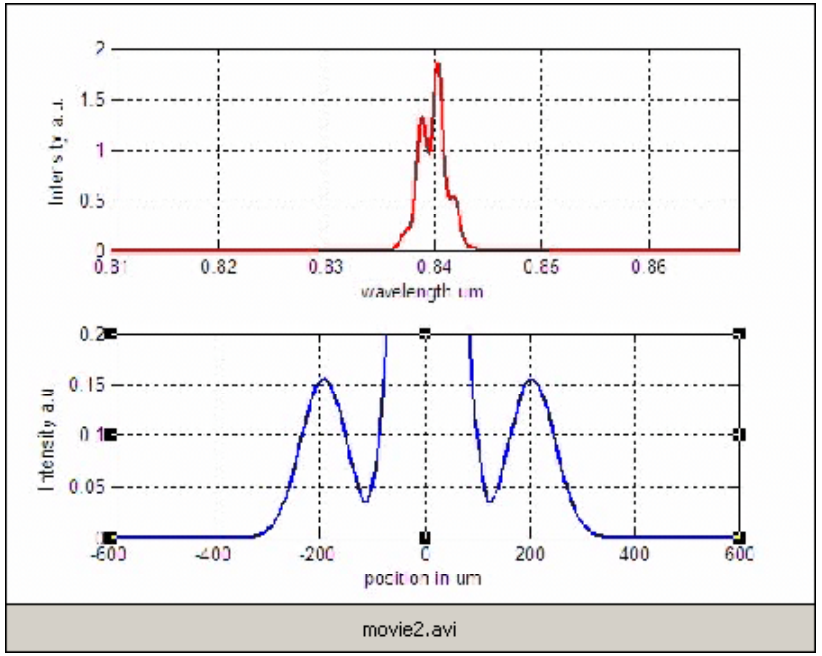


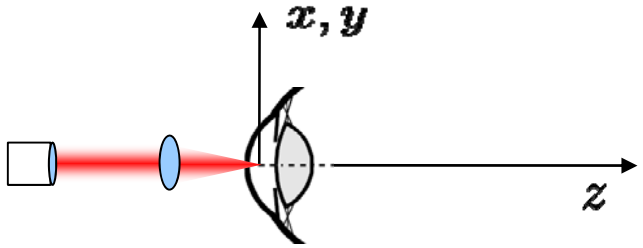


Frequency in k-space is proportional to OPD

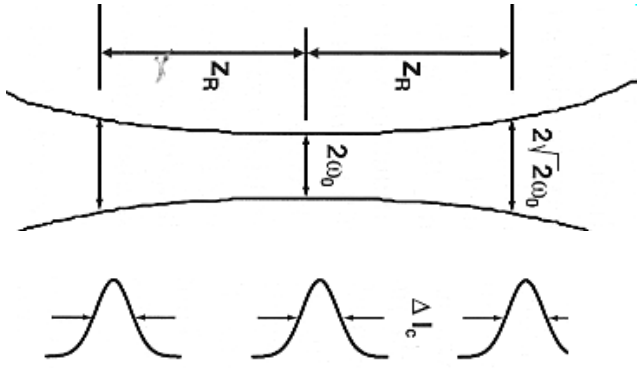
Reflectivity profile is obtained by a Fourier transformation





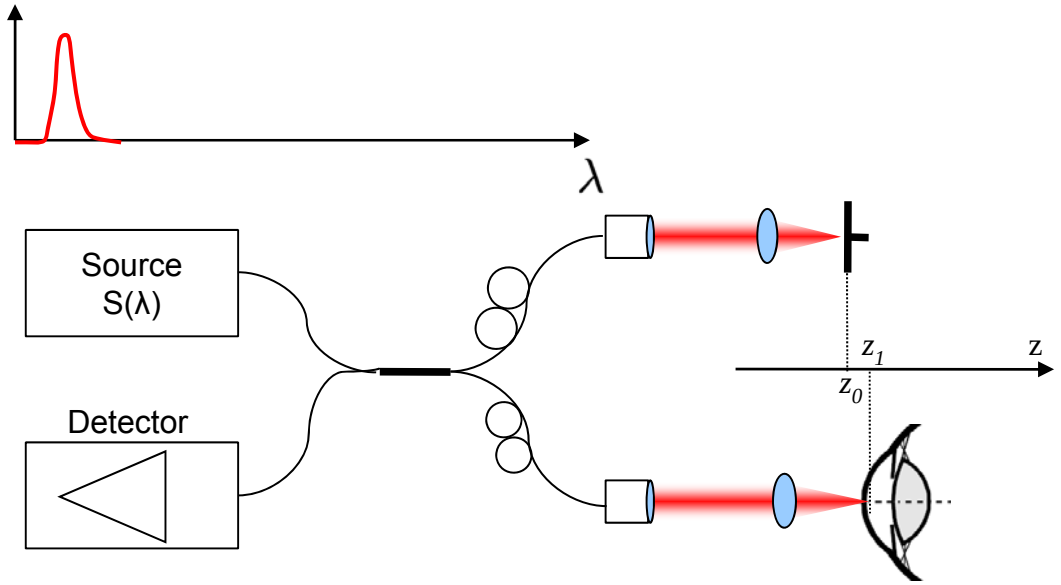


Axial resolution = coherence length

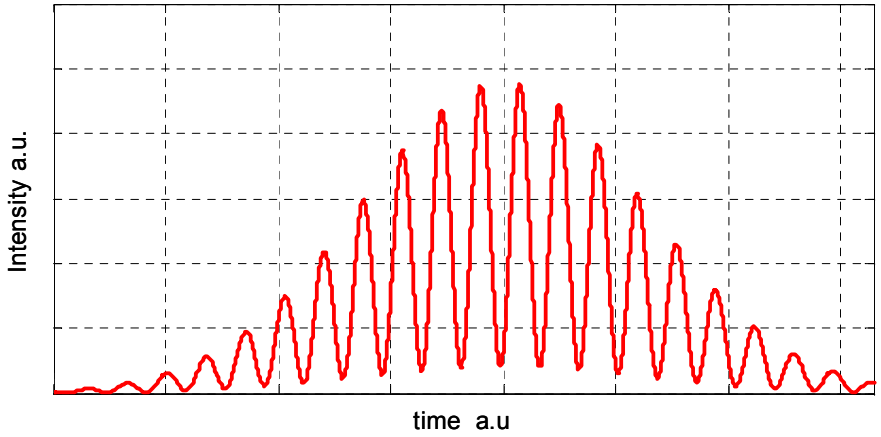


FD OCT, swept source

Narrow band Laser
Large wavelenth tuning range



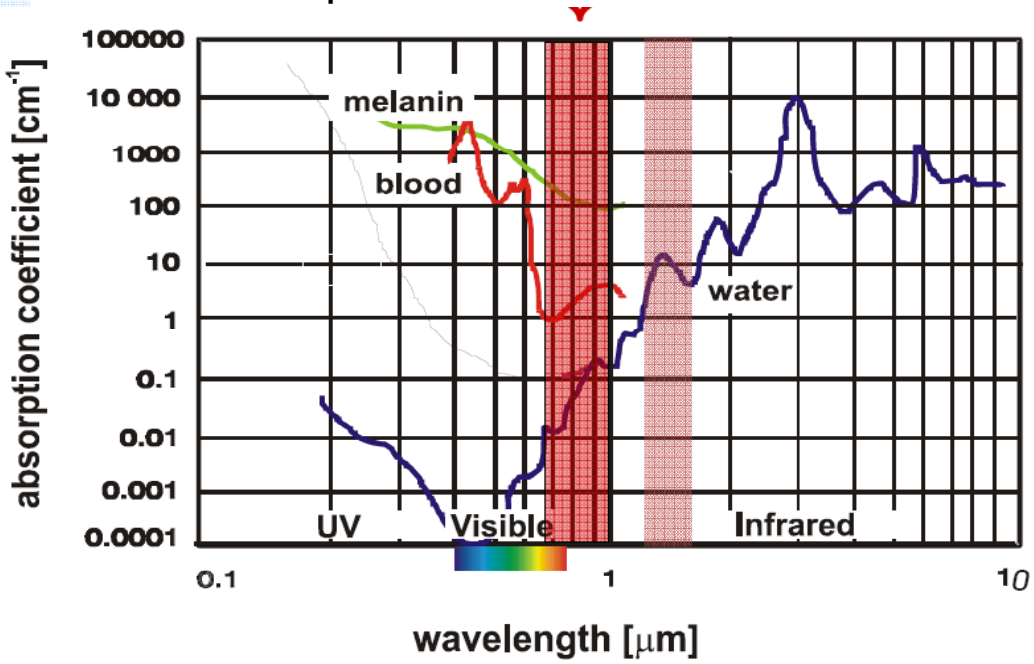
Time encoded
Fourier domain signal

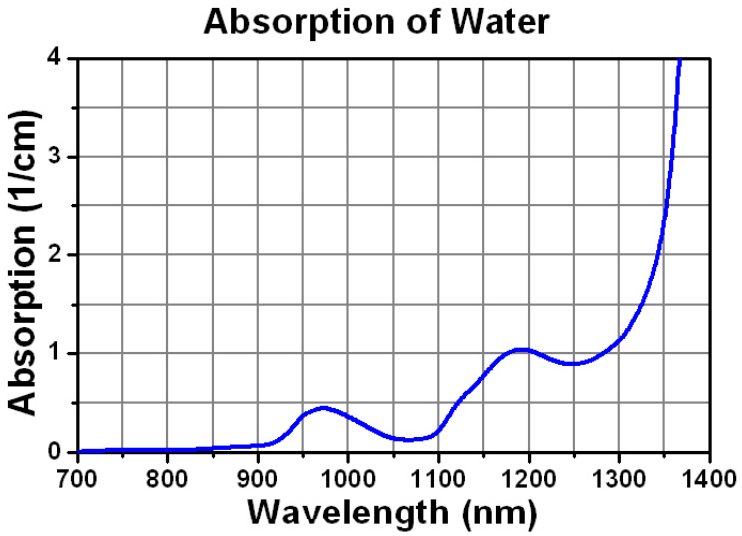


OCT Sources, needs

	Spectrometer based SeFD OCT	Swept Source TeFD OCT
Spectrum	800nm, 1000nm, 1300nm	800nm, 1000nm, 1300nm

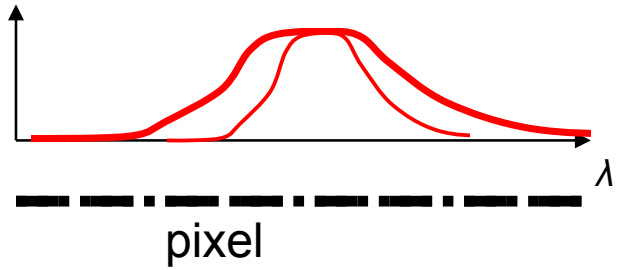
Hemoglobin and water have low absorption in near infrared





OCT Sources, needs

	Spectrometer based SeFD OCT	Swept Source TeFD OCT
Spectrum	800nm, 1000nm, 1300nm	800nm, 1000nm, 1300nm
Resolutiuon	Broad spectrum (up to 200nm)	High scanning range



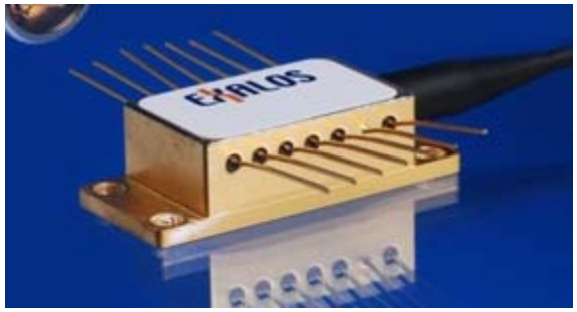
up to 140 kHz

FDML laser
up to 200 kHz

Sources for Spectrometer based FD-OCT

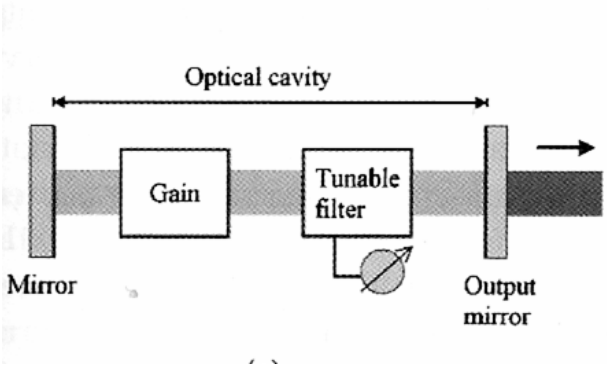
high resolution ► **broad bandwidth** or **low temporal coherence**
Interferometry ► plane wave or **high spatial coherence**

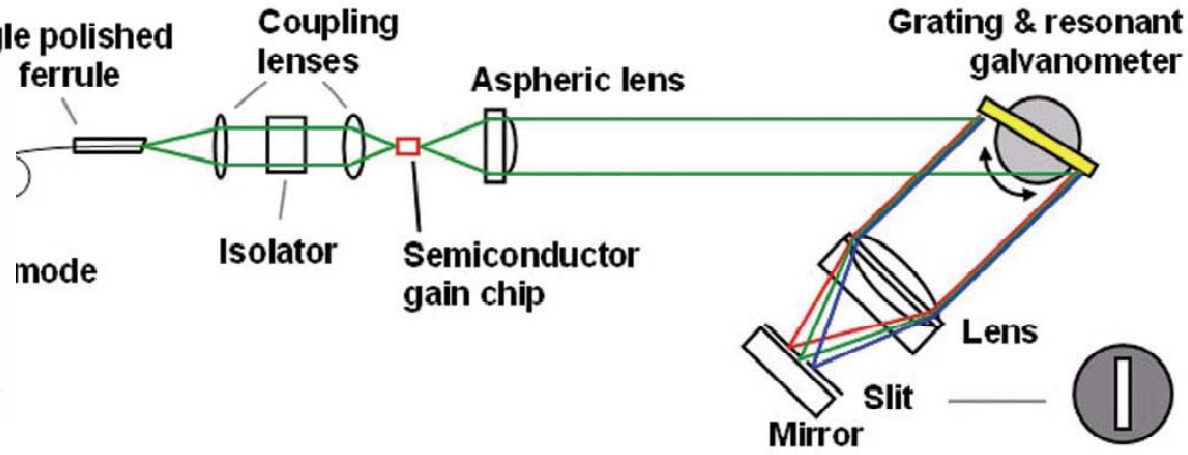
Super Luminescend Diode SLD or SLED
Center wavelength 840 nm – 1310 nm
Bandwidth 30 – 100 nm



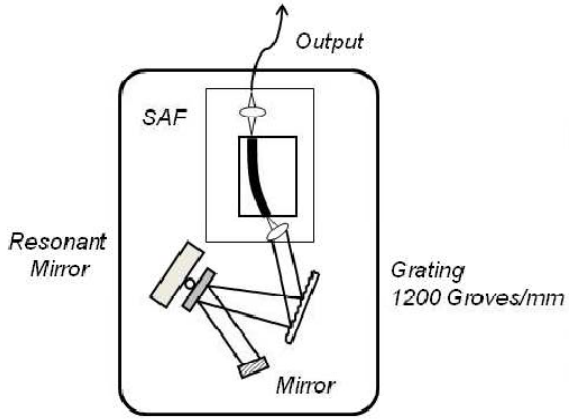
Fs Laser (Ti:S)
Center wavelength 820 nm
Bandwidth 120 – 240 nm

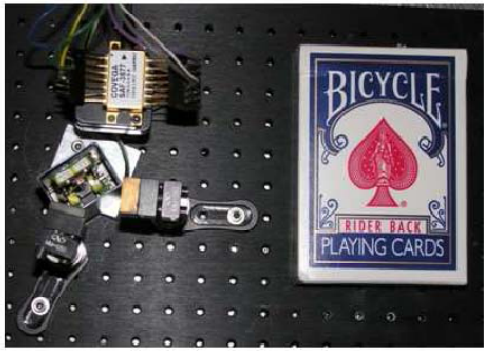
Swept sources





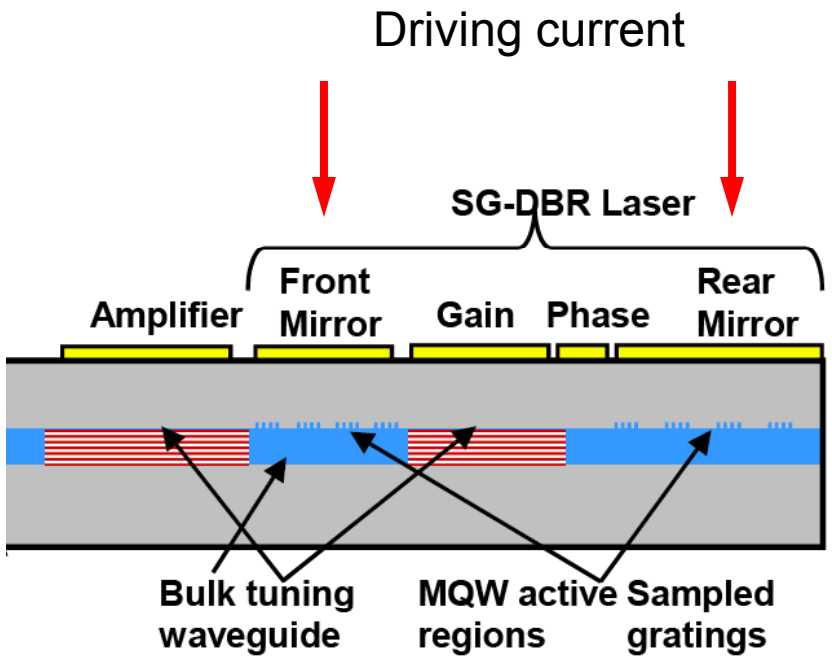
- Wall plug Systems available
- 16 kHz – 20 kHz
- ~ 125 nm sweep range
- ~30 k€

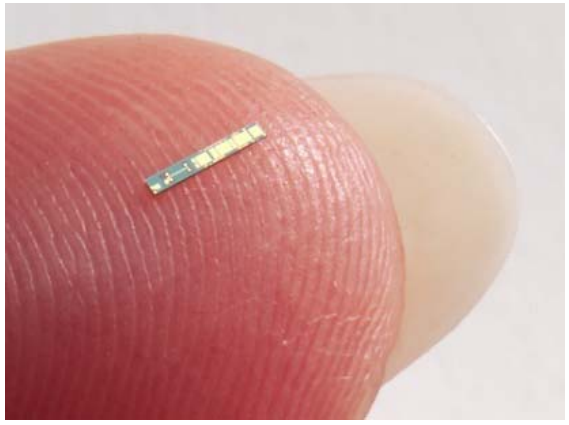




Goldberg, OpticsExpress 2009

Integratete swept source: SG-DBR (sampled grating)





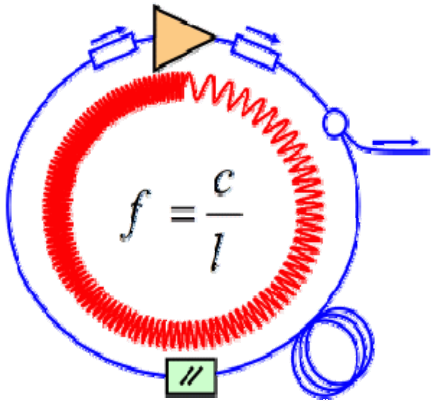
From: Judson

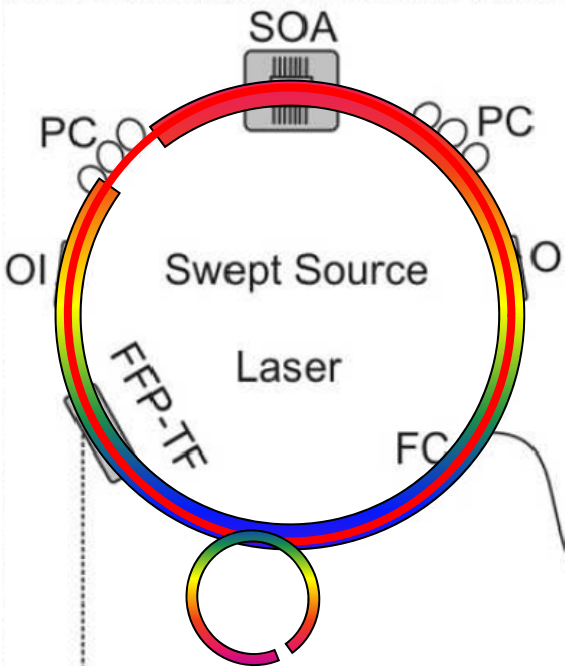
+ Small size (3 mm chip length)
+ Low cost
+ Wavelength can be engineered
+ 5 ns frequency switching time

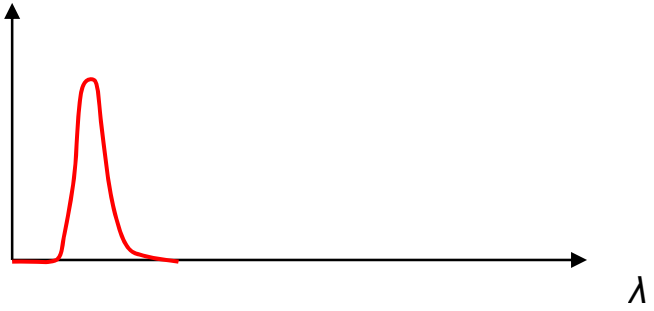
- complicated driving sceme
- wide laser line width (10MHz)
- Moderate output power (10 mW).

FDML Laser (Fourier Domain Mode Locking)

SOA	Broadband semiconductor optical amplifier
FFP	Fabry-Perrot tunable filter
OI	Optical Isolators
FC	Fiber coupler
FDL	Fiber delay line

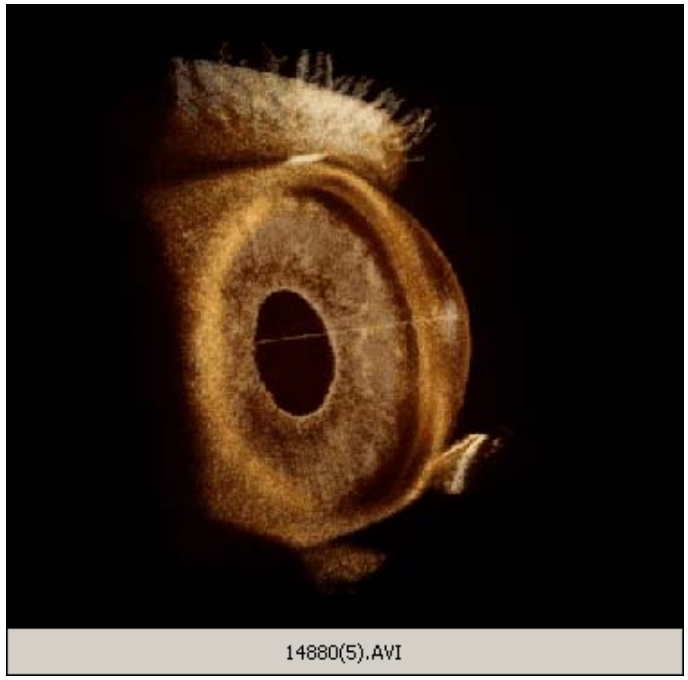


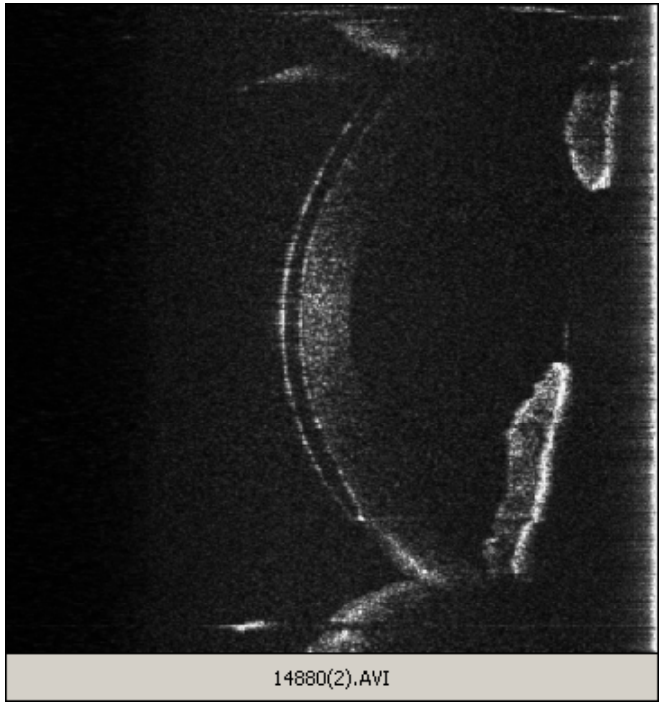




up to 200 kHz sweep rate
Gora, 17. Aug. 2009,
OpticsExpress

FDML





Gora, M.;…Wojtkowski, M.
OpticExpress, Aug. 2009

OCT summary

- Modern OCT Systems are based on Fourier/Frequency Domain (FD-OCT)
- Static broadband source and Spectrometer –> Se FD-OCT
- Swept source and single detector -> Te FD-OCT
- OCT need high speed, scan rates > 100kHz are demonstrated
- Movies or high resolution 3D images without motion artefacts are feasible

OptoLab in Biel

- Different projects in the field of OCT are running
- Places for master student available
- Master Thesis in the field of OCT are possible, for Biomedical Master and MSE Laser + Photonics
- Partial financing is possible

Thank you for your attention