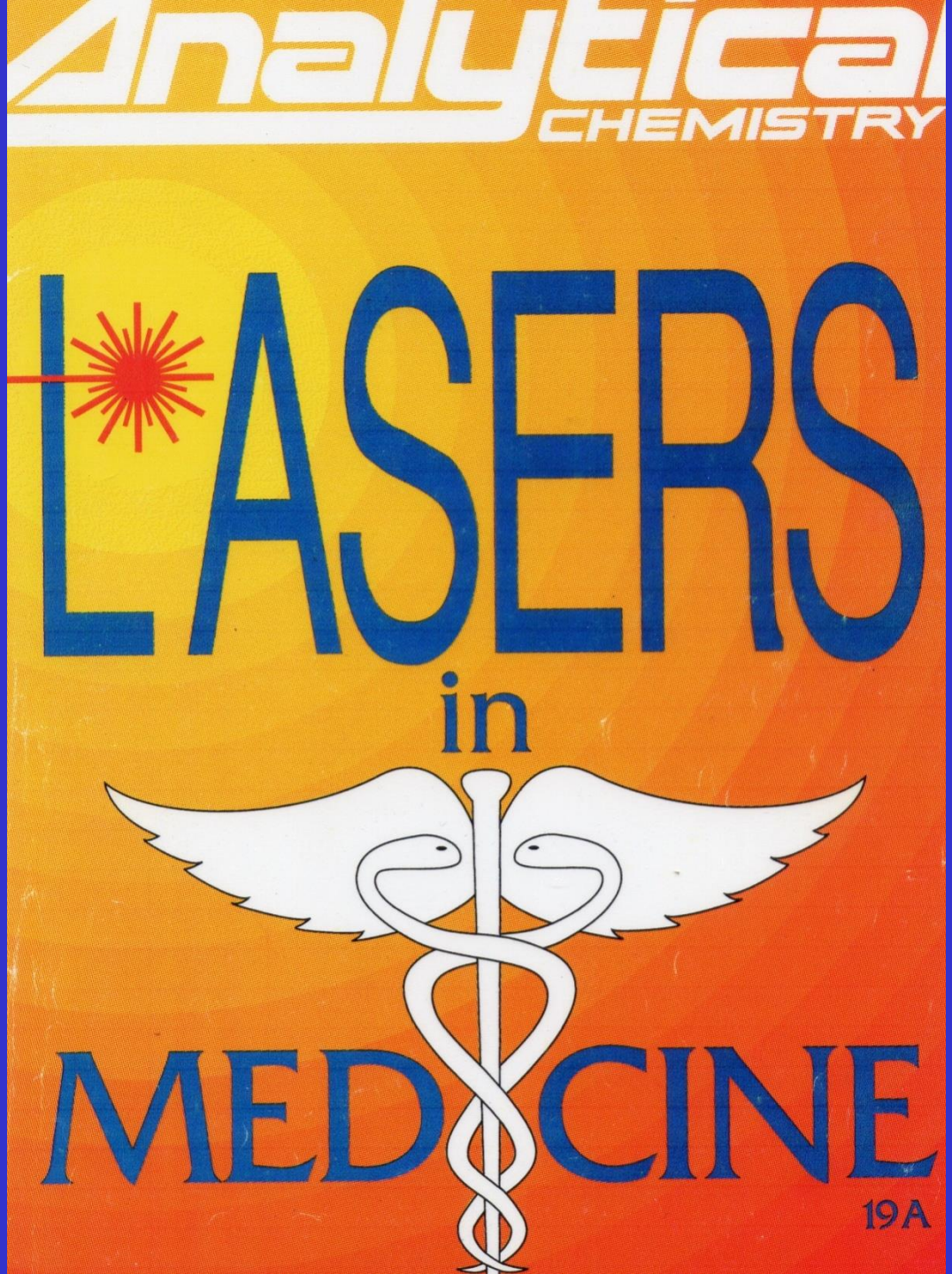
Lasers and Spectroscopy in Medicine

Based on a lecture in connection with
a symposium in honour of Prof. Bo Baldetorp,
outgoing chair of Department of Clinical Sciences, Lund University Hospital

Katarina Svanberg
Sune Svanberg

Lund Medical Laser Centre
LLC
Lund University
Sweden



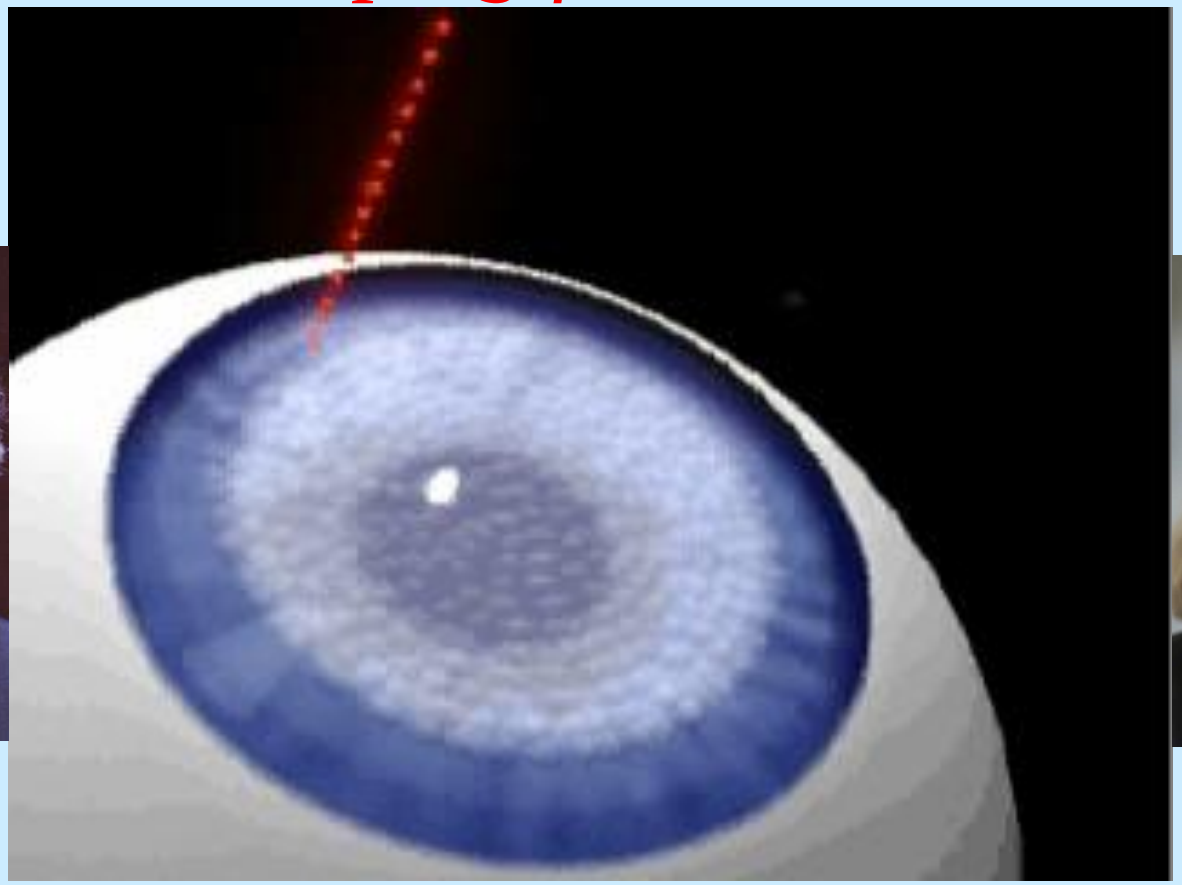
Analytical Chemistry Review by Lund University Researchers (1989)

Medical Laser Treatment

Early LU work:
Stig-Björn Lundqvist
Zoltan Bekassy
Sven-Erik Karlsson
Birgitta Bauer
Karl Tranberg

- Laser surgery
  - Eye (Ar-ion, Nd:YAG, Excimer lasers, CPA Ti:S)
  - Skin (CO_2-, Dye, Ruby, Ar-ion lasers)
  - General Surgery (Nd:YAG, diode, CO_2 lasers)

Femtosecond Surgery
Corneal Reshaping for Vision Correction



Courtesy: T. Juhasz, R. Kurtz, G. Mourou

Enabled through chirped-pulse amplification (CPA) lasers

24 million patients treated – Nobel Prize Physics 2018 (Strickland and Mourou)

Lund Laser Medicine Group 1983 - Medical Laser Centre 1991 -

Laser-Induced Fluorescence Studies of Hematoporphyrin Derivative (HPD) in Normal and Tumor Tissue of Rat

Appl. Spectr. 1984

J. ANKERST, S. MONTÁN, K. SVANBERG, and S. SVANBERG

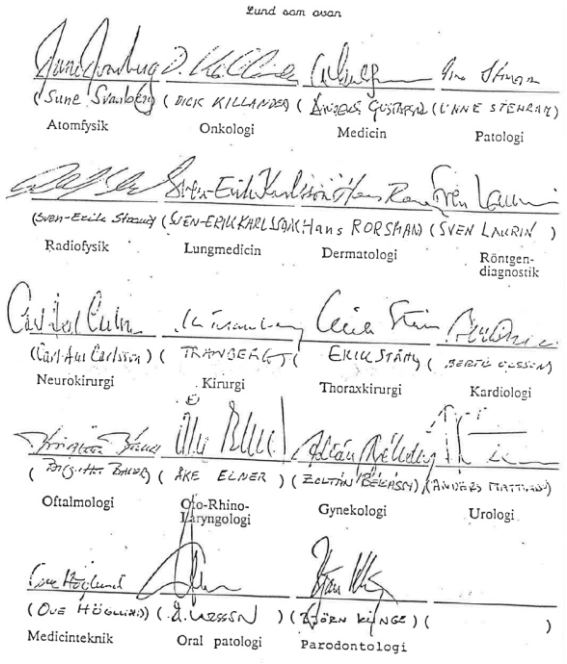
Multicolor imaging and contrast enhancement in cancer-tumor localization using laser-induced fluorescence in hematoporphyrin-derivative-bearing tissue

Optics Lett. 1985

S. Montán, K. Svanberg,* and S. Svanberg

1990 LUMLAC Proposal

Framställan om inrättande av ett för Medicinska och Tekniska Fakulteten gemensamt Medicinskt Lasercentrum



Present biophotonics in Lund (partial list)

N. Reistad, Chr. Sturesson *et al.* *Tissue spectr.*

V. Fellman, E.K. Svanberg et al., *oxygenation*

S. Kröll, L. Edvinsson et al., *Slow light appl.*

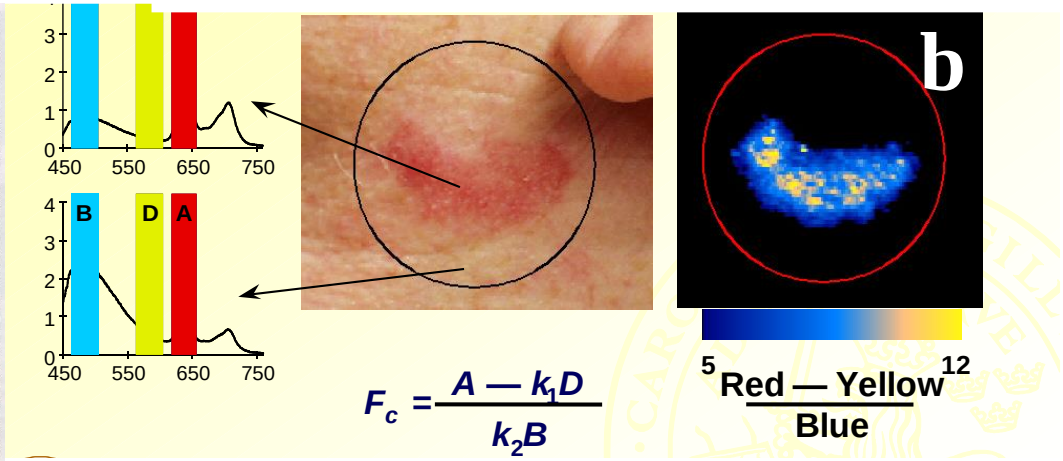
M. Malmsjö, N. Reistad et al. *Clin. Ph.acoust.*

J. Bood et al. *GASMAS*

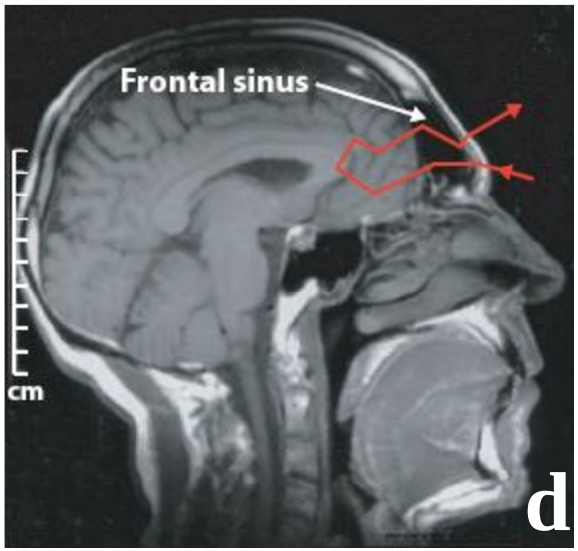
N. Bendsoe et al. *Dermal PDT*

Spectracure AB, Gasporox AB, GPX Medical ..

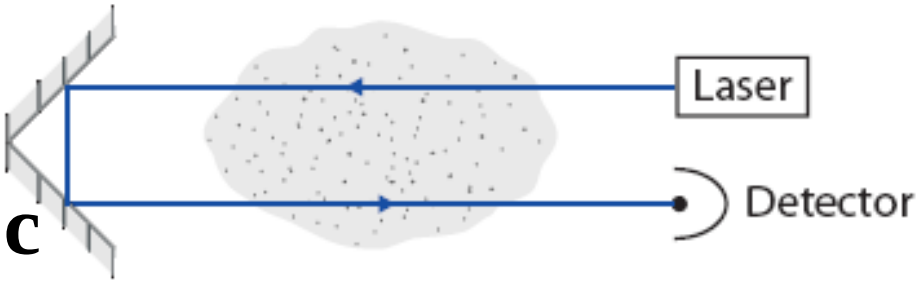
Example of Cross-Disciplinary Approach at Lund University: Environmental Monitoring connected to Biophotonics



Medicine



Environment

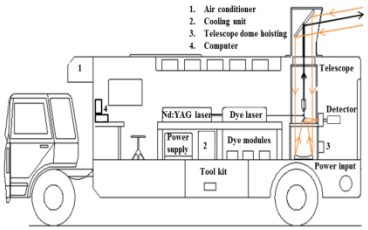


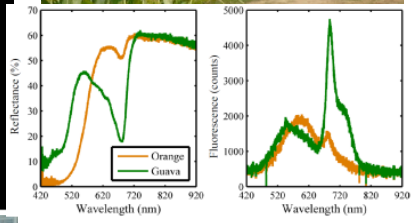
Along the same lines:

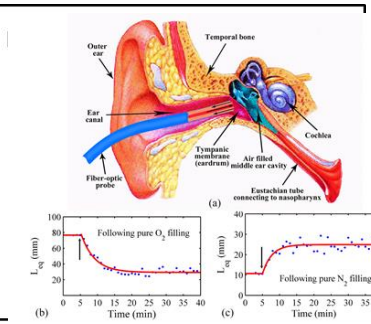
Interdisciplinary Sensing Group in Applied Laser Spectroscopy
South China Normal University, Guangzhou

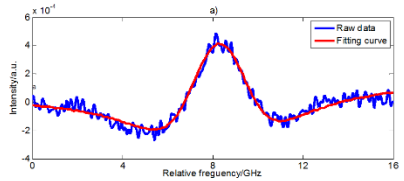
(Katarina Svanberg, Sune Svanberg; LU researcher with part-time China affiliation)

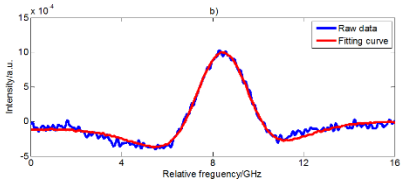
Environment - Ecology - Agriculture - Food Safety - Biomedicine

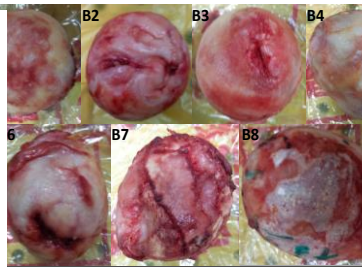


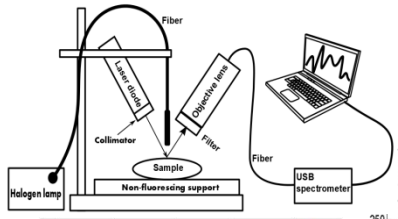


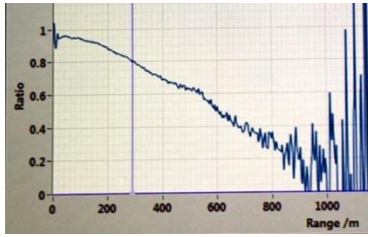


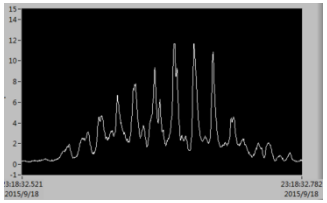


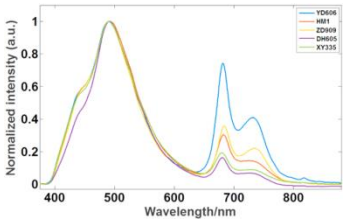


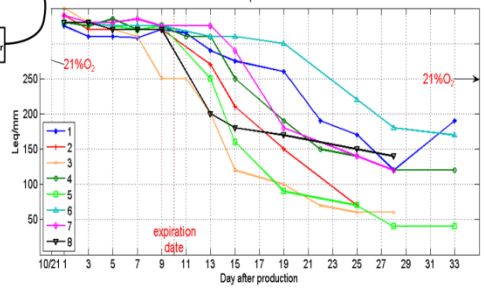


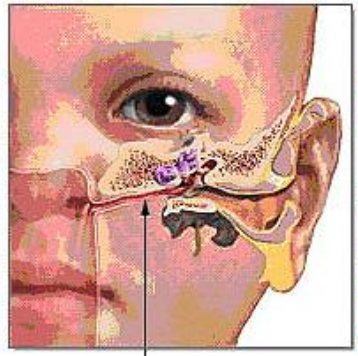






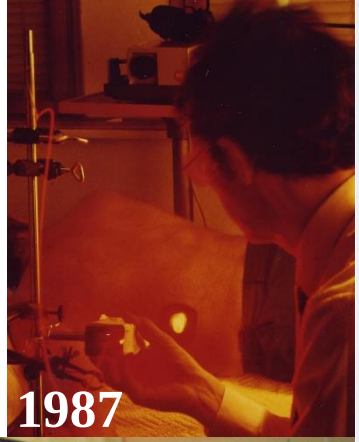


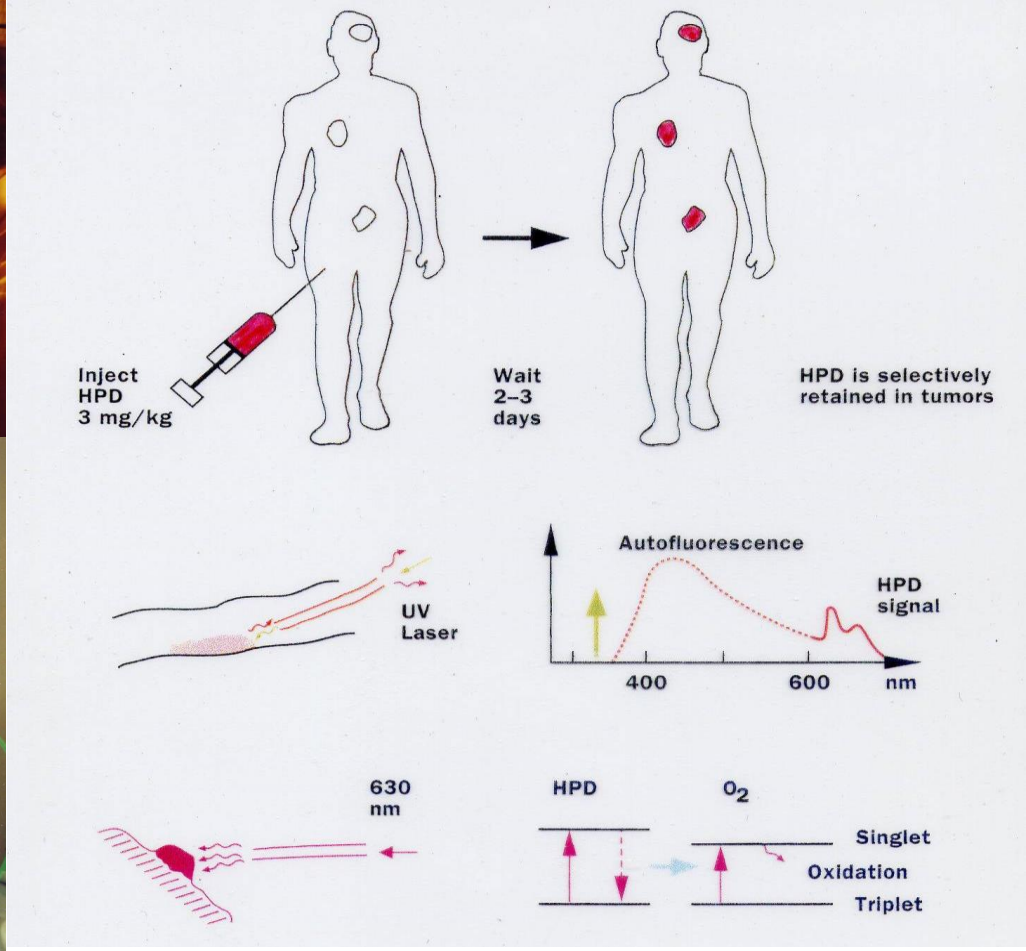




Photodynamic therapy (PDT) of malignant tumours

Early Coll.: E. Kjellén

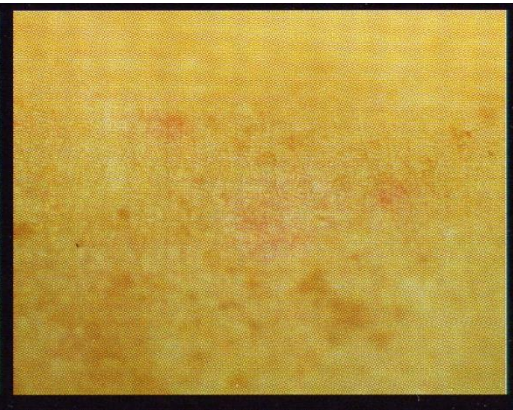




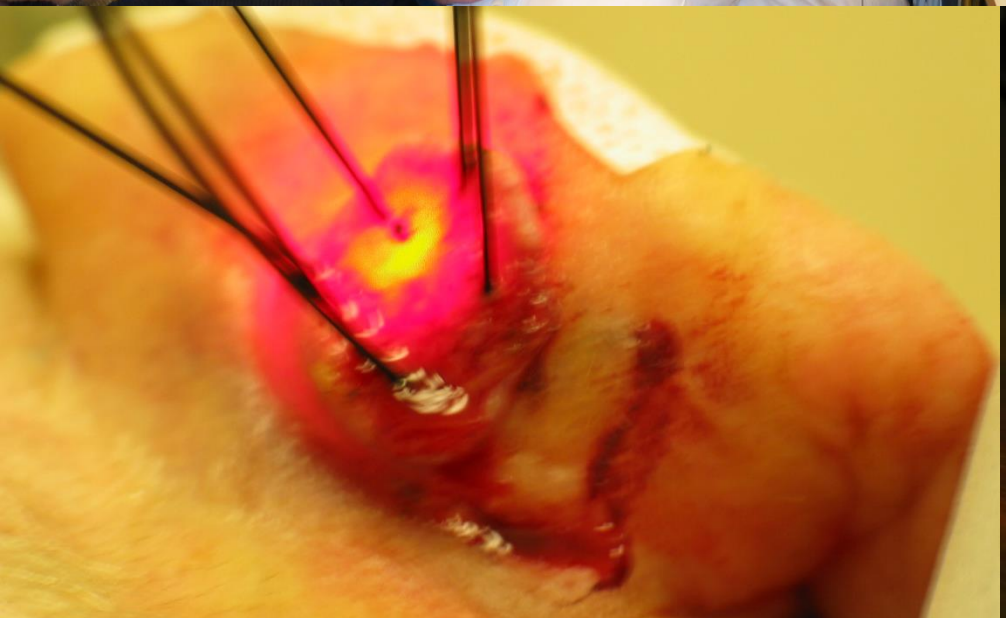
Coll.: D. Killander, T. Andersson, N. Bendsoe

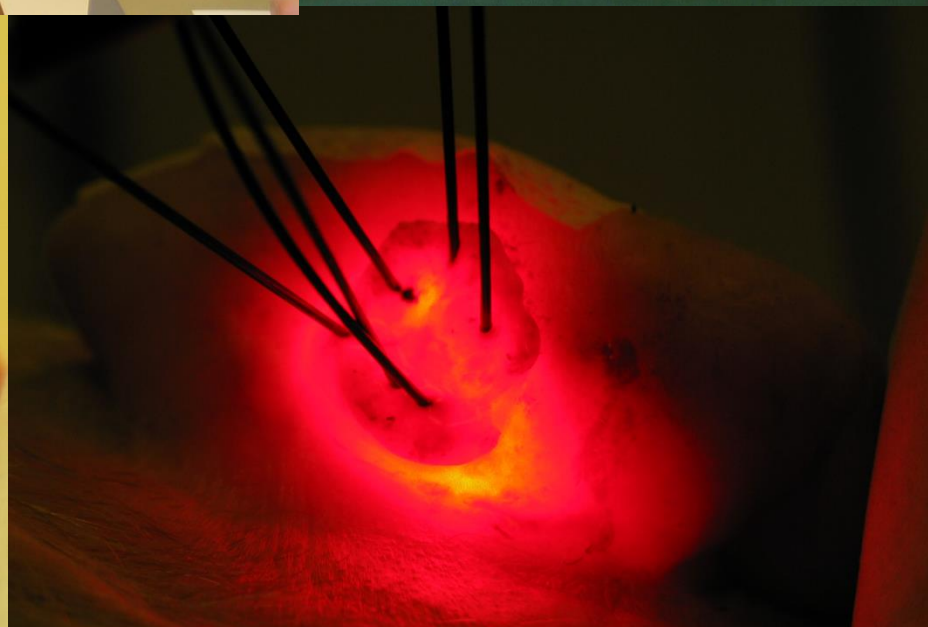
PDT of basal cell carcinoma and squamous cell carcinoma

Br. J. Derm. (1994)

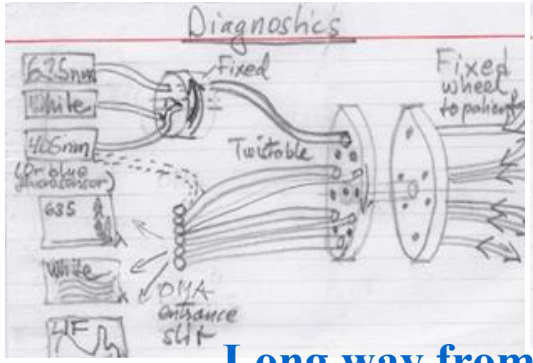


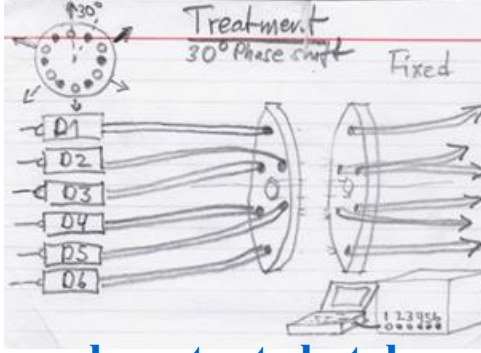
Interstitial Photodynamic Tumour Therapy



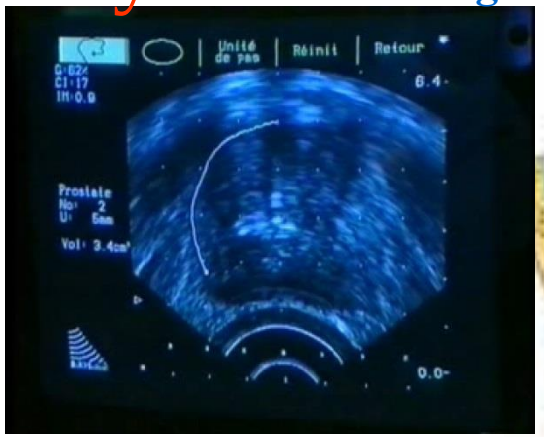


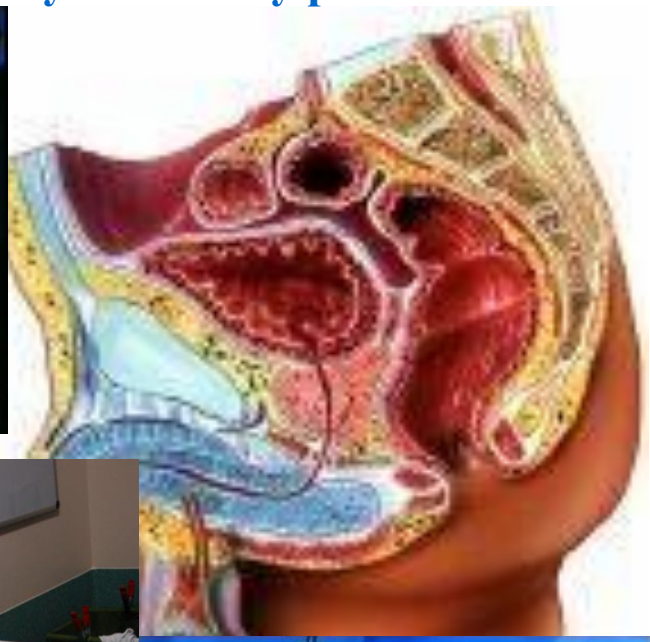
PDT interstitial treatment of recurrent prostate cancer integrated with dosimetry

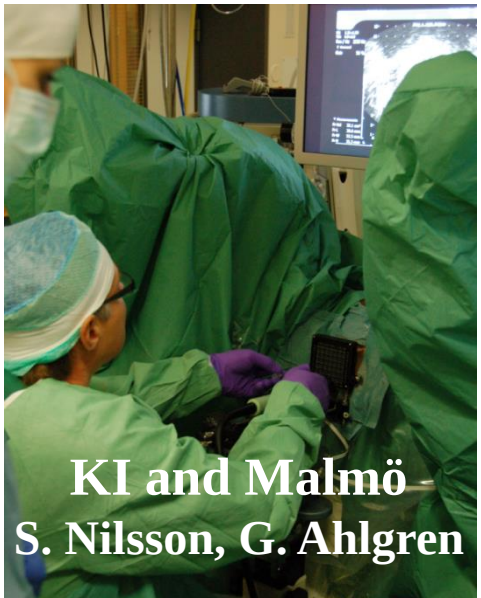




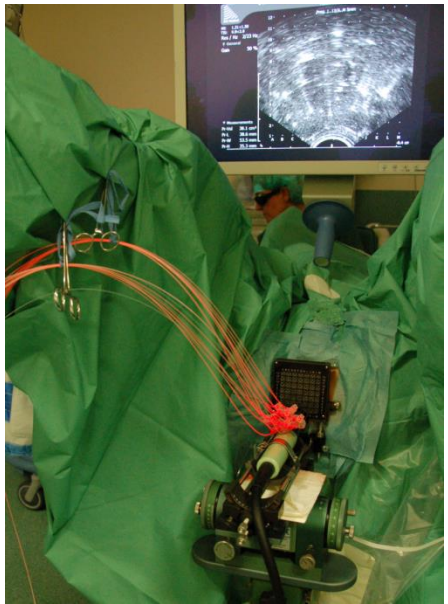
Long way from early patent sketch …

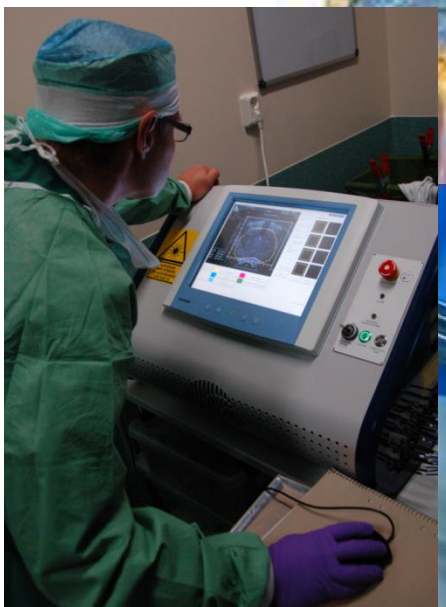




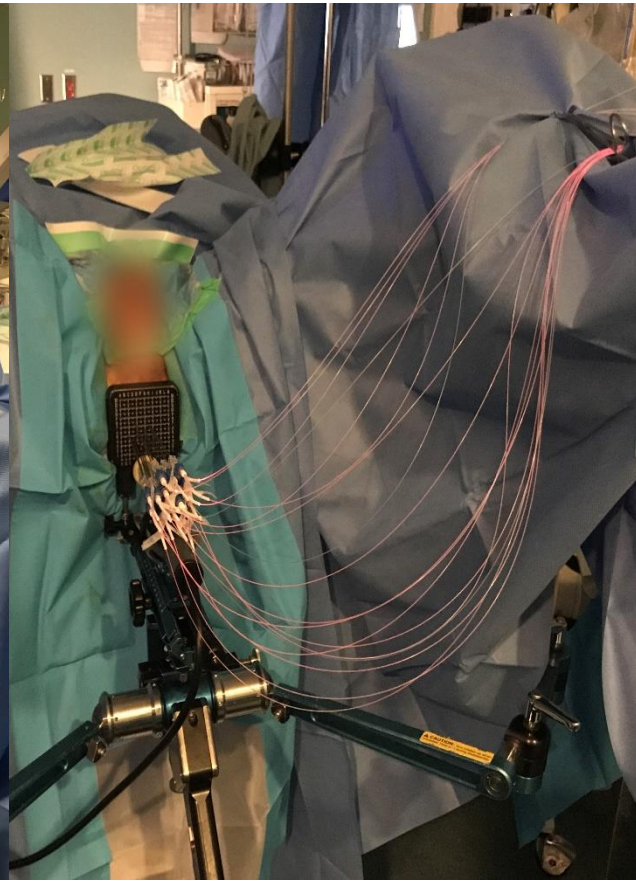


KI and Malmö
S. Nilsson, G. Ahlgren





Interstitial PDT of recurrent prostate cancer



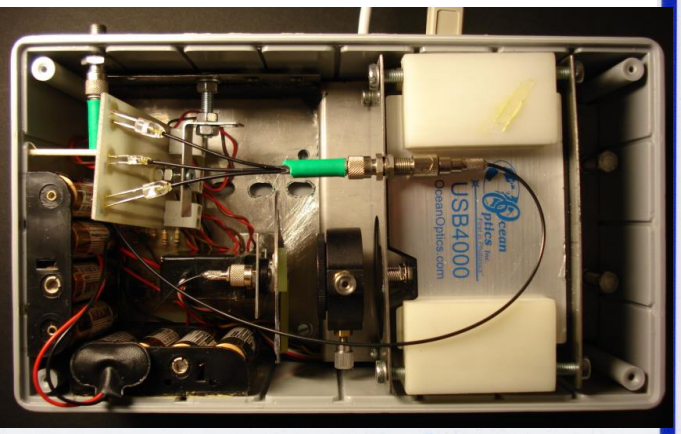
Treatment planning Fiber positioning Therapy

Nathan Perlis and Robert Weersink, Princess Margret Hospital, Toronto

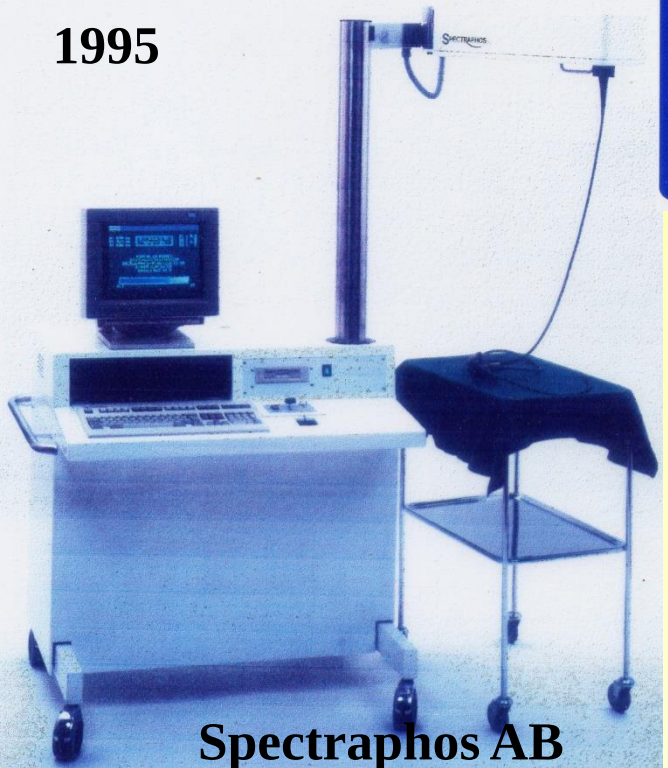
(April 2017)

Clinical studies in Toronto, Philadelphia and London

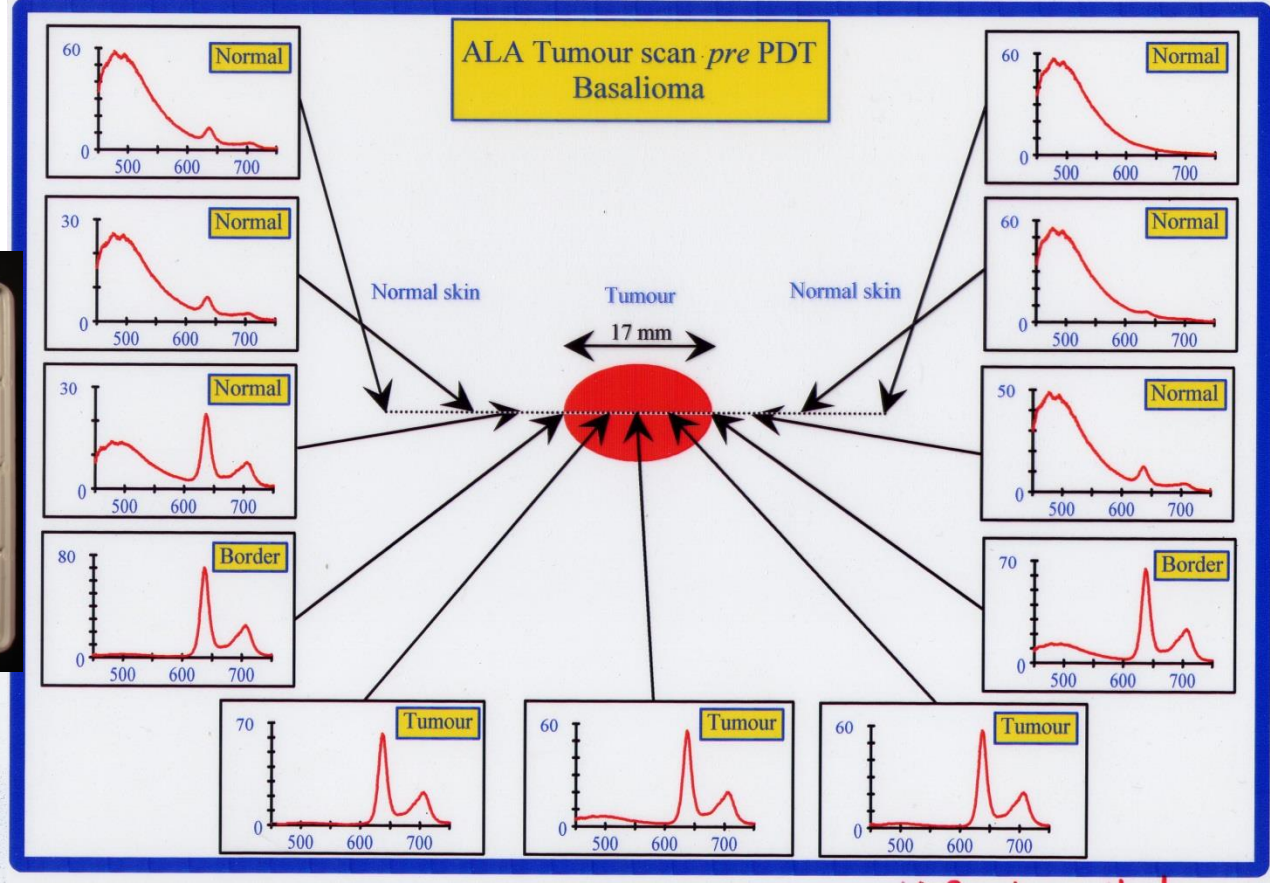
Fluorescence Diagnostics of Malignant Disease

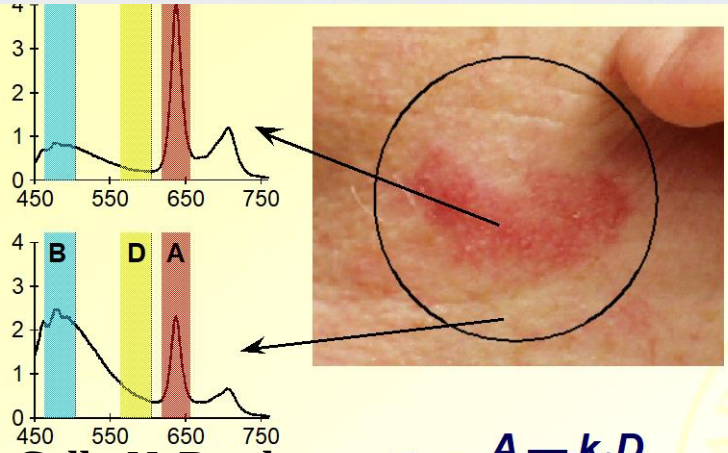


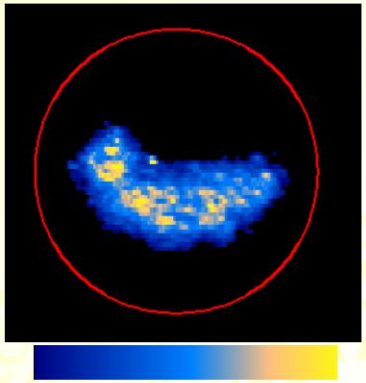
1995



Spectraphos AB







$$F_c = \frac{A - k_1 D}{k_2 B}$$

$$\frac{\text{Red} - \text{Yellow}}{\text{Blue}}$$

Coll.: N. Bendsoe, L. Salford, S.E. Karlsson

Flow cytometry in cancer research (laser-induced fluorescence labelled malignant cells)

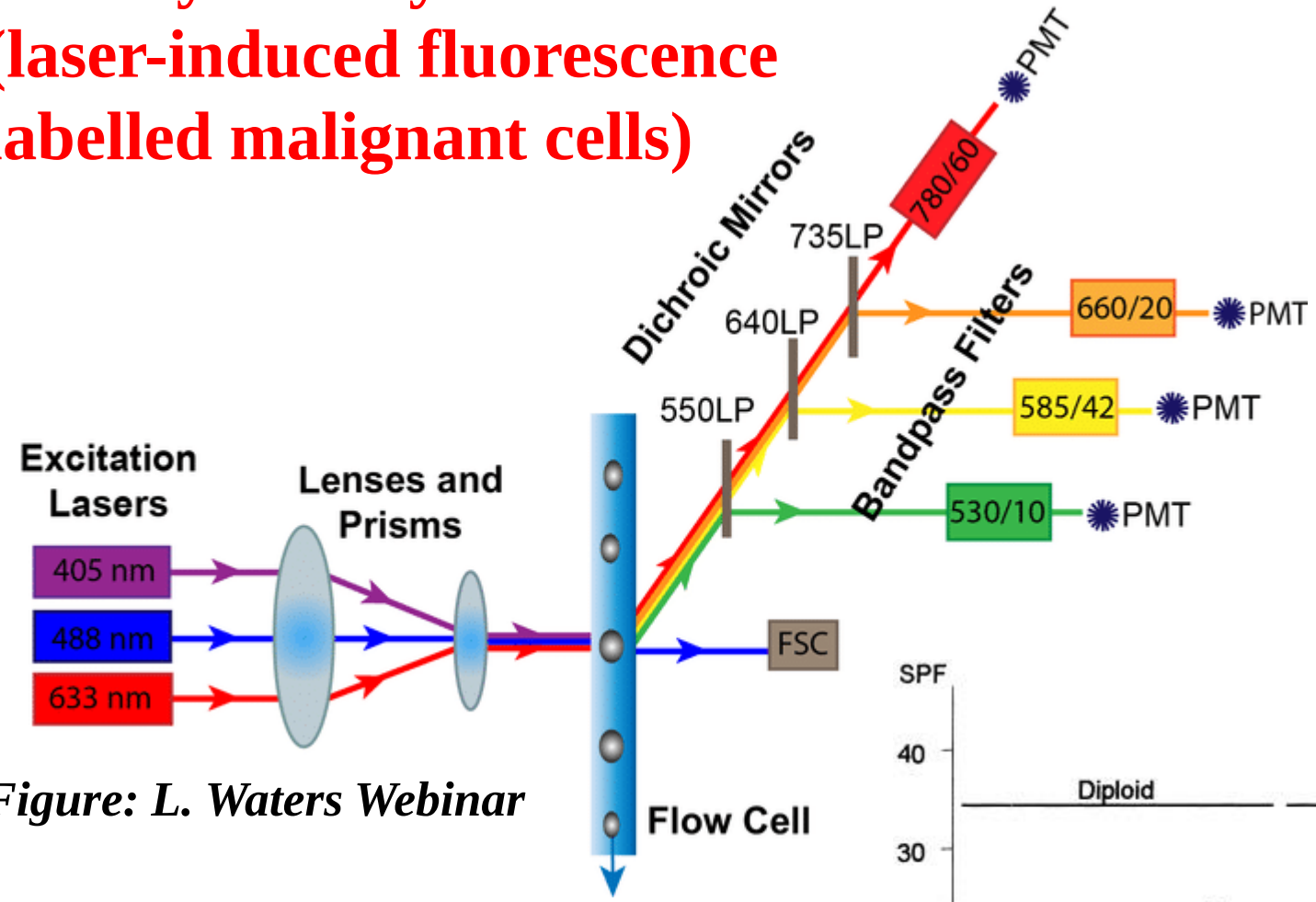
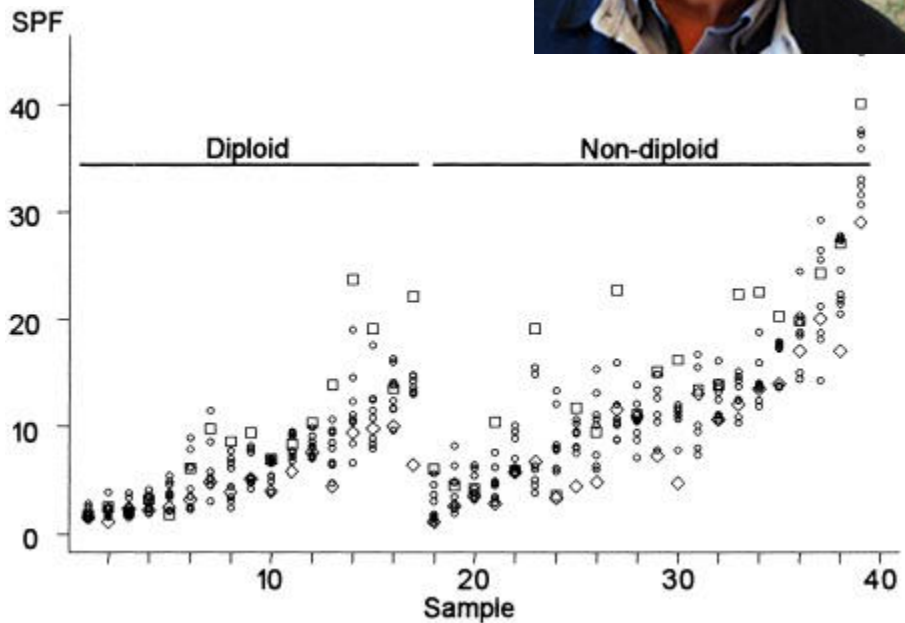
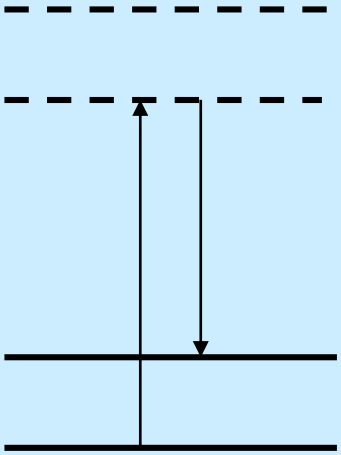


Figure: L. Waters Webinar



Baldetorp *et al.* (2013), and numerous studies before and after !! (with Killander, Fernö, Olsson….)

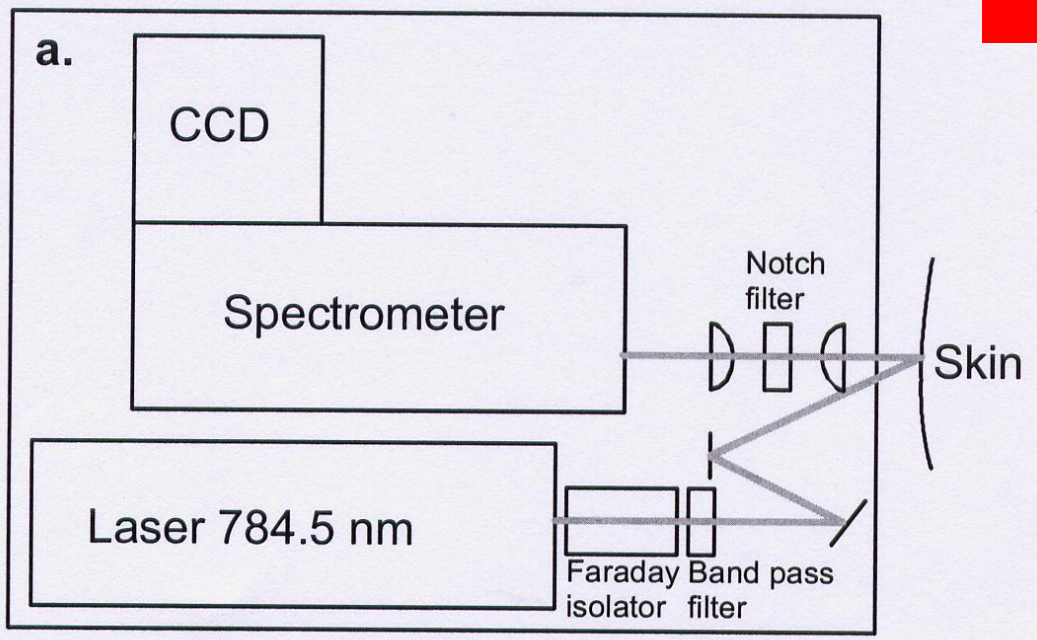
Raman Spectroscopy

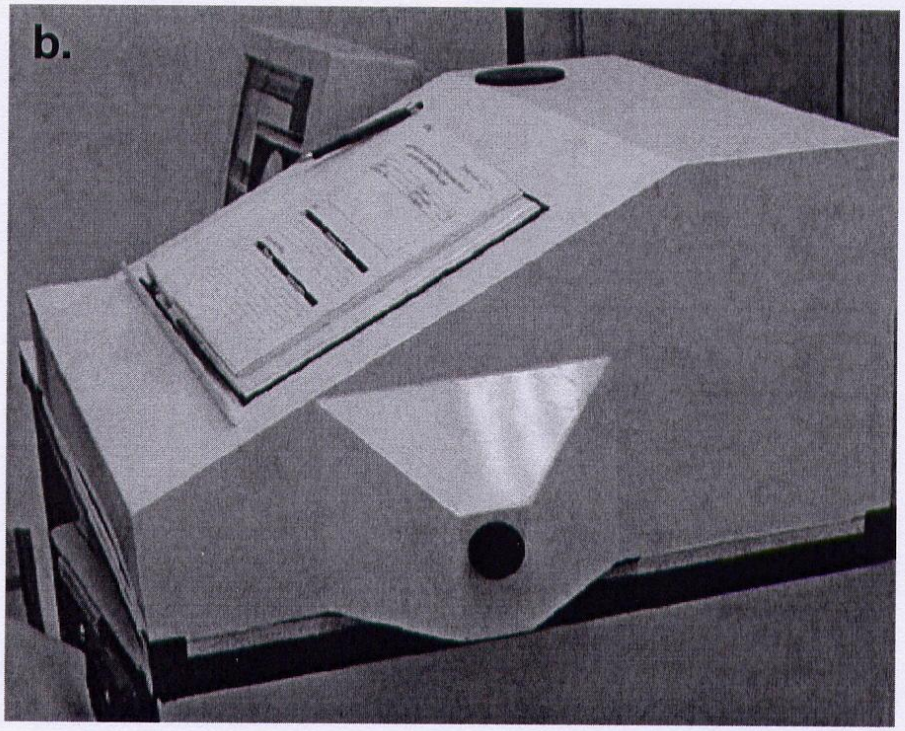


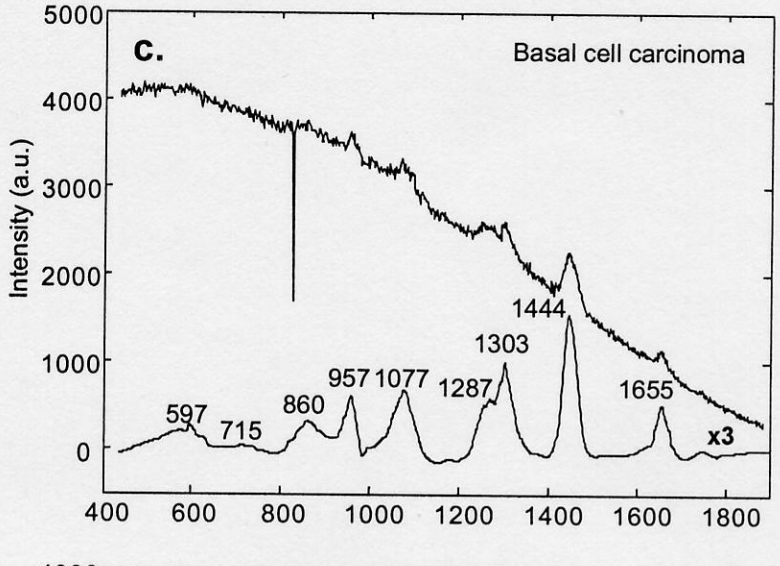
S. Pålsson *et al.* (2003)

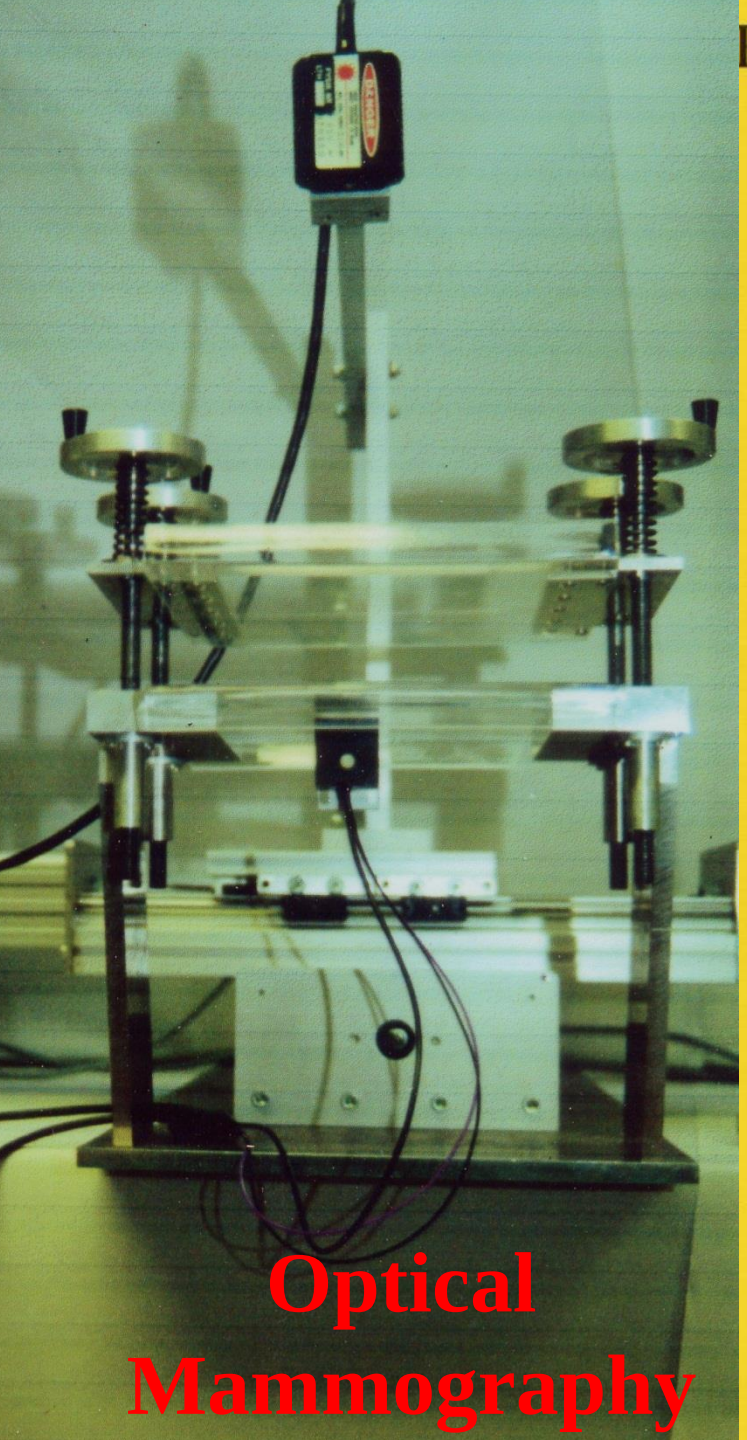
Clinical study on 64 patients

N. Bendsoe et al.





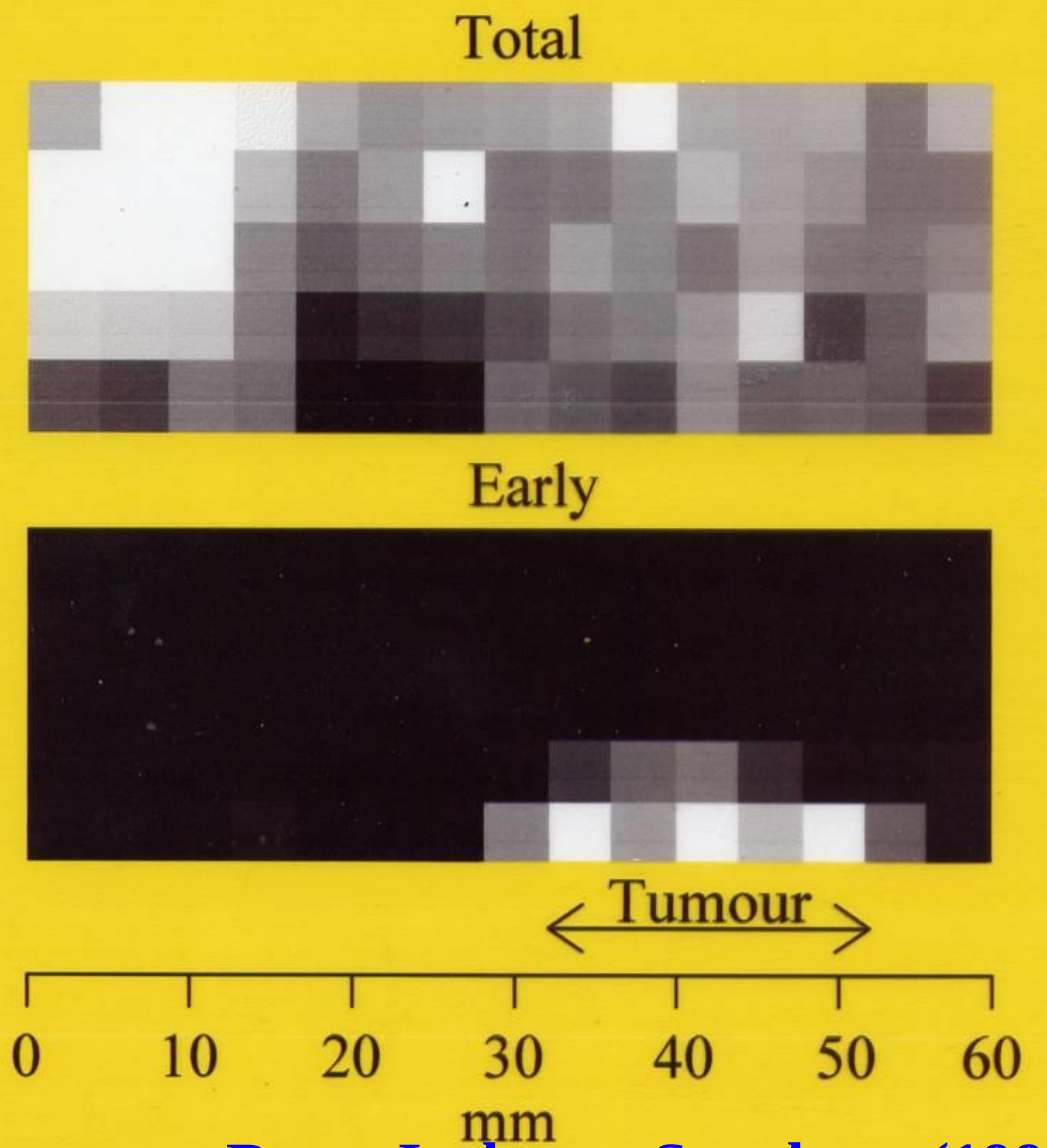




Optical Mammography

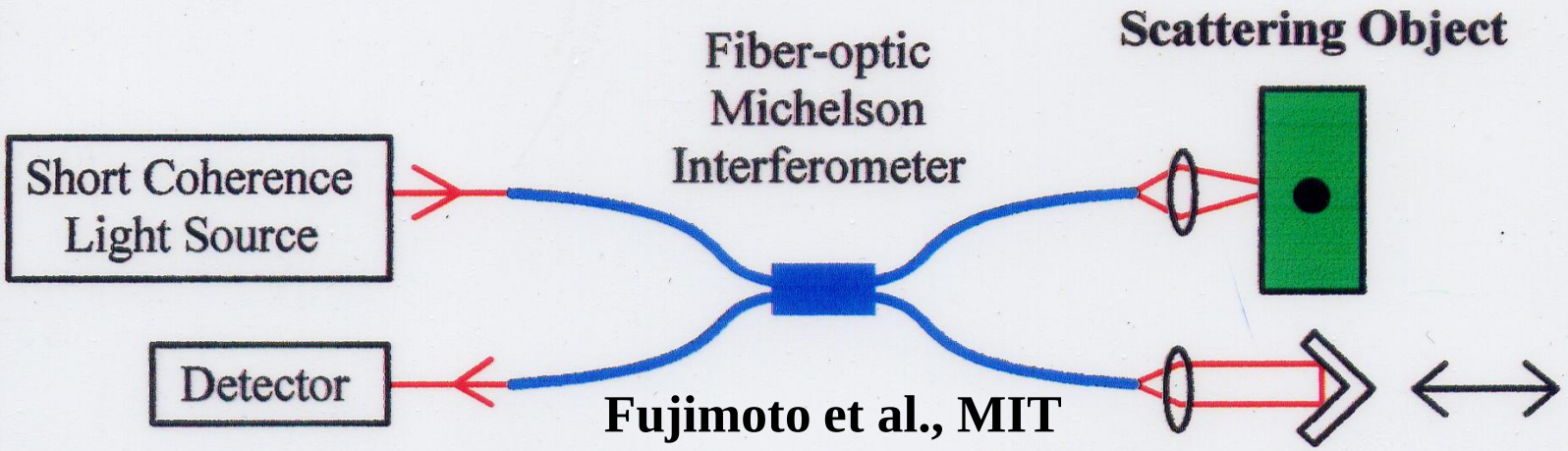
Picosecond Diode Laser Transillumination

Image of ductal cancer in female breast

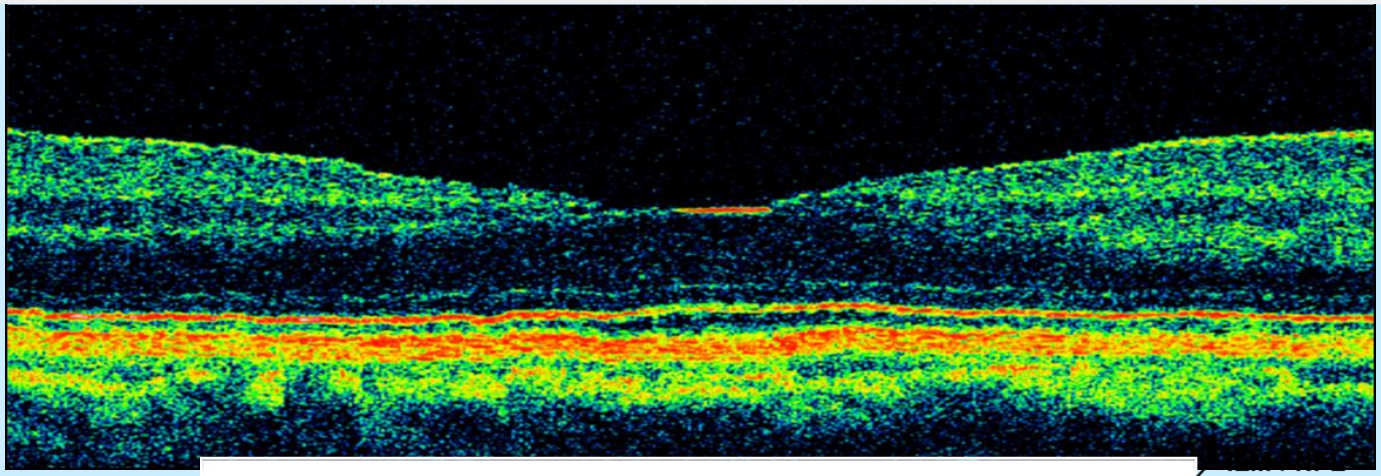


Berg, Jarlman, Svanberg (1993)

Optical Coherence Tomography

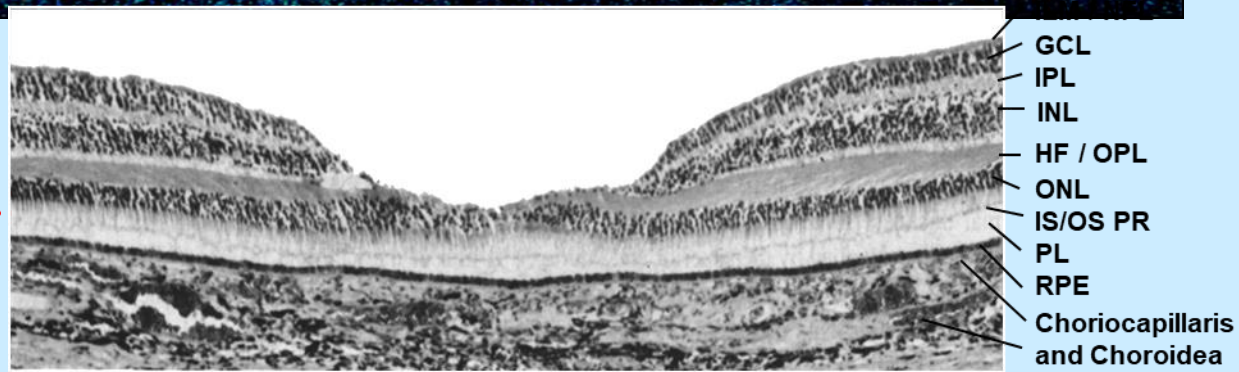


Fujimoto et al., MIT

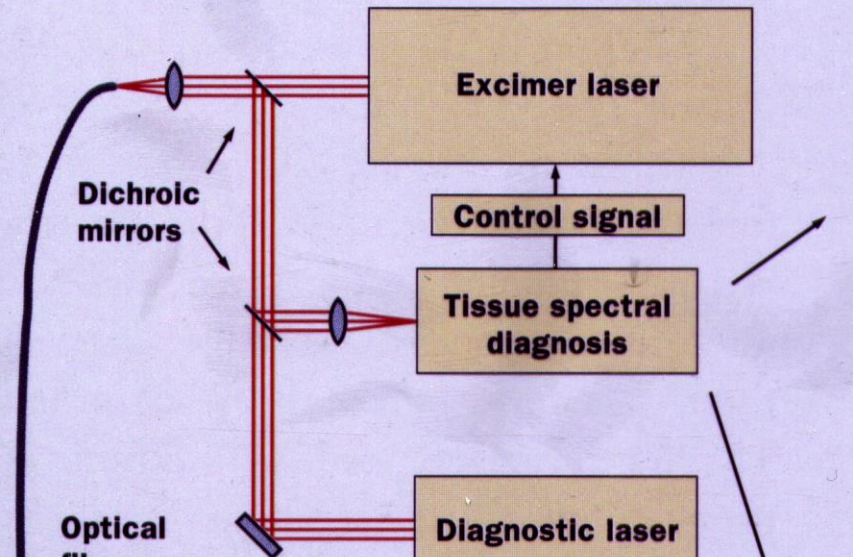


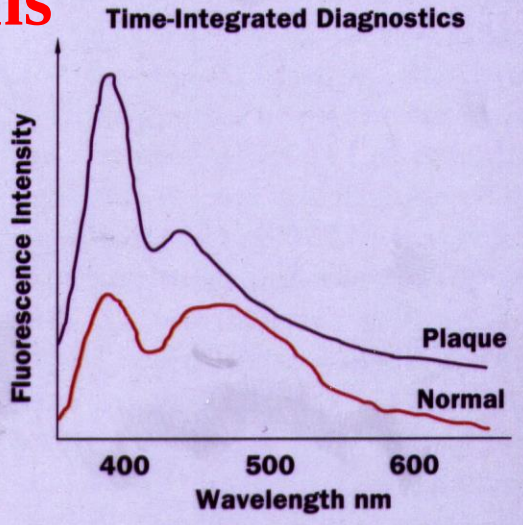
W. Drexler et al.

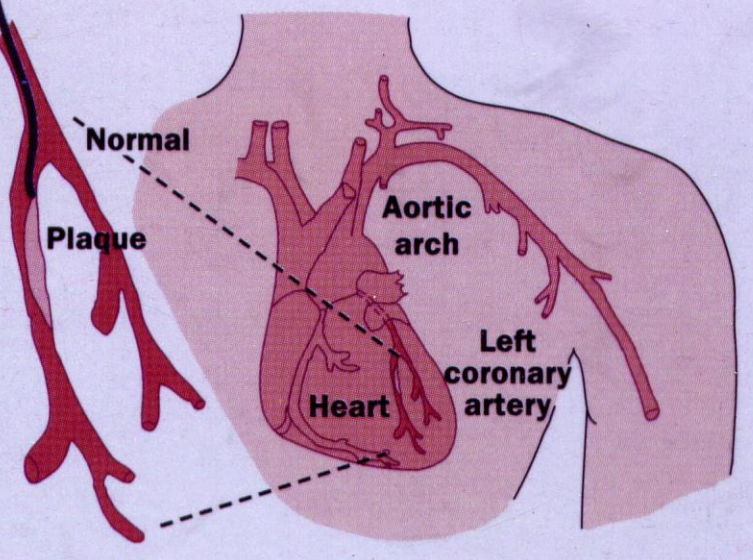
Vienna

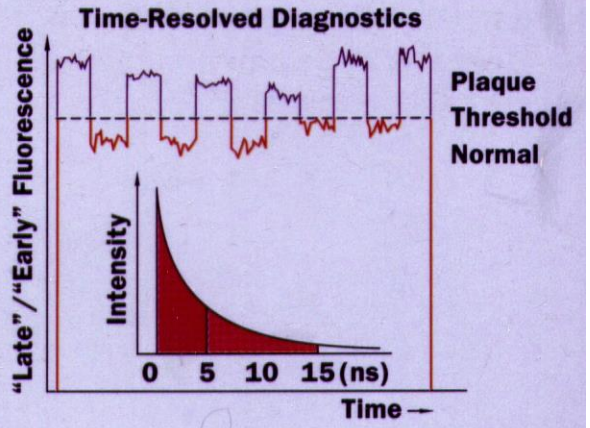


Cardiovascular applications



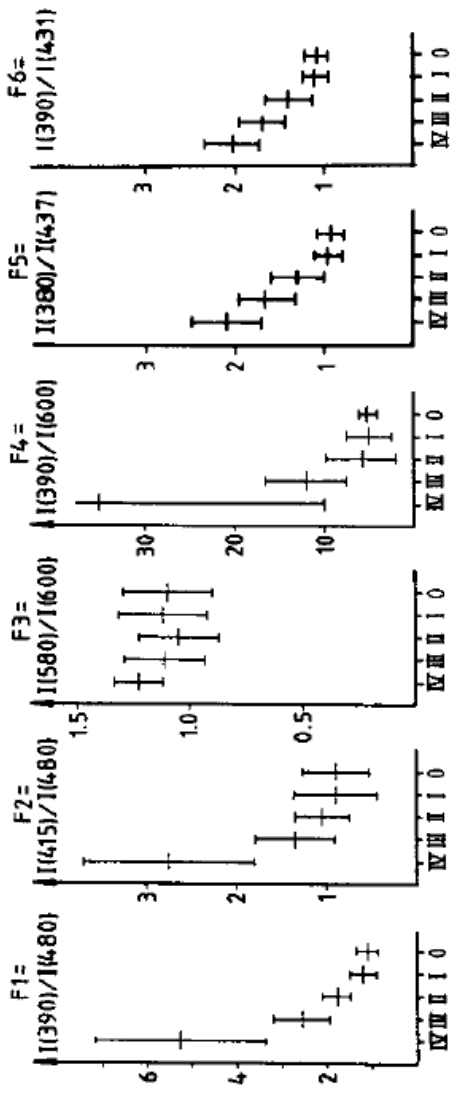




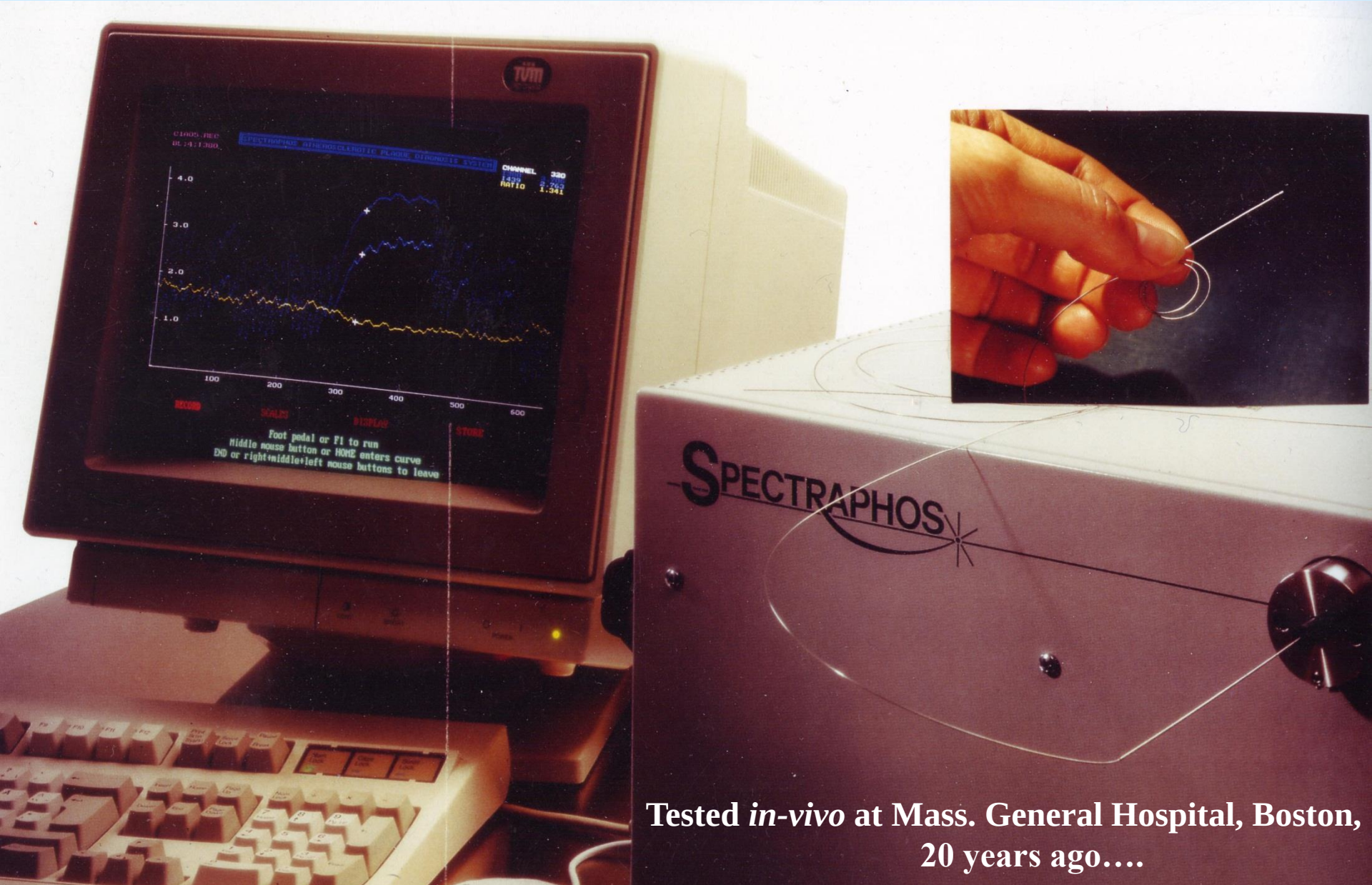


Collaboration: A. Gustafsson, S. Steen

Vessel spectroscopic diagnostics

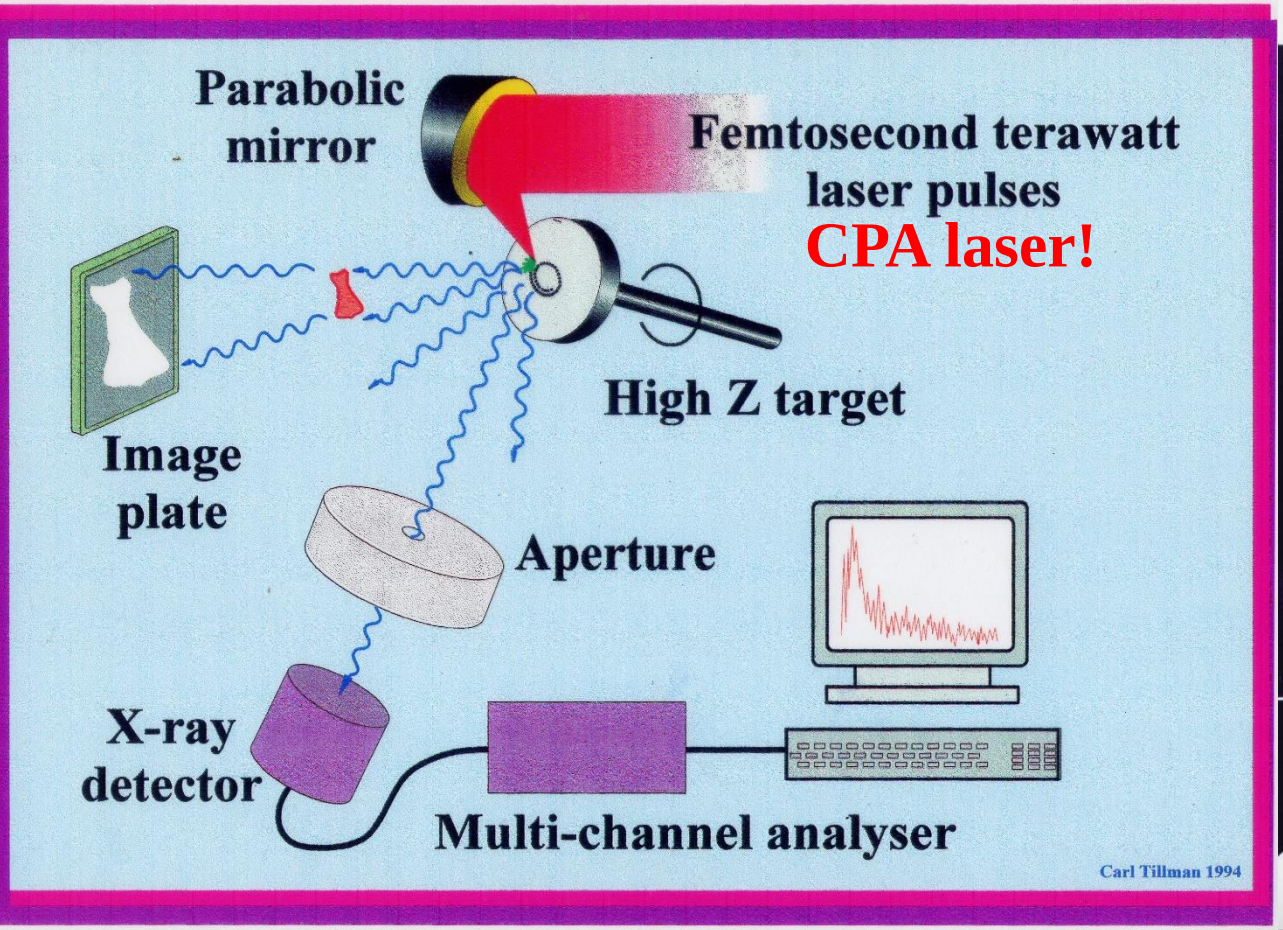


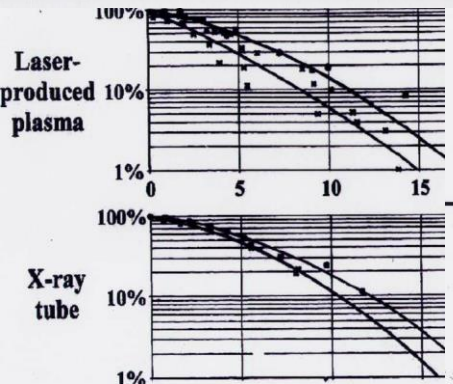
Atherosclerotic coronary artery real-time diagnostics (spectral and temporal)

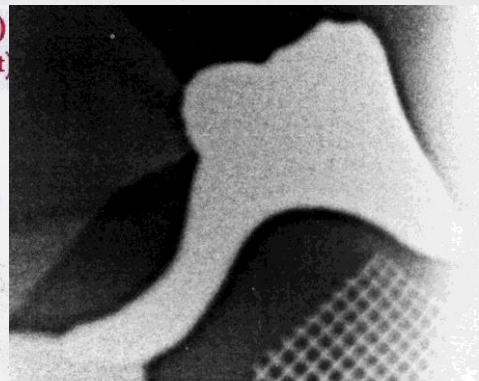


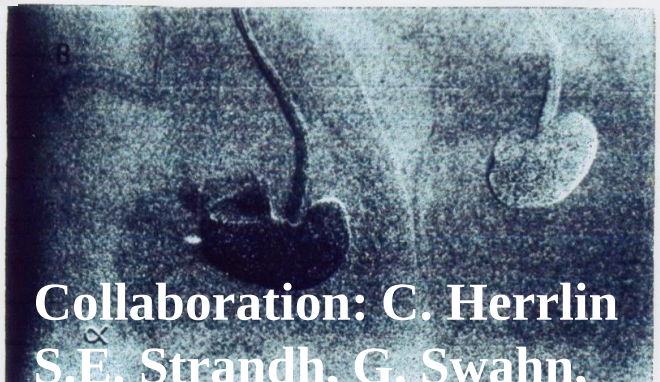
Tested *in-vivo* at Mass. General Hospital, Boston, 20 years ago….

Laser-produced hard X-rays









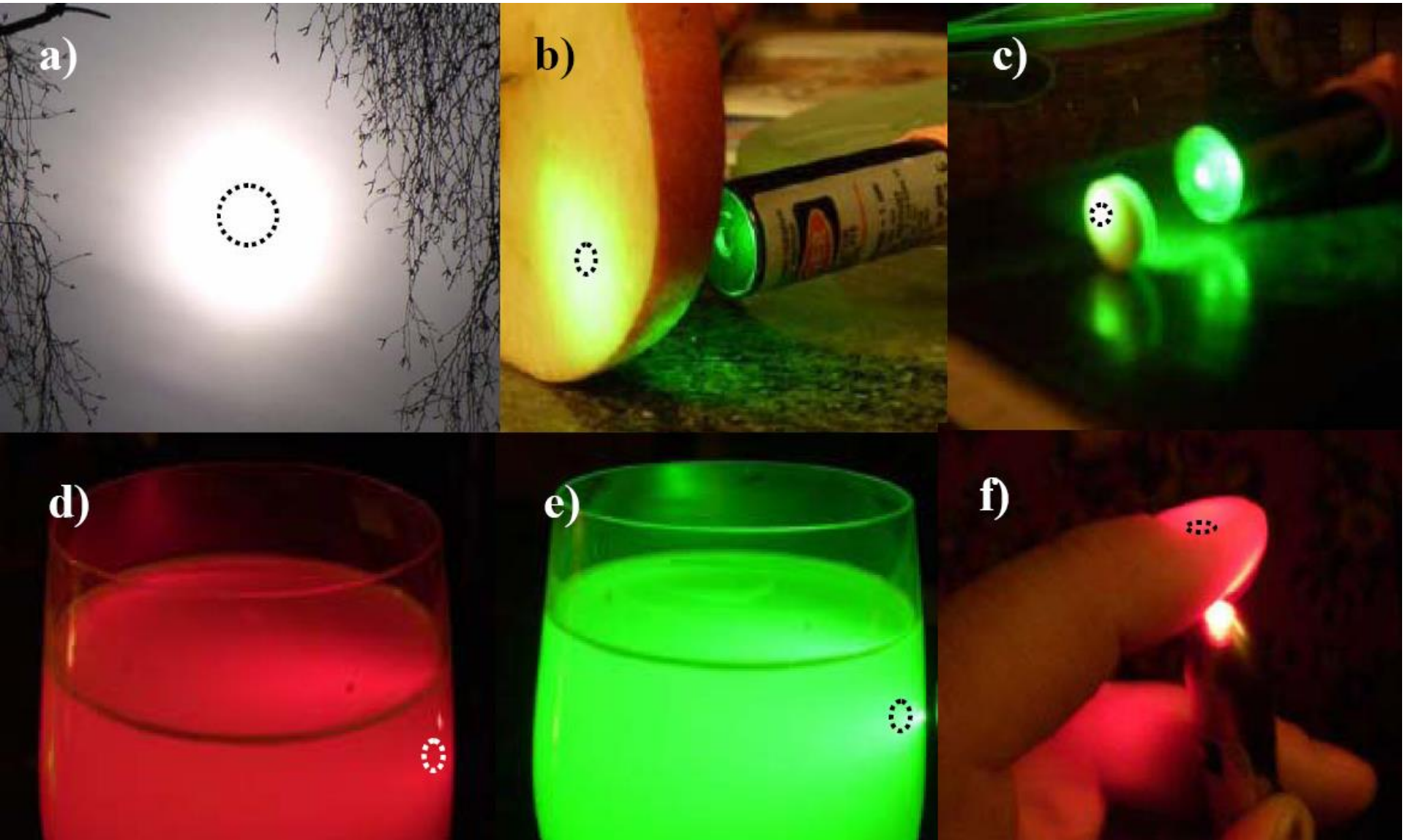
Lund Titanium-sapphire CPA Terawatt Laser

10^{+12} W x 10^{-13} s = 0.1 J !!!

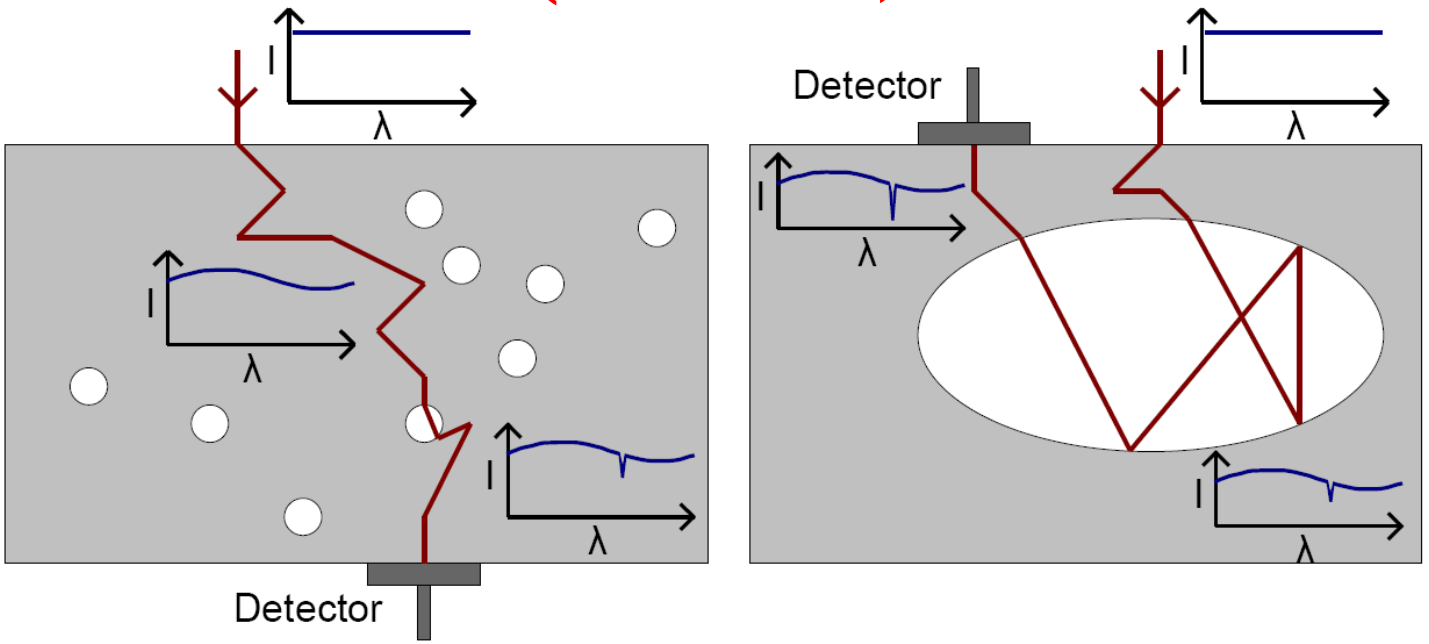
Nobelmottagning, Nordiska Museet 9 December 2018

Nobelföreläsningar
Aula Magna SU
8 december 2018

Optics in scattering media

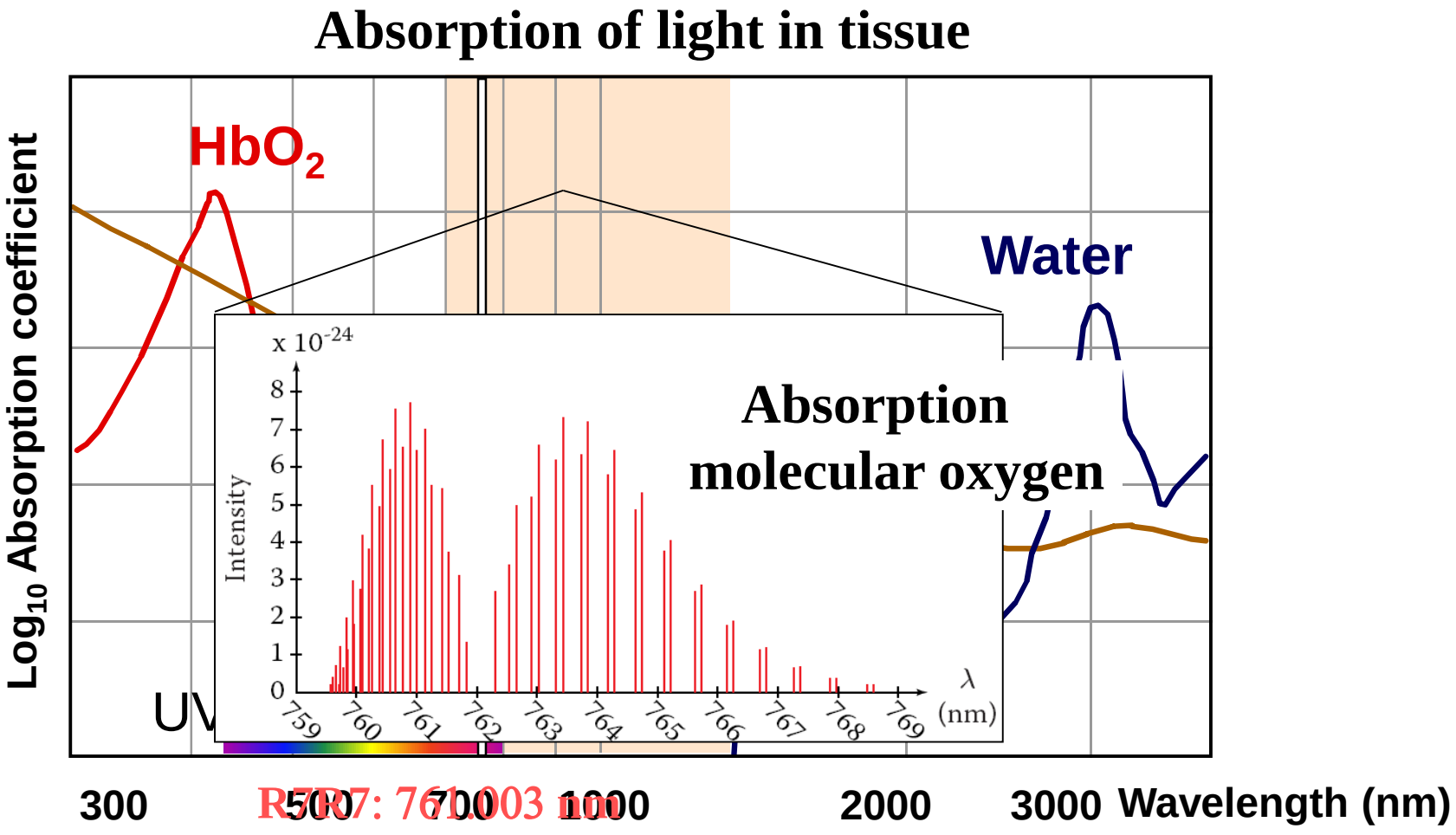


Gas in Scattering Media Absorption Spectroscopy (GASMAS)



Lewander

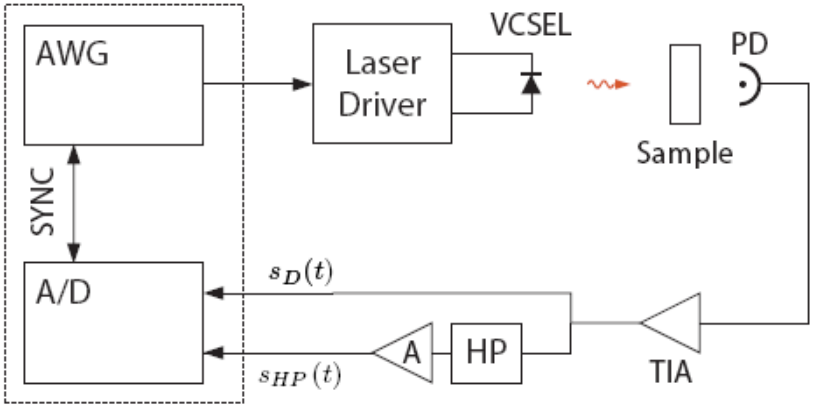
Tissue and Free-Gas Absorption

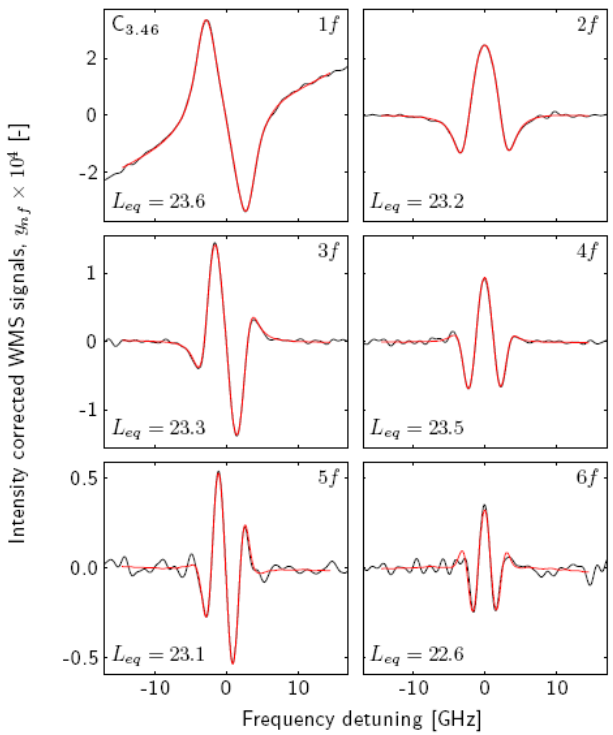


Spectroscopy on Pharmaceutical Tablets – Coll. AstraZeneca

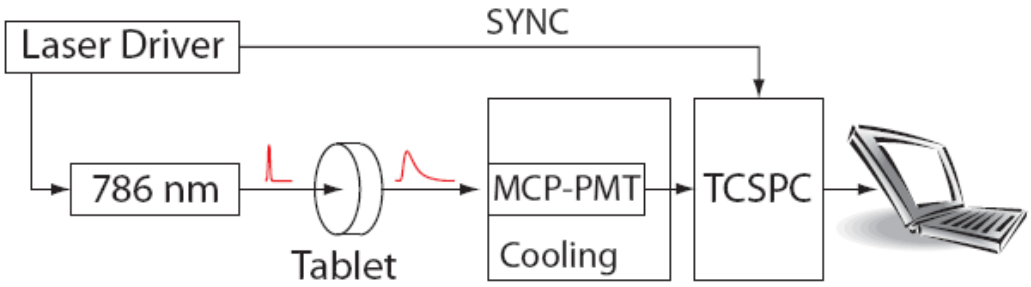
Porosity studies/delayed release

Frequency domain, oxygen

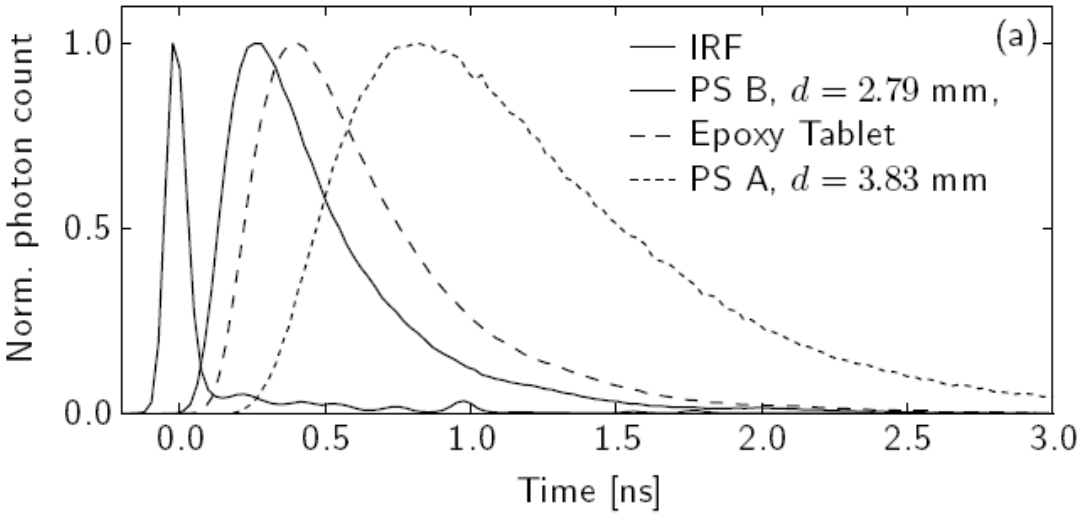




Time domain, TOF/Lidar



T. Svensson et al.



Follow-up: Alignment-free multi-pass gas cell made of nanoporous ceramics -750 times path enhancement !!

Svensson *et al.* PRL (2011)

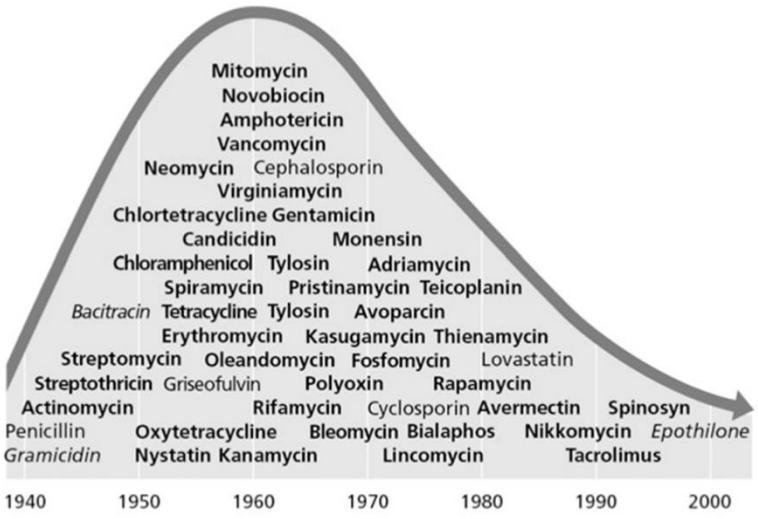
Fighting antibiotics resistance

A global challenge !

Antibiotics only work on bacteria – not on virii !

Sinusitis - Otitis

Alexander Flemming NP1945

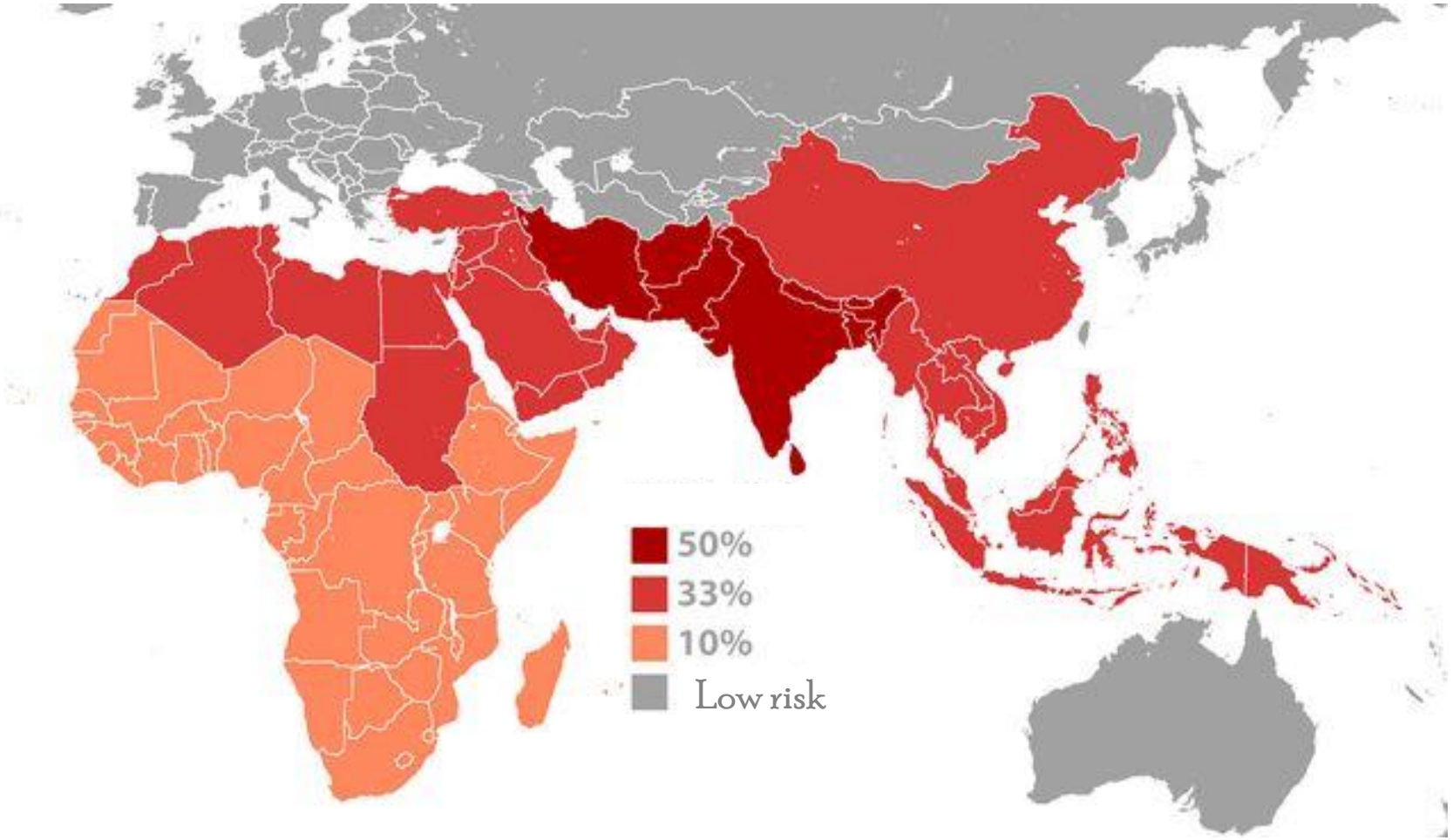


Pharmacy

in Guangzhou; free availability!

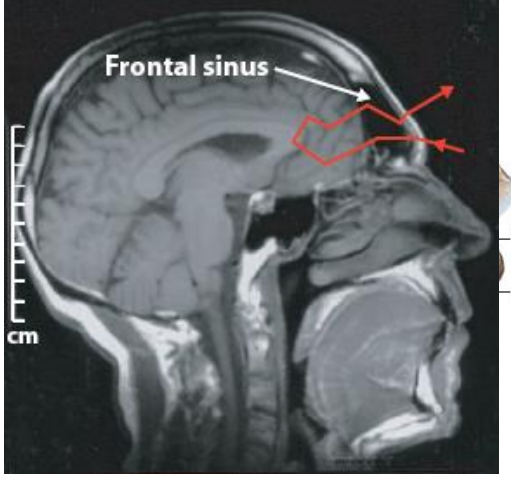
Very few new antibiotics are developed

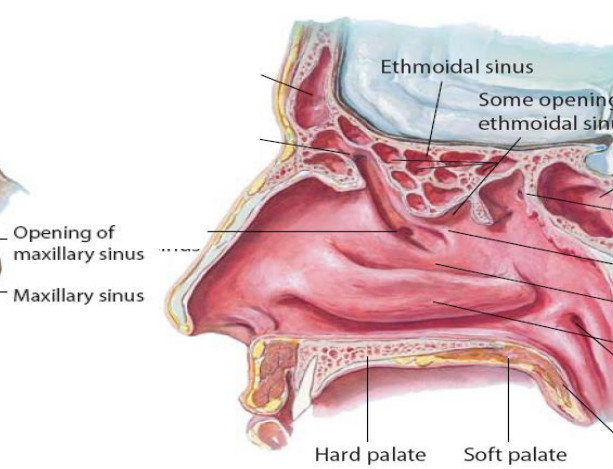
Percentage of carrier of antibiotic resistant bacteria ALARMING!

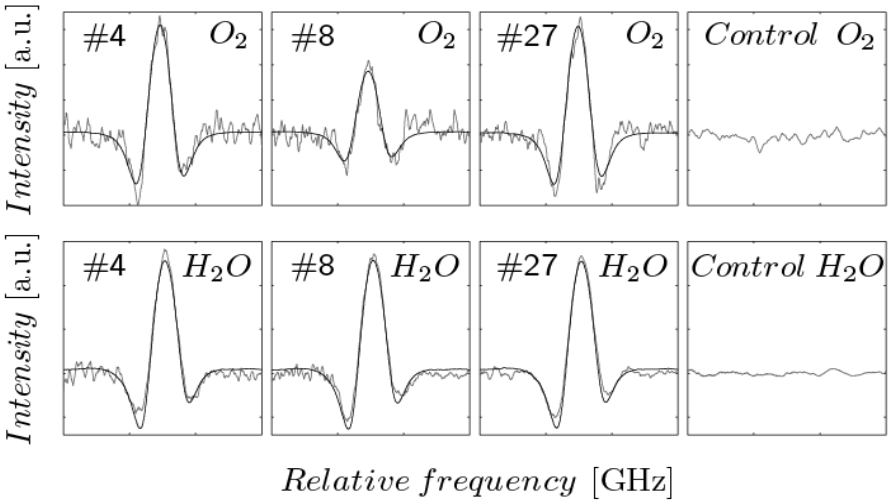


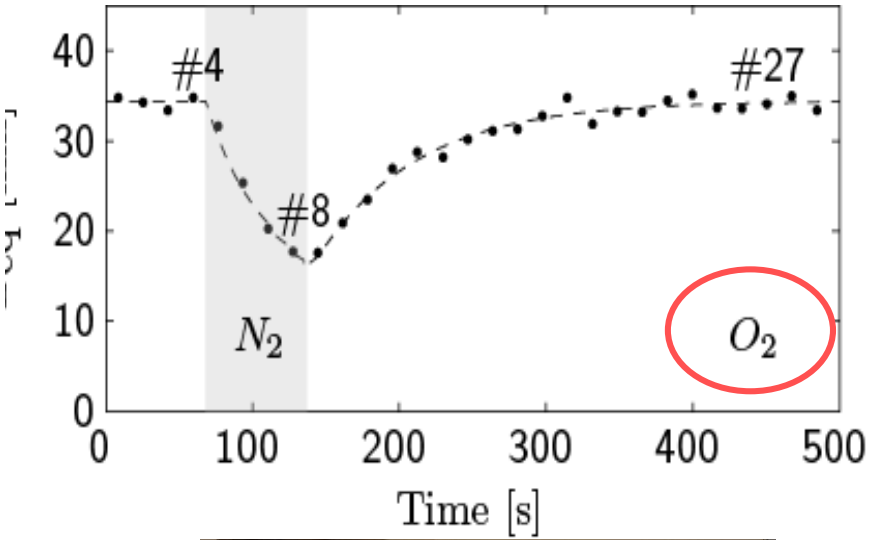
Fighting Antibiotics Resistance

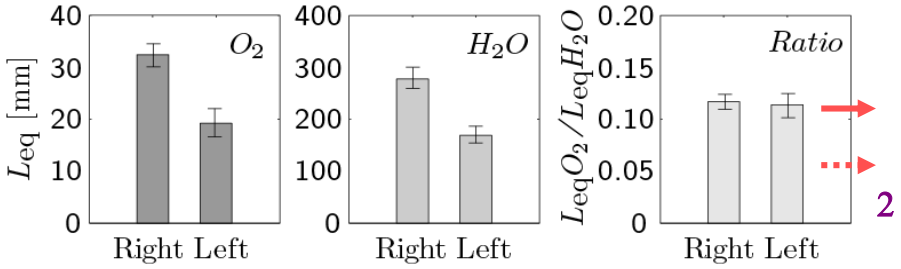
Sinusitis diagnostic by laser-spectroscopic measurement of oxygen and water vapour









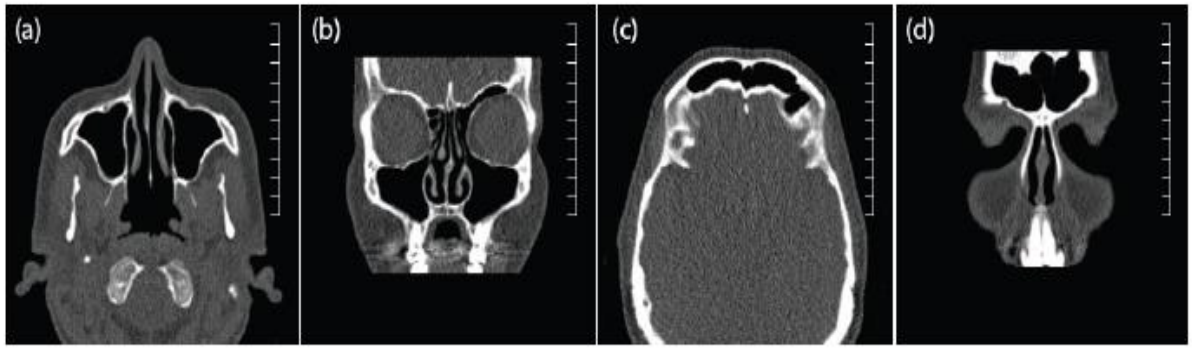


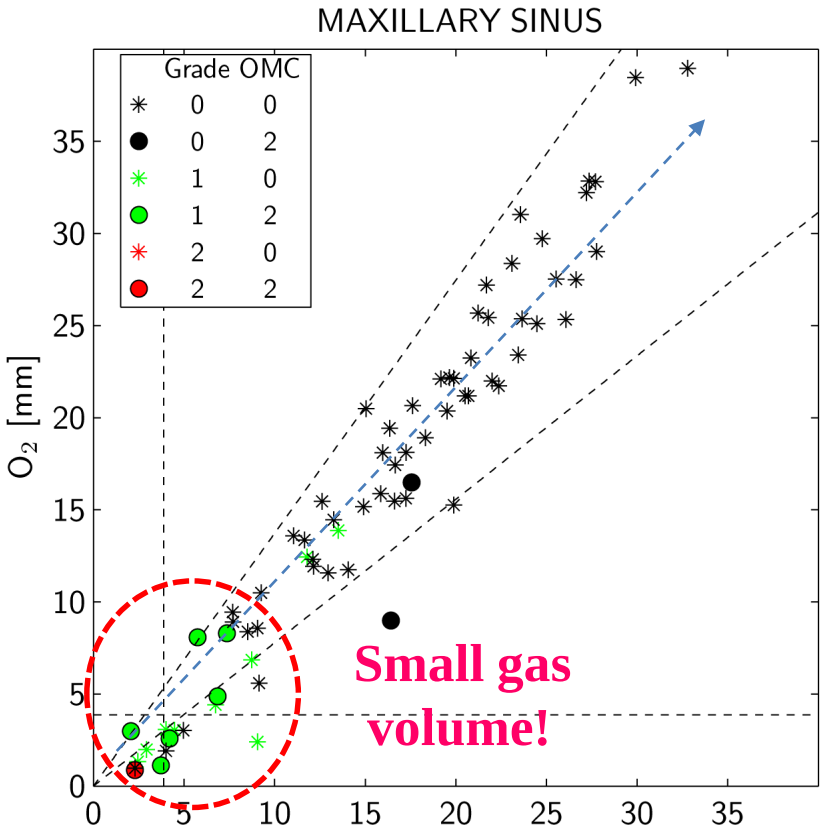
Persson et al. J. Biomed. Optics (2007); Rhinology 2012

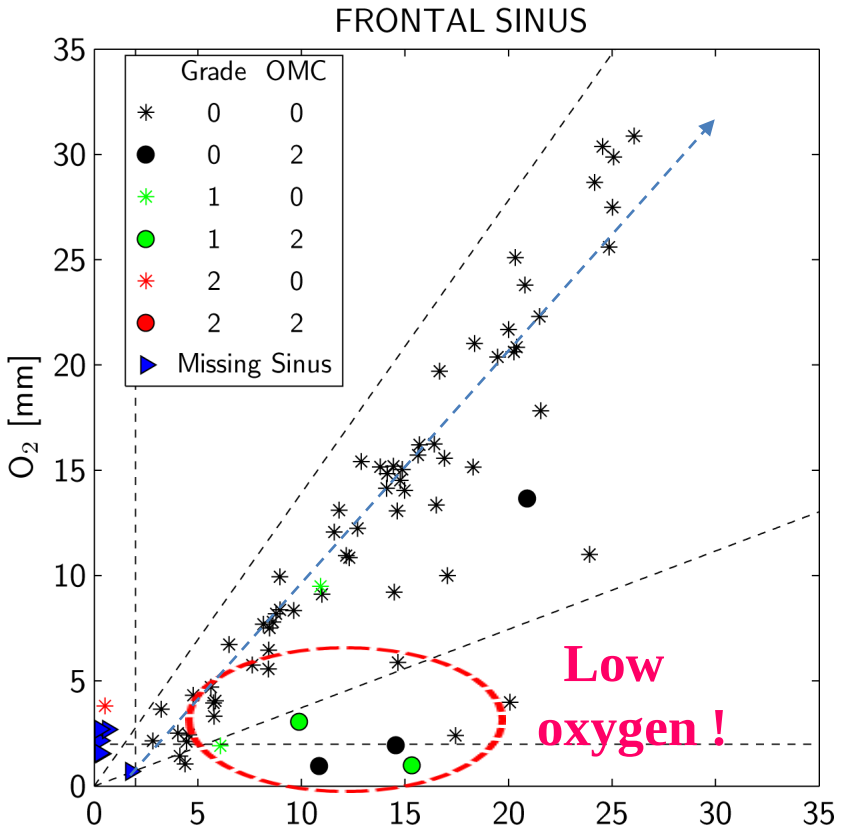
Clinical study on 40 patients

Lewander *et al.* Rhinology (2012) – Results comparable to CT

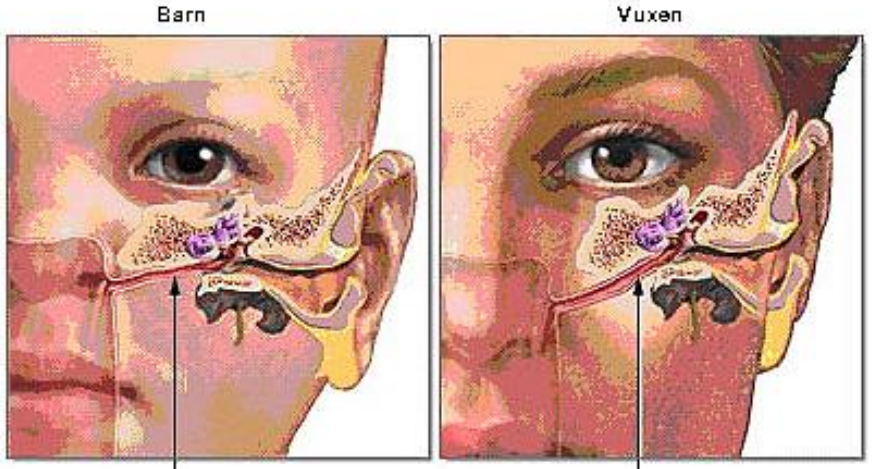
Collaboration:
S. Lindberg
R. Siemund



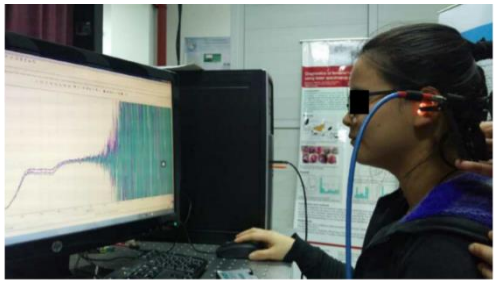


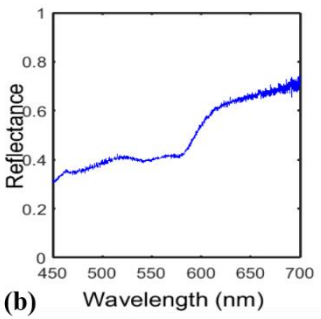


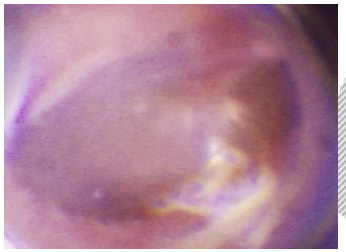
Middle ear infection (otitis)

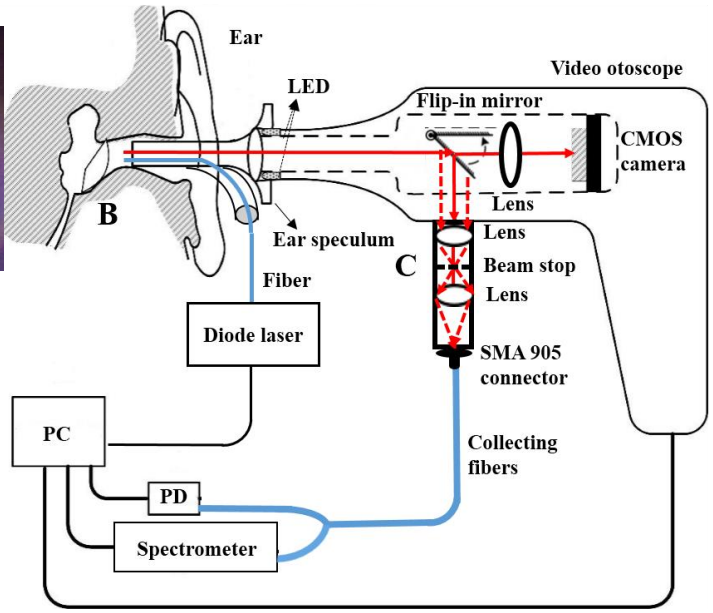


Ear-drum color monitoring



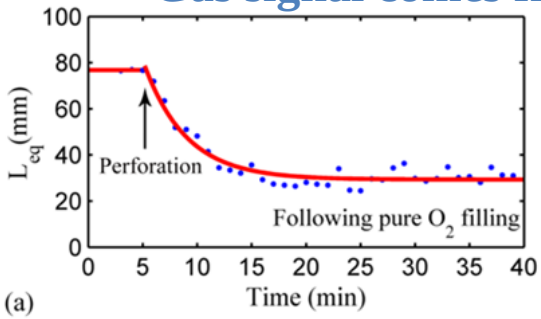


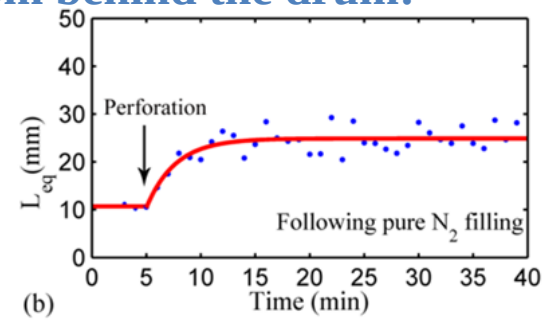




GASMAS Phantom experiments: Zhang *et al.* 2016

Gas signal comes from behind the drum!





Li *et al.* 2018

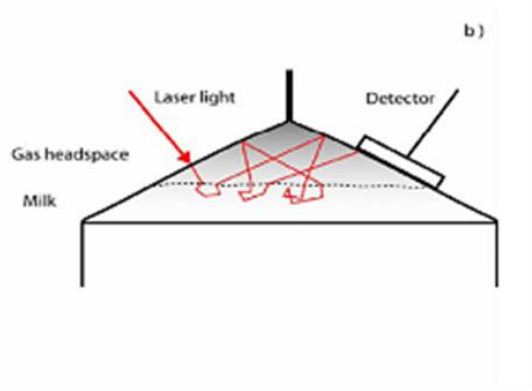
Food safety

FOOD MONITORING – FOOD SAFETY - FRESHNESS

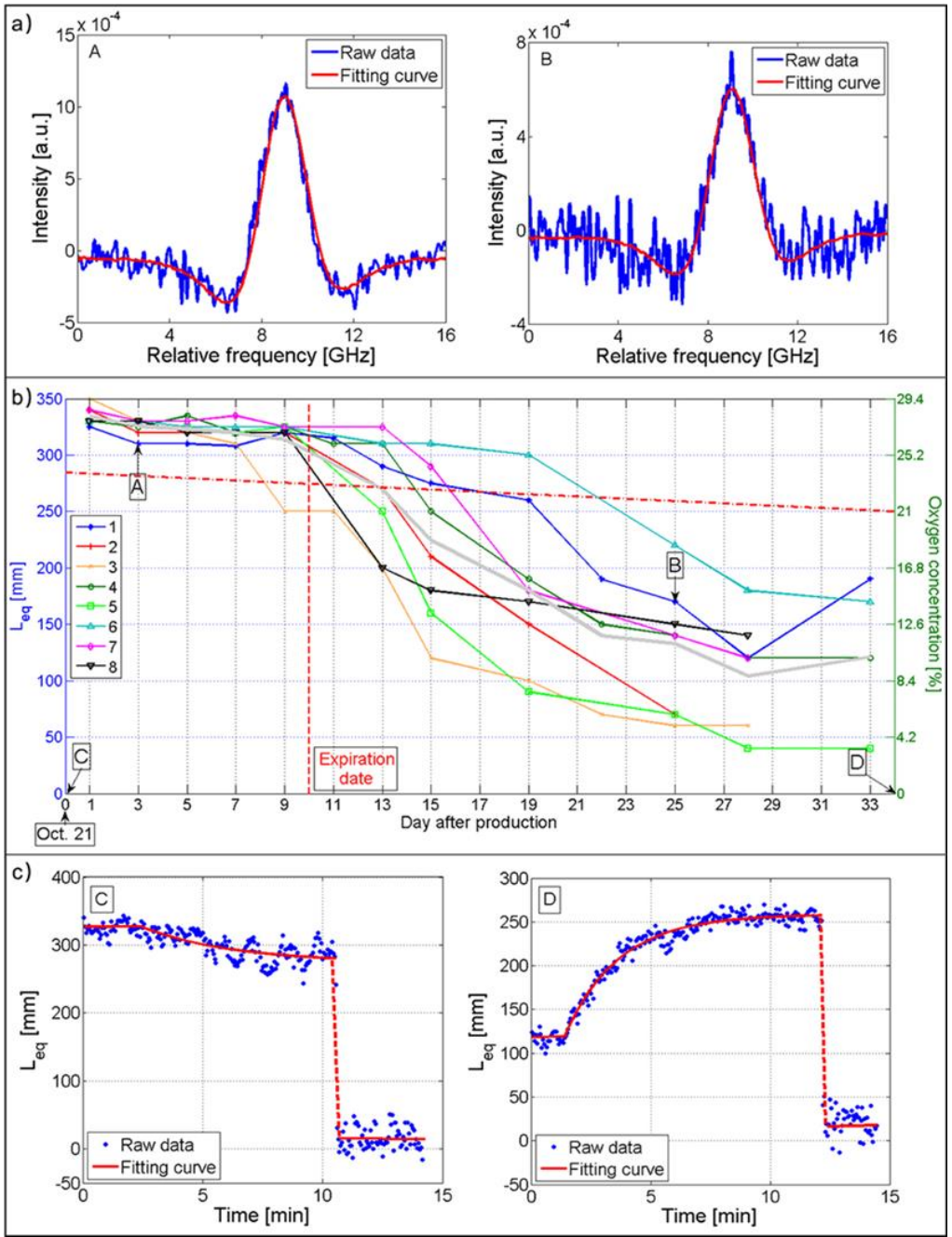
Most food is packed in modified atmosphere (low O_2, high N_2, CO_2)

Milk, bread, meat, eggs ..

Lewander *et al.*; Li *et al.*

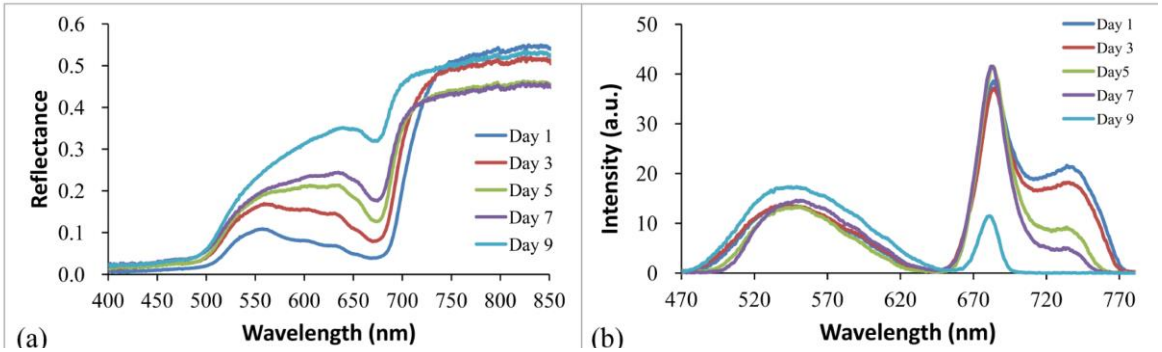


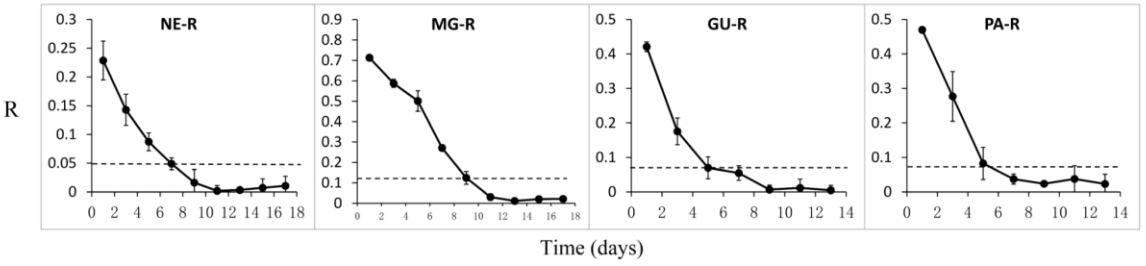
European SAFETYPACK project

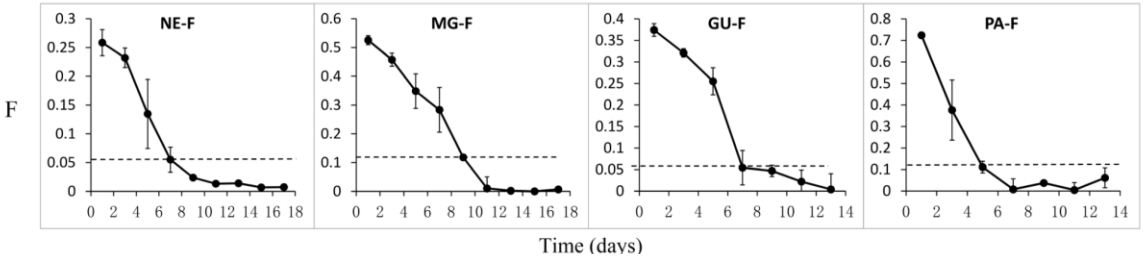


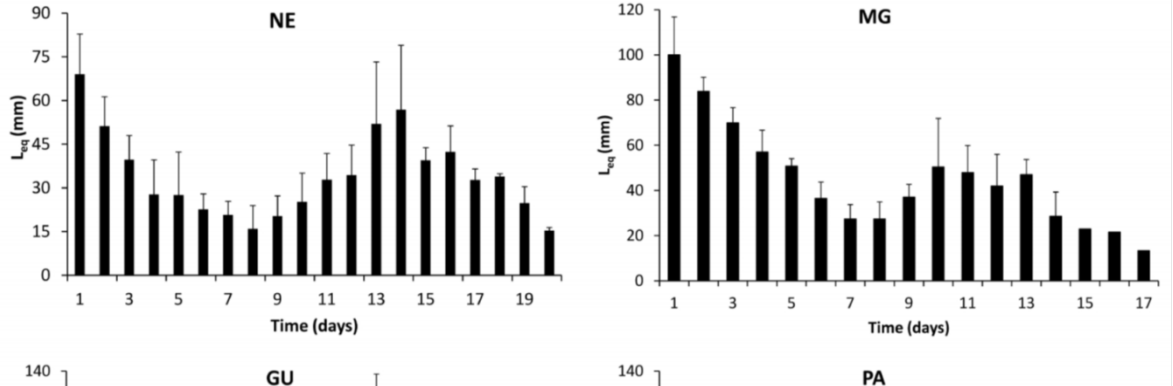
Fruit maturing

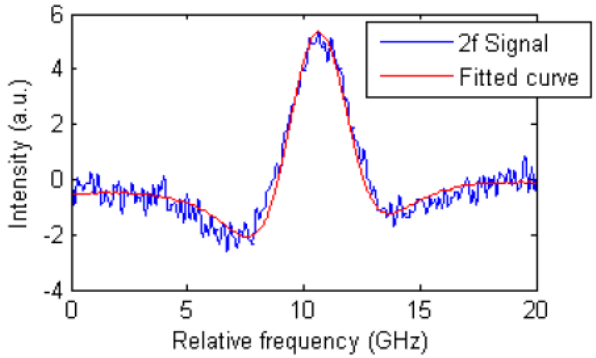
(Zhang *et al.* 2014)







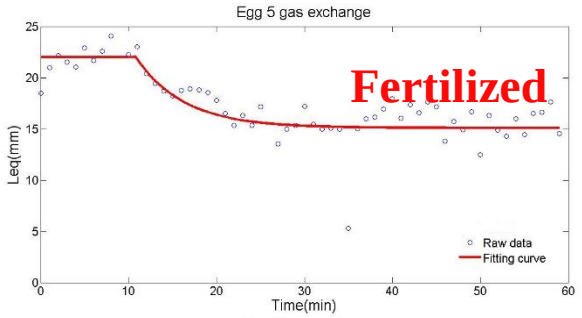


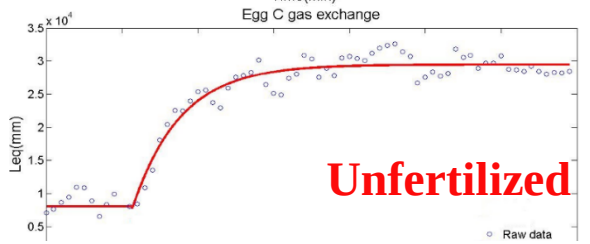


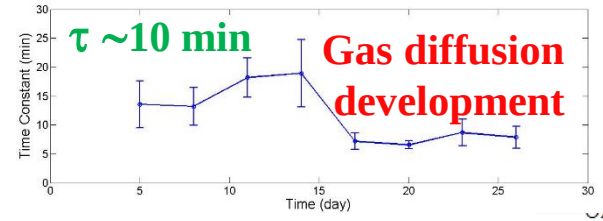
Detection of free oxygen and water vapor in hen eggs

Exploration of diagnostics possibilities

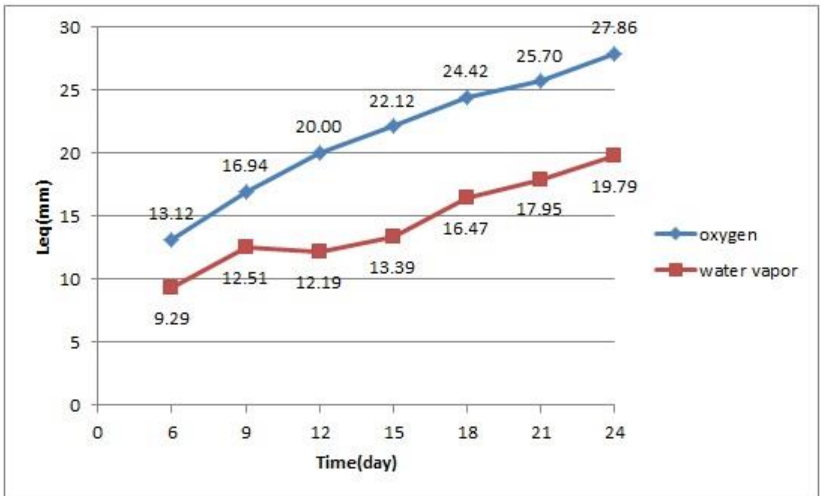
Li *et al.* J. Biophotonics 2017; 2018



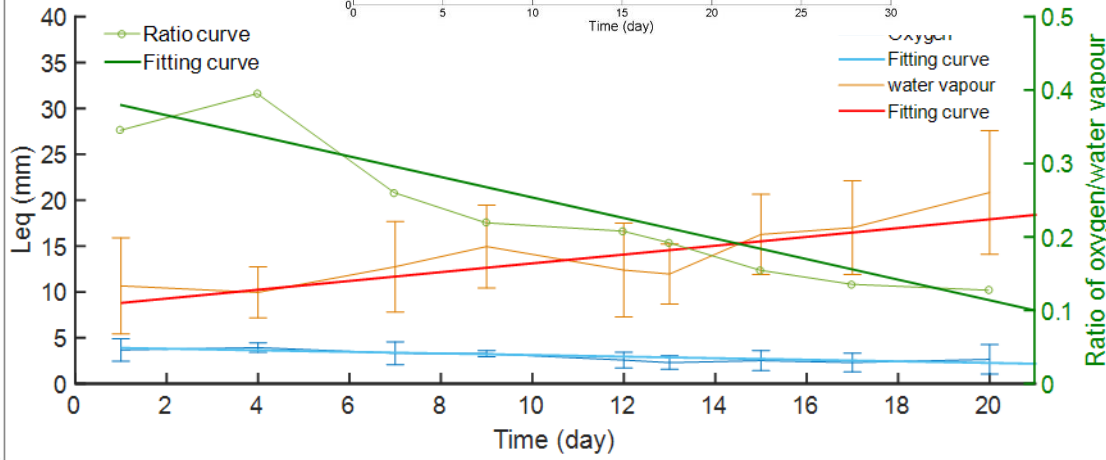




Unfertilized

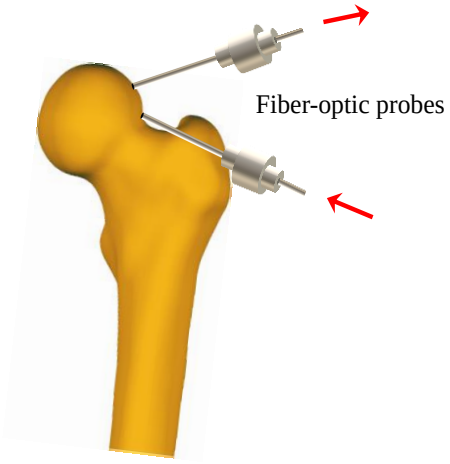


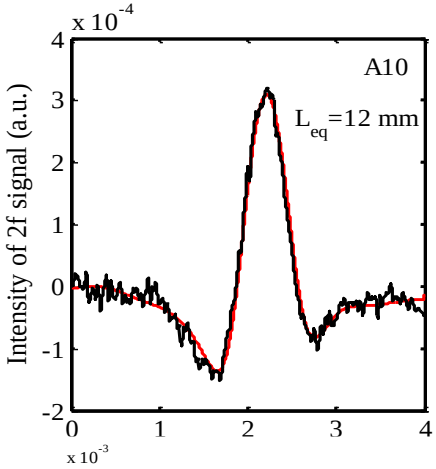
Fertilized

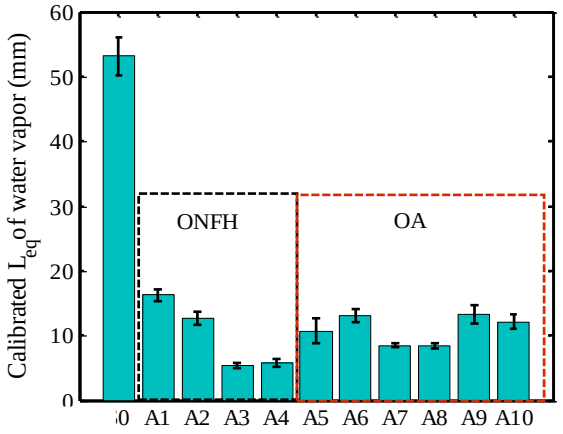


Femural head necrosis detection

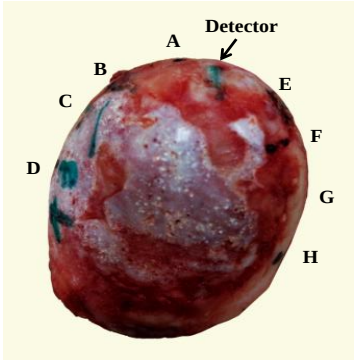
(a) (b)

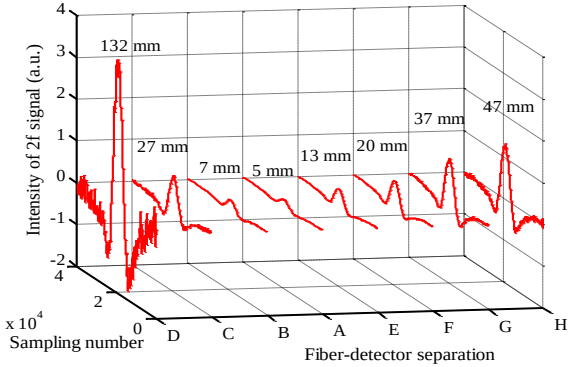




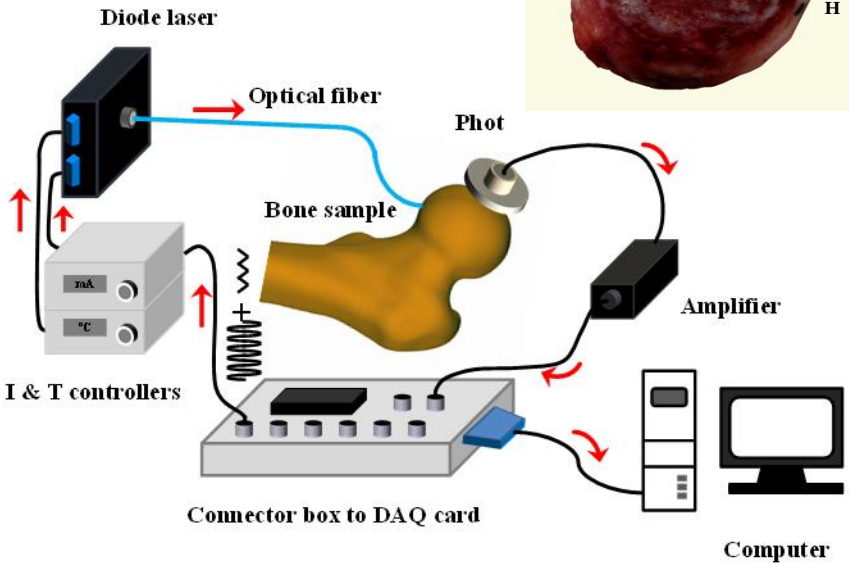


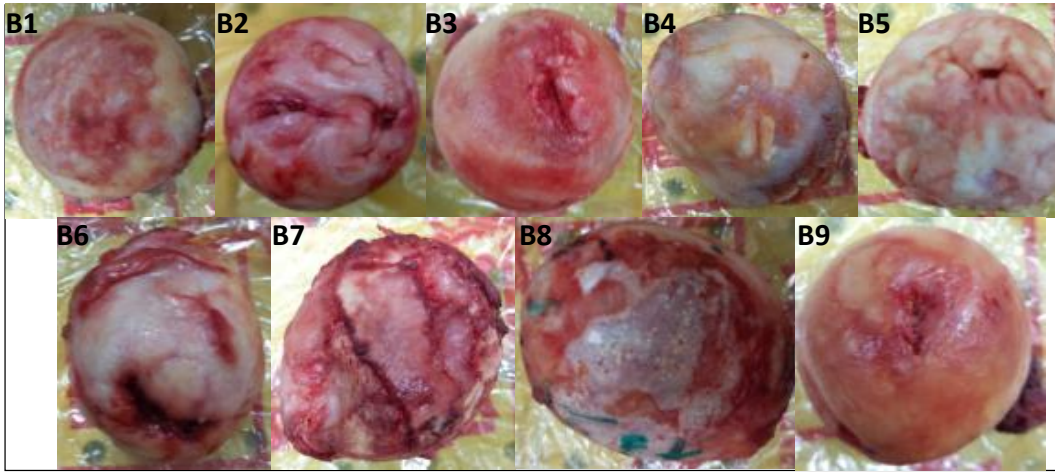
(b)





Li *et al.* 2017
Chen *et al.* 2018



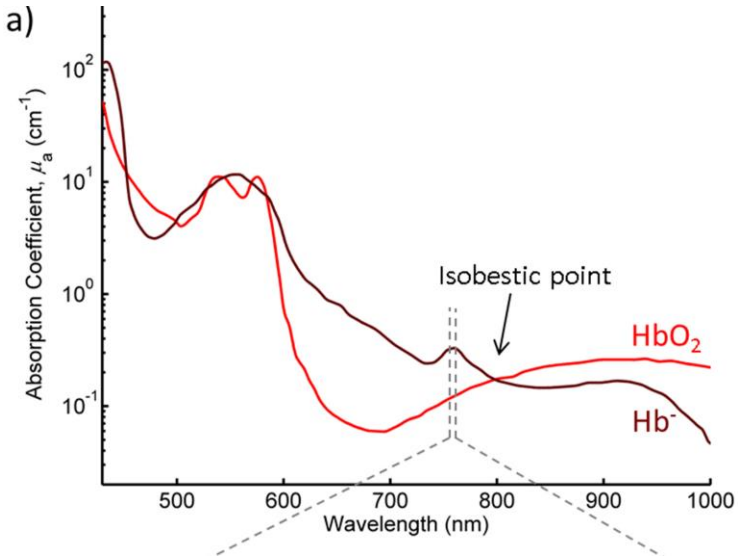


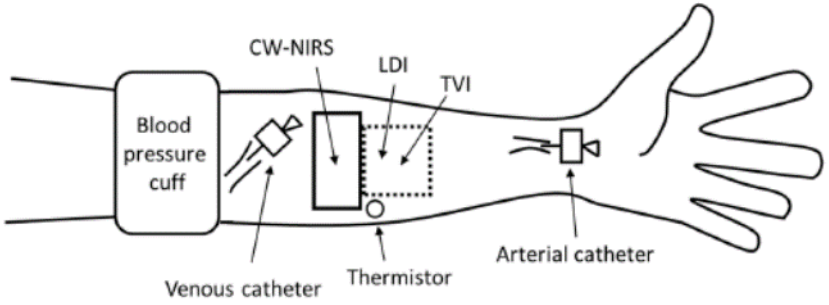
Patient oxygenation monitoring

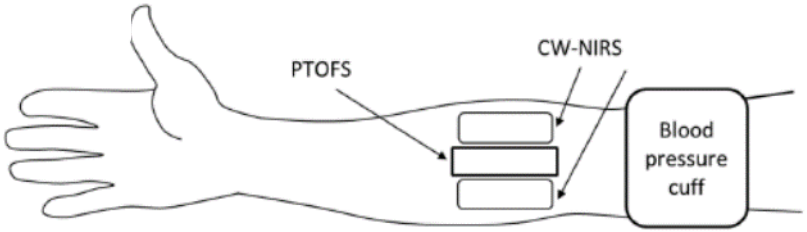
in general, and in intensive care

Steady-state or time-resolving diagnostics?

Different approaches…

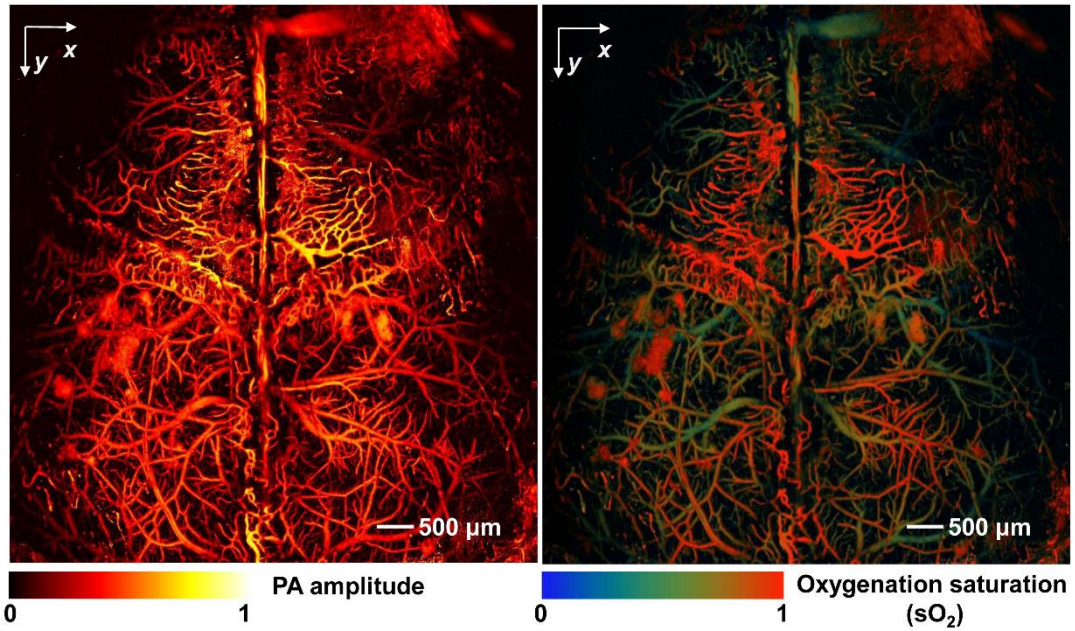




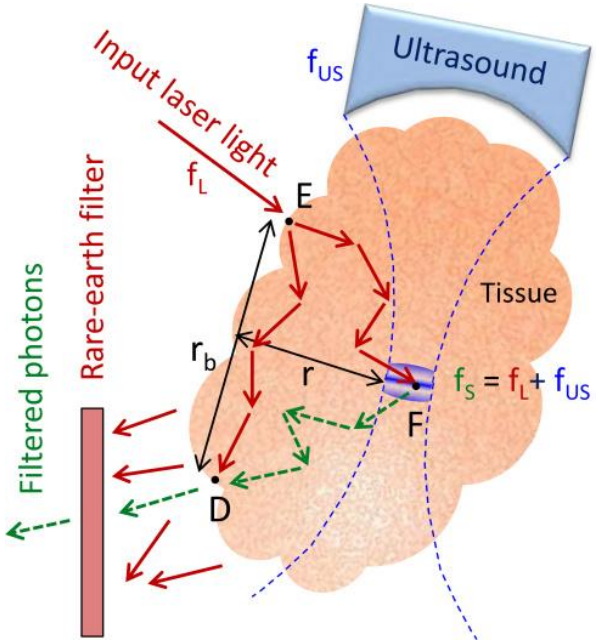


Krite Svanberg et al. (2015, and to appear)

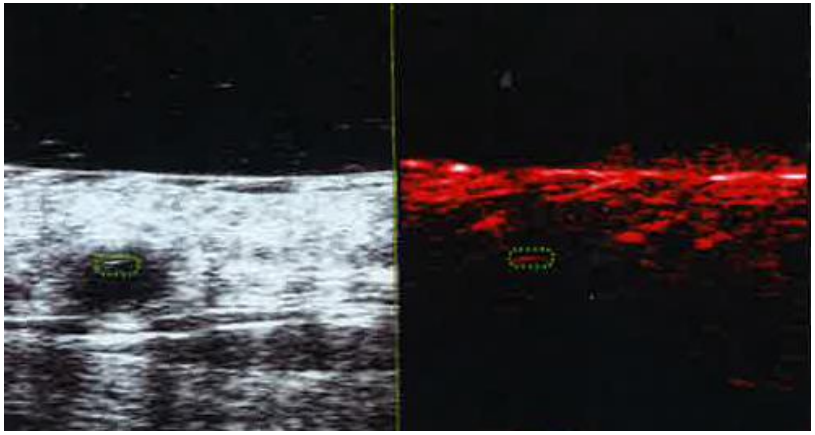
Photoacoustics for oxygenation studies



Lihong Wang *et al.*

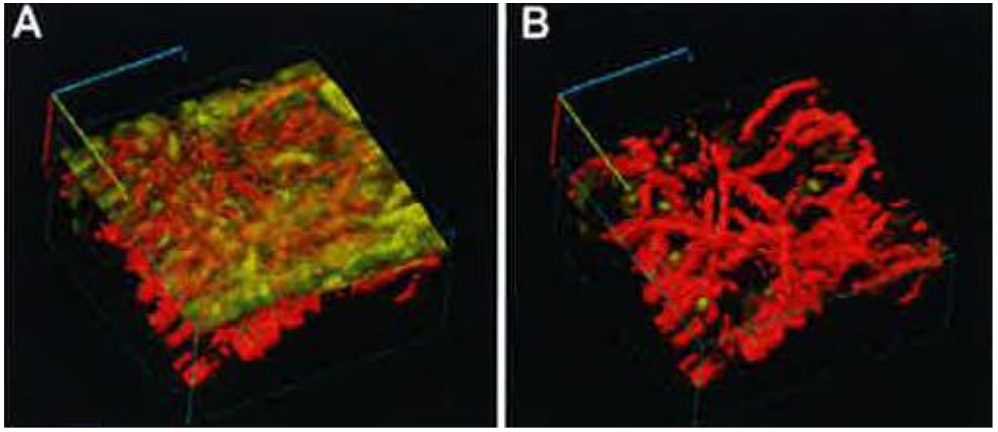


Walther, Kröll *et al.*, BOE (2017)



Temporalis arthritis

Scheikh, Malmsjö *et al.* (2018)

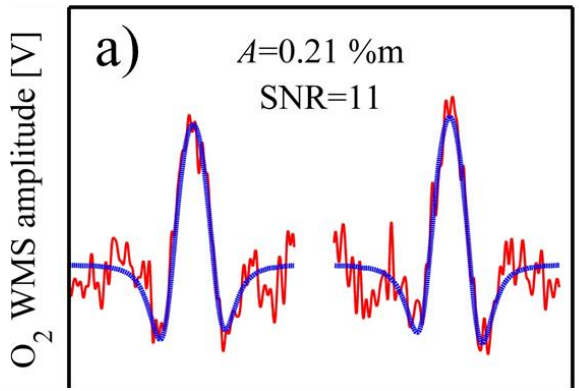


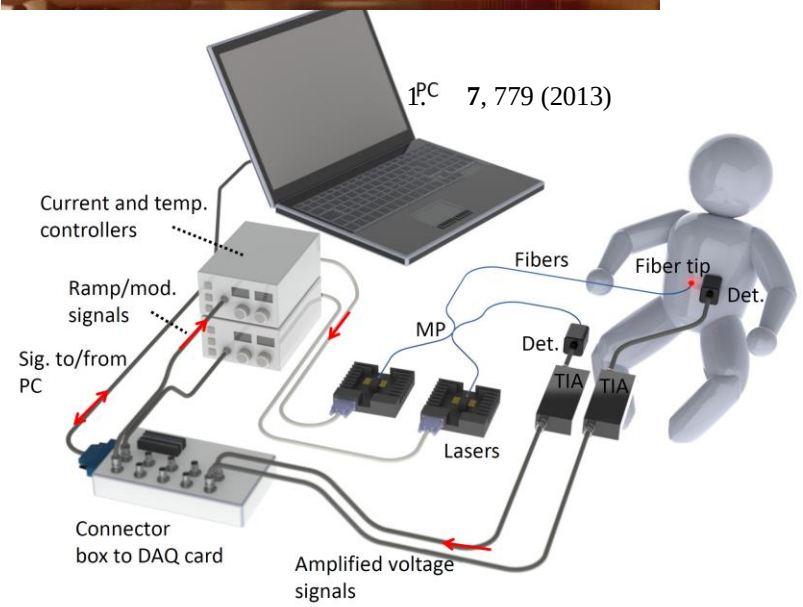
Skin vascular bed

Neonatal/Premature child monitoring

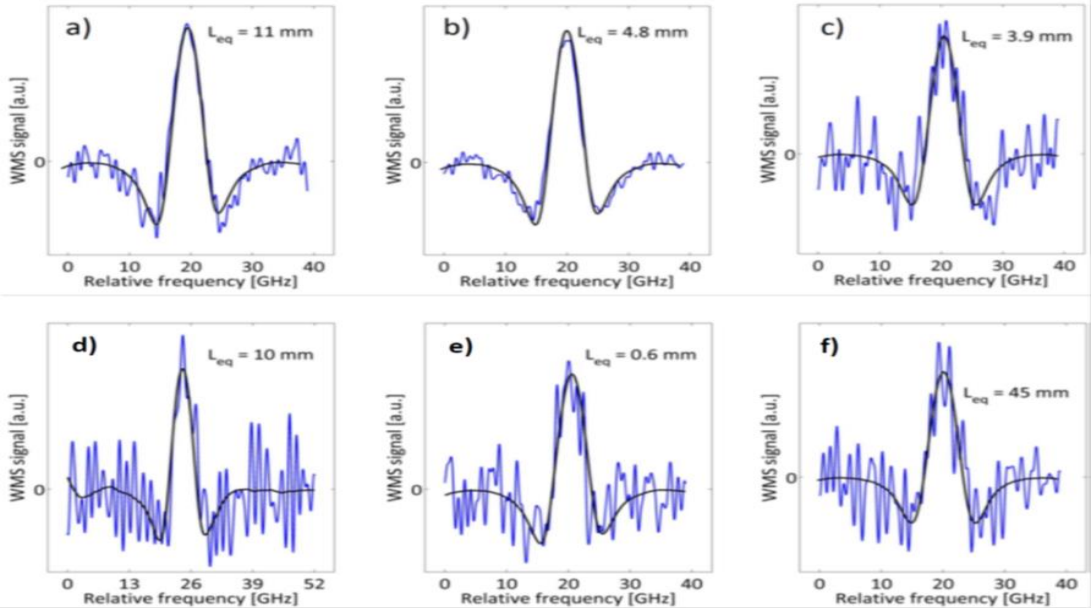
Lack of surfactant – lung problem! Eliminate X-rays! 24 h cot-side monitoring of O_2

P. Lundin *et al.*, V. Fellman, Krite-Svanberg *et al. (2015), and ongoing …*





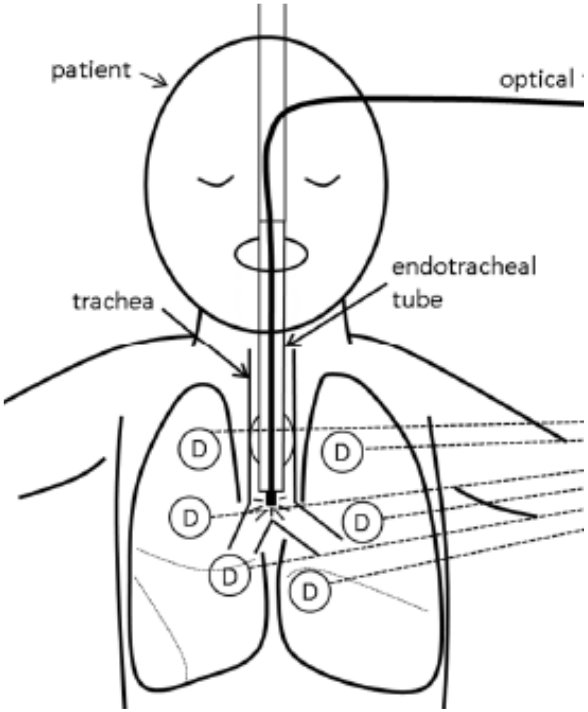
1. **7**, 779 (2013)

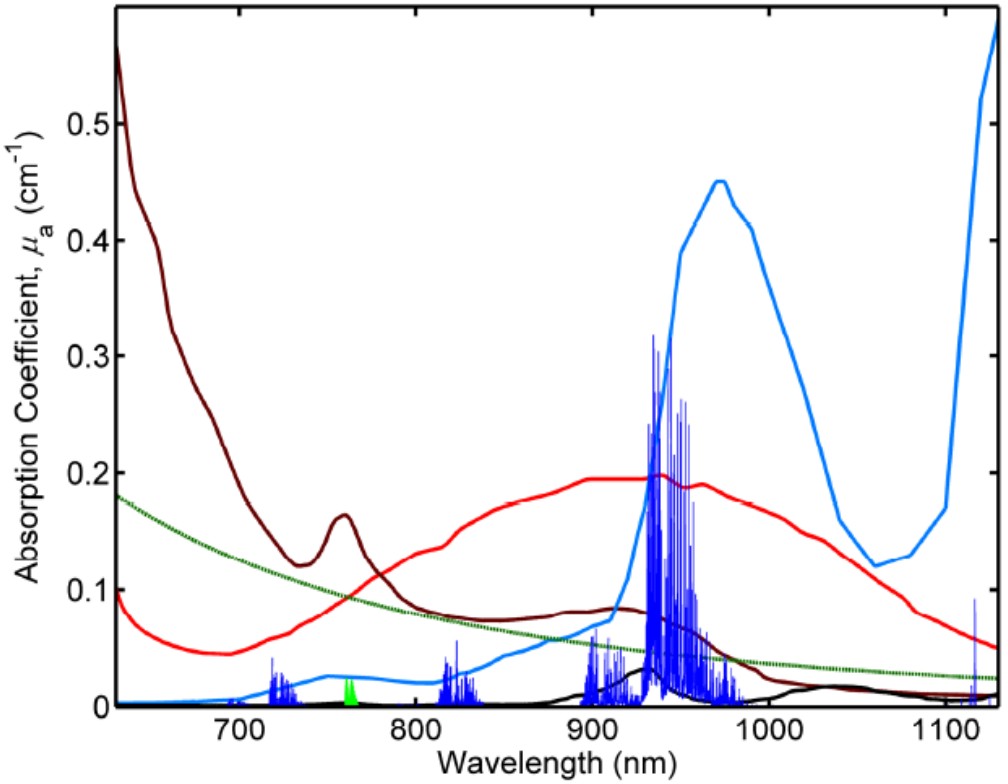


GASMAS Reviews: **S. Svanberg, Laser and Photonics Reviews 7, 779 (2013)**

K. Svanberg, S. Svanberg, in *Frontiers in Biophotonics for Translational Medicine*, in U.S. Dimish and M. Olivo (eds) (Springer, Singapore 2015) 307-321

Adult free-oxygen-in-lung monitoring?
With respirator feed-back?





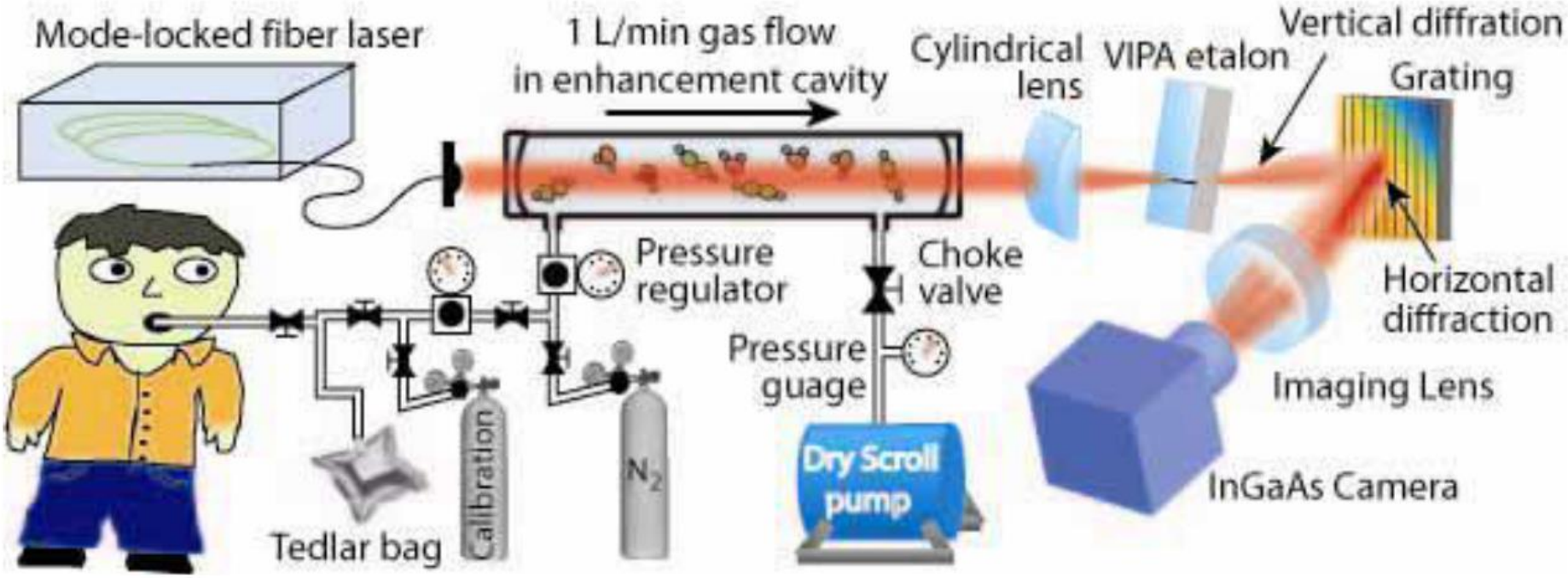
E. Krite Svanberg, S. Svanberg
SE 1500335-3 (2015)

Broad- and narrow-band absorption:
De-oxygenated blood
Oxygenated blood
Free Oxygen
Water vapour

Examples of biomarking gases - - indicating disease

Biomarkers	Metabolic Disorders / Diseases
Acetone ($OC(CH_3)_2$)	Lung cancer, diabetes, dietary fat losses, congestive heart failure, brain seizure
Acetaldehyde (CH_3CHO)	Alcoholism, liver related diseases, lung cancer
Ammonia (NH_3)	Renal diseases, asthma
Butane (C_4H_{10})	Tumor marker in lung cancer
Carbon monoxide (CO)	Oxidative stress, respiratory infection, anaemias

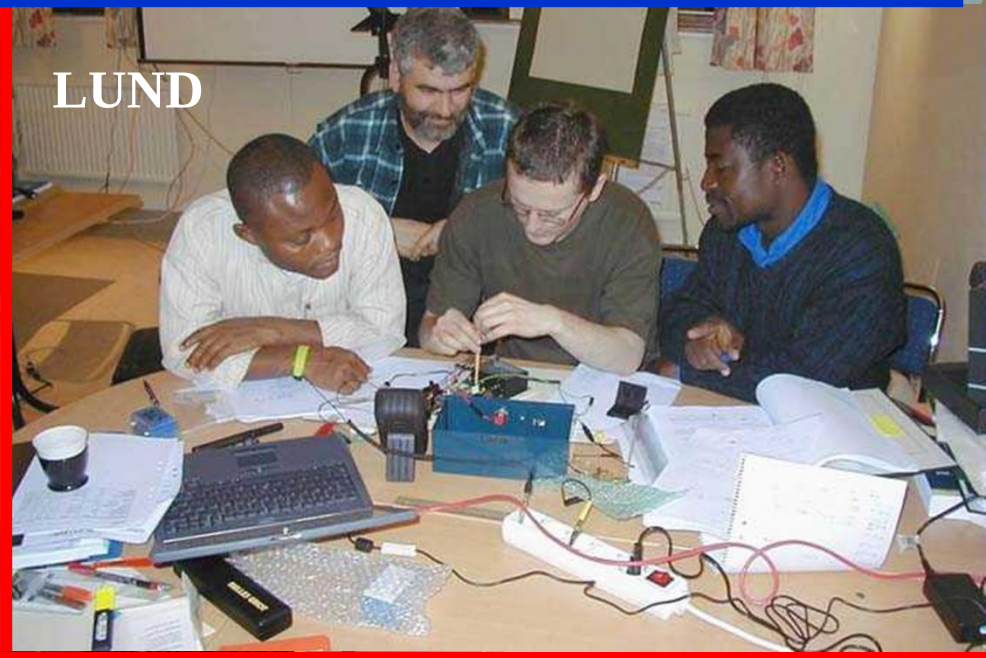
Breath analysis by laser spectroscopy

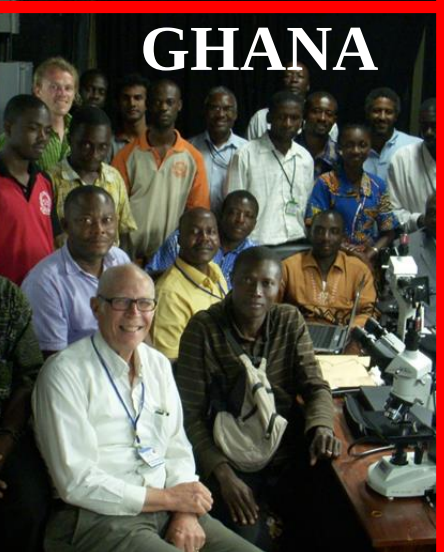


From: Thorpe et al.: Opt. Exp. 2008

Going beyond the borders…..

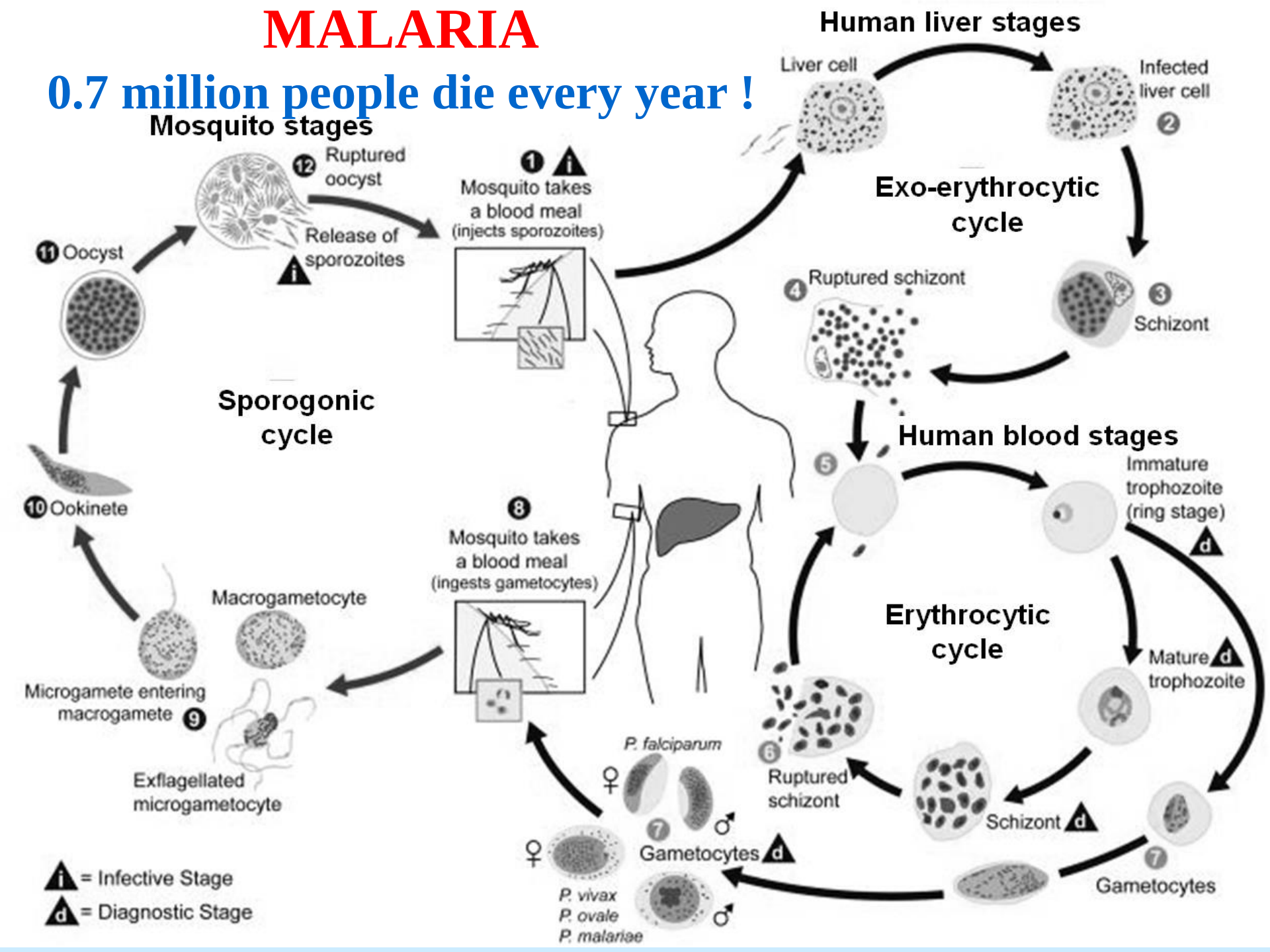
Realistic Applications for the Developing World



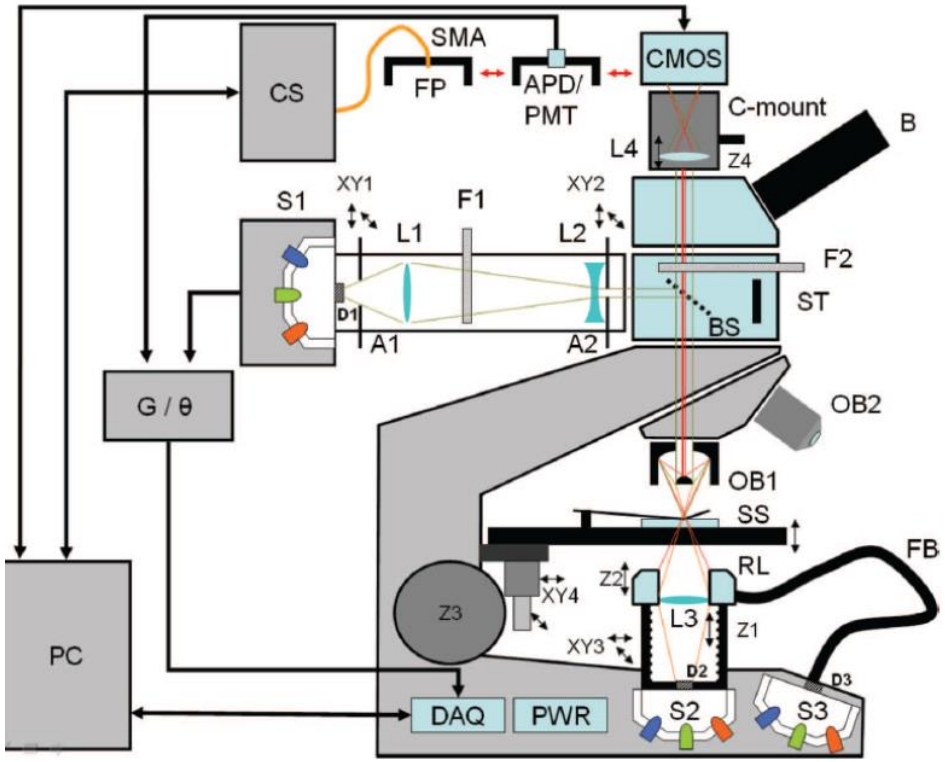


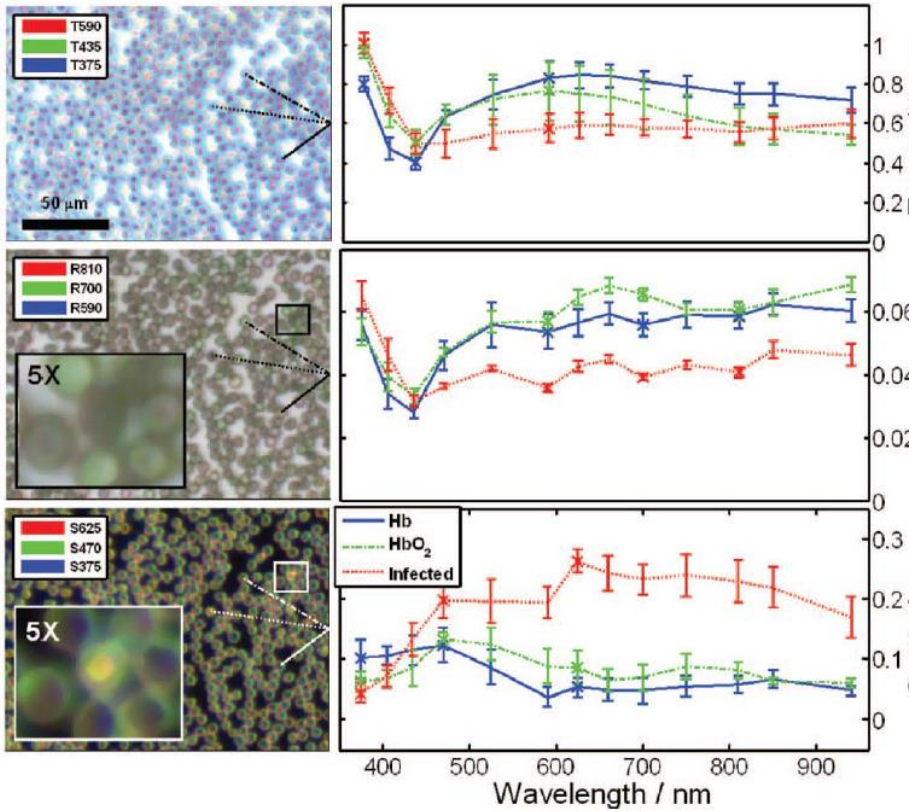
MALARIA

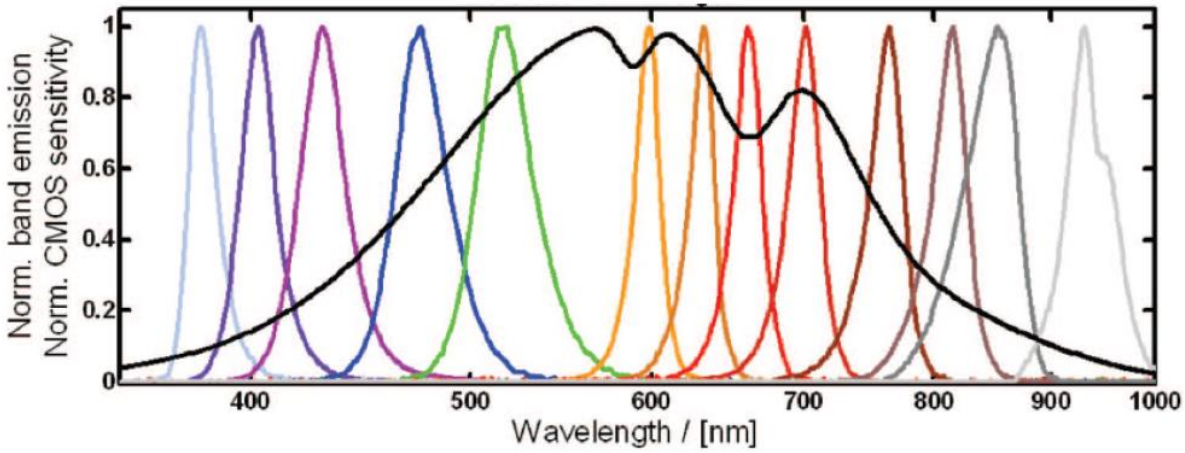
0.7 million people die every year !



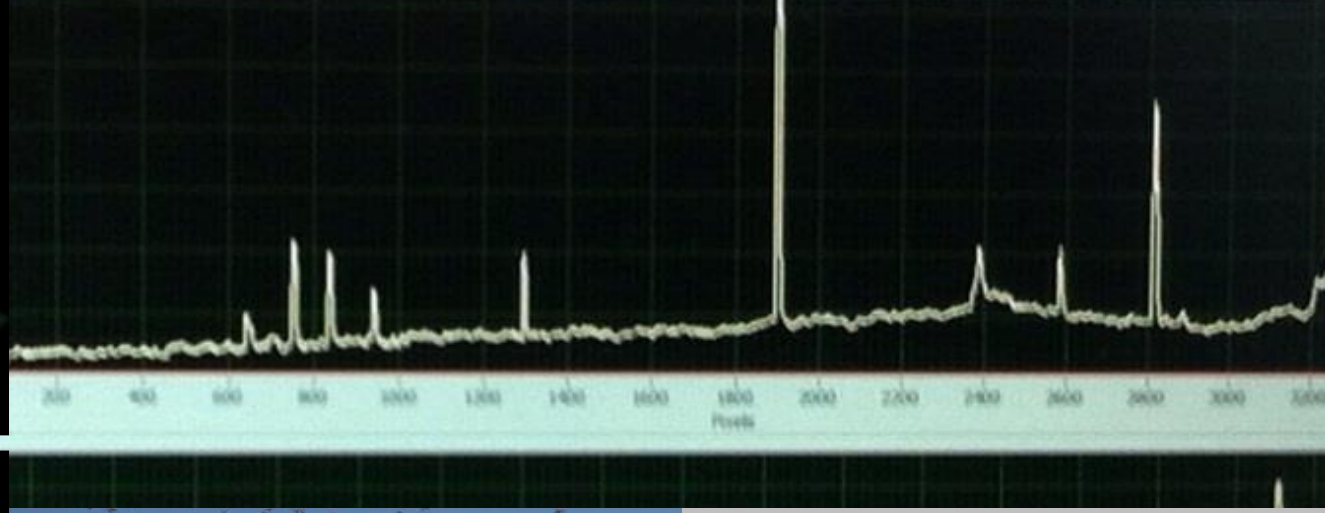
LED Multispectral microscopy malaria detection





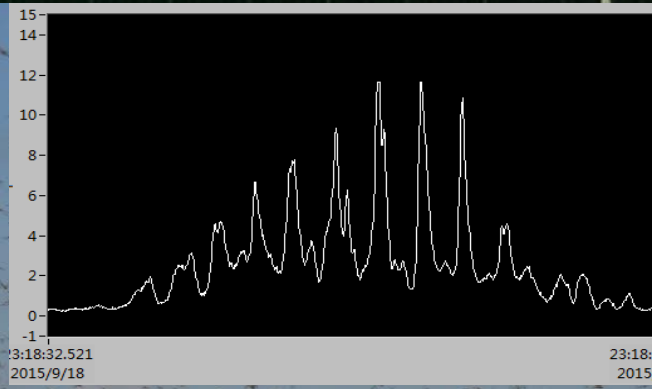


Brydegaard et al.



Insect monitoring

Pollinators
Disease vectors
Agricultural pests



The perspective:
Blue Planet Earth
seen from Saturn
(NASA Cassini Mission)

Let us take care of each other on spaceship Earth !