

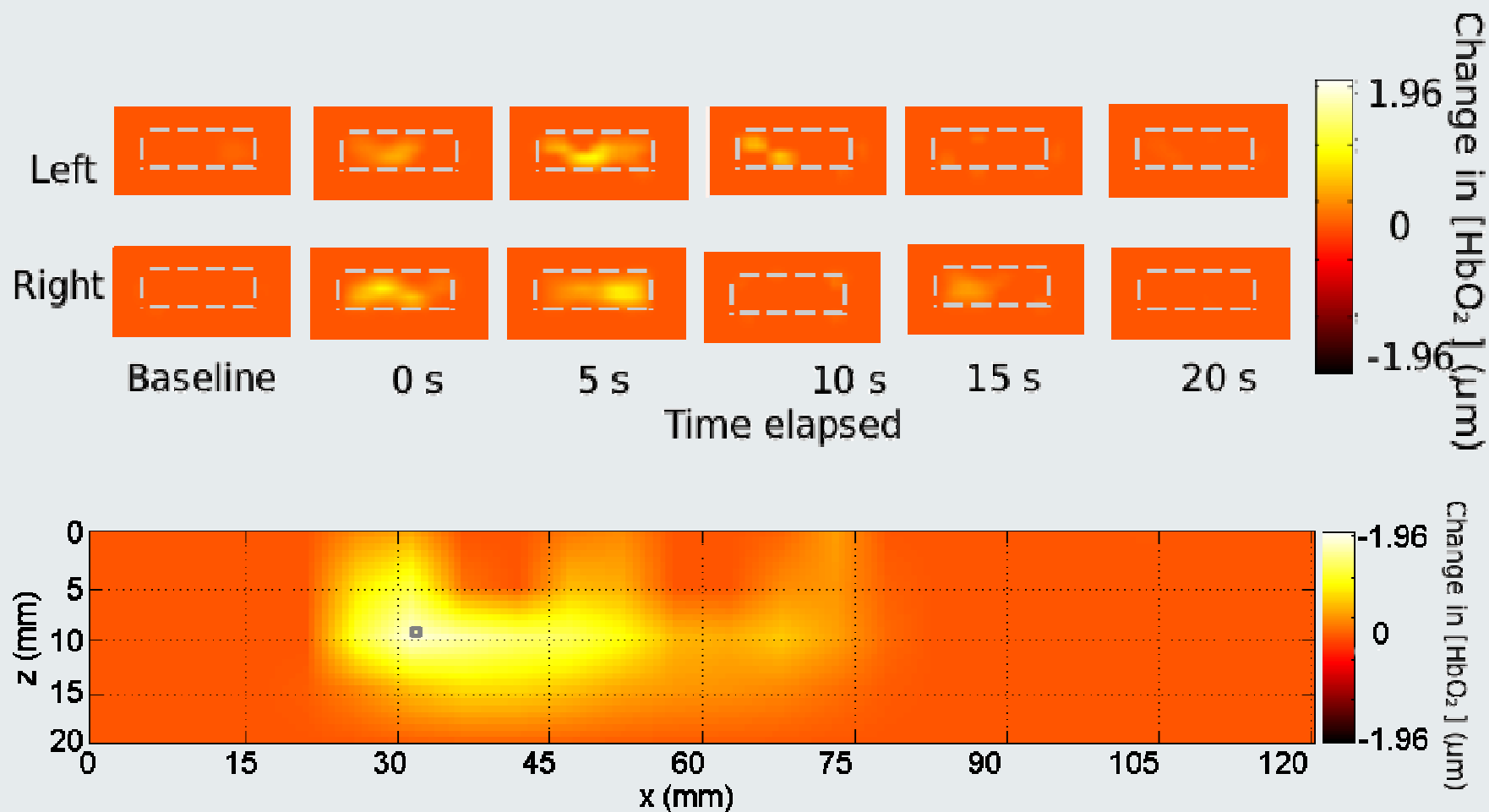
Diffuse optical imaging of brain and breast

Adam Gibson

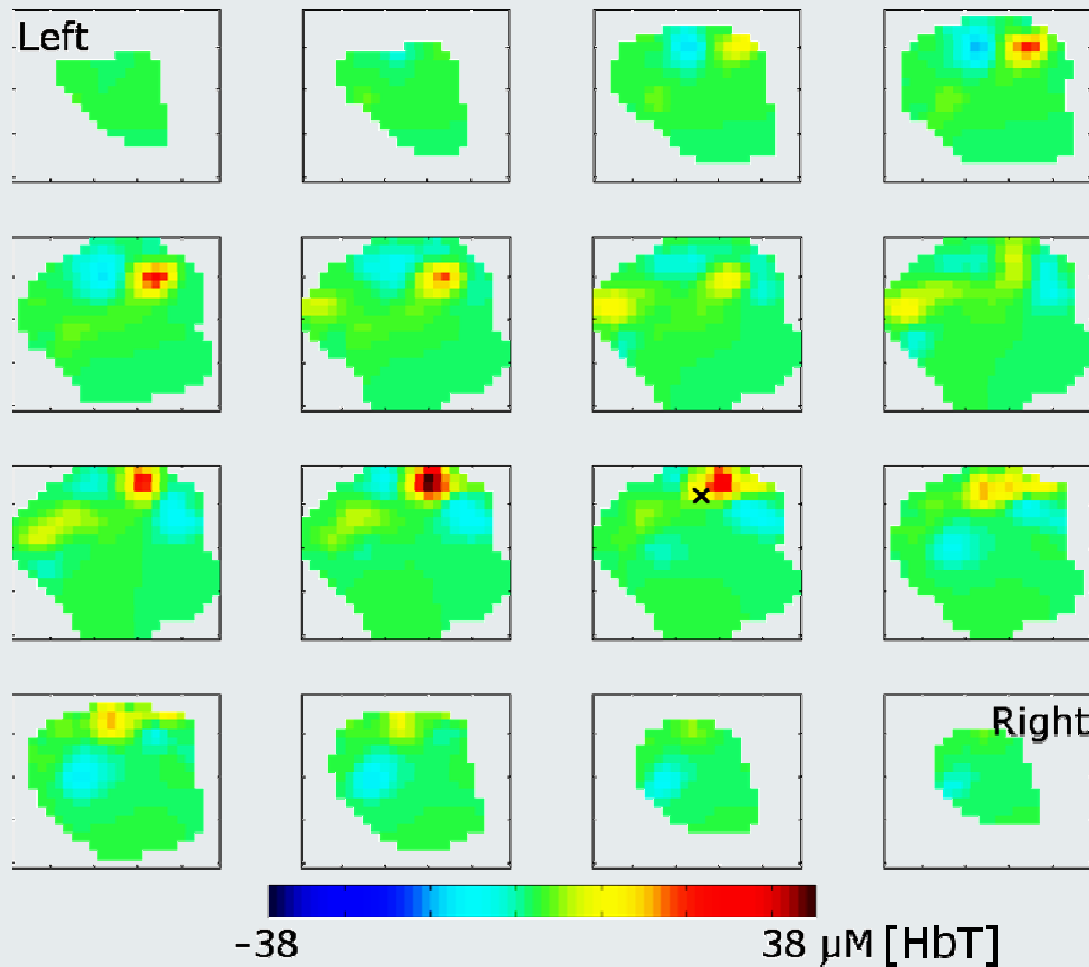
Dept Medical Physics and Bioengineering
University College London

Biomedical signal and image processing
University of Porto
10 Mar 2012

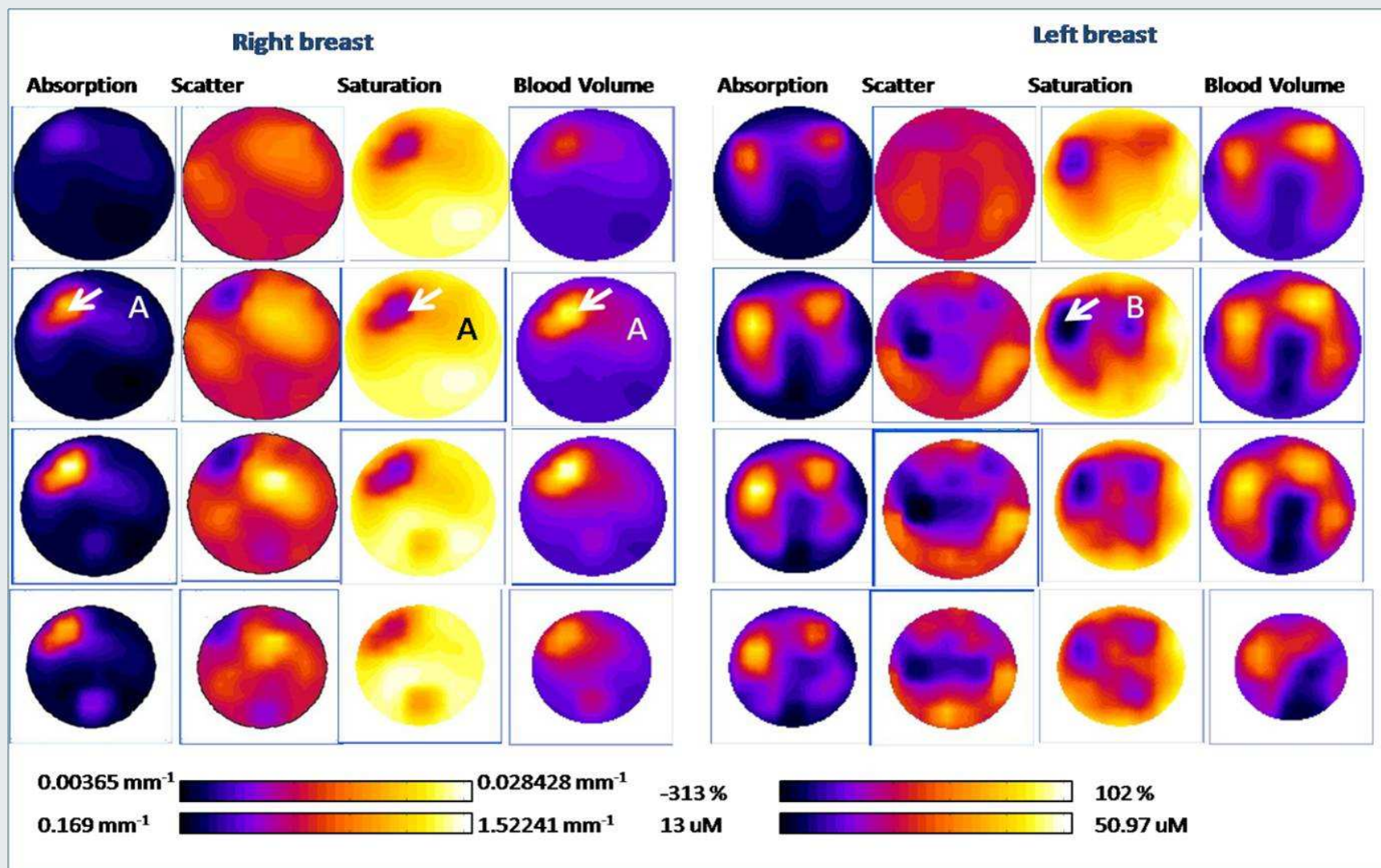
Optical topography of brain function



Optical tomography of neonatal brain



Optical mammography



Diffuse optical imaging

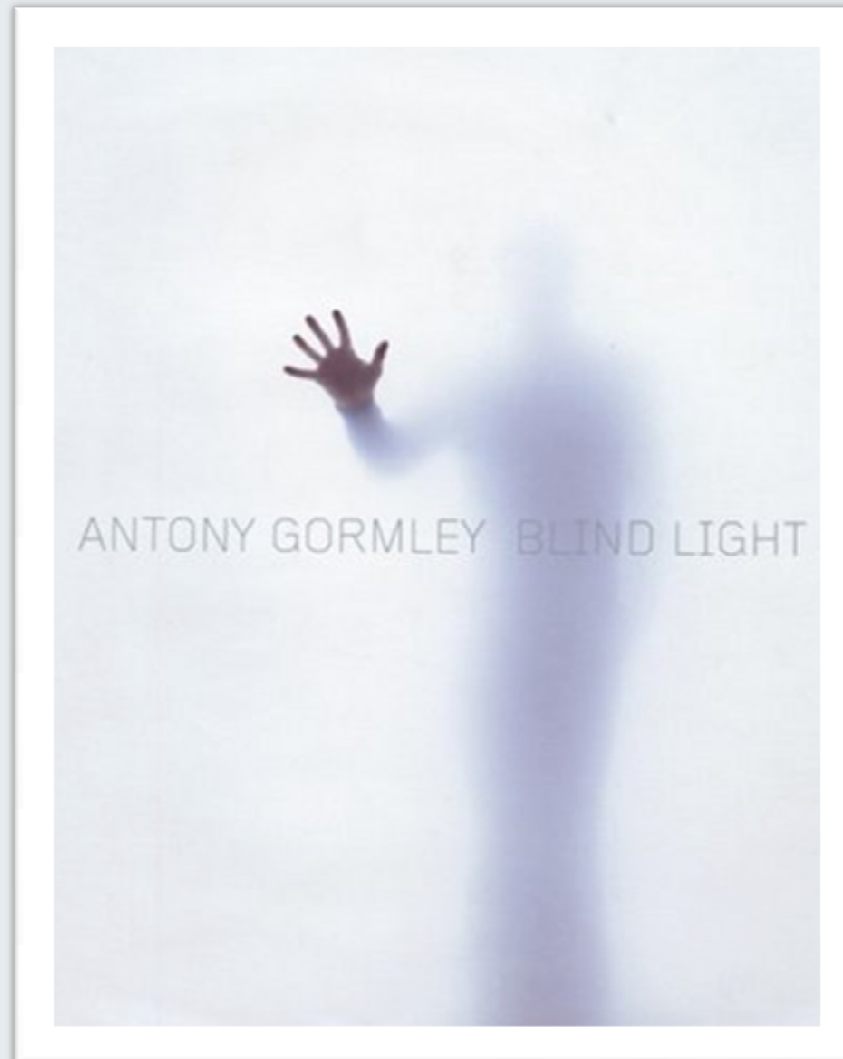
A long history...



‘ If a candle was held behind his head, or the sun happened to be behind it, the cranium appeared semi-transparent and this was more or less evident until he attained his fourteenth year’

Richard Bright, Guy’s Hospital, on a patient with hydrocephalus, 1831.

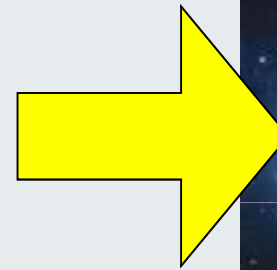
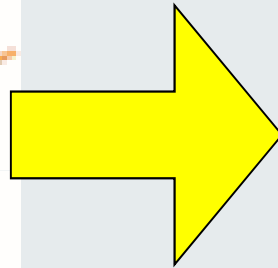
Tissue optics is dominated by scatter



High attenuation

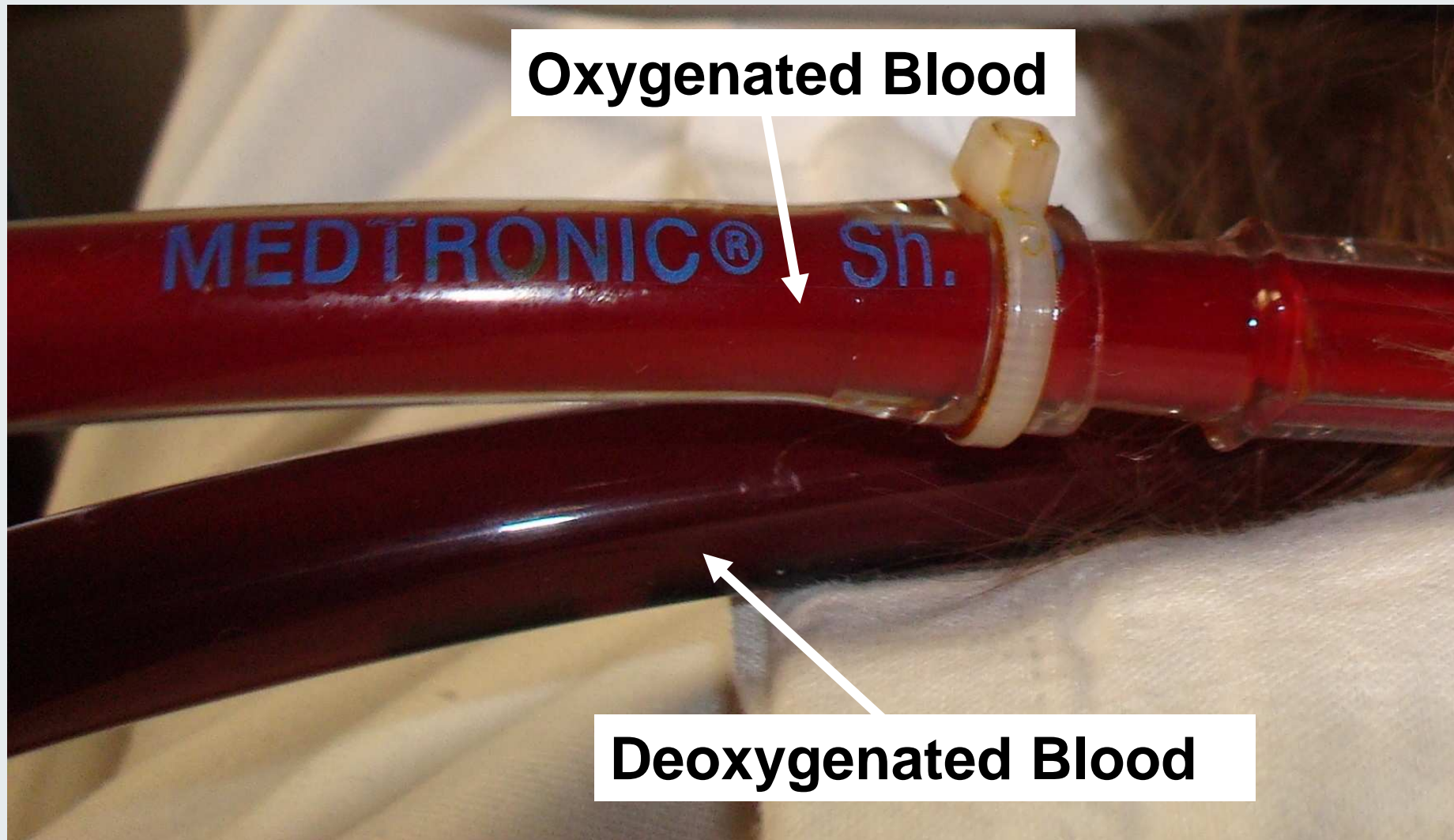


500 W m^{-2}

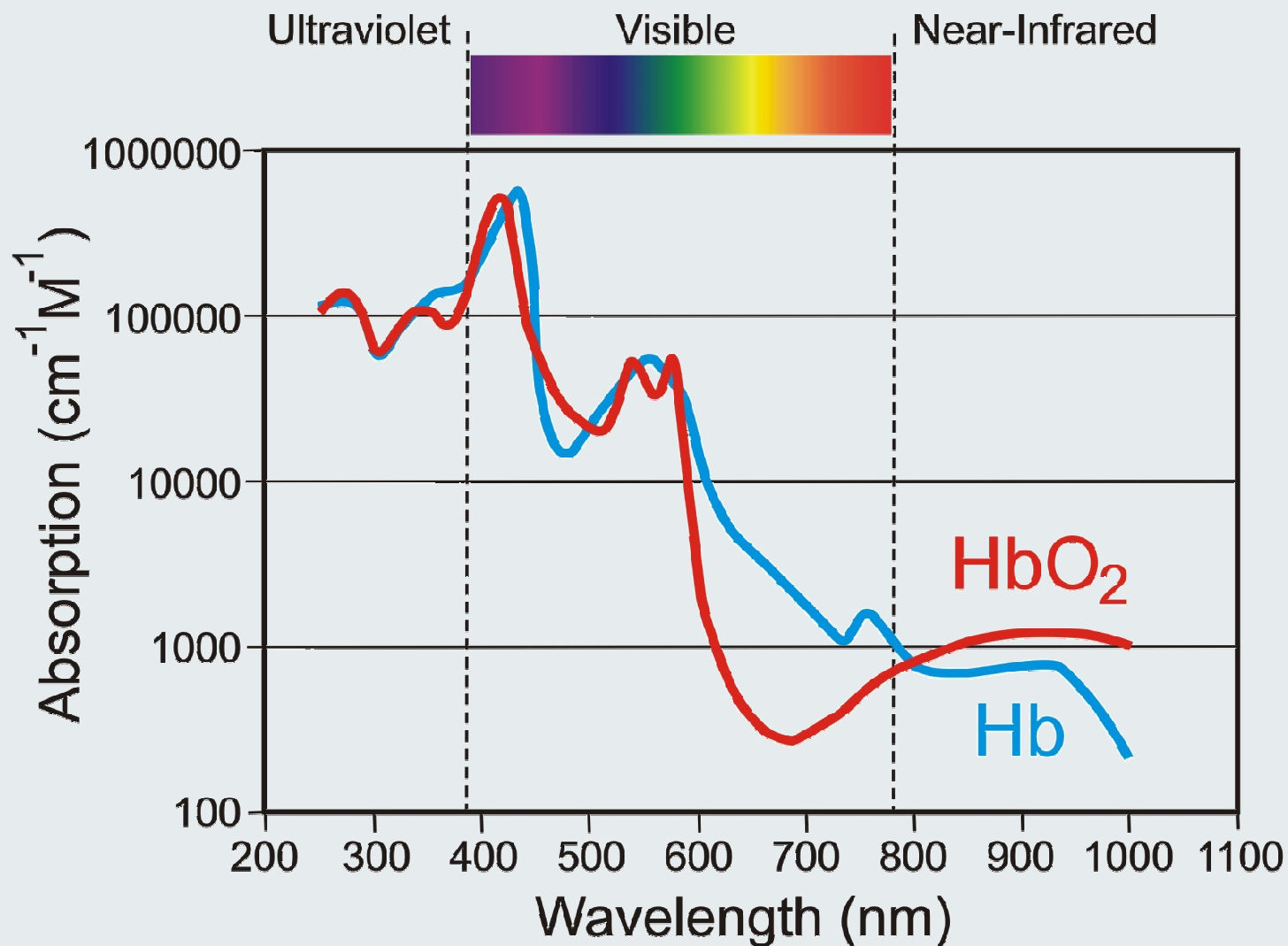


$10^{-14} \text{ W m}^{-2}$

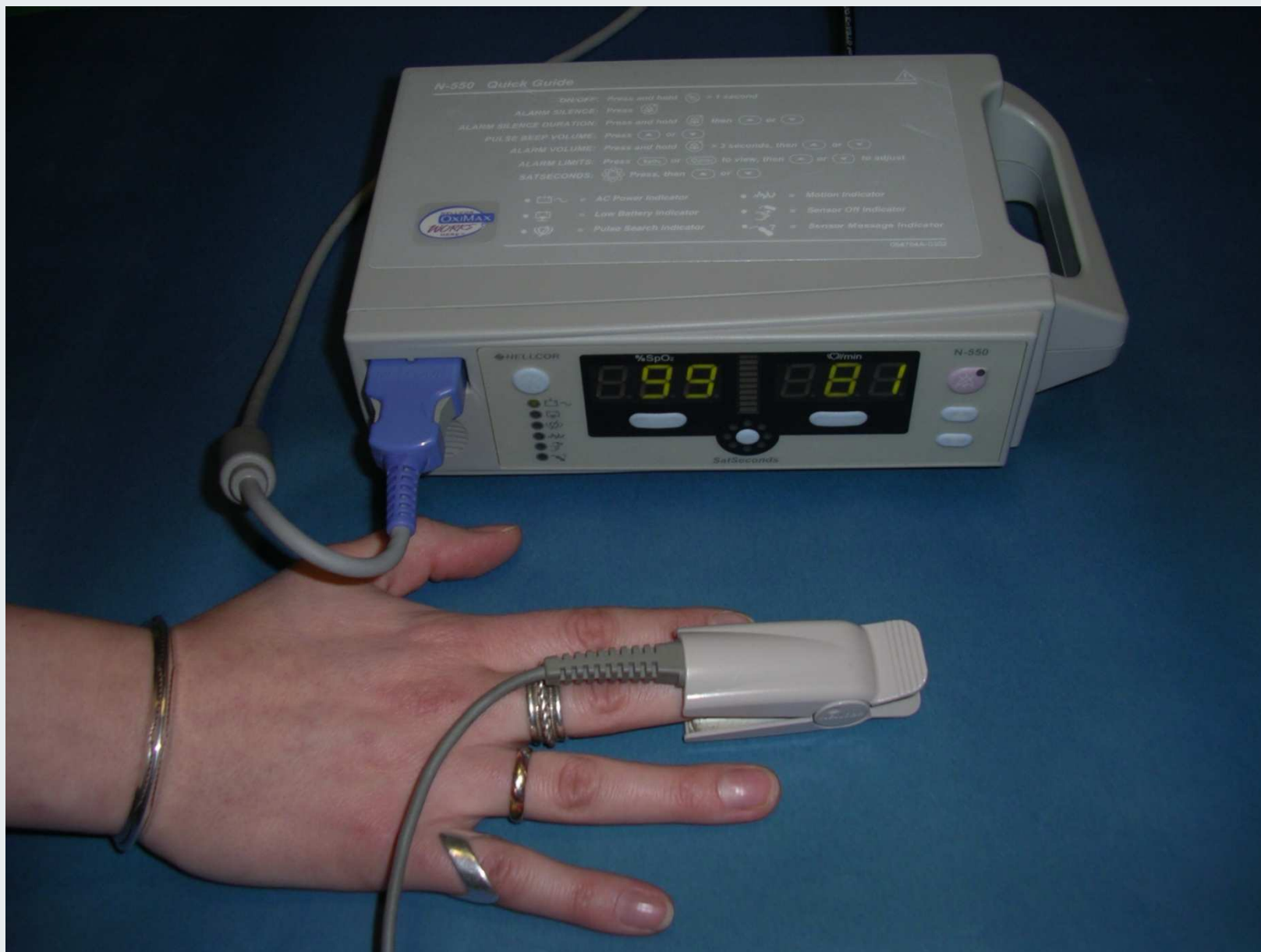
Optical absorption depends on haemodynamics

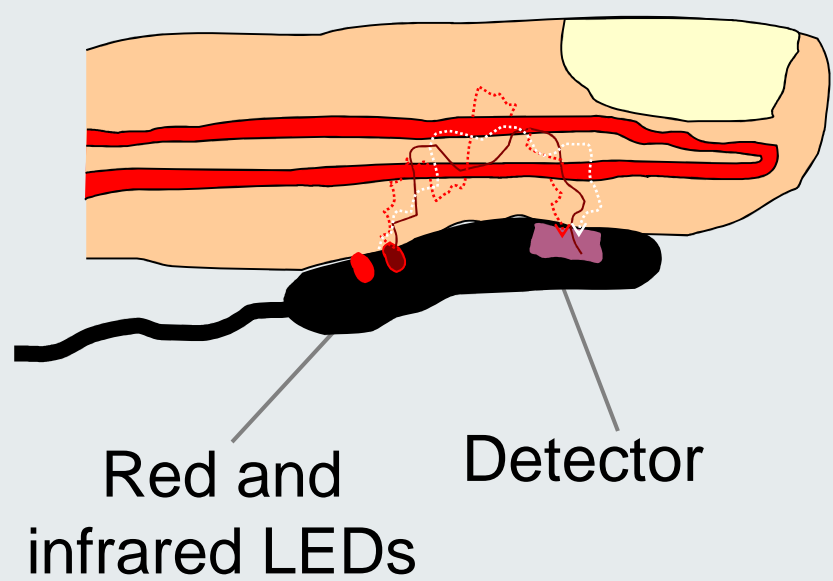
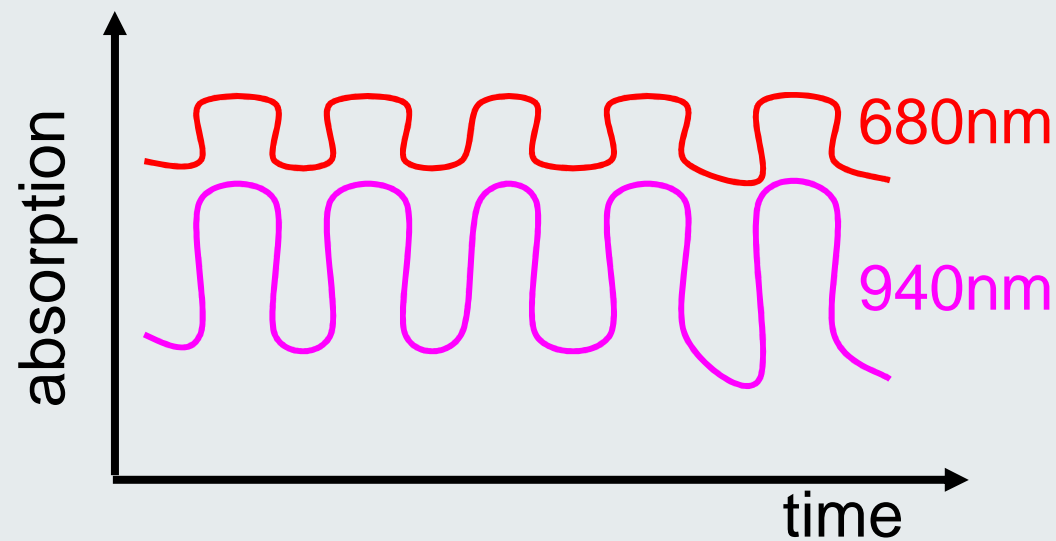


Optical absorption depends on haemodynamics



Pulse oximetry

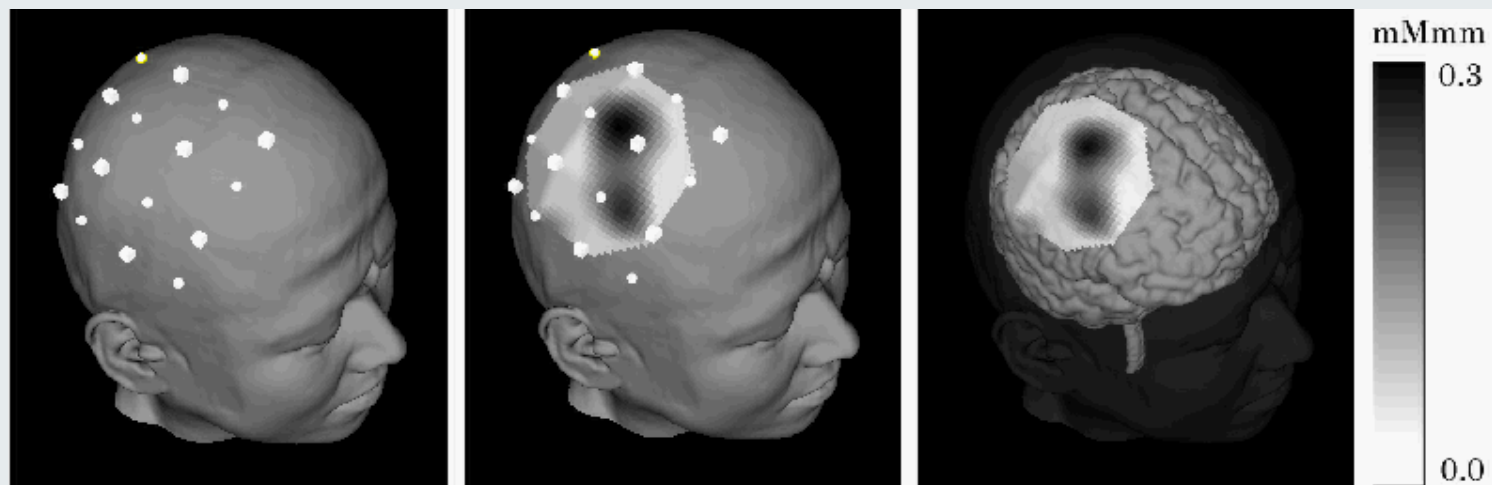




Optical topography of brain function

Hitachi ETG-100

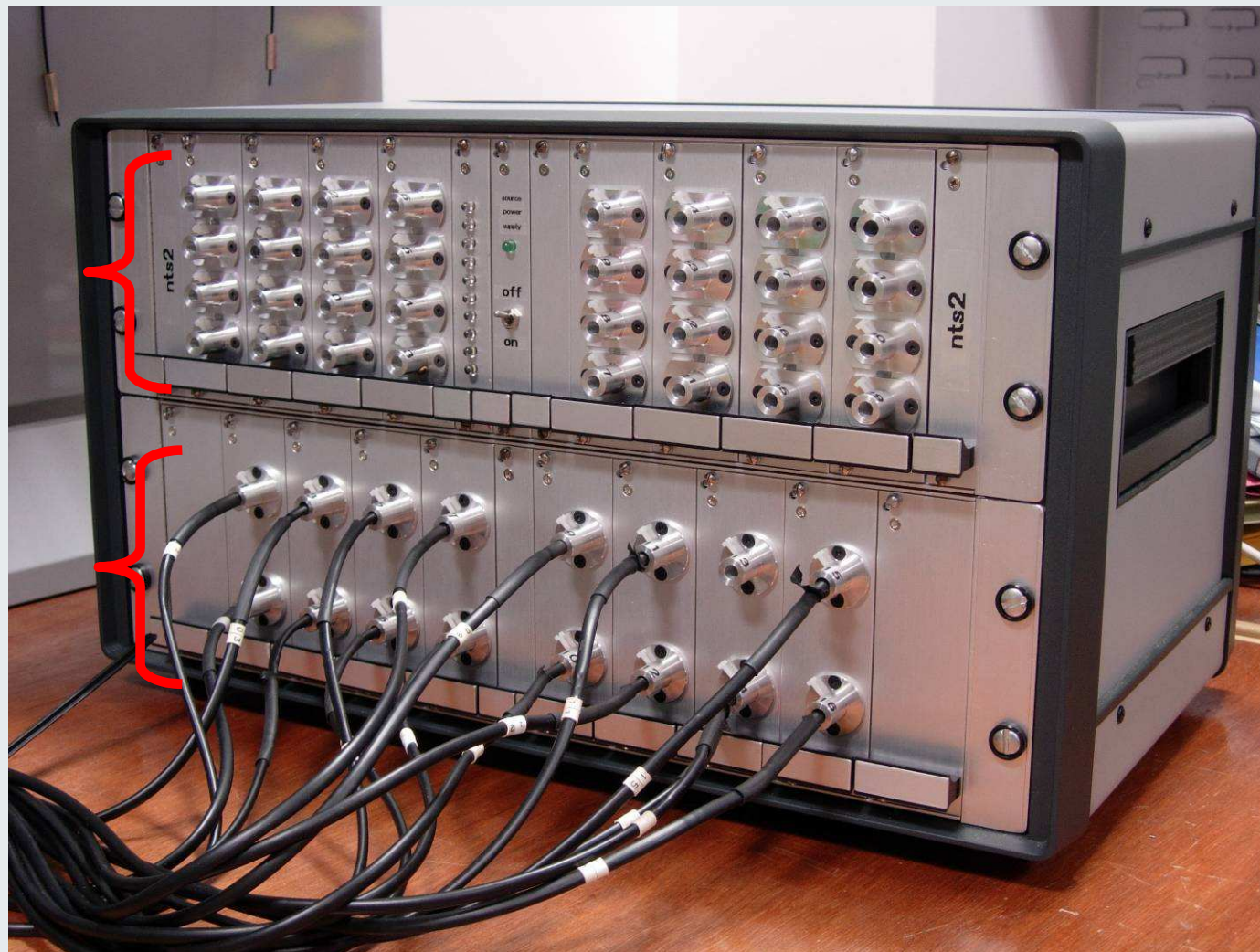
Commercially available for clinical and research studies



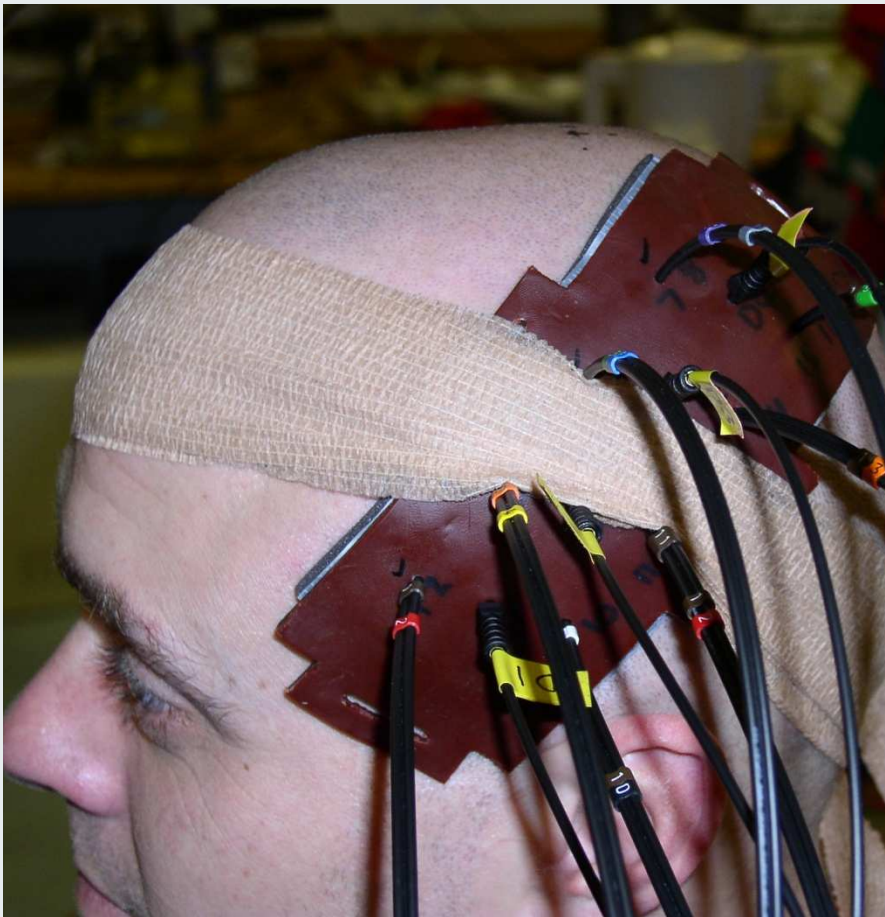
UCL optical topography system

32 laser diodes
 - 16 at 775 nm
 - 16 at 850 nm

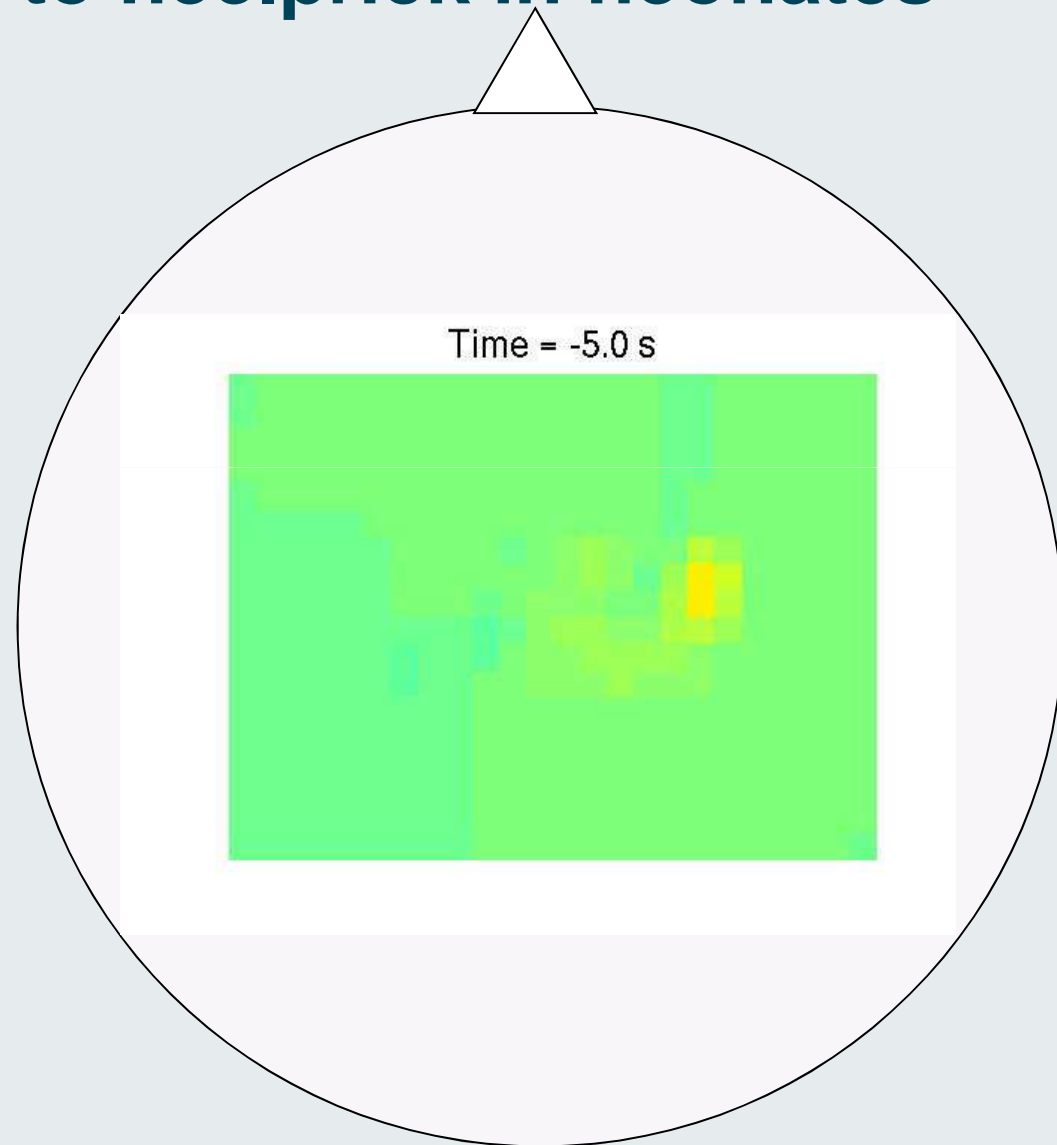
16 detectors



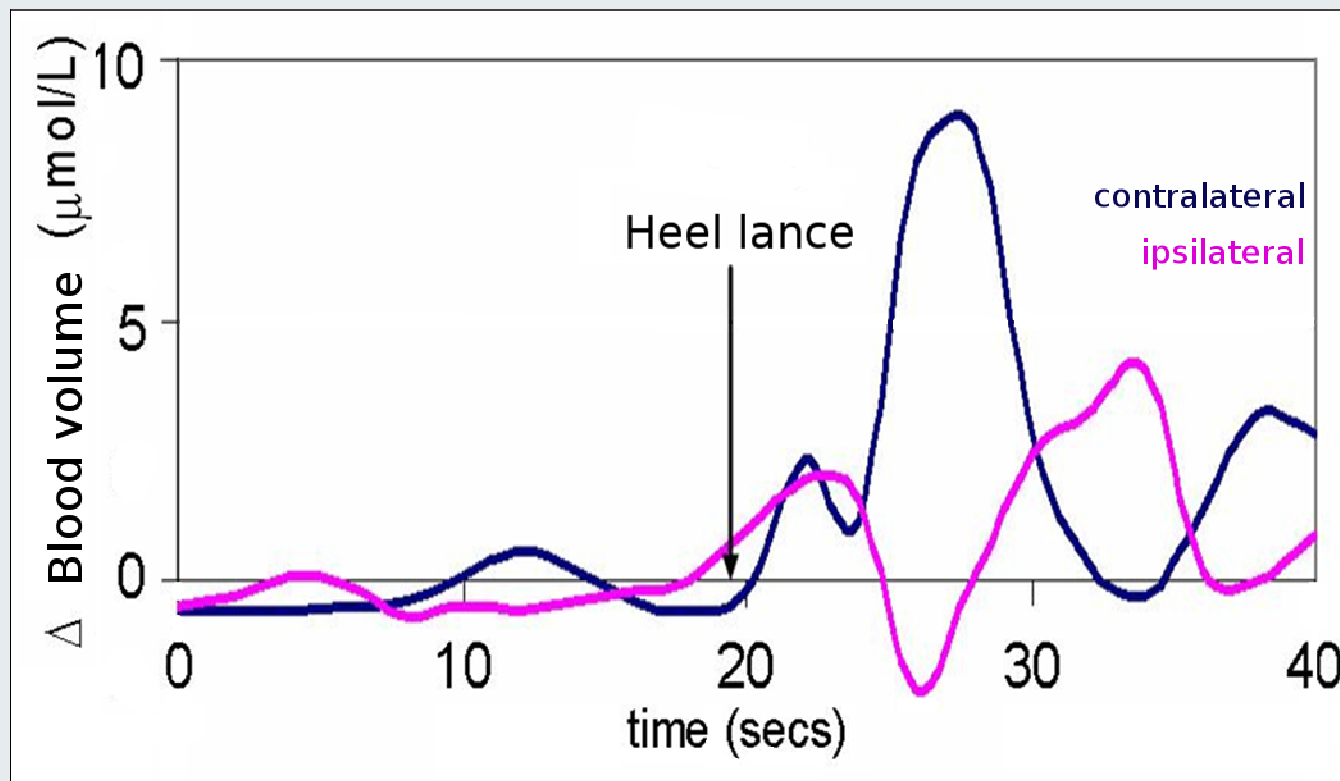
Patient interface



Cortical response to heelprick in neonates

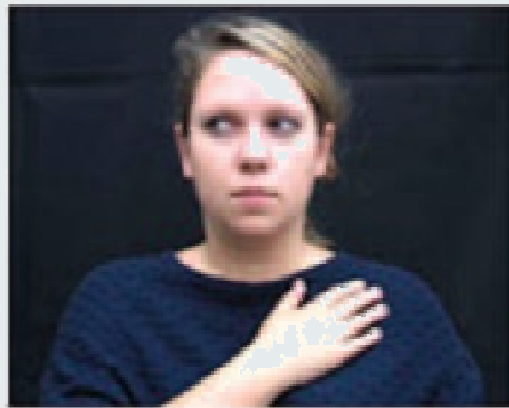


Cortical response to heelprick in neonates



Slater et al (2006)

Imaging brain activity in infants watching videos of human movement

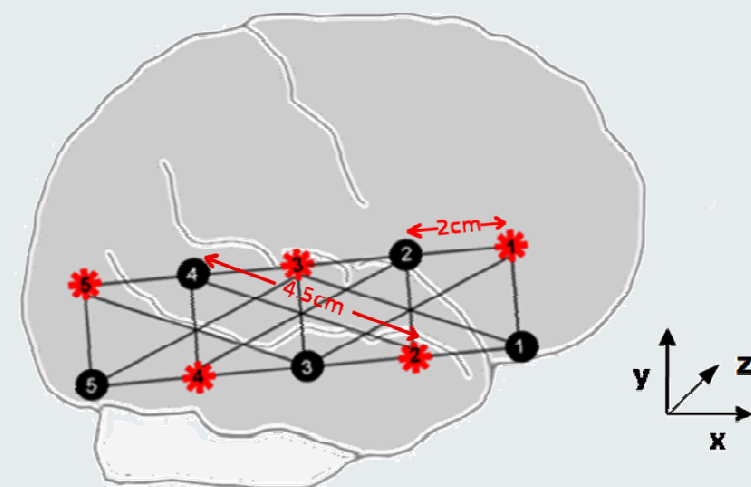


Eye
condition

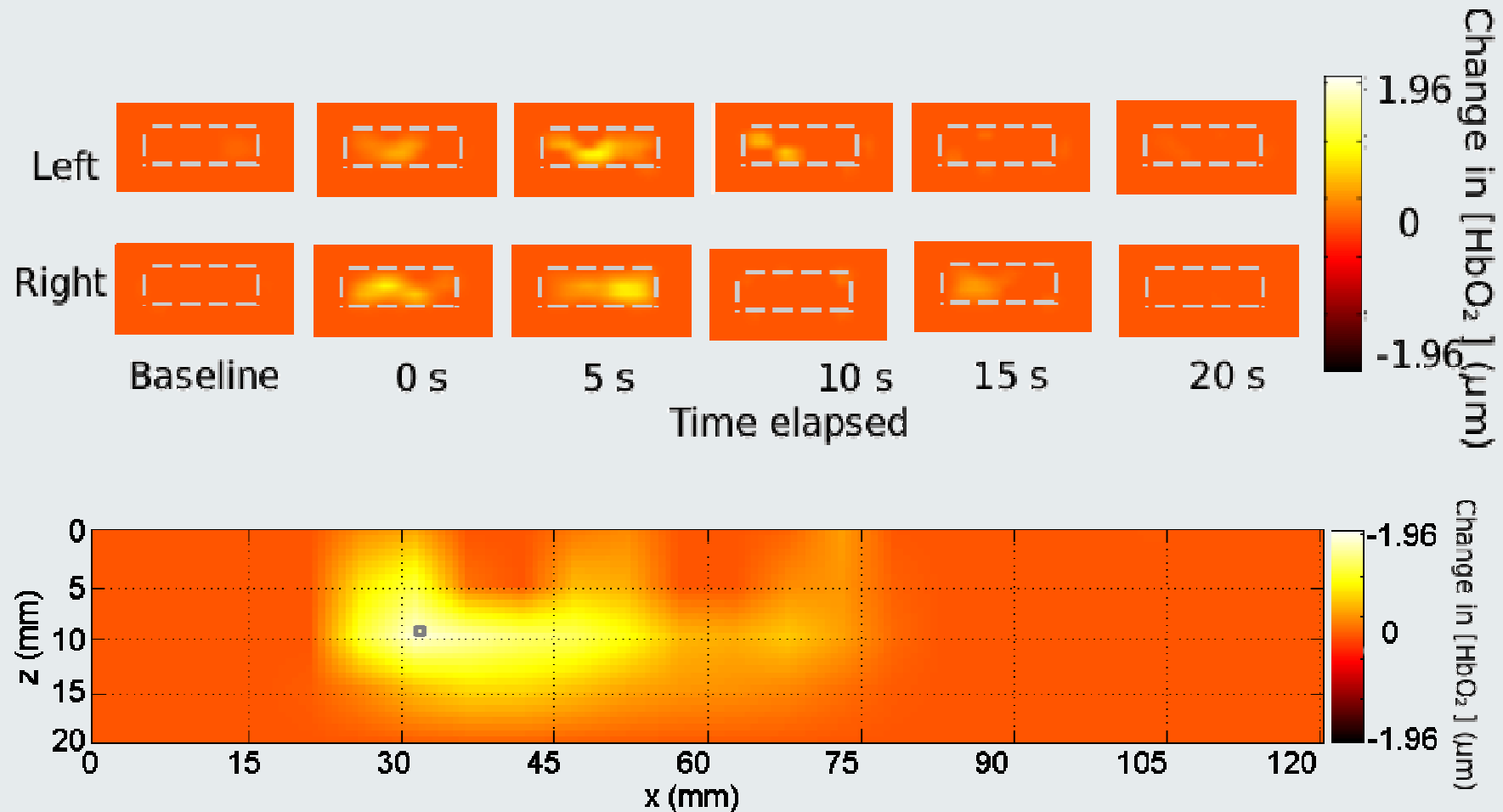
vs.



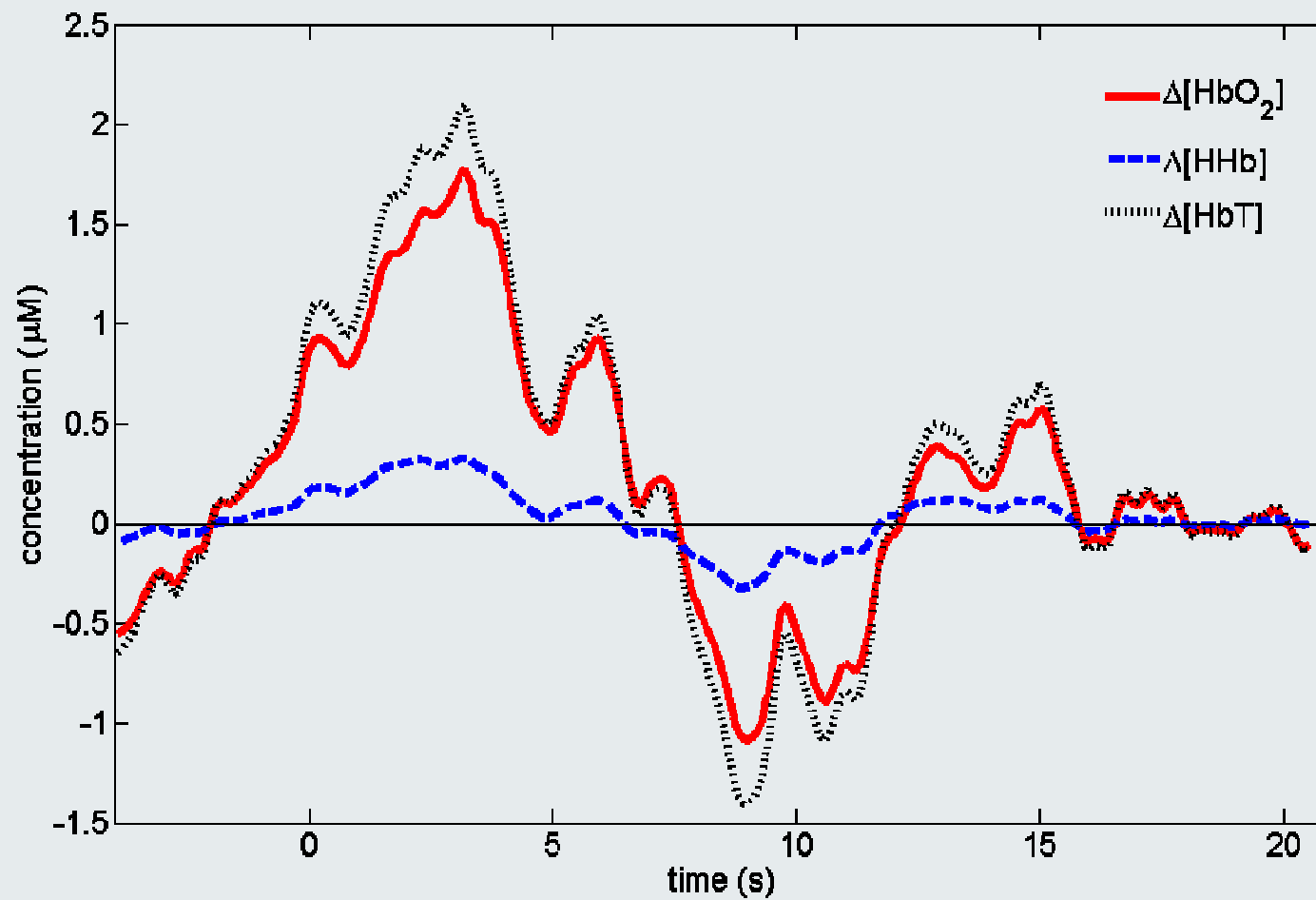
Mechanical
condition



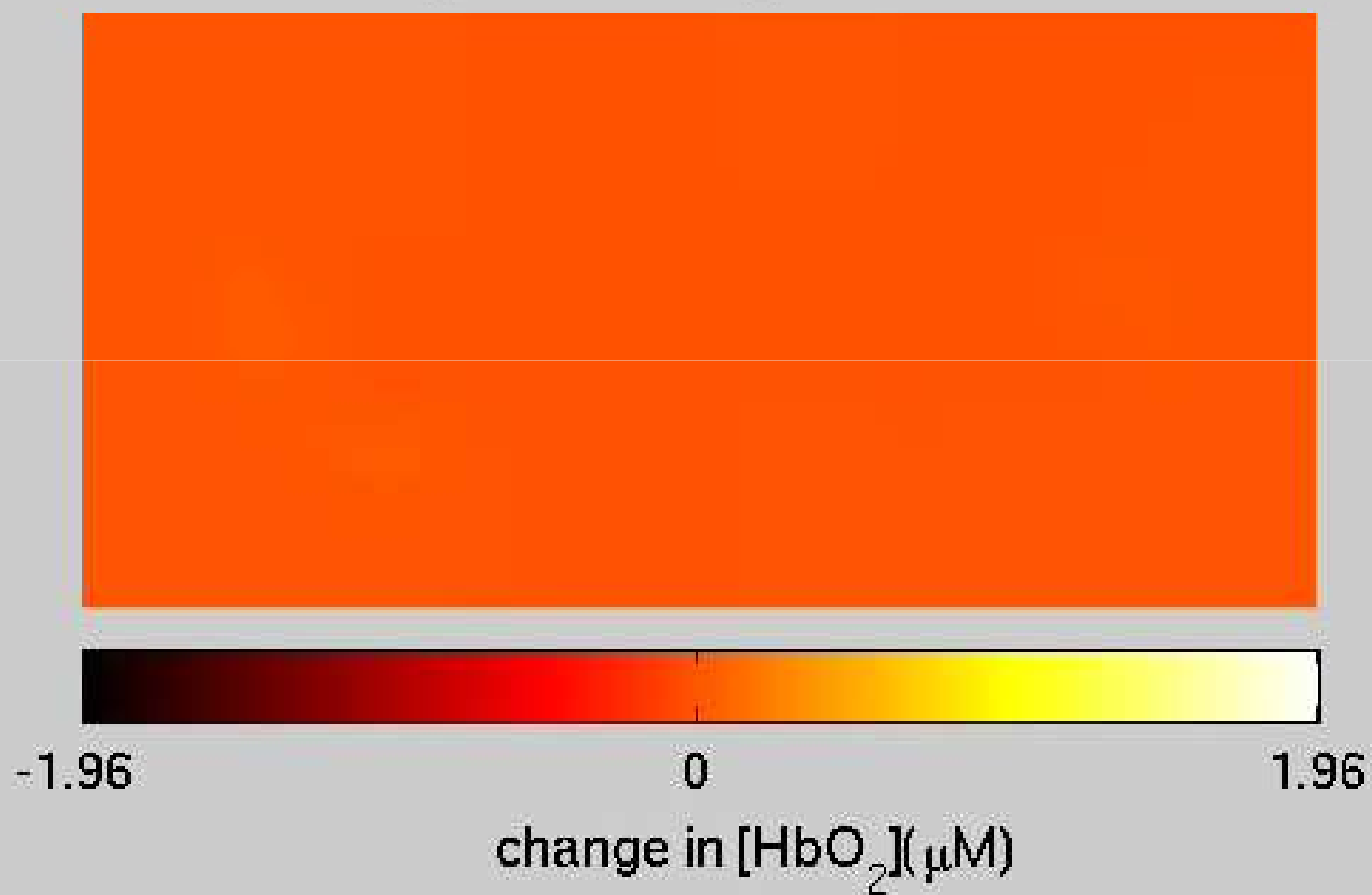
Imaging brain activity in infants watching videos of human movement



Time-course analysis



E right - Time elapsed: -3.9 s.



Optical topography

- Advantages

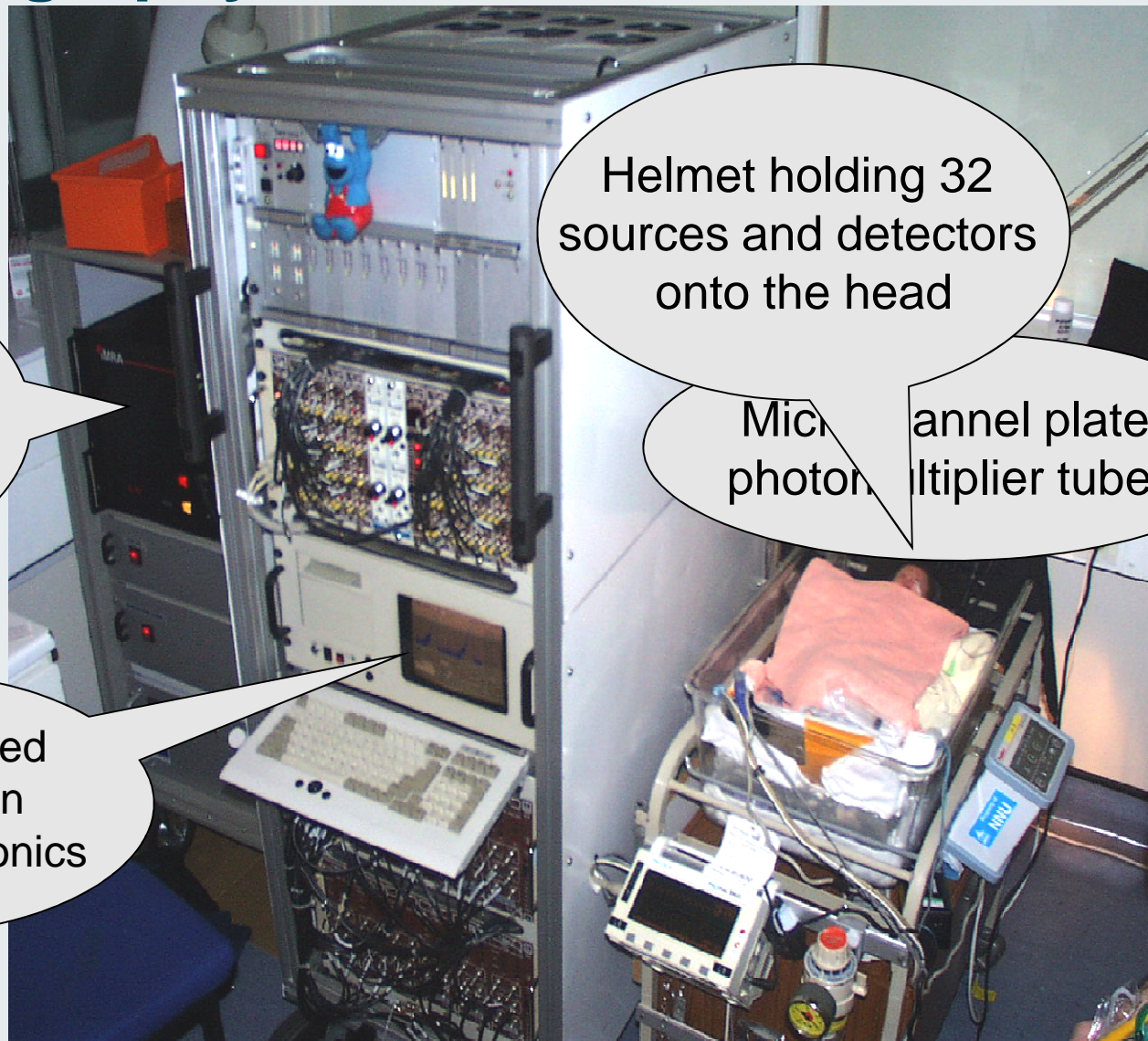
- Functional, low-cost, safe, imaging of moving subjects
- Becoming a standard method for psychology studies

- Disadvantages

- Needs trained, expert user
- Difficult to register activation to anatomy

Optical tomography

Optical tomography

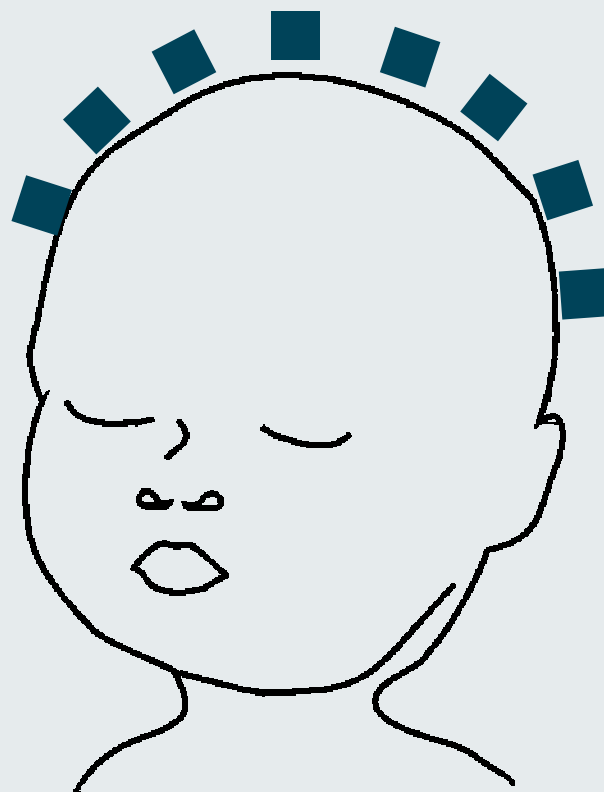
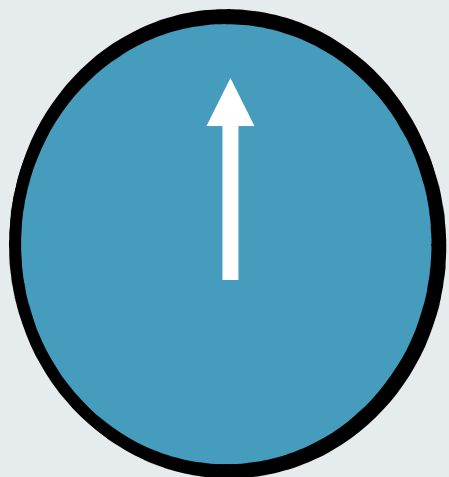


50mW laser.
80 MHz pulses
interlaced at
780 nm and 815 nm

Time-correlated
single photon
counting electronics

Helmet holding 32
sources and detectors
onto the head

Micro-channel plate
photomultiplier tubes



Laser

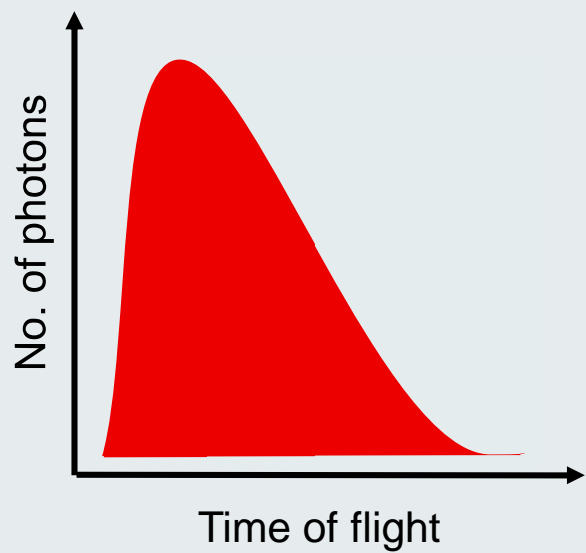


Image reconstruction

Optical tomography is a hard problem:

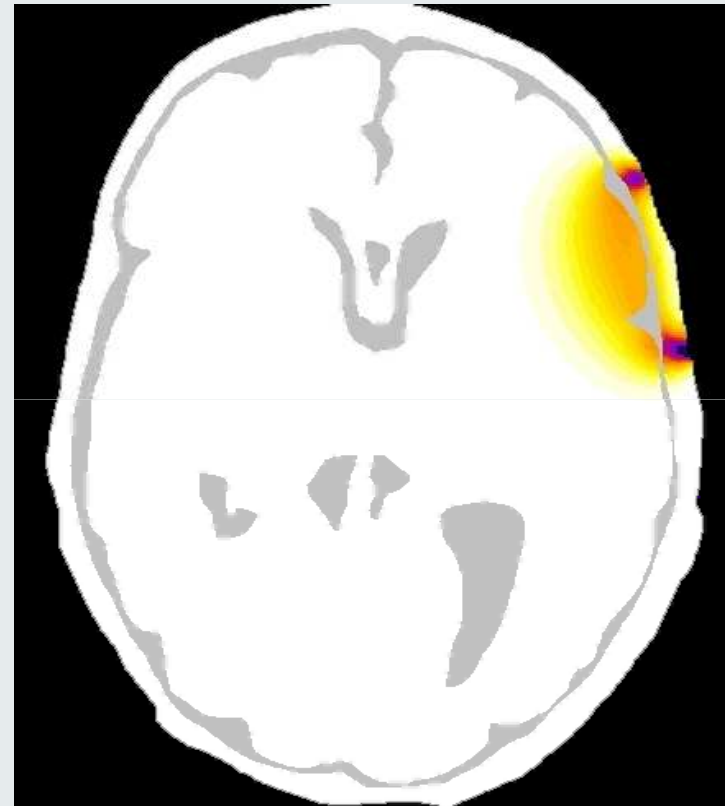
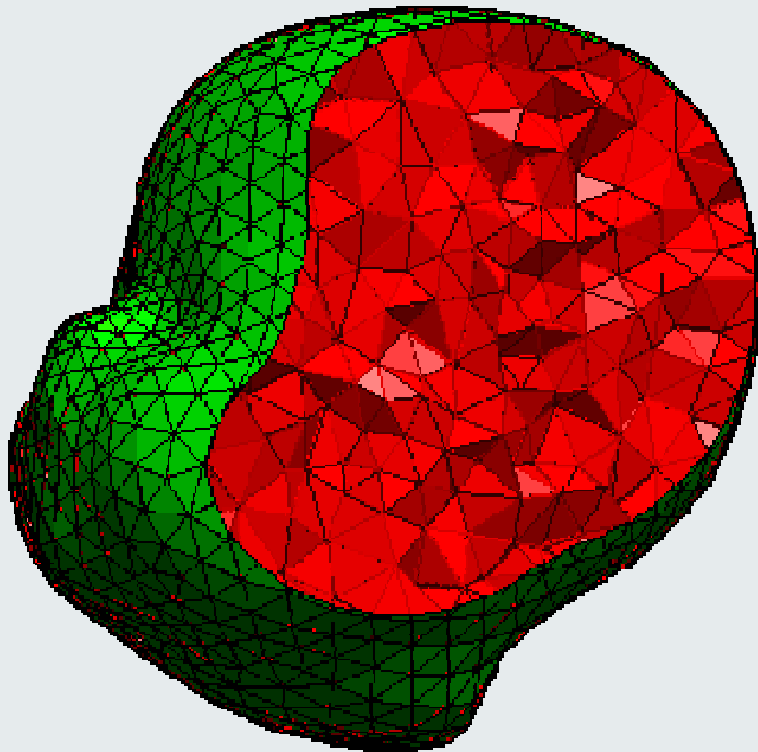
- Underdetermined
 - More unknowns than measurables
- Ill-posed
 - Small changes in optical properties may lead to large changes in data
 - May be many solutions

Arridge et al

1988-2012

www.medphys.ucl.ac.uk/~martins/toast

Forward model

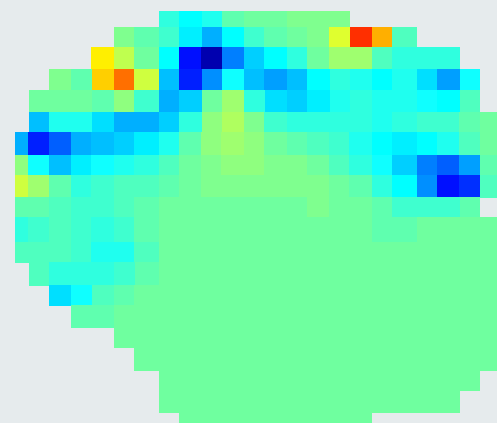
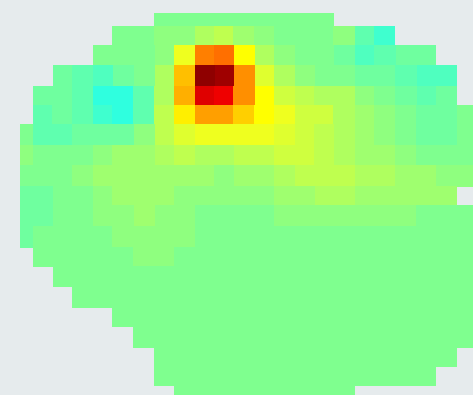
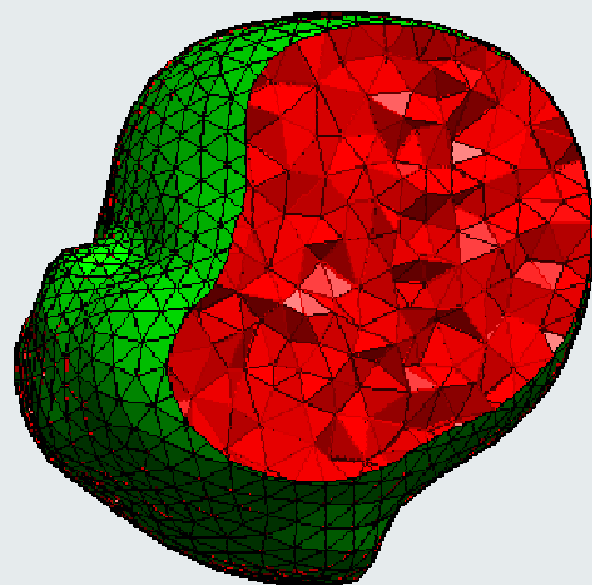


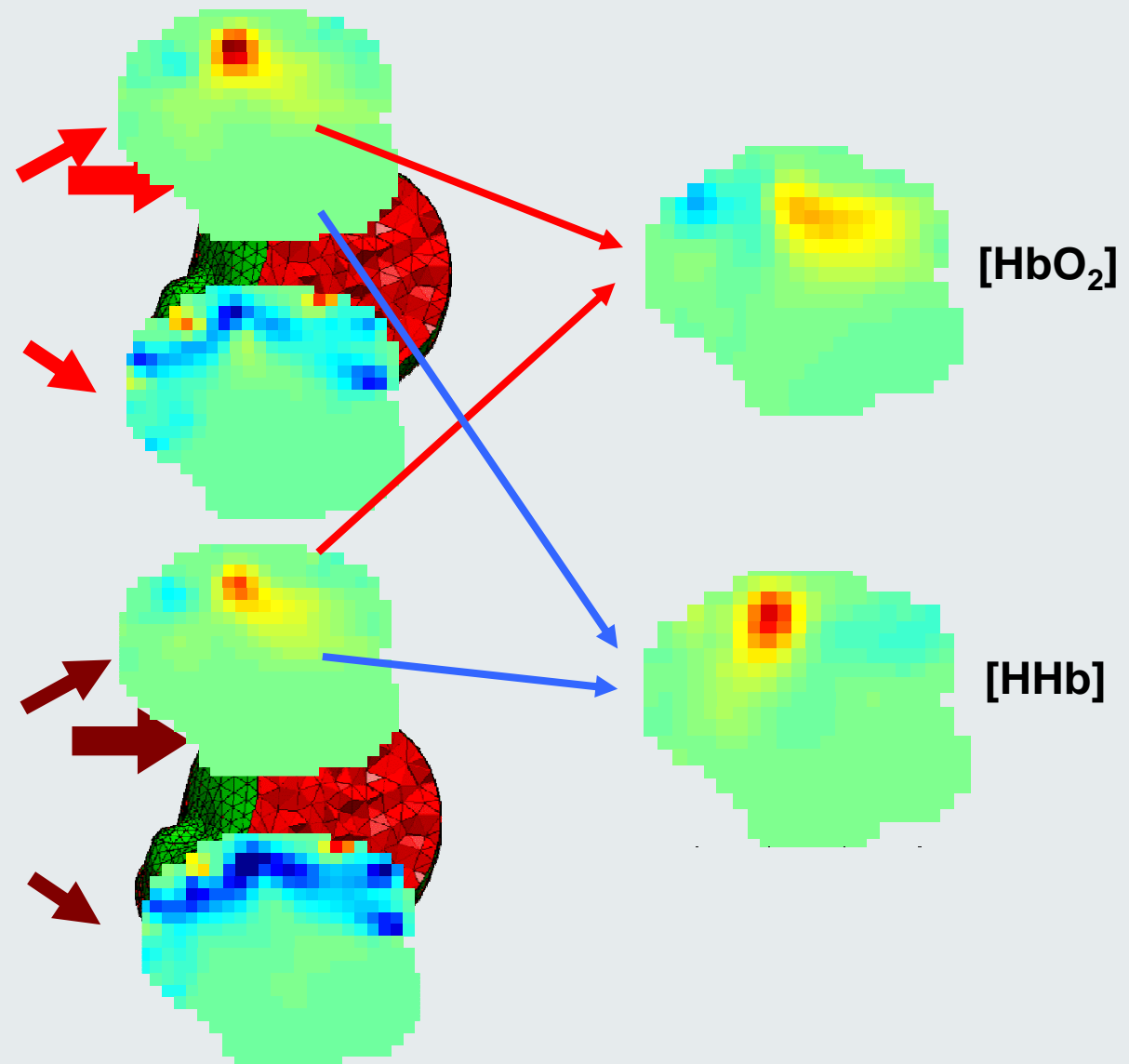
Sensitivity:

Change in measurement for a given change in optical properties

Image reconstruction: non-linear





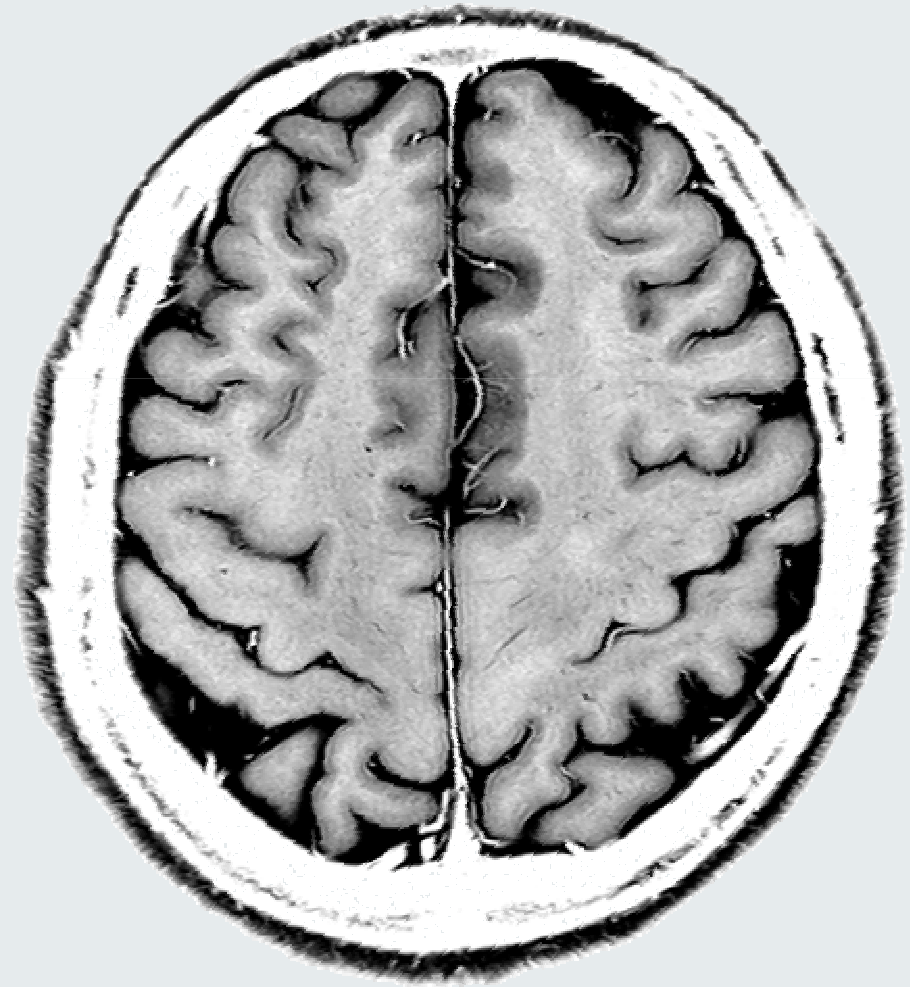


Optical tomography of the neonatal brain

Ultrasound



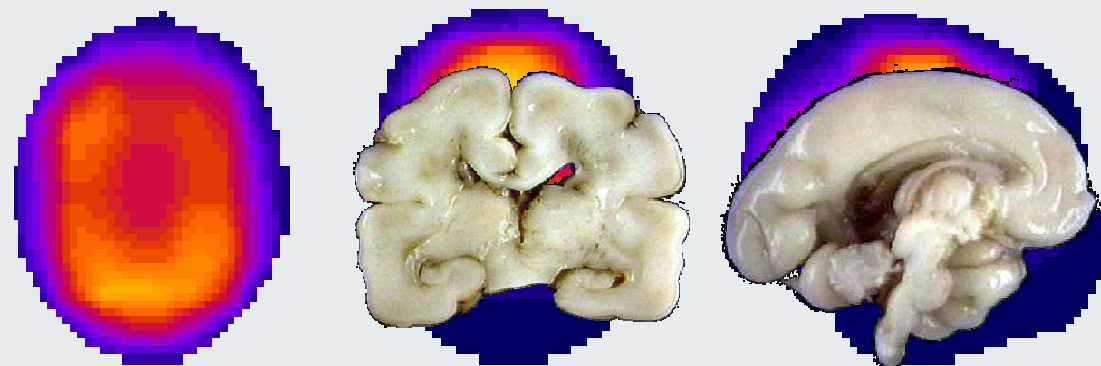
MRI



Patient helmet

Optical images of normal brain

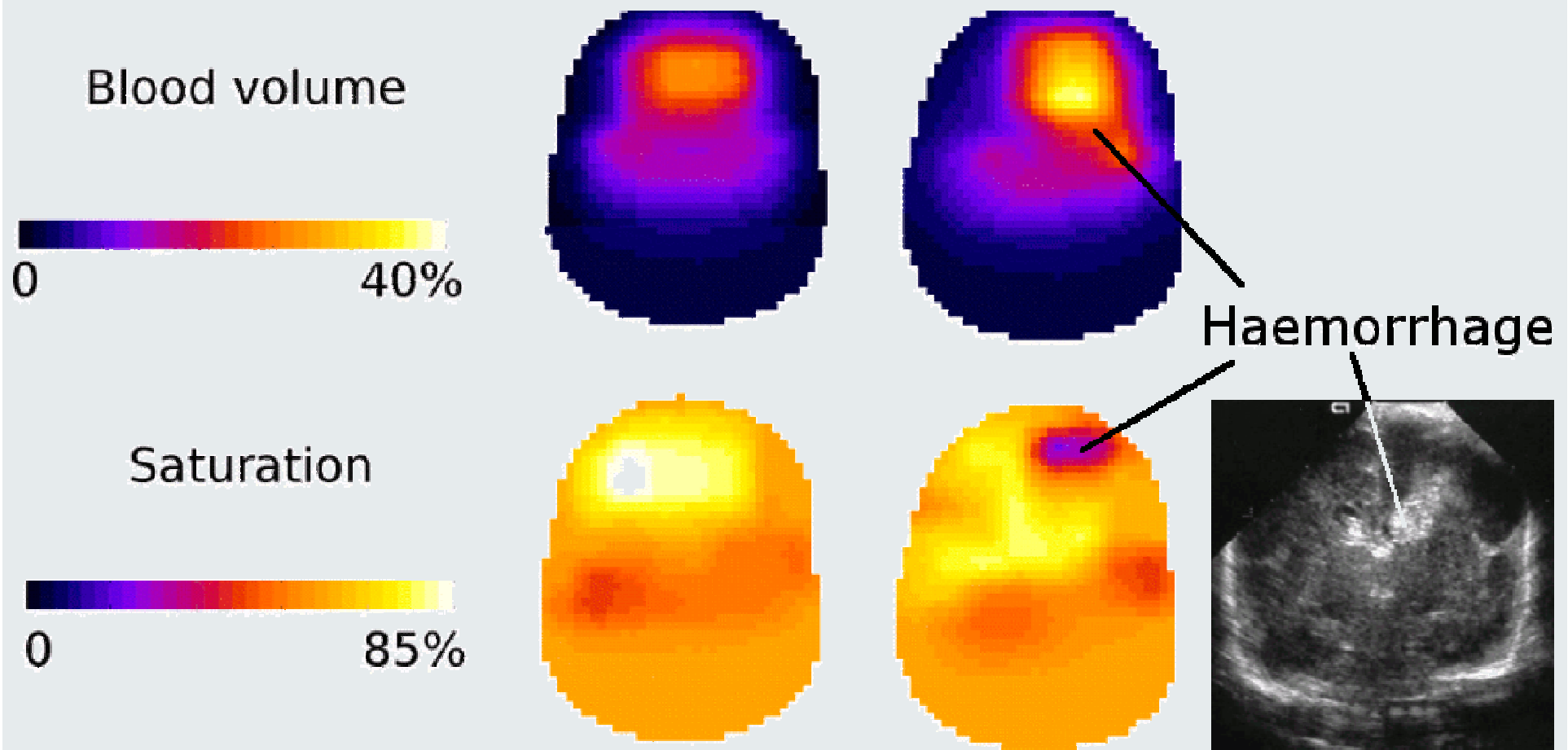
Optical image:
Anatomical slices
of pre-term brain



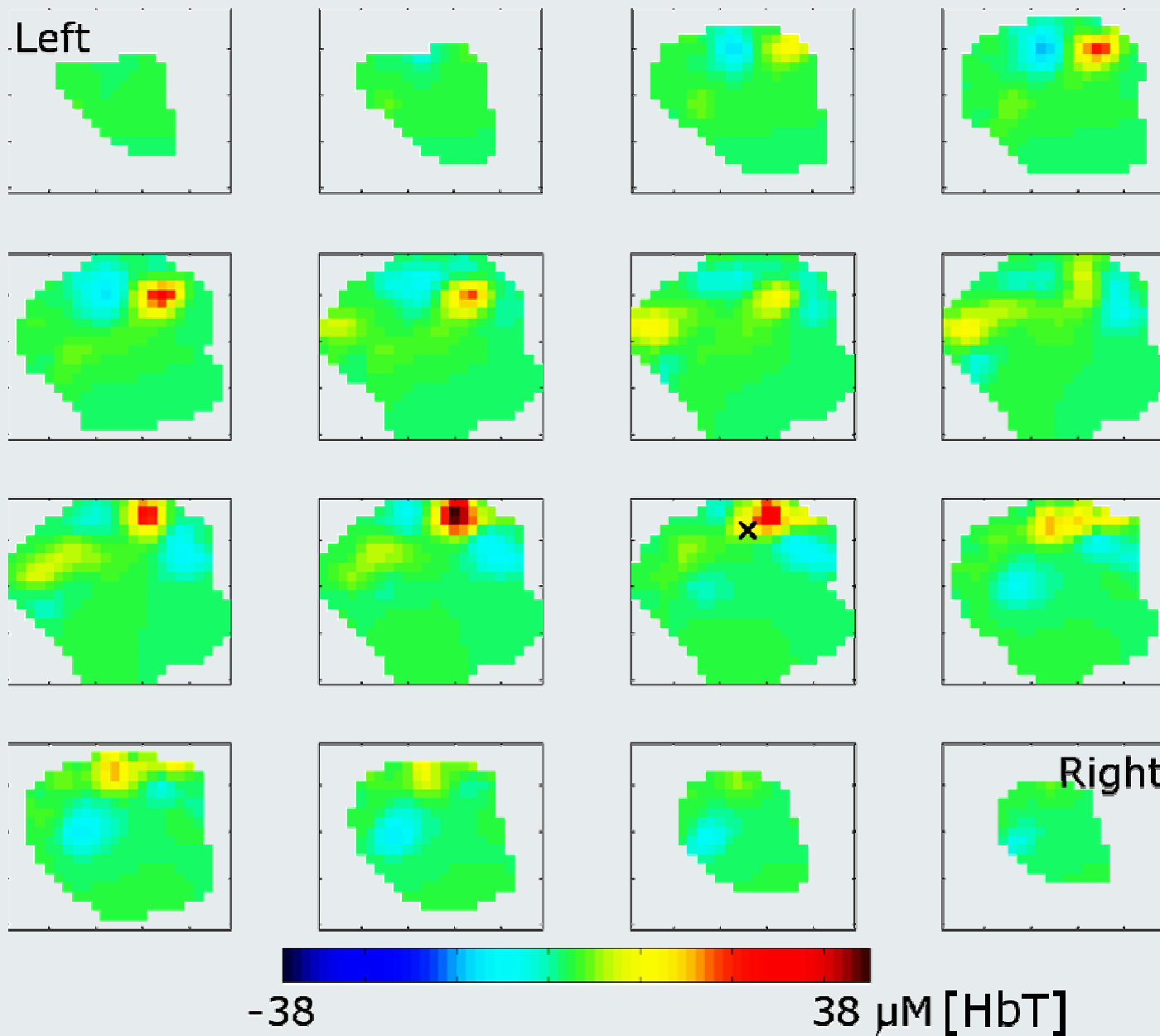
PET image:
of neonatal brain (1985)



Static imaging of haemorrhage



Motor evoked responses



Clinical use of optical tomography

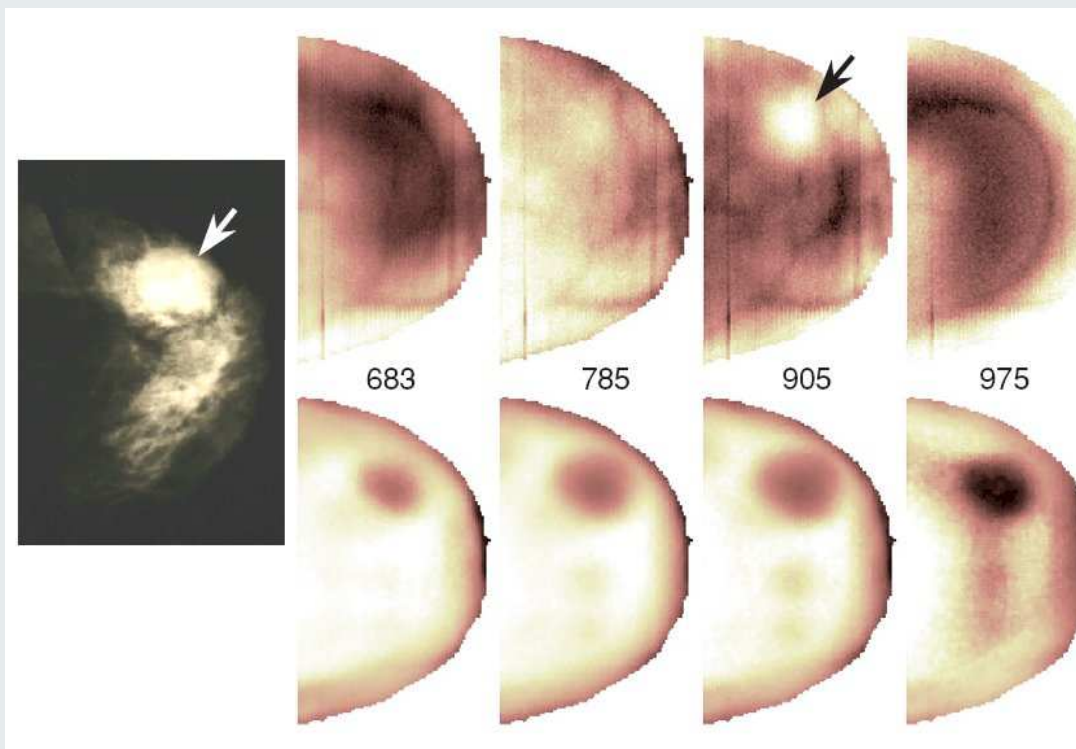
- Advantages
 - Functional, low-cost, safe, bedside imaging
 - Quantitative images
- Disadvantages
 - Difficult, unreliable, unrepeatability
 - Poor localisation
 - Non-quantitative images

Optical tomography of the breast

Compressed breast

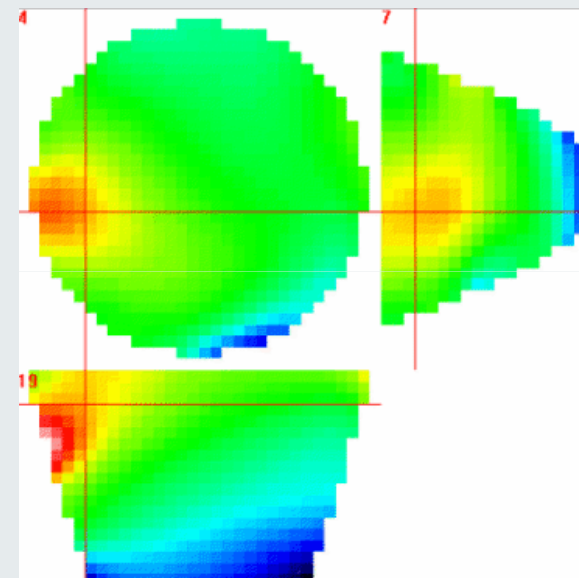
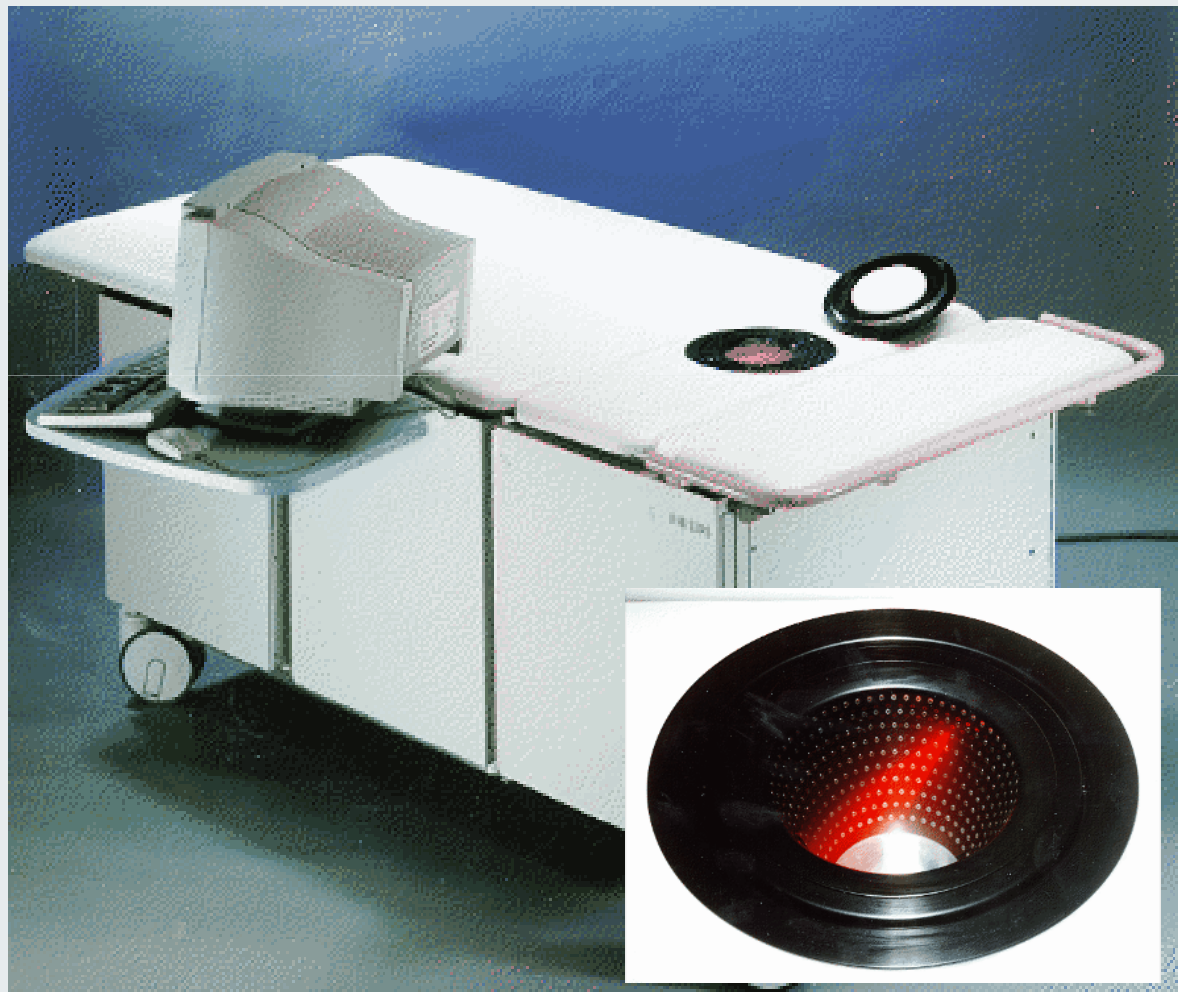


Berlin



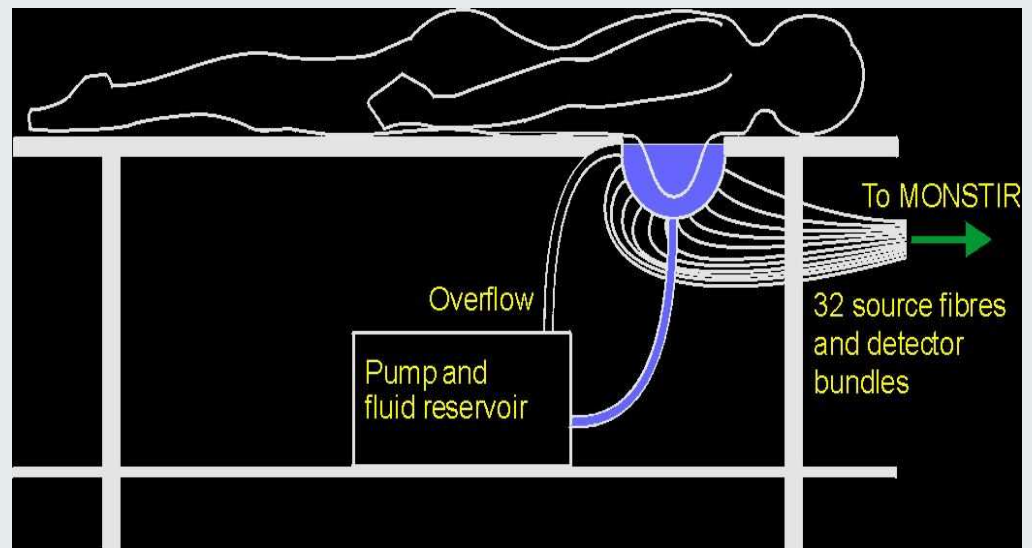
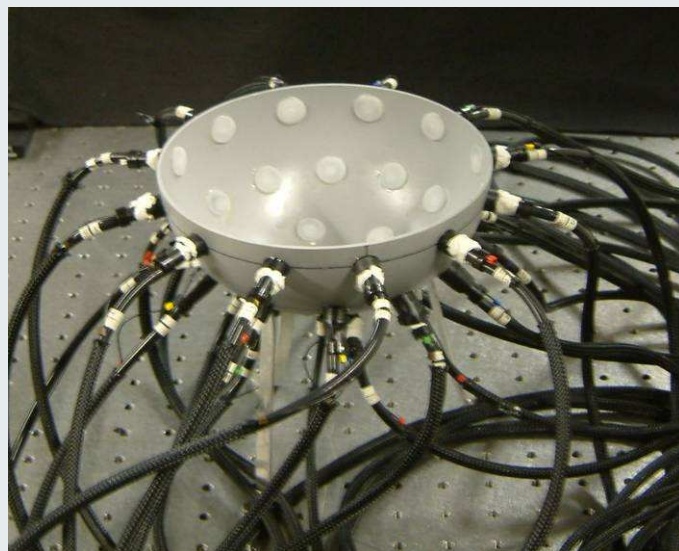
Milan

Uncompressed breast imaging by Philips

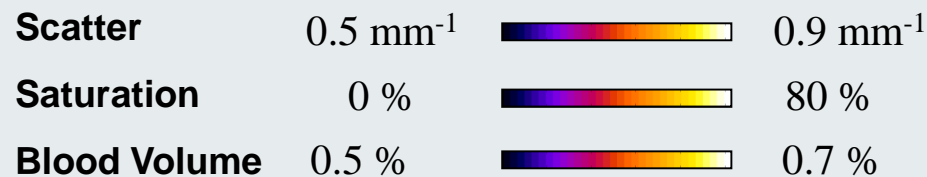
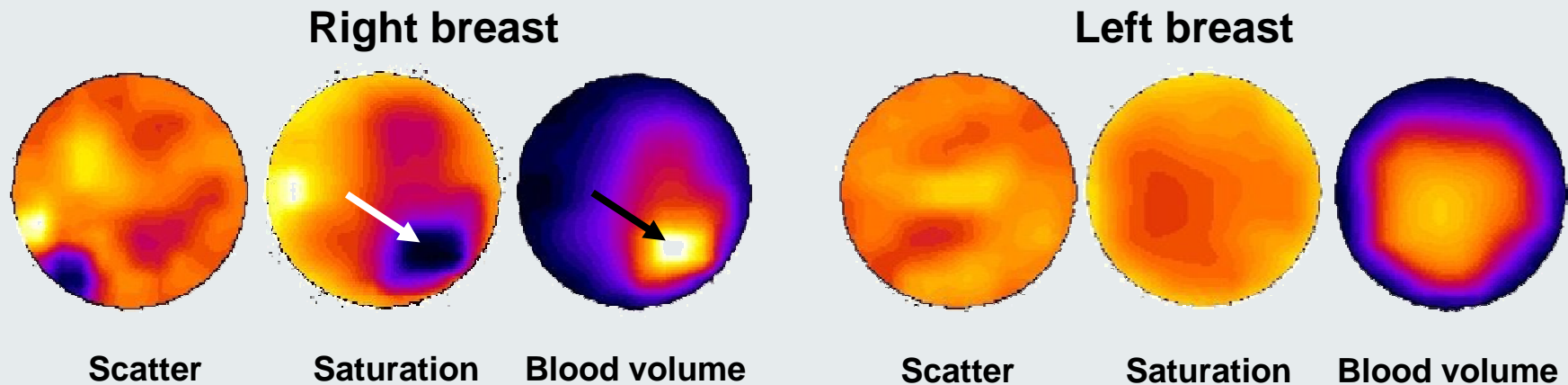


3D image of tumour

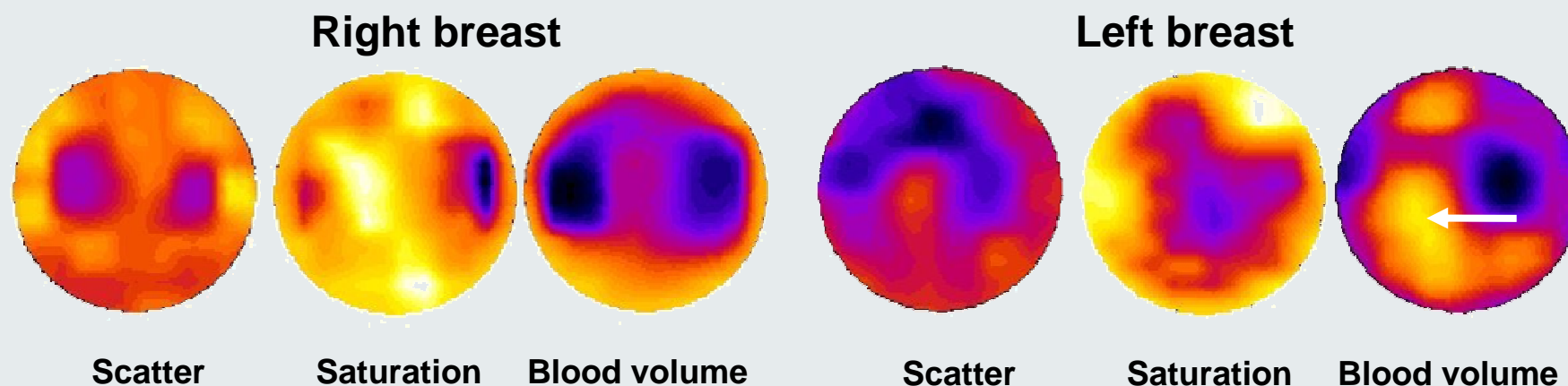
UCL optical mammography scanning table






48 year old women with fibroadenoma in right breast.



45 year old women with carcinoma in left breast.



Scatter	0.6 mm ⁻¹		1.4 mm ⁻¹
Saturation	33 %		87 %
Blood Volume	1.4 %		2.3 %

Optical mammography at UCL

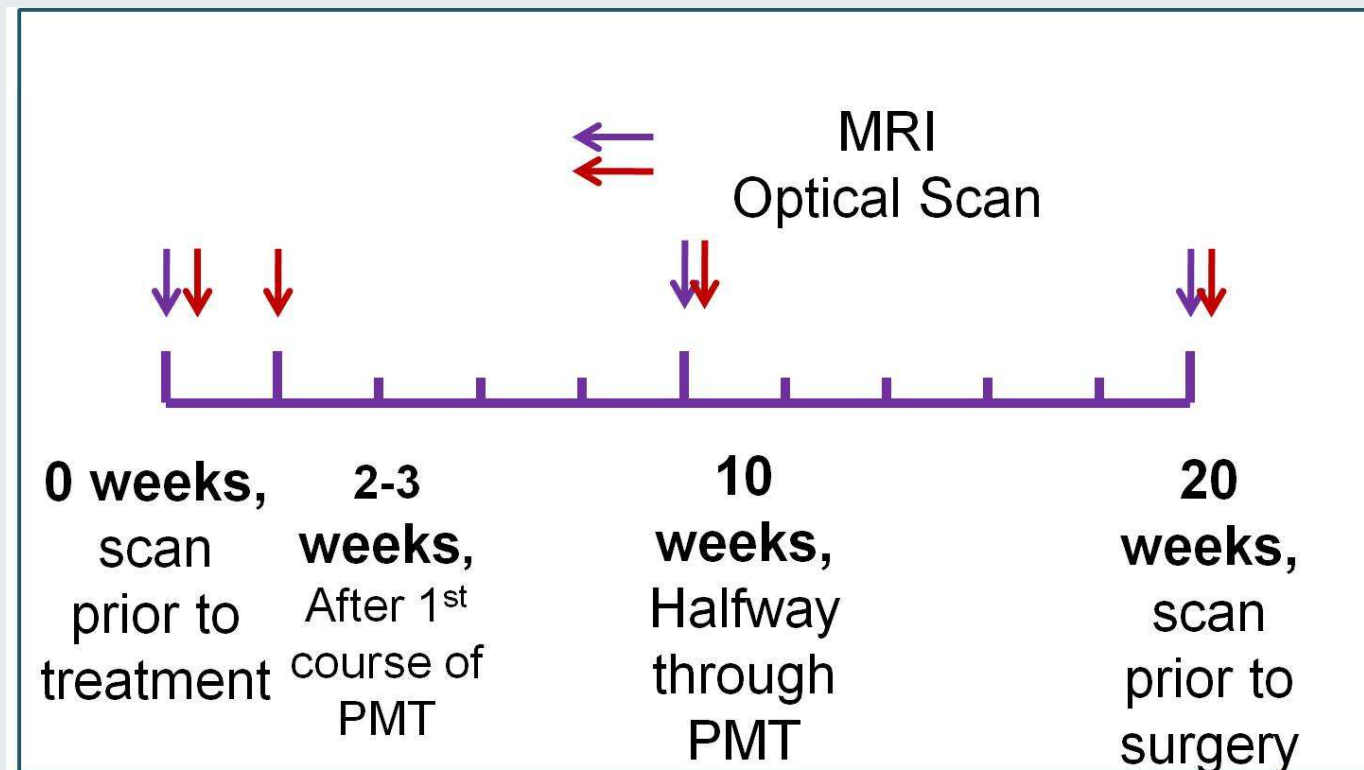
- >50 patients
- Malignant tumours and cysts seen reliably
 - Sensitivity 64%
 - Specificity 98%
- Fibroadenomas and other benign conditions less visible
 - Sensitivity: 57%
 - Specificity: 88%

Worldwide optical mammography

- >2000 patients.
- ~12 centres, >12 systems
- For all lesions:
 - Sensitivity: 88%
 - Specificity: 89%

The Plan

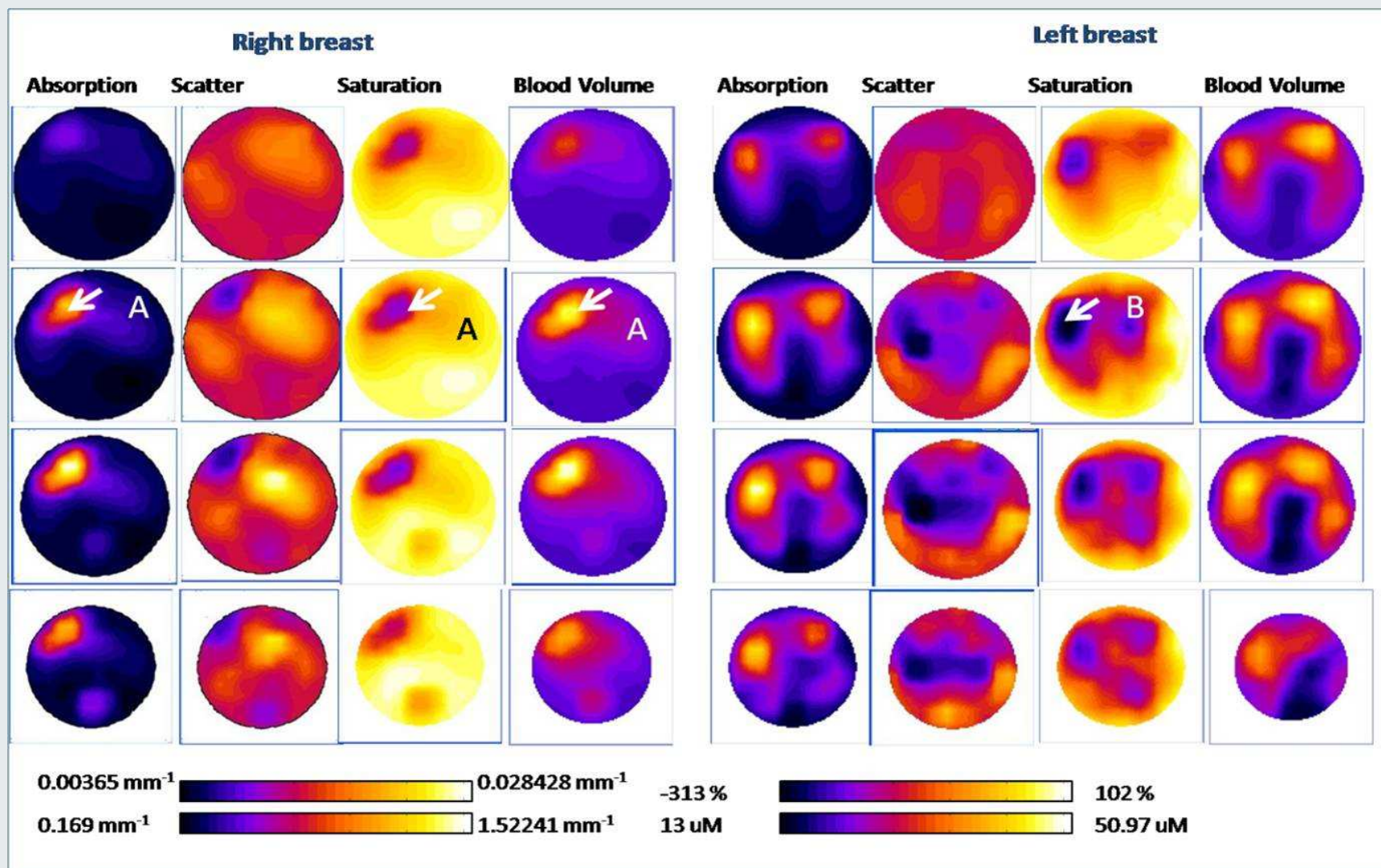
Image 50 women with breast cancer tumours >10 mm undergoing neoadjuvant therapy to assess tumour response to treatment.



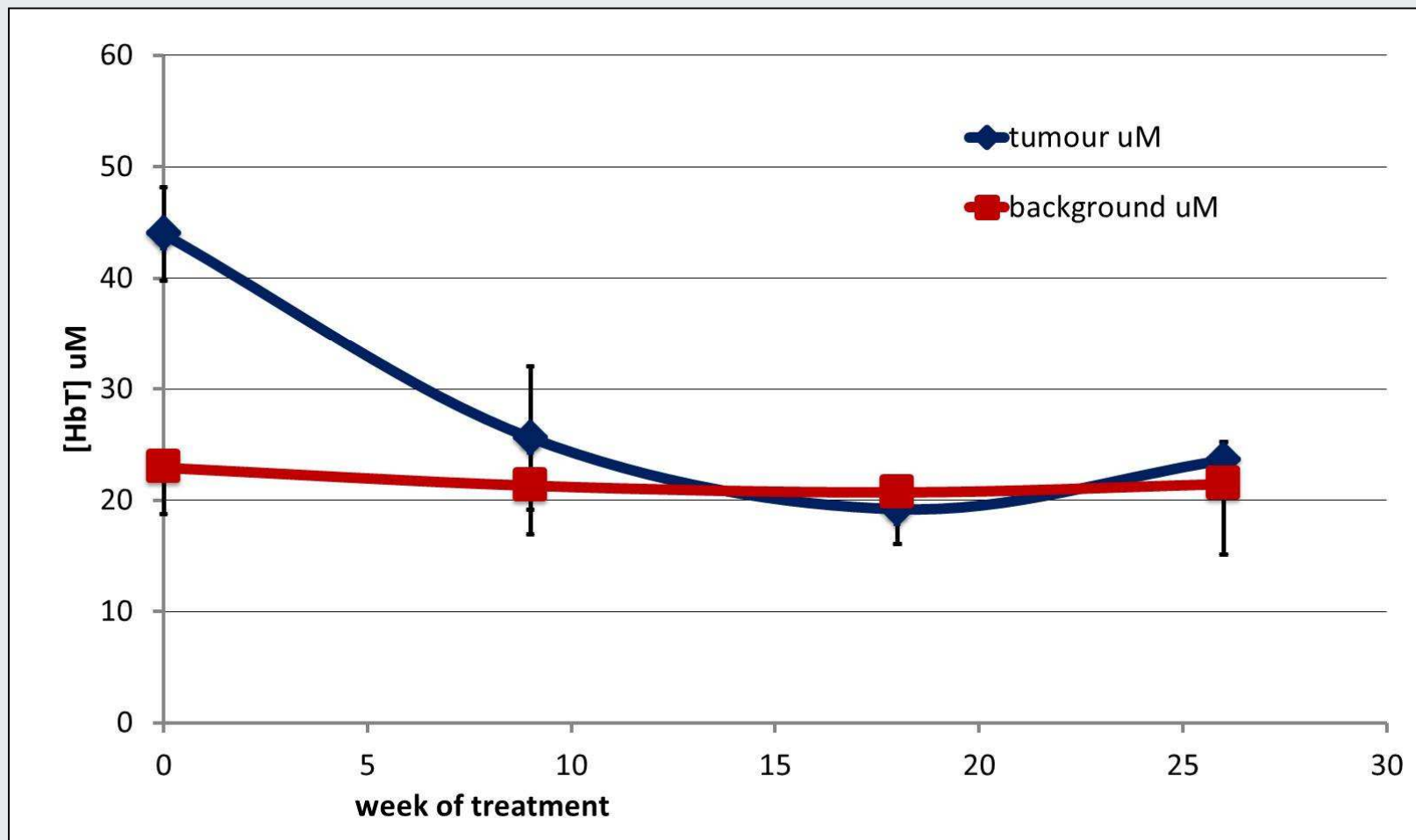
Case Study 1

- 45 year old woman with Grade II Carcinoma in right UOQ
- Lesion ER Positive (7/8), HER2/neu Negative
- Treatment: epirubicin and cyclophosphamide, then docetaxel
- Clinical Findings
 - Initial MRI lesion- 26 x 21 x 34 mm tumour, Type II enhancement
 - Mid MRI treatment scan - 34x26 - no enhancement
 - Final MRI scan - 19 x 14 mm - no enhancement
 - On completion - Good response to treatment with no residual enhancement, localised wide local excision

Case Study 1



Case Study 1



Summary

Lesions show increased [HbT] and absorption, and sometimes decreased SatO₂, compared to background.

Changes in optical properties occur after ~2 weeks.

Patients with complete response of MRI and biopsy show return to background [HbT].

Changes are seen in background tissue, possibly due to systemic treatment effects.

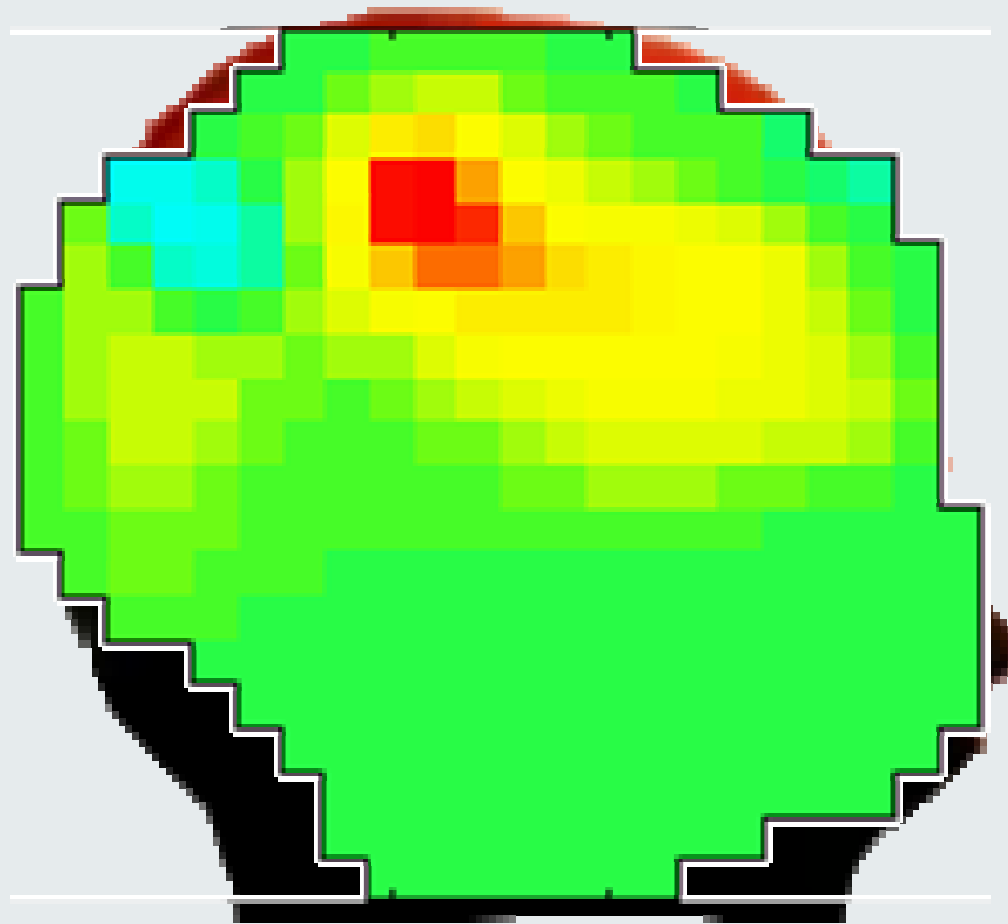
Optical mammography

- Advantages

- Functional, low-cost, safe, comfortable imaging
- Quantitative images of physiology
- Suitable for repeated studies

- Disadvantages

- Poor spatial resolution
- Difficult, unreliable, unrepeatability



Thanks to

Jem Hebden
Simon Arridge
Teresa Correia
Nick Everdell
Louise Enfield
Salavat Magazov
Martin Schweiger
Marta Varela

John Wyatt
Judith Meek
Topun Austin
Michael Douek

...and all other collaborators

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