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TECHMED CENTRE

Non-contact imaging for monitoring vital functions and diagnostics using ‘smart’ technologies

Prof dr ir Rudolf Verdaasdonk

Chair of Health Technology Implementation

Prof of Physics and Medical Technology

Biomedical Photonics & Imaging
TechMed Center, University of Twente
The Netherlands

BMPI
Biomedical Photonic Imaging

TECHNICAL MEDICAL CENTRE
at the University of Twente

10%

EDUCATION

Three educational programs (BME, TM and HS)

50%

SPIN-OFF

50% of UT spin-off is health-related

40%

RESEARCH

40% of EU funded research is healthcare focused

GRAND OPENING TECHMED CENTRE NOV 29TH 2019

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Intensive Care Units

Operation Rooms

Hybrid OR

2 x MRI

TECHMED CENTRE

ACCELERATE INNOVATIONS TO HEALTH CARE

FACULTY OF ENGINEERING TECHNOLOGY (ET)

FACULTY OF SCIENCE AND TECHNOLOGY

FACULTY OF ELECTRICAL ENGINEERING, MATHEMATICS AND COMPUTER SCIENCE

STRATEGIC BUSINESS DEVELOPMENT (SBD)

NovelT

FACULTY OF BEHAVIOURAL, MANAGEMENT AND SOCIAL SCIENCES (BMS)

(source: T. Degawa, V. Ehlers, L. Branscomb)

JSR

TECHMED INNOVATION HUB
WHAT DO WE DO?

- Support Technology & Knowledge Transfer
- Boost innovation by connecting stakeholders in & beyond the region
- Offer (access to) a wide diversity of services
- Offer access to state-of-the art research facilities
- Stimulate new innovations with funds & voucher programs

Novel T

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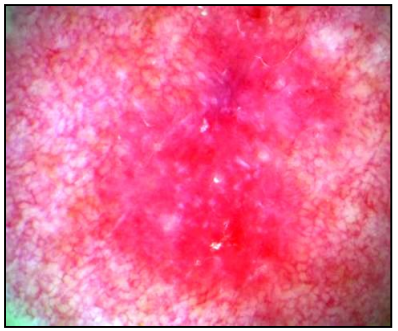
Need for non-contact monitoring

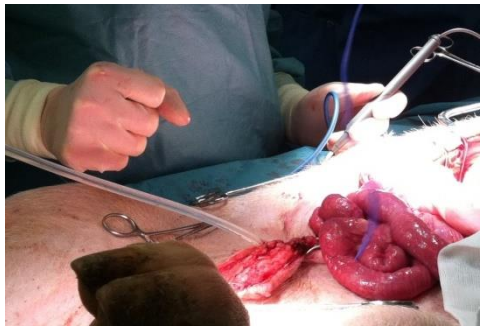
- safe for the patient
- overview of area of interest
- no interference with contact sensors
- no obstructing wires
- freedom to move
- no contact artifacts
- ‘sterile’ no risk for infections
- .....

What do we like to monitor ?

- Vital functions
  - heart rate
  - breathing
  - perfusion
  - oxygenation
  - temperature



- Discriminate diseased from healthy tissue
  - (pre) cancerous tissue
  - inflammation
  - tissue damage



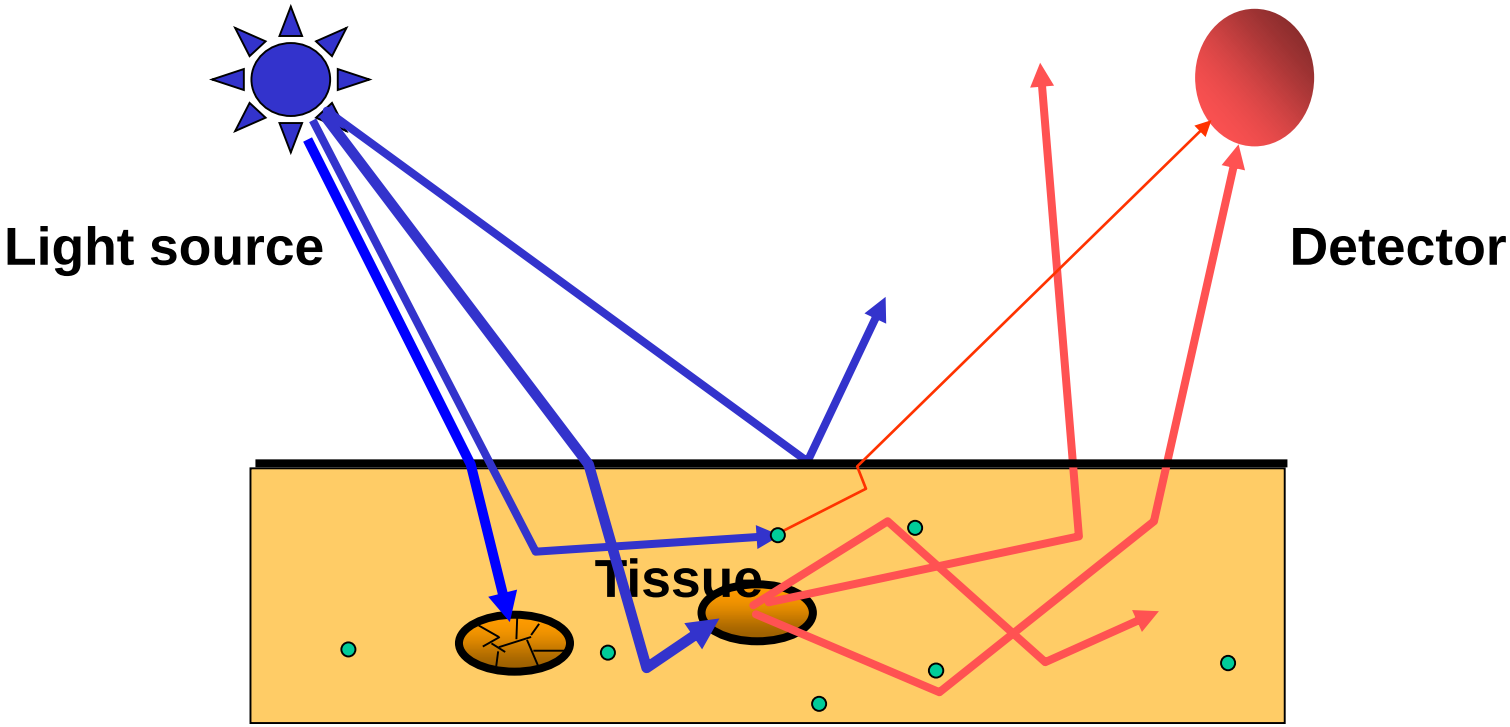
- Treatment monitoring

Qualitative and Quantitative

Light interaction with tissue

Interaction with tissue changes characteristics of incoming light that is scattered and reflected

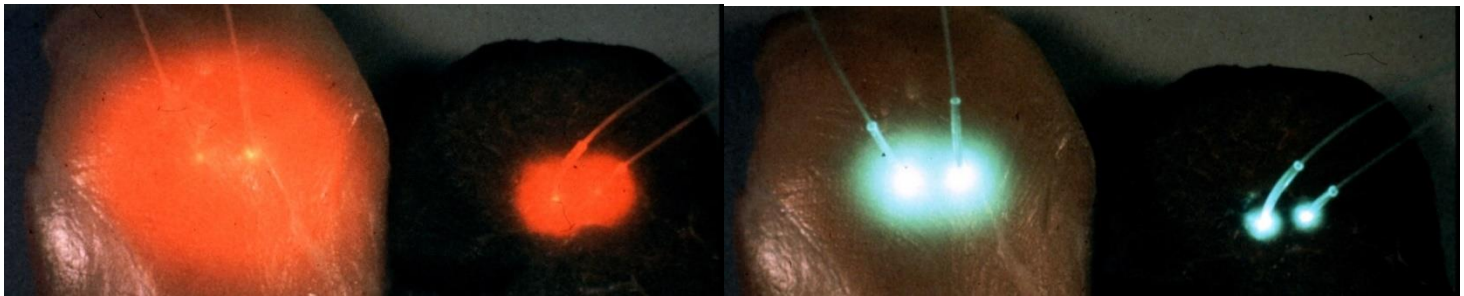
- ☞ diagnostics



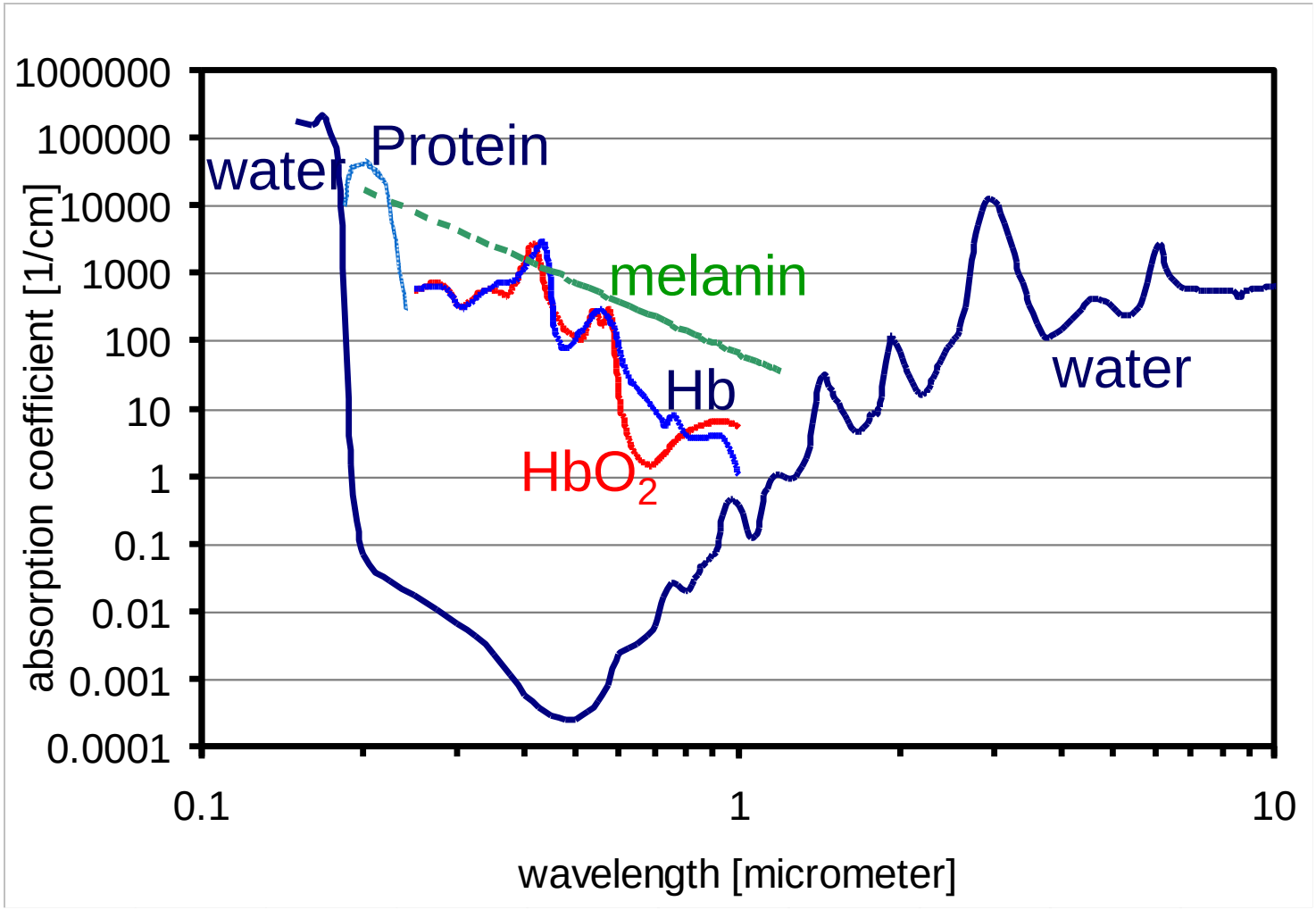
Interaction with tissue changes the characteristics of light

- intensity drop due to absorption (λ dep)
- direction due to scattering (λ dep)
- wavelength distribution
- wavelength change
- polarisation
- coherence

which ‘refect’ the characteristics of the tissue



absorbing chromophores in tissue



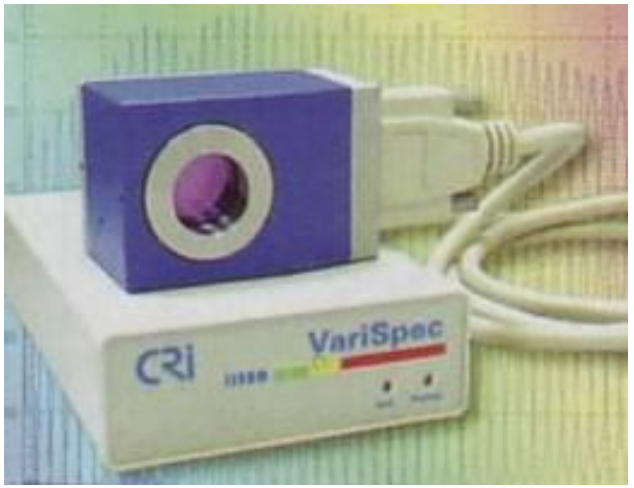
The contrast in image is enhanced by using the optimal combination of

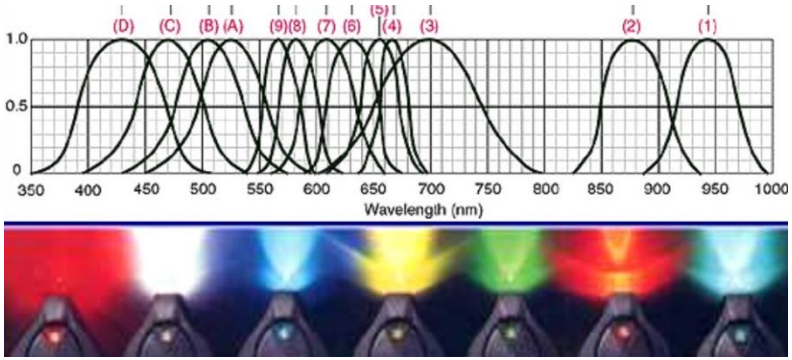
light source for illumination

sensor for imaging

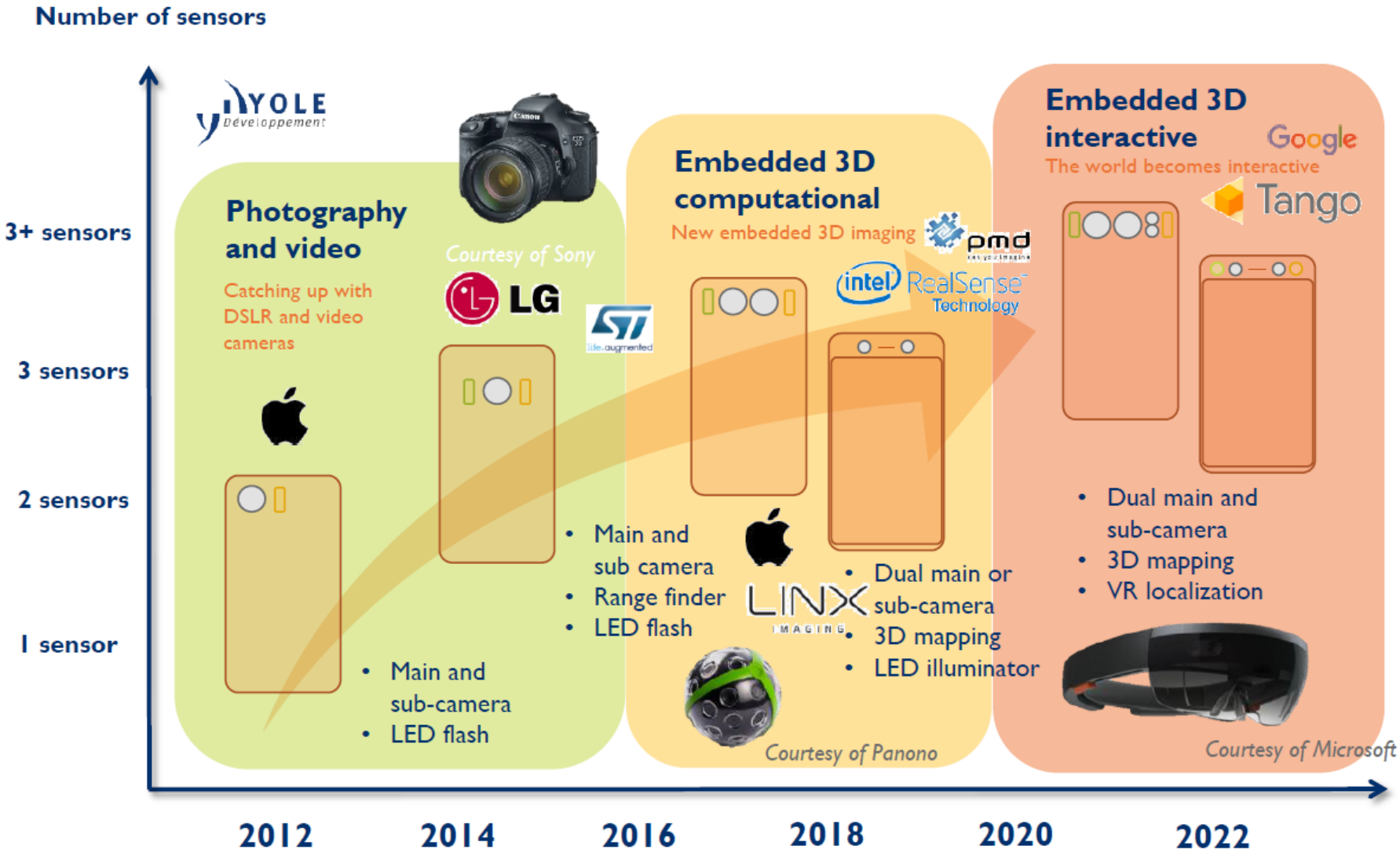
Control over the wavelength of the light source

- spectrograph
- filter wheel
- tunable LCD
- tunable laser source
- Light Emitting Diodes





increasing grow in number of sensors in smart devices



extend the wavelength sensitivity of camera sensor removing ‘hot’ filter

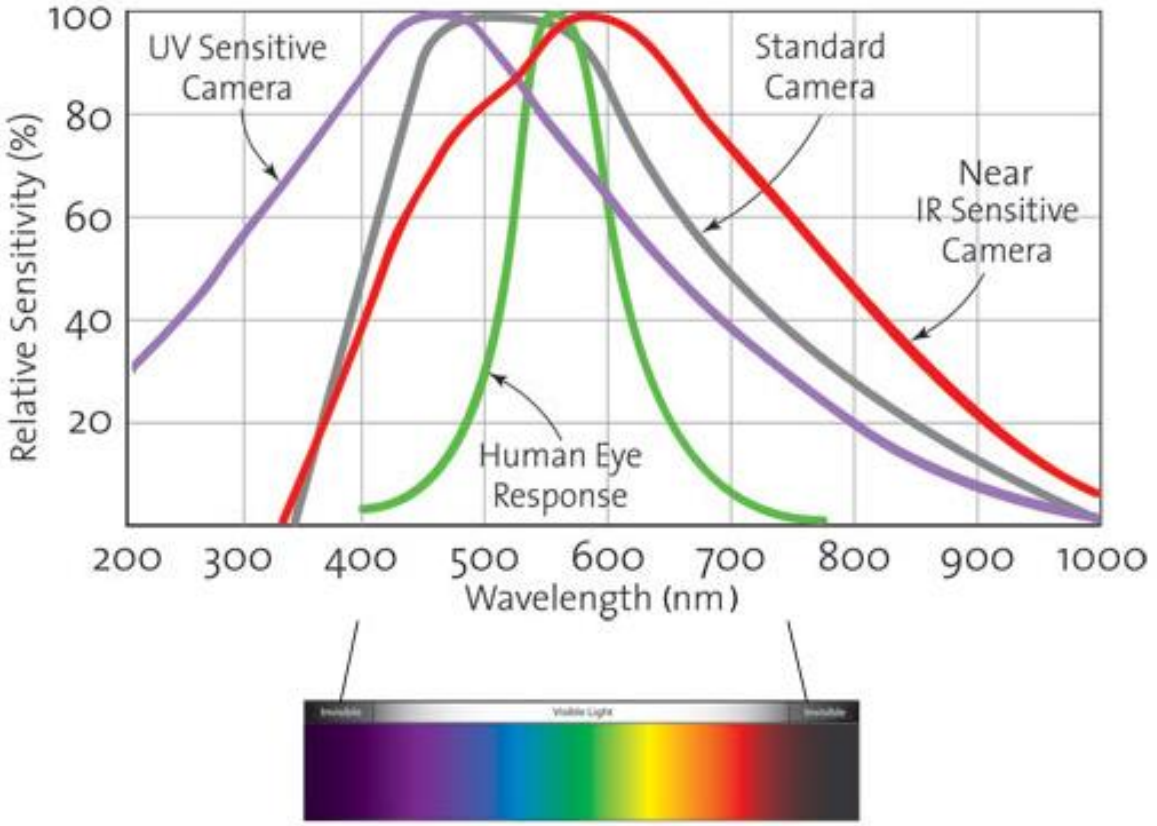


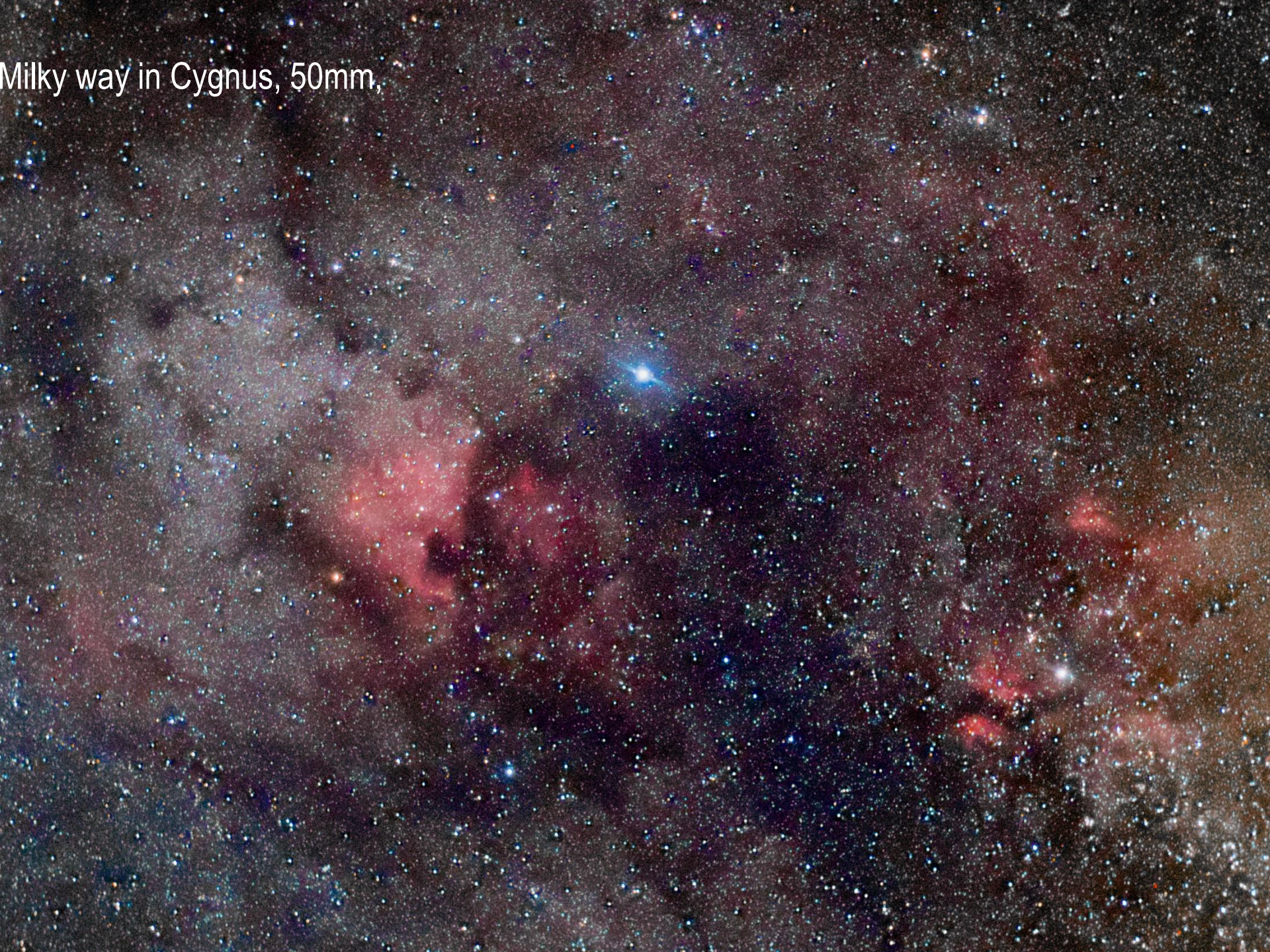
Figure 2. Comparison of Camera Sensor and Human Eye Spectral Responses
Courtesy of Firstsight Vision

Special
CCD
CMOS
Optics

Sony NEXT 5T full spectral camera

wifi camera
with tablet control

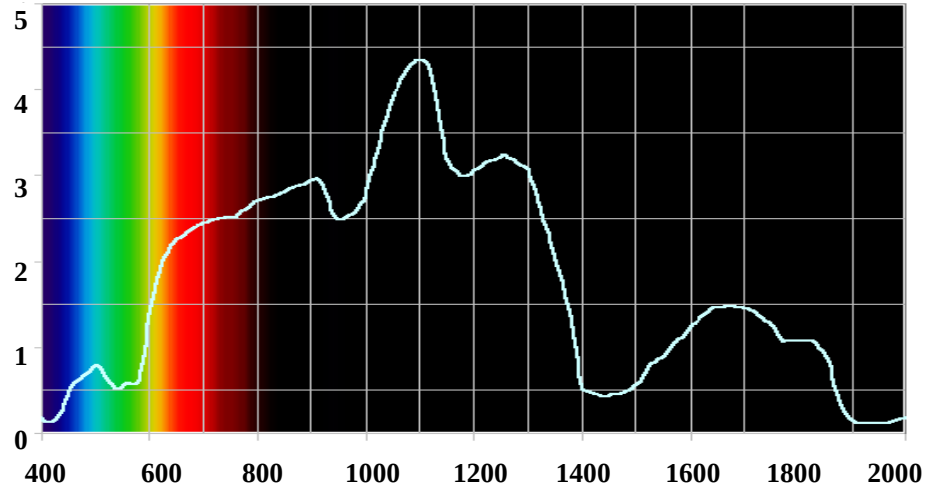
buy through Ebay
astrophotography
ghost hunting


Milky way in Cygnus, 50mm,

your face in UV – VIS - NIR

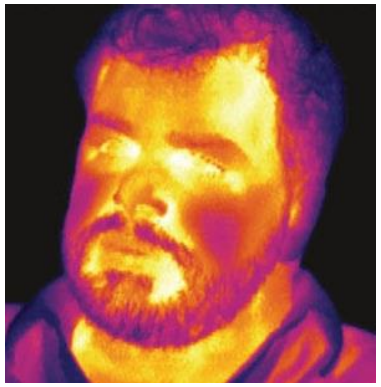
your face in NIR narrow bands

Short-Wave Infrared Face Images captured when using no filter, or when using band pass filters.



your face in InfraRed

vis (0.4-0.7) near (1-3) middle (3-5) far (8-12 µm)



Clinical applications of ‘non contact imaging’

Multi spectral Imaging

Oxygenation Imaging

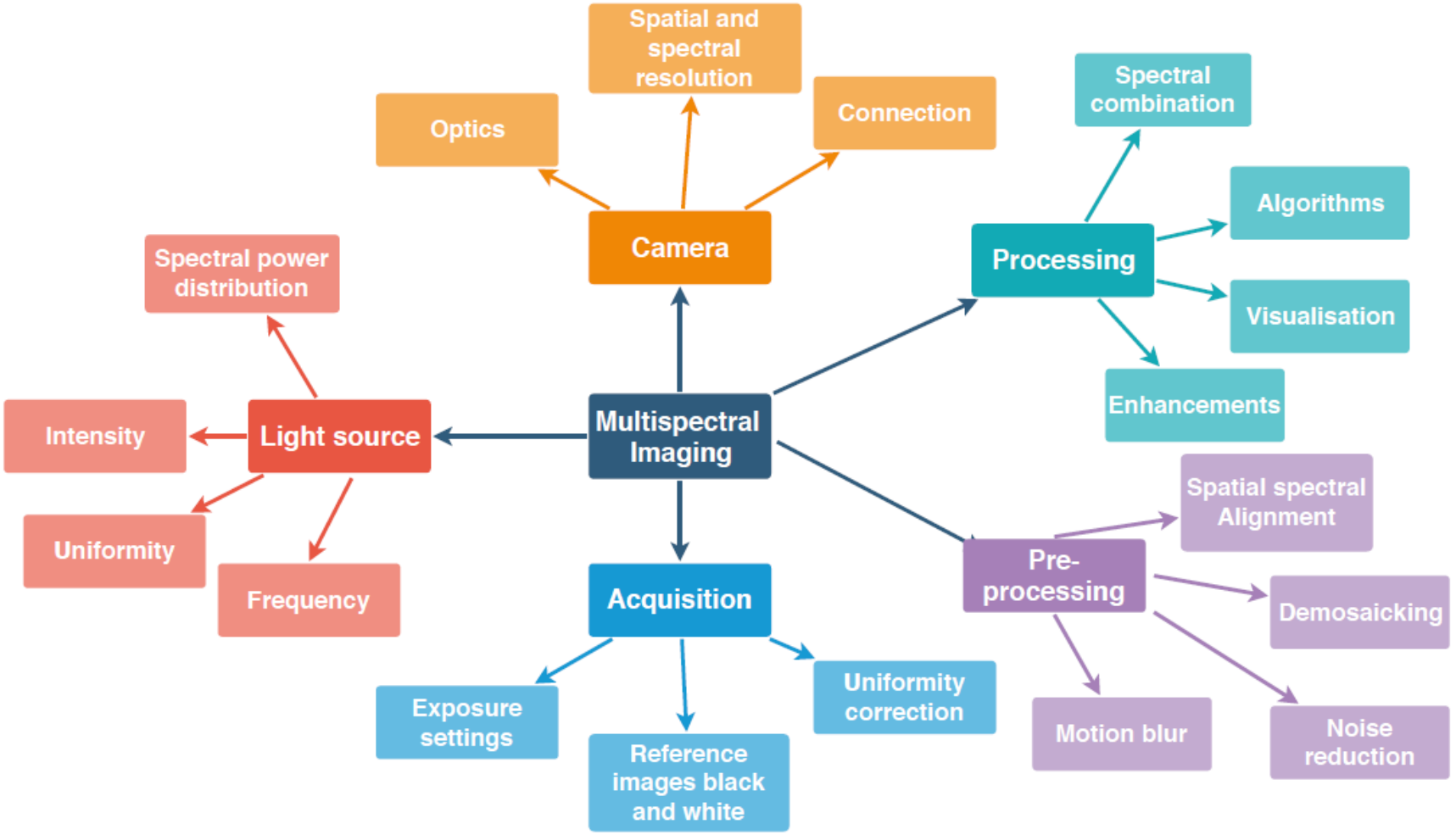
Heart rate monitoring

Vessel Imaging

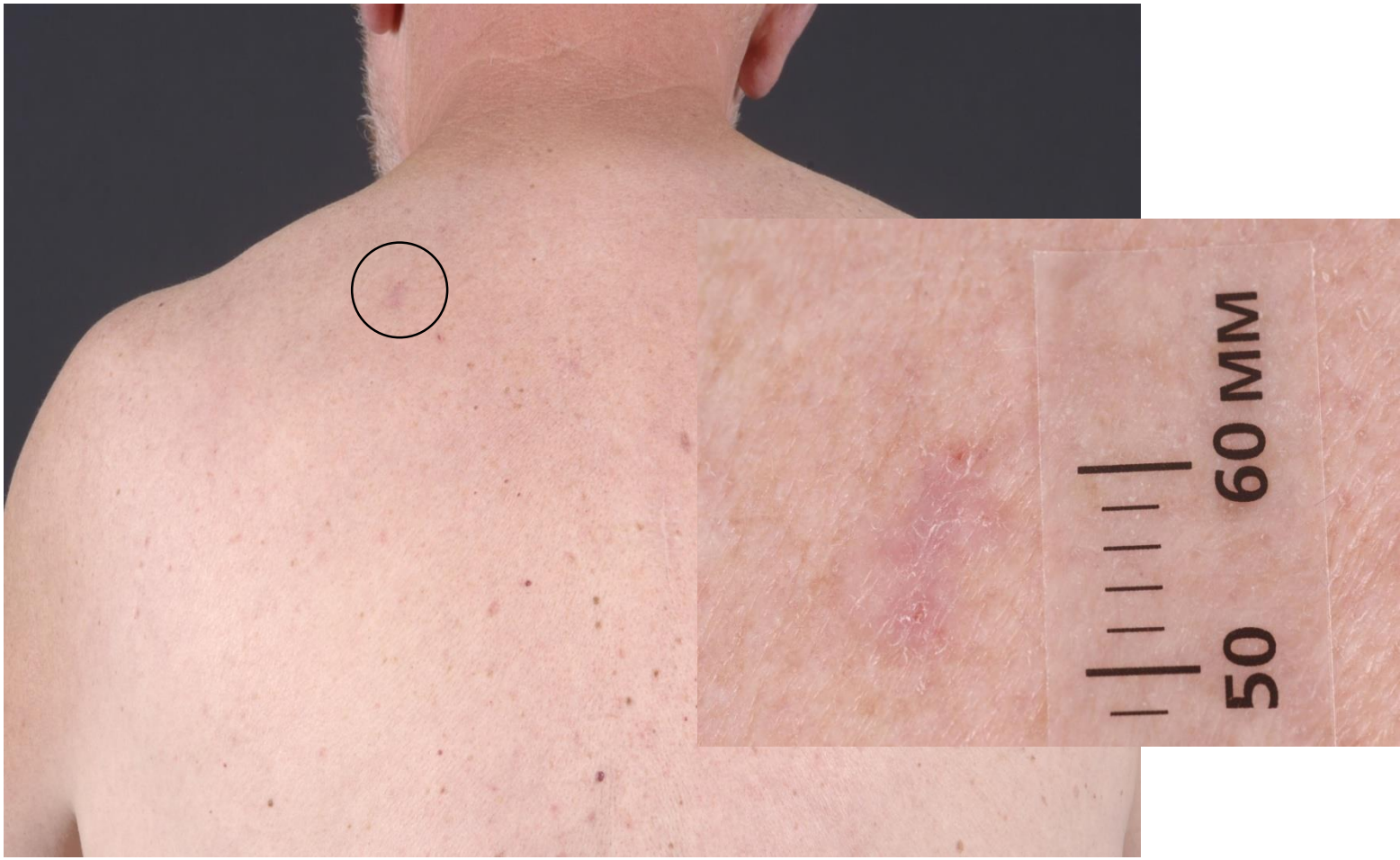
Thermal Imaging

3D scanning

Understanding Multispectral Imaging

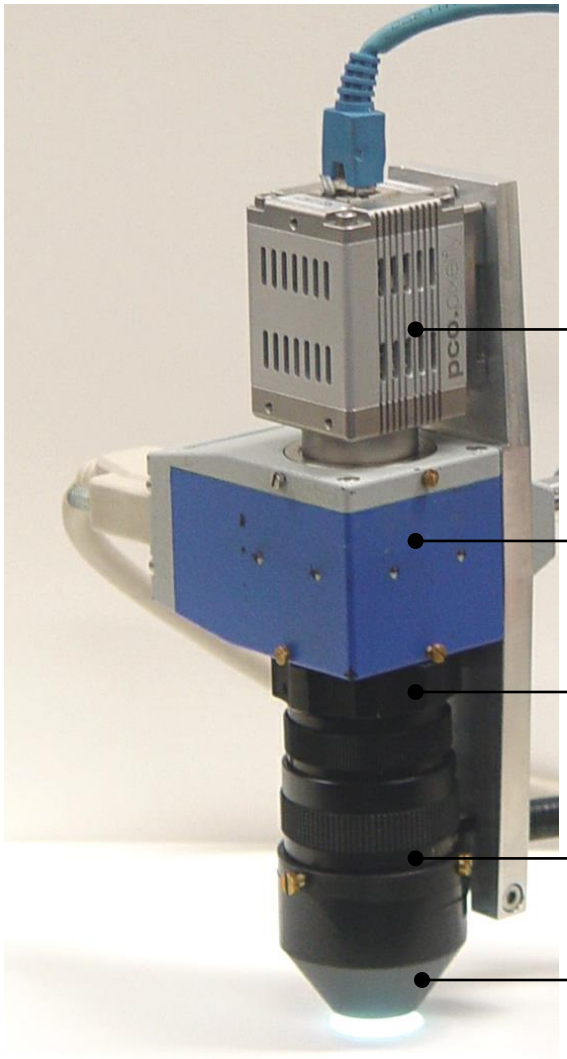


Multi spectral Imaging
for the detection of skin cancer



superficial basal cell carcinoma

Multispectral Imaging system with tunable filter



Super sensitive 12 bit CCD Camera

(1362 X 1280) QE 65%

Spectral tunable filter, passes through one selected wavelength.

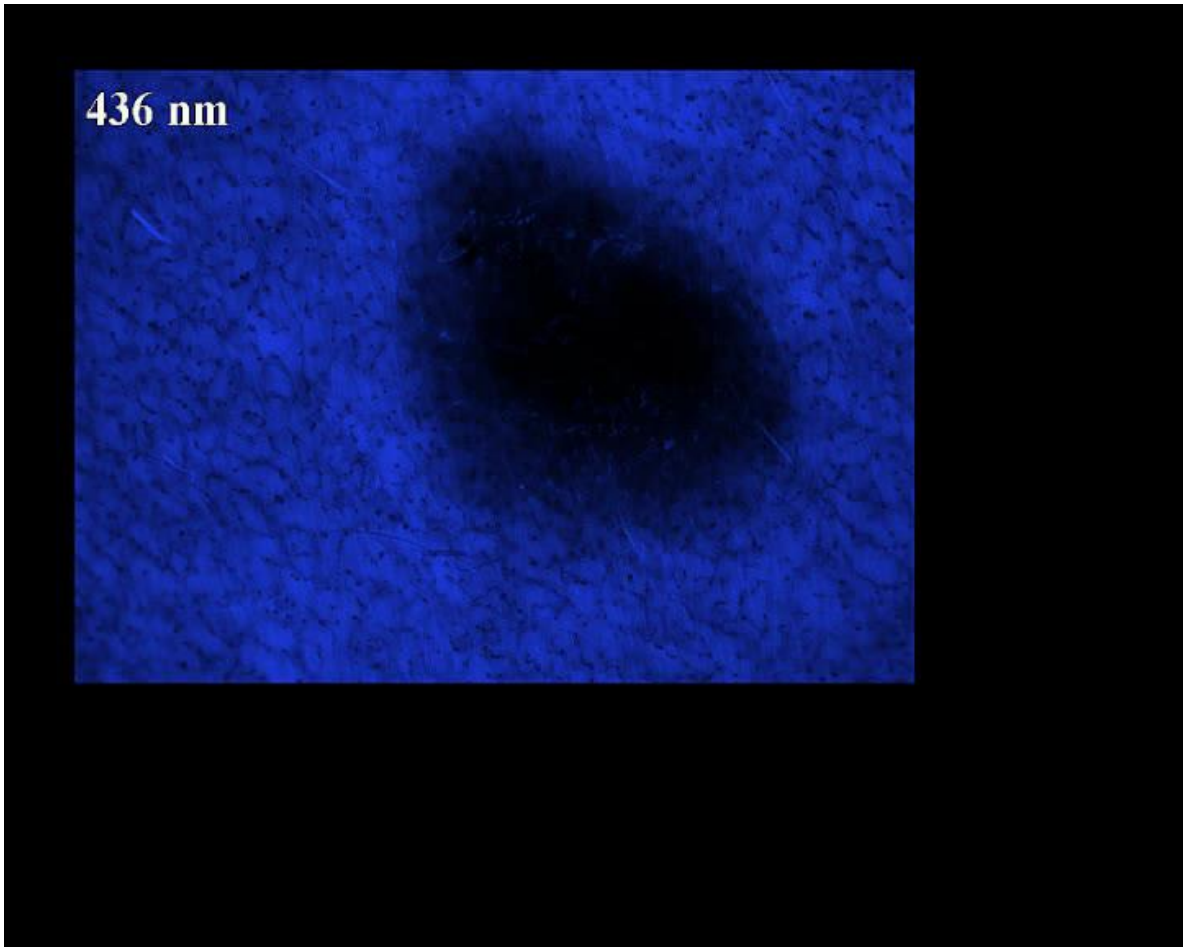
Lens

Ring shaped fiber-optic illuminator connected to power LED

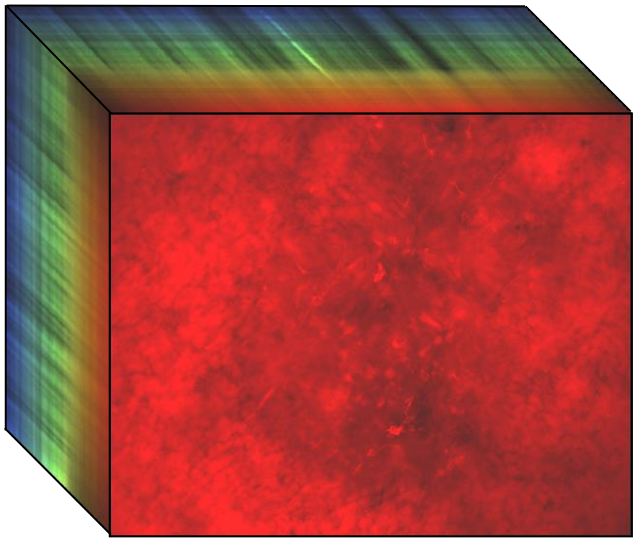
Light shield

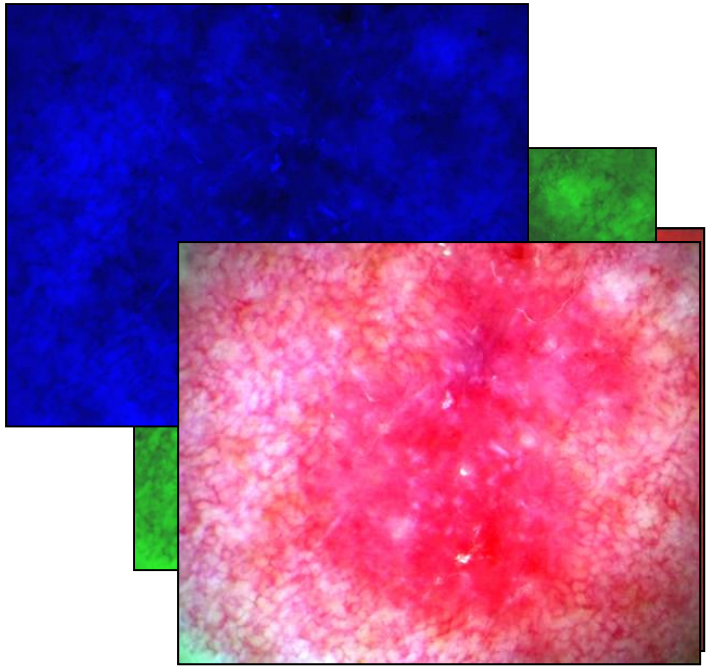
Multi-spectral scan

The skin will show different features at each wavelength / color going through the spectrum from blue to red.

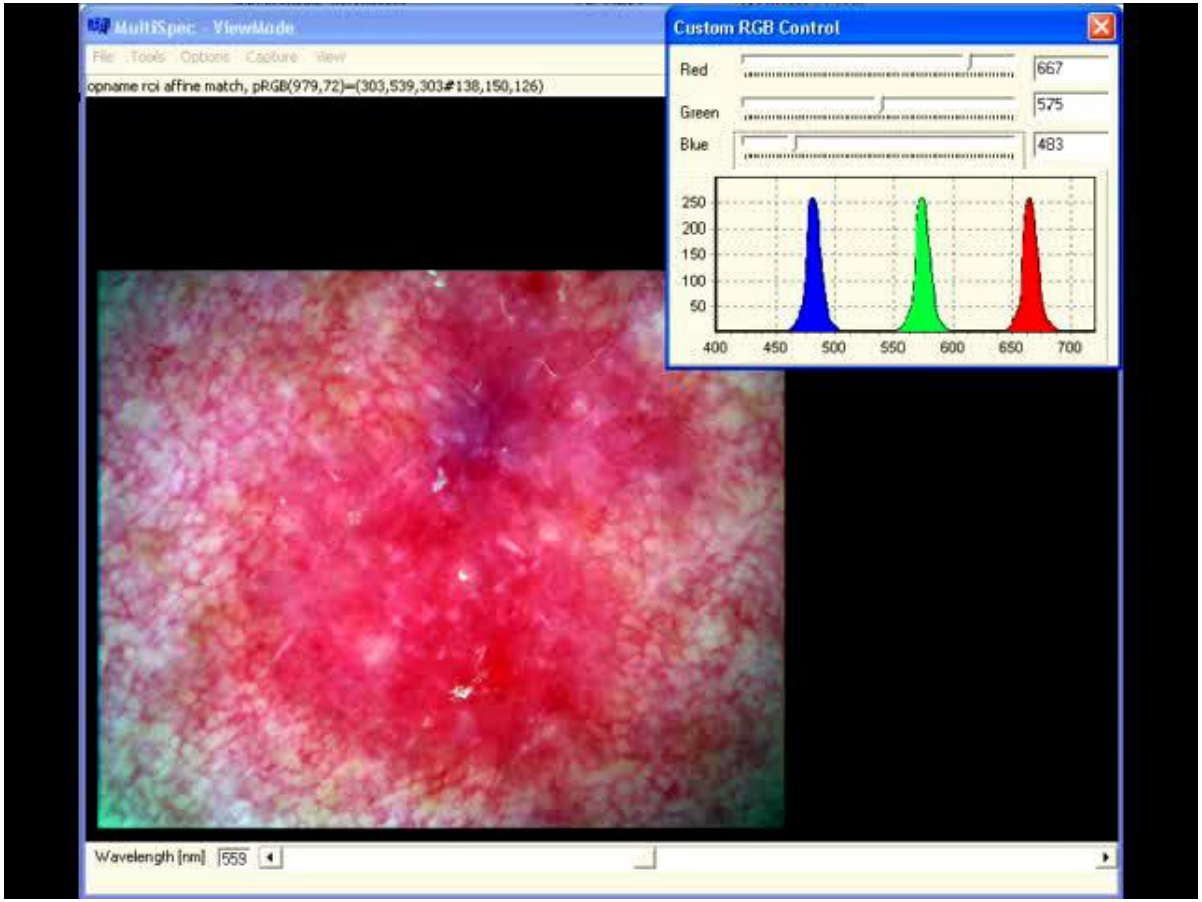


Combination of multi spectral images for contrast enhancement



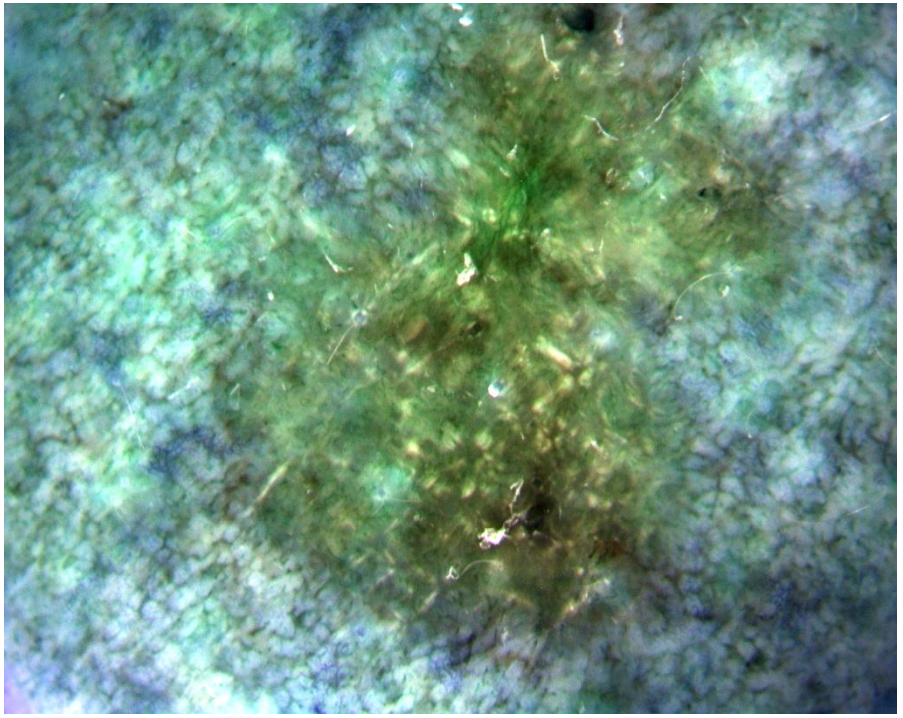


Creation of a (false) color image from multi-spectral image set



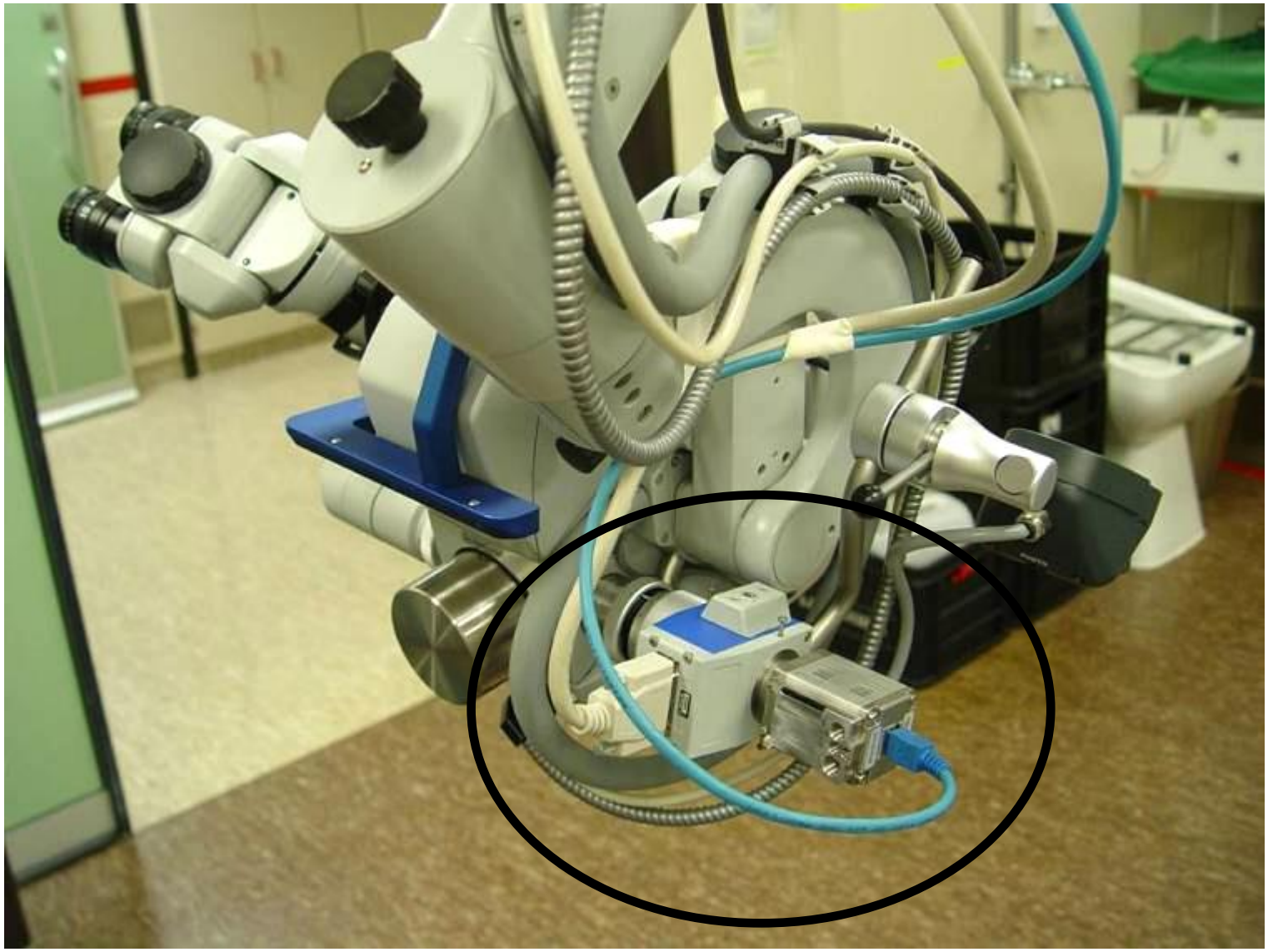
maximum visual enhancement of malignancy

normal color image

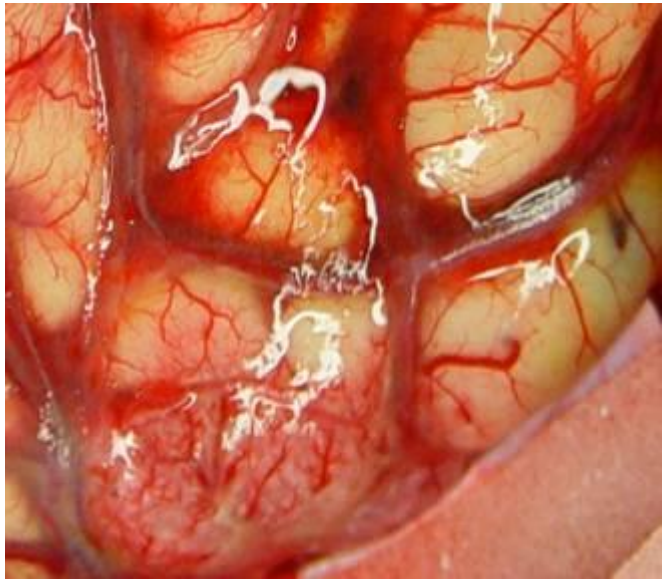


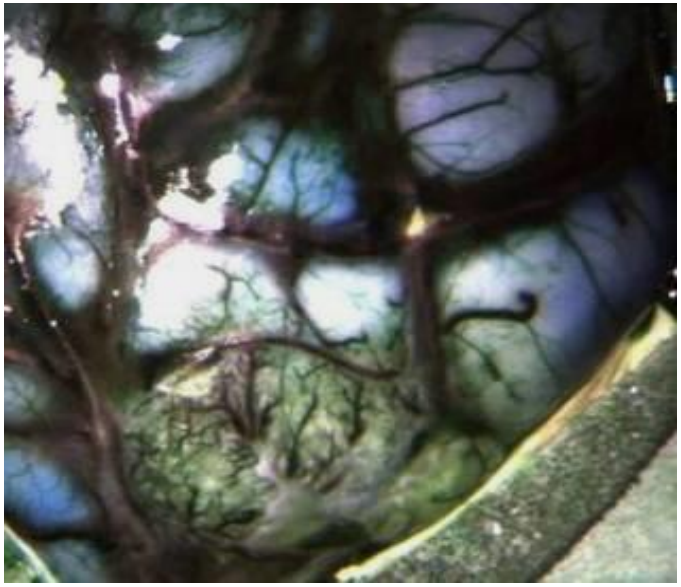
false color image

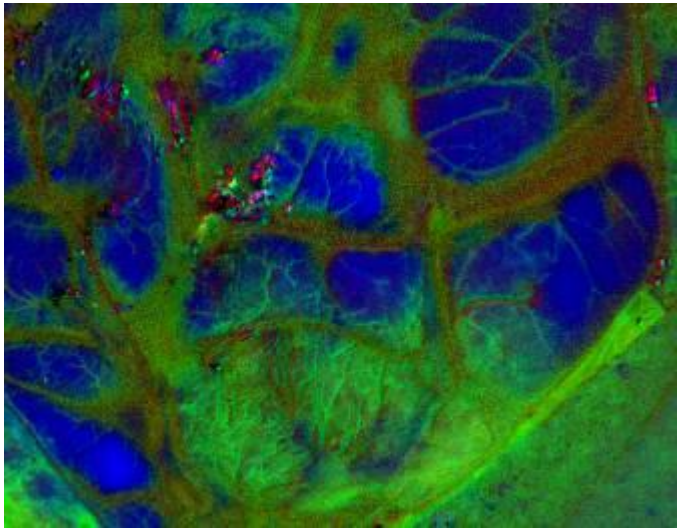
Brain surgery application



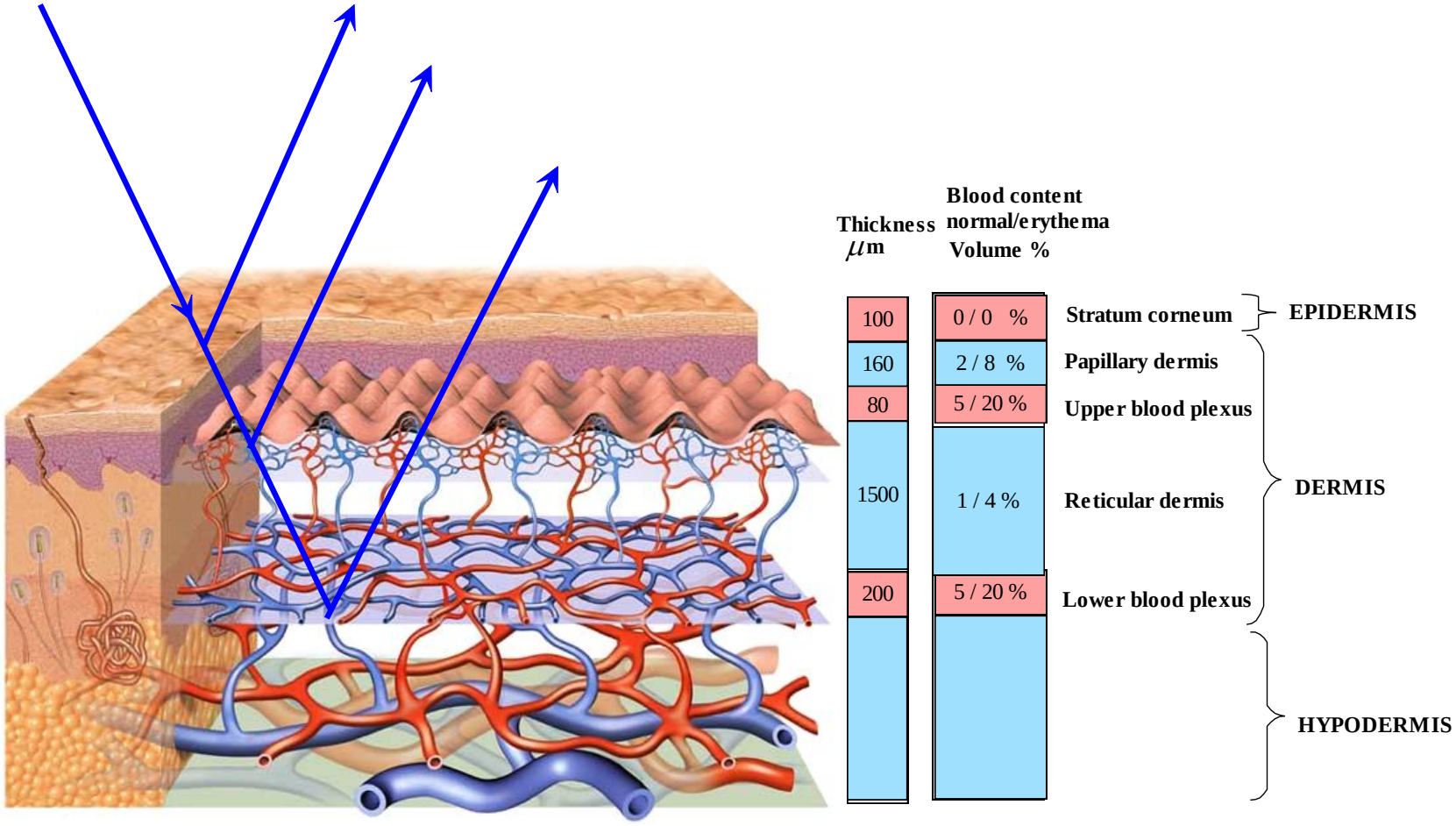
Neurosurgery : tumor demarcation



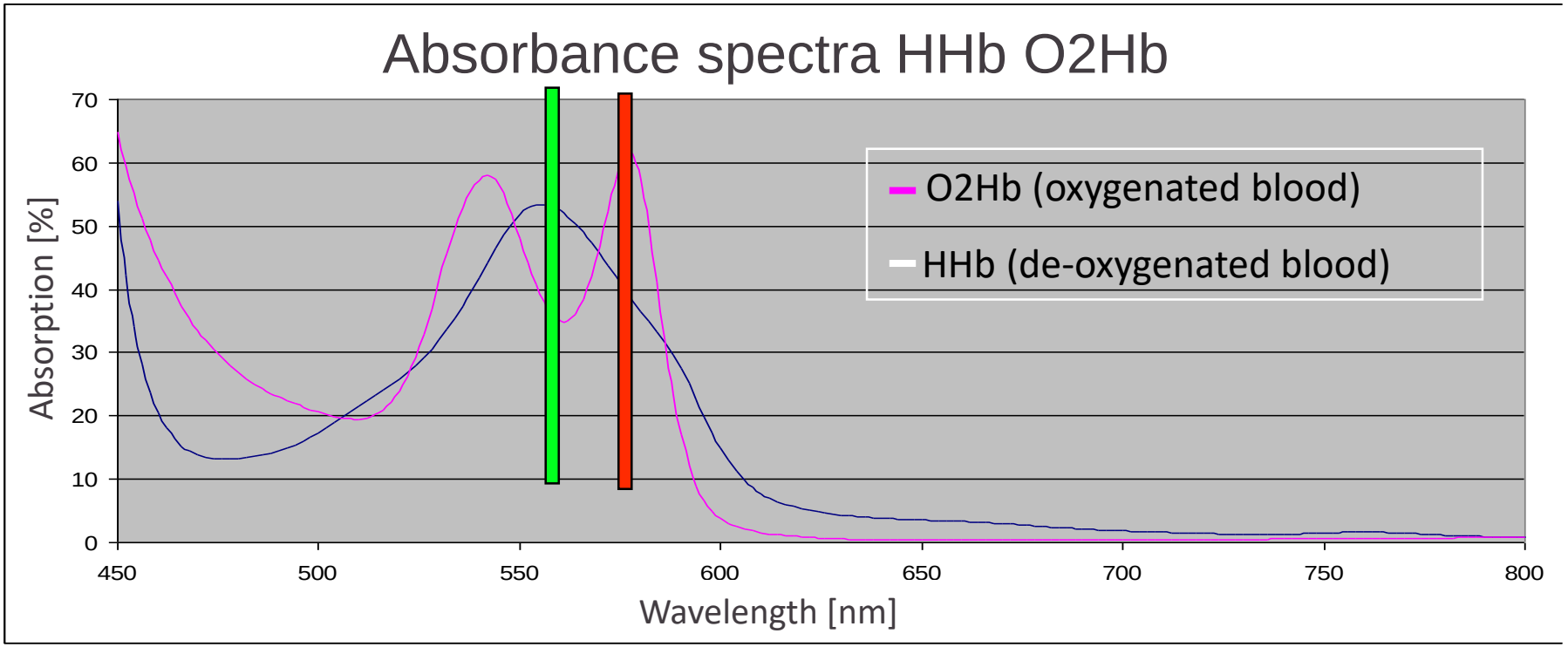




Perfusion / Oxygenation Imaging in skin

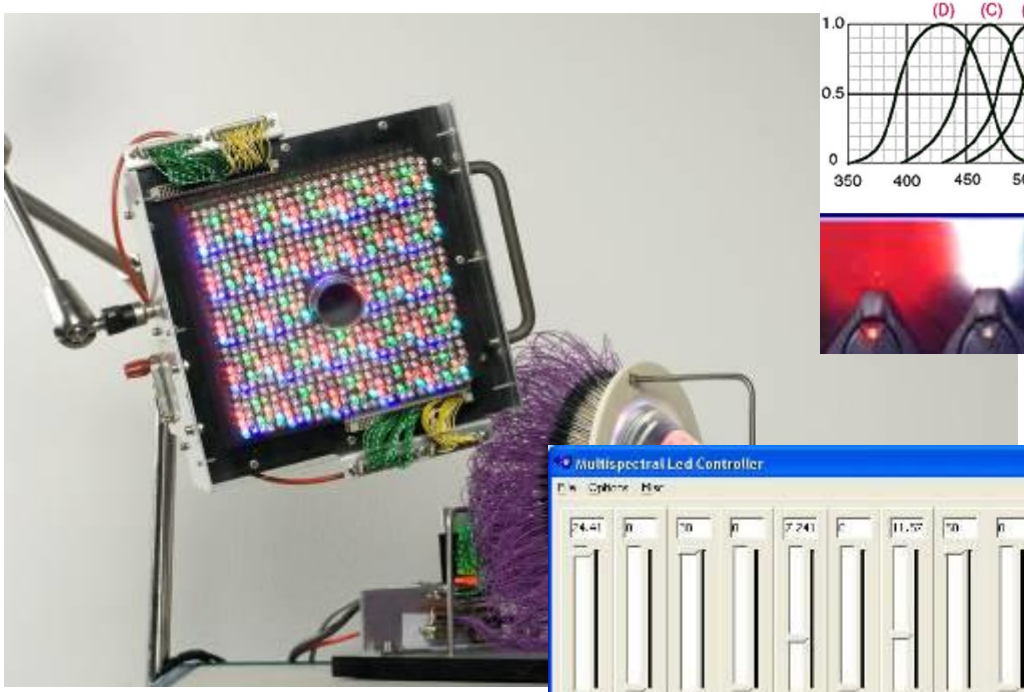


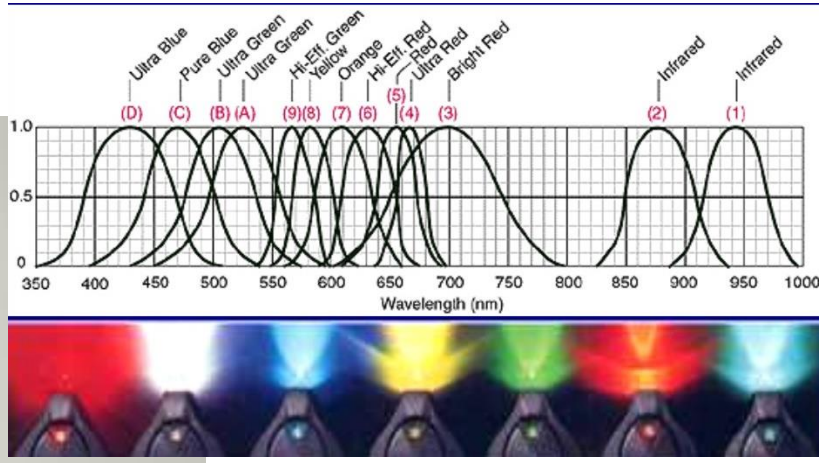
Blood (de-)oxygenation spectra

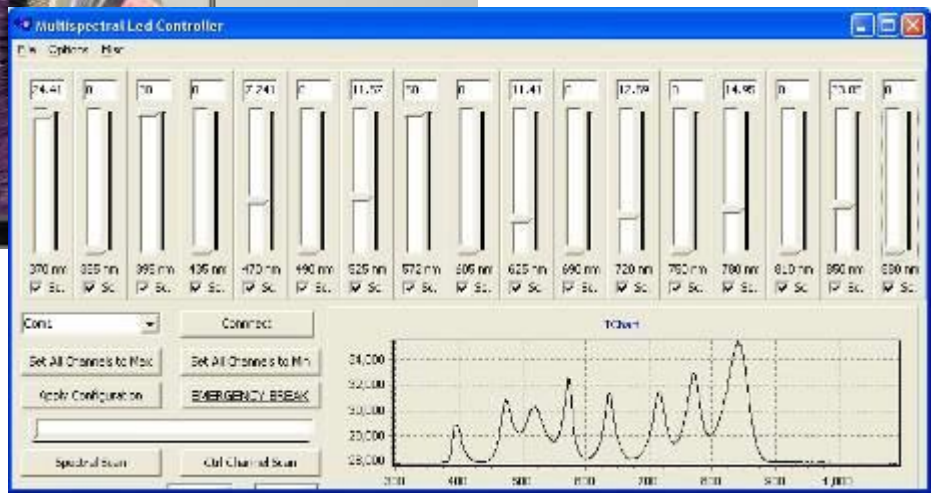


$$\begin{pmatrix} \Delta C_{HHb} \\ \Delta C_{O2Hb} \end{pmatrix} = \begin{pmatrix} \mu HHb_{\lambda 1} & \mu O2Hb_{\lambda 1} \\ \mu HHb_{\lambda 2} & \mu O2Hb_{\lambda 2} \end{pmatrix}^{-1} \begin{pmatrix} \Delta OD_{\lambda 1} \\ \Delta OD_{\lambda 2} \end{pmatrix}$$

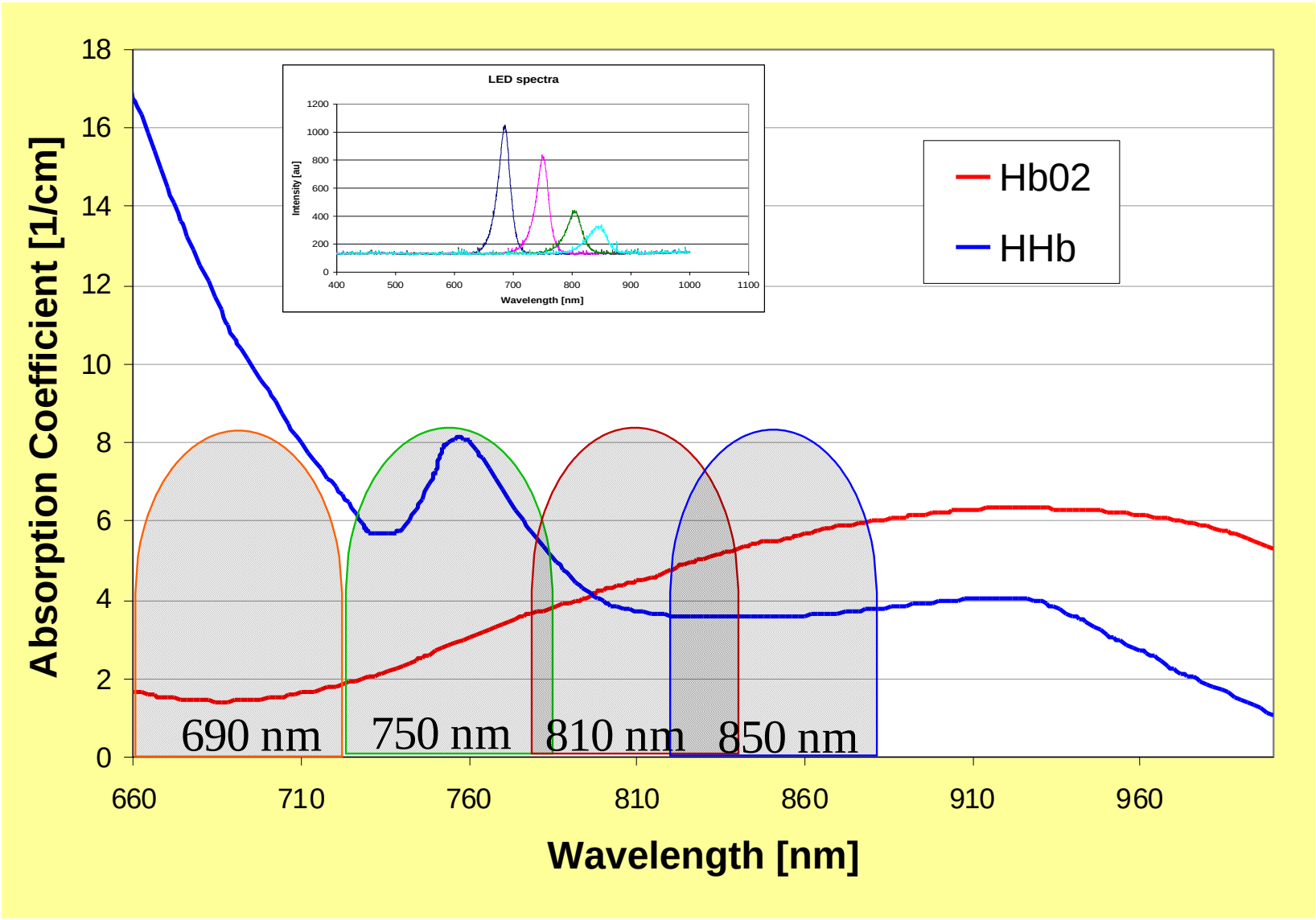
Multispectral LED source



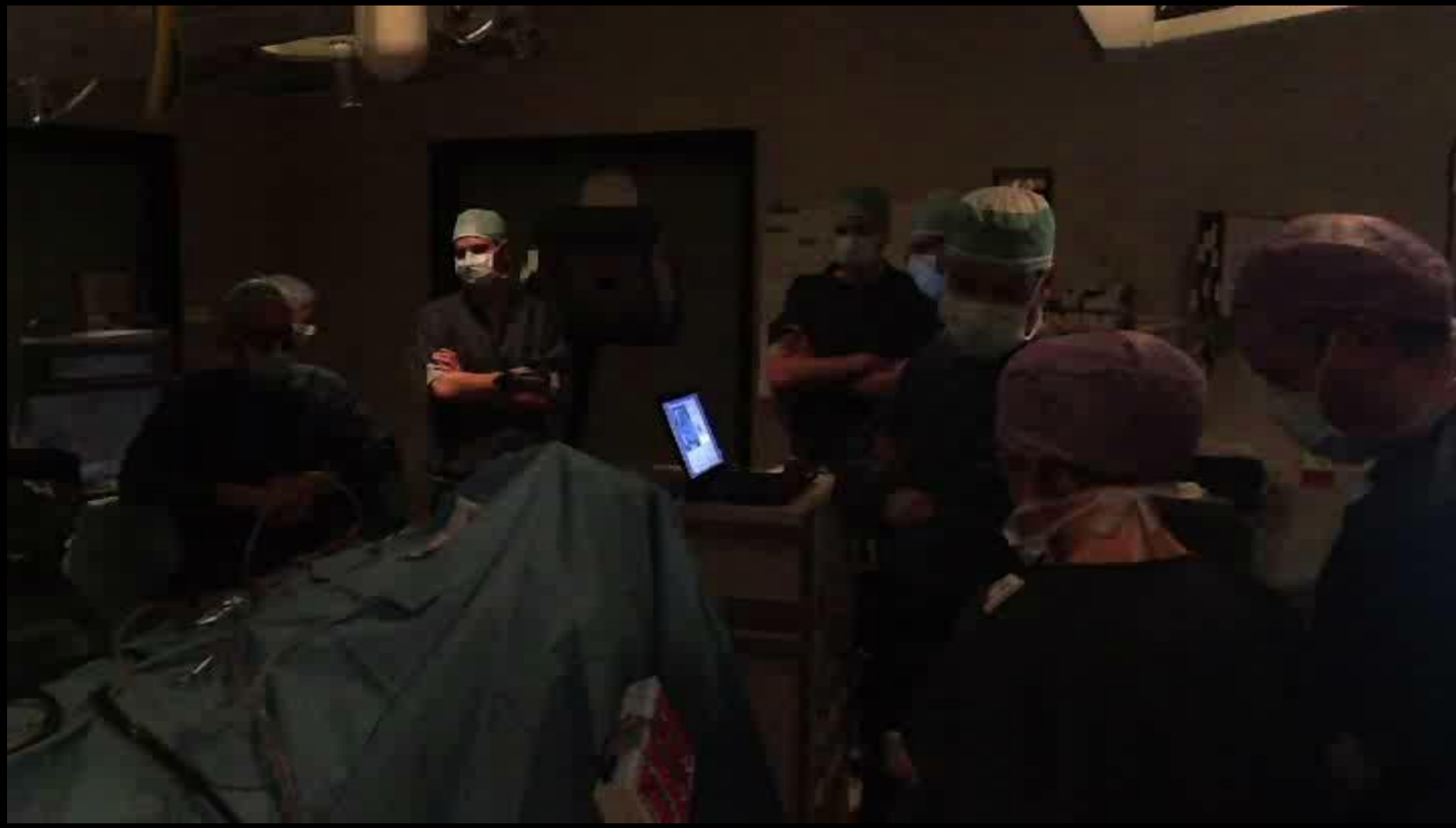




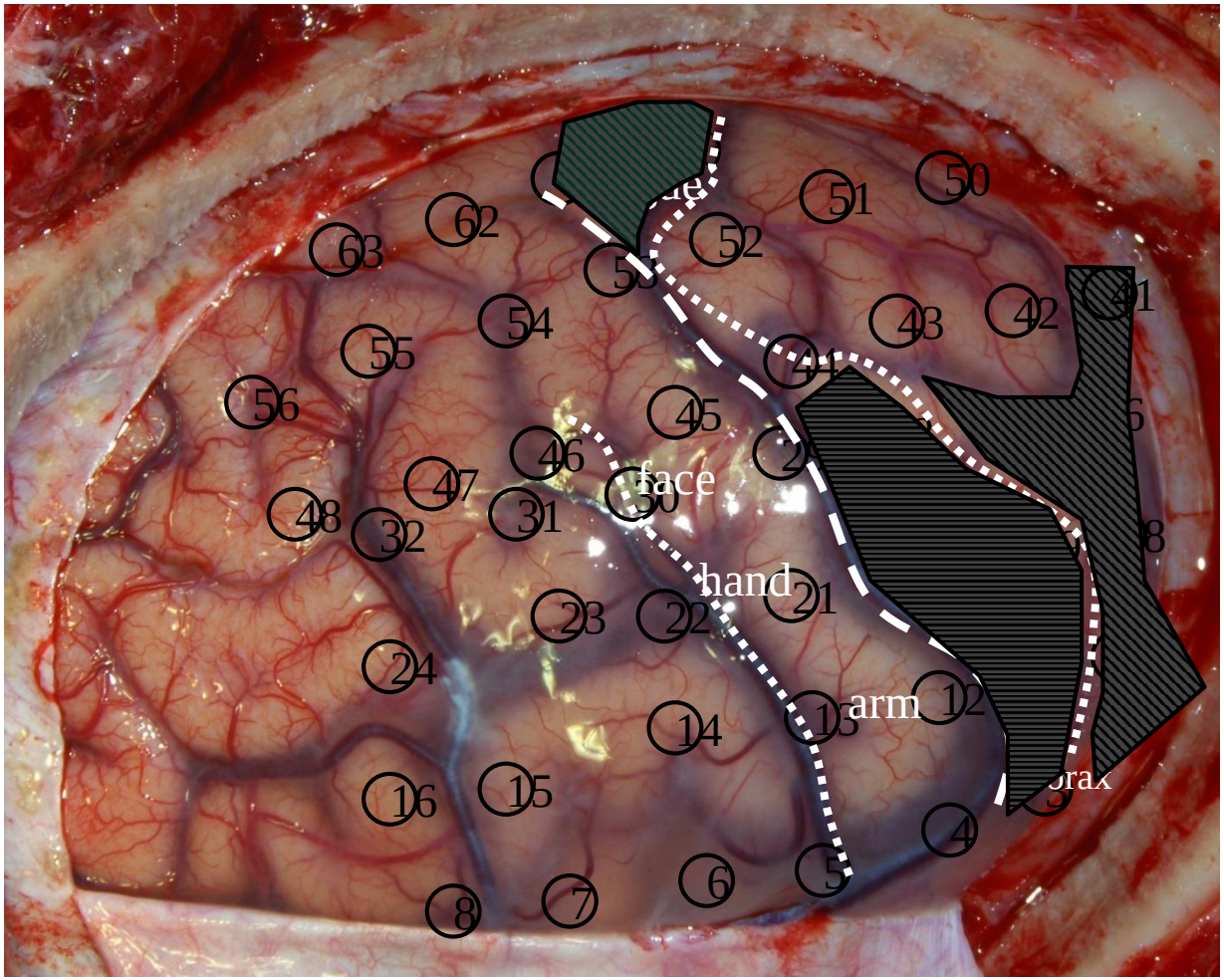
LED wavelengths bands for oxygenation



multispectral imaging during epilepsy surgery



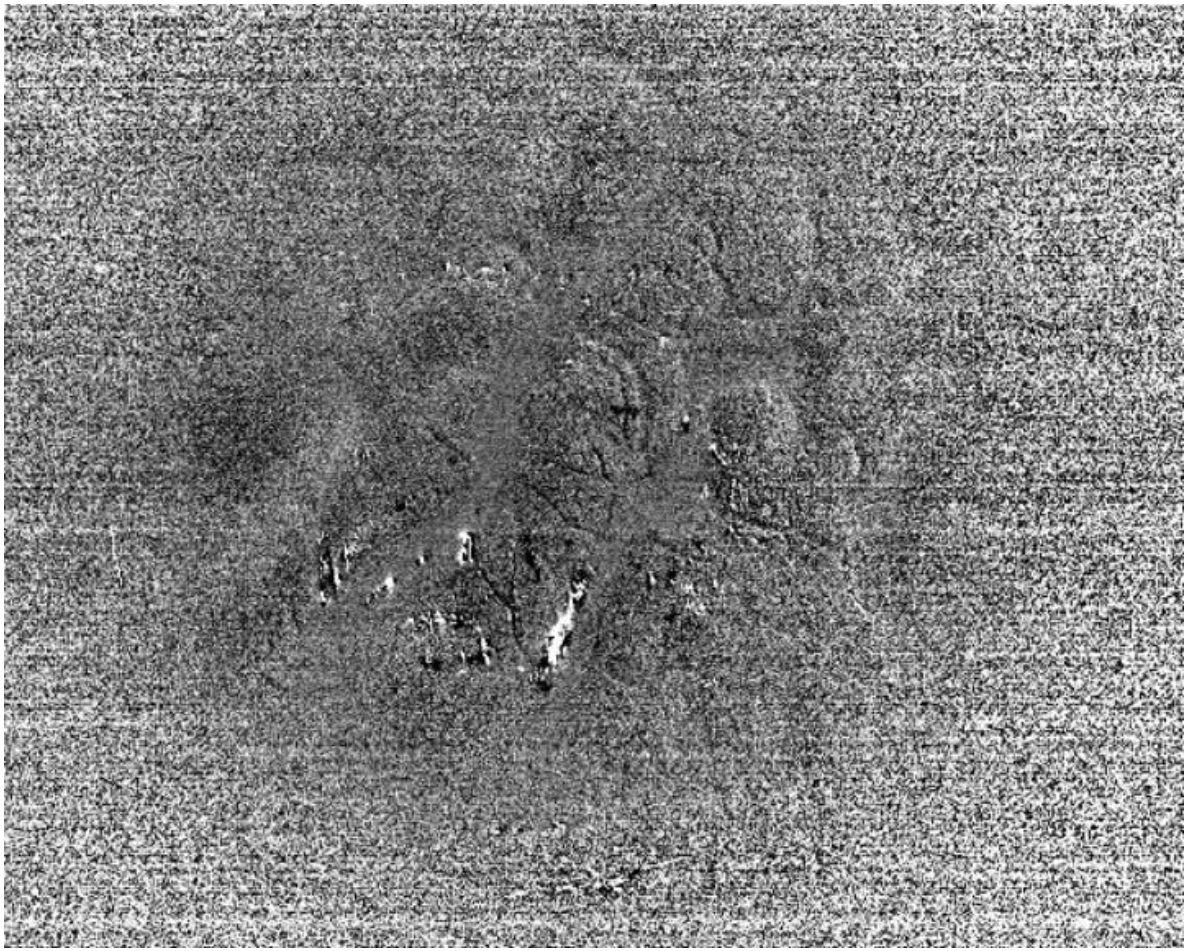
Imaging oxygenation on brain cortex during epileptic seizure



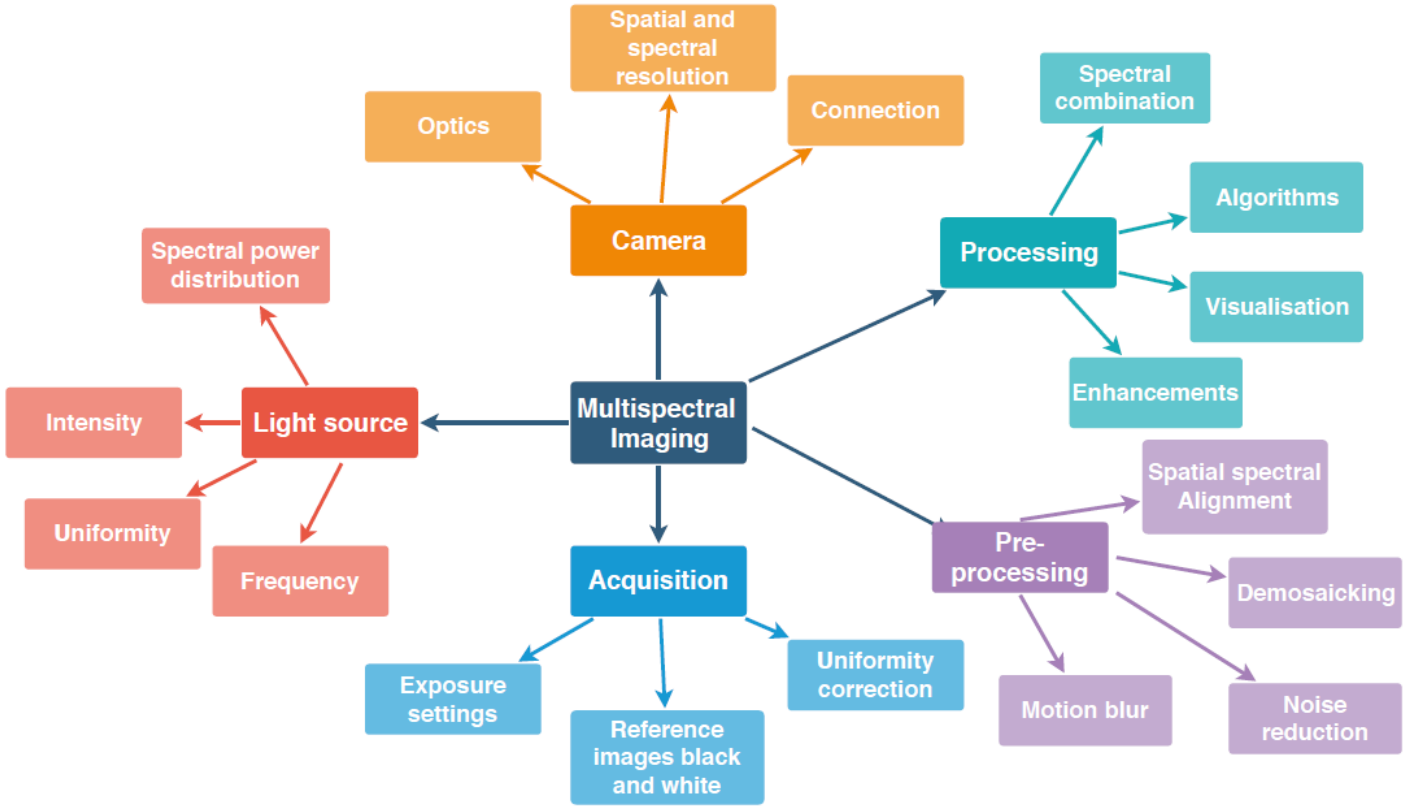
Imaging the seizure during surgery with a hyperspectral camera

*Herke Jan Noordmans, †Cyrille Ferrier, *Rowland de Roode, †Frans Leijten, †Peter van Rijen, †Peter Gosselaar, ‡John Klaessens, and ‡Ruud Verdaasdonk

Epilepsia, 54(11):e150–e154, 2013
doi: 10.1111/epi.12386

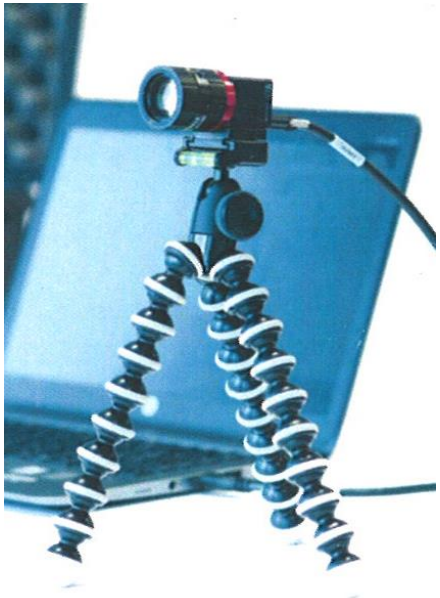


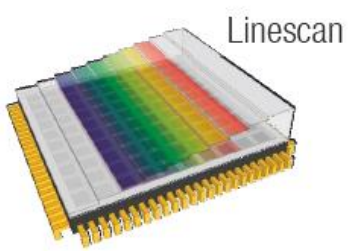
Need for Multispectral Imaging in real time

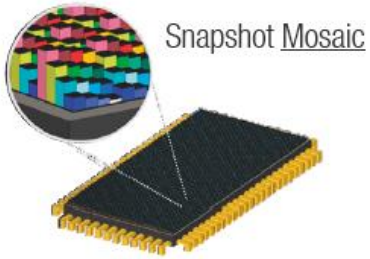


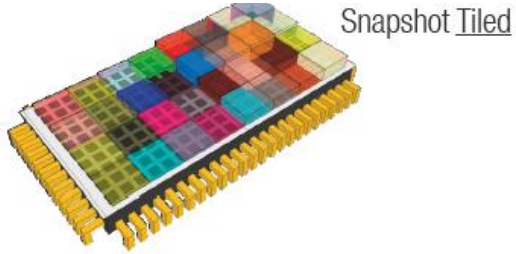
Multispectral ‘snap shot’ camera
IMEC / Ximea

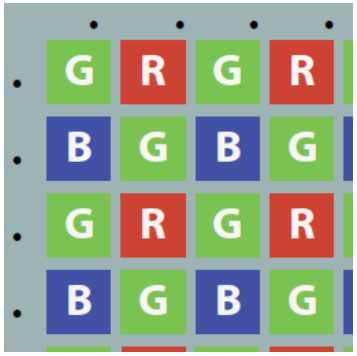
16 bands Visual
25 bands NIR

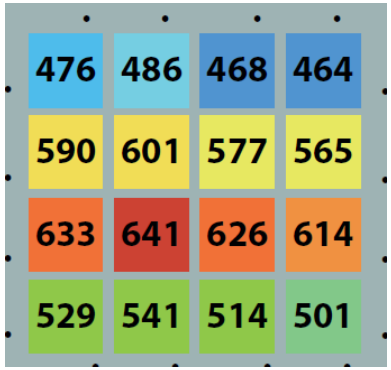




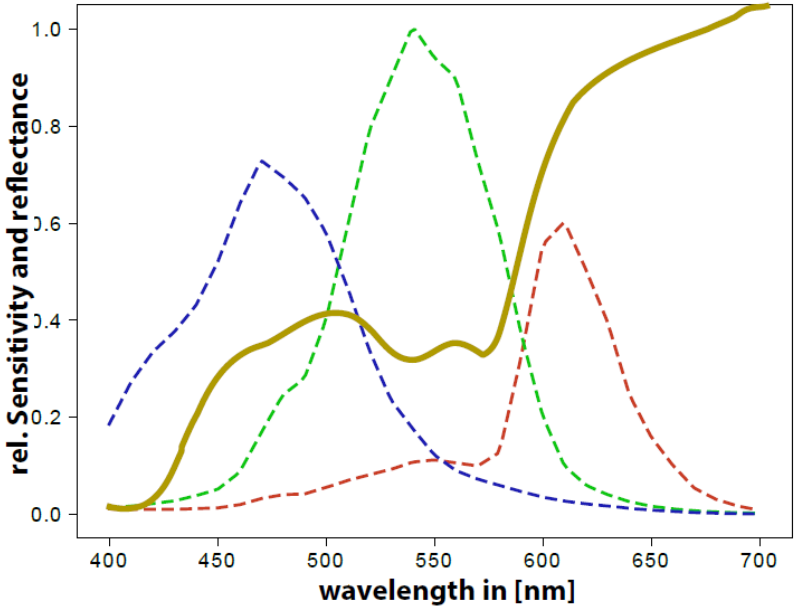




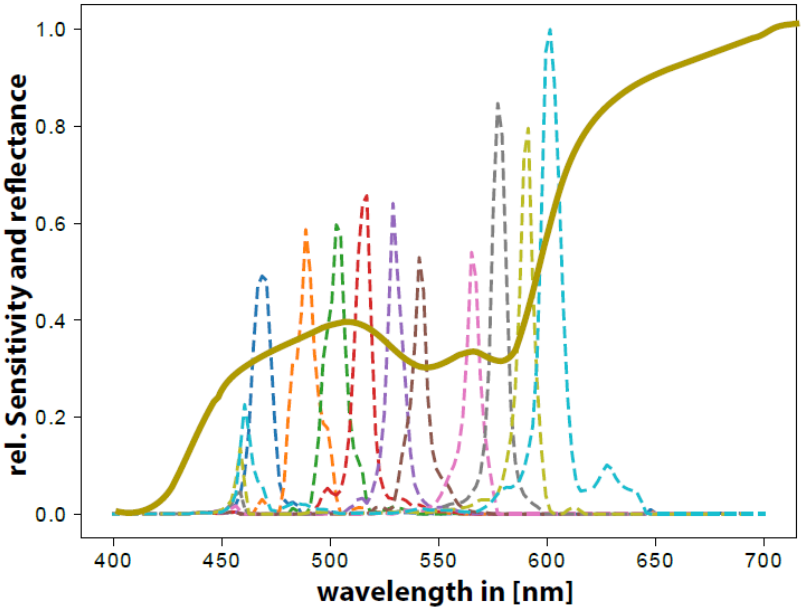




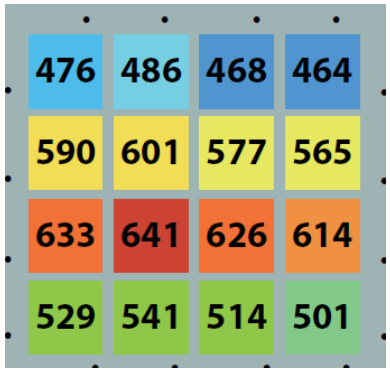
RGB Sensitivities and Skin



SFA Sensitivities and Skin



Problem with second order peak ‘leak’



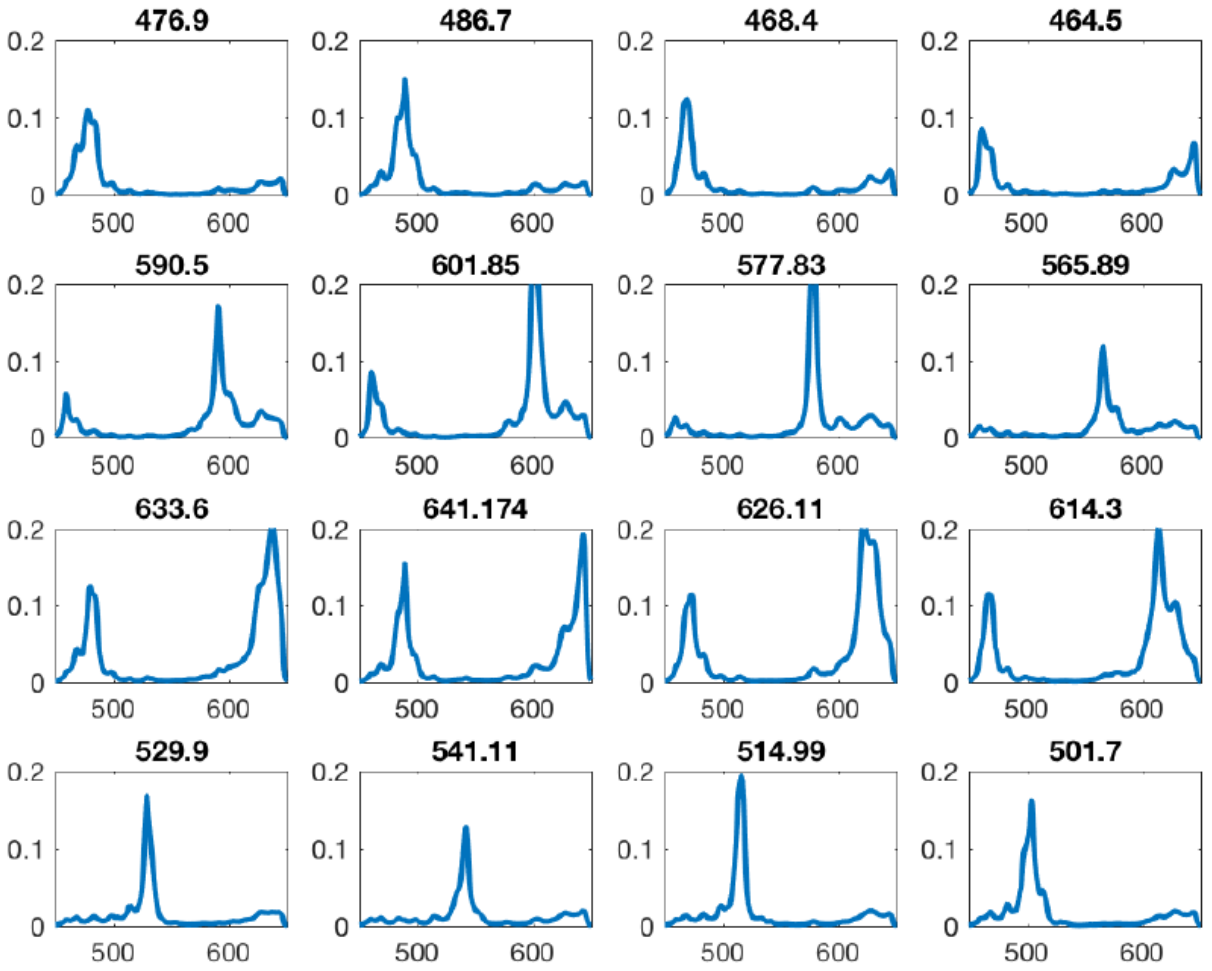


Figure 5. All filter sensitivity multiplied by the bandpass. Many filters show a second order peak inside the sensitive area. Intended peak wavelength shown above of each filter sensitivity curve.

Correction / calibration needed

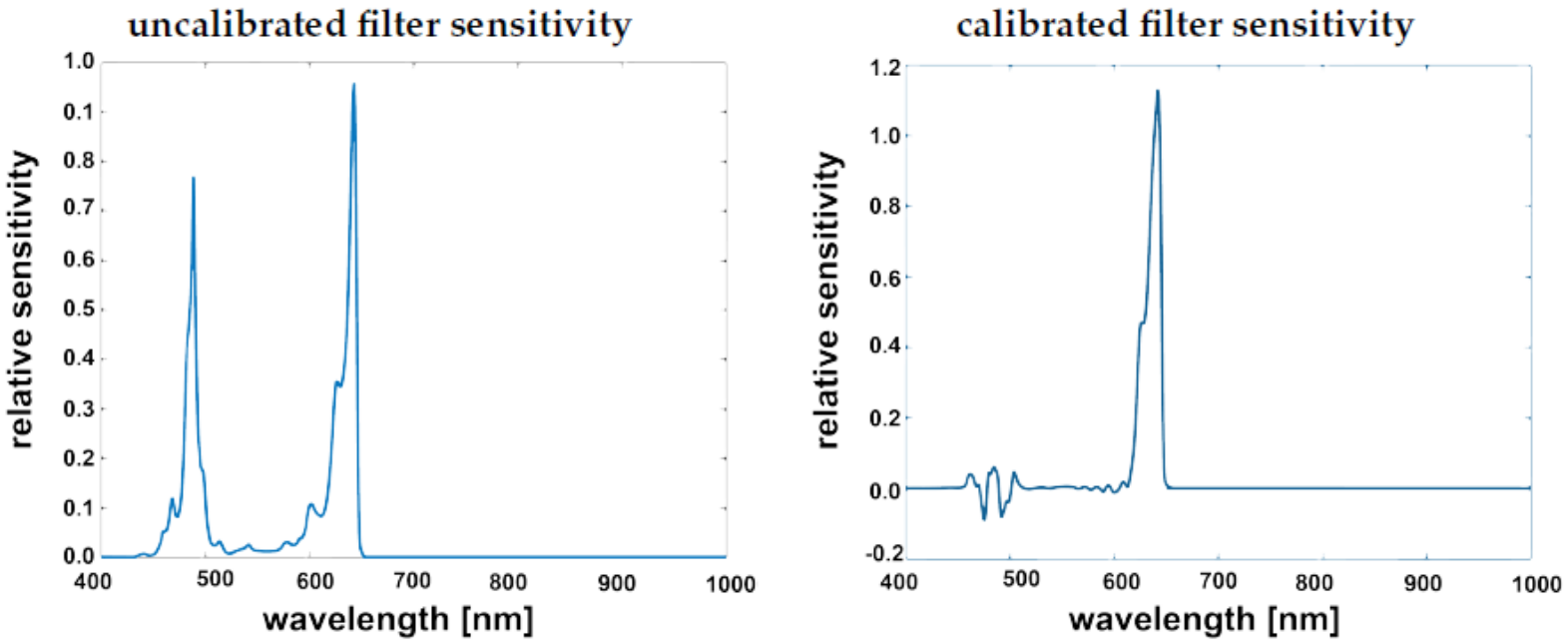


Figure 6. Filter sensitivity given by manufacturer [27] from the calibration file (**left**) filter band-passed showing clear second order harmonics, corrected filter after applying the spectral correction (**right**).

A spectral filter array camera for clinical monitoring and diagnosis: proof of concept for skin oxygenation imaging

Jacob Renzo Bauer [1] *, Arnoud A. Bruins [2], Jon Y. Hardeberg [1] and Rudolf Verdaasdonk [3]

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2 Dept. of Anesthesiology, VU University Medical Center, Amsterdam, Netherlands; a.bruins@vumc.nl
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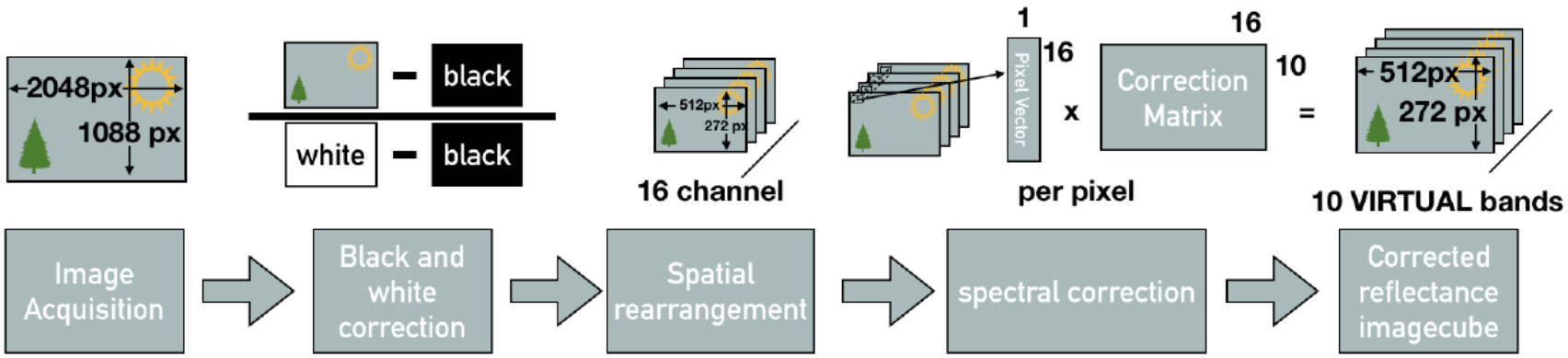
* Correspondence: jacob.bauer@ntnu.no;

Academic Editor: name
Version March 28, 2019 submitted to J. Imaging

VU medisch centrum

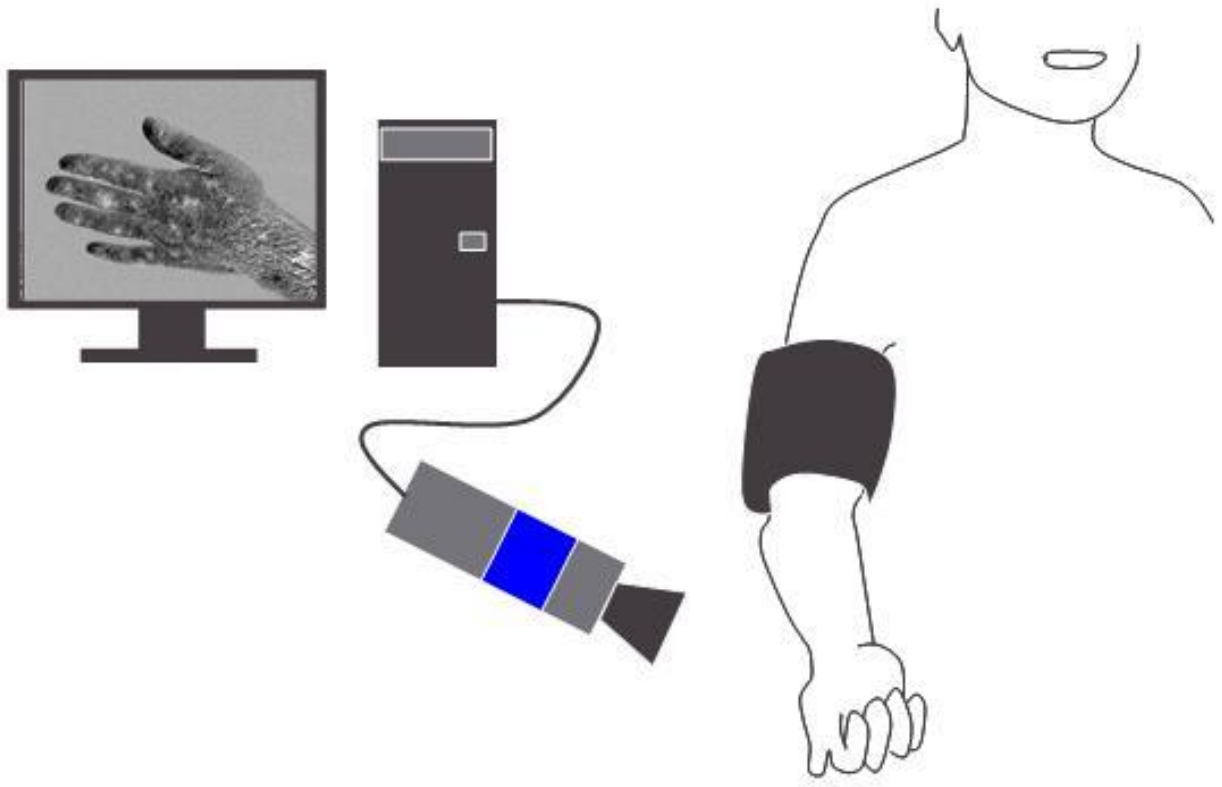
NTNU

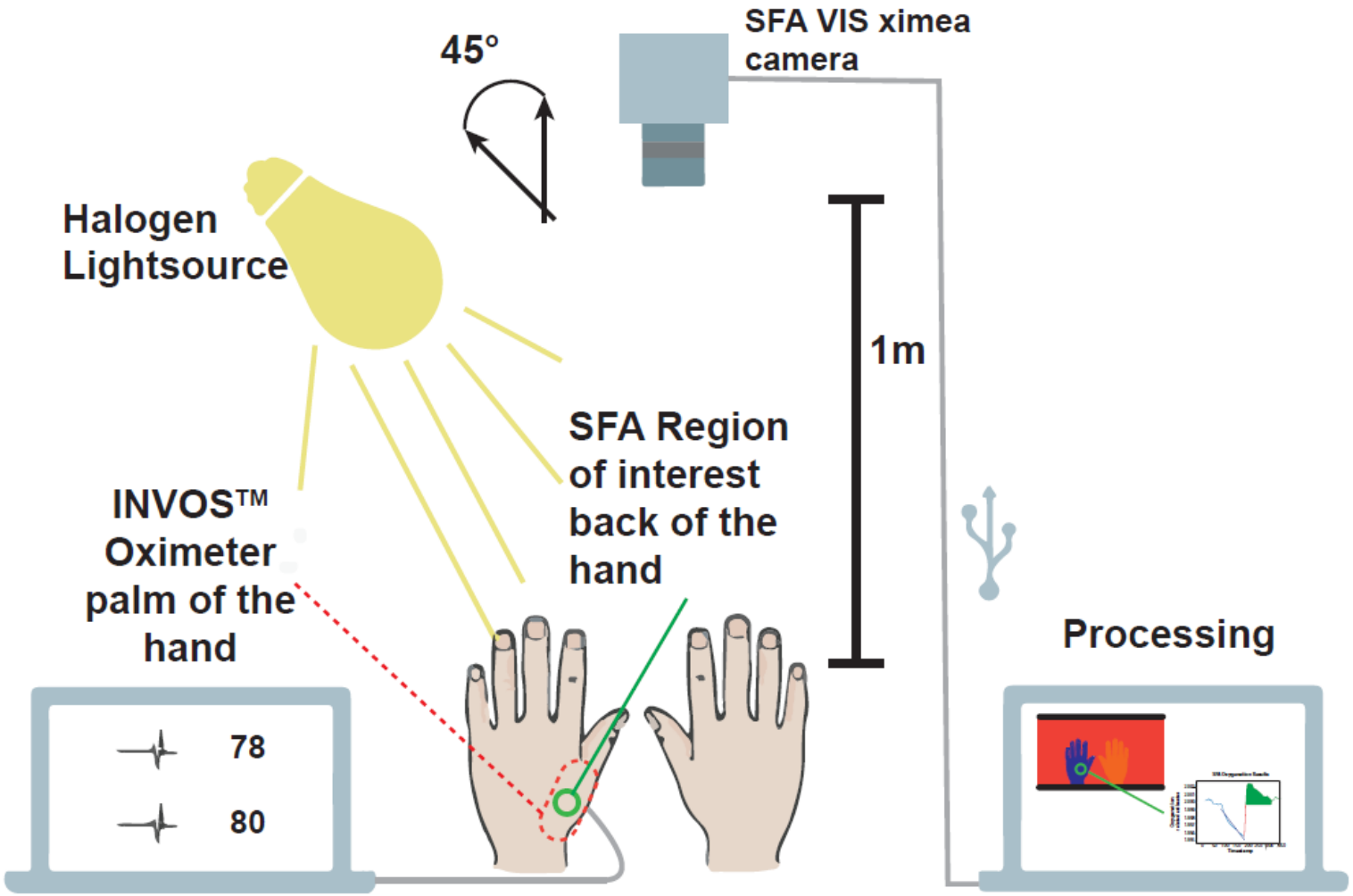
The Norwegian Colour and Visual Computing Laboratory



workflow for SFA MSI

Perfusion and oxygenation imaging during arm clamp and release




45°
SFA VIS ximea camera
Halogen Lightsource
1m
SFA Region of interest back of the hand
INVOS™ Oximeter palm of the hand
78
80
Processing

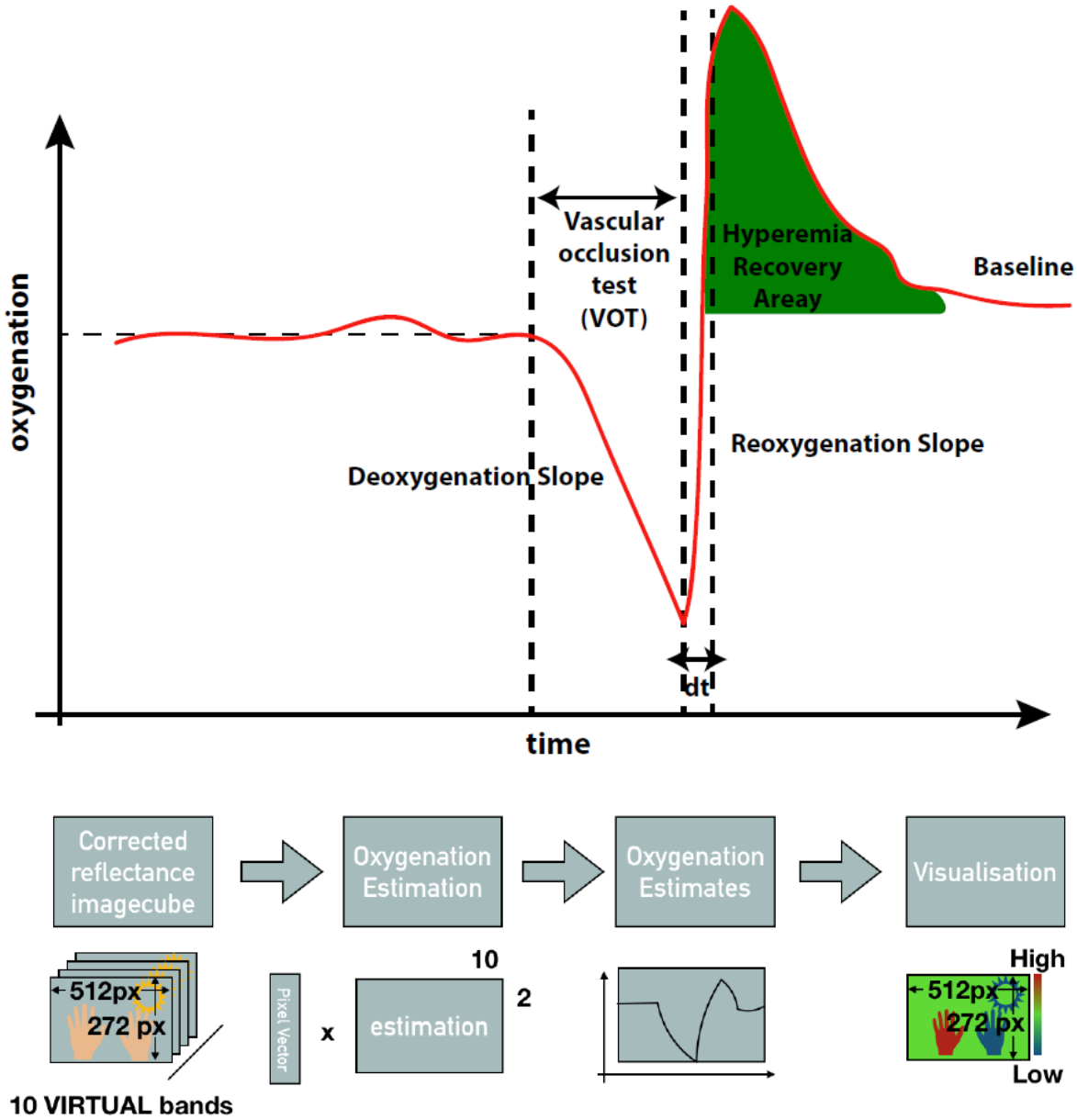
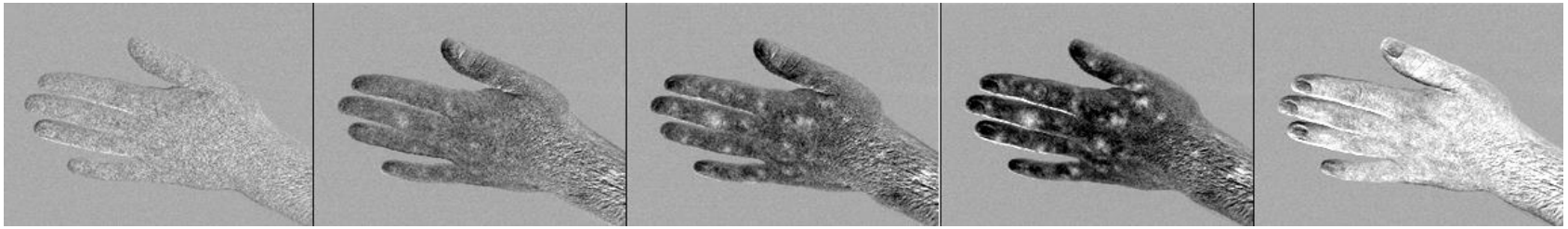


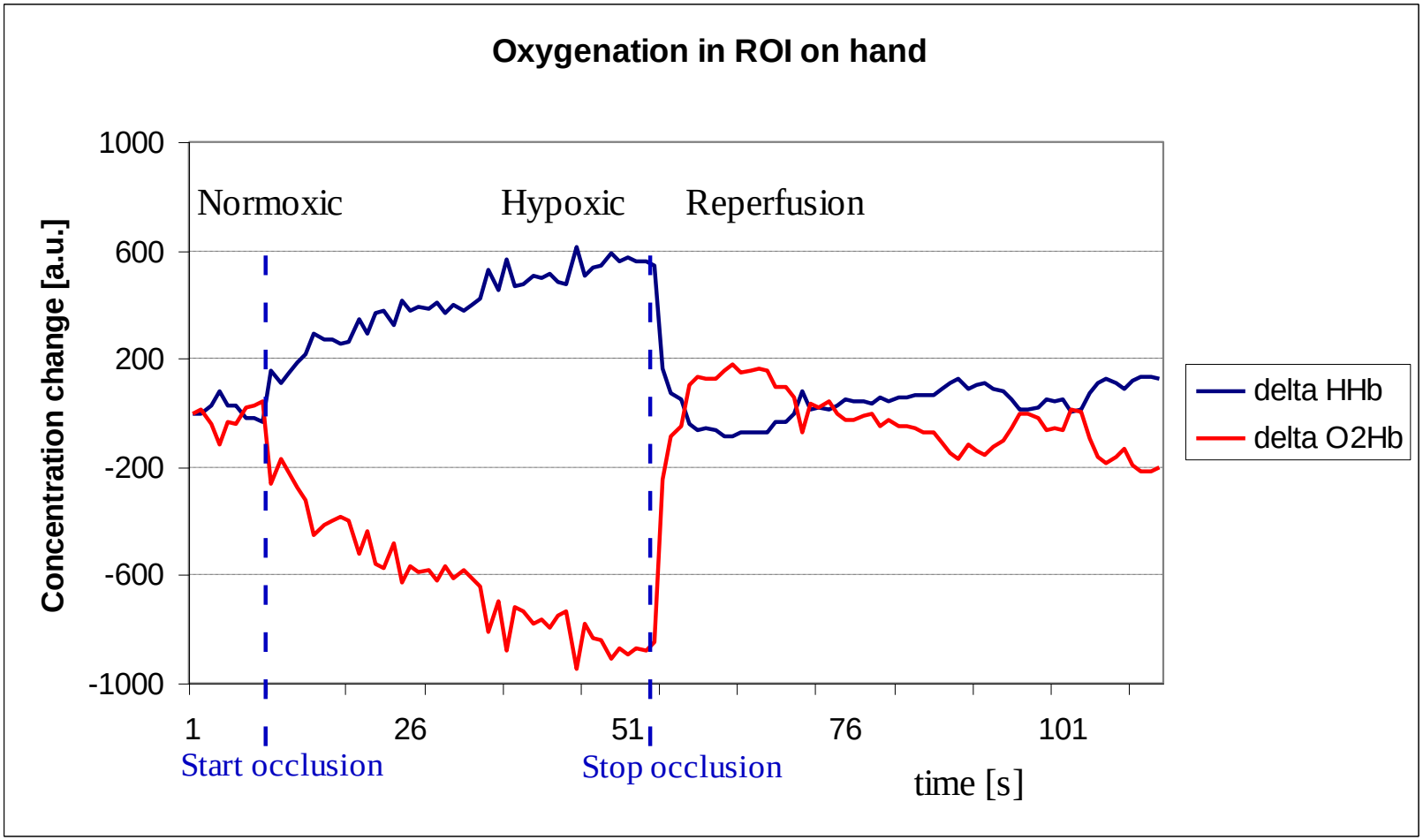
Figure 8. Oxygenation estimation from spectral reflectance cube.

Visualization of oxygenation changes of the hand



0 sec 20 sec 40 sec 60 sec 65 sec

Point measurement in image



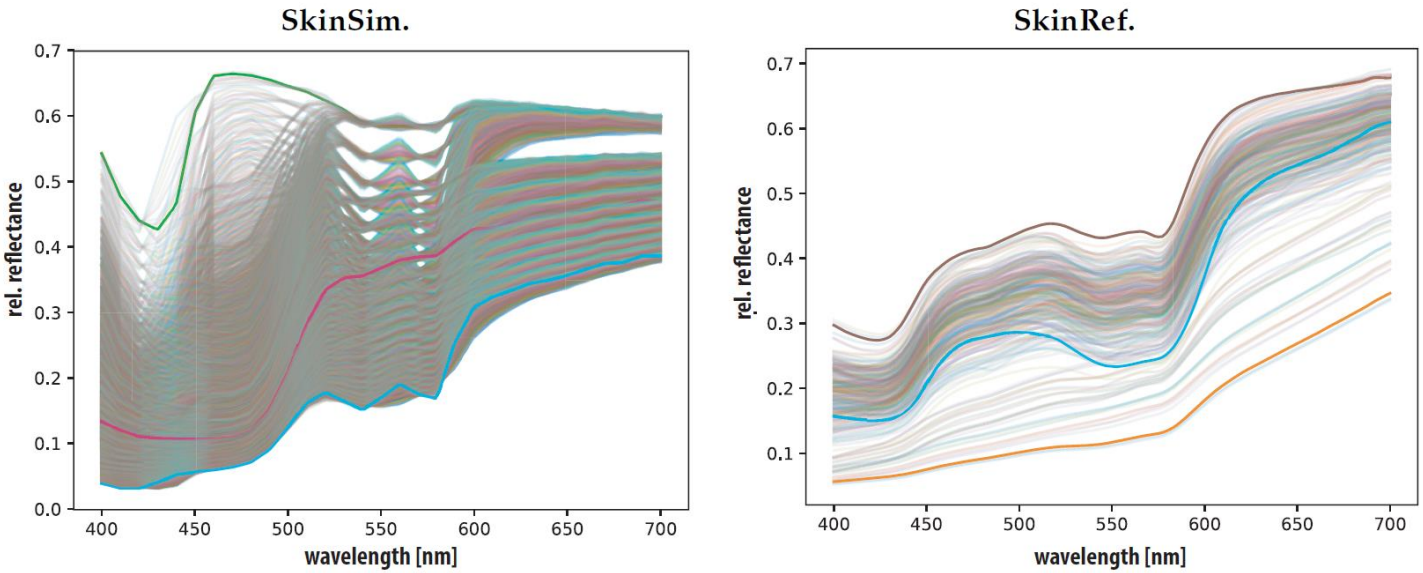
sensors november 2019

MDPI

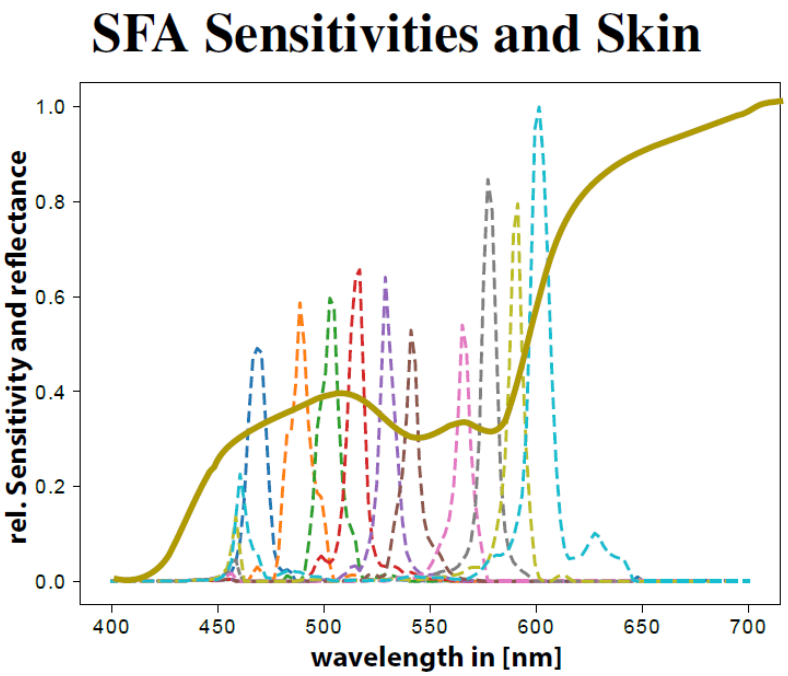
Article

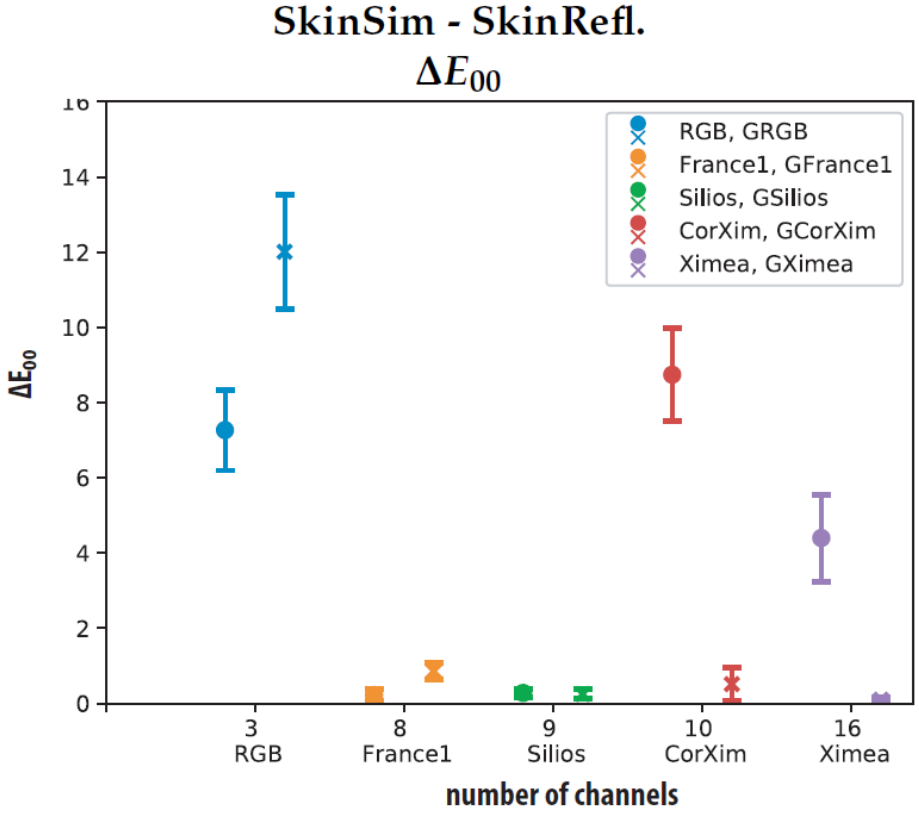
An Evaluation Framework for Spectral Filter Array Cameras to Optimize Skin Diagnosis

Jacob Renzo Bauer [1,*], Jean-Baptiste Thomas [1], Jon Yngve Hardeberg [1] and Rudolf M. Verdaasdonk [2]



The filter set of Spectral Filter Array cameras needs to be optimized for specific clinical applications





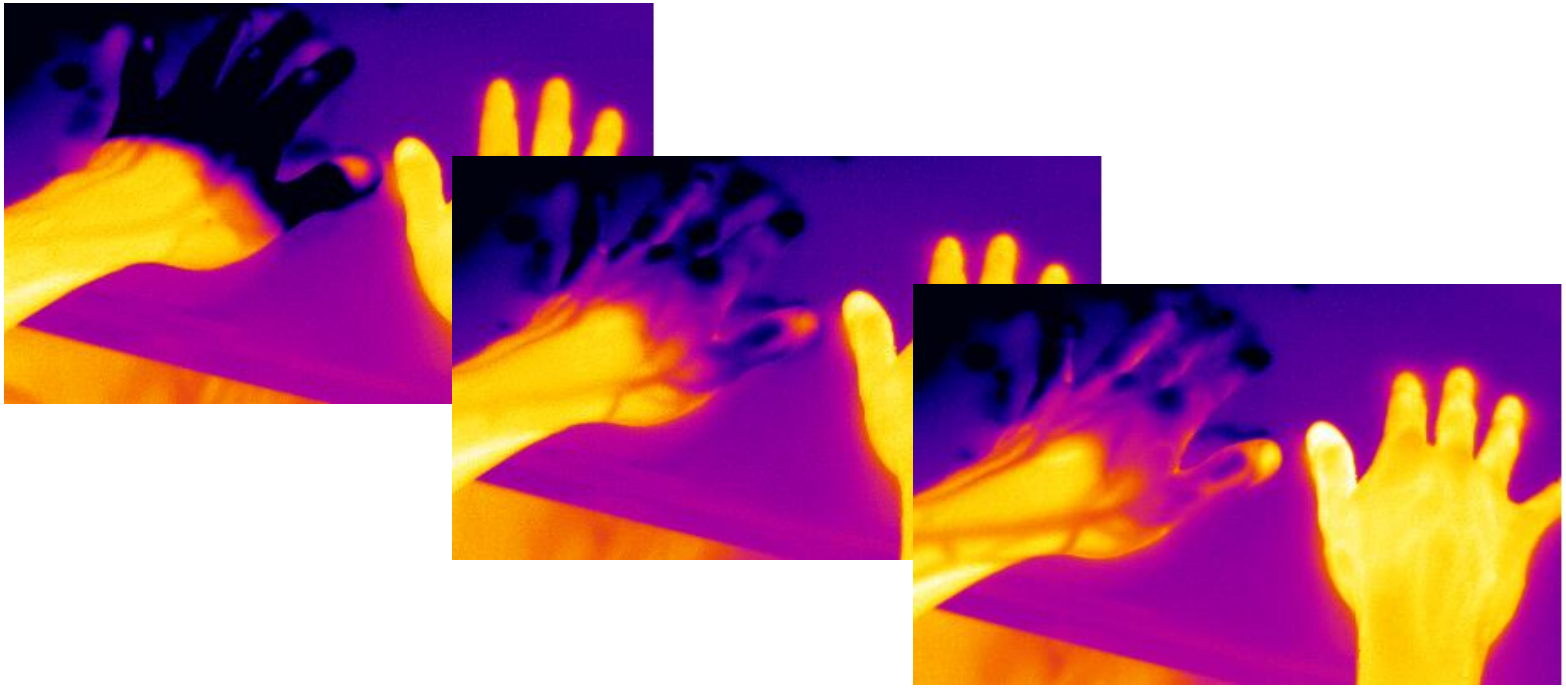
Thermal Imaging
new camera development

cooperation with FLIR and Xenics
leading thermo camera companies

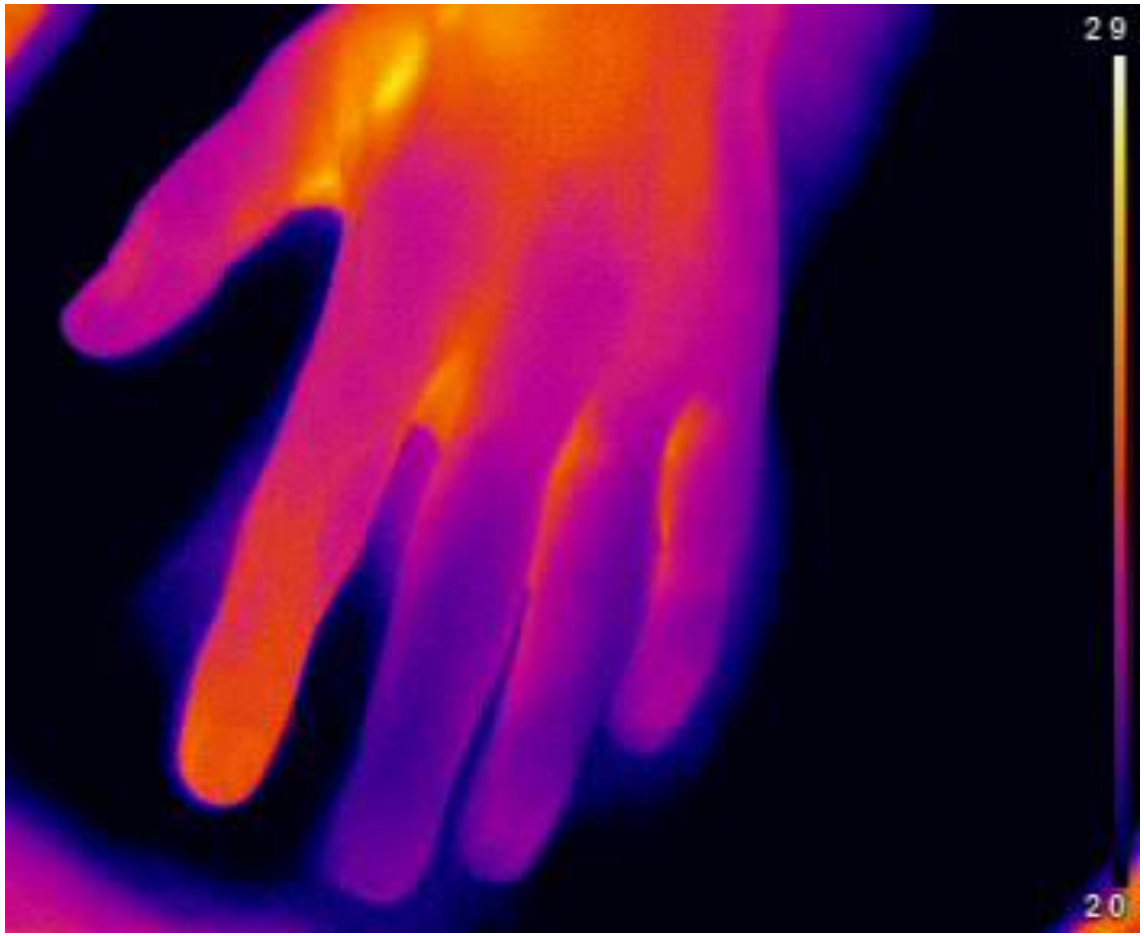
- Smart phone add-on
- FLIR-ONE
- Apps
- Only ~300 €

Methods to apply thermography

- ‘static’ temperature distribution
- dynamic temperature change during time
- dynamic temperature change after controlled intervention



Example
non-effective anesthetic block of hand

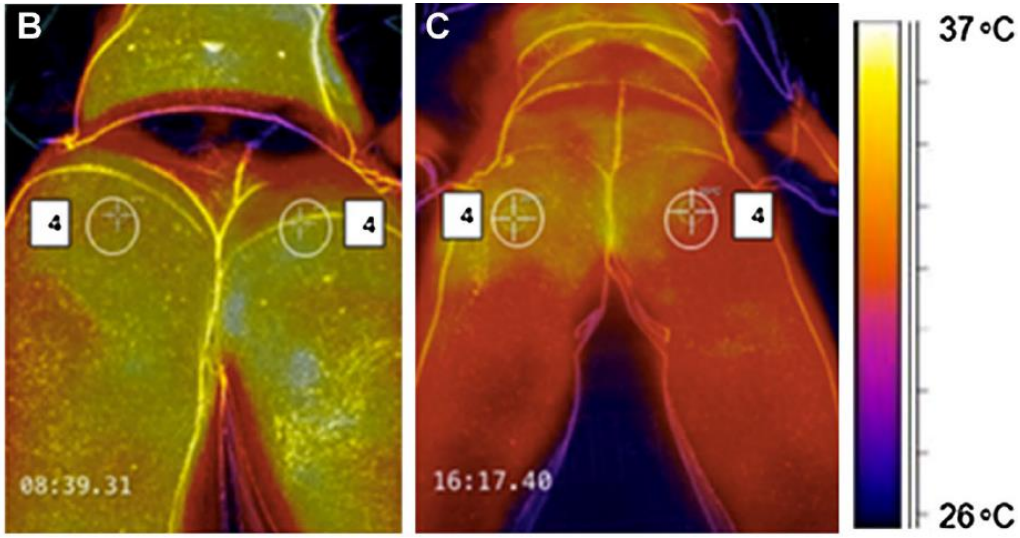


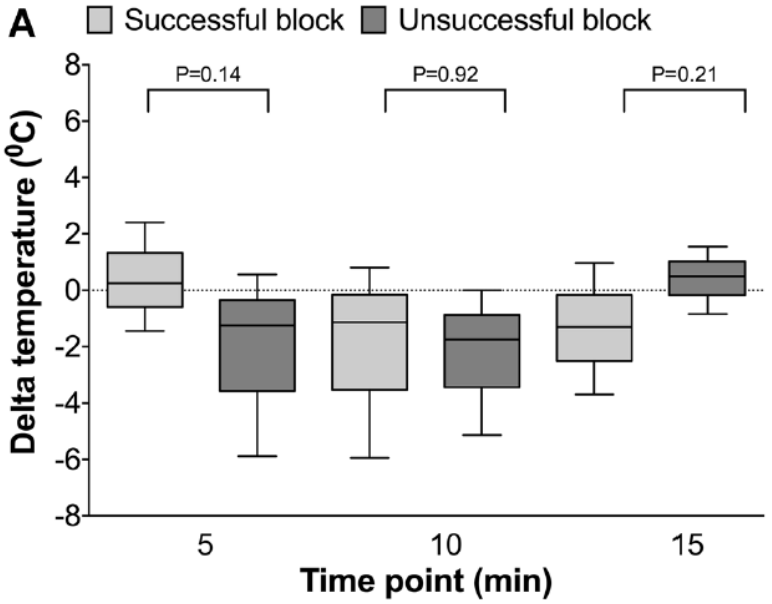
Thermographic skin temperature measurement compared with cold sensation in predicting the efficacy and distribution of epidural anesthesia

Arnoud A. Bruins[1] · Kay R. J. Kistemaker[1] · Annemieke Boom[2] · John H. G. M. Klaessens[3] · Rudolf M. Verdaasdonk[3] · Christa Boer[1]

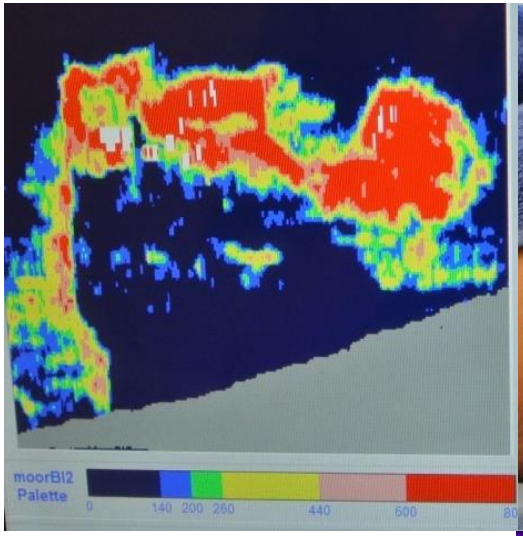
Received: 15 December 2016 / Accepted: 28 April 2017

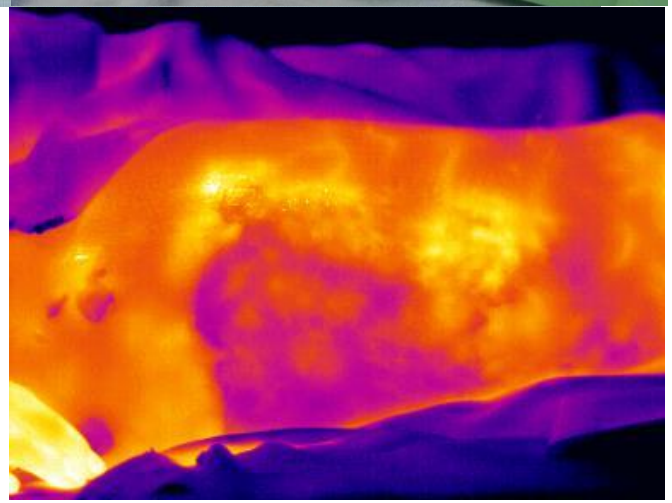
J Clin Monit Comput





Detection of degree of burn comparing perfusion and thermal image





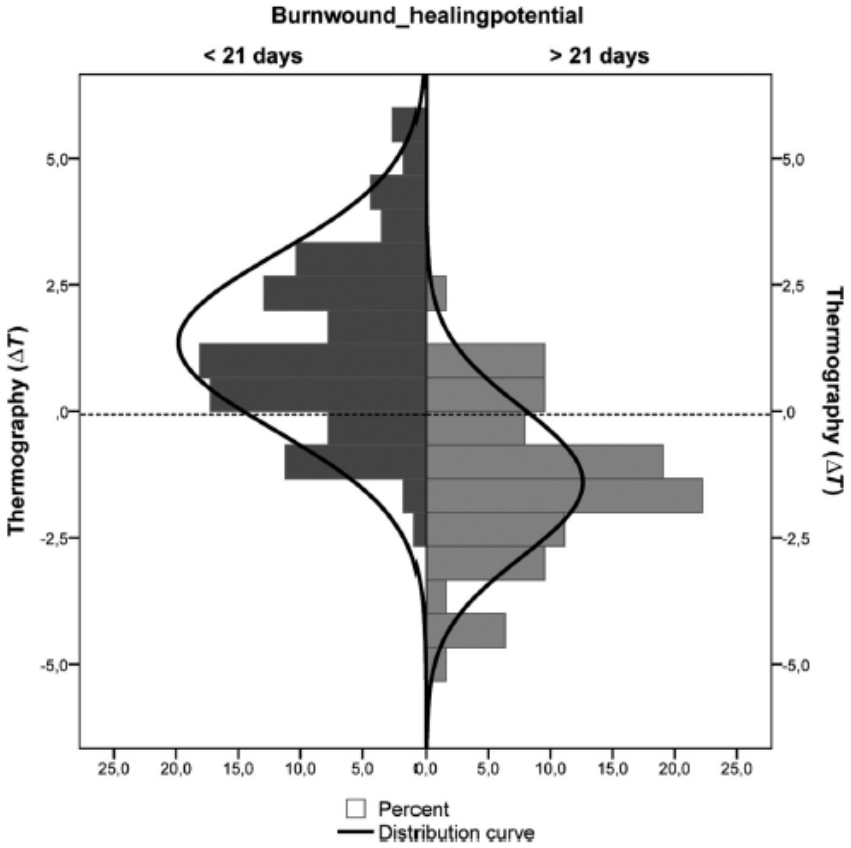
Dutch Burn Centre
Beverwijk

Journal of Biomedical Optics 21(9), 096006 (September 2016)

Insights into the use of thermography to assess burn wound healing potential: a reliable and valid technique when compared to laser Doppler imaging

Mariëlle E. H. Jaspers,[a,b,c,d,e,*] Ilse Maltha,[a] John H. G. M. Klaessens,[f] Henrica C. W. de Vet,[g,h] Rudolf M. Verdaasdonk,[f] and Paul P. M. van Zuijlen[a,b,c,d,e]

Dutch Burn Centre Beverwijk



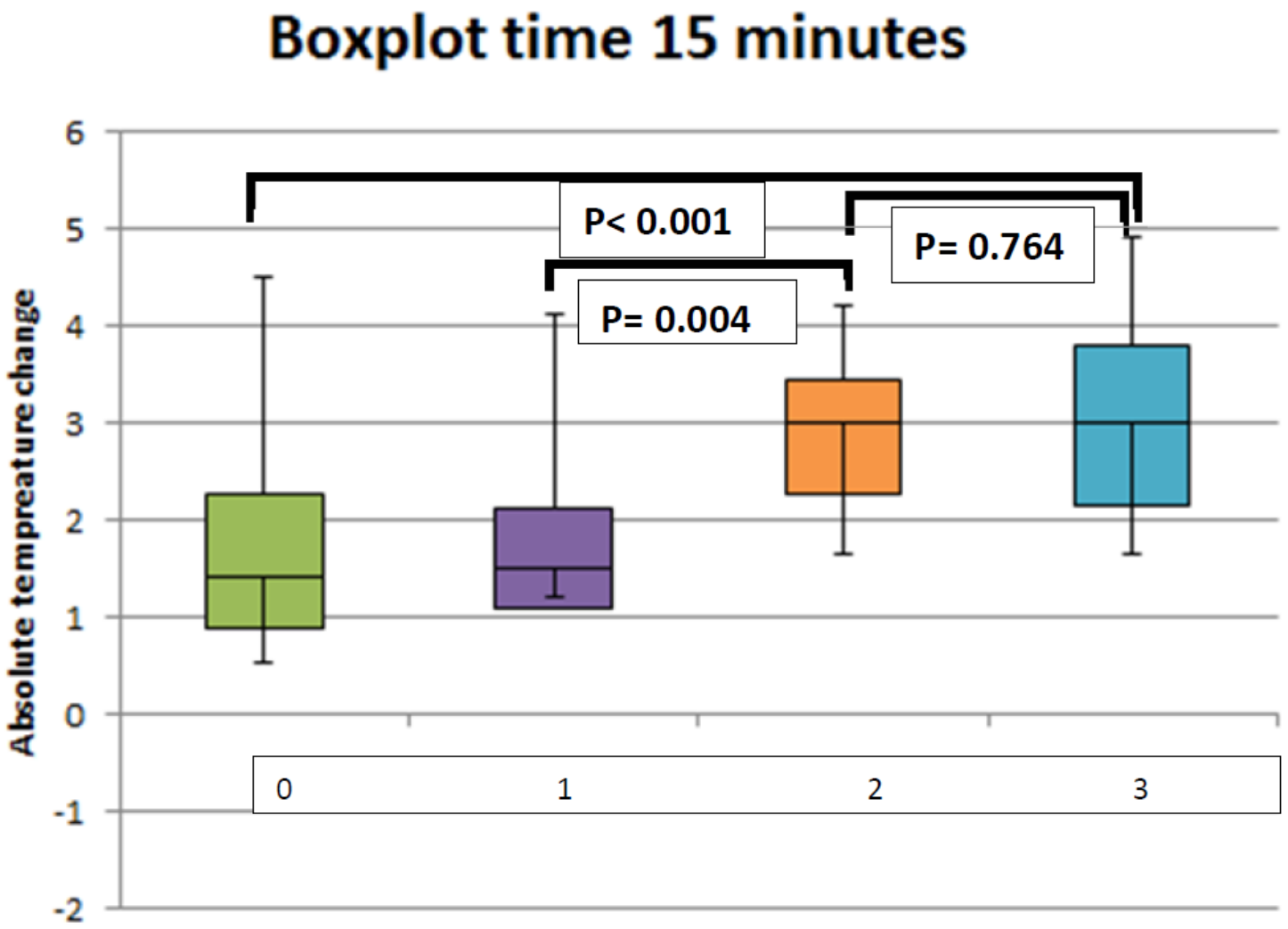
Dermatology allergy testing

- Fluids drops on skin with potential allergens
- Puncture in drop for passage through epidermis
- 15 minute waiting before reaction rating by dermatologist (blinded for allergen)
- rating based on skin color and touch

- Quantitative ?
- Sensitivity ?
- Can thermo imaging improve

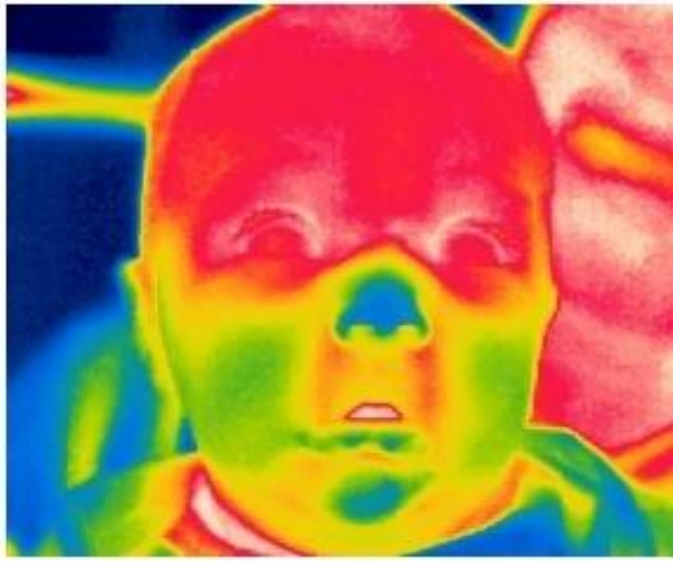
Time-lapse 15 minutes allergy reaction

Grading allergy reaction

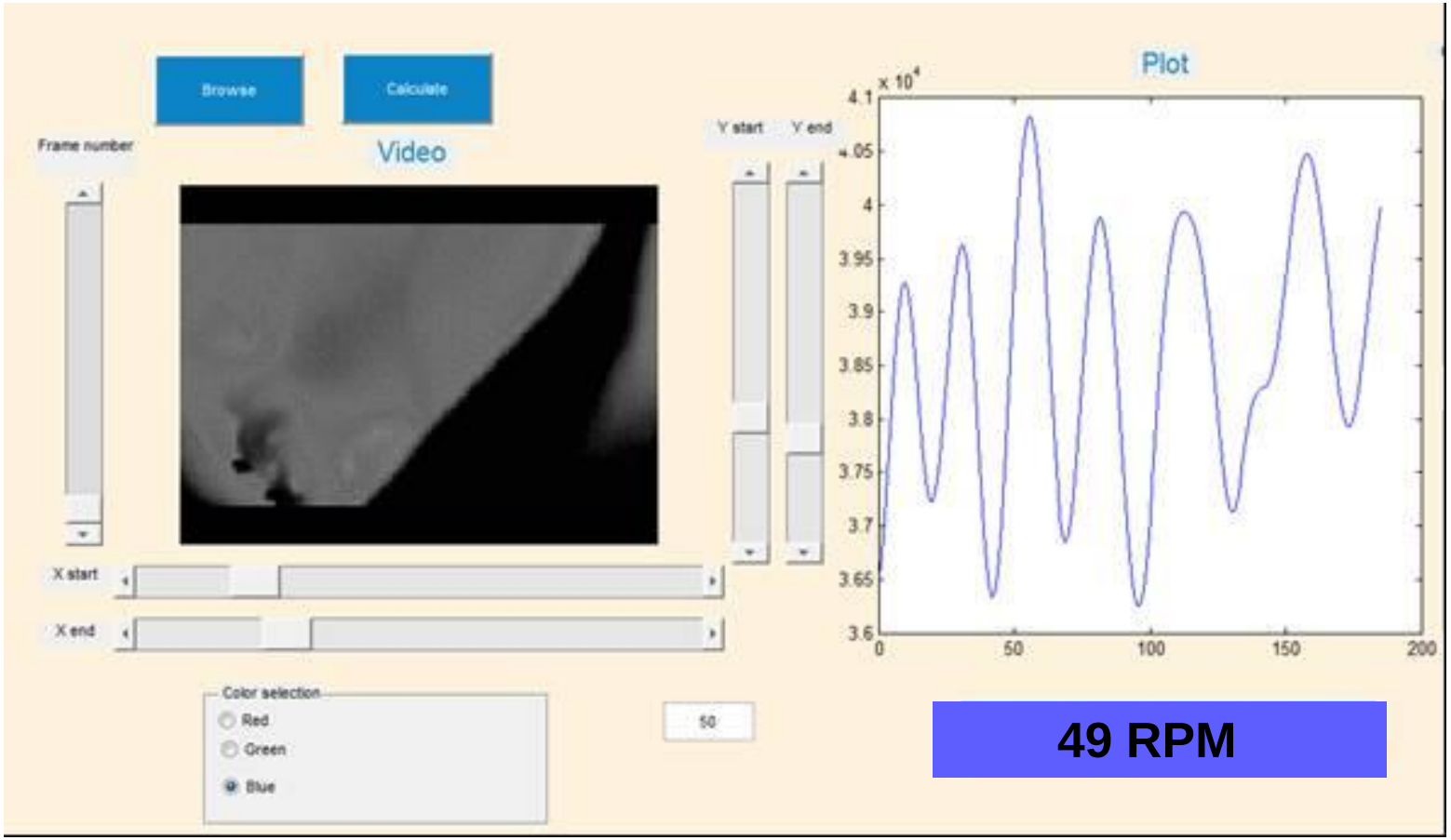


Respiration monitoring

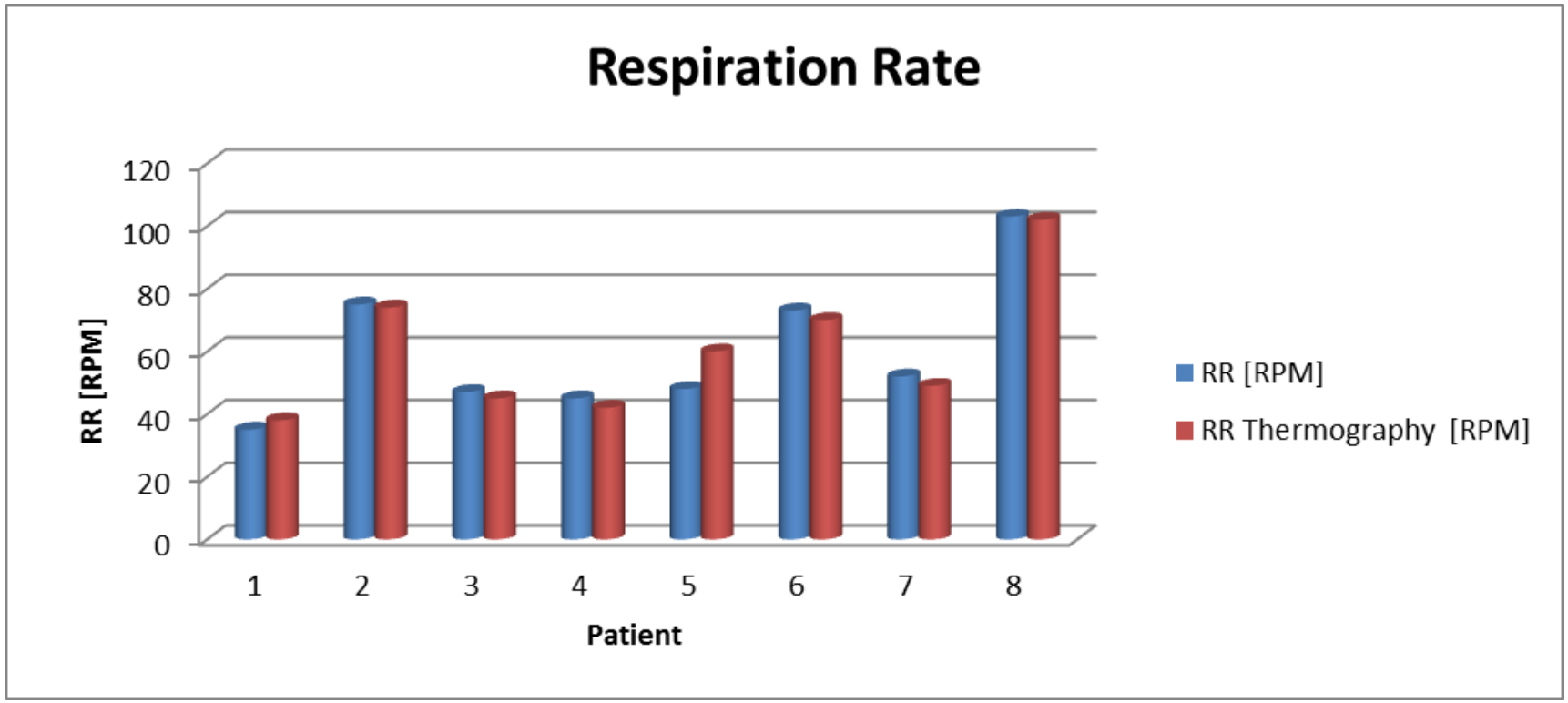
- breathing
  - Nostrils
- temperature distribution
  - head
  - hands, feet



Results respiration rate



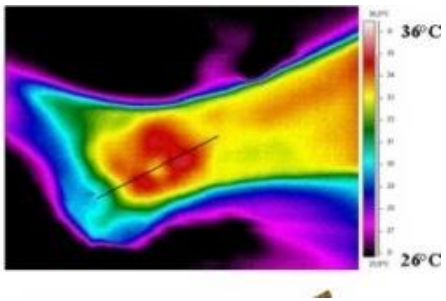
Results

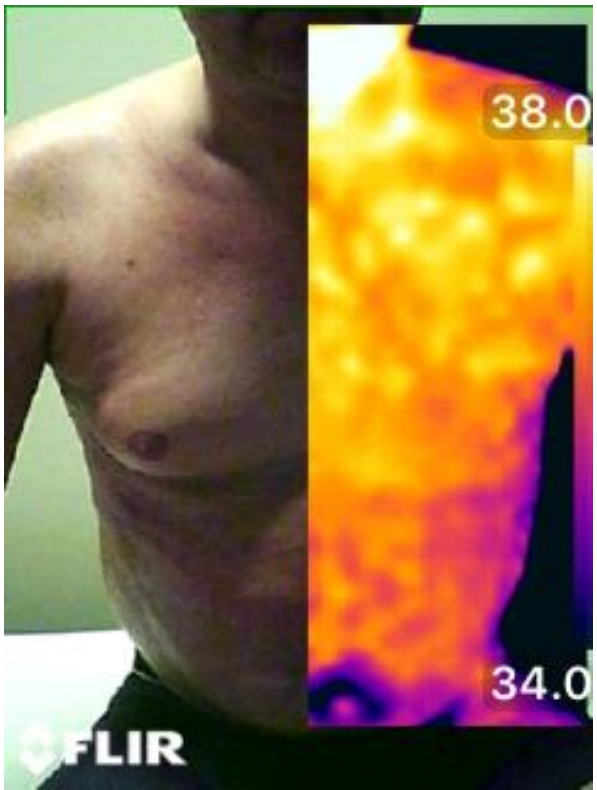


Difference < 3% (n=7) < 20% (n=1)

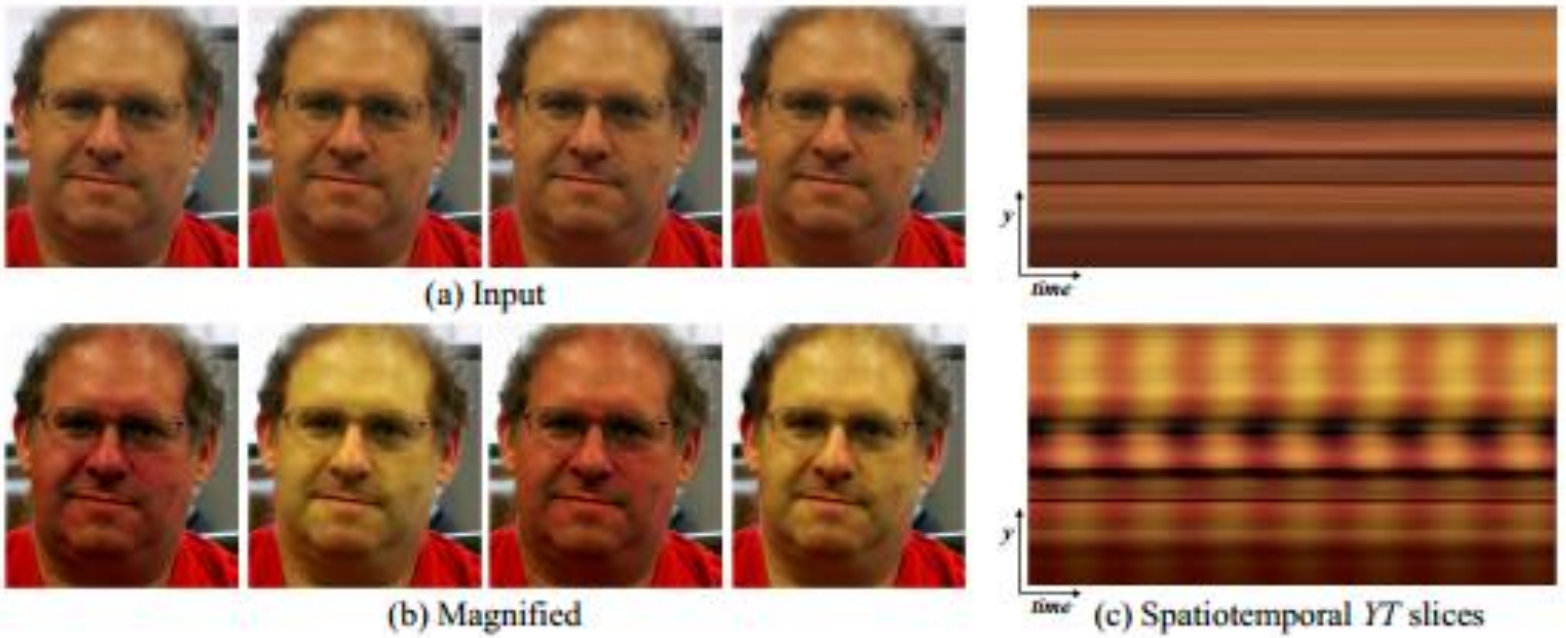
Other applications under investigation

- Cardiology: prediction of spasm of the artery
- Carotid condition
- Urology: cause of impotence after radical prostatectomy
- Surgery: colon leakage
- Tumor detection
- Sport: training, injury
- Diabetes foot (open wounds)
- Decubitus





Heart Rate Monitoring
(MIT*)



Based on color changes of skin caused by blood flushes by heart pumping

Neonatology HR ~ 120 BPM apply band pass filter 1.6 - 2.4 Hz

* Hao-Yu Wu, Michael Rubinstein,Eugene Shih,John Guttag, Fredo Durand and William T. Freeman, Eulerian Video Magnification for Revealing Subtle Changes in the World,ACM Transactions on Graphics (Proc. SIGGRAPH 2012)}, 31,(4)

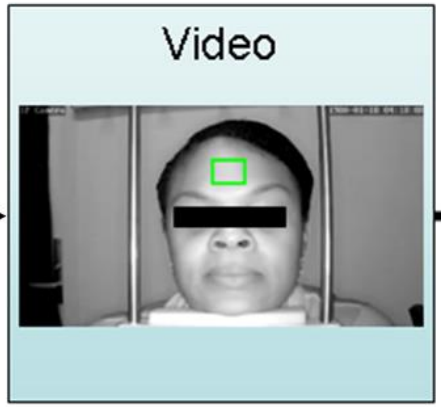
Processing color videos for heart rate

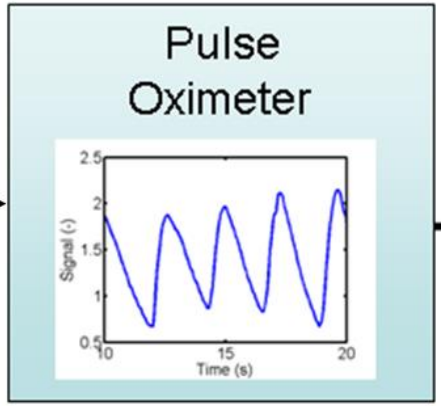
Iphone / Ipad App

- Philips Vital Signs camera
- Special algorithm for subtle color changes

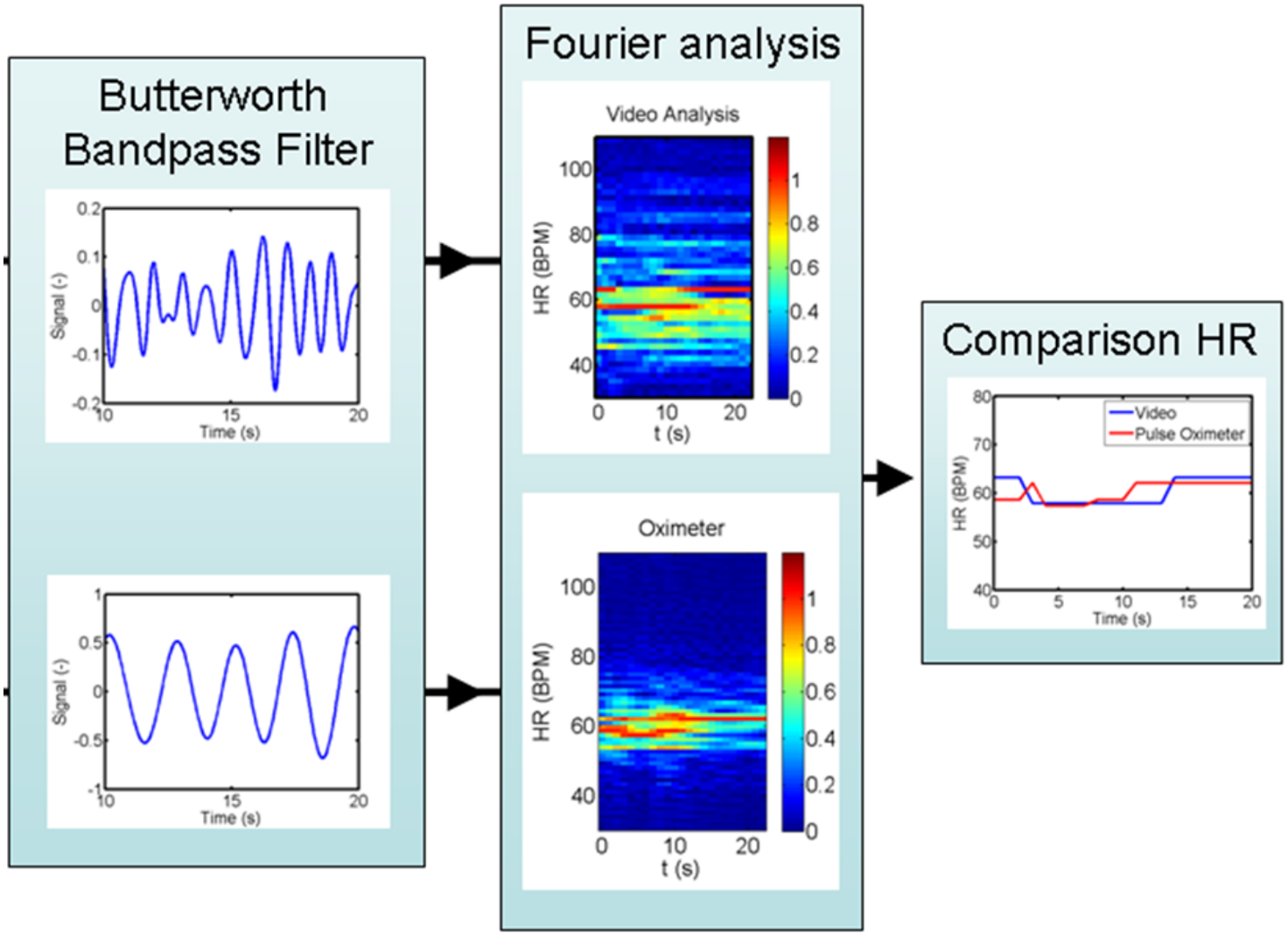
- Verkruysse, W., et al.Opt.Express16, 21434-21445 (2008)
- Aarts,L.A. et al. Early Hum. Dev. (2013)
- http://www.vitalsignscamera.com/

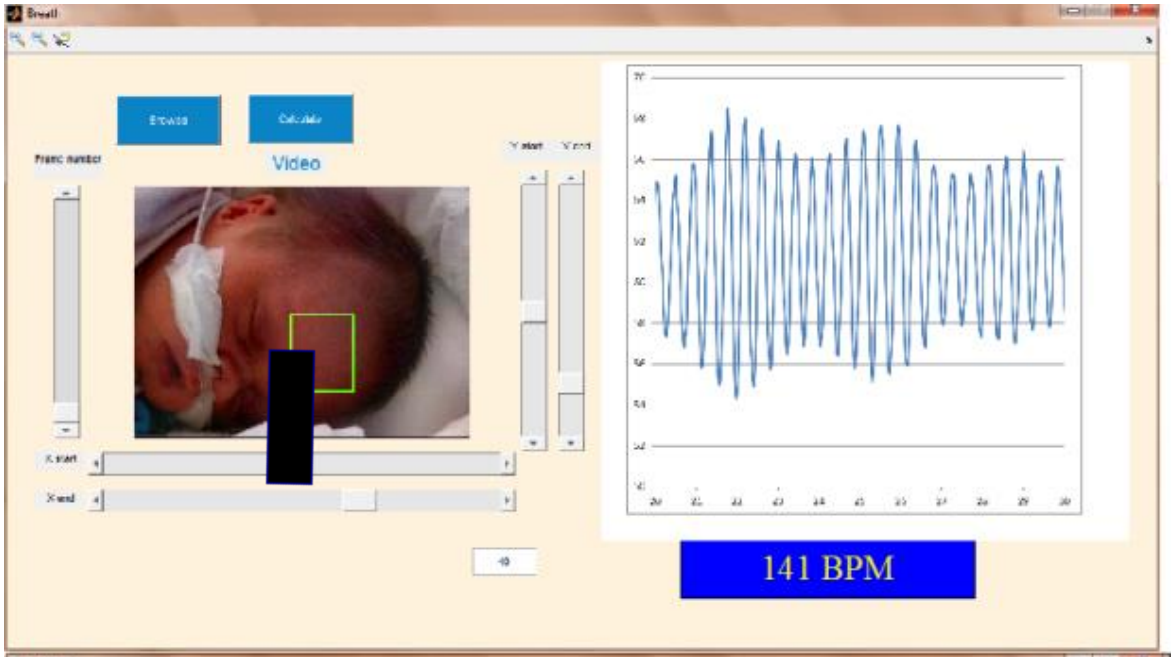
Video Near IR
HD surveillance camera



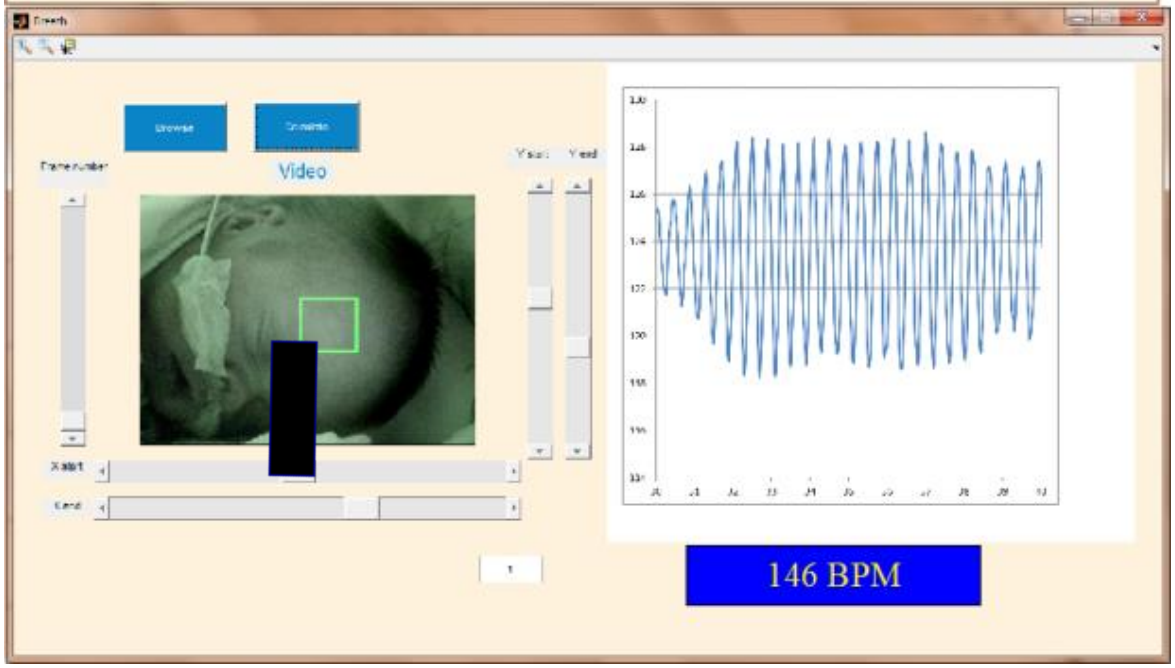


Heart rate monitor


Butterworth Bandpass Filter
Signal (-)
Time (s)
Fourier analysis
Video Analysis
HR (BPM)
t (s)
Oximeter
Comparison HR
Video
Pulse Oximeter
HR (BPM)
Time (s)

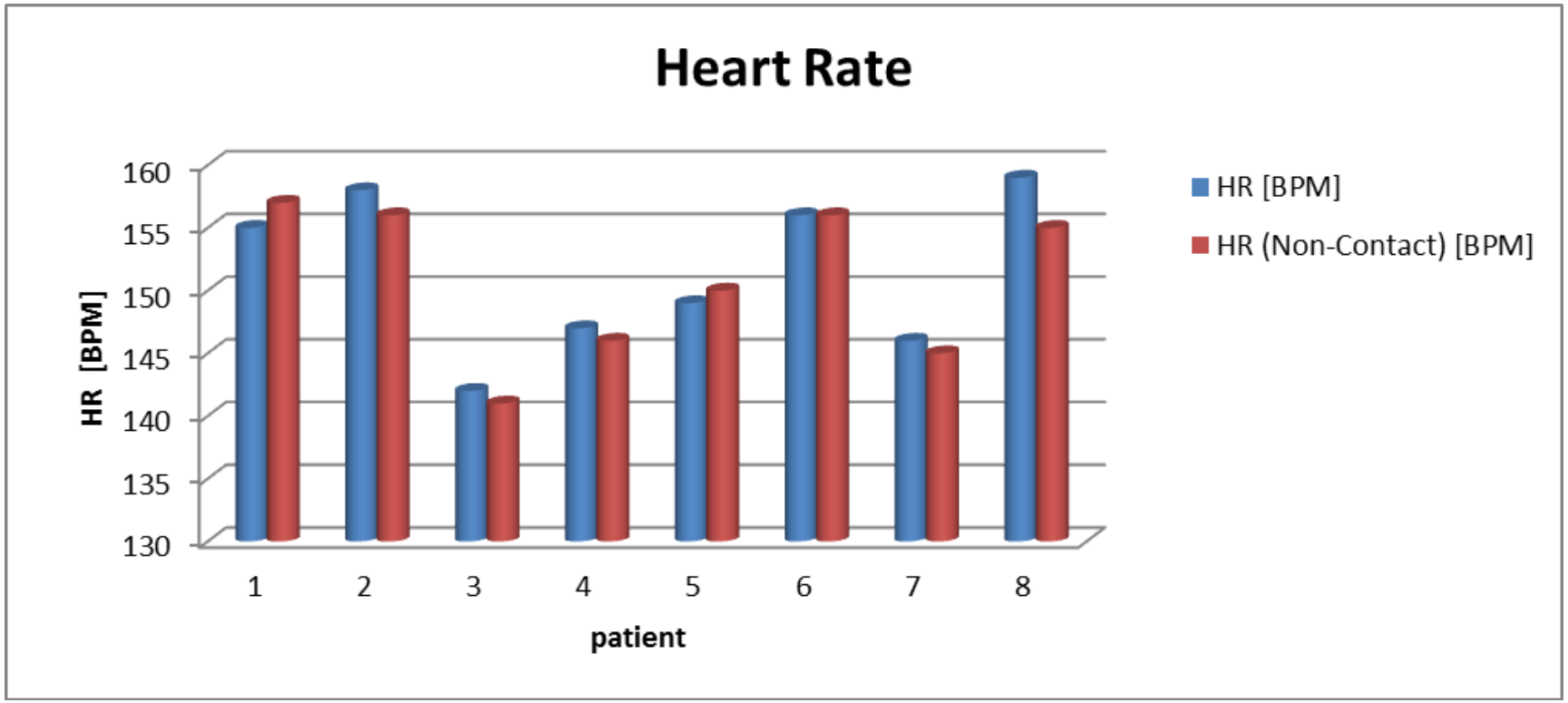


Room light



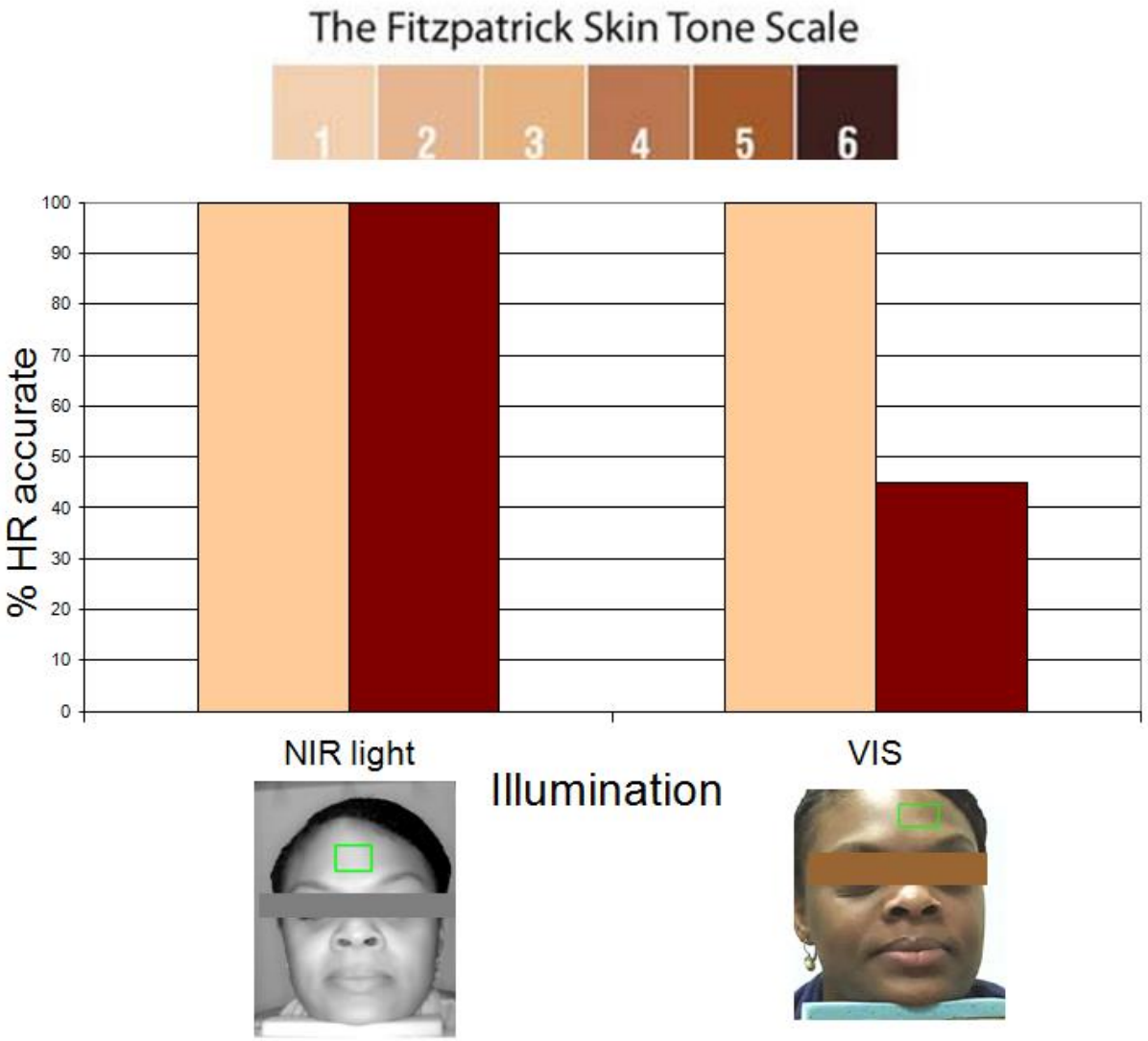
NIR light

Results



Difference < 3%

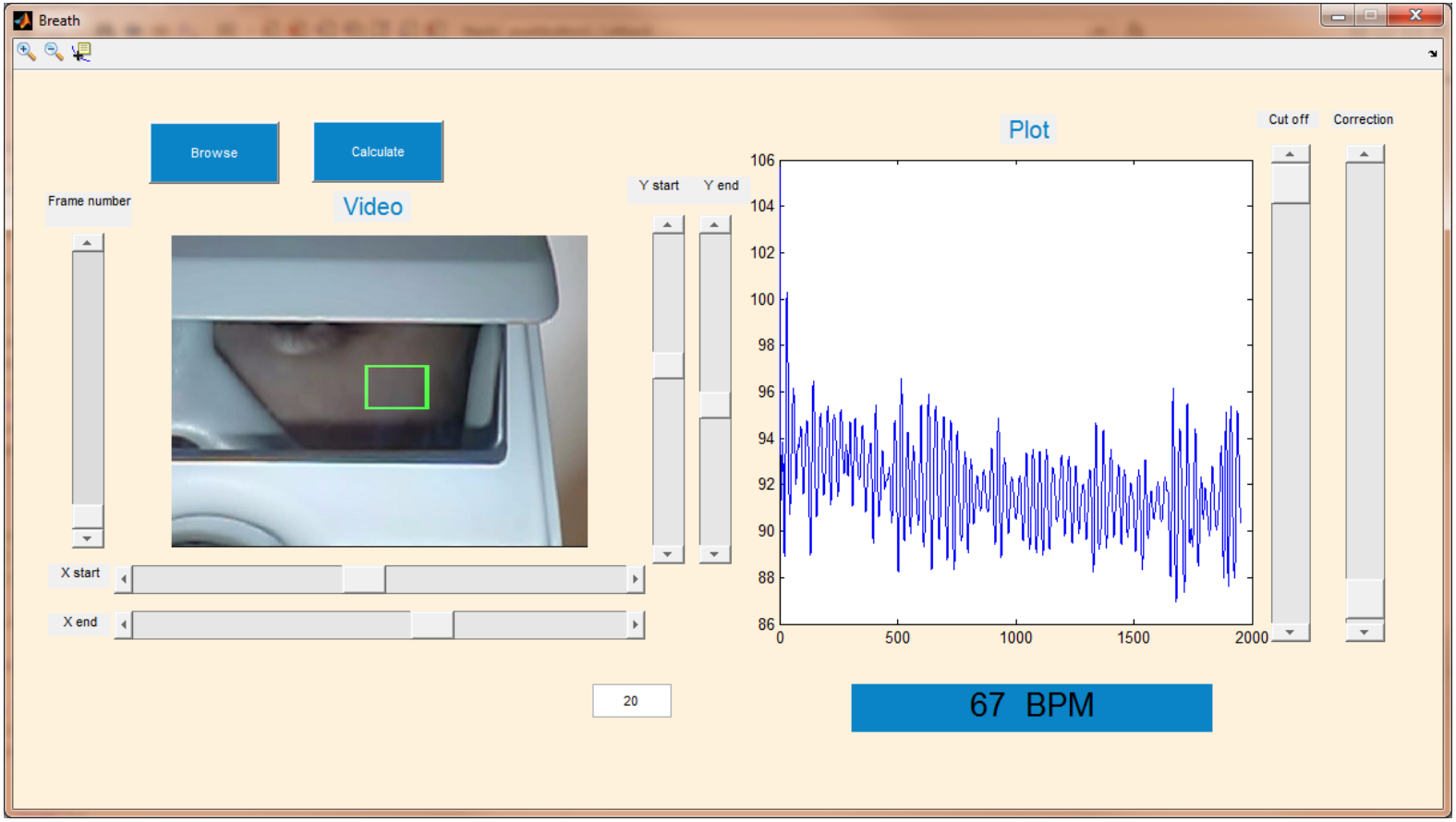
Accuracy depending on skin tone using NIR



MRI setup

- Camera in control room
- Camera: Panasonic TZ3
- Distance 5 - 6 m
- Light source
- Head Coil with mirror

MRI monitoring



Video based non-contact heart rate monitoring is possible independent of light conditions and skin color using NIR light and has

Potential for many applications :

- baby monitoring
- surveillance of elderly,
- patients in medium care or
- during MRI or CT diagnostic procedures

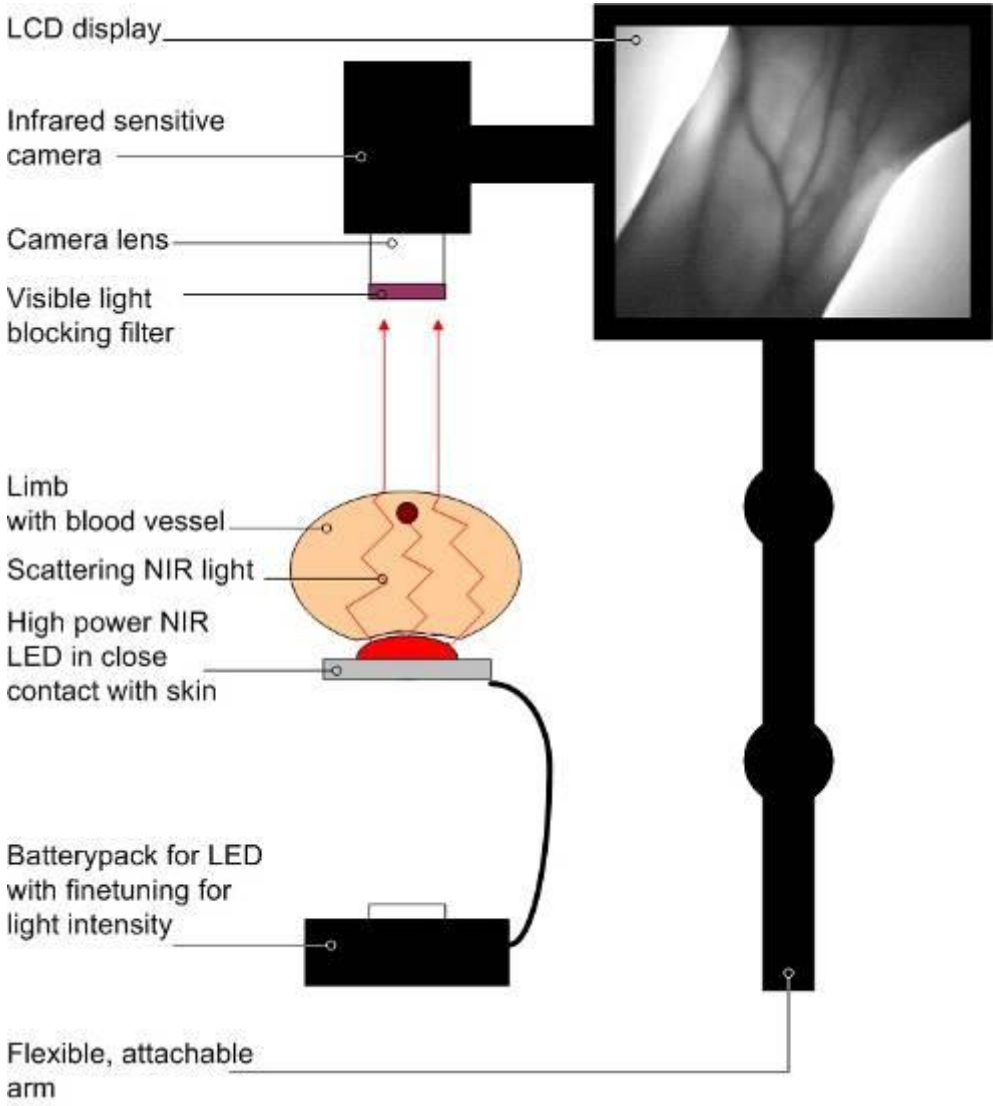
Vein punctures can be challenging

Especially in children:

- baby fat
- dark skin color
- vessel deviations due to illness
- repeated punctures

Development of vessel viewing system

- IR sensitive CCD
- LCD display
- IR blocking filter
- IR LED
- articulated arm

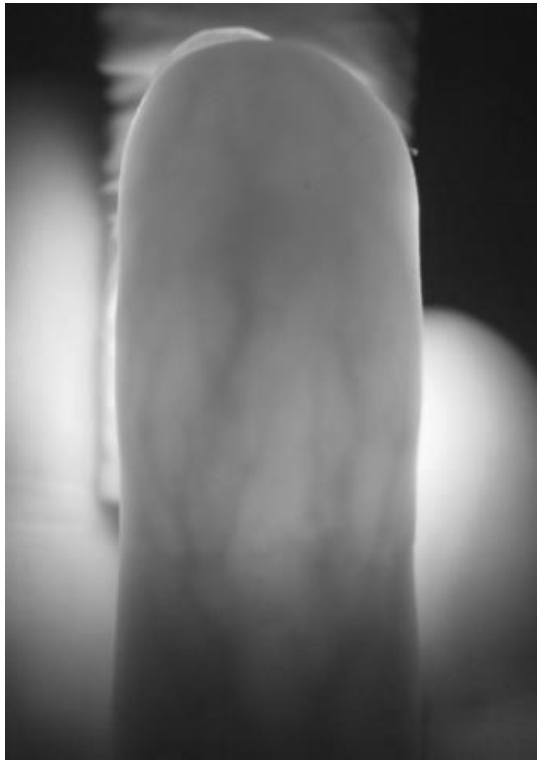


Veins in the hand

Normal vision

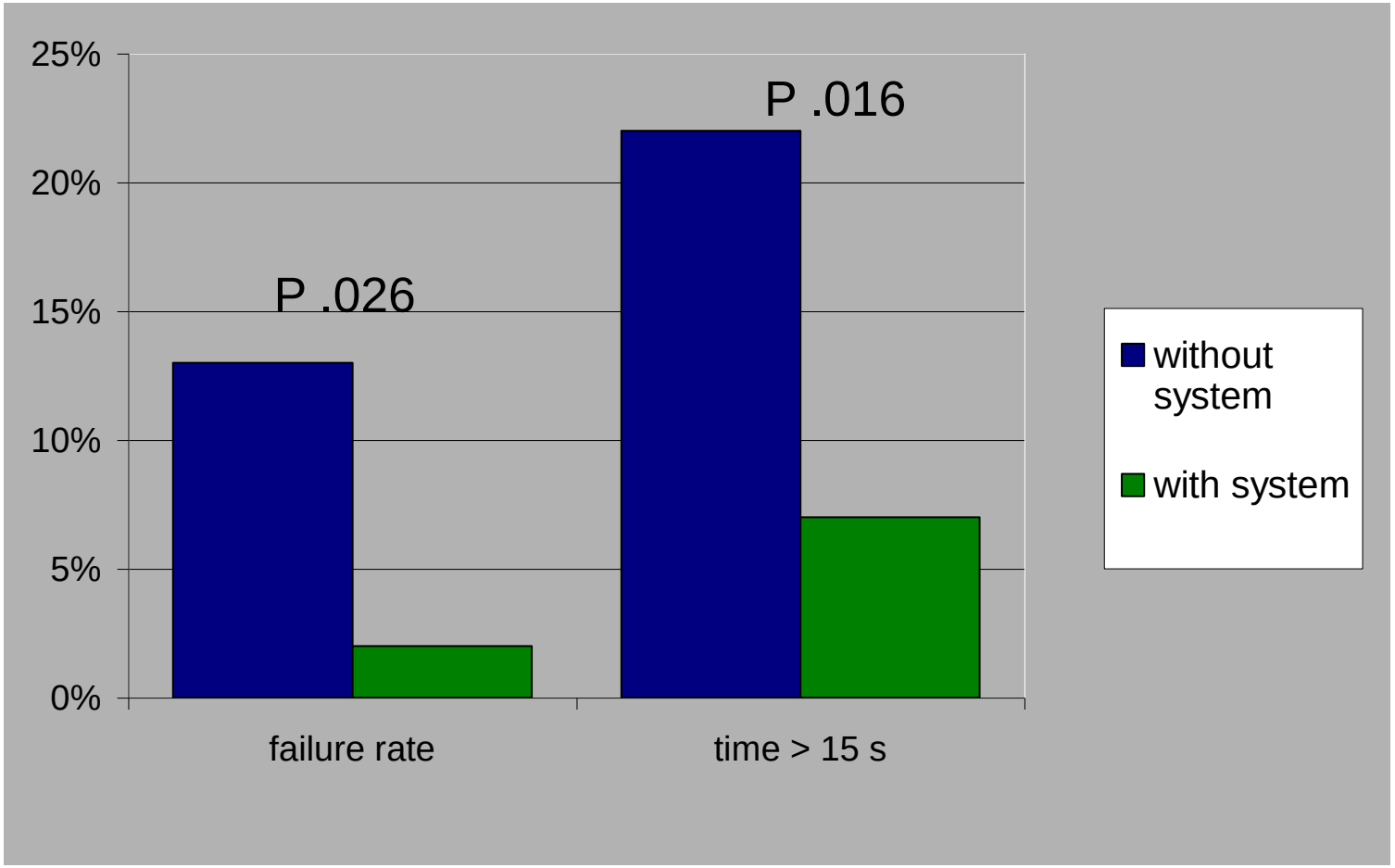
NIR vision

Visualisation of micro vessels

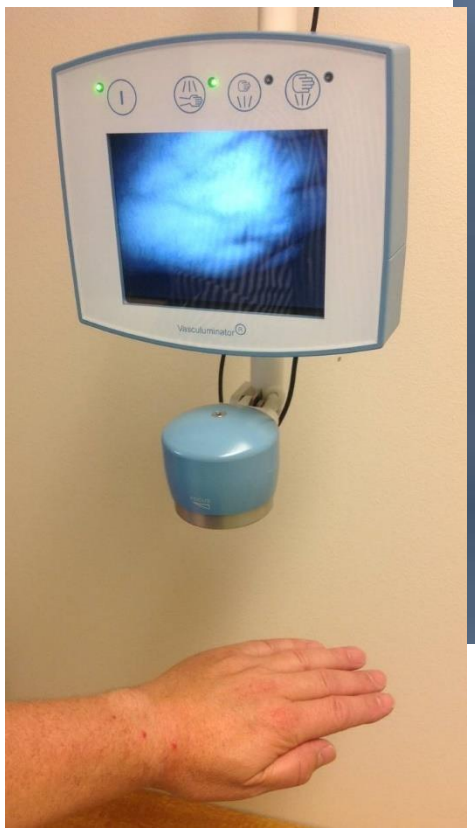


Results effectiveness venipuncture

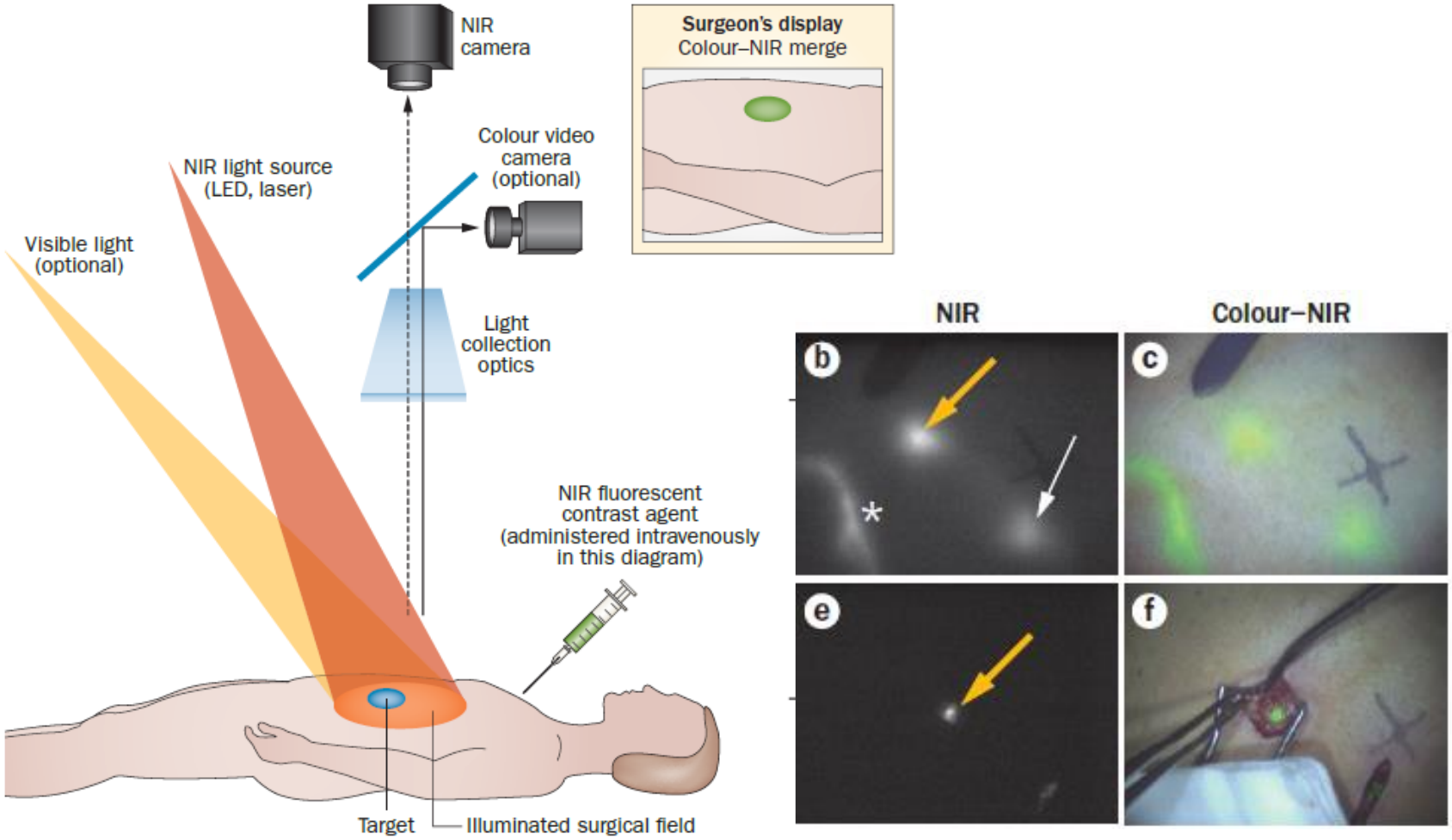
Percentage of failure rate and time > 15 s



‘The VascuLuminator’
‘navigation device’
to find blood vessels for puncture



Near IR fluorescence guided surgery



(from review NIRF Image-guided surgery AL. Vahrmeijer et al.)

Low cost NIRF imaging system using consumer components

Pulsar Laser IR

150mW 785nm flashlight

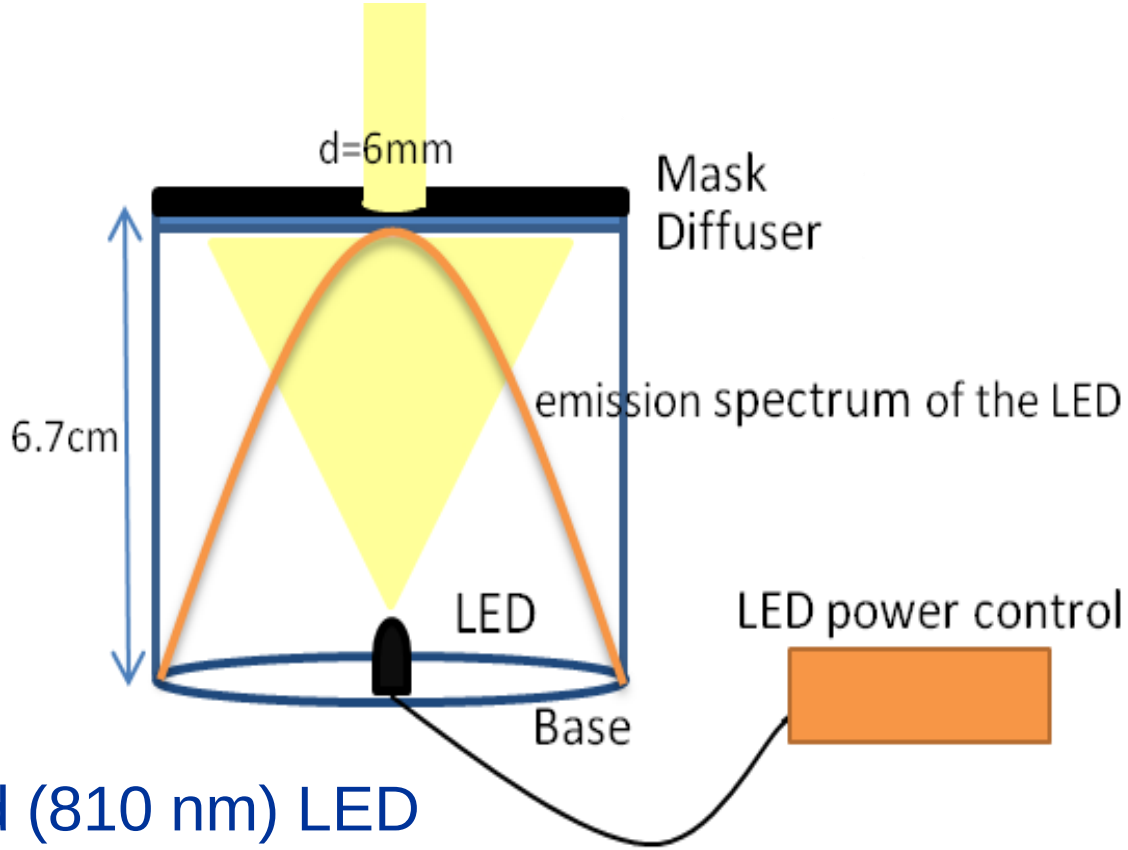
NiteCore CI6

3W, 850nm flashlight

Sony NEX 5T

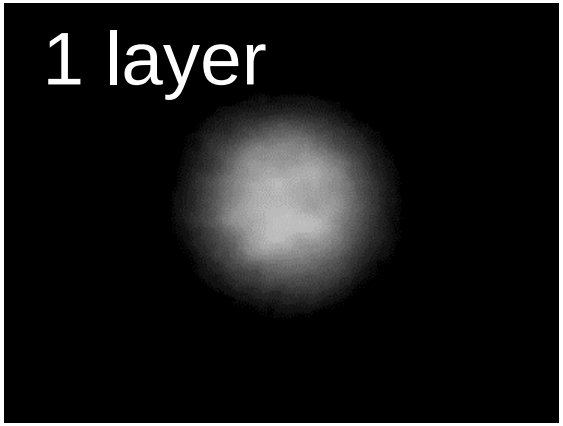
(full spectral adapted)

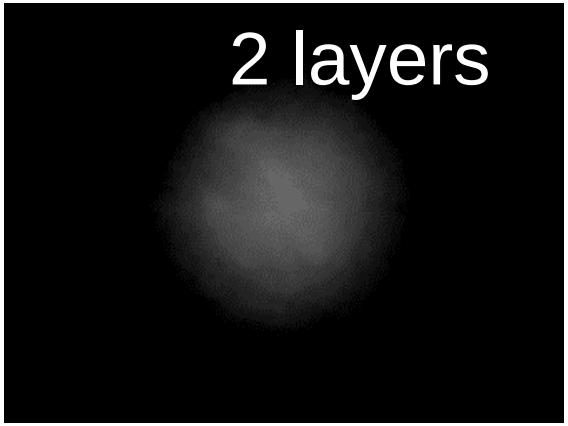
Development NIR fluorescence phantom for testing/validation camera systems

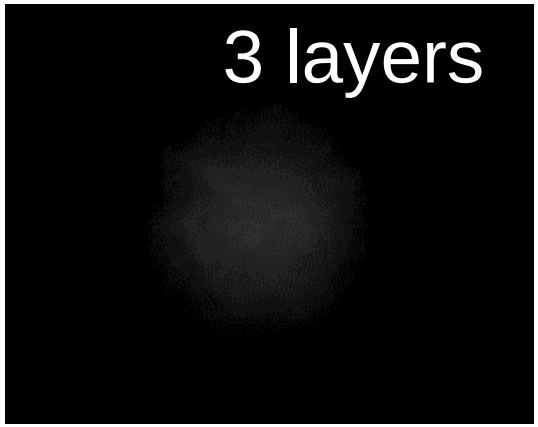


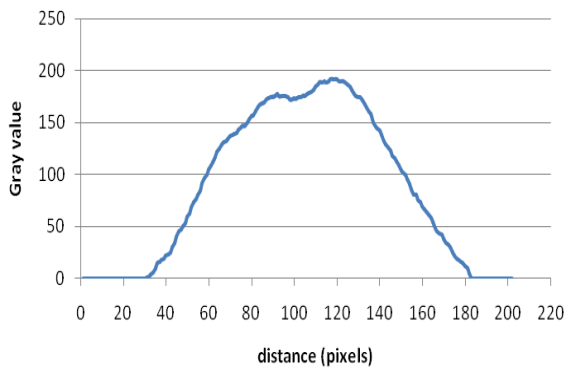
- Power controlled (810 nm) LED
- Intensity range nW-mW
- 6 mm uniform fluorescence spot

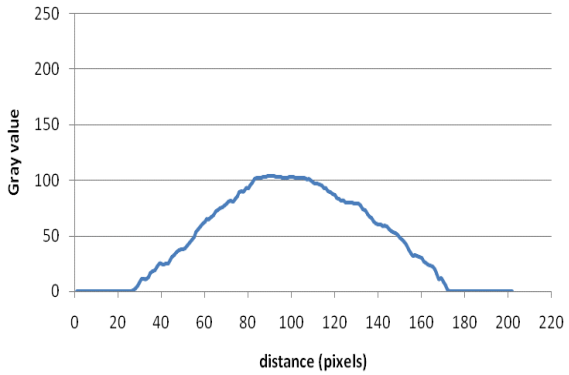
Results : tissue transmission

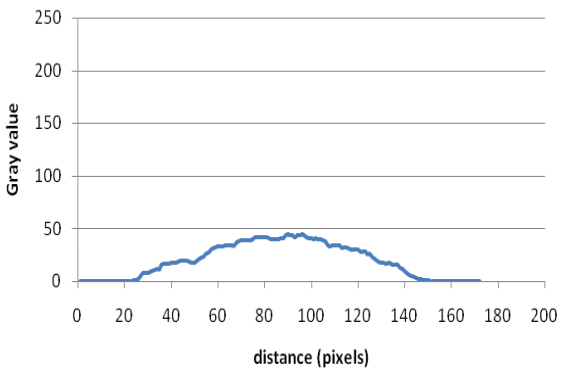




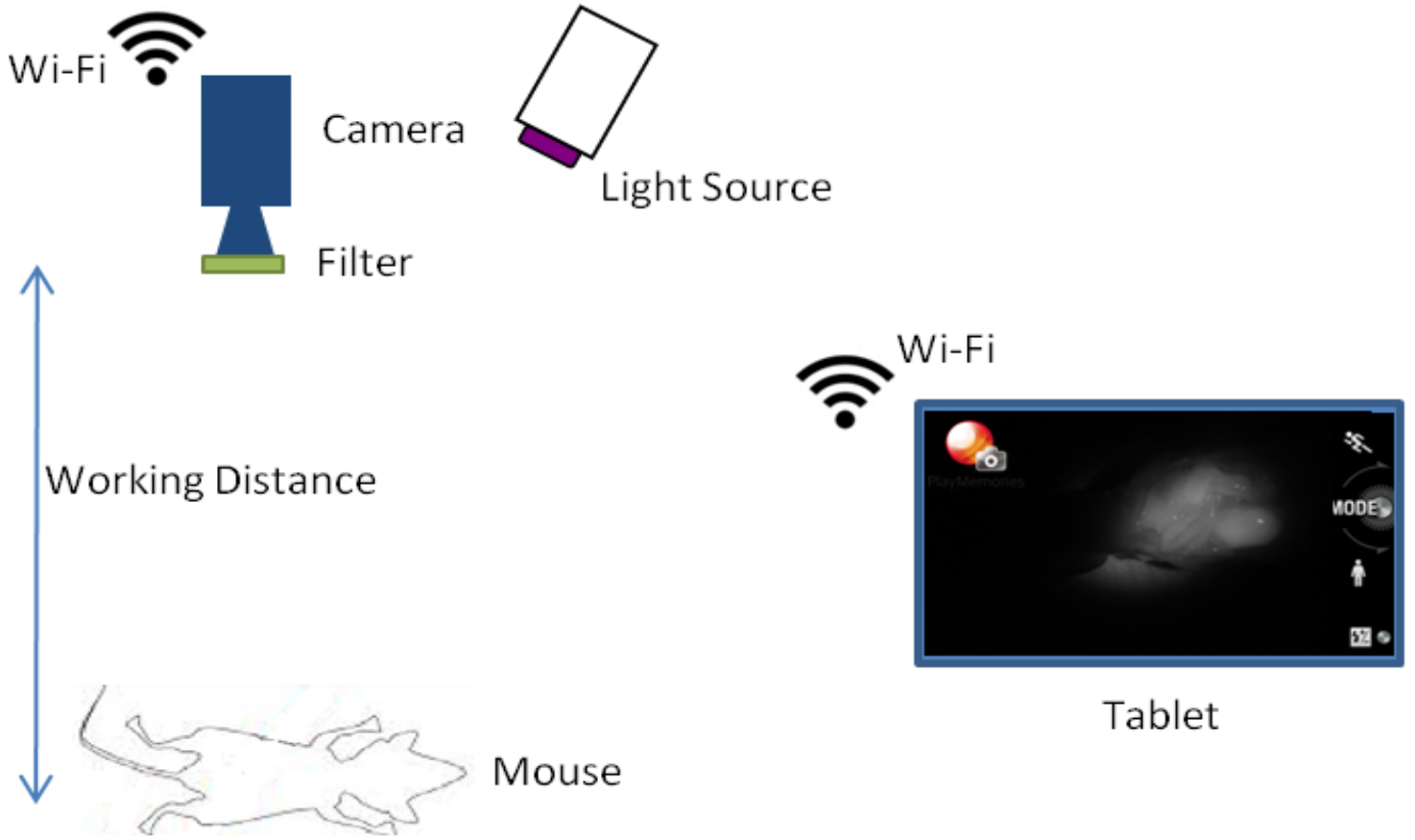




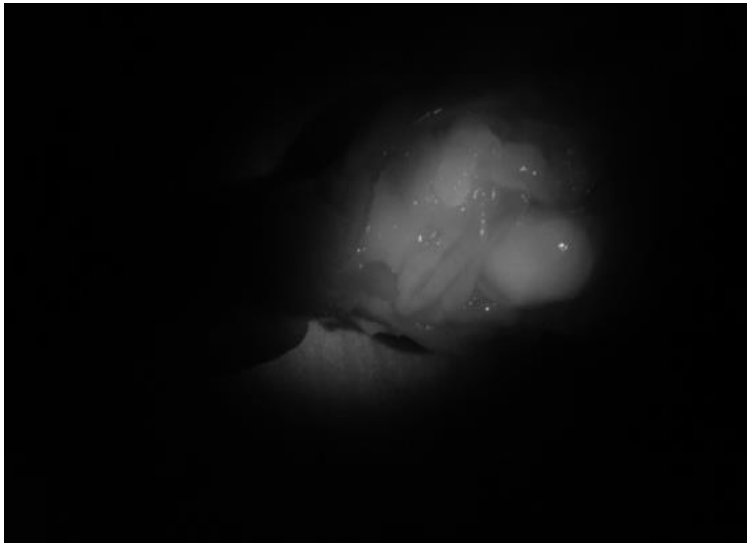


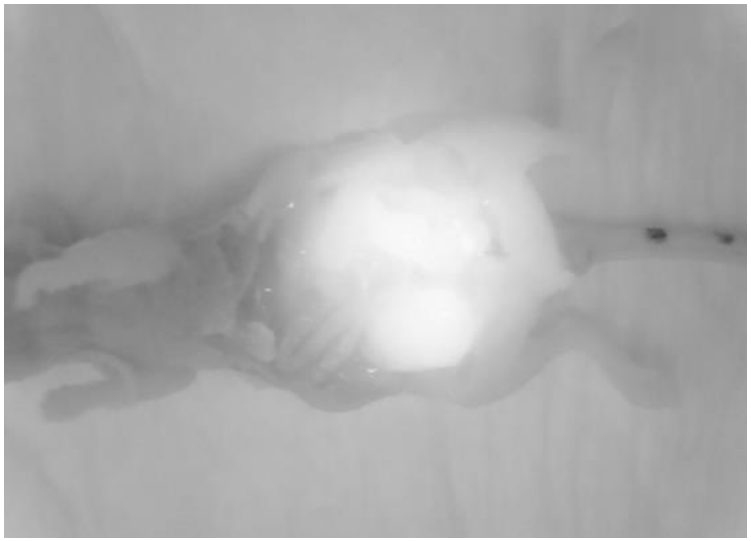


NIR fluorescence in-vivo imaging setup in practise



NIR fluorescence in-vivo imaging setup





CW800 labeled tumor grown in the belly of a mouse

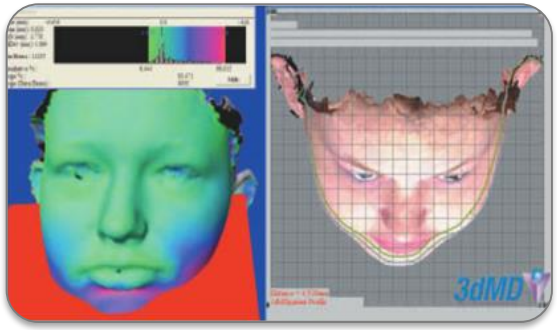
Using a 850nm LED flashlight, the mouse itself and environment becomes also visible

‘The VascuLuminator’ will be adapted to NIR fluorescence imaging for image guided surgery

3D Printing and Scanning

Diagnostics

- Growth defects
- Abdominal shape
- Lung volume
- Melanomas



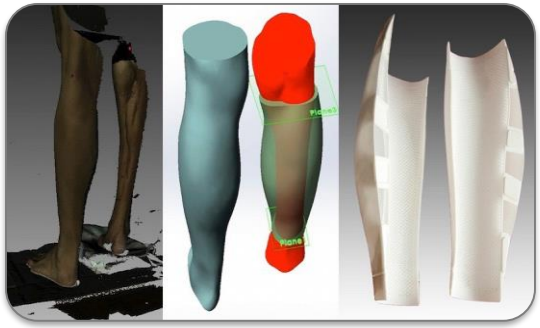
3D InnovationLab
Kaakchirurgie-FMT

Monitoring

- Fitness and diet
- Obesity
- Diabetes

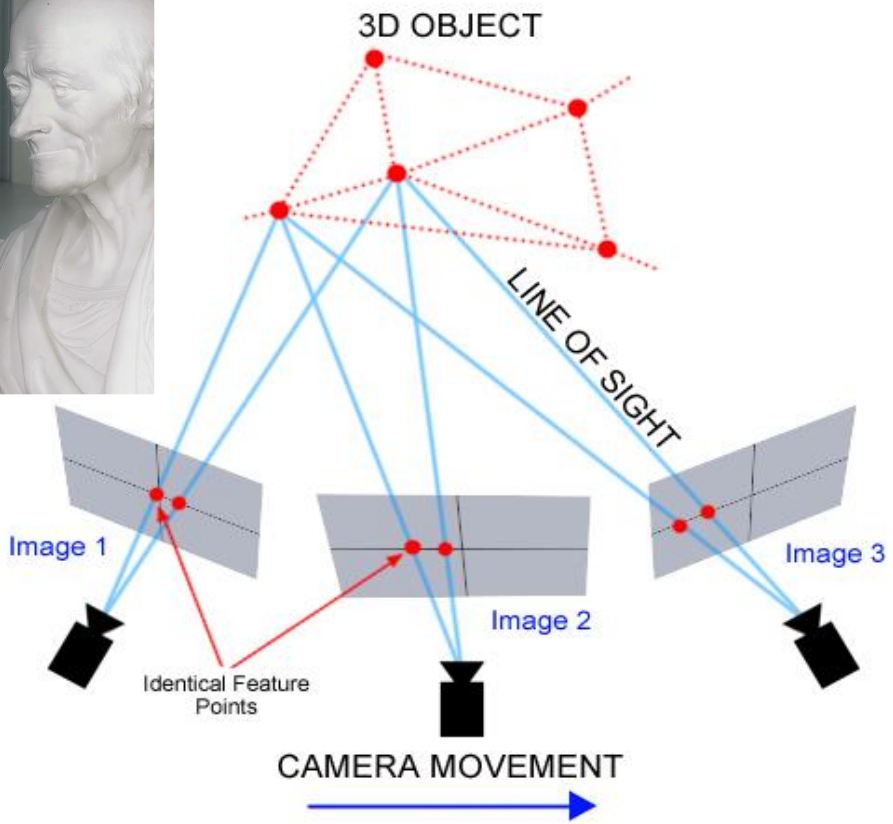
Treatment

- Scoliosis
- Prosthetics
- Burns
- Facial reconstruction



8
9

3D scanner Artec Spider



Comparison 3D scanners

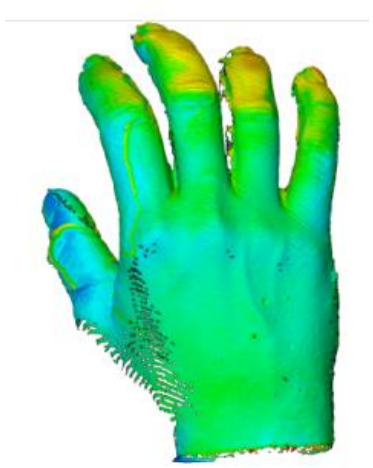
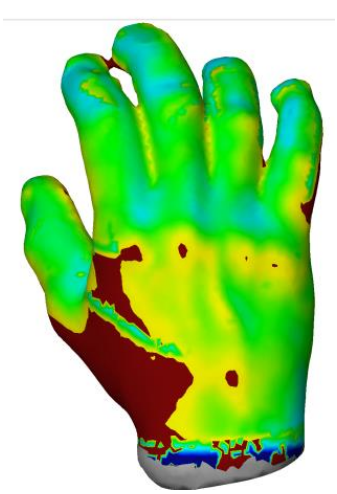
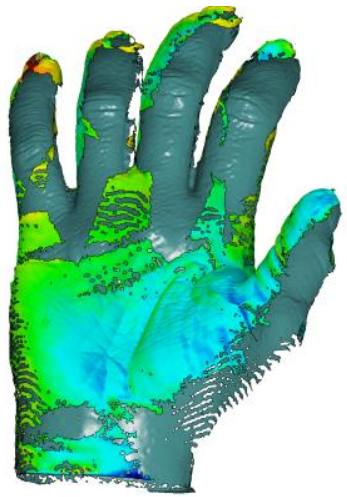
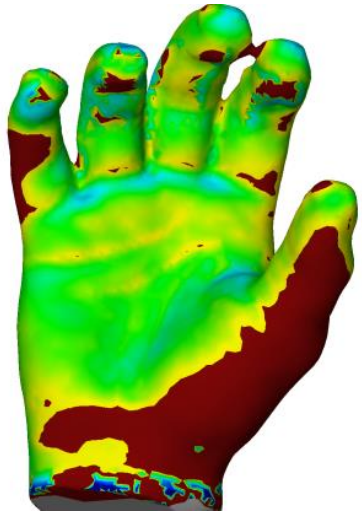
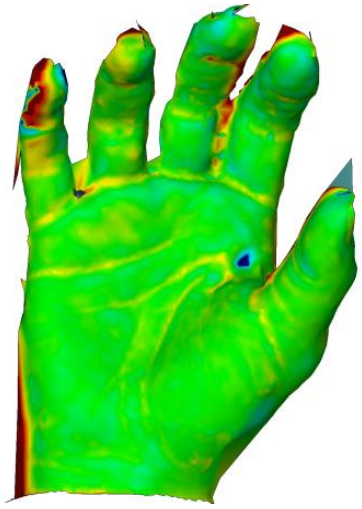
Artec Spider

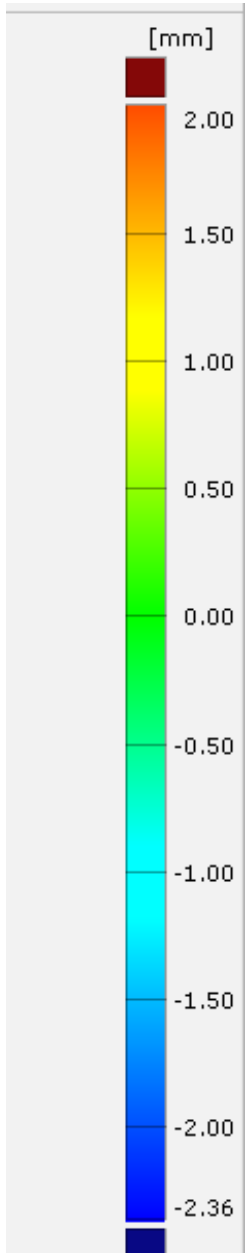
Sense

Sprout HP

Vectra M3

Comparison study

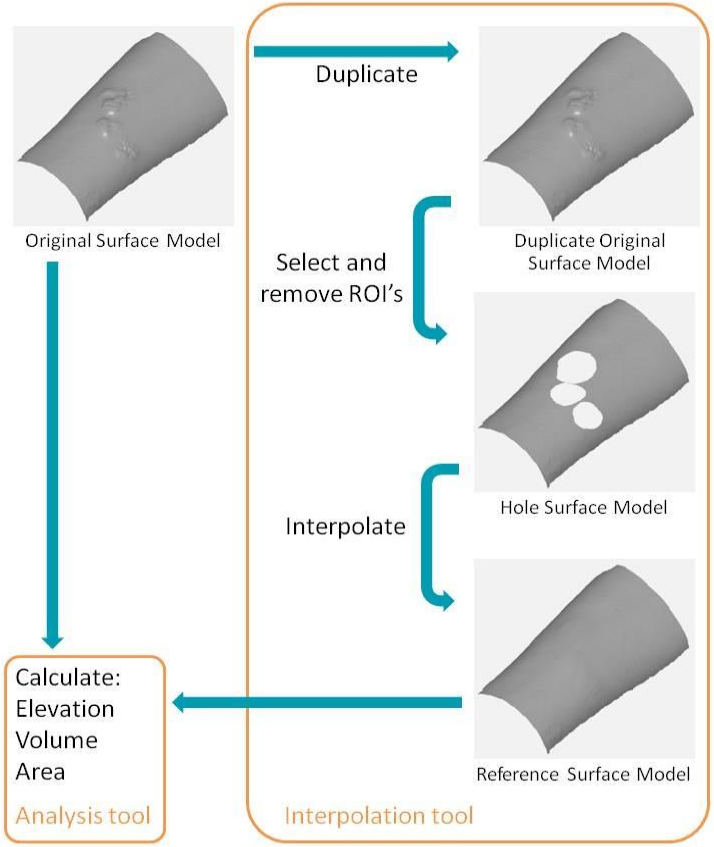
Sprout HP	Sense	Vectra M3
		
		

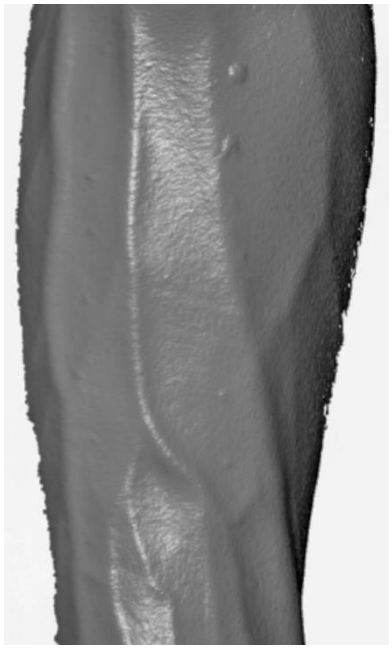


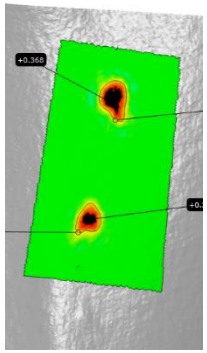
Quantification of cutaneous allergic reactions using 3D optical imaging: A feasibility study

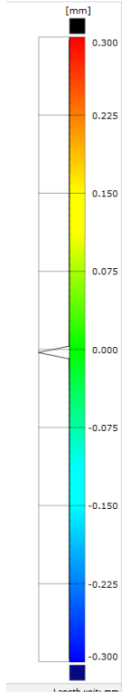
Skin Res Technol. 2019;00:1–9.

Mark D. den Blanken[1] | Sebastiaan van der Bent[2] | Niels Liberton[3] | Matthijs Grimbergen[1] | Mark B. M. Hofman[1] | Ruud Verdaasdonk[4] | Thomas Rustemeyer[2]









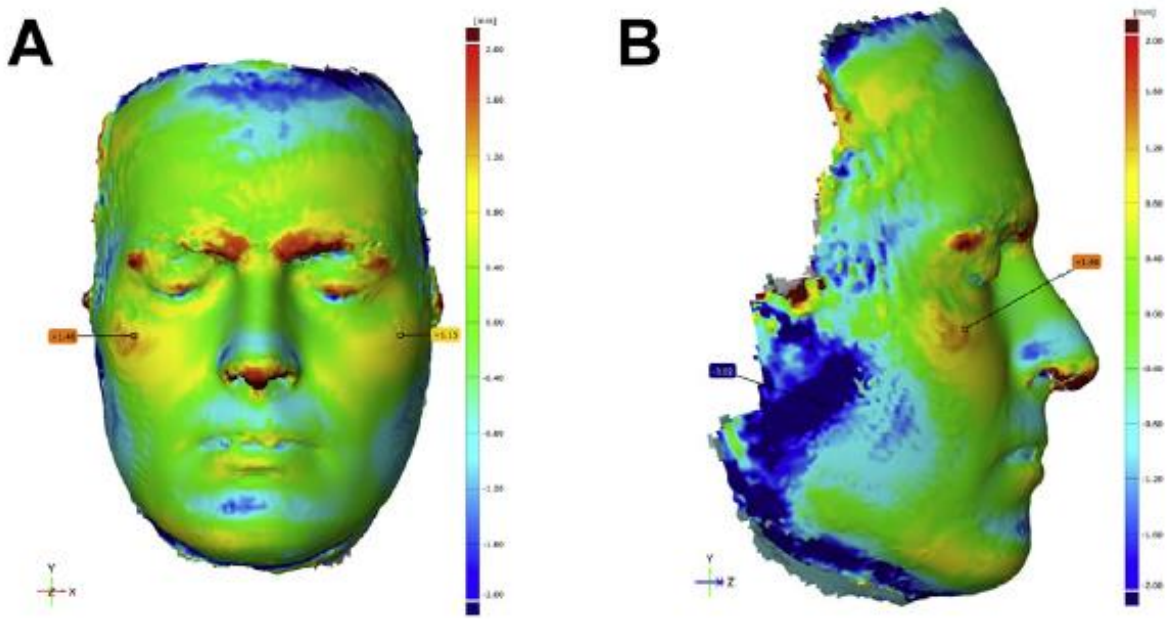
THE JOURNAL OF
SEXUAL MEDICINE

J Sex Med 2019;16:746–754

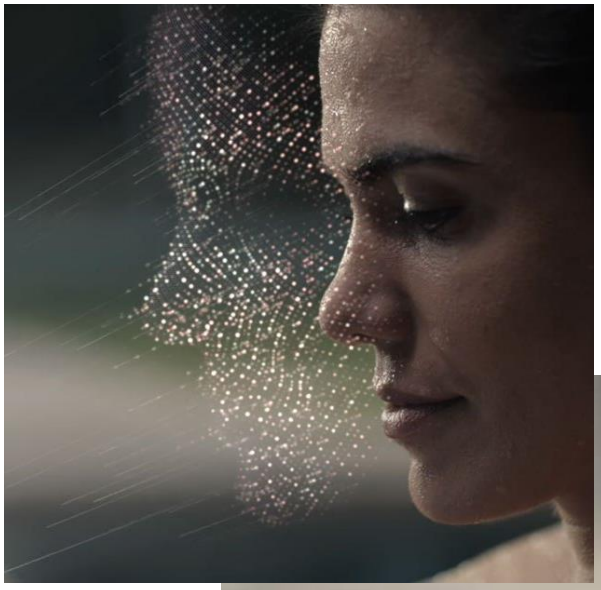
TRANSGENDER HEALTH

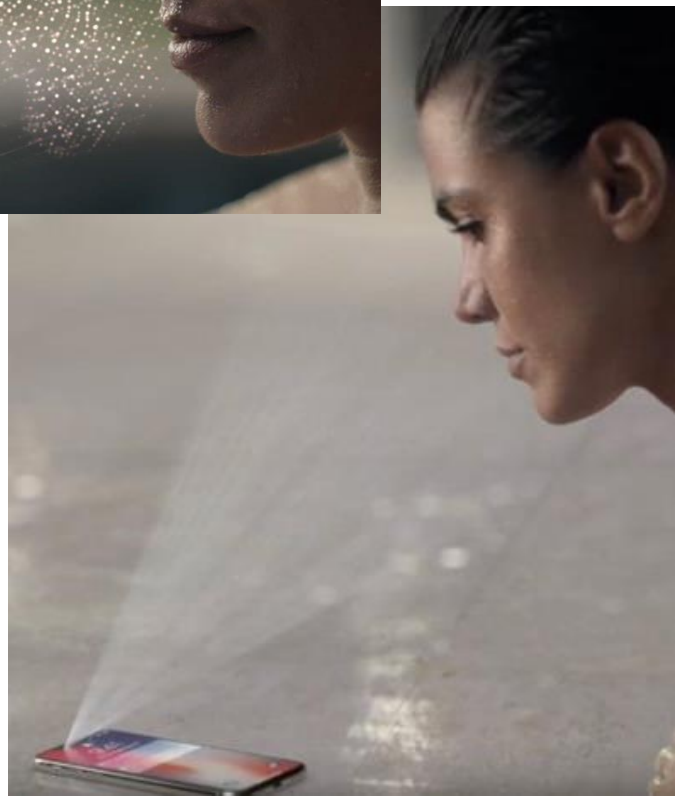
Gender-Affirming Hormone Treatment Induces Facial Feminization in Transwomen and Masculinization in Transmen: Quantification by 3D Scanning and Patient-Reported Outcome Measures

Marieke Tebbens,[1] Nienke M. Nota,[1] Niels P. T. J. Liberton,[2] Brigitte A. Meijer,[3] Baudewijntje P. C. Kreukels,[4] Tim Forouzanfar,[3] Rudolf M. Verdaasdonk,[2] and Martin den Heijer, MD, PhD[1]



Latest development: Smart phone based 3D scanner



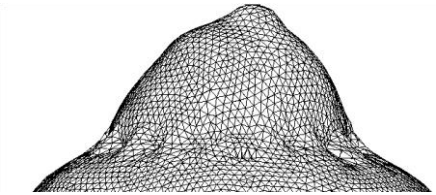


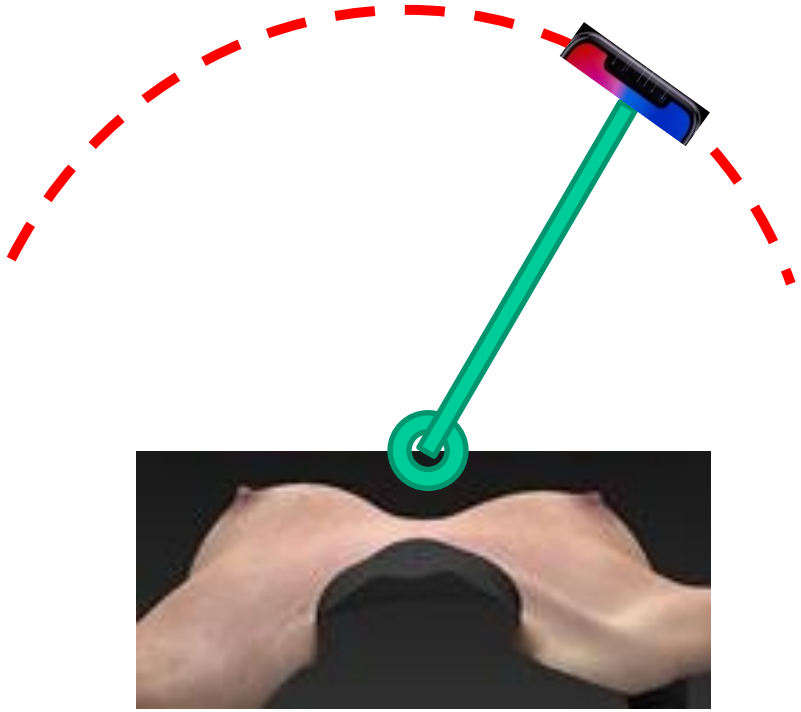
Face ID (True Depth camera) of Iphone X is a fully functional 3D scanner !!

New study 3D scanning breast development

Amsterdam UMC
Universitair Medische Centra

- Setup with Iphone X as 3D scanner

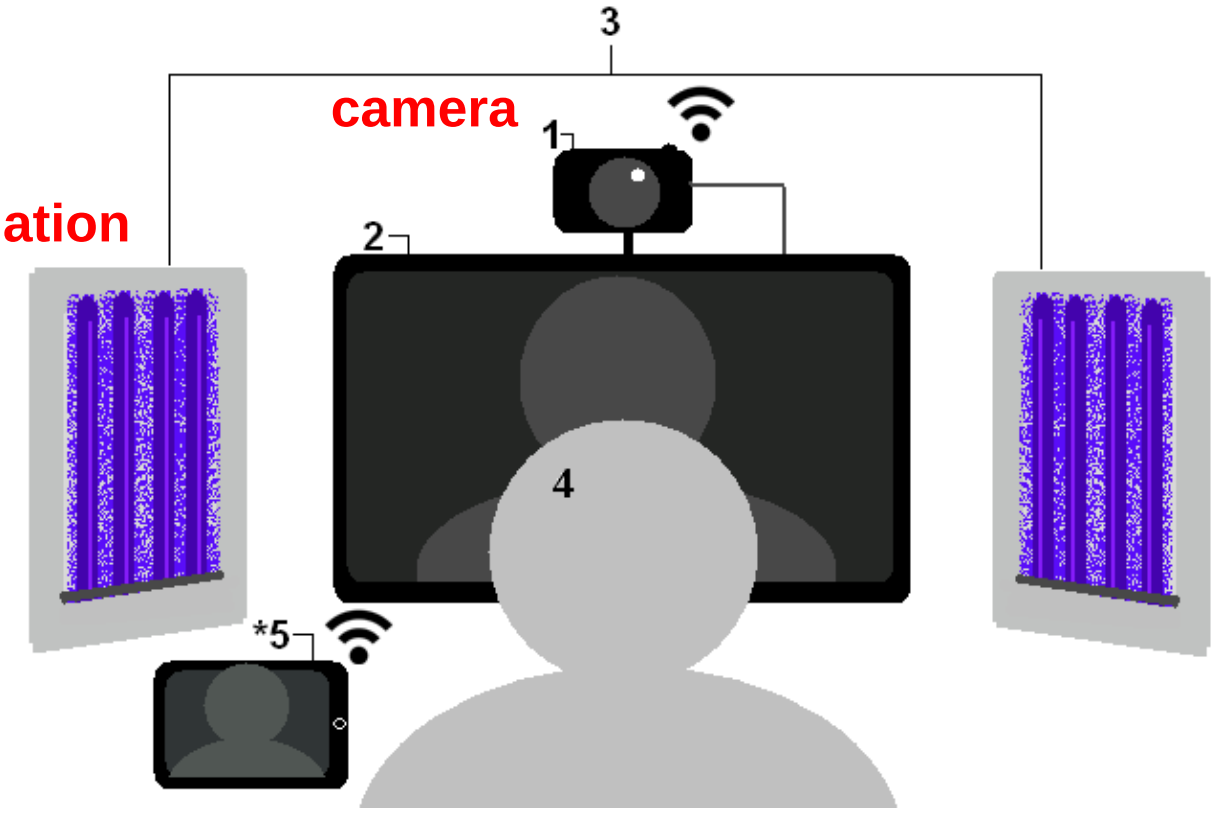




How to raise public awareness of damaging effect of UV light ?

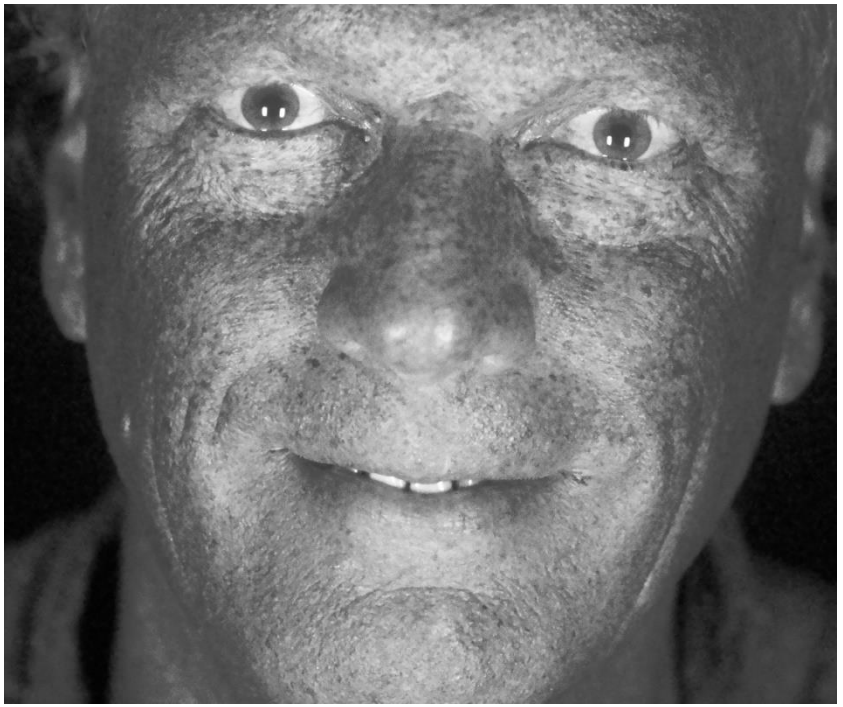
- Confronting people by showing UV skin damage
- showing effect of protection by sunscreen
- inspiration by youtube video
  ‘ How the sun sees you ‘
  by photographer Thomas Leveritt

Design of UV imaging system ‘Magic Mirror’



Examples ‘young faces’

Examples ‘old faces’



Effect of sun screen

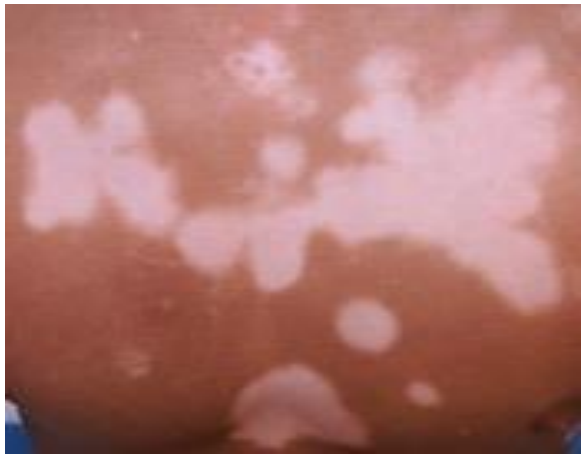




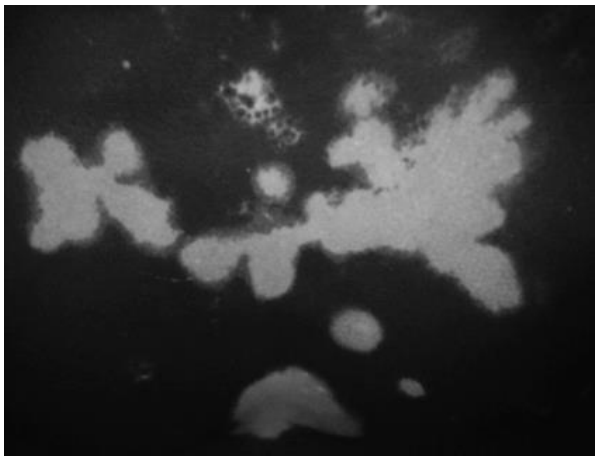

Public Awareness Activities
Skin cancer day
Marathon Amsterdam
Open air festivals

Patients with Vitiligo

UV visualisation of the distribution of the patches



Visible



UV

The ultraviolet light camera, a promising measurement instrument for lesion assessment in Vitiligo, a study on image quality, validity and reliability.

SE Uitentuis[1], MN Heilmann[1], RM Verdaasdonk[2], JM Bae[3], RM Luiten[1], A Wolkerstorfer[1], MW Bekkenk[1]
[1] Netherlands Institute for Pigment Disorders, Department of Dermatology,
Amsterdam University Medical Centers, University of Amsterdam, Amsterdam, the Netherlands
(submitted)

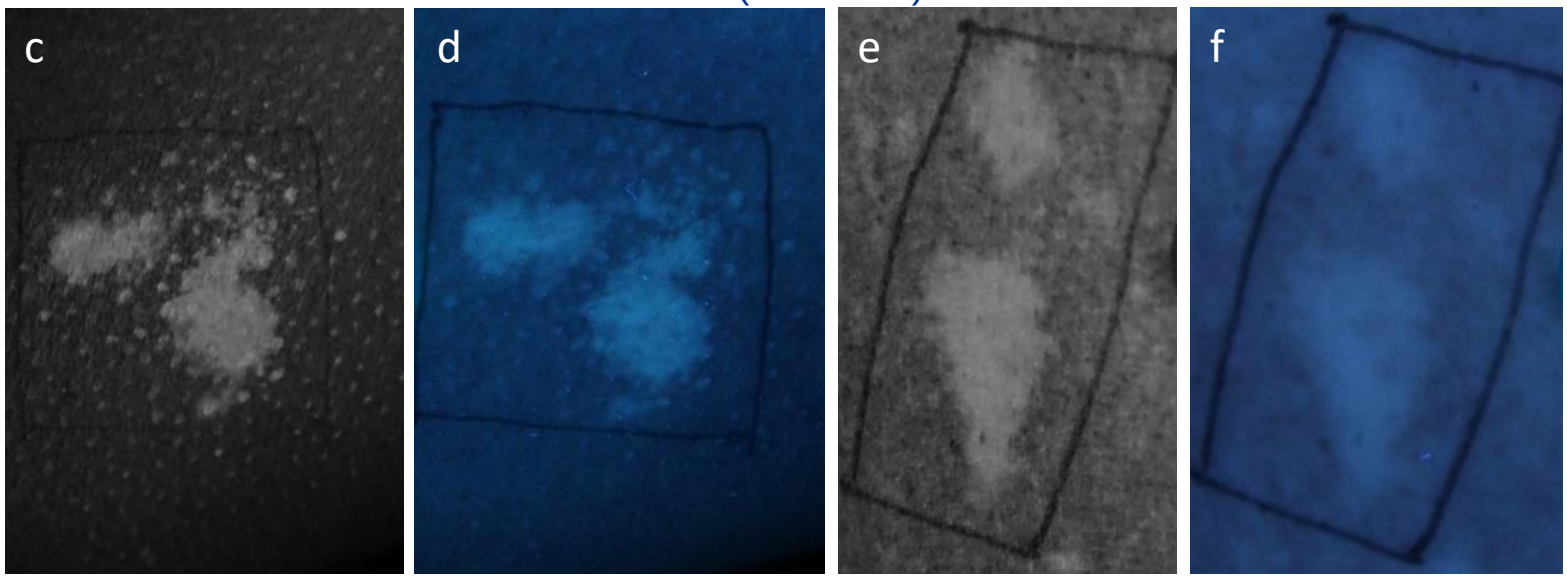


Table 1 Quality scores for images of vitiligo lesions made with a conventional camera and UV camera

	Overall image quality: frequency (%)				
	Very poor	**Poor**	**Average**	**Good**	**Very good**
Vitiligo experts					
Conventional camera	4 (6.5%)	11 (17.7%)	31 (50%)	13 (21%)	3 (4.8%)
UV camera	0 (0%)	0 (0%)	0 (0%)	12 (19.4%)	50 (80.6%)
Medical interns					
Conventional camera	5 (8.1%)	15 (24.2%)	25 (40.3%)	15 (24.2%)	2 (3.2%)
UV camera	0 (0%)	0 (0%)	0 (0%)	25 (40.3%)	37 (59.7%)

Monitoring with Imaging technologies

- Vital functions
  - heart rate +
  - breathing +
  - perfusion +
  - oxygenation +
  - temperature +
  - physiological changes in time +
- Discriminate diseased from healthy tissue
  - (pre) cancerous tissue +
  - inflammation +
  - tissue damage +
- Treatment monitoring +

Qualitative + and Quantitative +

Conclusions

- None-contact imaging techniques prove to be successful in a wide range of applications.
- They can easily be introduced in the clinic with approval of ethical committee since the risk for the patient is minimal.

Future Perspective

Besides the many potentials in the hospital, handheld ‘smart cameras’ should become standard equipment in the office of general practitioners

+

Acknowledgements

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