The Abdus Salam
International Centre
for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

2443-20

Winter College on Optics: Trends in Laser Development and Multidisciplinary Applications to Science and Industry

4 - 15 February 2013

Sensing applications (part 1+2)

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Lund University
Sweden

Winter College, ICTP, February 2013

Optical Sensor Applications

Sune Svanberg

LUNDS UNIVERSITET

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Lund University
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Center for Optical and
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South China Normal University
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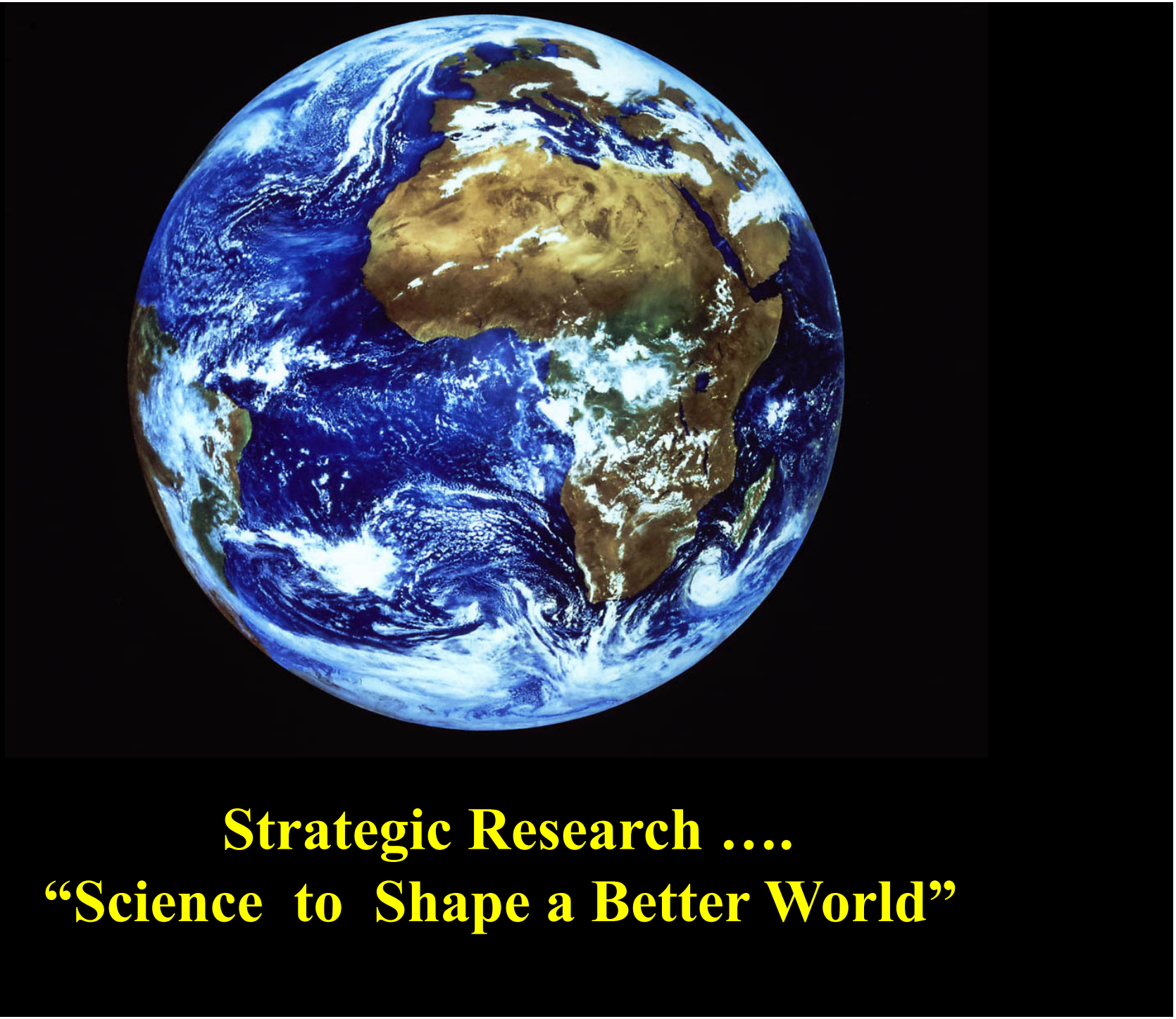
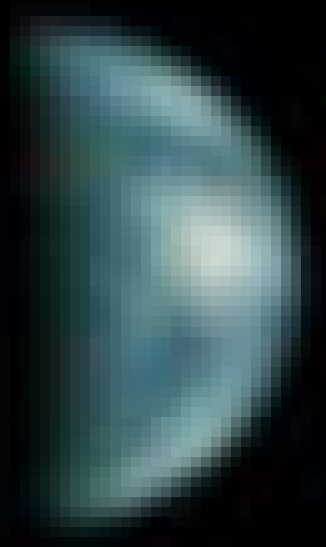
G. Cecchi et al., Firenze, A. Papayannis, Athens;
African LAM Network, African Multispectral Network



Strategic Research ….

“Science to Shape a Better World”

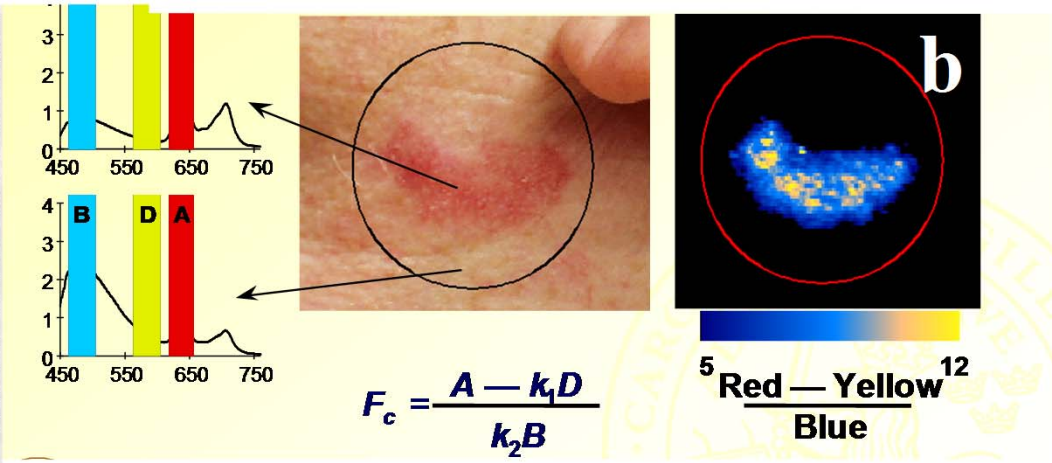
The cosmic perspective……



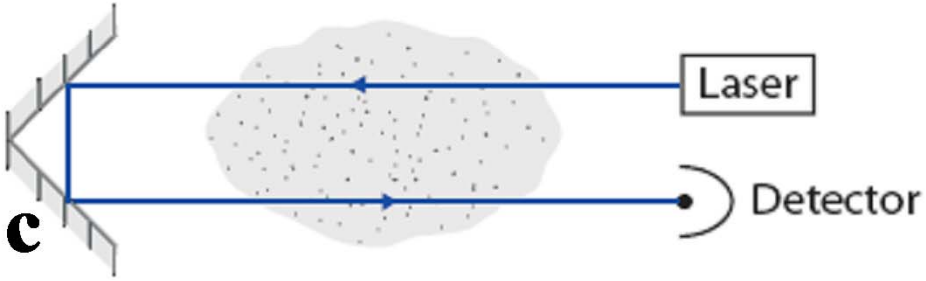
Earth and Moon photographed from Mars


ENVISAT
Space sees no borders!
ESA

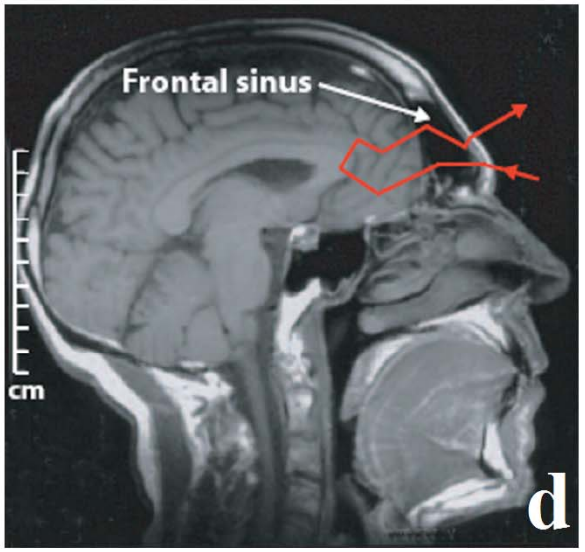
Environmental Monitoring - Biophotonics



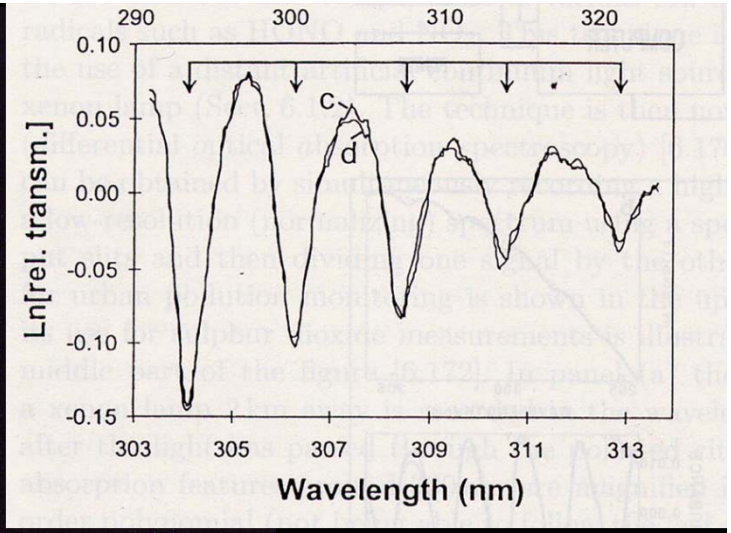
Environment

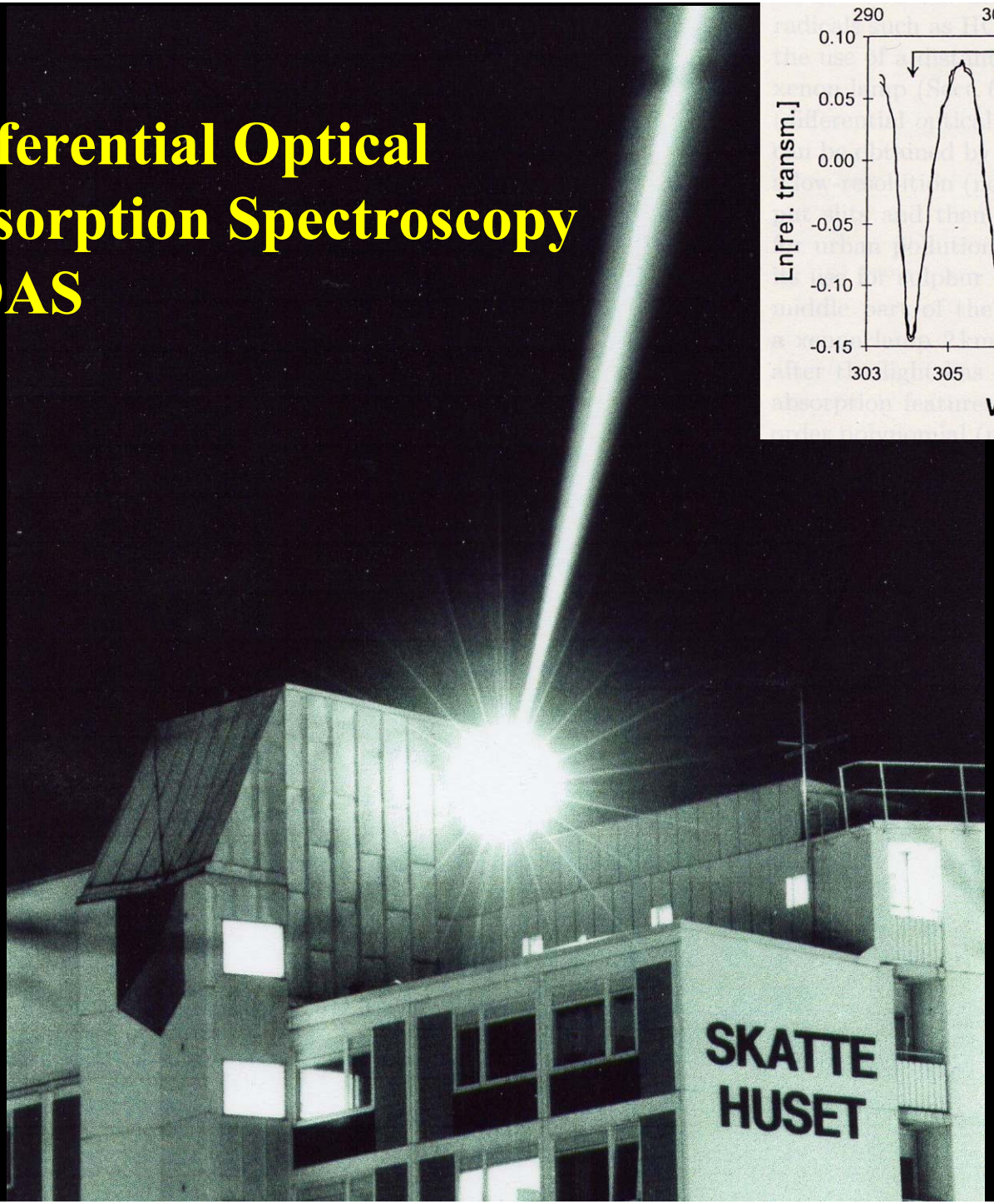


Medicine



Differential Optical Absorption Spectroscopy DOAS

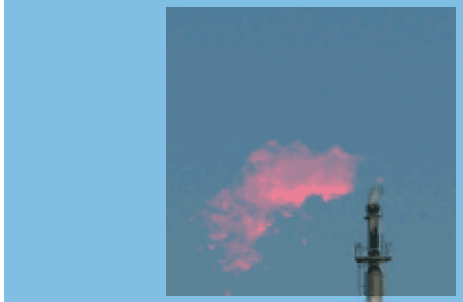


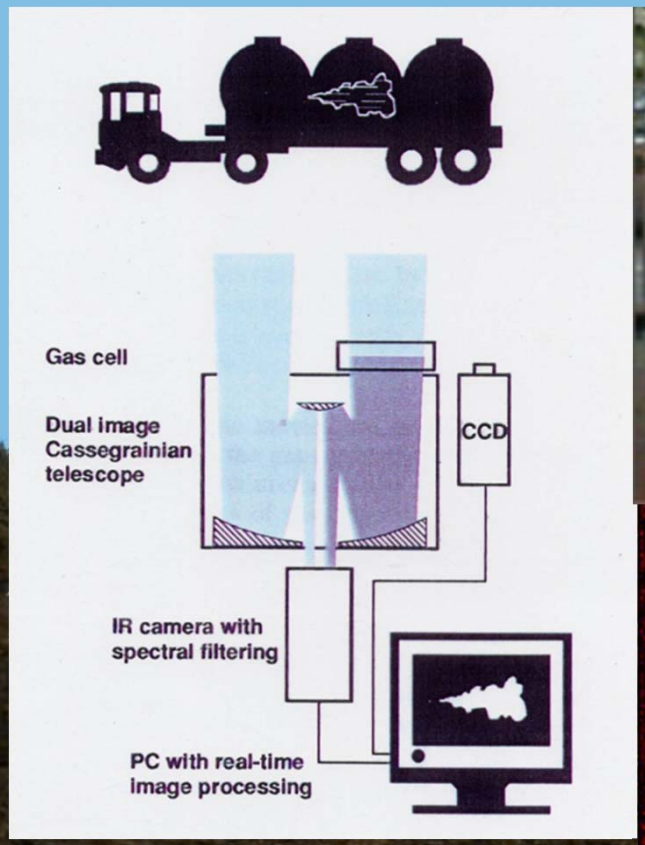


Opsis AB

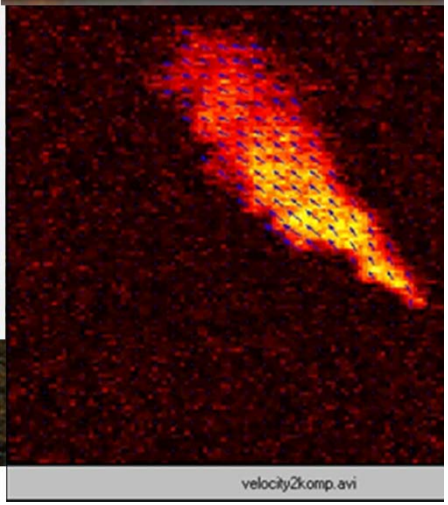
IR passive gas-correlation imaging

Which flare is leaking ethylene?



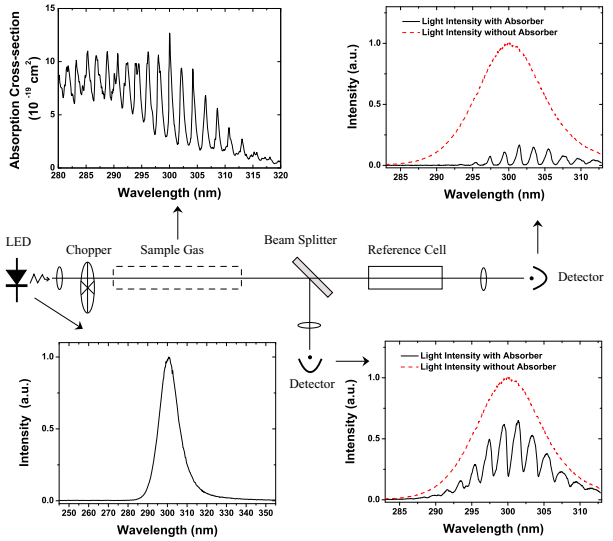


Sandsten et al.

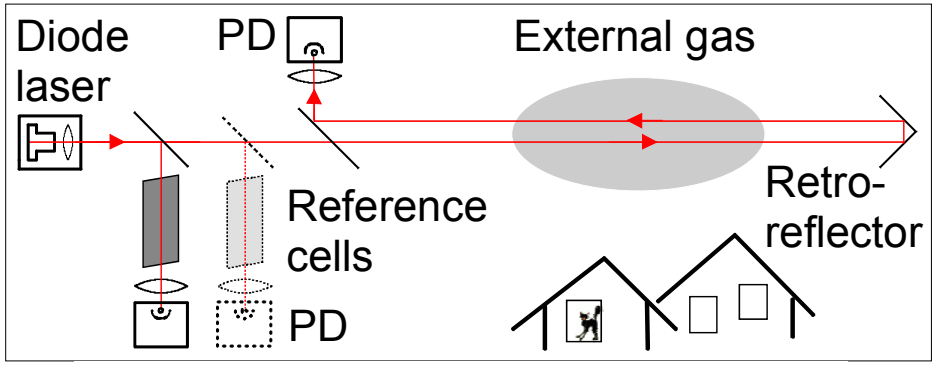


New techniques for sensitive gas measurements (long path absorption):

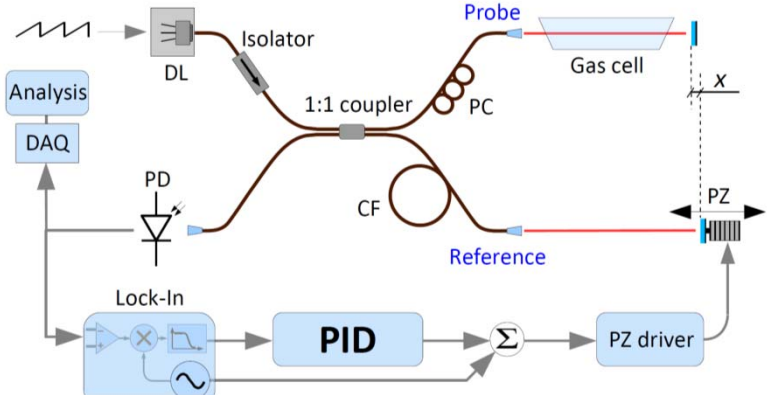
Gas Correlation
LED spectroscopy
Appl. Phys. B94 (2009)



Temporal correlation multi-mode diode laser spectroscopy
Appl . Phys. Lett. 86 (2005)

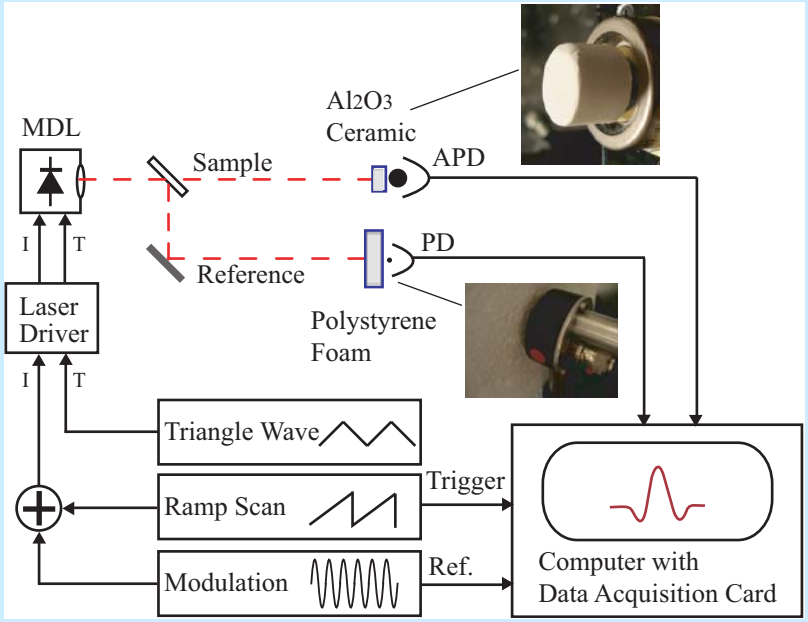


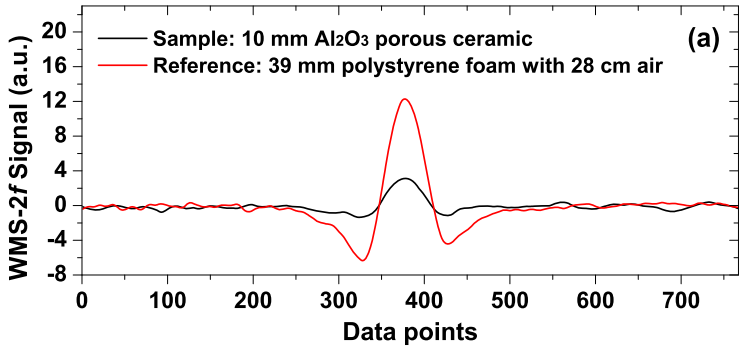
Zero background absorption spectroscopy
Opt. Expr. 16 (2009), Appl. Opt. (2011)

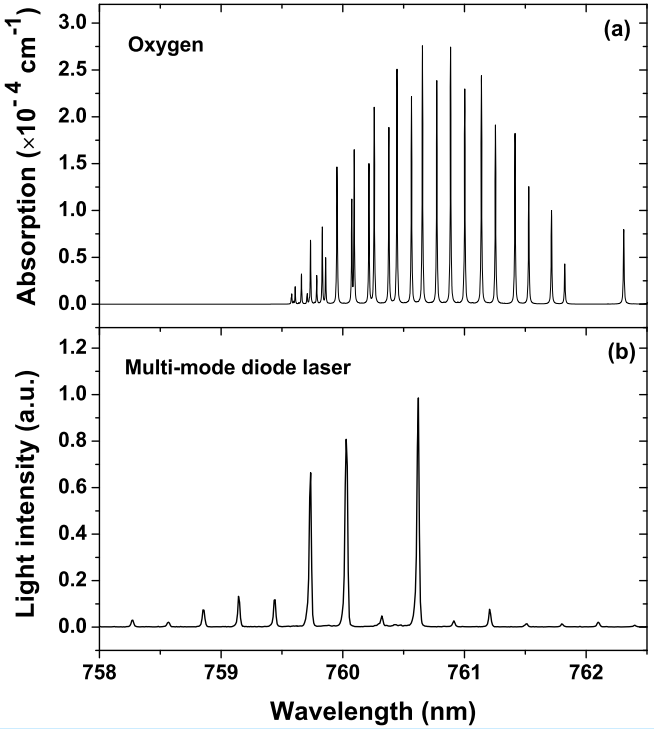


Gas correlation spectroscopy using multi-mode diode lasers

Luo et al., Appl. Phys. B 2011



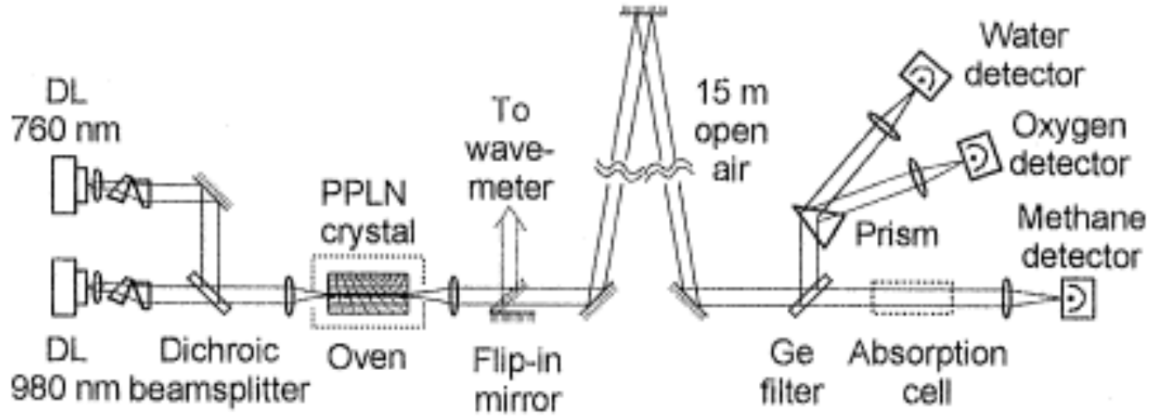


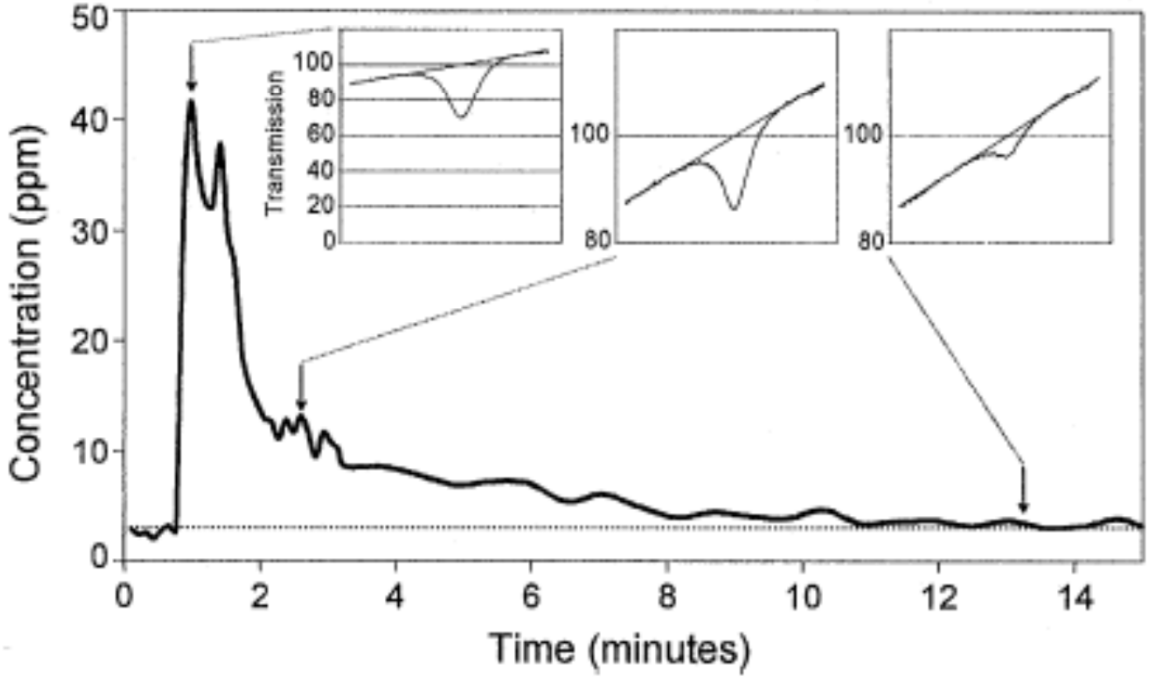


Diode laser difference frequency generation

Simultaneous monitoring of Oxygen, Water vapour and Methane

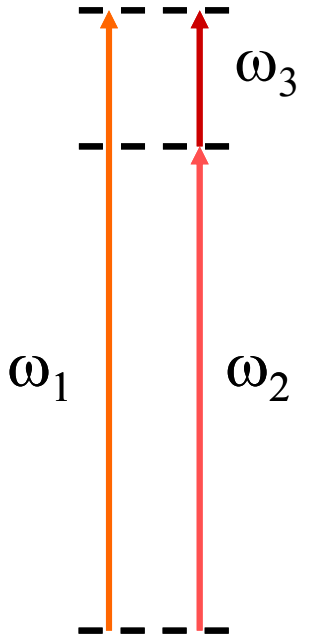
ω_1 ω_2 ω_3



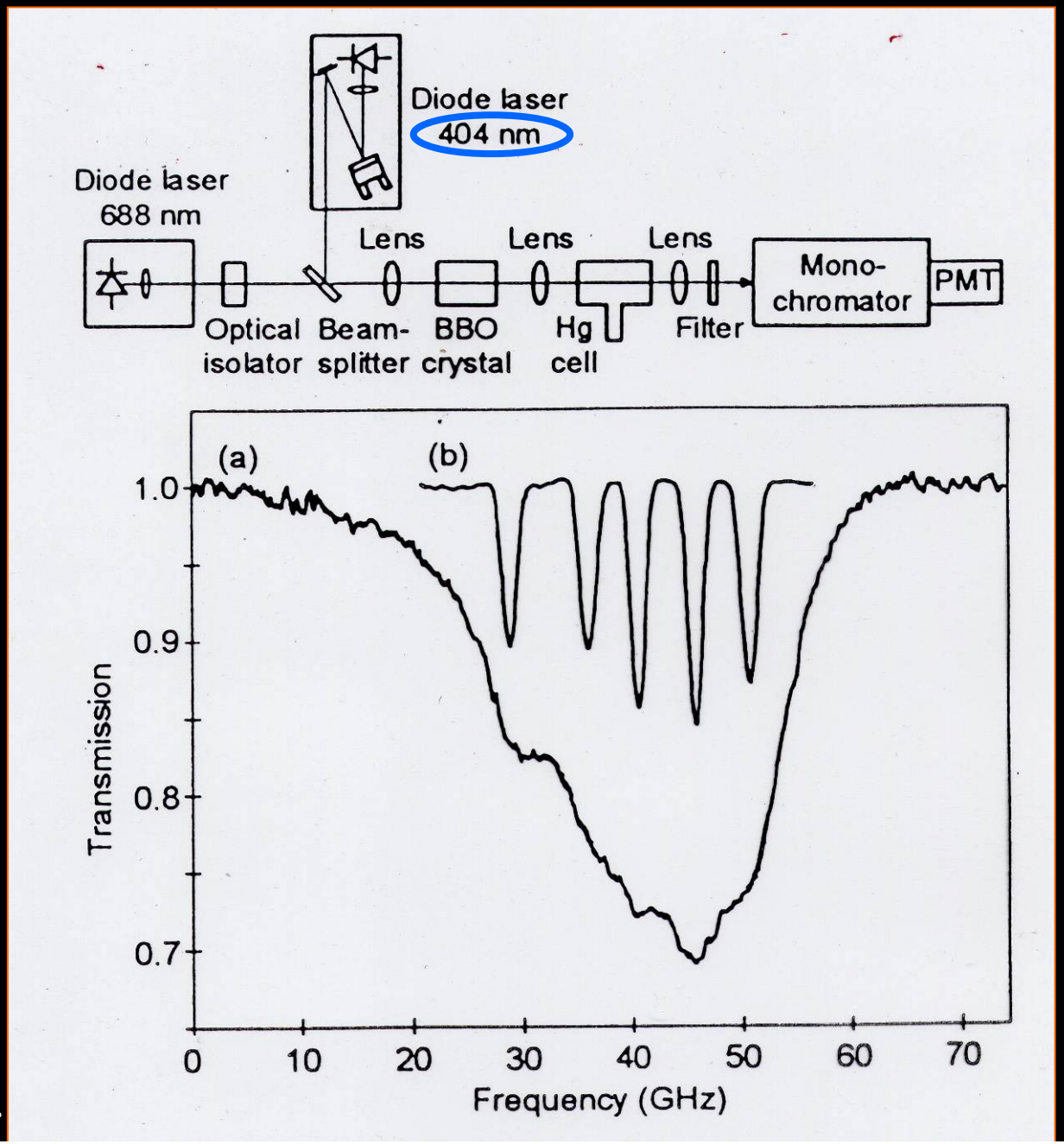


Gustafsson et al. Appl. Phys. B

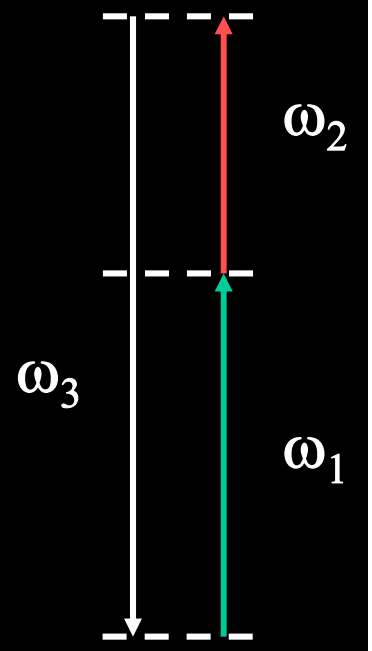
$\omega_3 = \omega_1 - \omega_2$



Sum-frequency generation to 254 nm: Hg



$\omega_3 = \omega_1 + \omega_2$

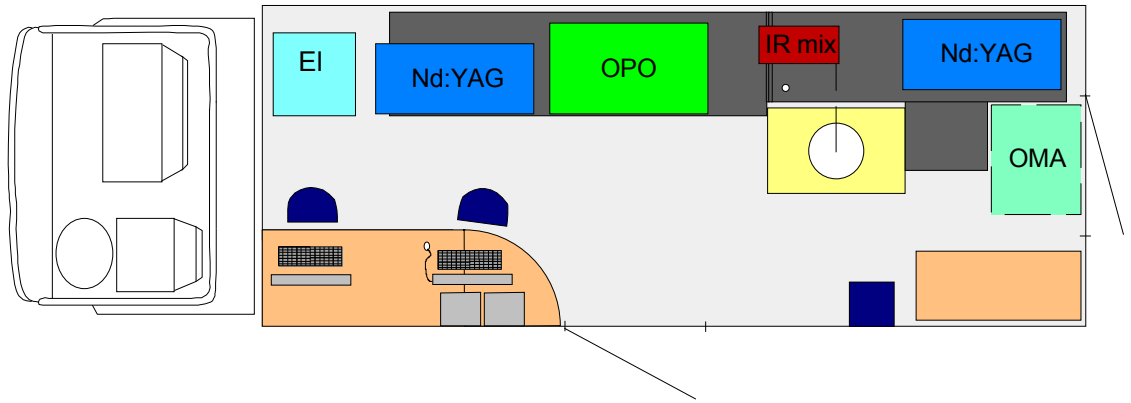


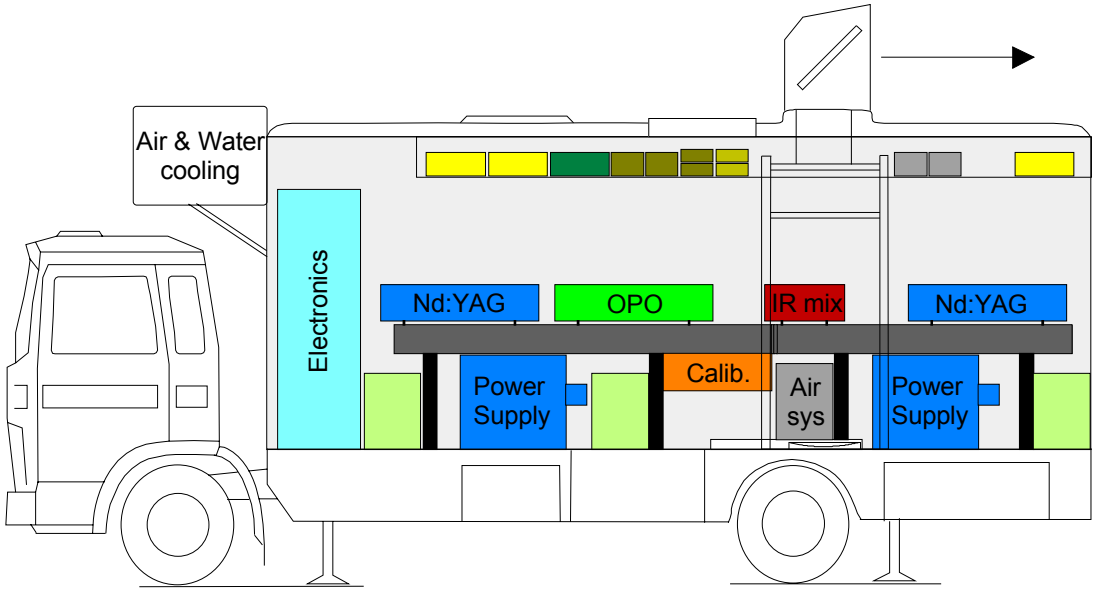
Also:
SO_2, NO_2
H_20

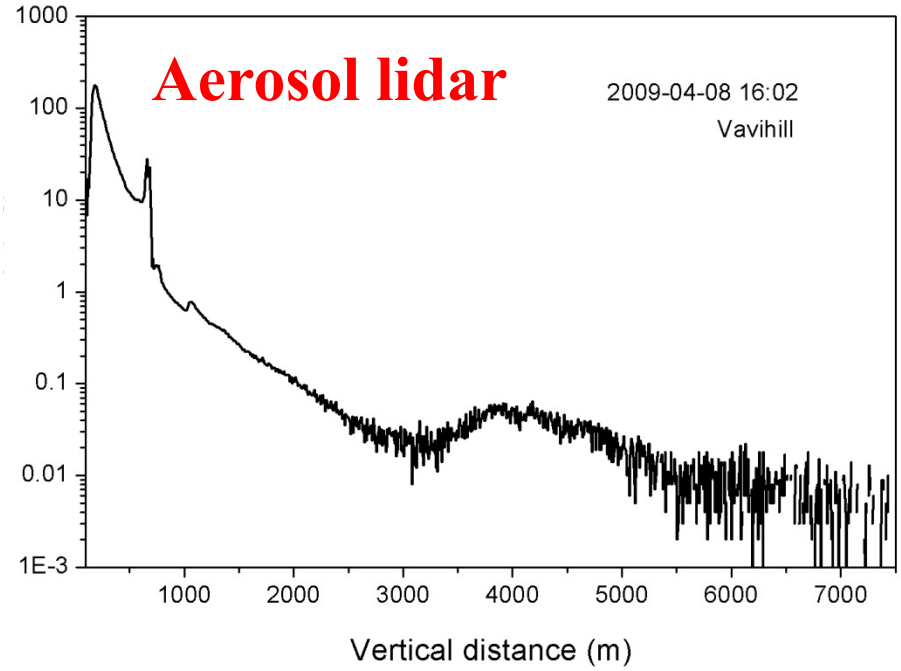
Alnis et al.
Appl. Phys. Lett.

LIDAR

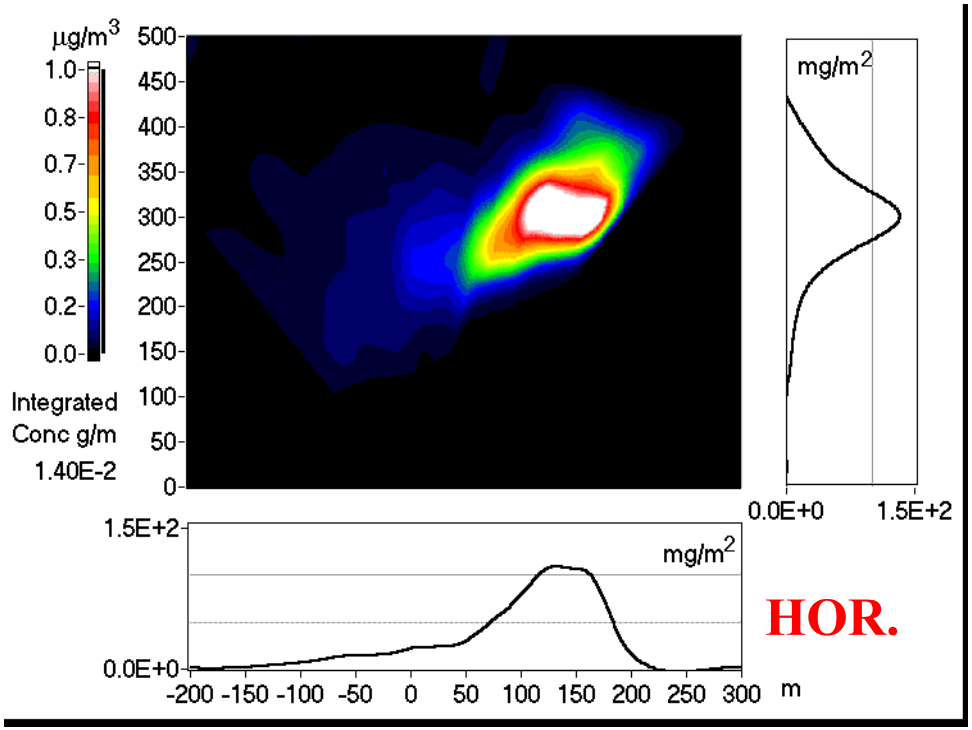
Lund mobile Lidar system





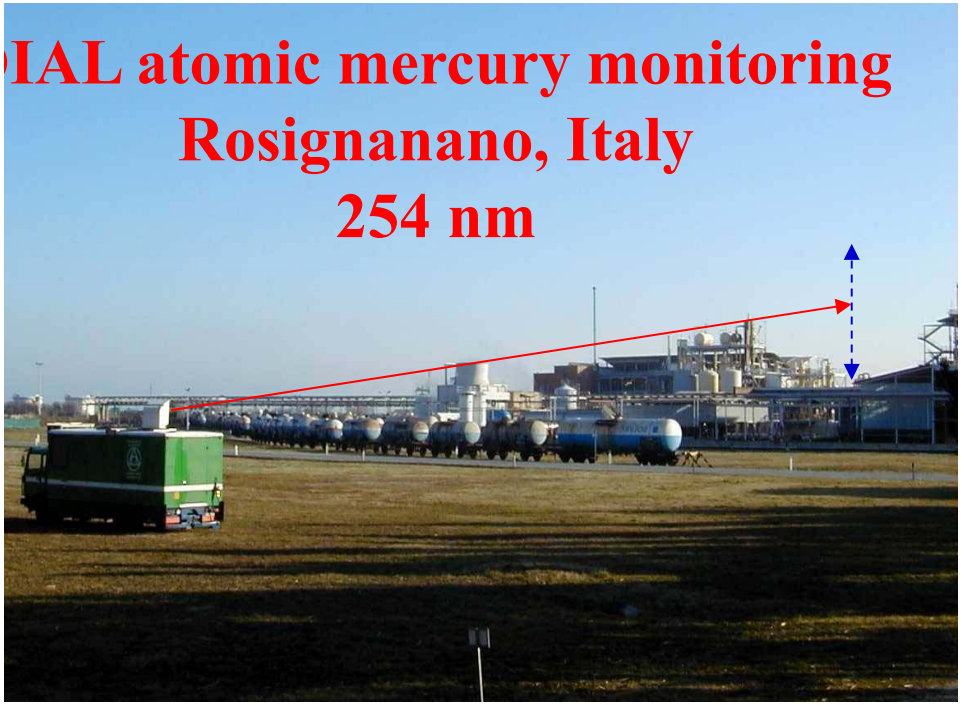


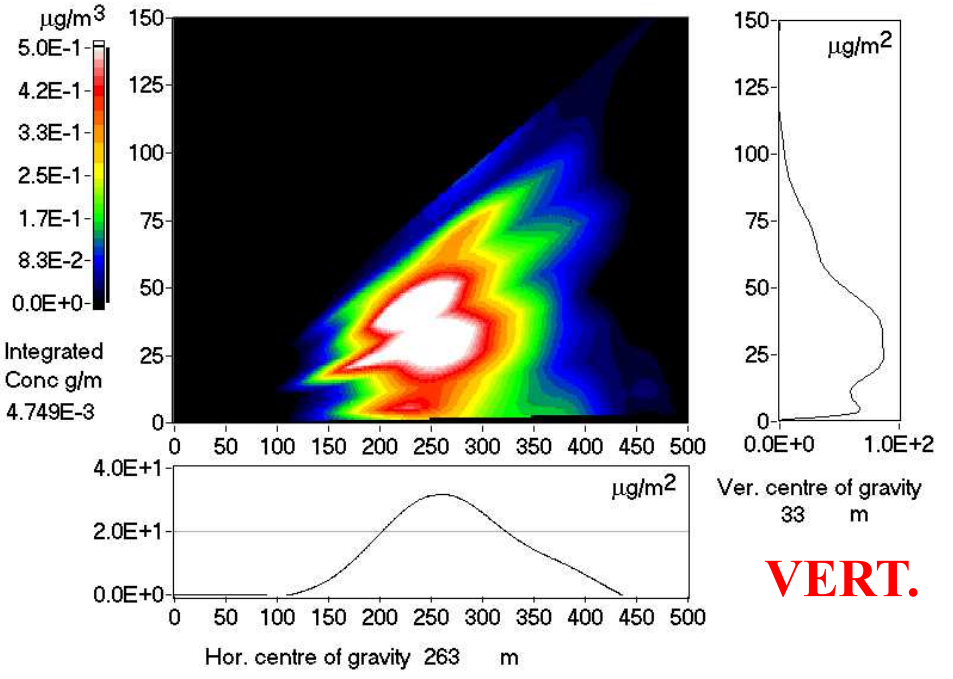
Vertical sounding



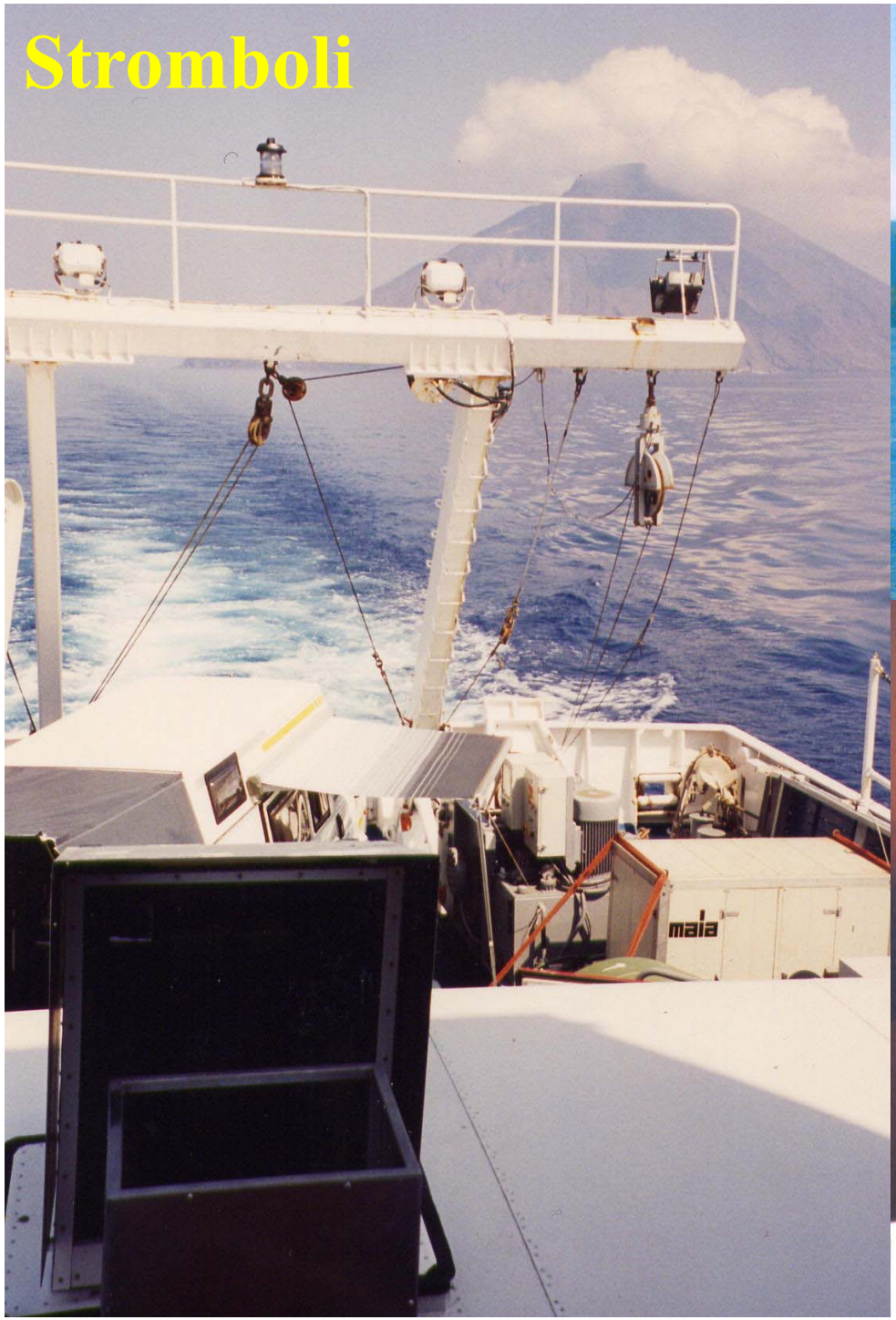
HOR.

IAL atomic mercury monitoring
Rosignanano, Italy
254 nm





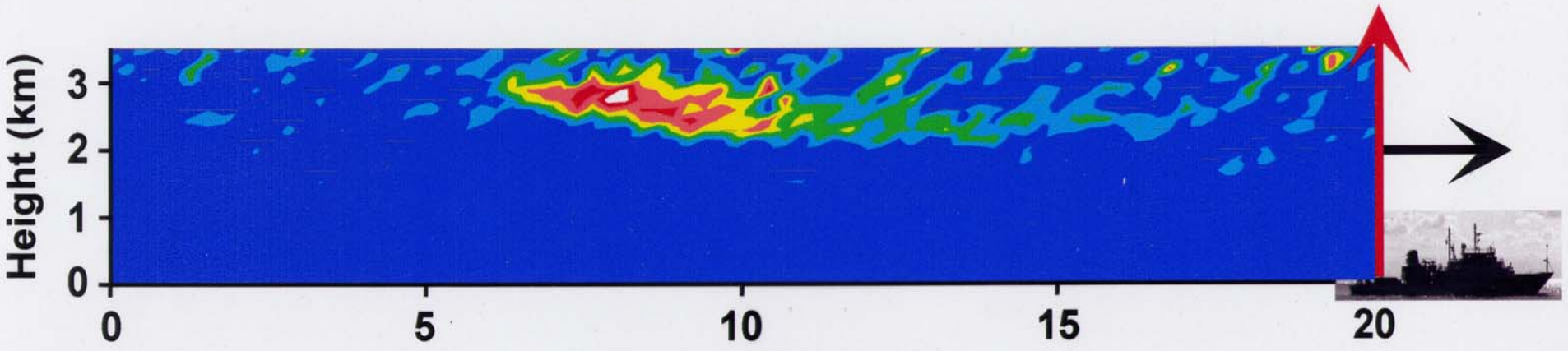
VERT.

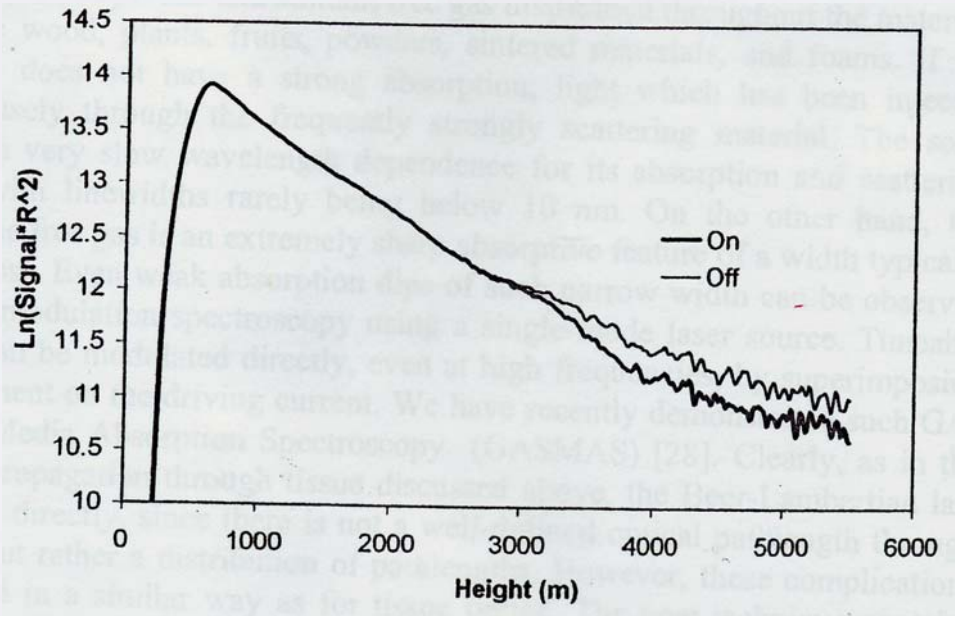

Stromboli


Vulcano


Etna

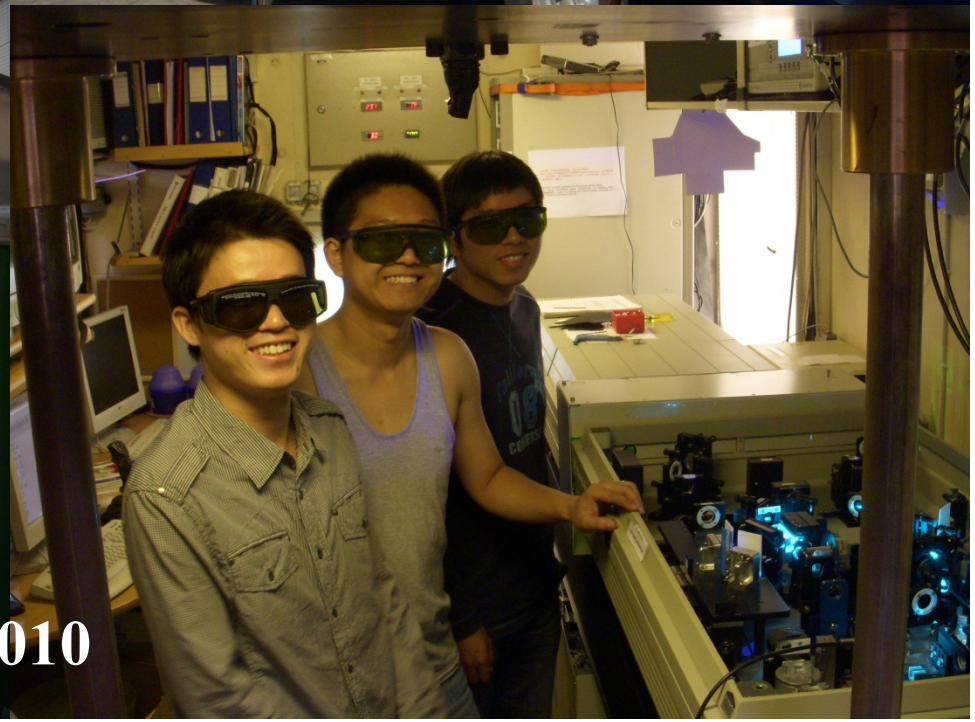
Sulphur dioxide plume from Etna - Flux: 50 tonnes/h





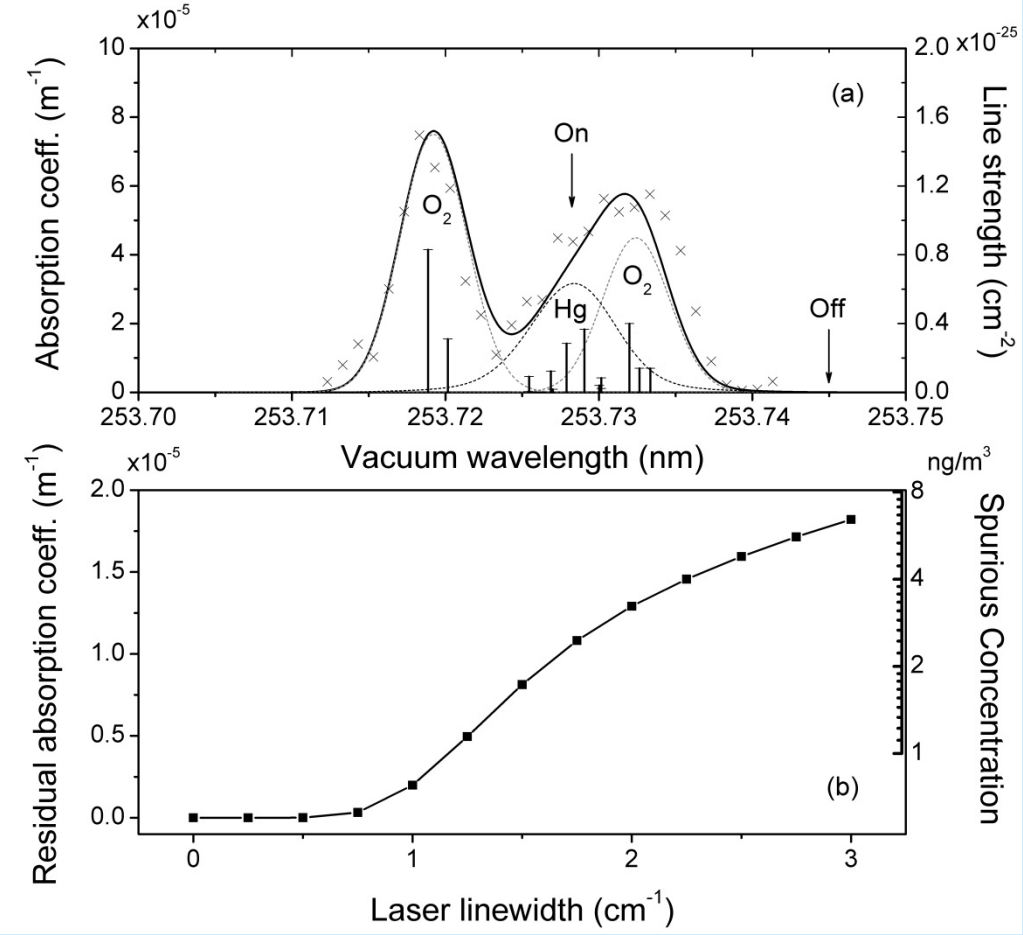
Edner et al.

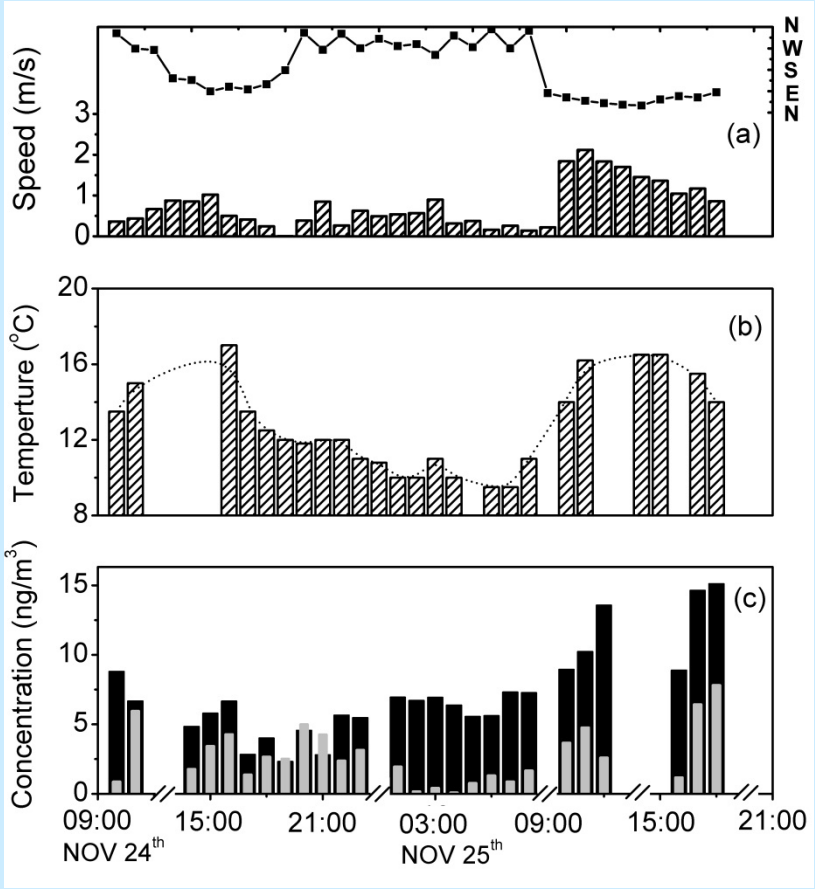
Lund Lidar at ZJU, Hangzhou



2010

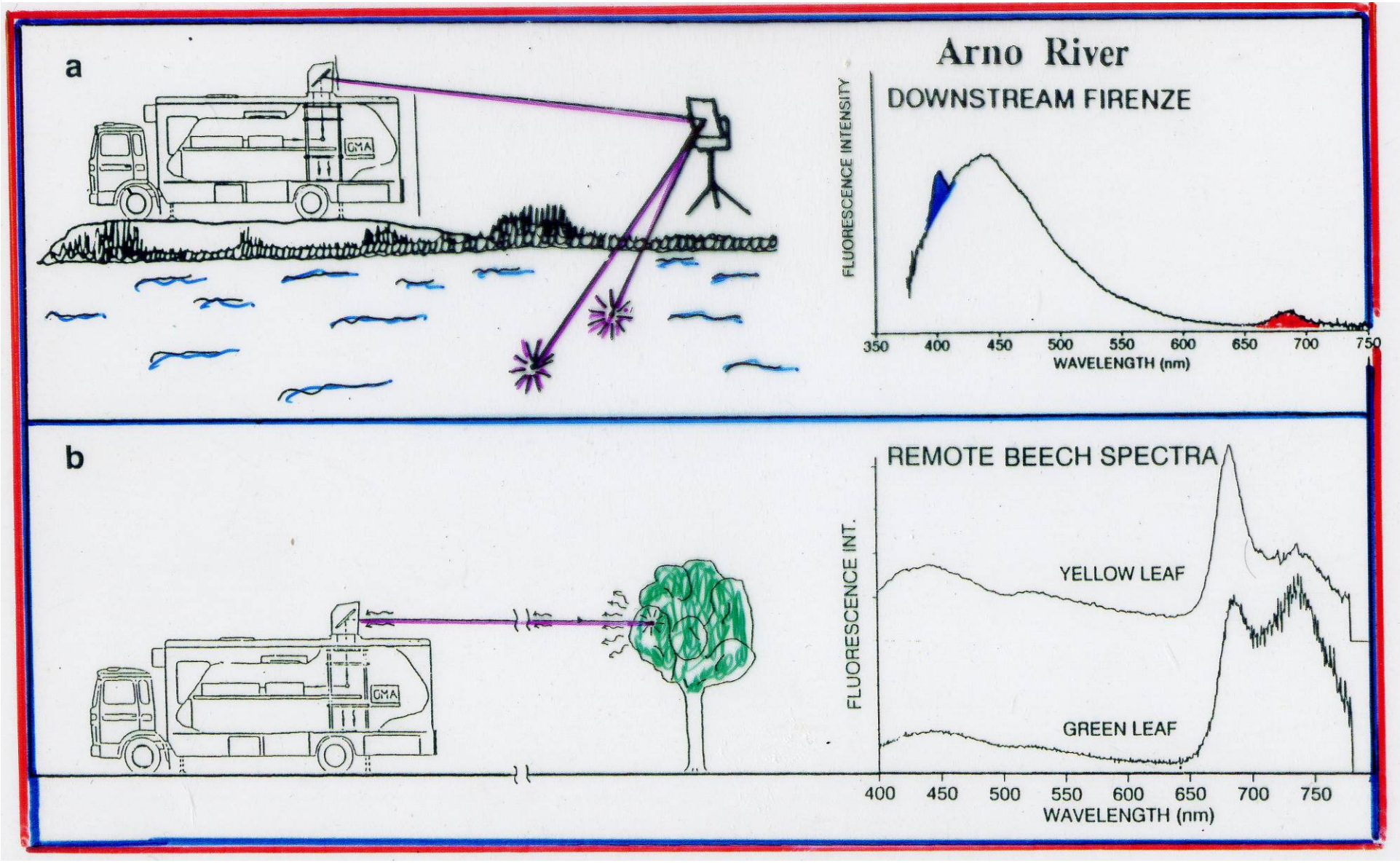
Atomic Mercury Vertical Lidar Monitoring
Hangzhou, China



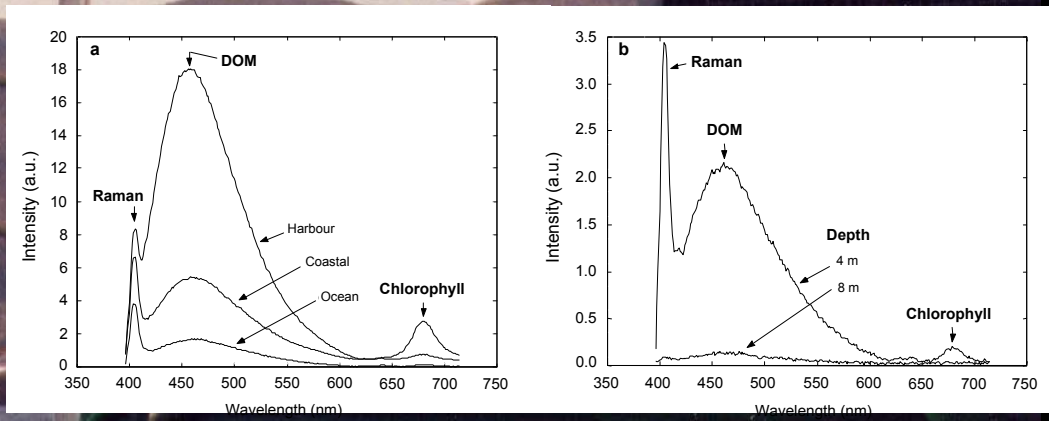


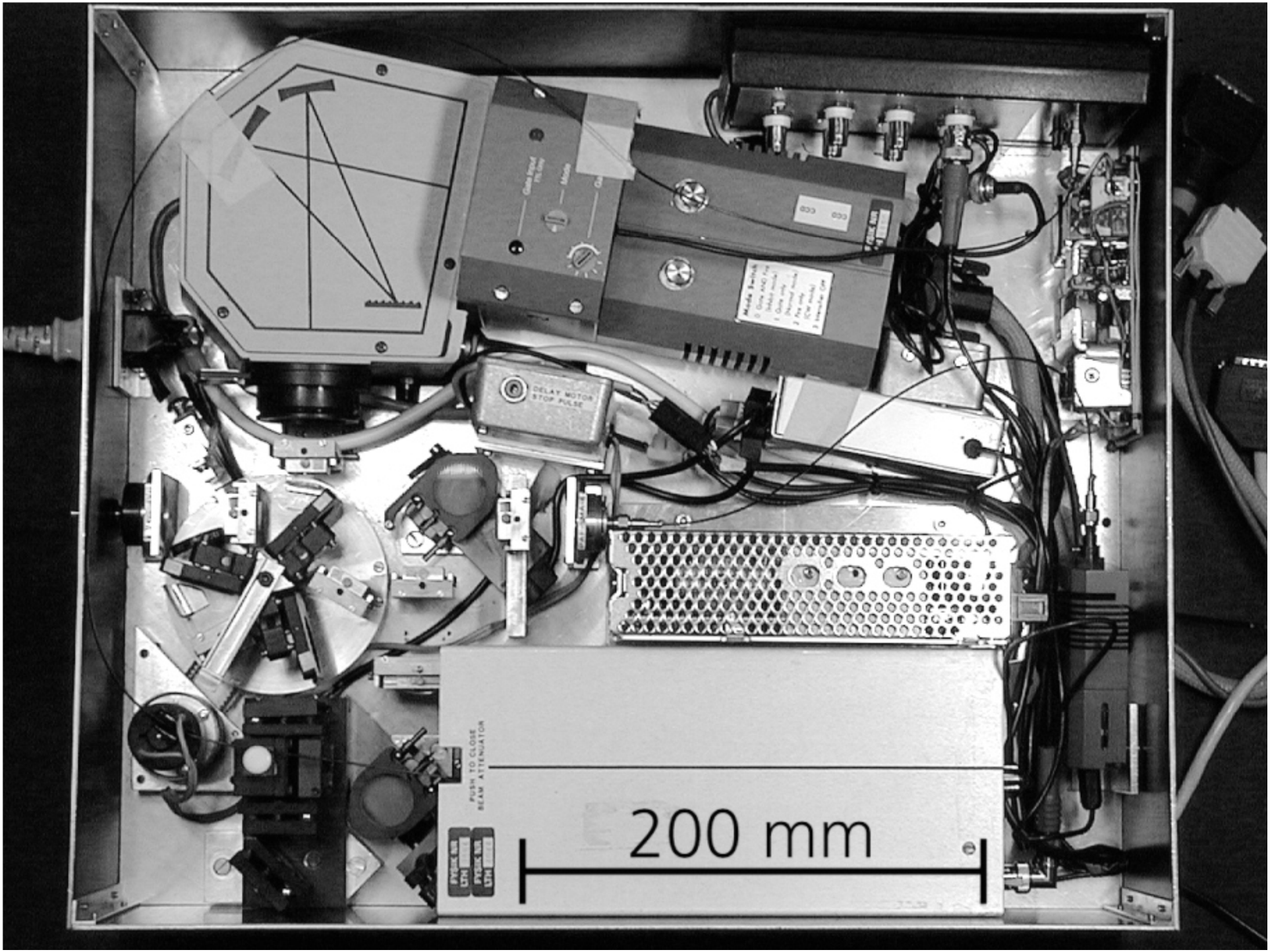
FLUORESCENCE

LIDAR REMOTE FLUORESCENCE MONITORING

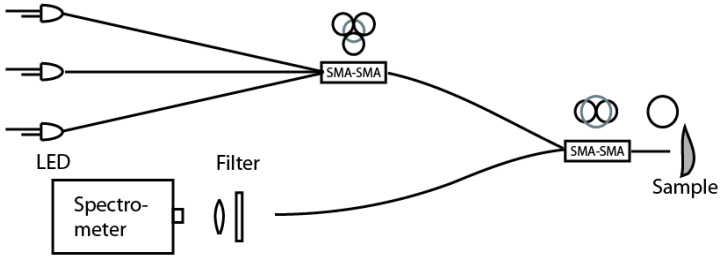


Aquatic Monitoring Favignana, Sicily

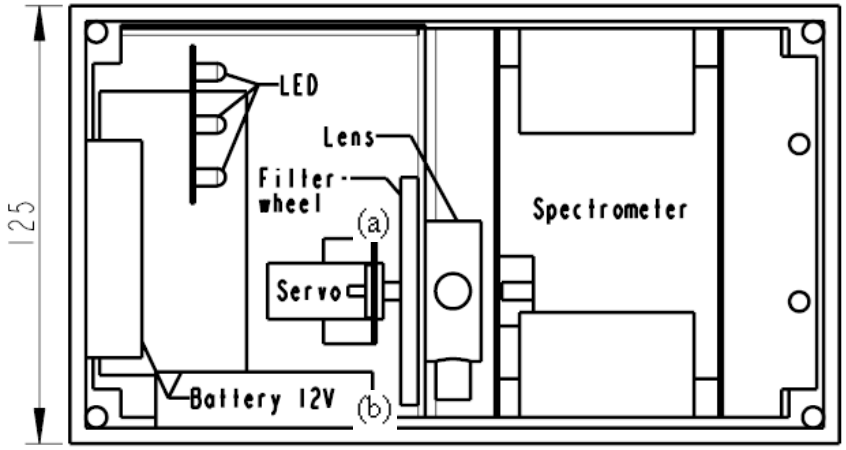


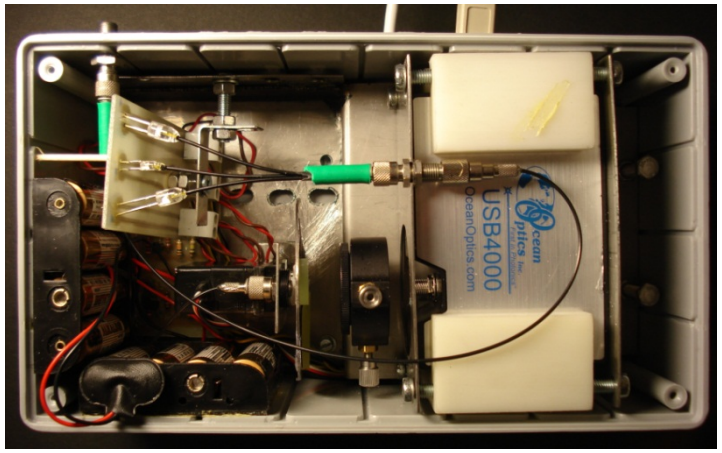

DELAY MOTOR
STOP PULSE
PUSH TO CLOSE
BEAM ATTENUATOR
200 mm

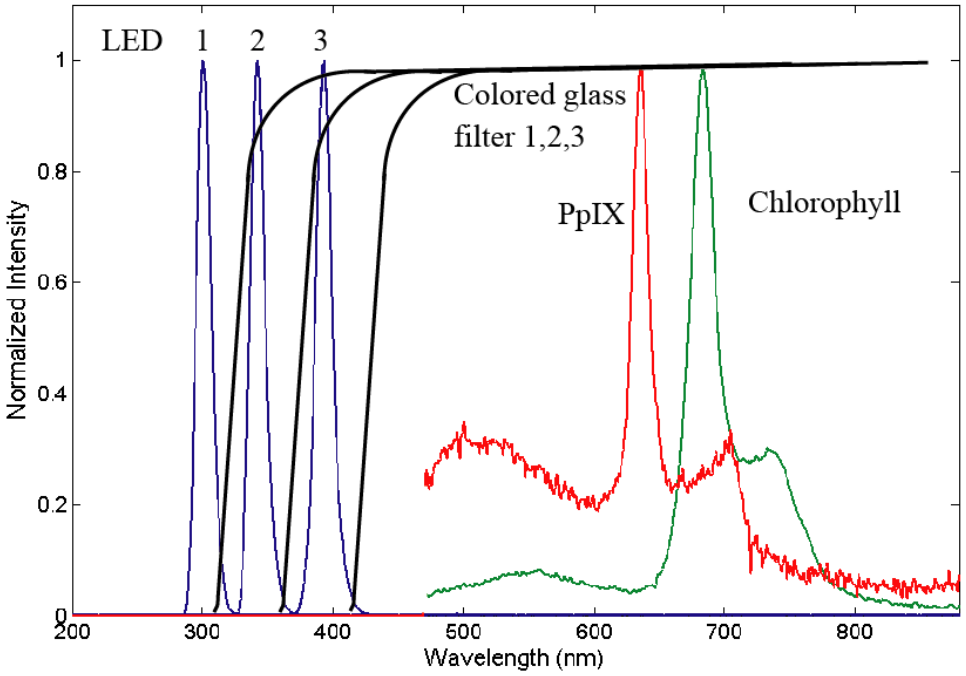
Compact UV LED Based Fluorosensor

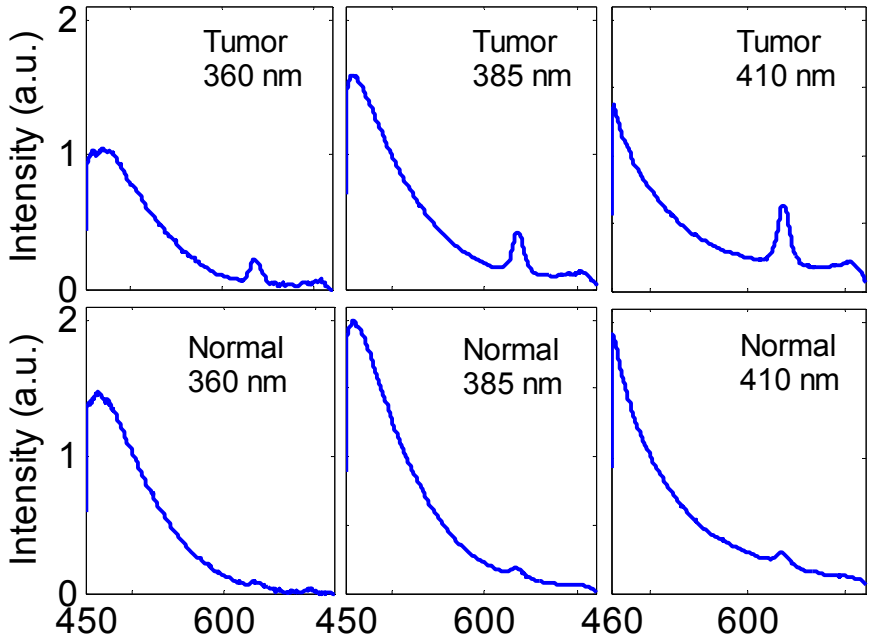


S. Ek et al.
Spectrochim Acta A
2007







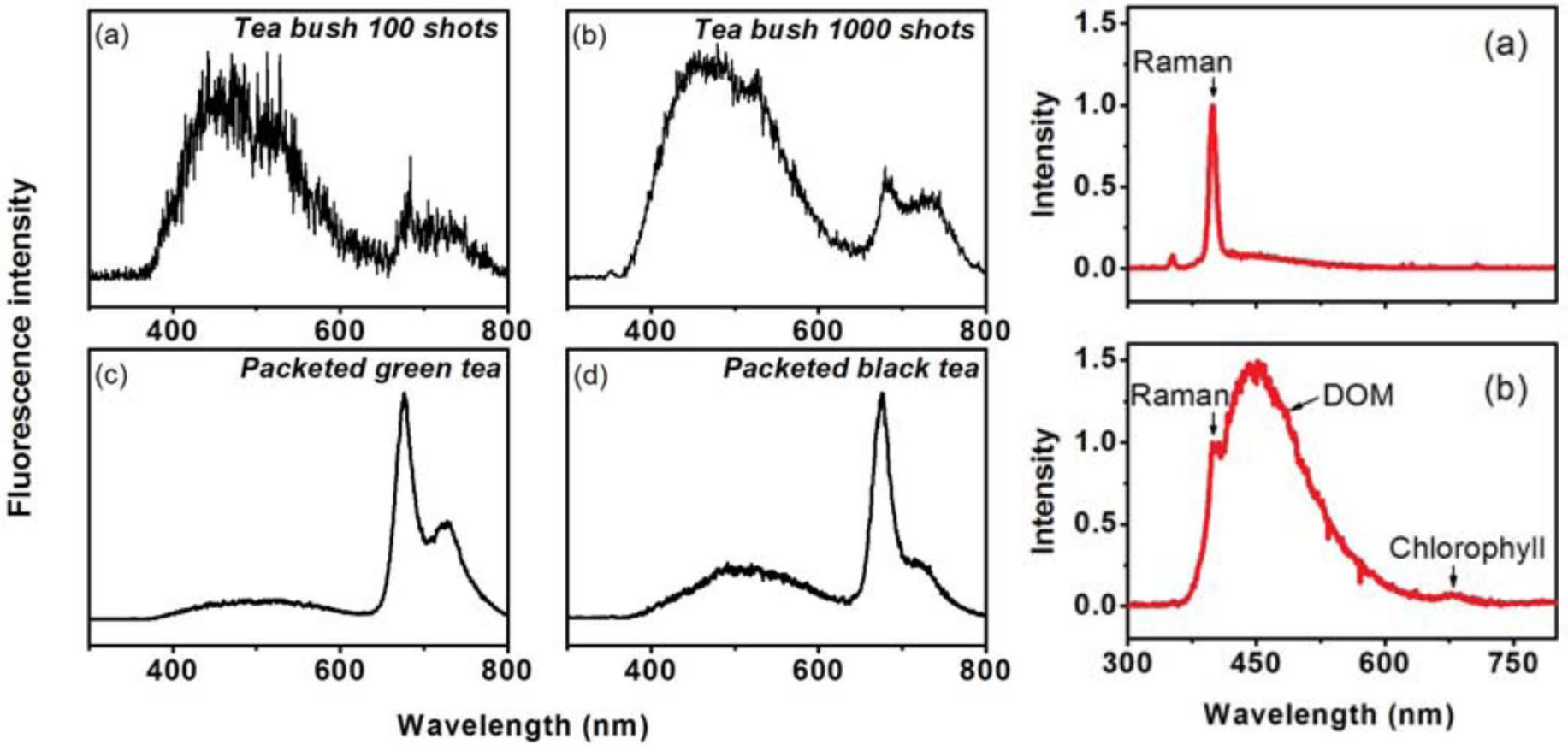


Fluorescence monitoring of tea **Fluorescence monitoring of water**

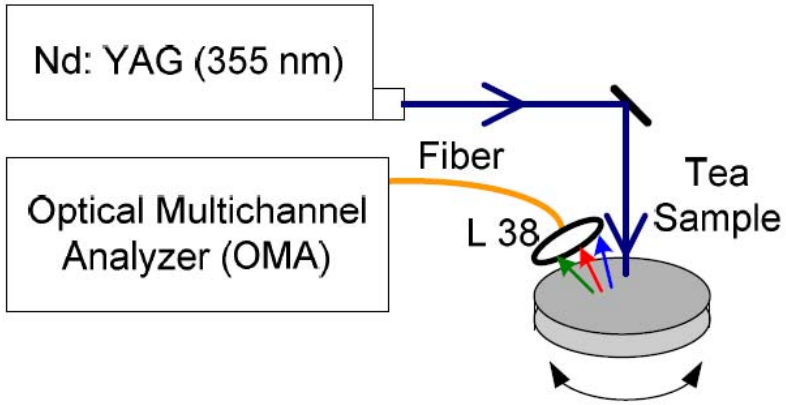
50 meter distance

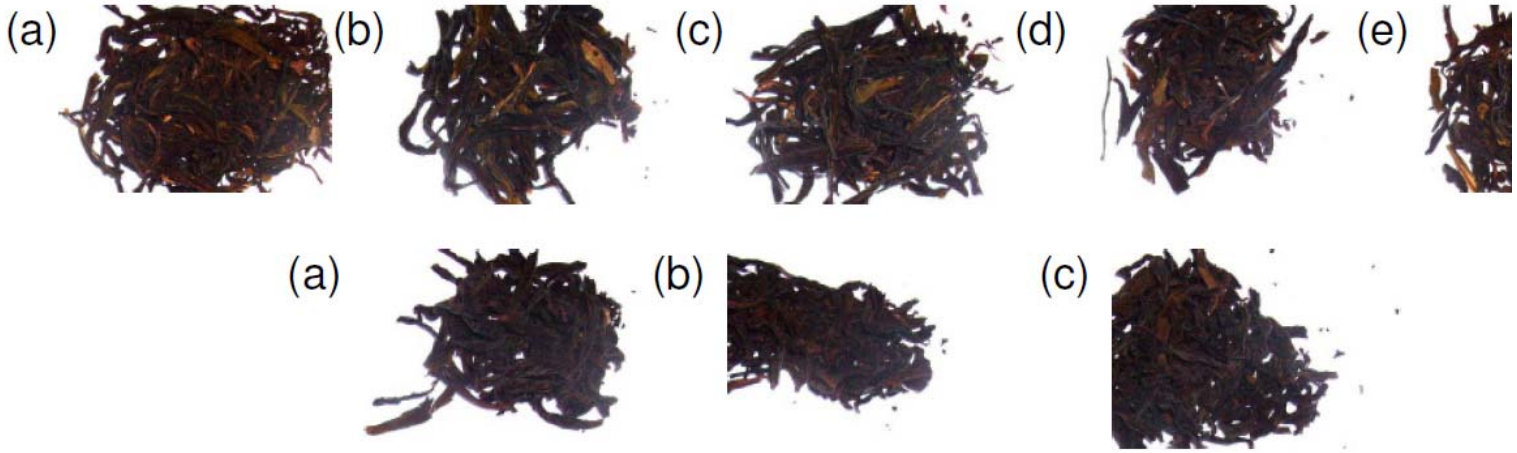
Hangzhou, China

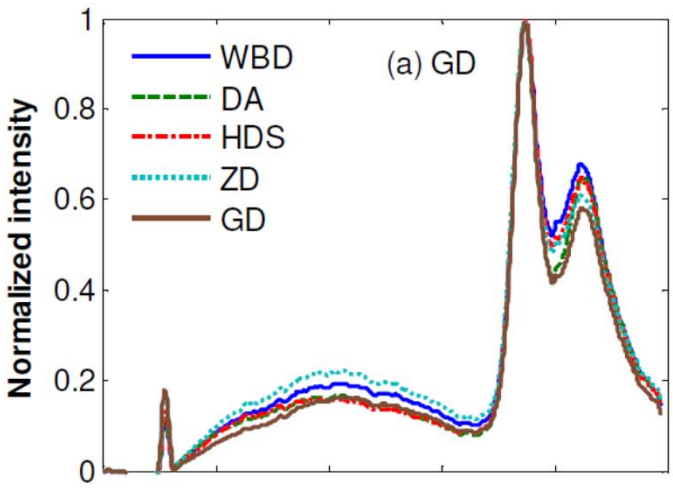
Mei Liang et al., 2012

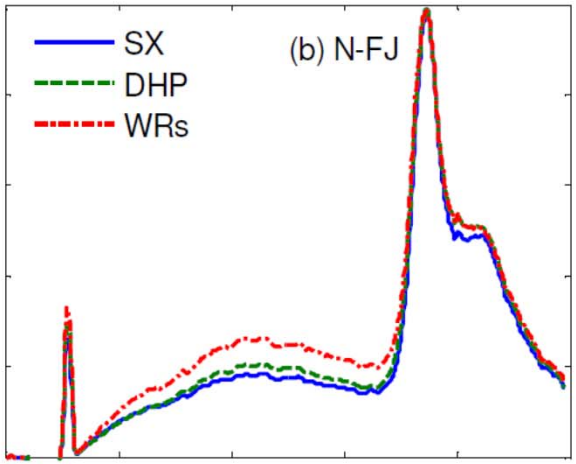


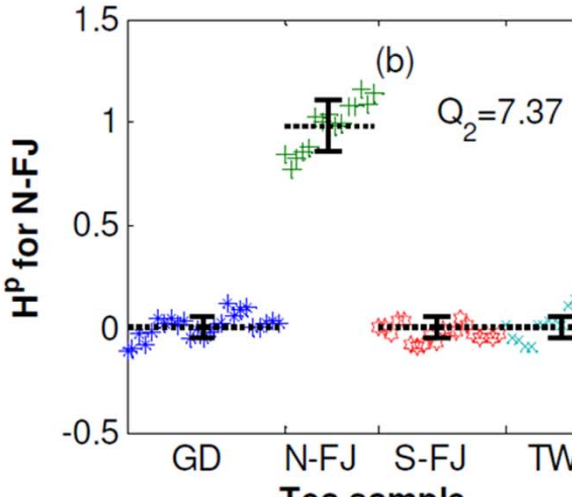
Assessing tea quality by fluorescence spectroscopy



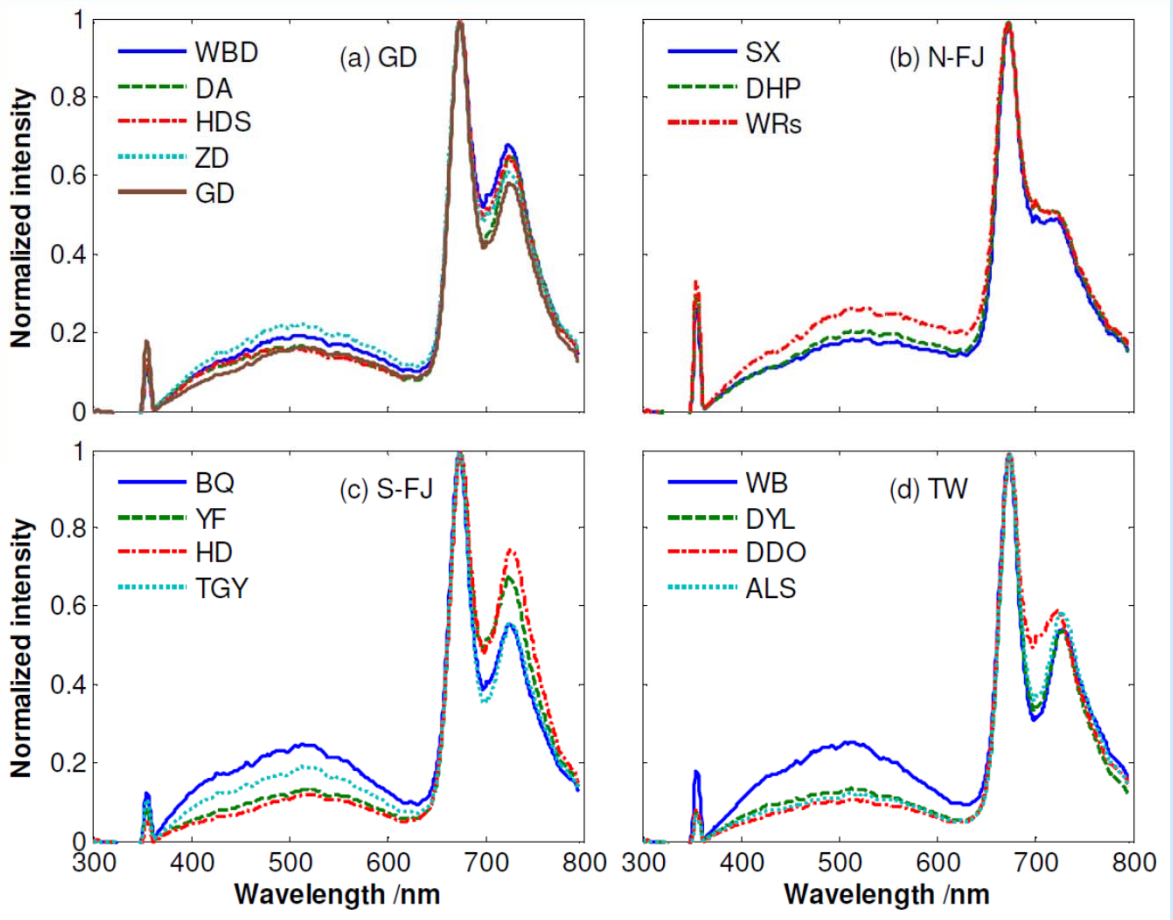


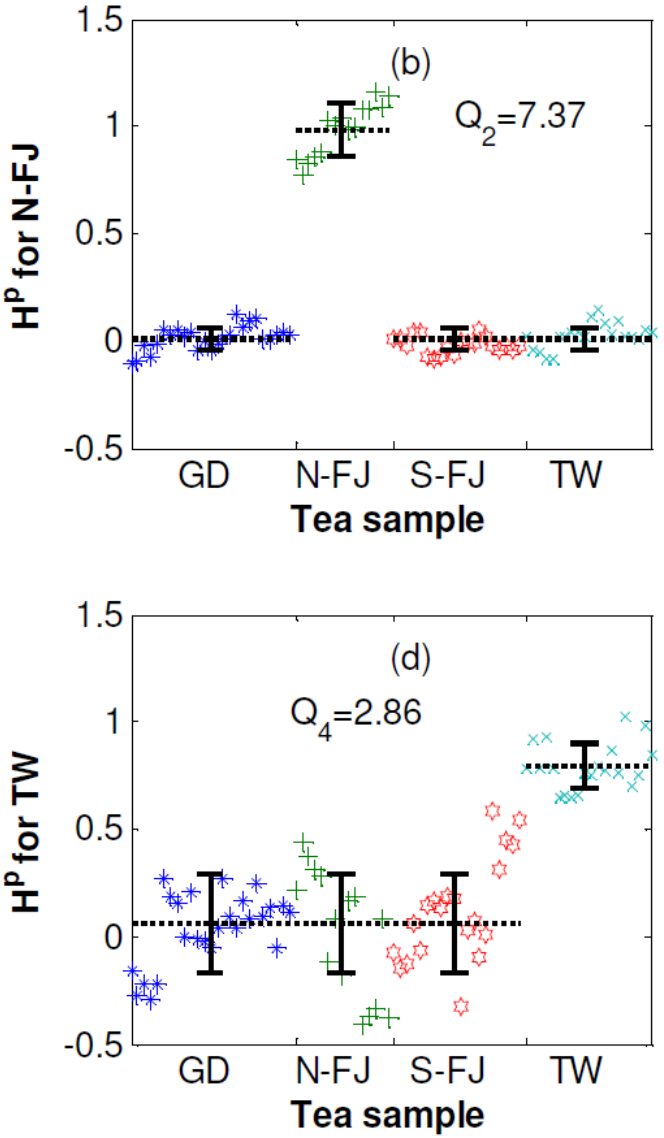






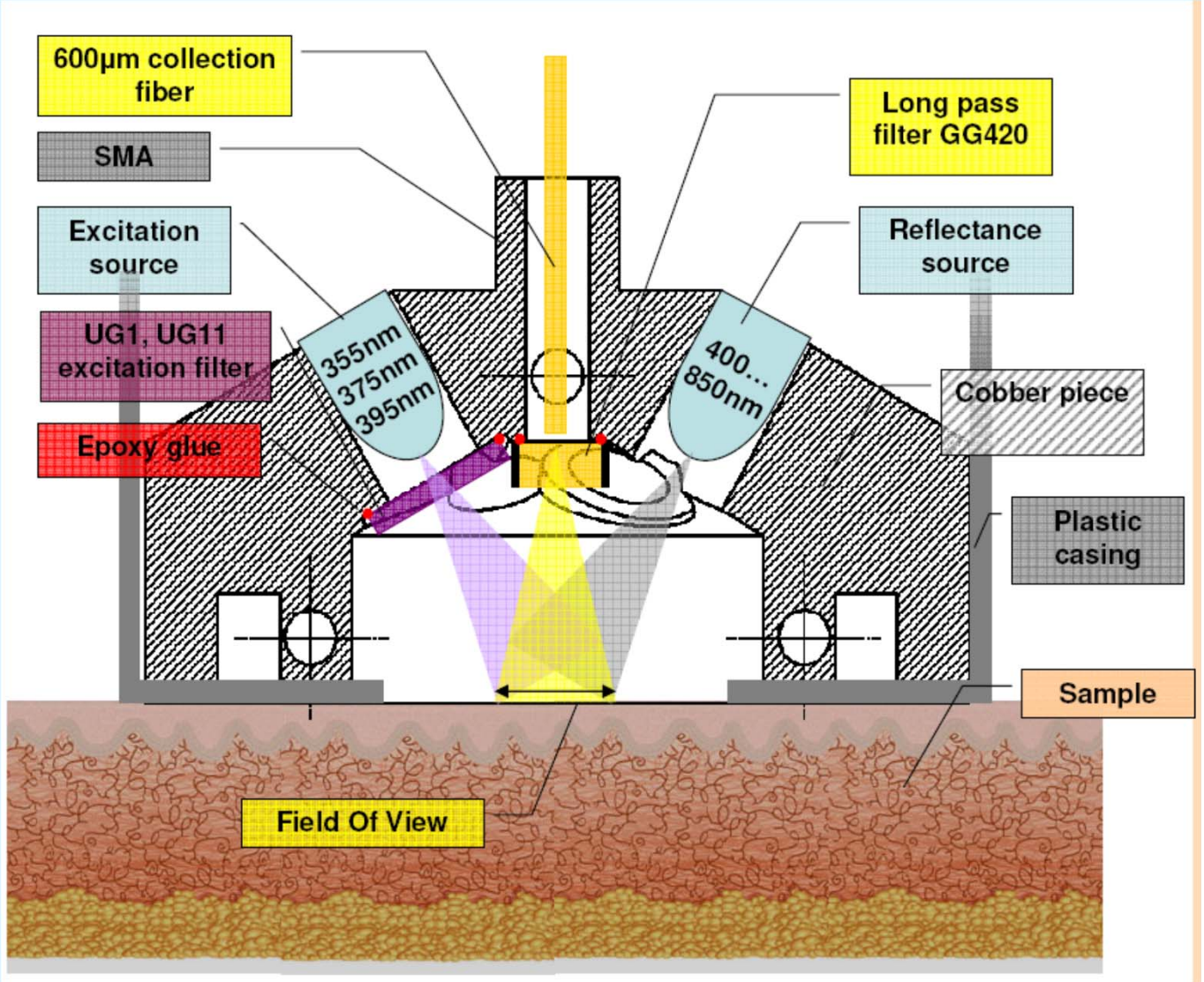
Finding out the Origin of Chinese Teas Using Laser-Induced Fluorescence





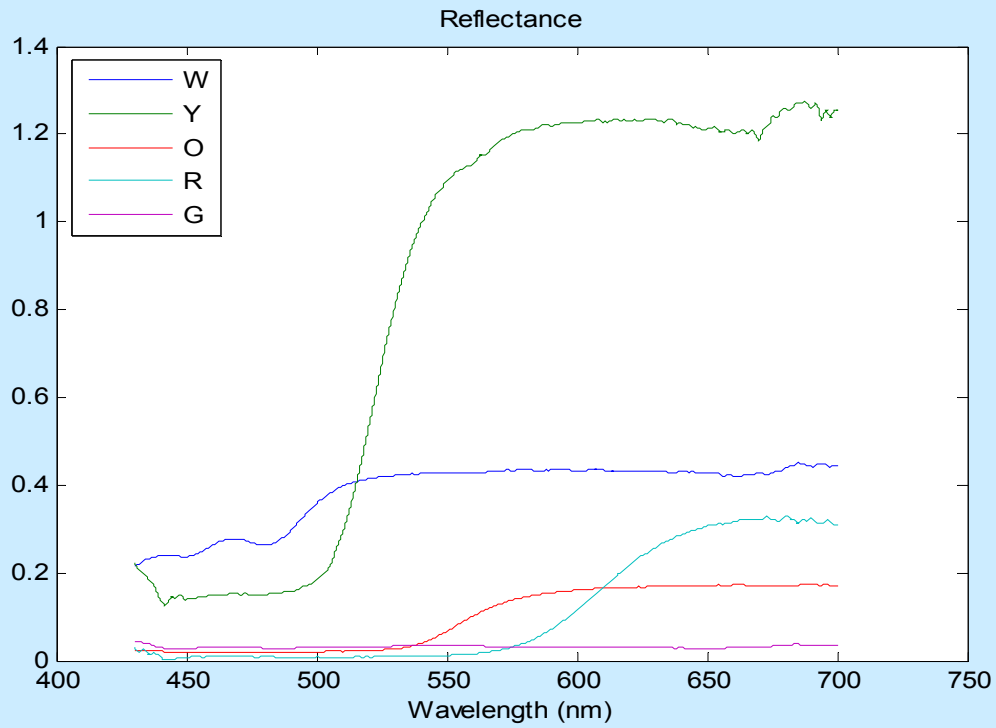
LED-based, Non-contact Spectrometer Reflectance – Fluorescence

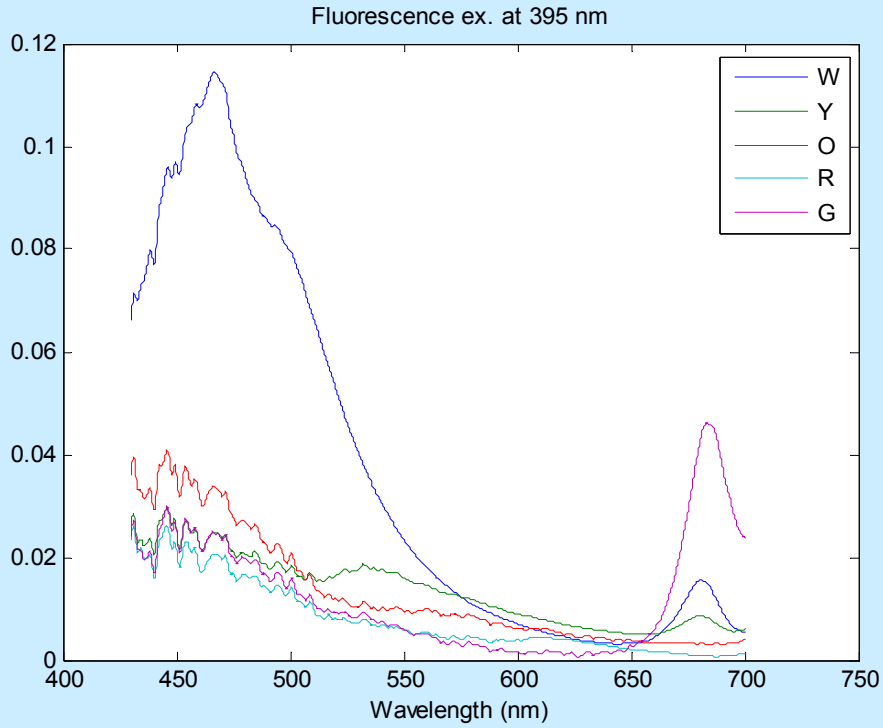
Brydegaard et al., to appear



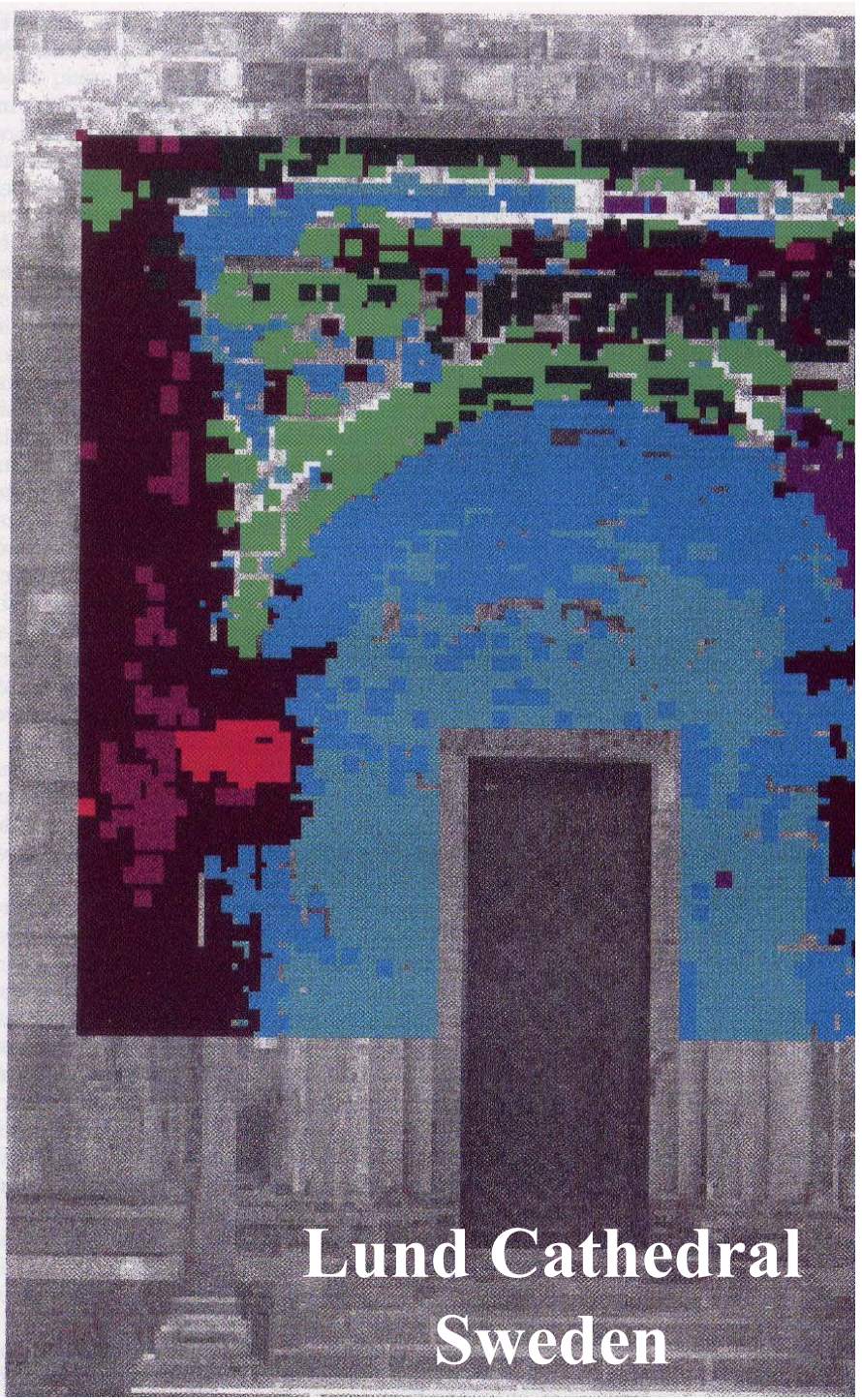
Reflectance and Fluorescence Paprika Varieties

Jayaweera, Andersson, Brydegaard, Svanberg, to appear

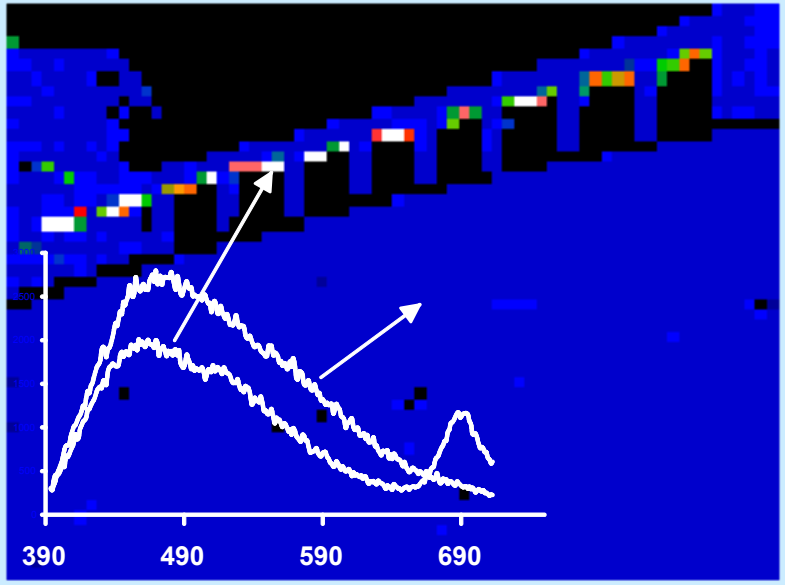


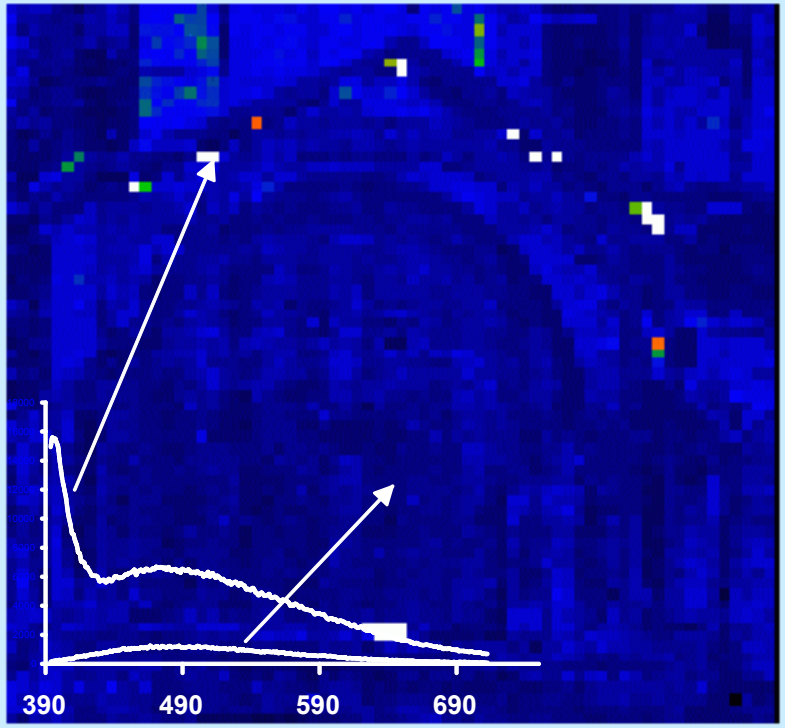


LIDAR IN CULTURAL HERITAGE MONITORING

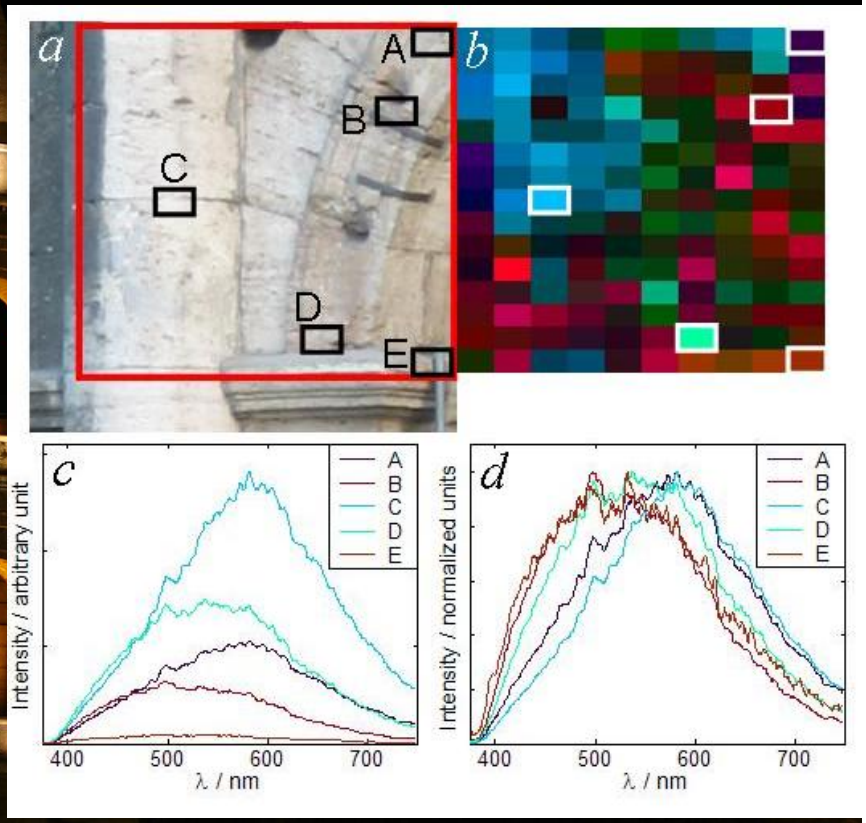


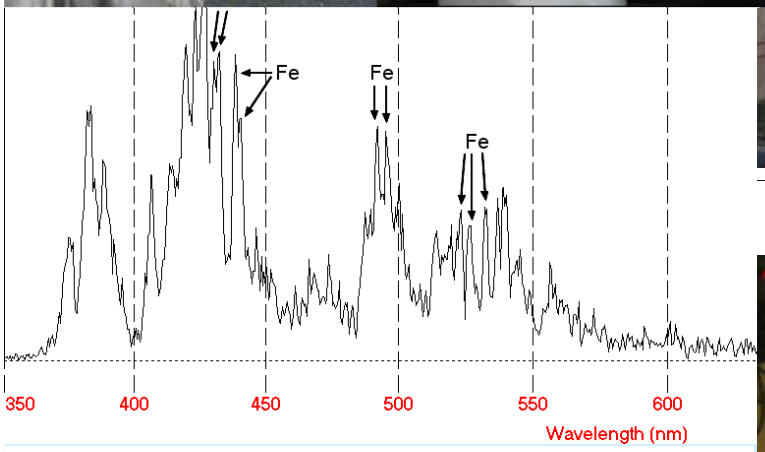
Lund Cathedral
Sweden

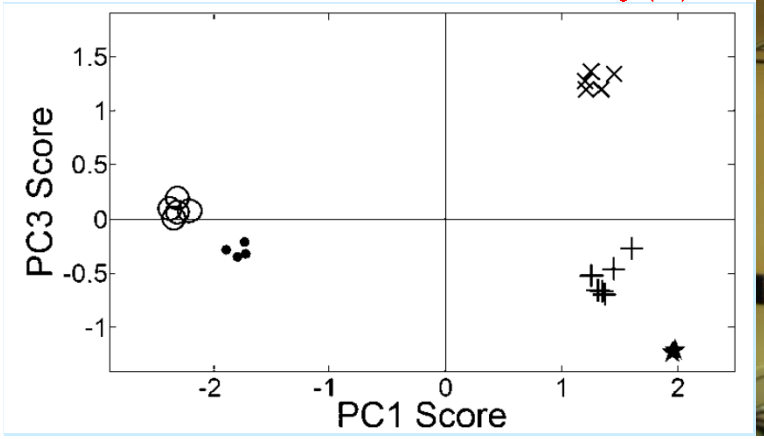

390
490
590
690

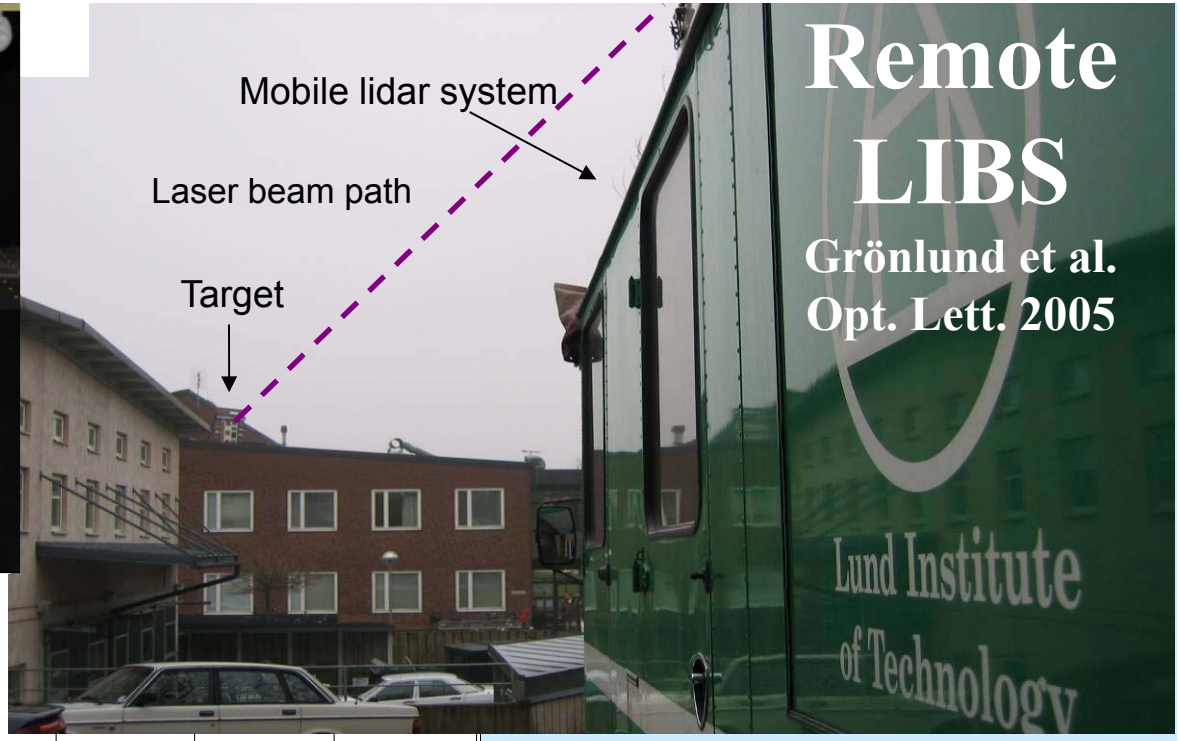

390
490
590
690

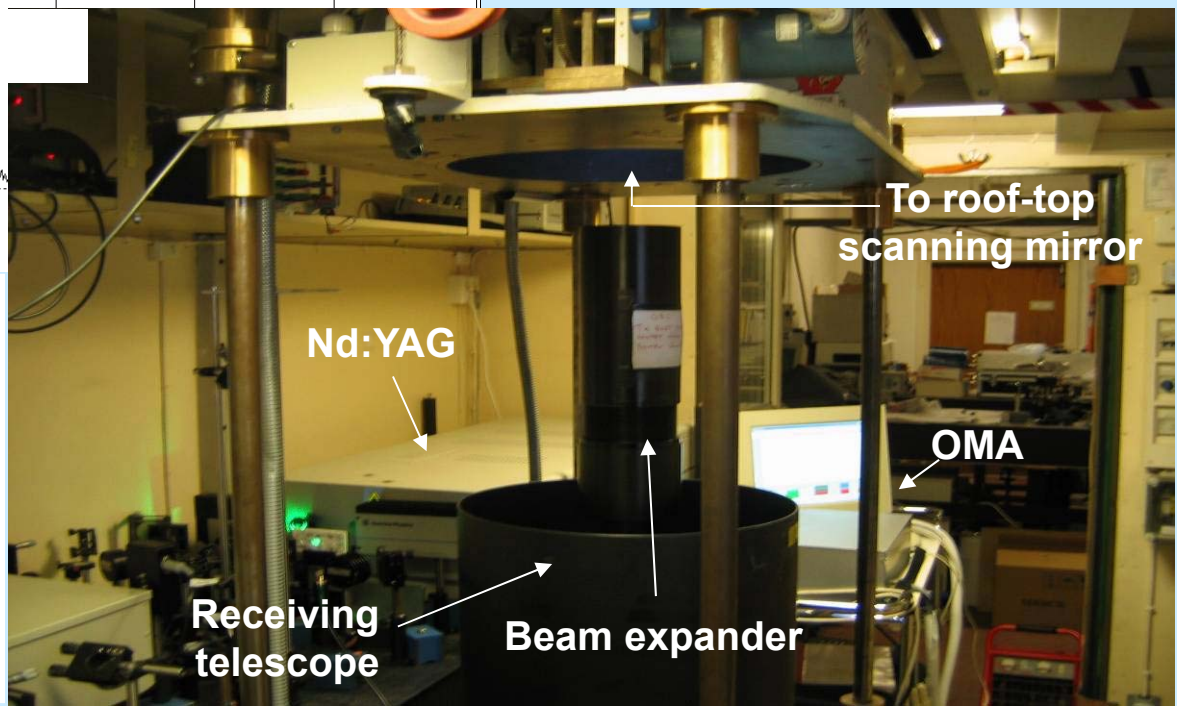
Rome Coliseum



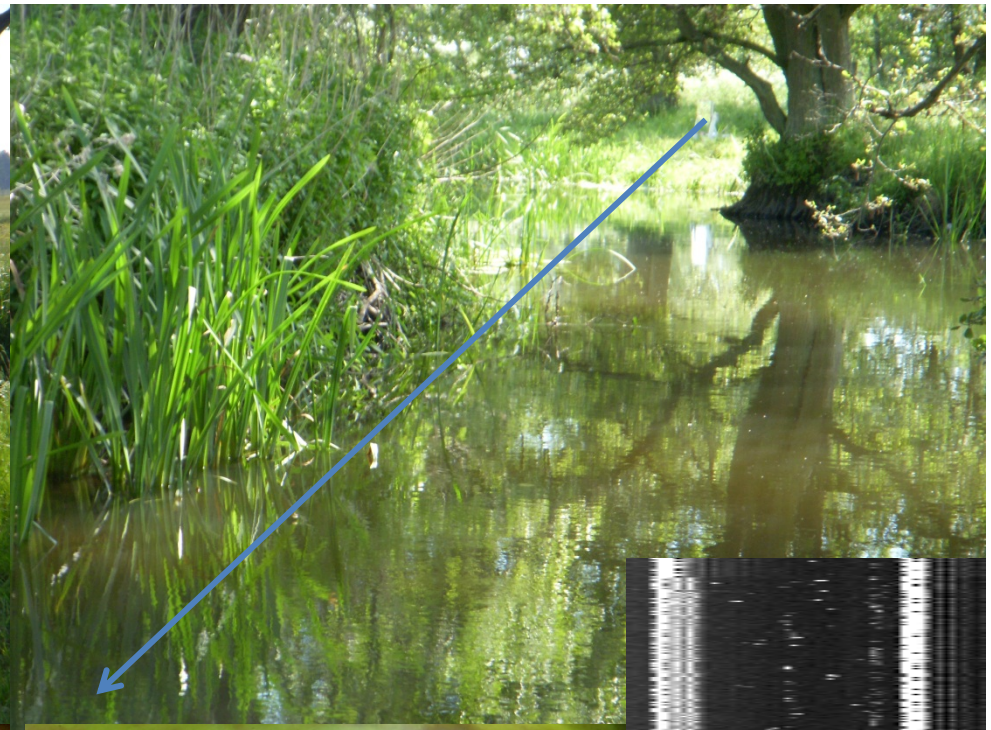

Fe
Fe
Fe
350
400
450
500
550
600
Wavelength (nm)

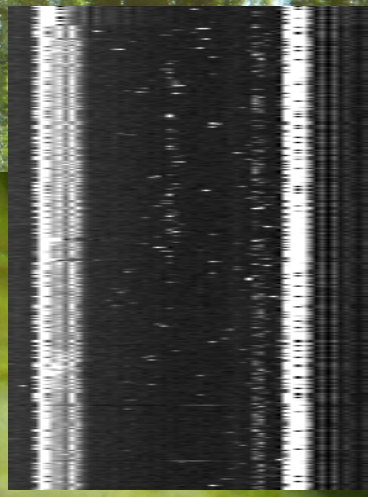

PC3 Score
PC1 Score
1.5
1
0.5
0
-0.5
-1
-2
-1
0
1
2

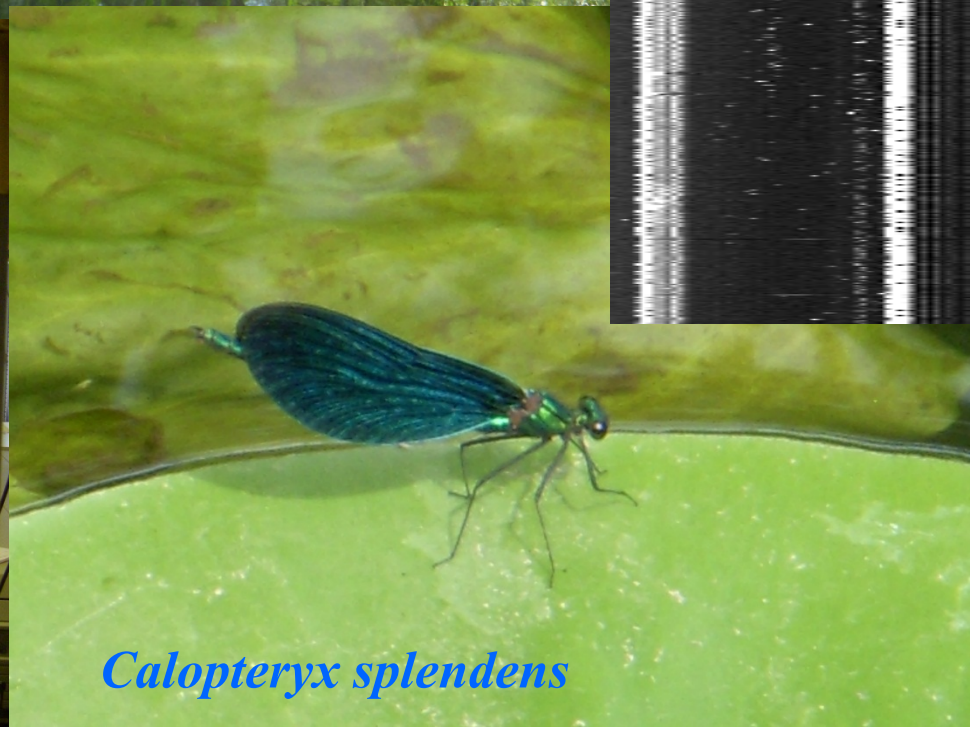

Mobile lidar system
Laser beam path
Target
Remote LIBS
Grönlund et al.
Opt. Lett. 2005
Lund Institute of Technology


To roof-top scanning mirror
Nd:YAG
OMA
Receiving telescope
Beam expander

Lidar in ecology

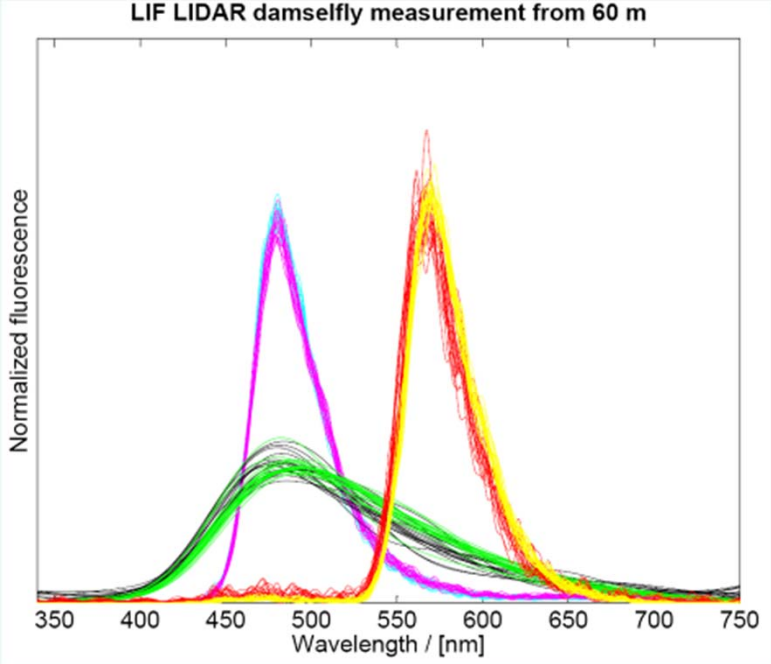


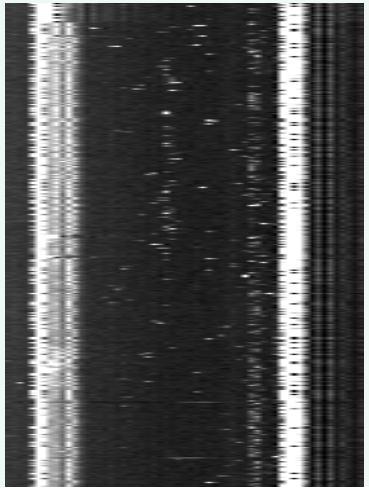


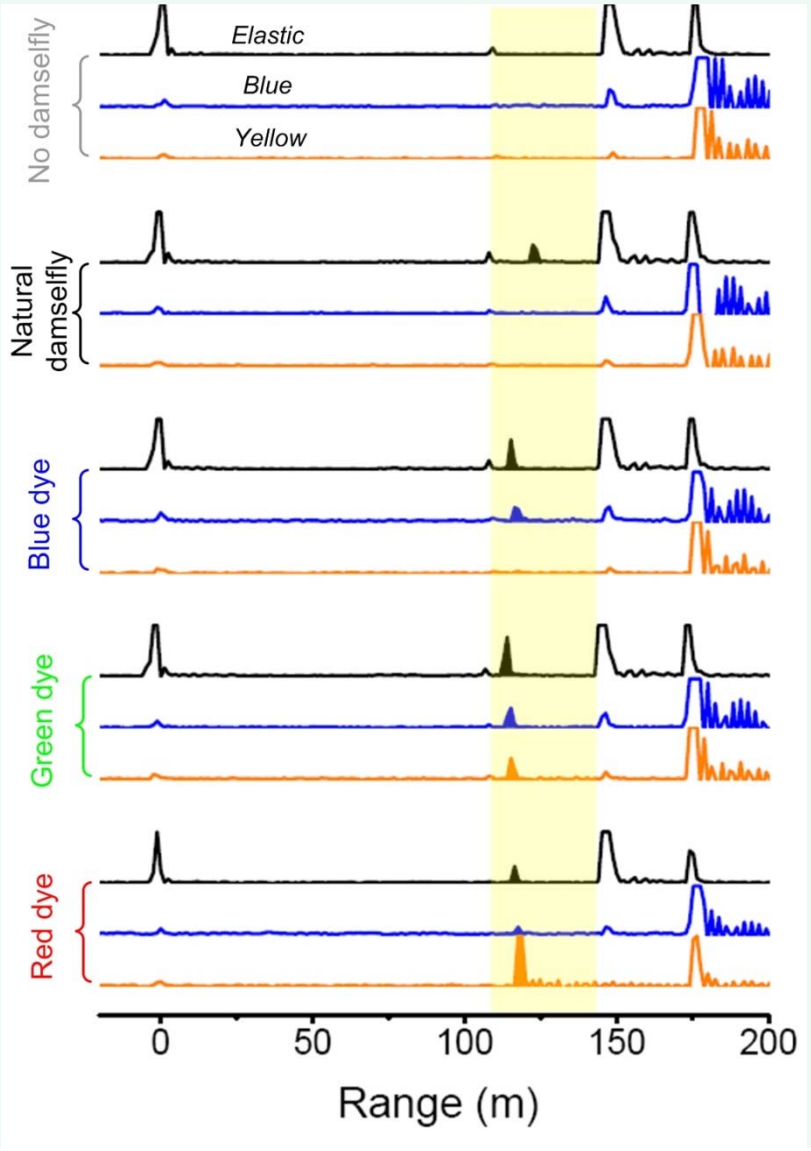


Calopteryx splendens

Damselfly
Fluorescence Lidar

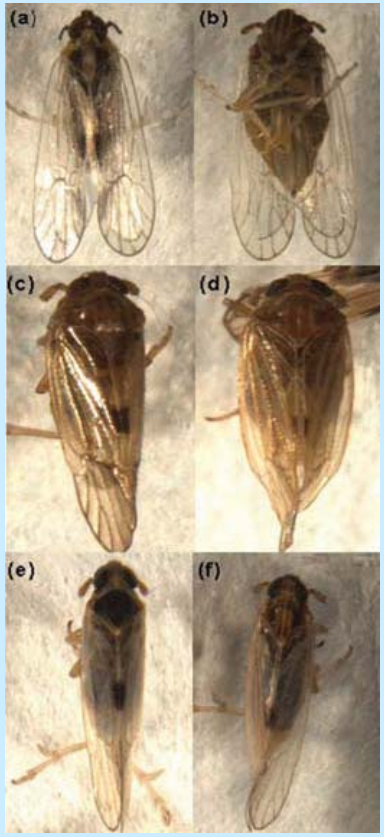


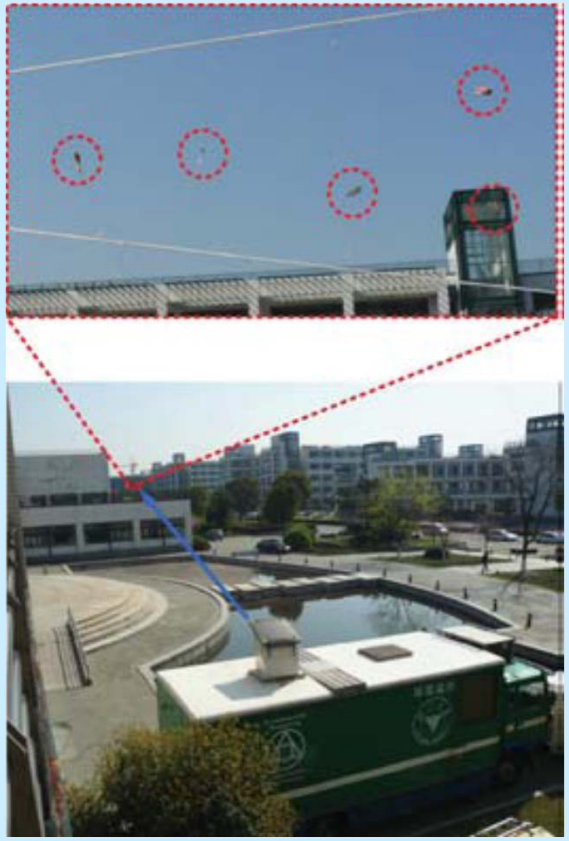


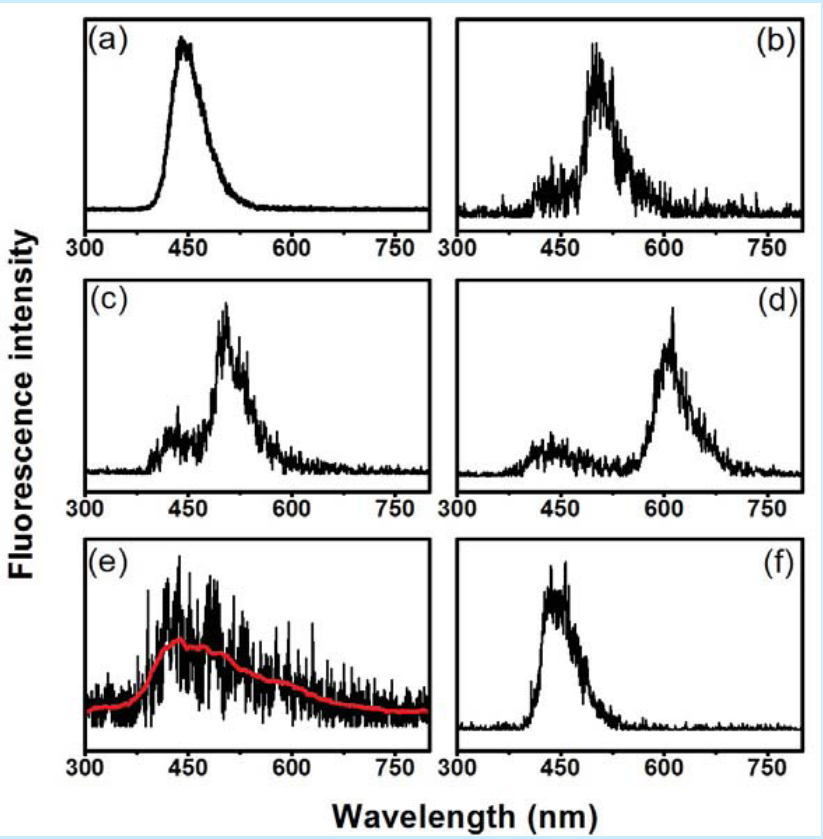


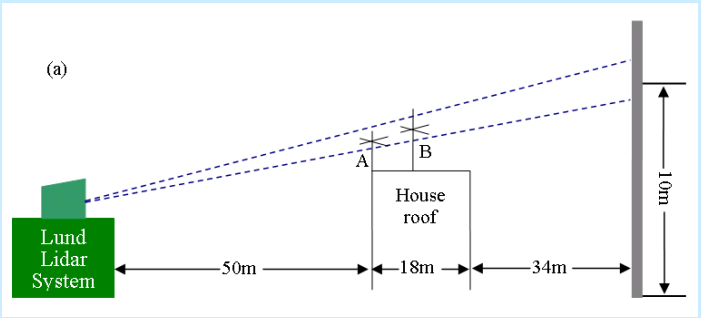
Fluorescence lidar monitoring of Chinese agricultural pests

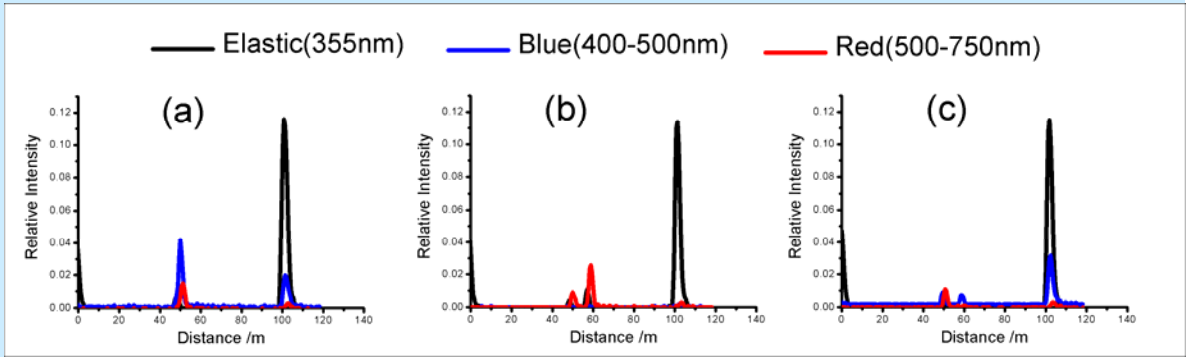
Pheromons to replace pesticides? Mei Liang et al., Appl. Phys. B (2011)





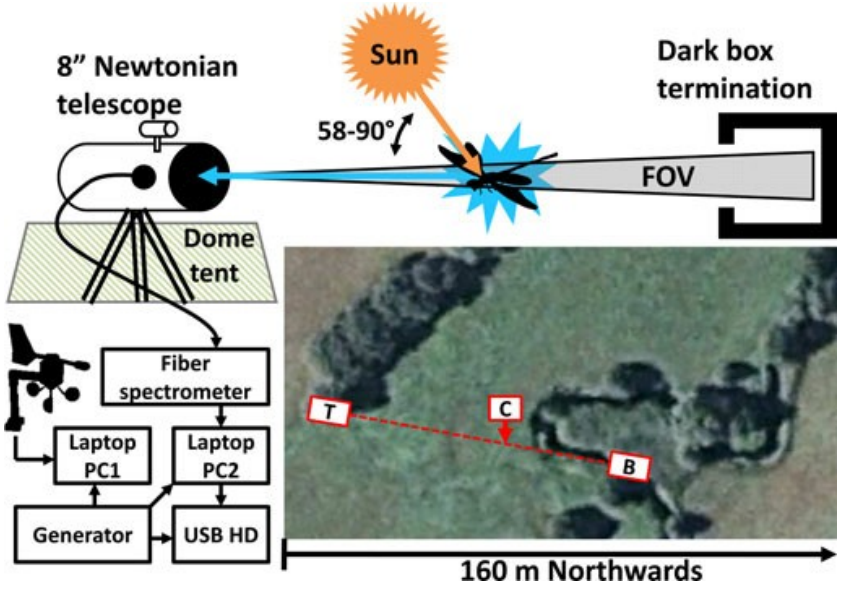


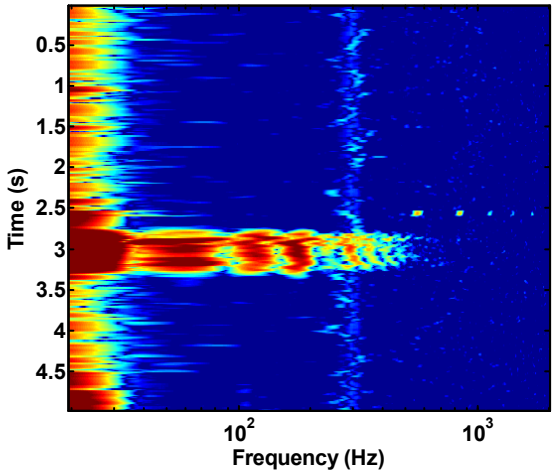




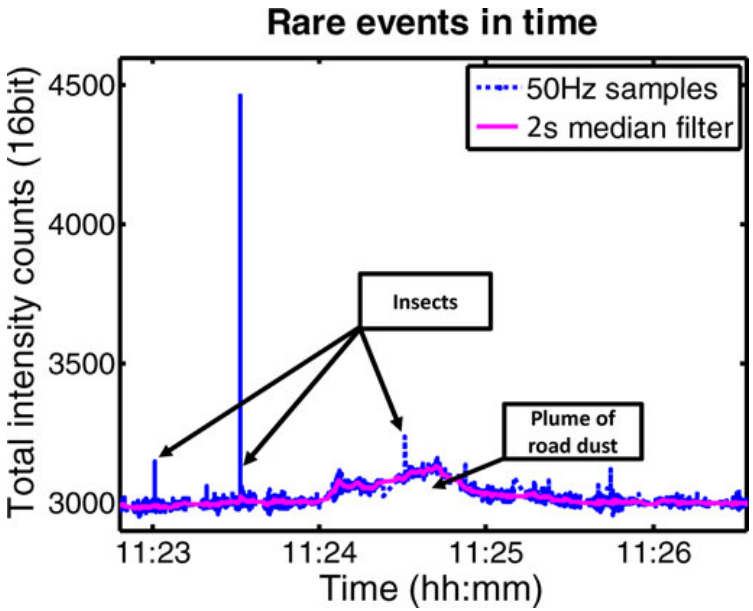
Passive spectral monitoring of insects/agricultural pests

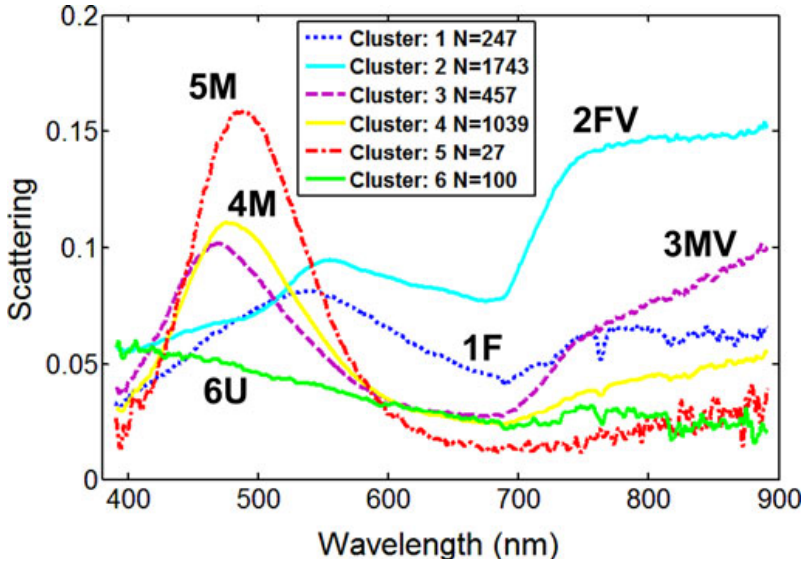
Brydegaard et al. IEEE (2011)





Wing-beat frequency analysis



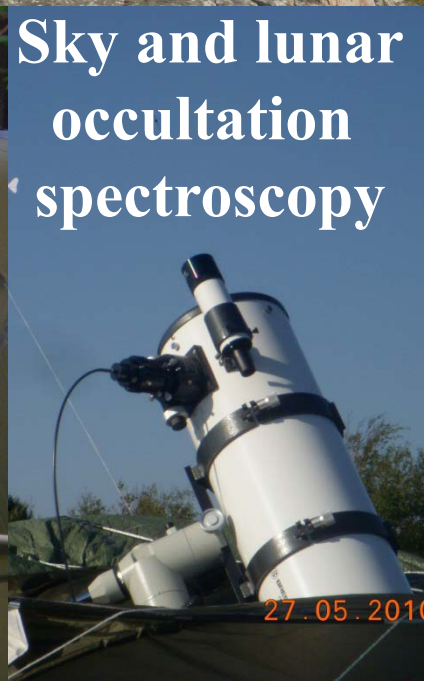


Monitoring of Night-Migrating Birds

4-channel fluorescence lidar

IR differential emission

Sky and lunar occultation spectroscopy



GUANGZHOU


China
International boundary
Province-level boundary
National capital
Province-level capital
Railroad
Road
Autonomous regions and municipalities in italics.
RUSSIA
MONGOLIA
KAZAKHSTAN
KYRGYZSTAN
TAJ.
AFG.
PAK.
INDIA
NEPAL
BHUTAN
BURMA
LAOS
VIETNAM
BANGLADESH
PHILIPPINES
Taiwan
Astana
Bishkek
Almaty
Barnaul
Semey (Semipalatinsk)
Irkutsk
Ulan-ude
Chita
Khabarovsk
Bratsk
Ulaanbaatar
Burqin
Ürümqi
Korla
Kashi
Golmud
Xining
Lanzhou
Yinchuan
Hohhot
Baotou
Beijing
Tianjin
Shijiazhuang
Taiyuan
Jinan
Qingdao
Dalian
Shenyang
Harbin
Changchun
Hailar
Vladivostok
Seoul
NORTH KOREA
P'yŏngyang
SOUTH KOREA
Demarcation Line
Yellow Sea
East China Sea
South China Sea
Lianyungang
Xi'an
Zhengzhou
Nanjing
Shanghai
Hangzhou
Wuhan
Chengdu
Chongqing
Changsha
Nanchang
Fuzhou
Taipei
Xiamen
Kao-hsiung
Guiyang
Kunming
Nanning
Guangzhou
Hong Kong
Macau
Special Administrative Regions
Zhanjiang
Haikou
Hainan Dao
Luzon
Hanoi
Vientiane
Chiang Mai
Rangoon
Mandalay
Myitkyinā
Ledo
Thimphu
Kathmandu
New Delhi
Āgra
Lhasa
Golmud
Indian claim
Chinese line of control
Line of Control
XINJIANG
XIZANG (TIBET)
QINGHAI
GANSU
NEI MONGOL
NINGXIA
SHANXI
SHAANXI
HEBEI
SHANDONG
JIANGSU
ANHUI
HENAN
HUBEI
HUNAN
JIANGXI
ZHEJIANG
FUJIAN
GUIZHOU
YUNNAN
GUANGXI
GUANGDONG
SICHUAN
CHONGQING
HEILONGJIANG
JILIN
LIAONING
HAINAN
Lake Baikal
Lake Balkhash
Amur
Irtysh
Huang He
Chang Jiang
Mekong
Brahmaputra
Indus
Salween
Irrawaddy


华南先进光电子研究院成立庆典
华南先进光电子研究院
粤来粤好

Guangzhou


FAW
FAW


Guizhou, China
Wanshan Mercury Mines
*

Mercury monitoring for archeology

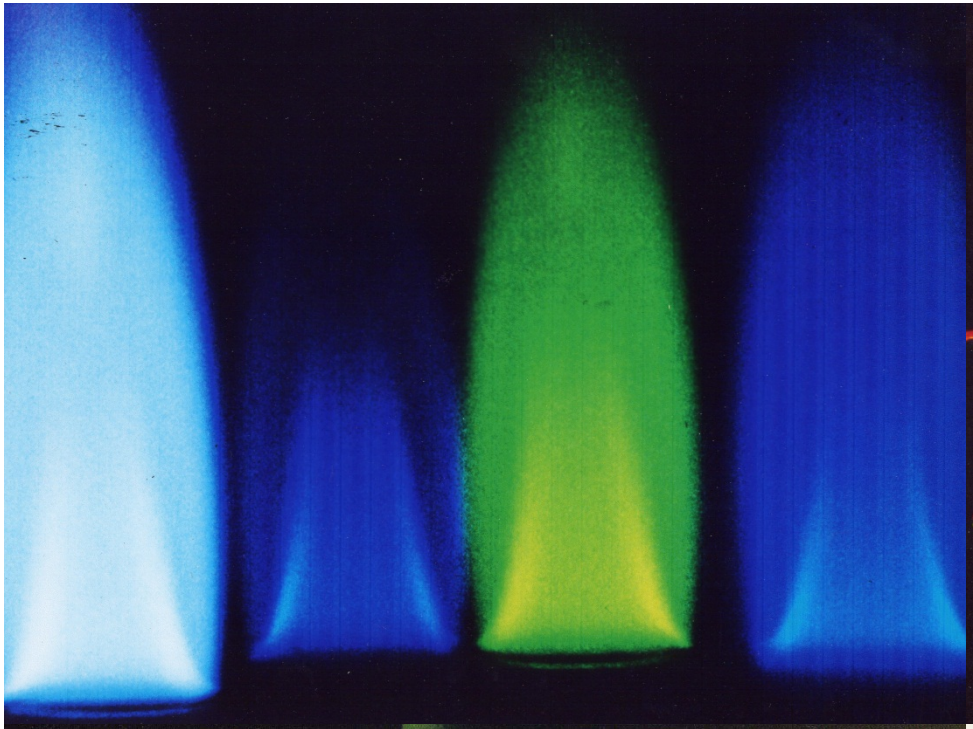
Qin Shi Huang Tomb in Xi´an

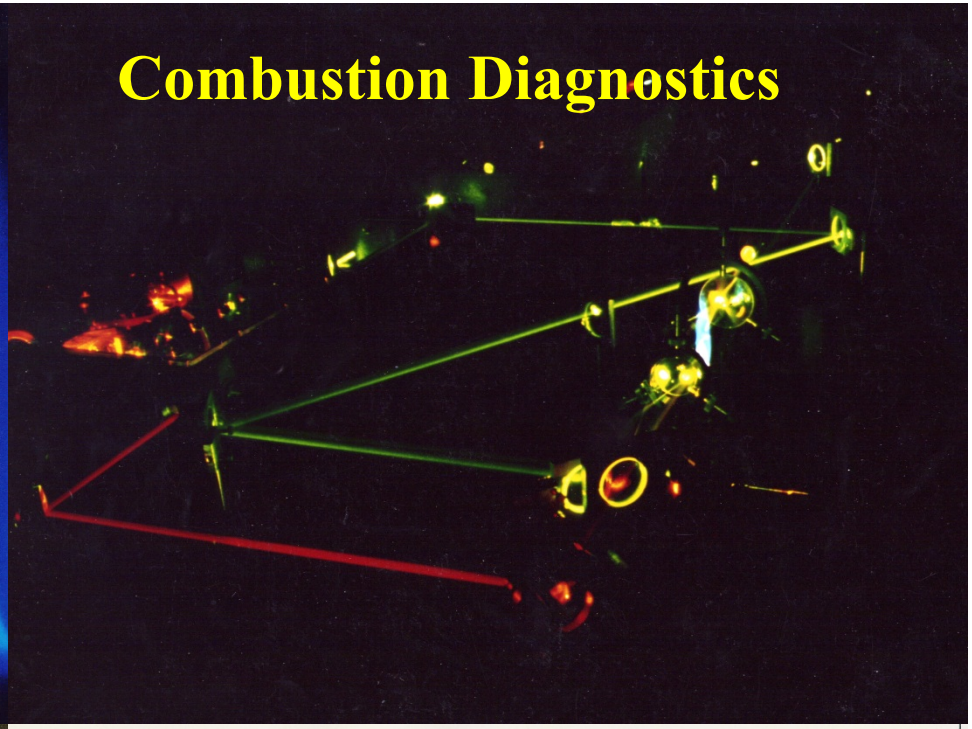
2nd century BC

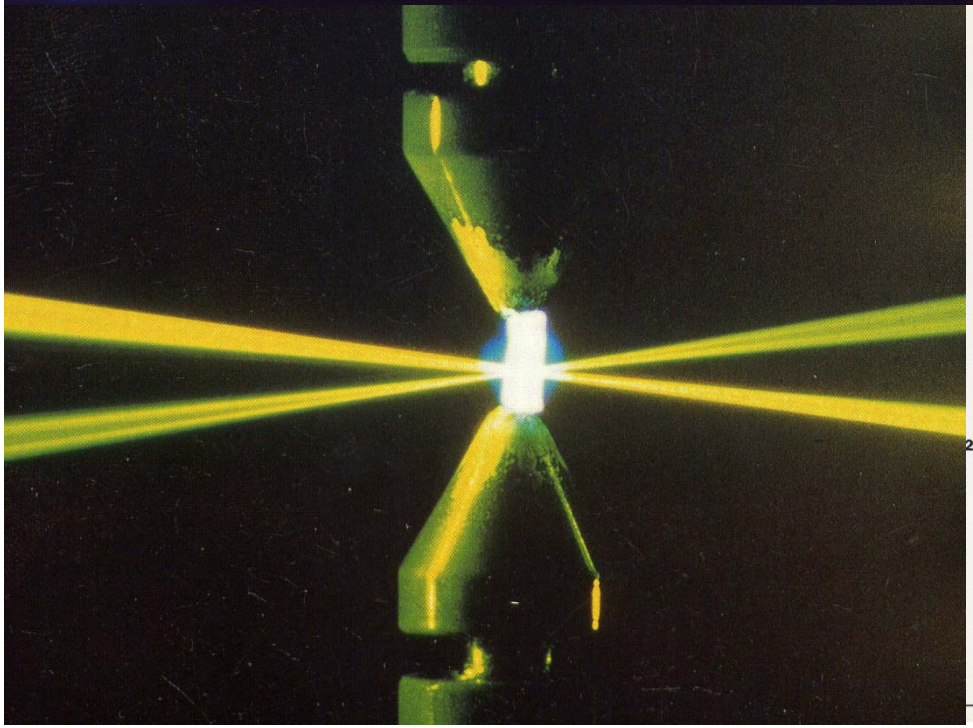
First Emperor of China

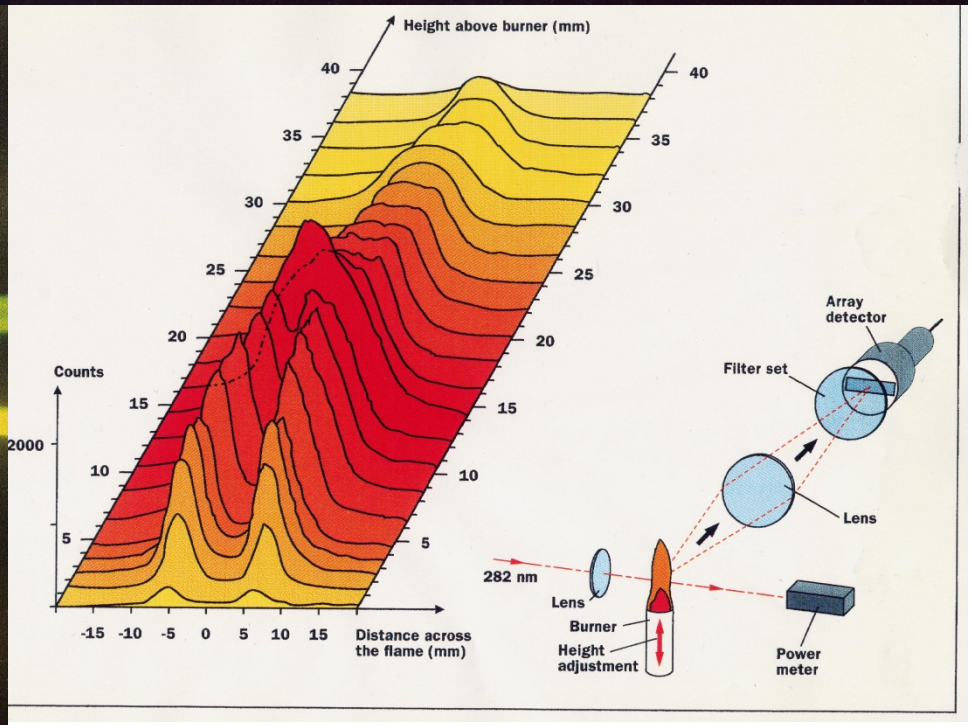
Lakes and rivers of Hg?

Combustion Diagnostics





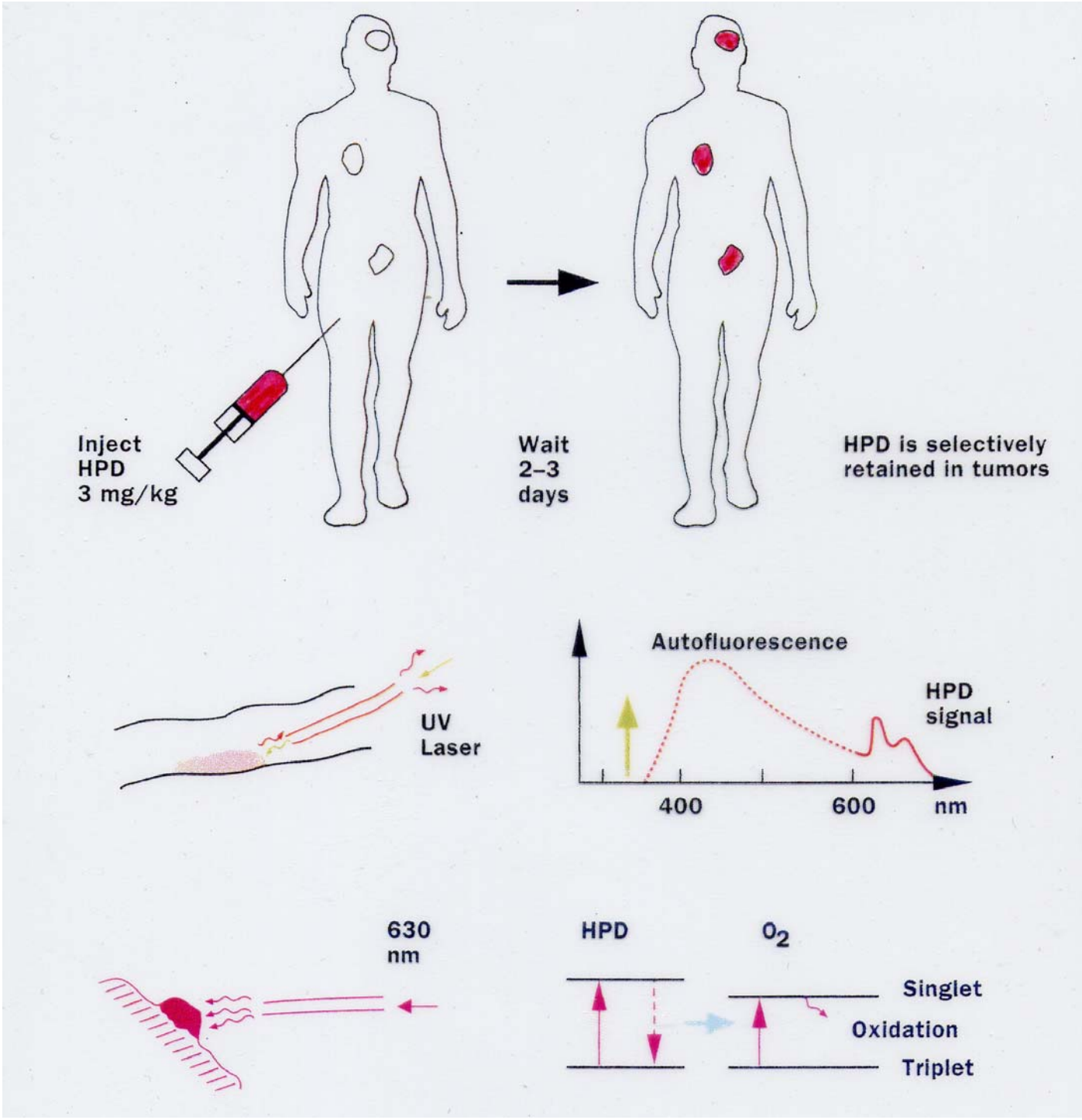




Analytical CHEMISTRY

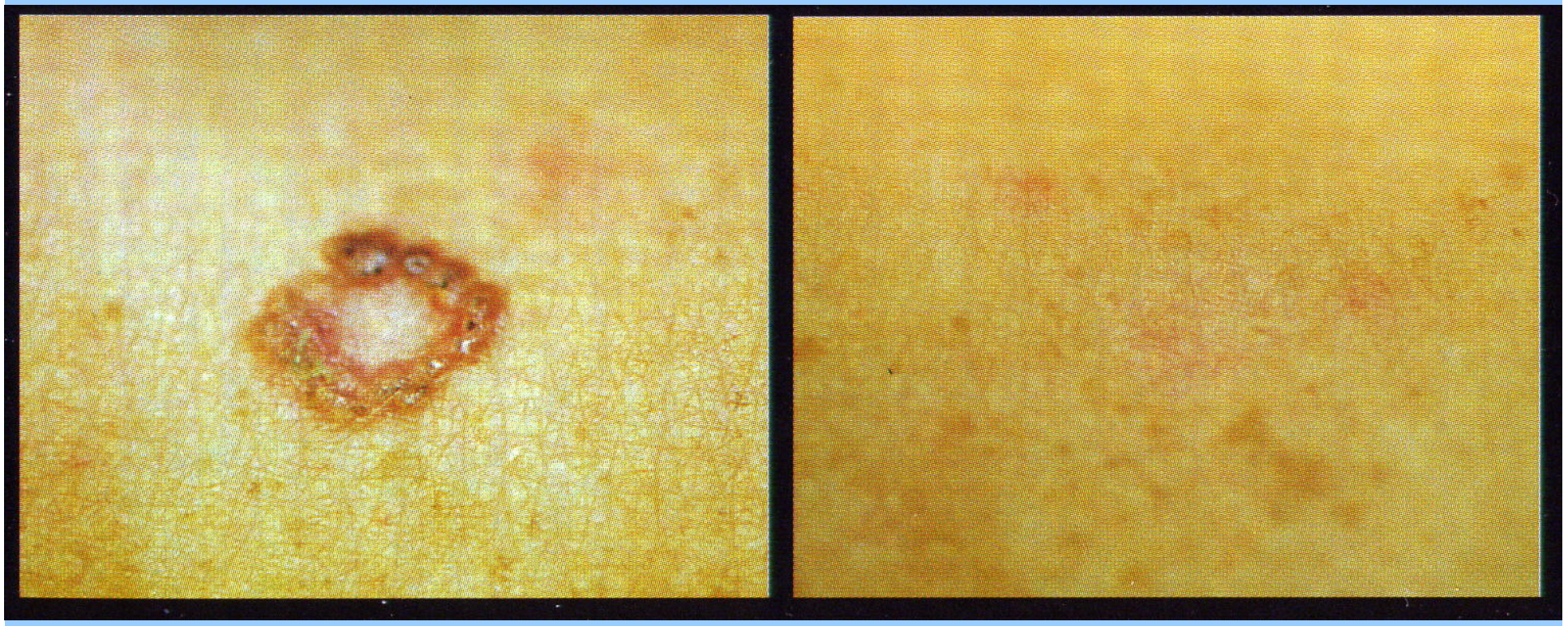
LASERS in MEDICINE

19A

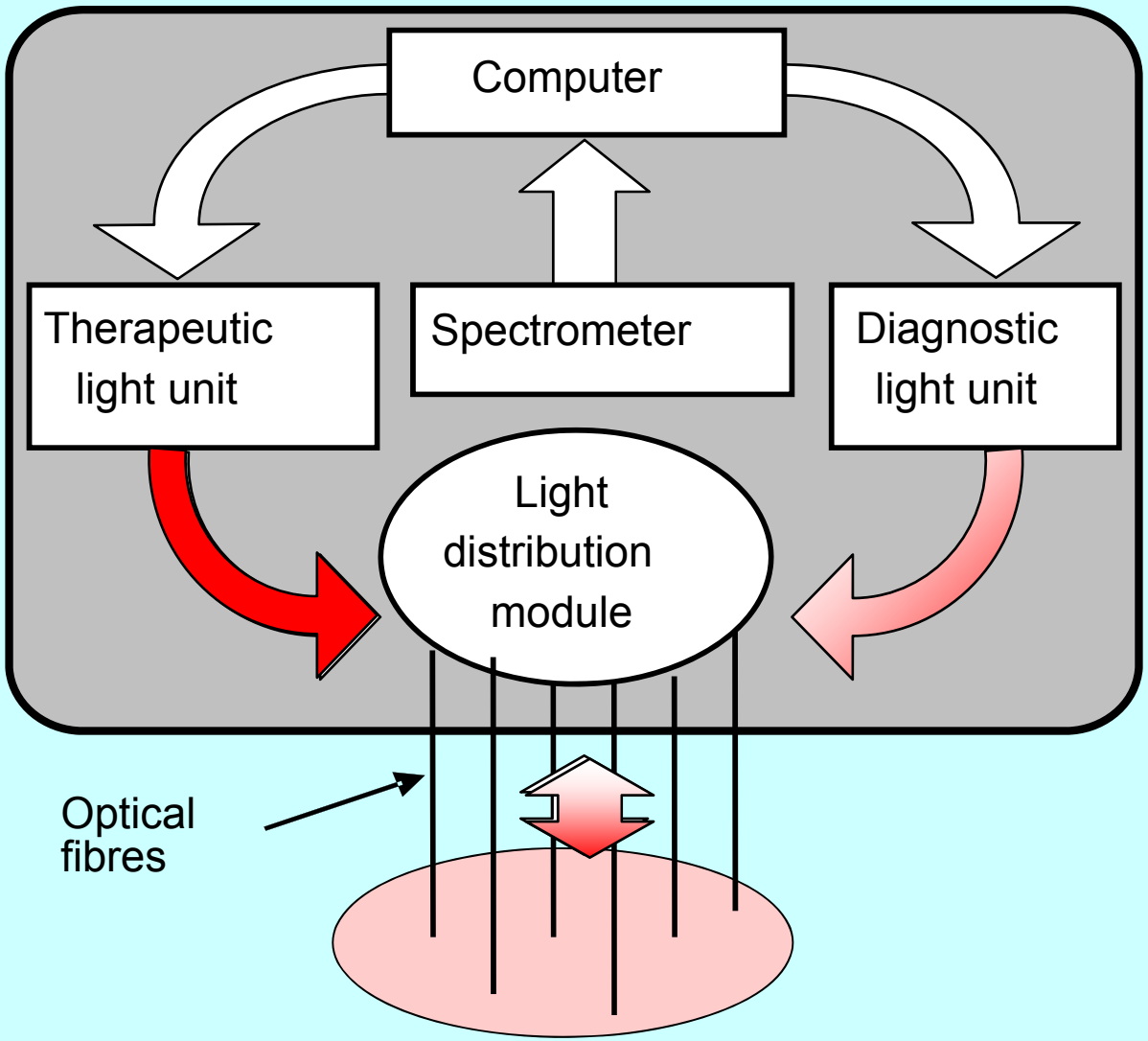


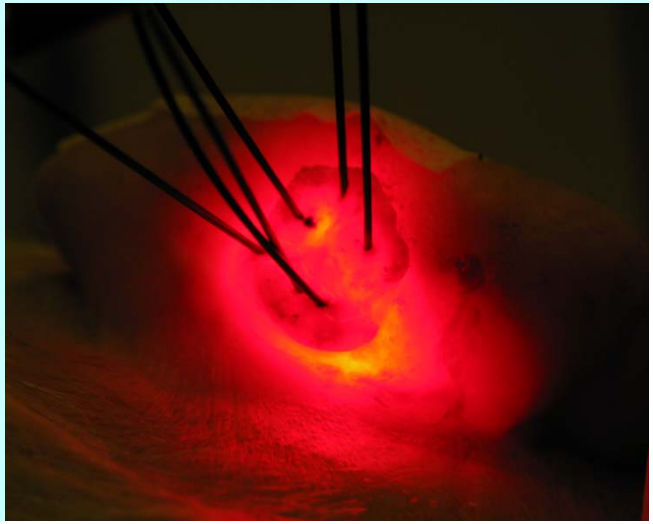
Photodynamic therapy

ALA PDT Treatment of Basal Cell Carcinoma



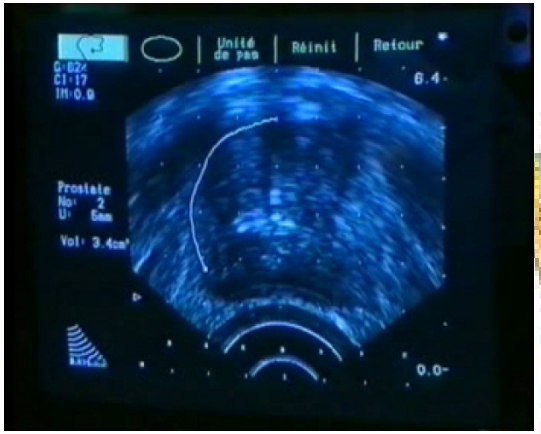
Challange: Deep-lying tumours
Fiber-based interstitial system

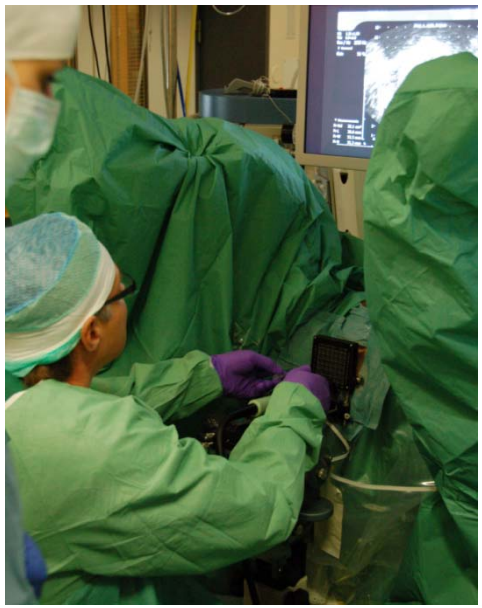


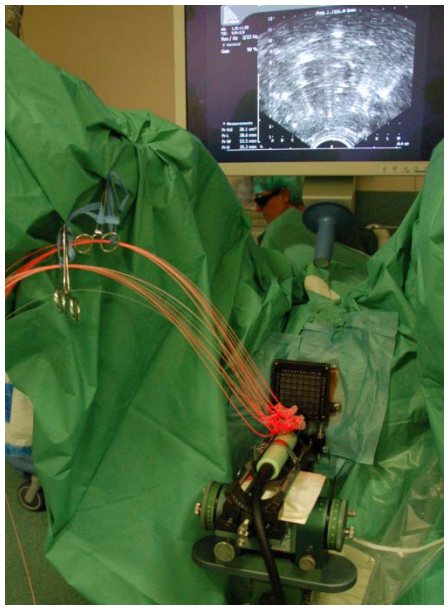


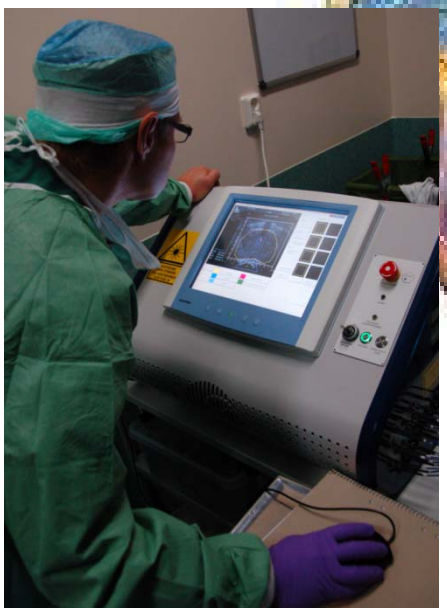
Example of clinical applications - prostate cancer

Lund collaboration with SpectraCure AB, Karolinska Hospital and Malmö University Hospital

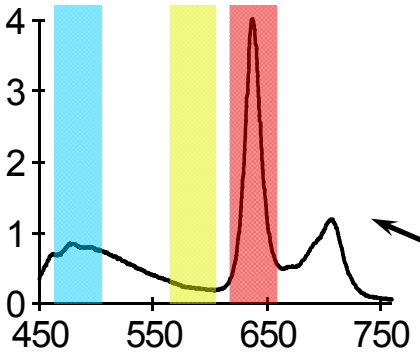


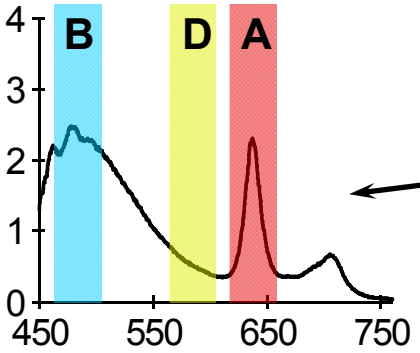


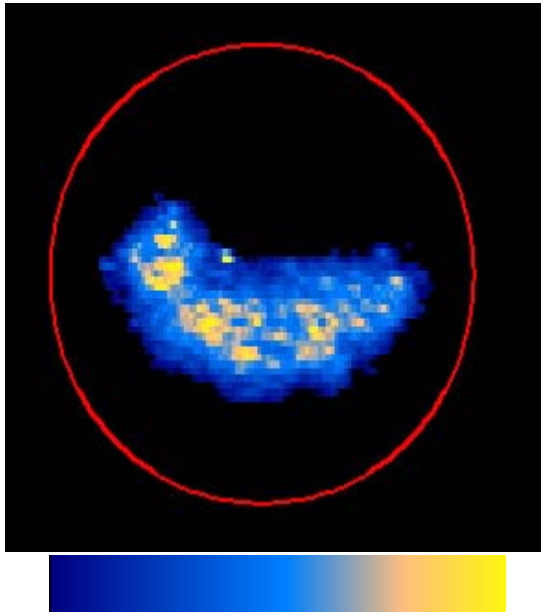




Multicolour Fluorescence Imaging





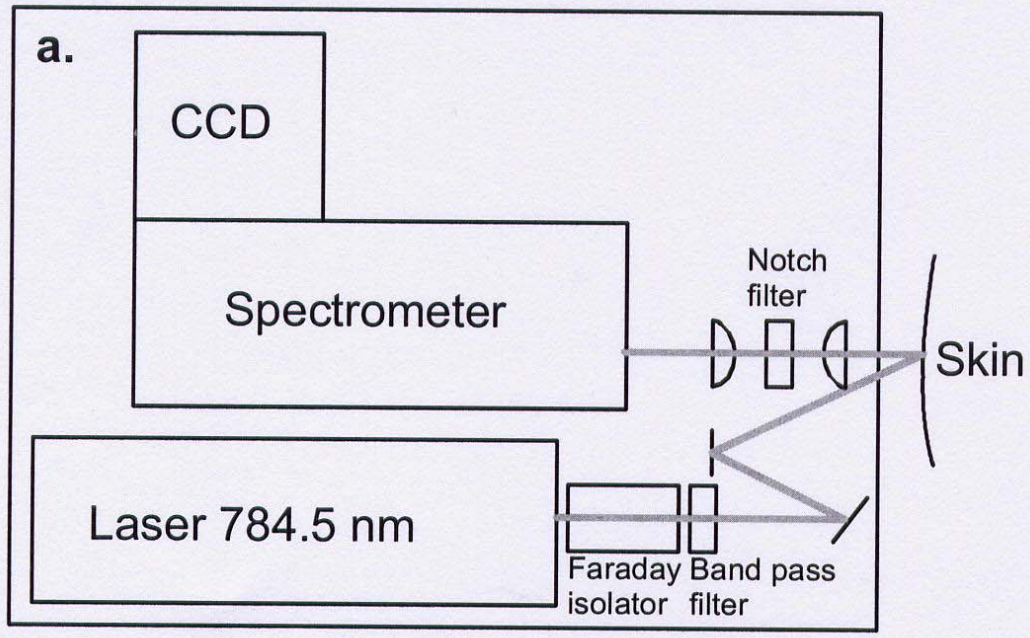


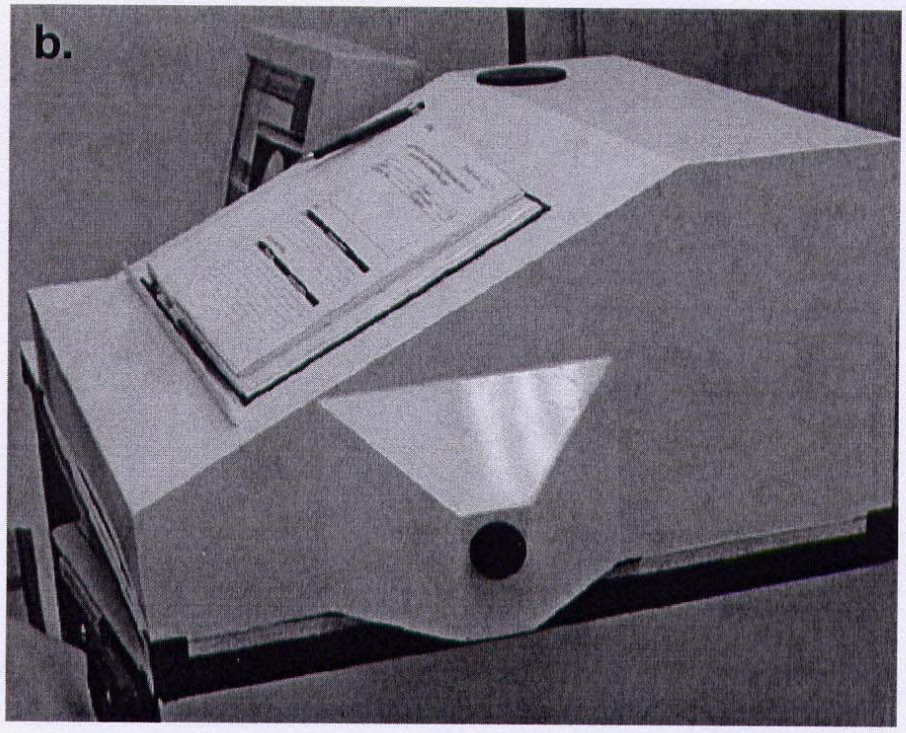
$$F_c = \frac{A - k_1 D}{k_2 B}$$

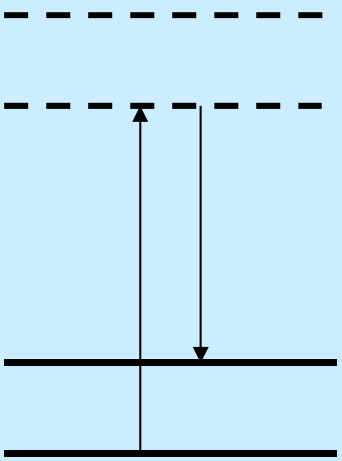
$$\frac{\text{Red} - \text{Yellow}}{\text{Blue}}$$

Andersson-Engels *et al.* LSM (2000)

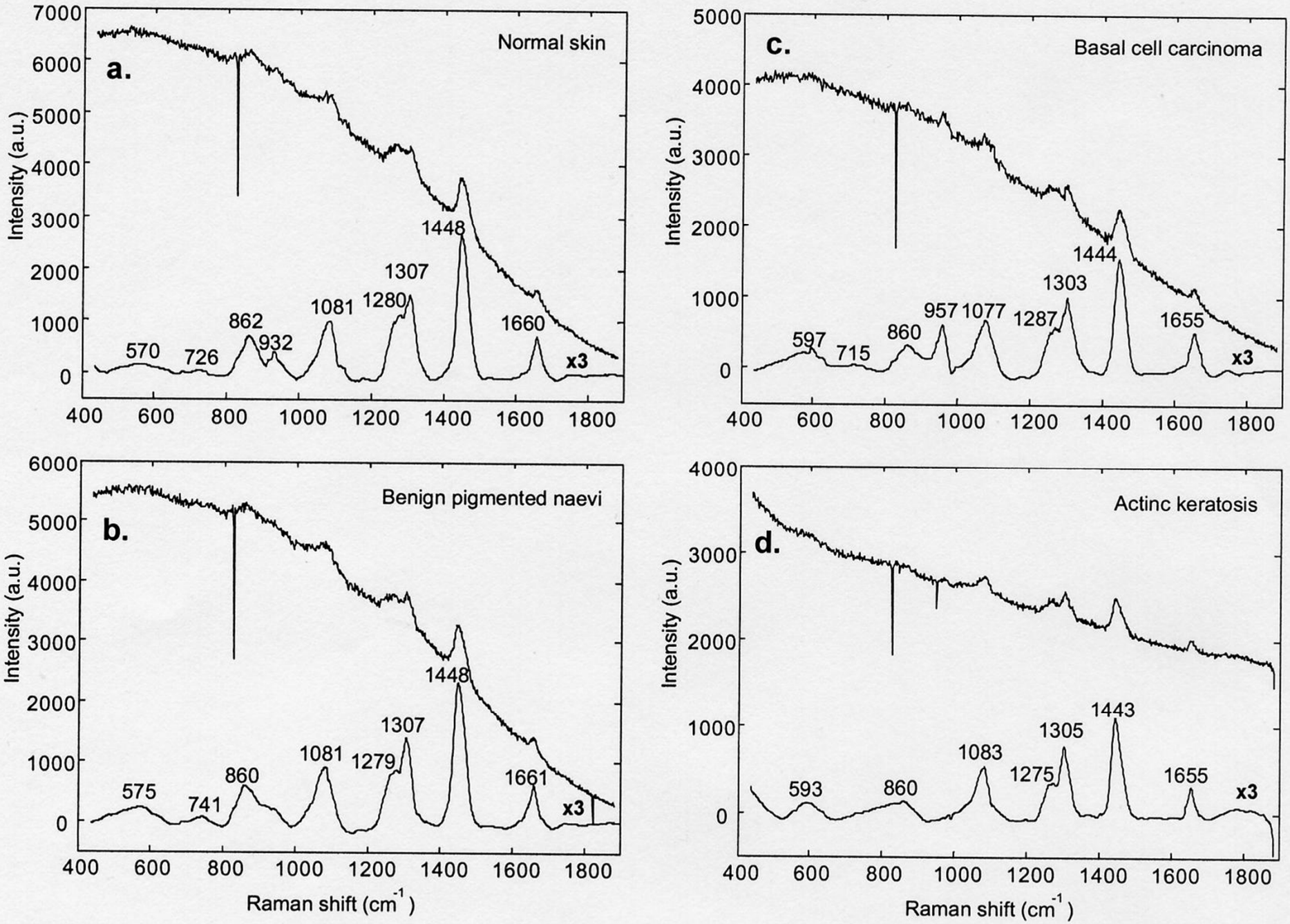
Raman Spectroscopy



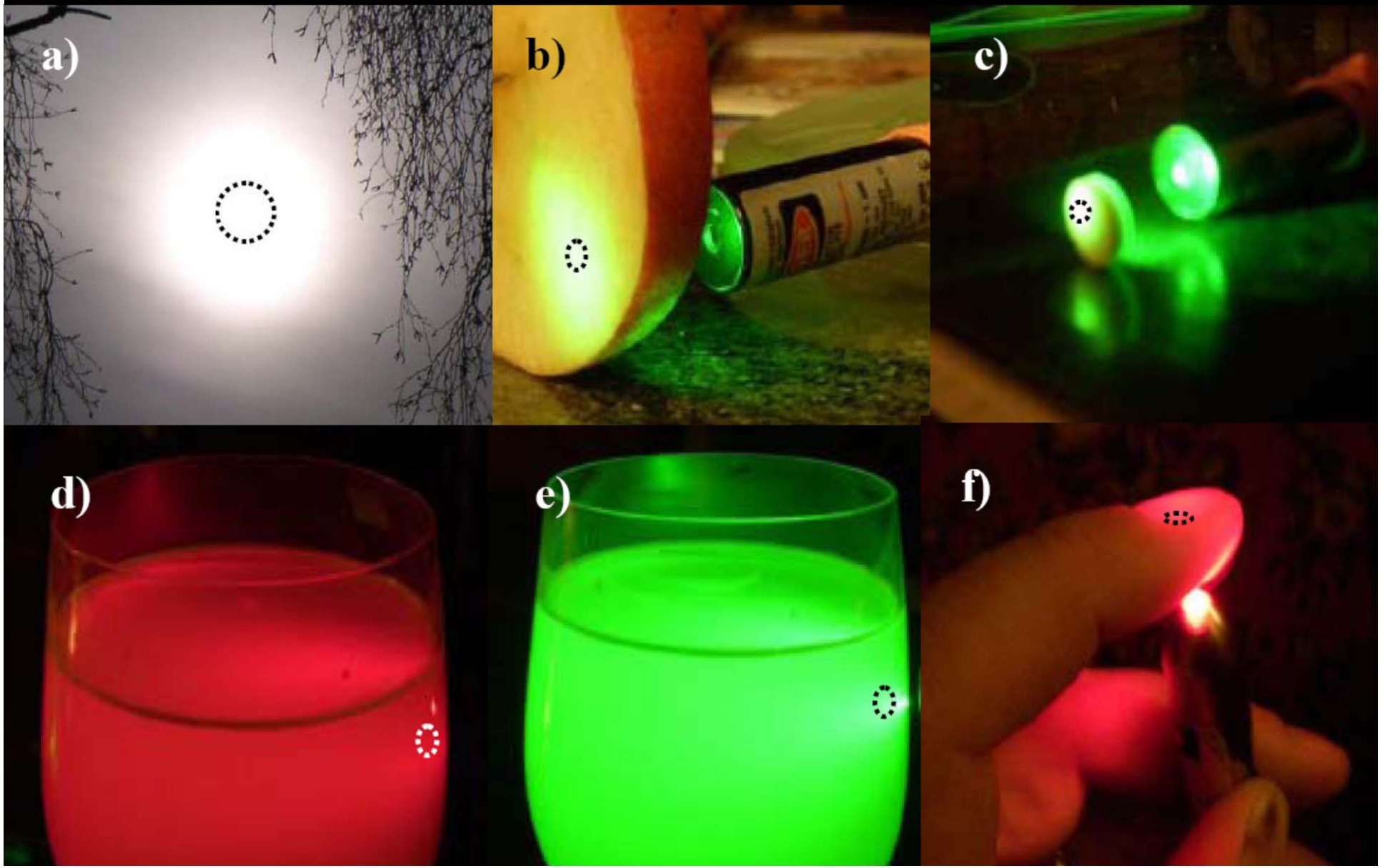


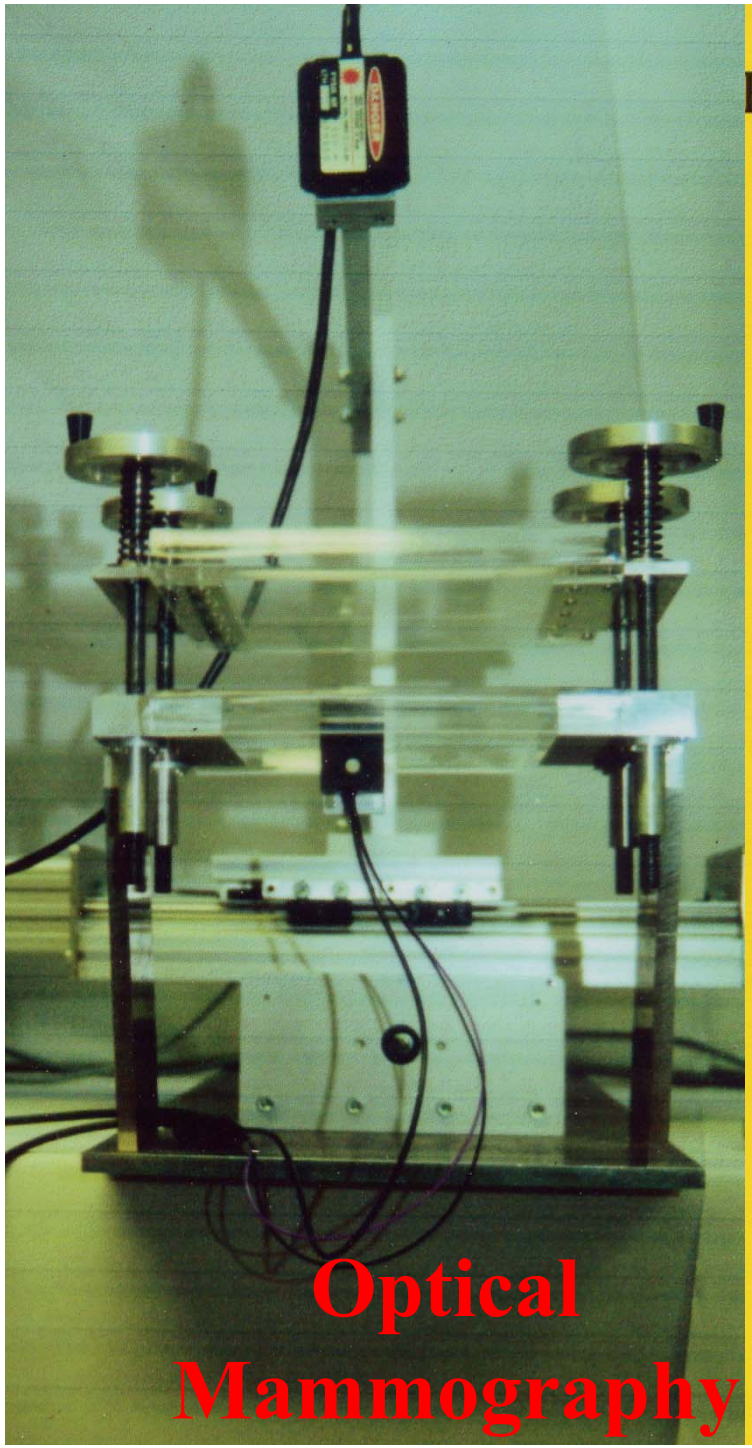


S. Pålsson et al.


a.
Normal skin
Intensity (a.u.)
570
726
862
932
1081
1280
1307
1448
1660
x3
b.
Benign pigmented naevi
575
741
860
1081
1279
1307
1448
1661
x3
c.
Basal cell carcinoma
597
715
860
957
1077
1287
1303
1444
1655
x3
d.
Actinc keratosis
593
860
1083
1275
1305
1443
1655
x3
Raman shift (cm-1)

SCATTERING MEDIA





Picosecond Diode Laser Transillumination

Image of ductal cancer in female breast

Total

Early

Tumour

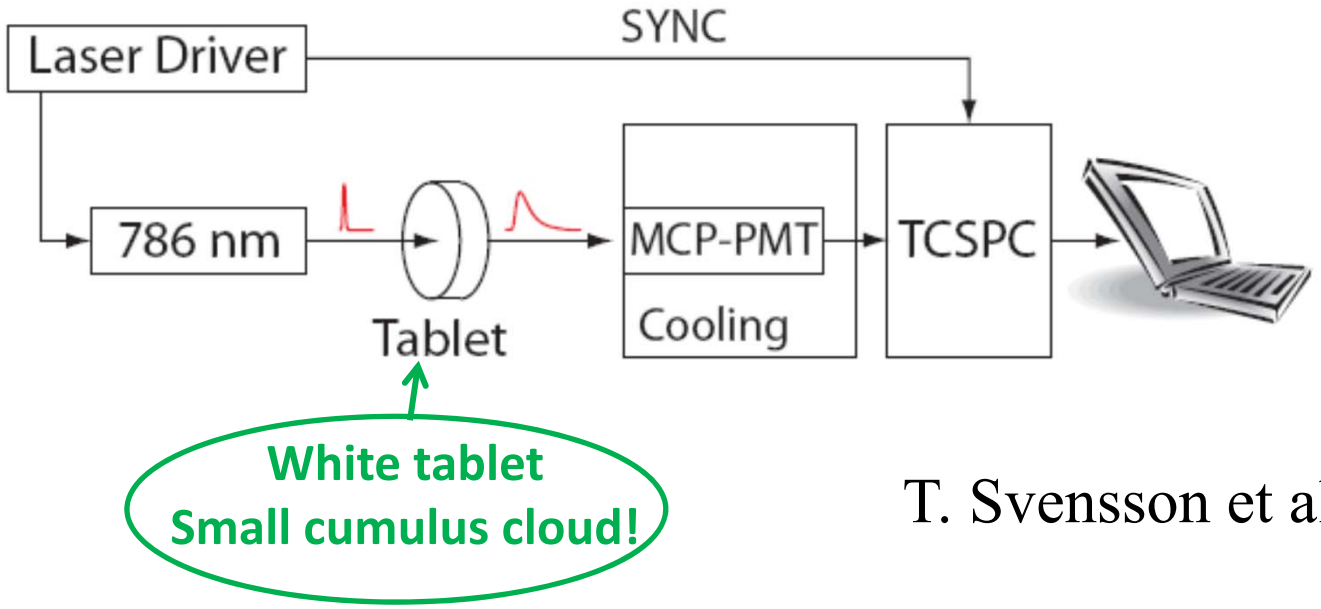
0 10 20 30 40 50 60

mm

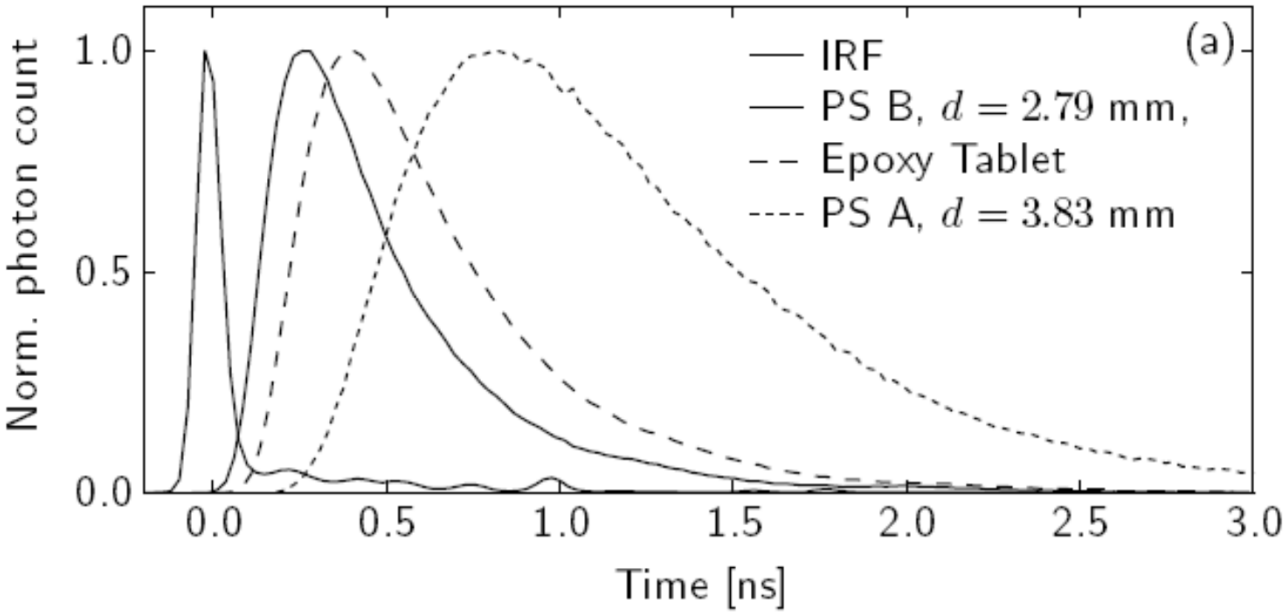
Berg et al.

Appl. Opt. R. Berg et al.

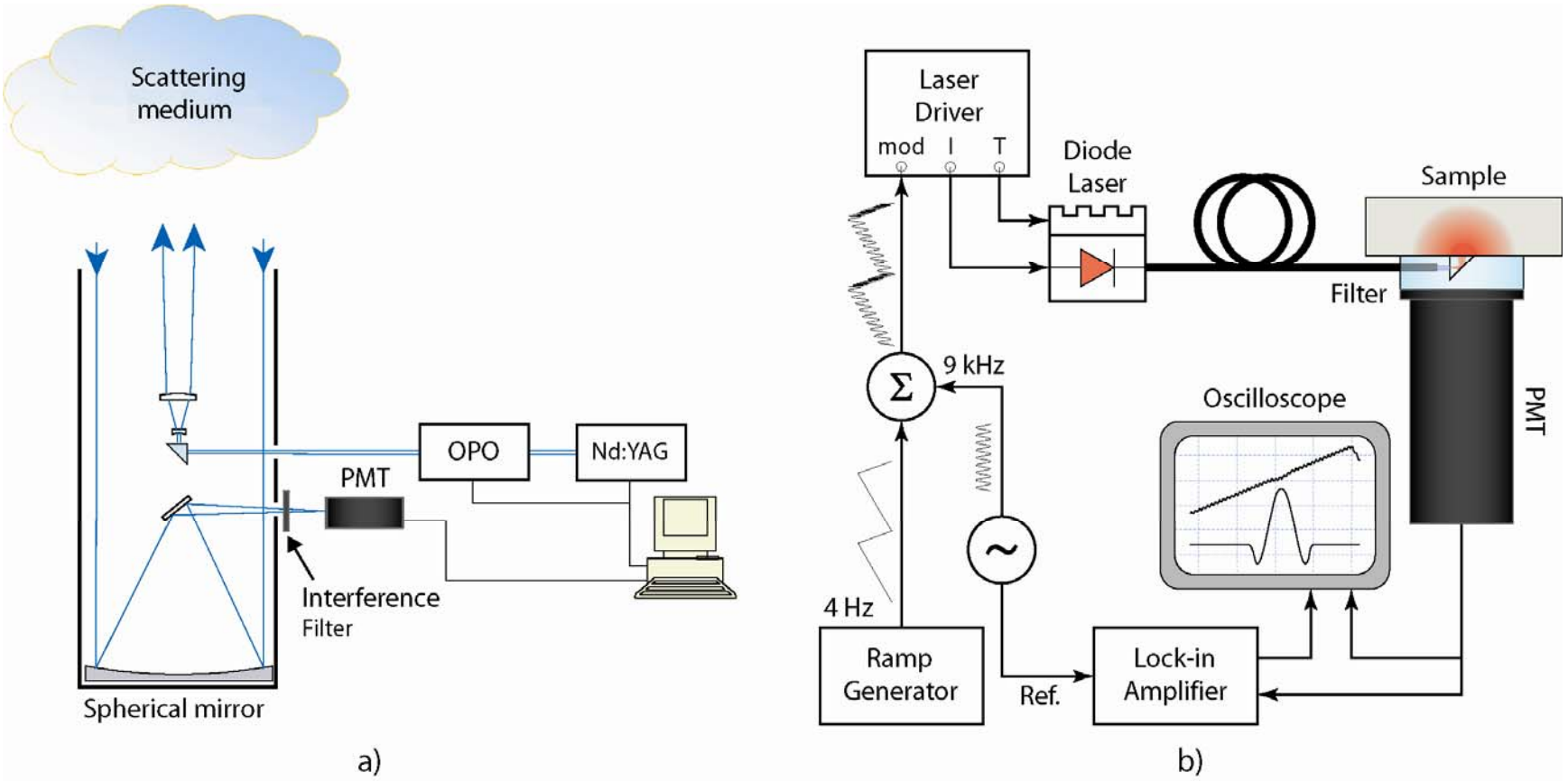
Pharmaceutical tablet laser radar

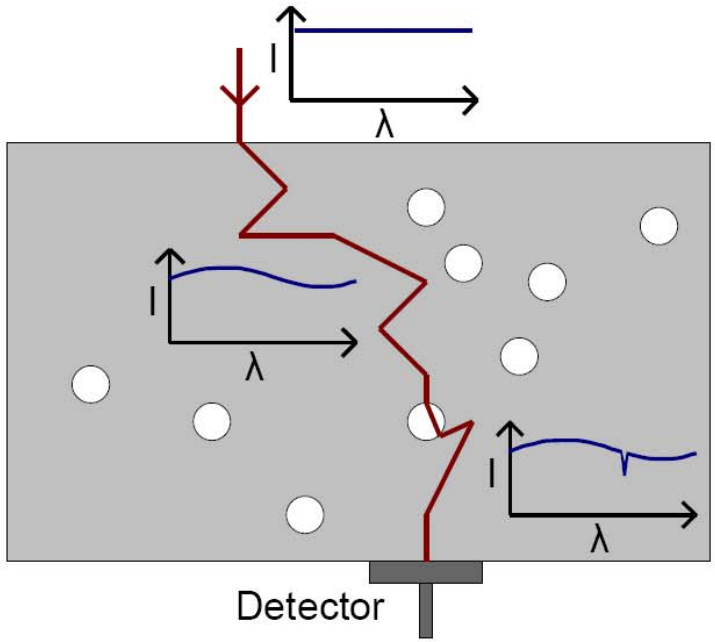


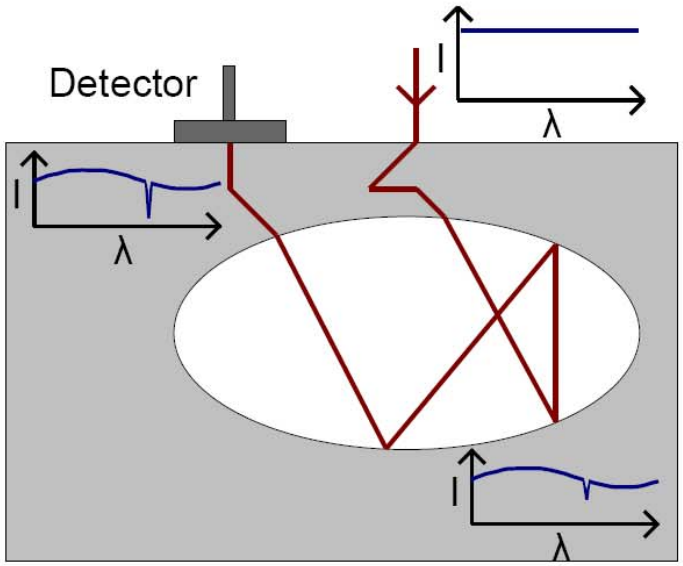
T. Svensson et al.



Large- and small-scale LIDAR

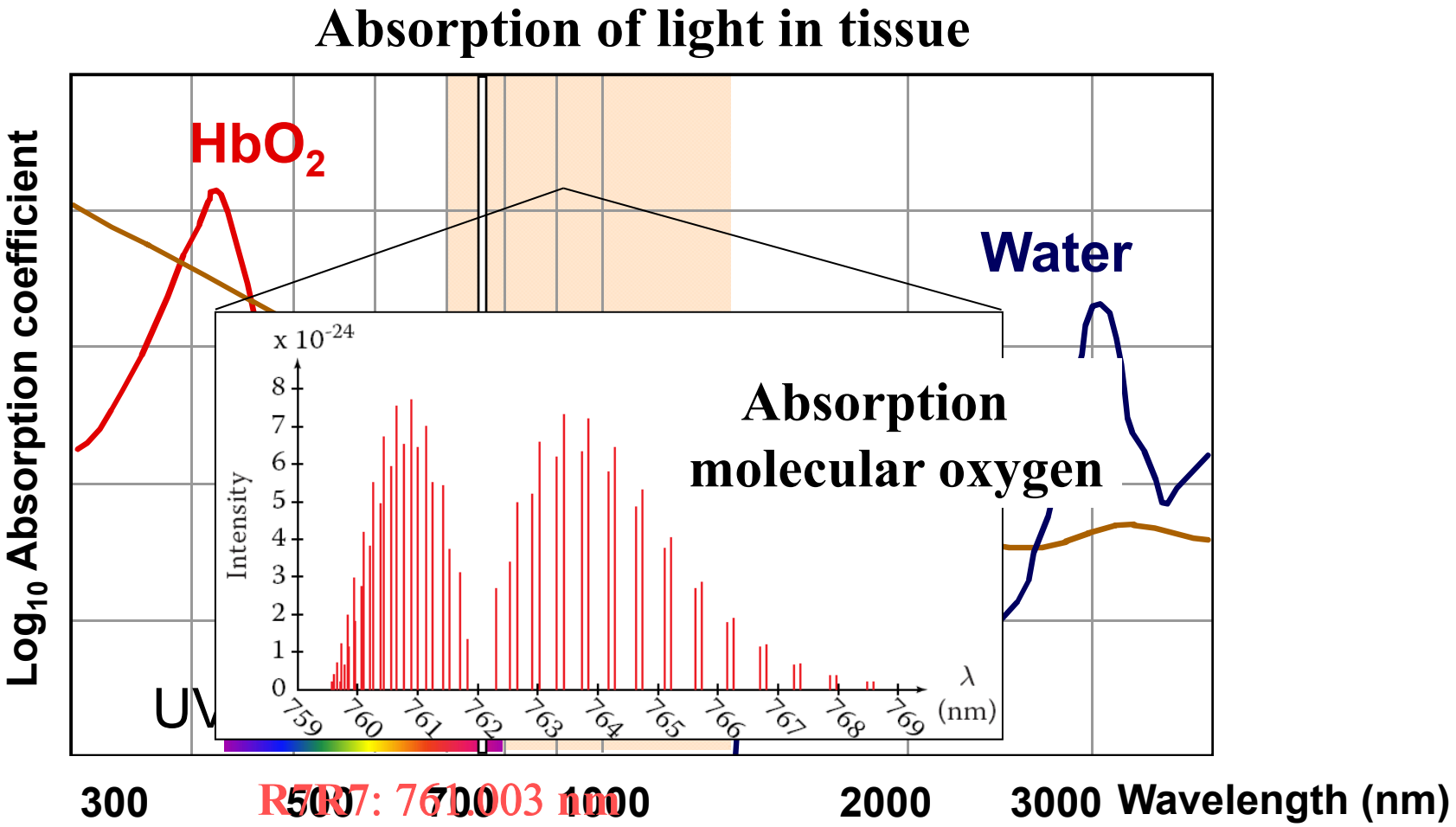




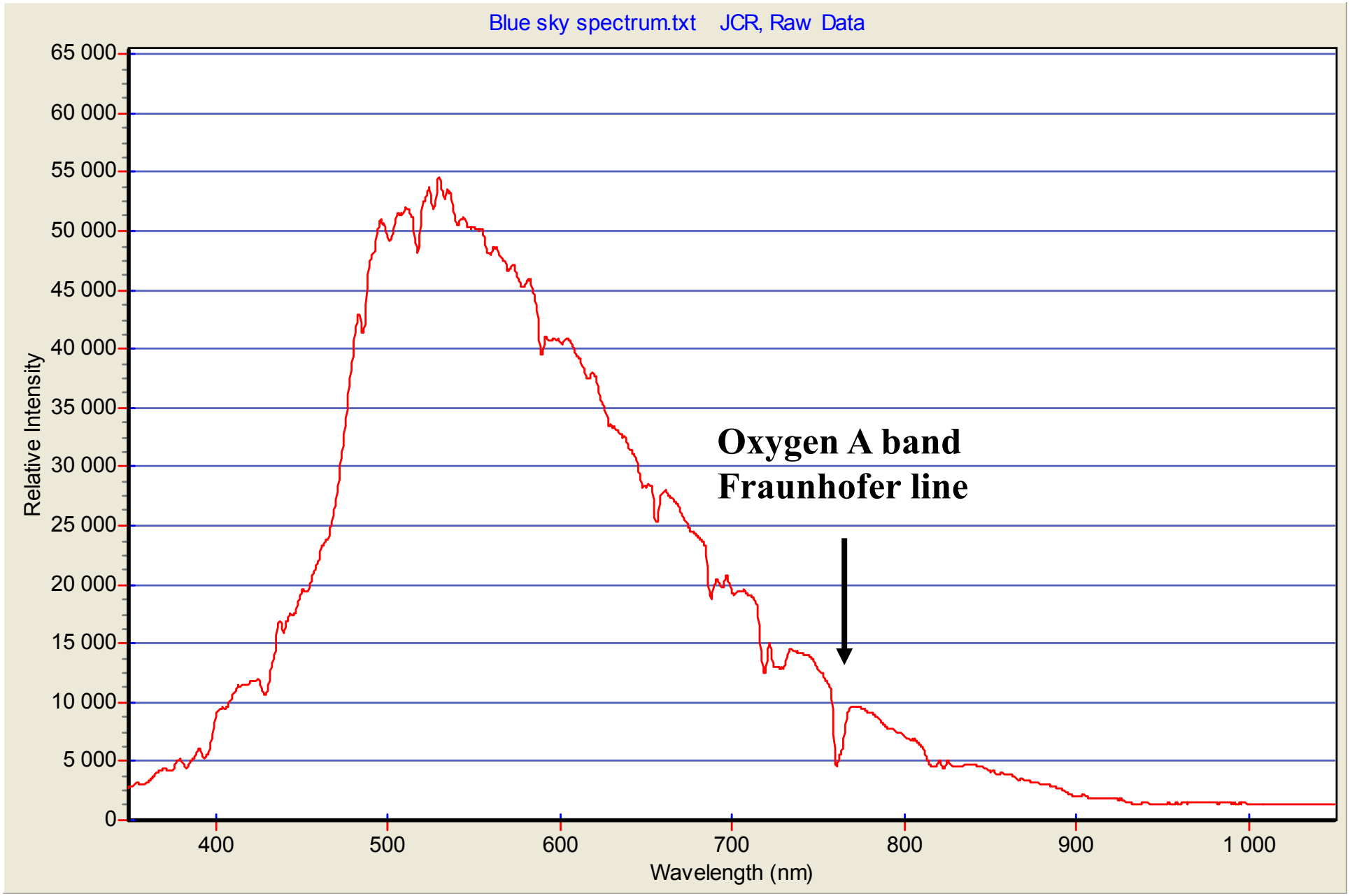


Lewander

Tissue Absorption

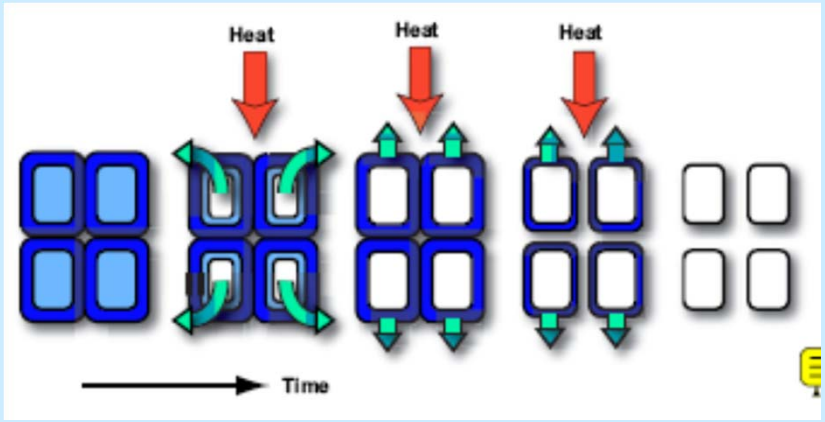


Blue sky spectrum with Fraunhofer lines, including Oxygen A



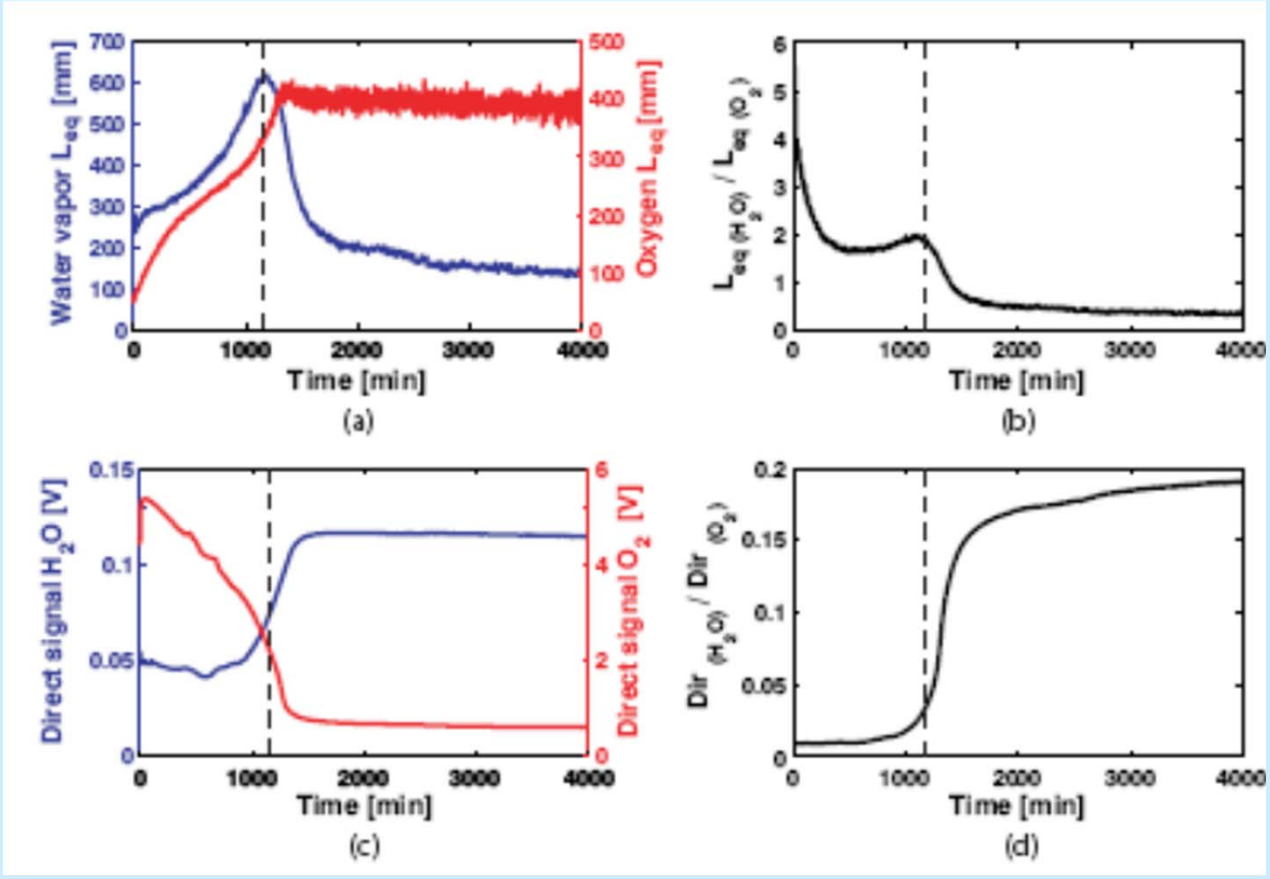
GASMAS studies of gas exchange in wood

Drying of wood

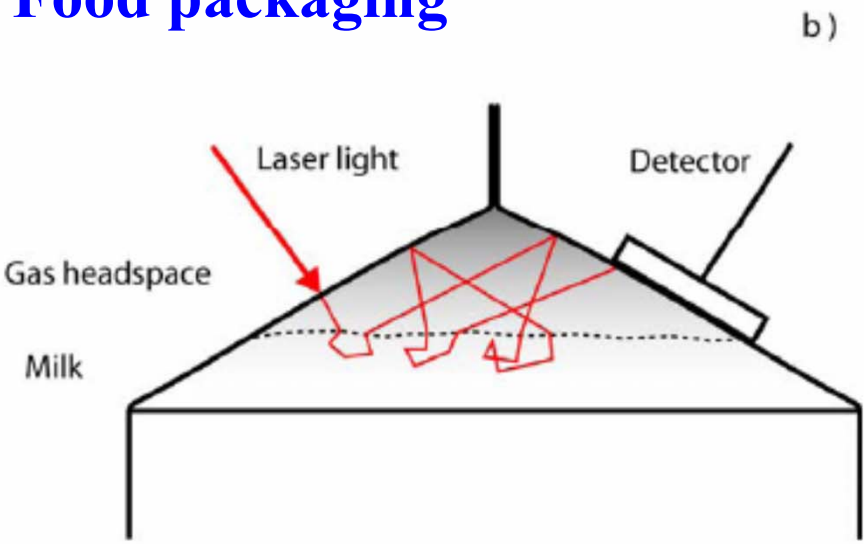


Swedish Warships
Vasa 1628

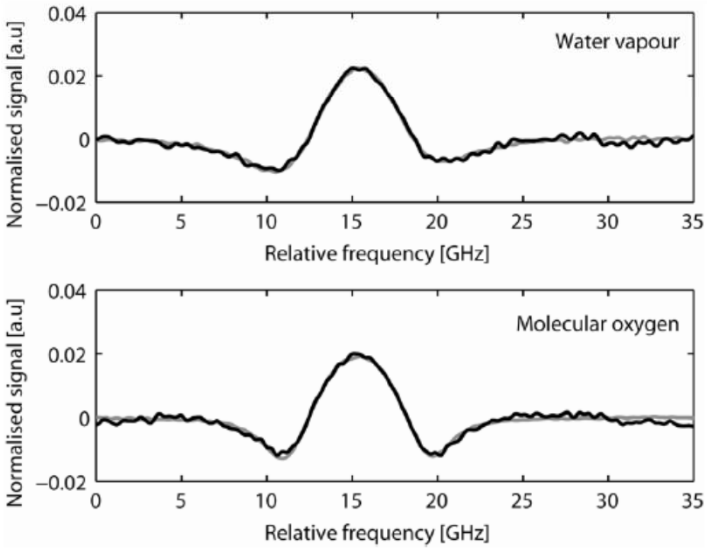
Vasa Museum
Stockholm



Food packaging



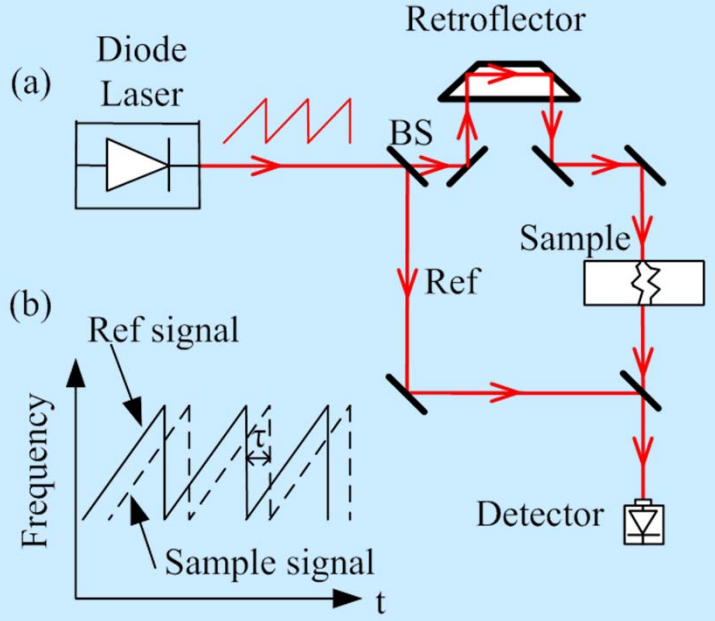
Lewander et al., Appl. Phys. B 2008;
Packaging Technology and Science 2011, in press



TetraPak Collaboration

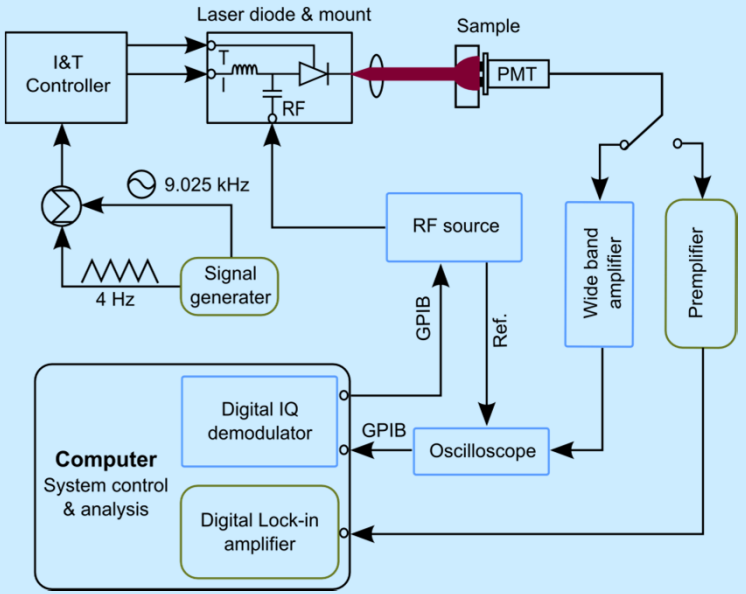
Gasporox AB

New techniques for optical pathlength assessment in connection with GASMAS:



Frequency-Modulated Continuous-Wave (FMCW) technique

Opt. Express (2009); Optics Lett. 36 (2011)



Frequency Domain Photon Migration (FDPM) technique

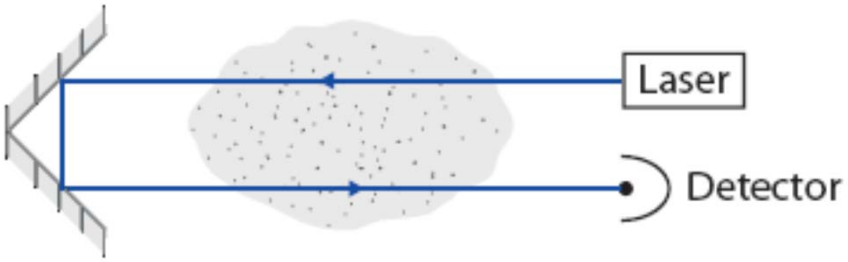
Phase-shift method

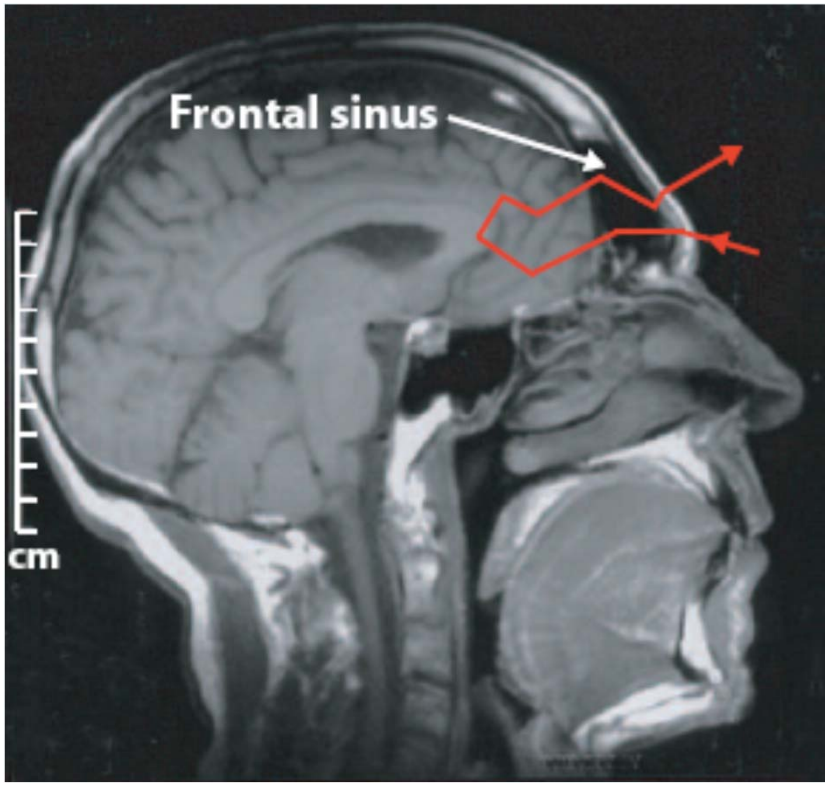
L. Mei, to appear

Techniques are compatible with single-mode operation!

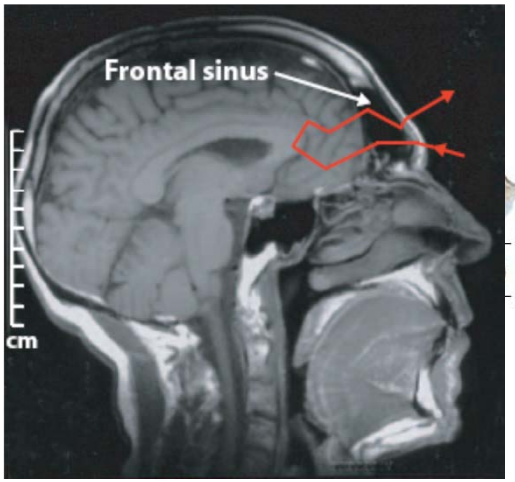
Environment

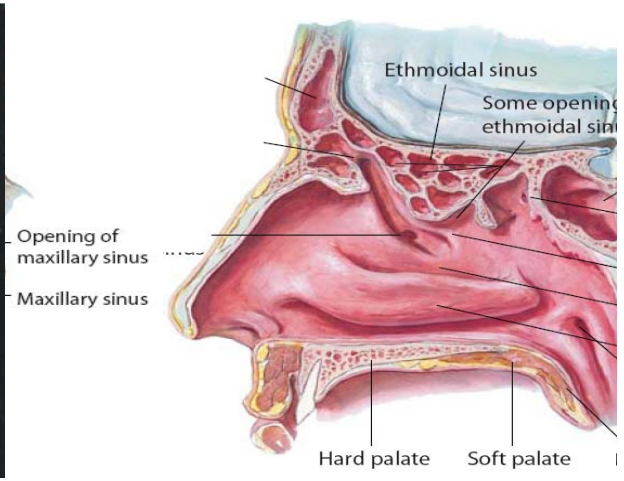
Medicine

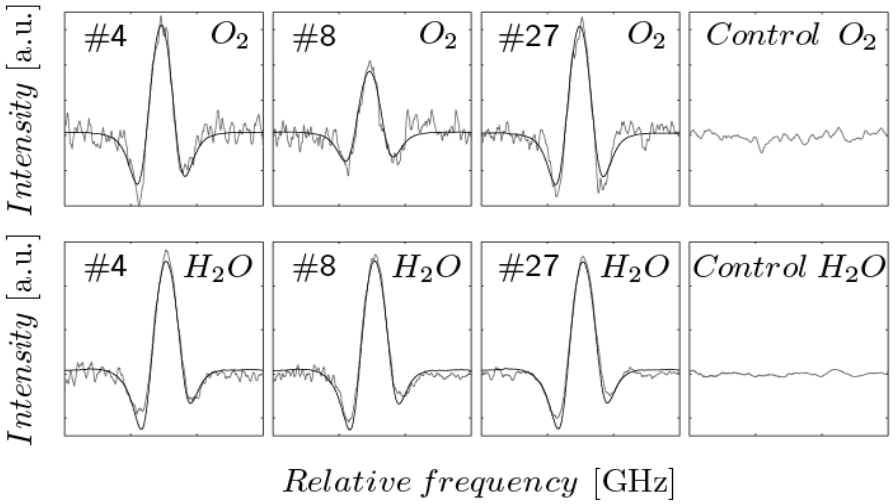


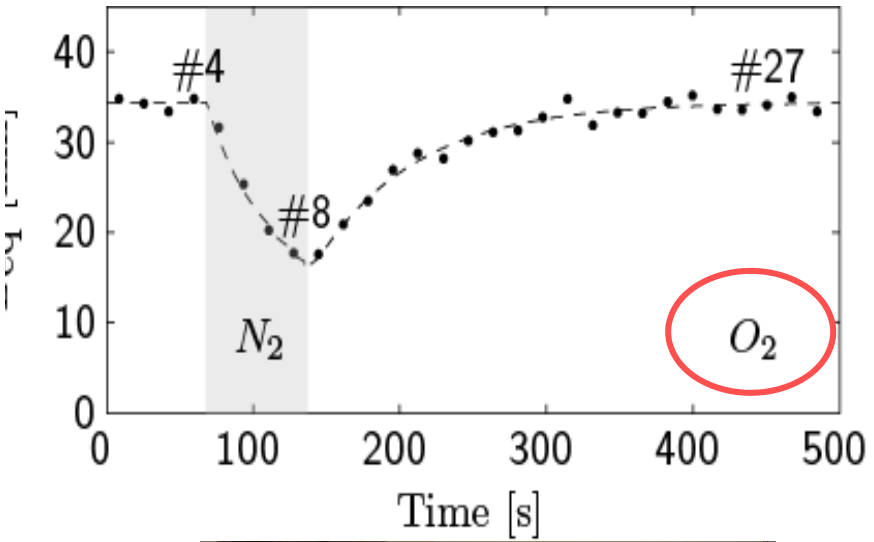


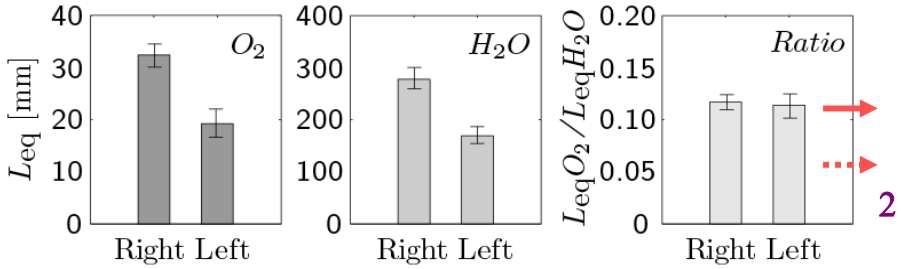
Sinusitis diagnostic by laser-spectroscopic measurement of oxygen and water vapour





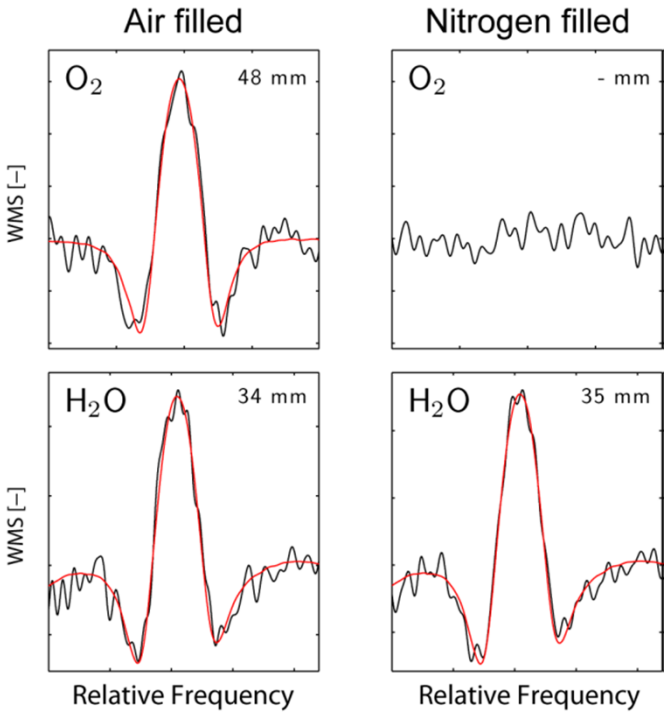


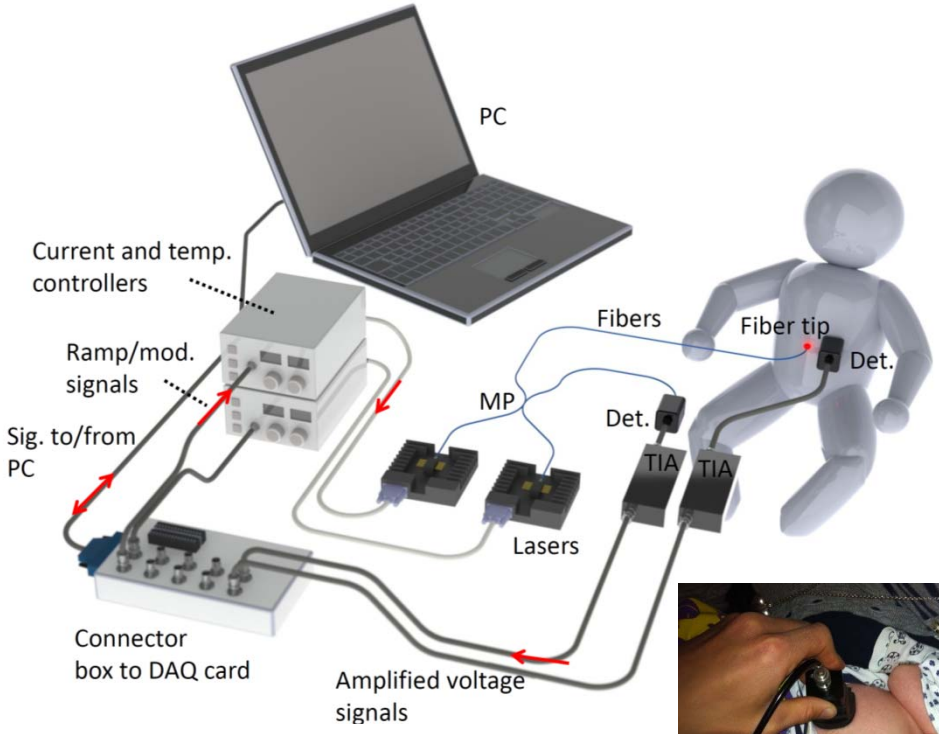


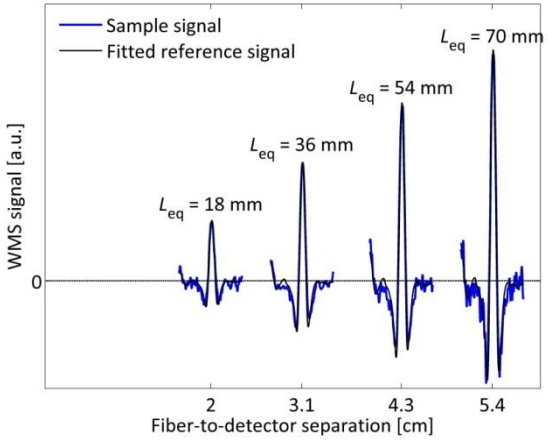


Persson et al. J. Biomed. Optics (2007); Rhinology 2012

Neonatal child monitoring







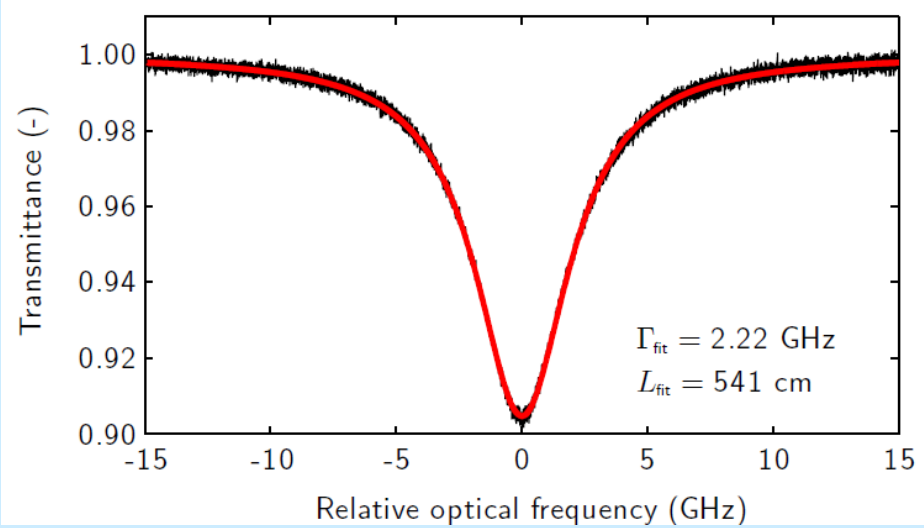
Alignment free multipass cells made of nanoporous ceramics

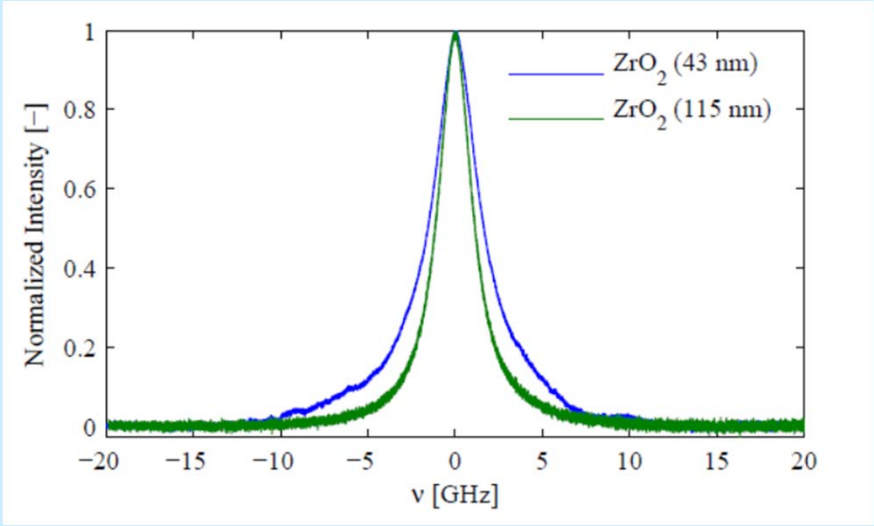
Zirconia, ZrO_2
115 nm pores

s = 7.2 mm → 5.4 m!

750 times physical thickness!

Pore size distribution determination !

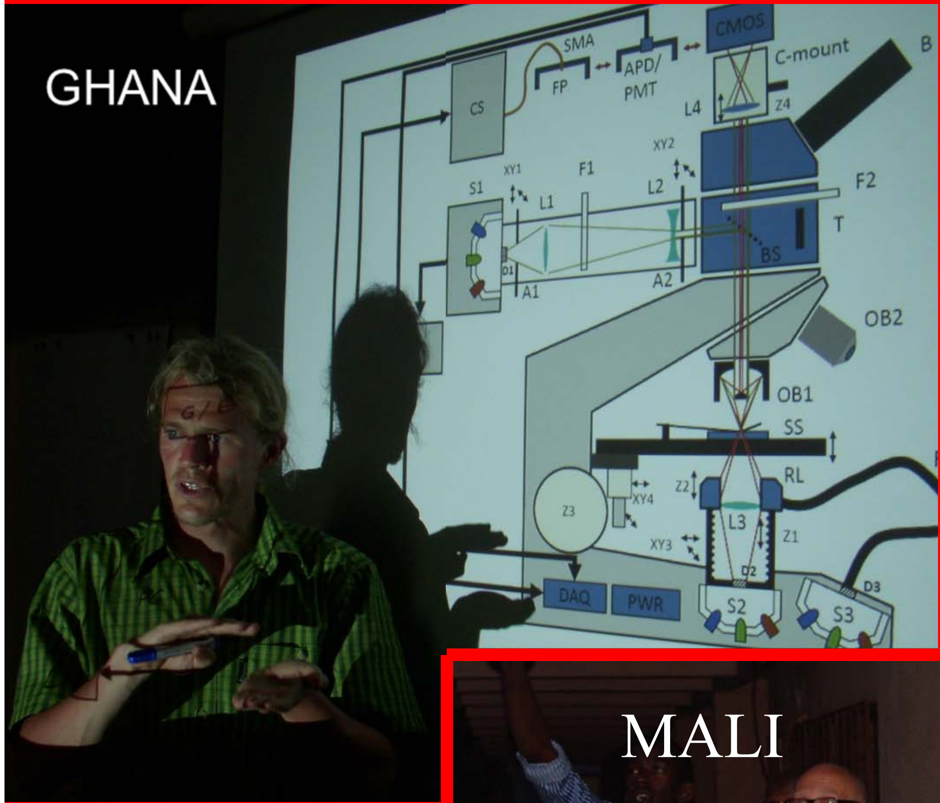


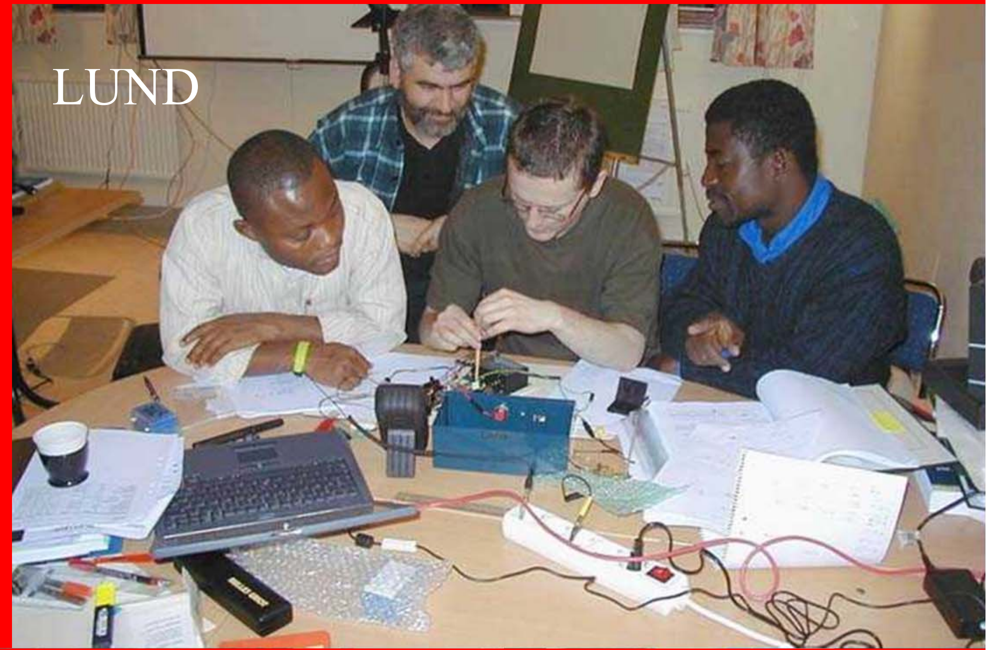


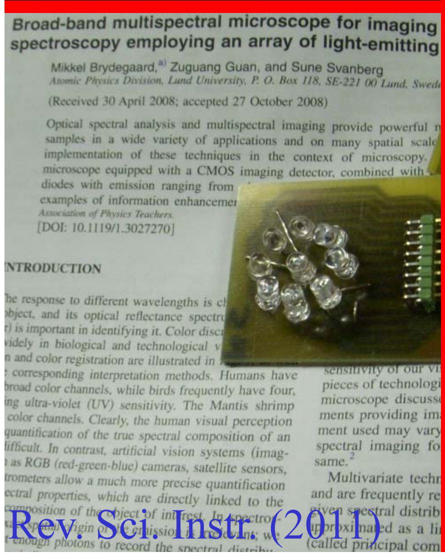
T. Svensson et al., Phys. Rev. Lett. 107 (2011) Xu et al., Phys. Rev. A (2011)

Rubidium high-resolution spectroscopy

Realistic optical diagnostics för 3rd world countries






Broad-band multispectral microscope for imaging spectroscopy employing an array of light-emitting

Mikkel Brydegaard,[a] Zuguang Guan, and Sune Svanberg

Atomic Physics Division, Lund University, P. O. Box 118, SE-221 00 Lund, Swede

(Received 30 April 2008; accepted 27 October 2008)

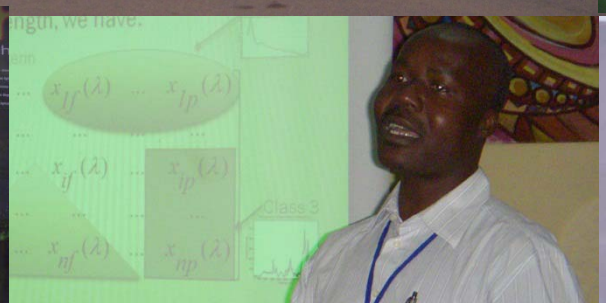
[DOI: 10.1119/1.3027270]

INTRODUCTION

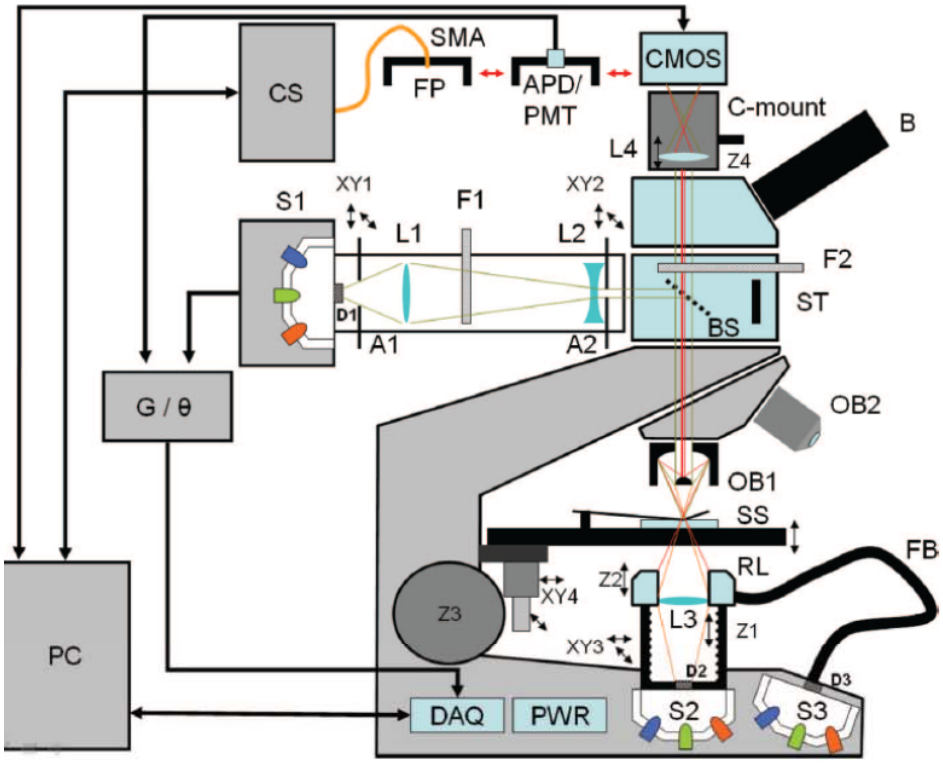
Rev. Sci. Instr. (2011)

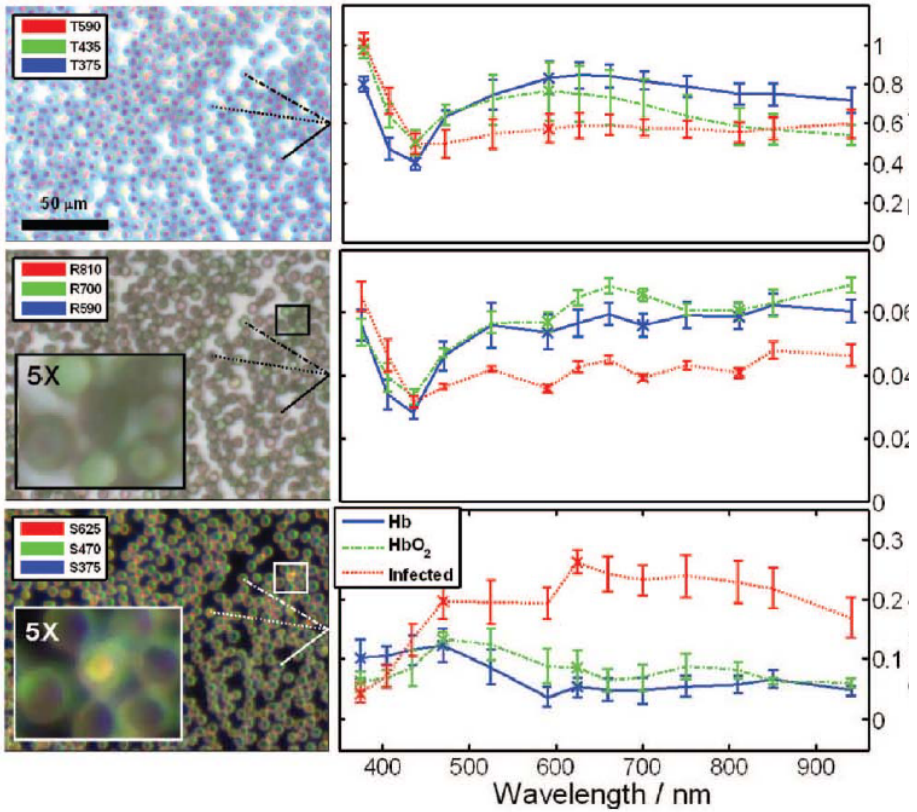
AFSIN Network

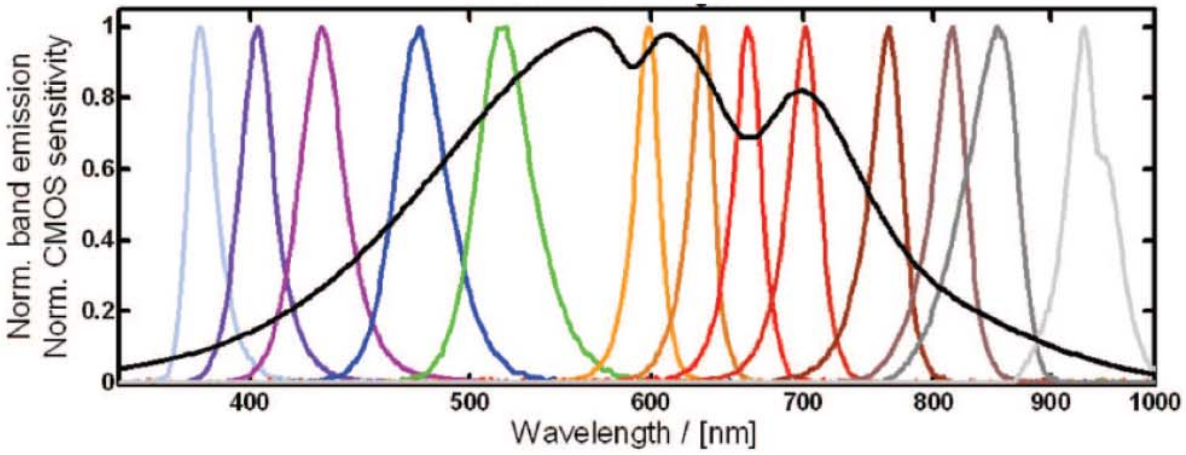
Cape Coast, Ghana



Multispectral microscopy malaria detection





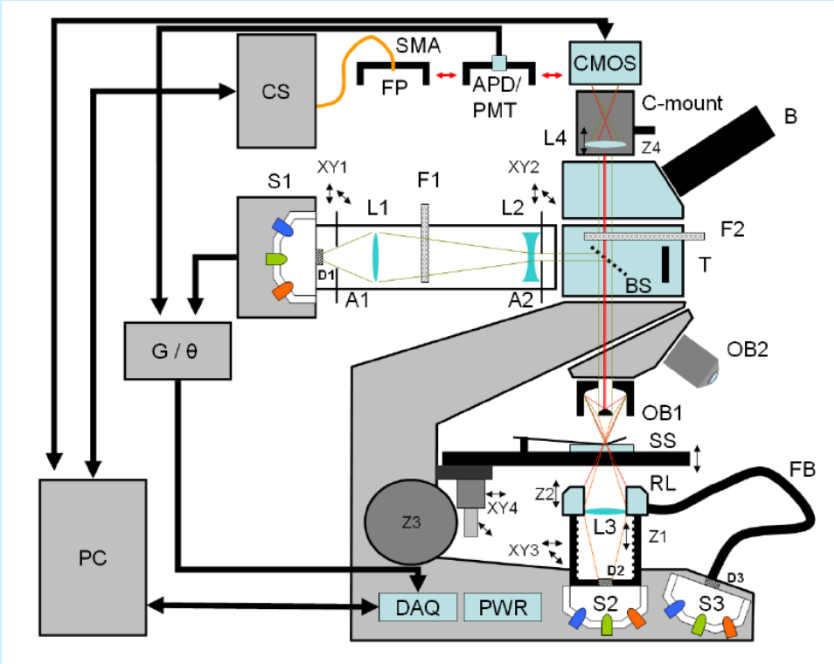


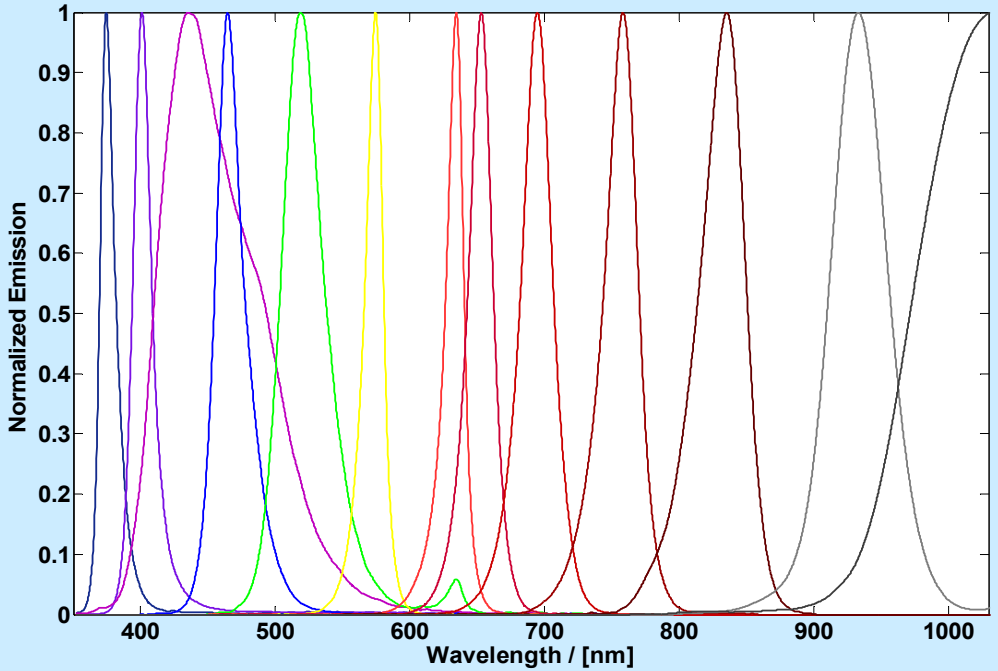
Medical Multispectral Microscopy using LEDs

Brydegaard et al., American J. Phys. 2008

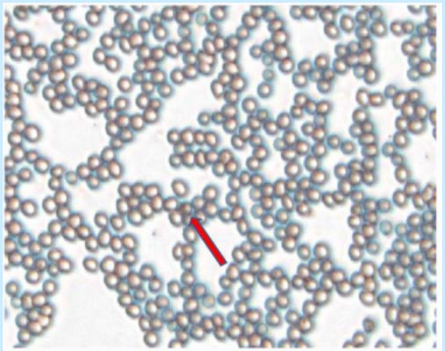
M. Brydegaard, A. Merdasa, J. Ålebring, S. Svanberg, RSI 2011

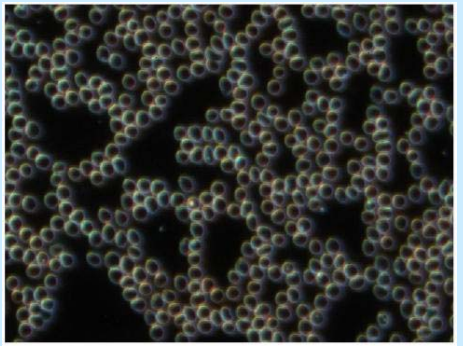
Transmission, Reflectance, Dark field, Fluorescence - 42 images



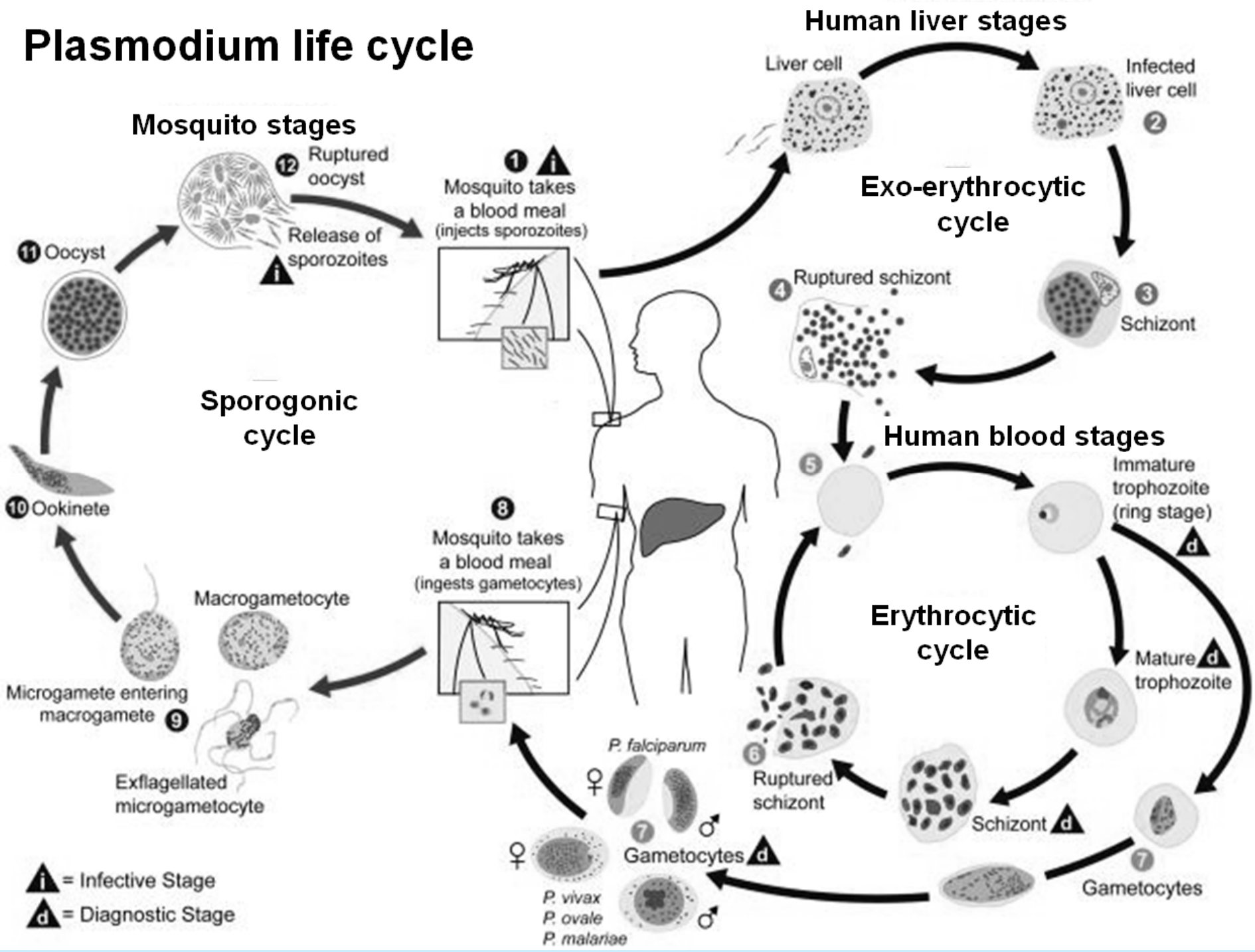


Application to
Malaria Detection
Plasmodium Falciparum
Collaboration with
J. Zueou, Cote d´Ivoire





Plasmodium life cycle

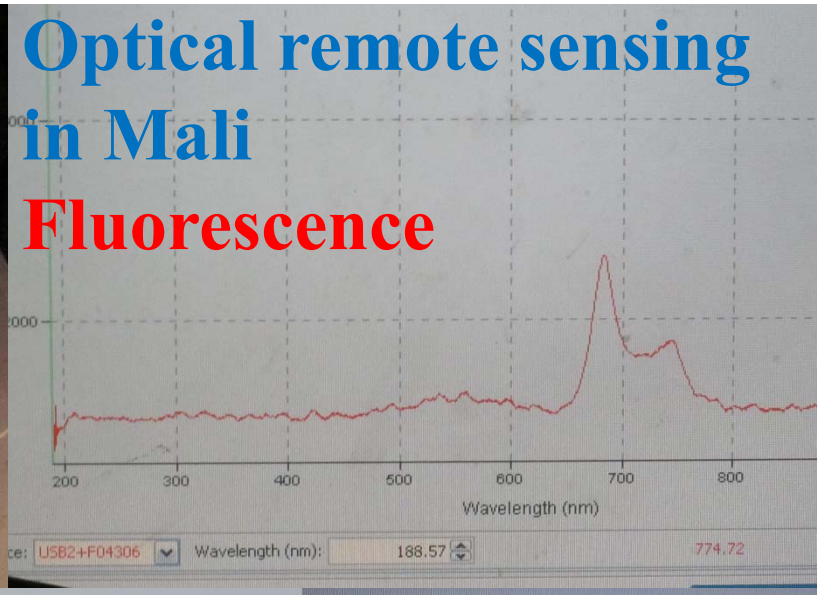


Multispectral microscopy for Malaria diagnostics, and more...

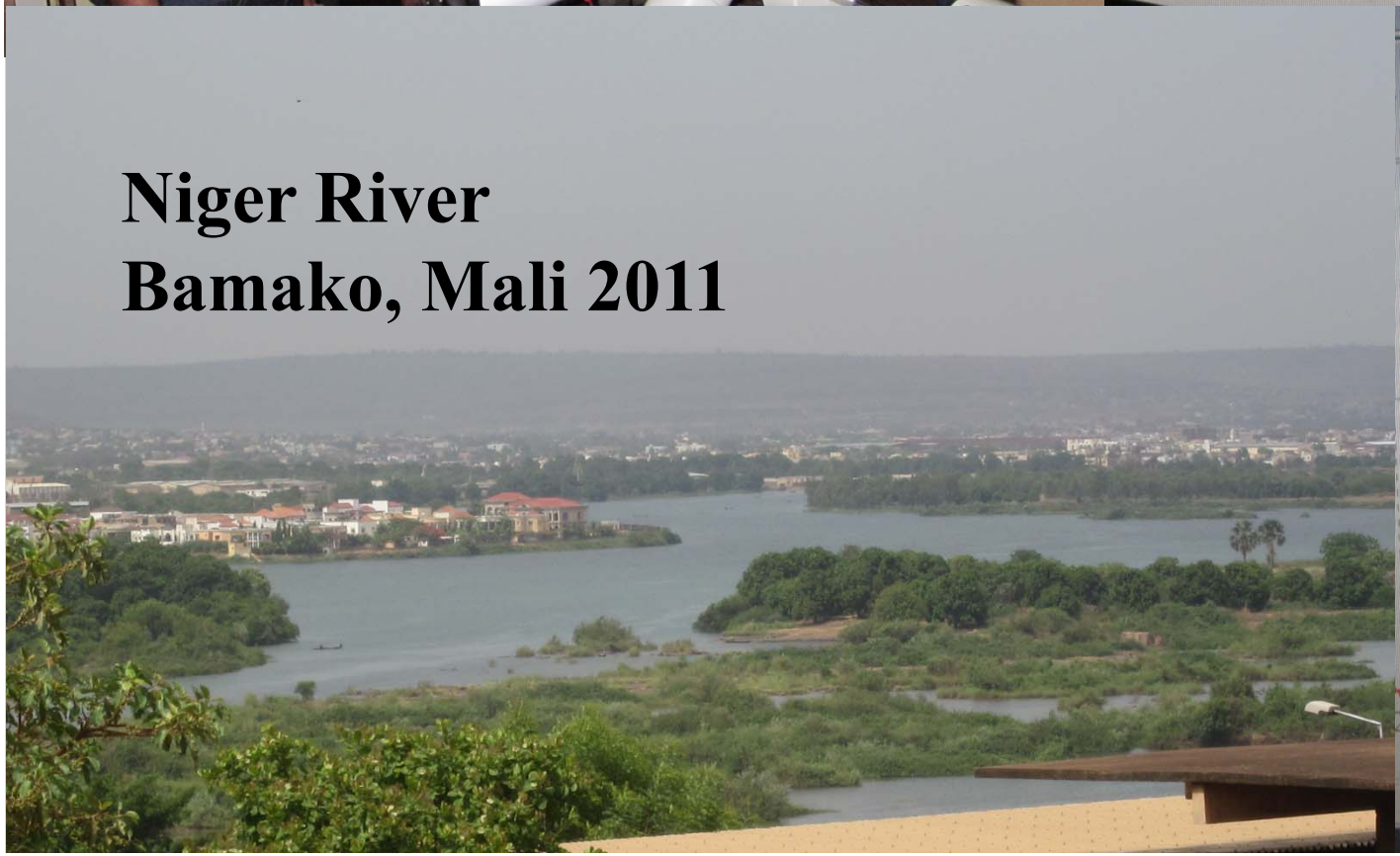
CapeCoast, Ghana

Optical remote sensing in Mali

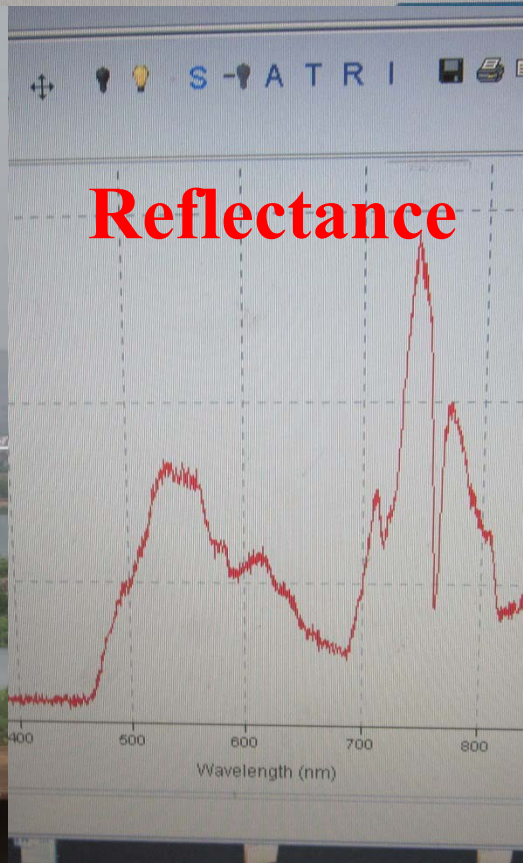
Fluorescence

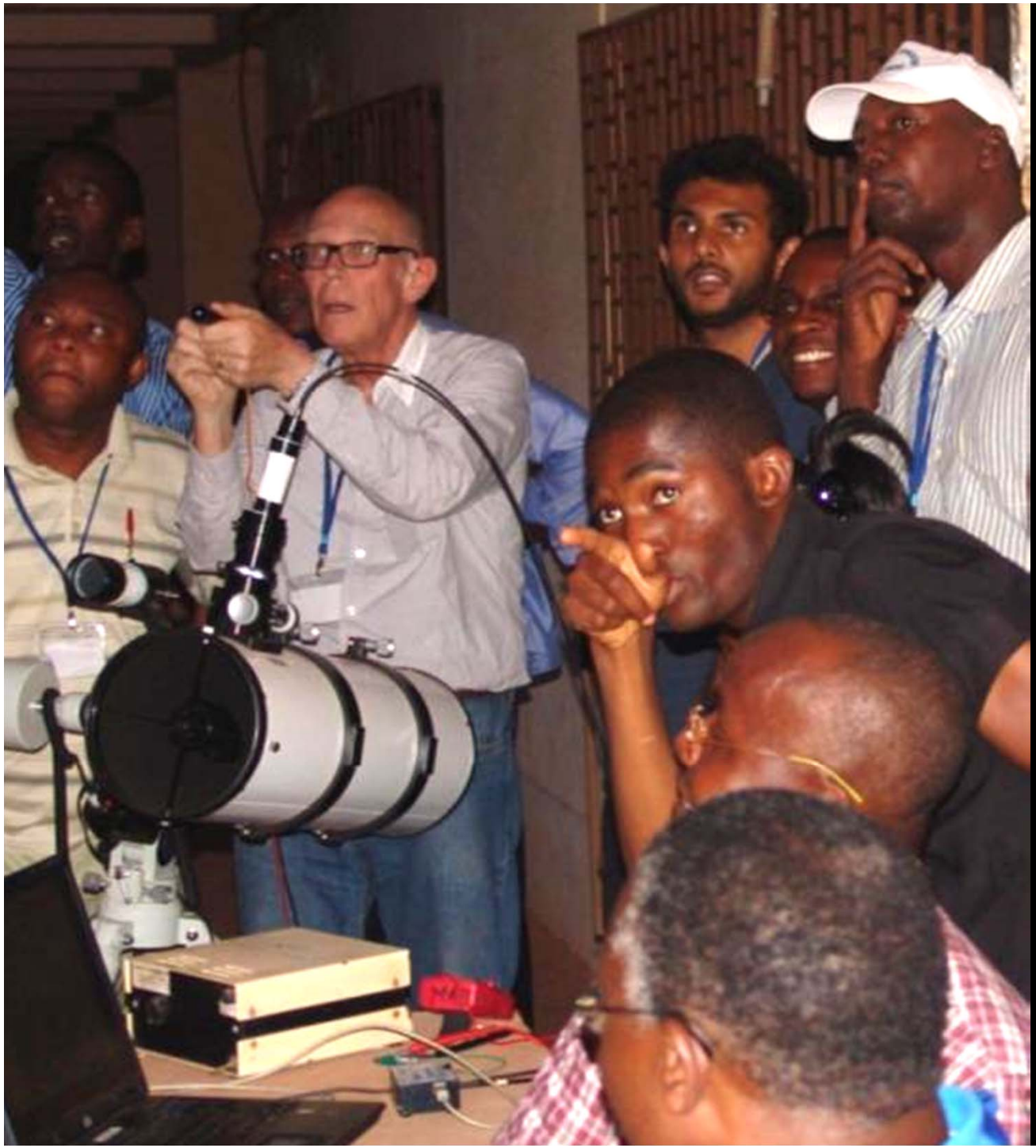


Niger River
Bamako, Mali 2011



Reflectance





Bamako
Mali


ORTM
Bamako
le Journal

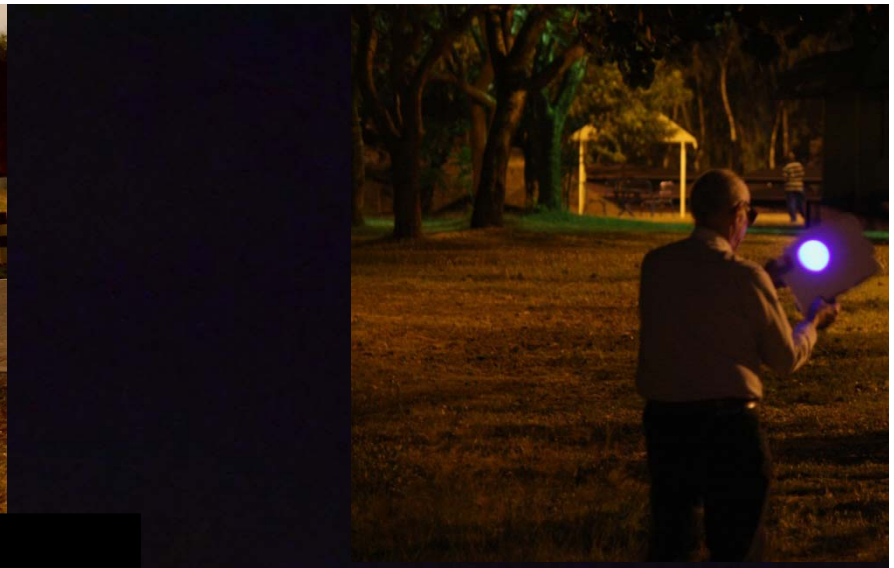

ORTM
LE JOURNAL
Edition
20h00


ORTM
SAMSUNG

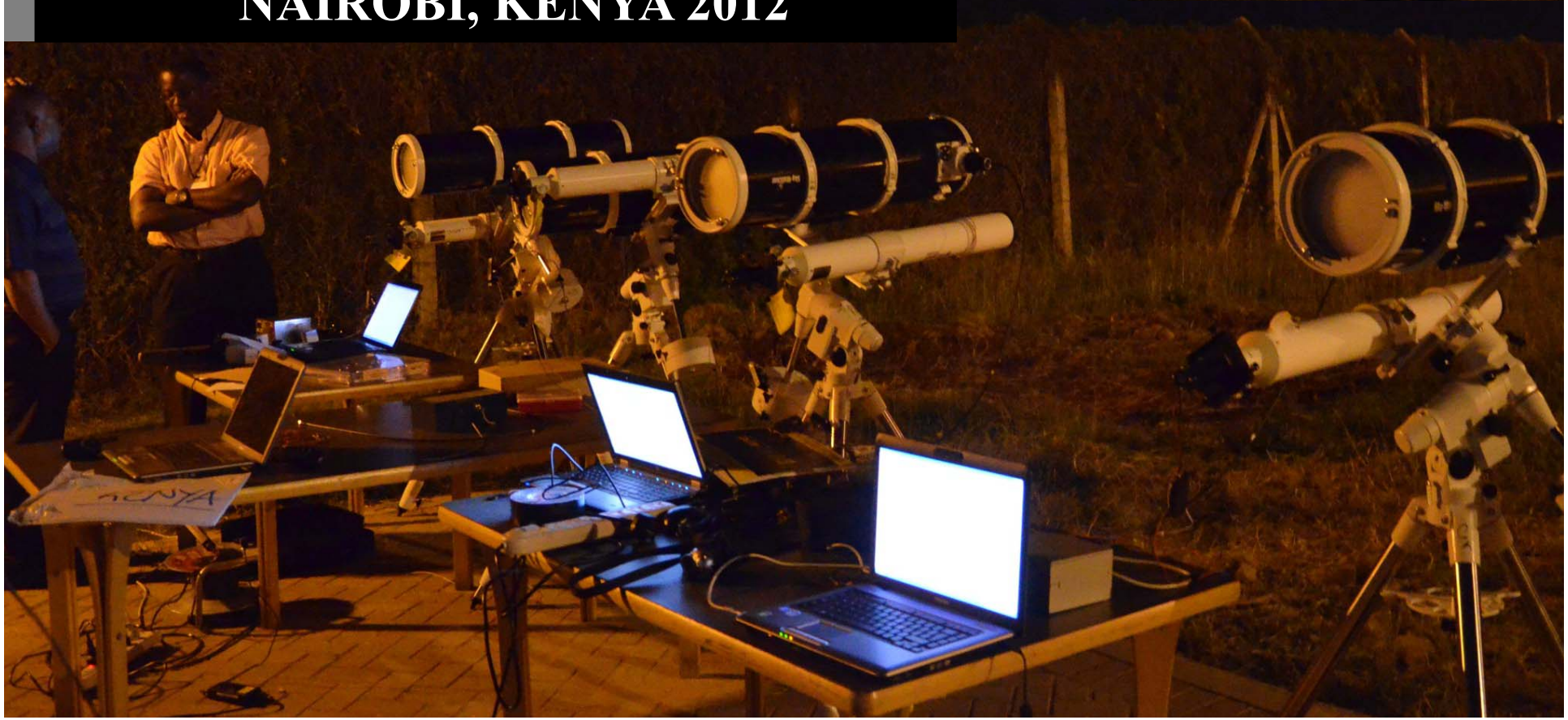

ORTM
Sune SVANBERG
Professeur à l'université de LUND
SAMSUNG

Nairobi, September 2012


TOSHIBA

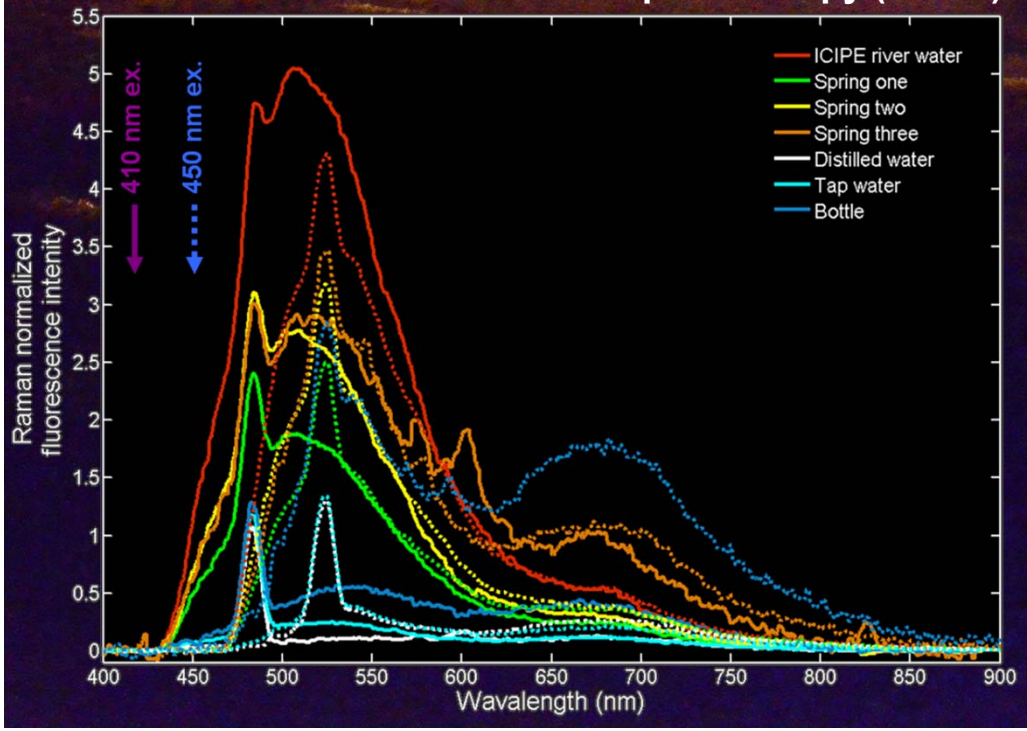


NAIROBI, KENYA 2012



Realistic instrumentation for active and passive remote sensing

First African remote Raman spectroscopy (120 m)



Brydegaard et al. Nairobi September 2012


Thank you for your attention !


Skäralid, Sweden


Jiu Zhai Gou China


Hangzhou, China


Capri, Italy


Science mediates Freedom!
El Condor pasa .....
Andes, Peru

Science brings people together !

Let us shape a better world!

Let us take care of each other!

Friendship and Science can make it happen !