Optical detection of skin reactions

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LETI-DTBS

Outline

- Skin tests for tuberculosis detection
- Principles of diffuse spectroscopy
- Instrument
- Reconstruction method
- Results
- On-going work and discussion

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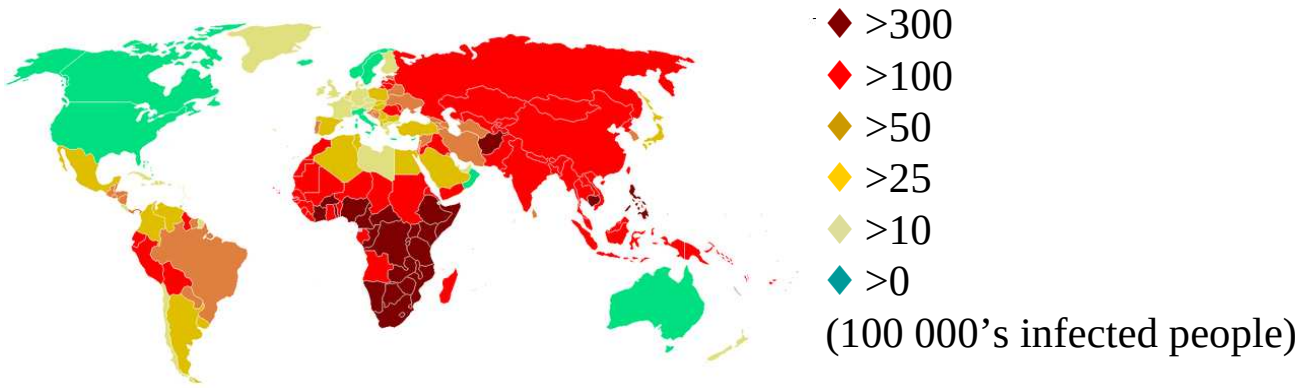
Introduction

- 2 billion people infected with latent tuberculosis
- Social disease
- Current skin test (Mantoux test): 48 to 72h



Challenges for new skin test:

- Rapid (6 to 8h)
- Reliable and quantitative
- Portable and low cost

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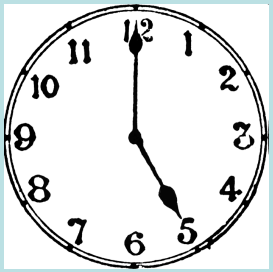
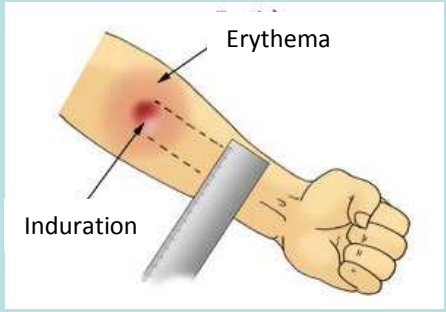
Introduction

- Current skin test (Mantoux test): 48 to 72h

Intradermal tuberculine injection



48-72h



Measurement of the induration size

Drawbacks of Mantoux technique:

- Operator dependent
- Operator must be trained for protein injection and test reading
- Low specificity (many false positive)

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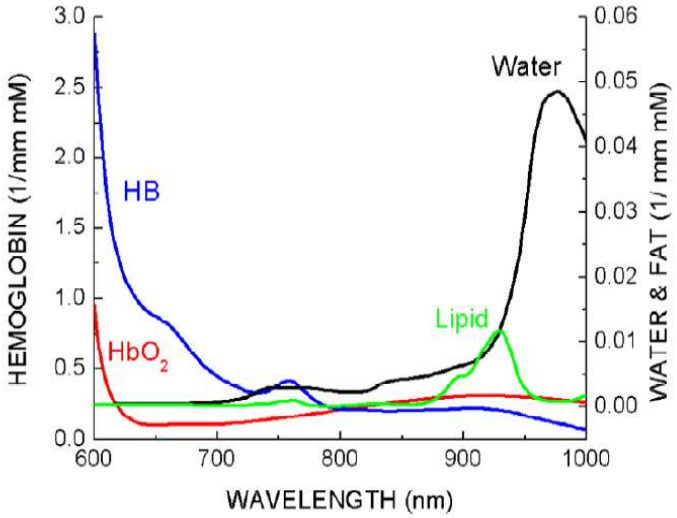
Principles of skin spectroscopy (1/3)

- Idea: following the skin composition through time after injection



Tissue chromophores:

- Hemoglobin
- Deoxy-Hemoglobin
- Water
- Lipids
- Melanin
- …

Chromophores = physiological biomarkers ?

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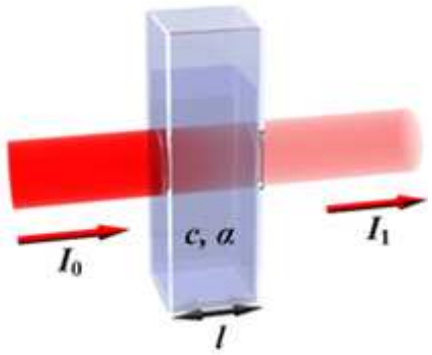
Principles of skin spectroscopy (2/3)

- Classical spectroscopy (clear sample)



1 chromophore: Lambert's law

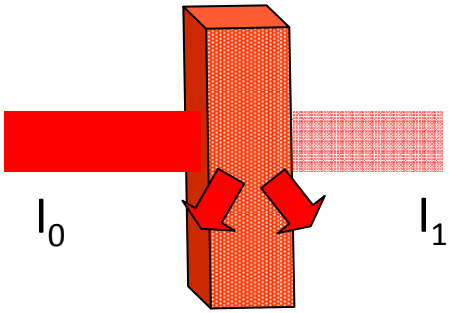
$$I_1 = I_0 \exp(-\mu_a \cdot l)$$

$$\mu_a = \alpha.c$$

Several chromophores

$$\mu a(\lambda) = \sum_i \mu a_i(\lambda) = \sum_i \alpha_i(\lambda).c_i$$

- Diffuse spectroscopy



$$I_1 = I_0 \exp[-(\mu_s + \mu_a) \cdot l]$$

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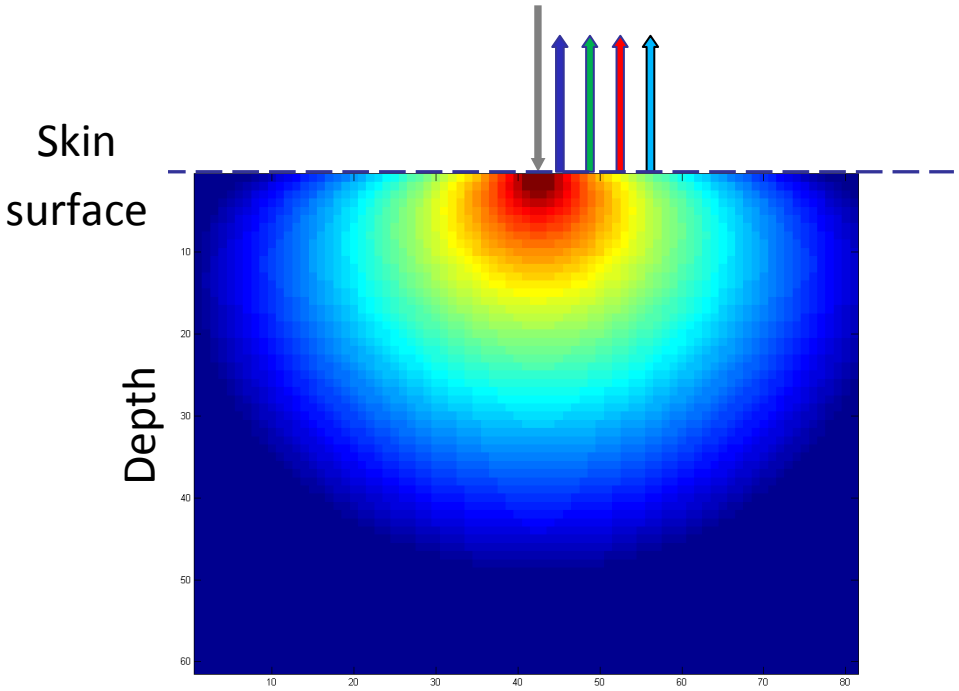
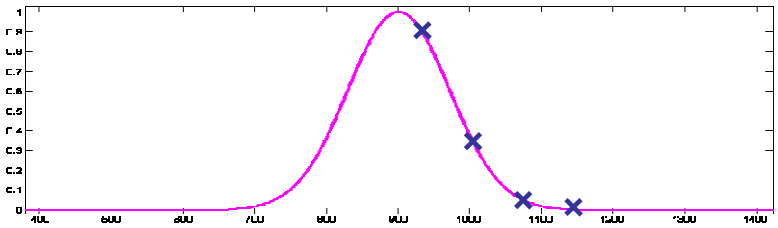
Principles of skin spectroscopy (3/3)

- Measurements on the same side as illumination
- Need to separate the effects of diffusion (µs') and absorption (µa)





Halo shape ⇨ optical properties of the medium

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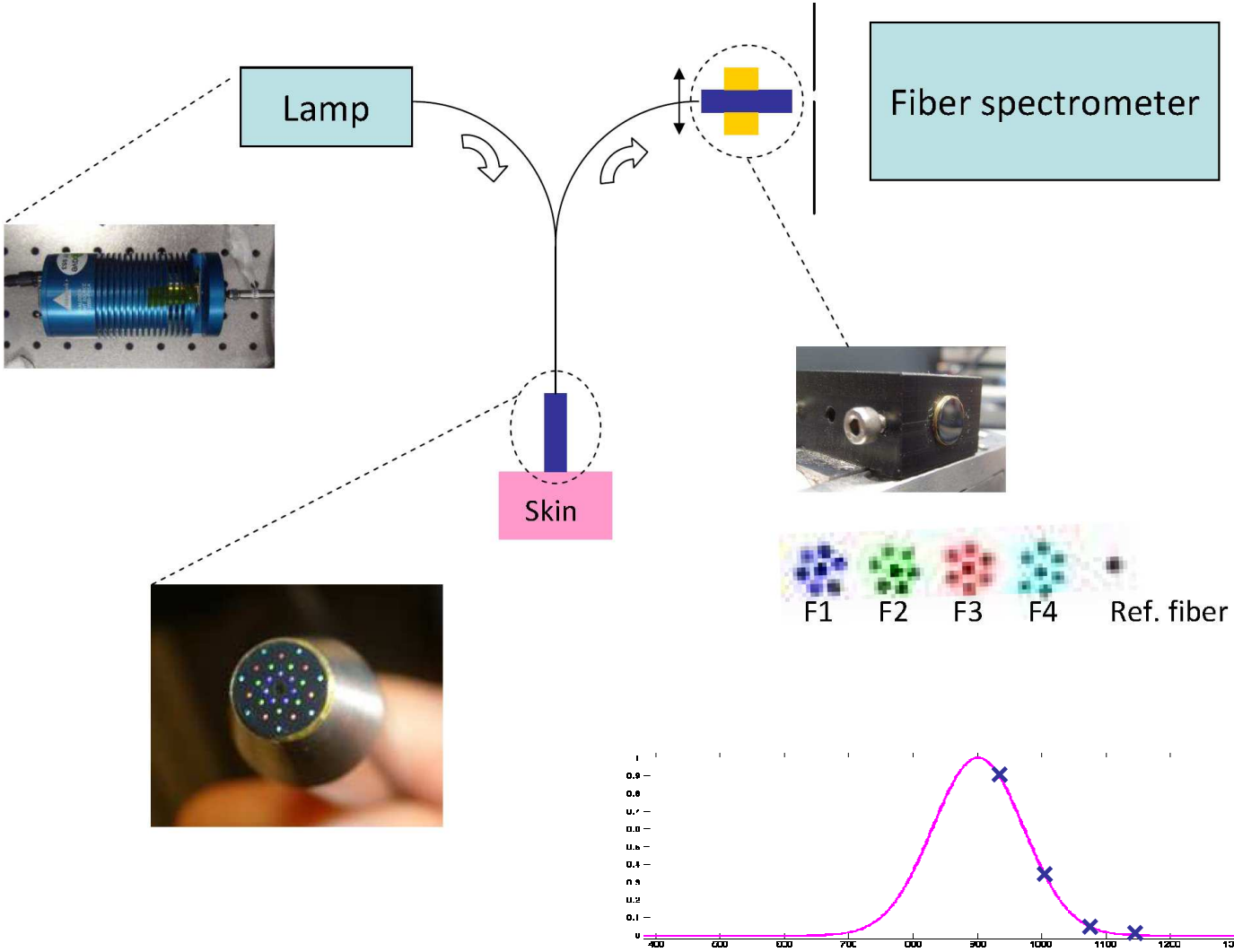
Instrument



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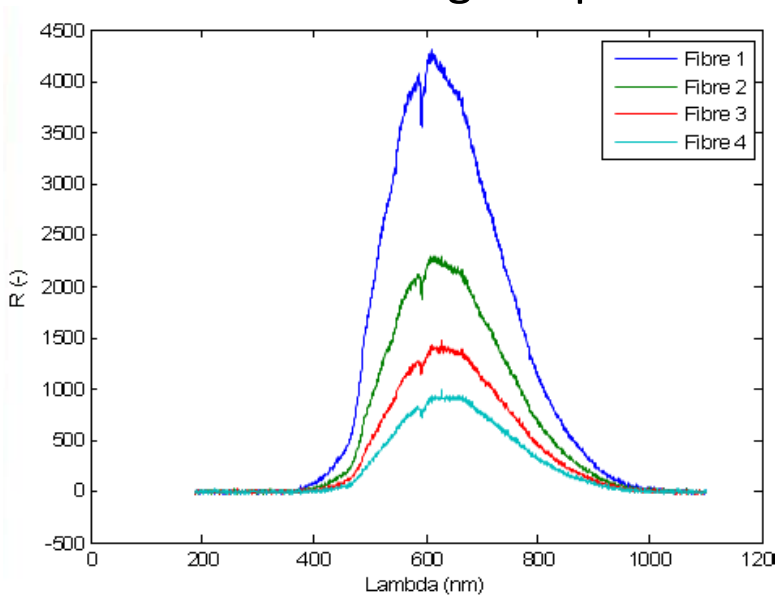
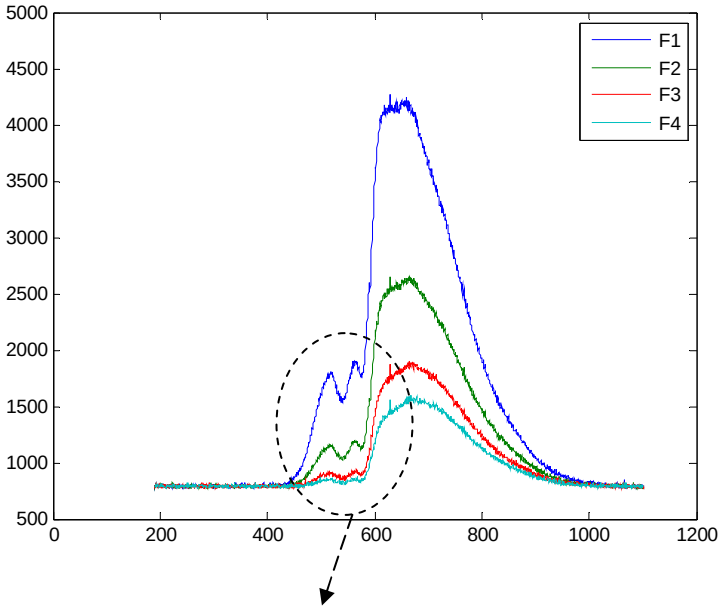
Instrument: raw measurements

Measurements on a white diffusing sample



Irritated skin



Hemoglobin

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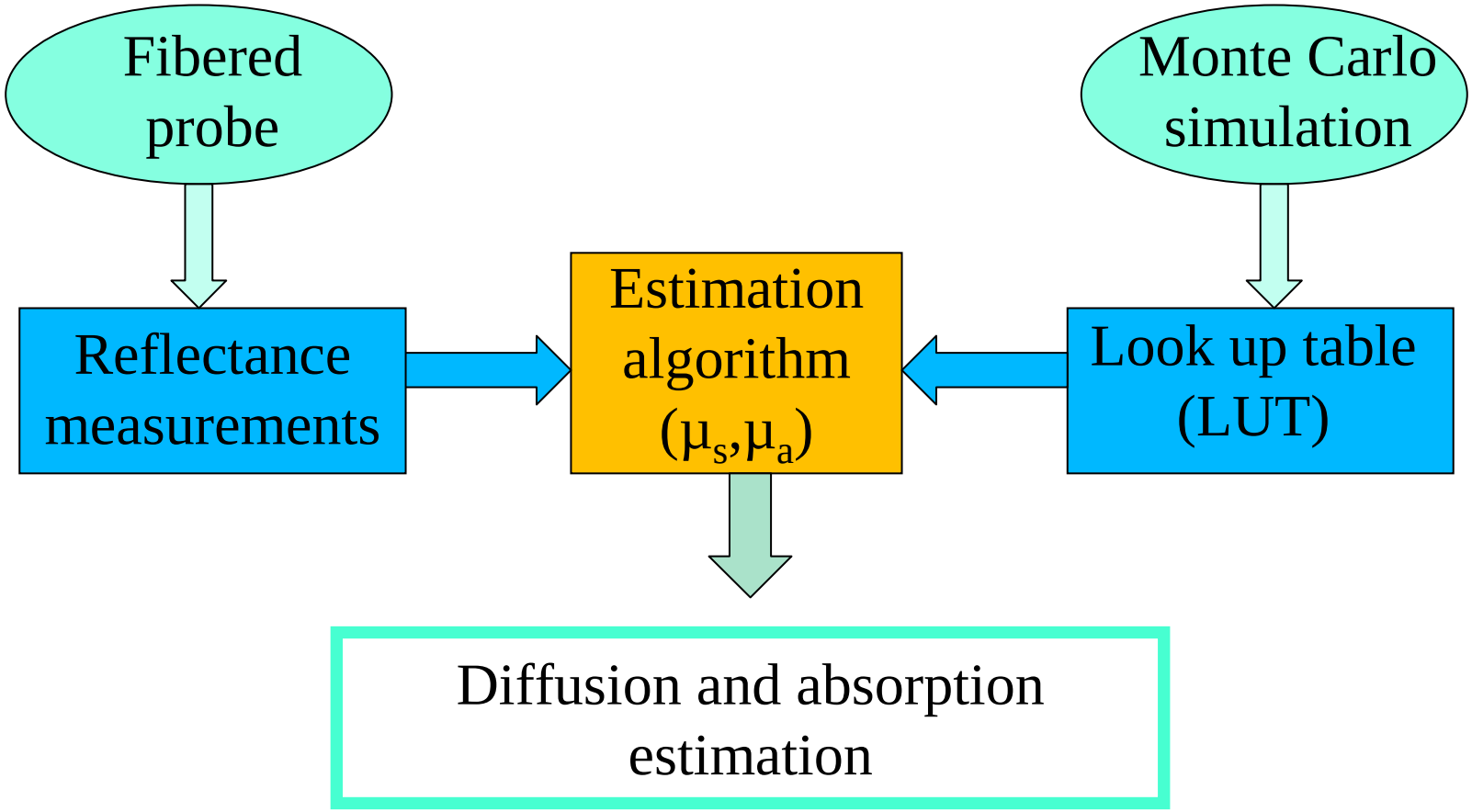
Reconstruction method (1/4)



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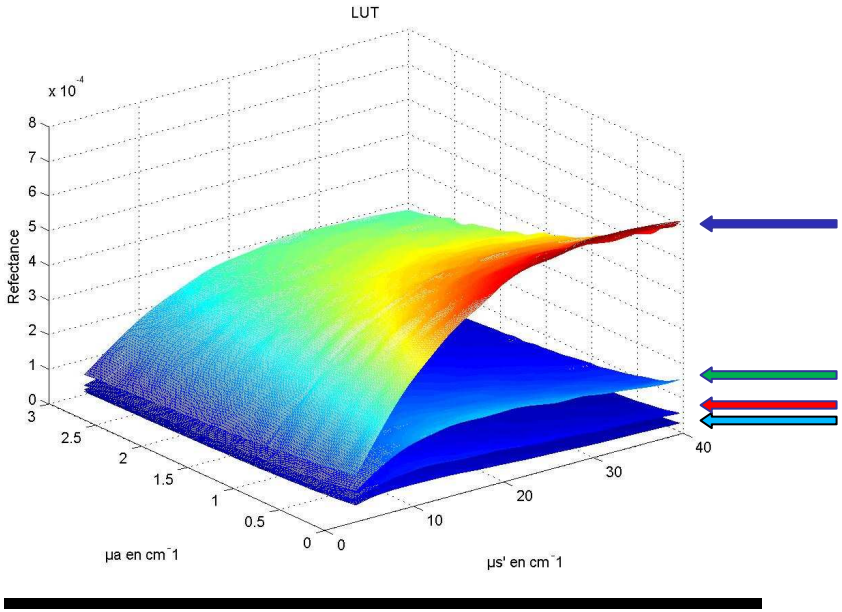
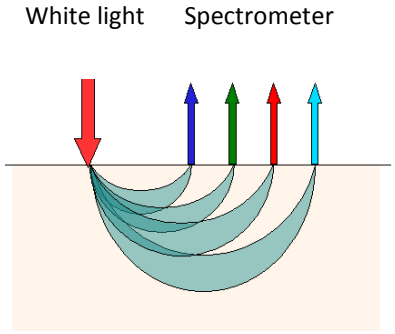
Reconstruction method (2/4)

Look up table calculation

- Monte Carlo algorithm to simulate photons travelling in the tissue (single λ)
- Look up table for different sample properties

Hypothesis: Semi-infinite medium, Snell laws apply at the tissue-air interface





µa € [0.05 cm-1, 3 cm-1]
µs' € [4 cm-1, 40 cm-1]

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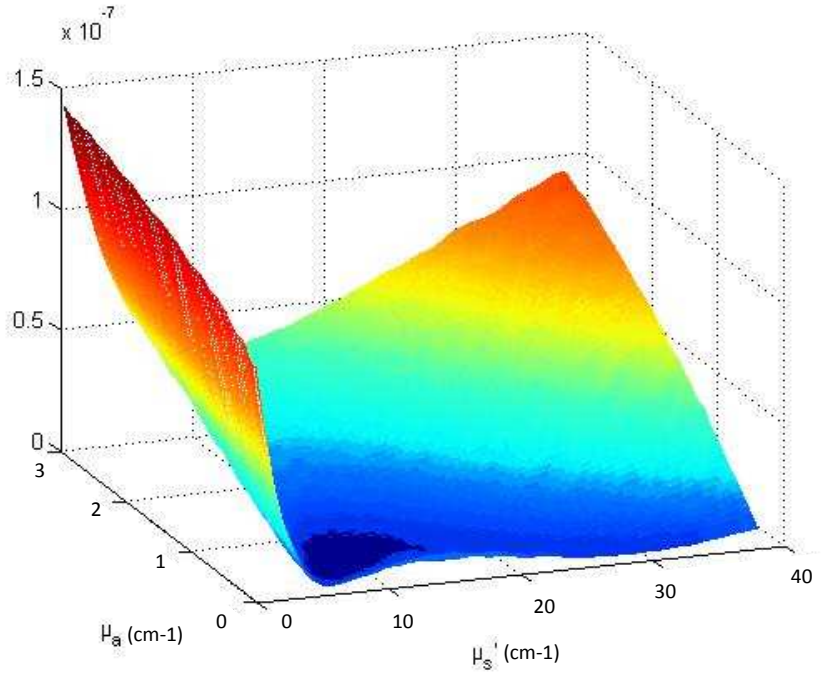
Reconstruction method (3/4)

Diffusion and absorption estimation (µs',µa)

- Minimization of the (LUT – Measurement) distance
- Repeat the operation for every wavelength across the spectrum



$$\forall(\mu_a, \mu_s) \in LUT, \qquad \left\|R_{exp}\right\| = \sum_{i=1}^{4} (R_{LUT}^{fibre\ i} - R_{mesure}^{fibre\ i})^2$$

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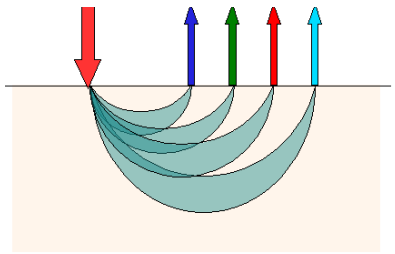
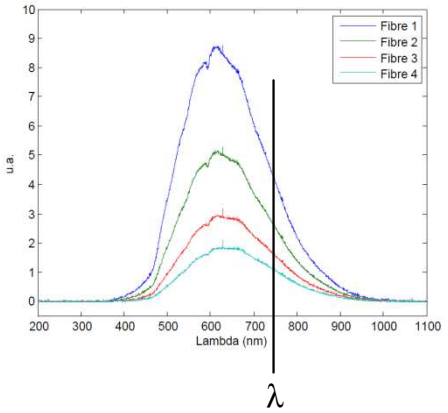
Reconstruction method (4/4)

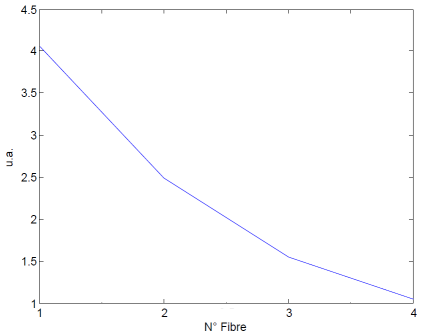
1. Measurement

White light Spectrometer





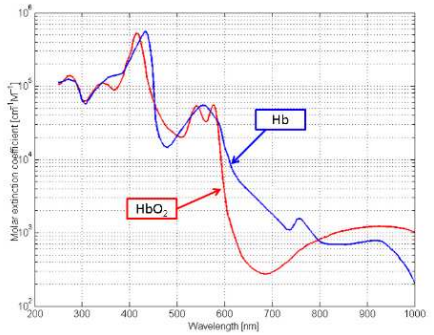
2. (μs',μa) separation



Monte carlo simuation

3. Computation of chromophore concentration

$$\mu_a(\lambda) = 2.303 \cdot \sum_{i=1}^{N} \varepsilon_i(\lambda) \cdot C_i$$



Diagnostic

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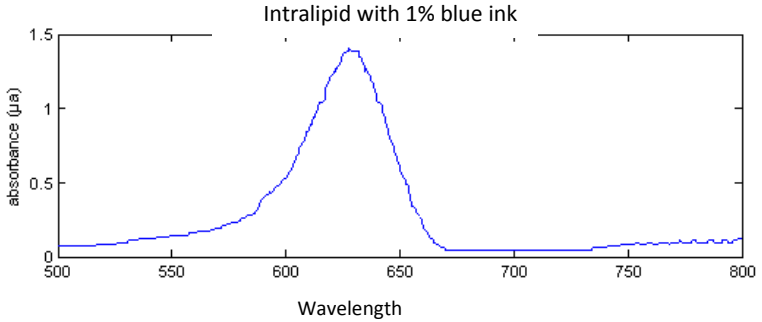
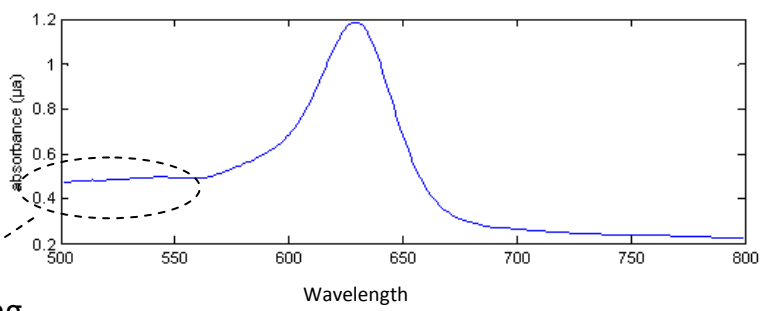
Results

Measurement on phantoms

- Blue + black inks into 1% intralipid (400mL)



estimated μ_a



expected μ_a (spectrophotometer)

Black ink aggregating

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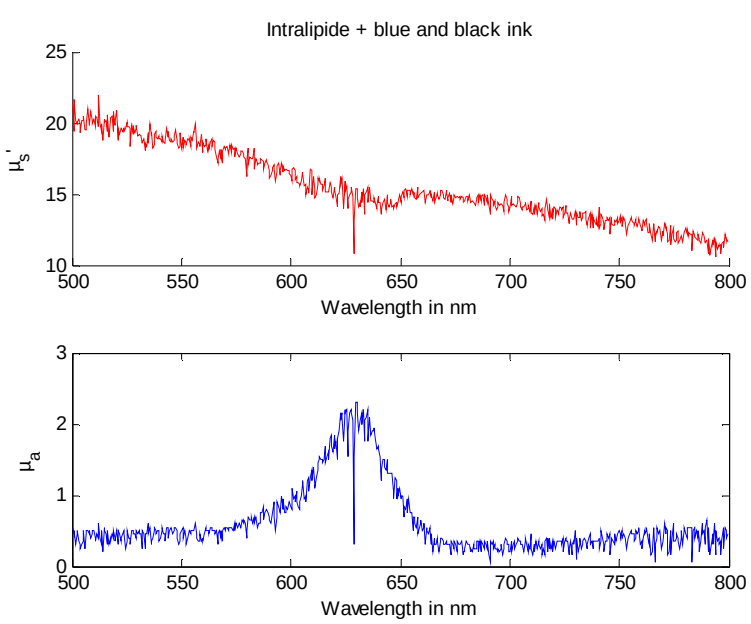
Results

Measurement on phantoms

- Blue ink into 1% intralipid (400mL)



Estimated μs’

Estimated μa

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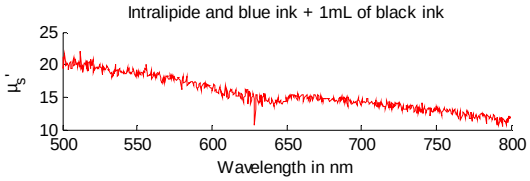
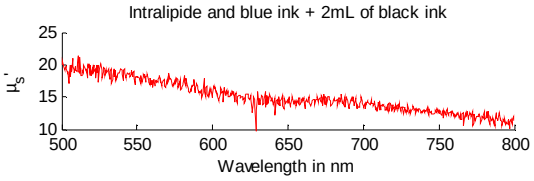
Results

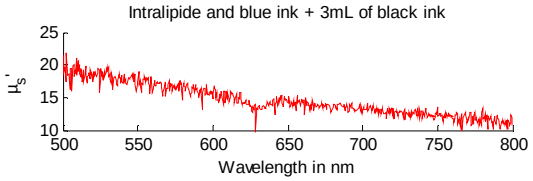
Measurement on phantoms

- Blue ink into 1% intralipid (400mL)

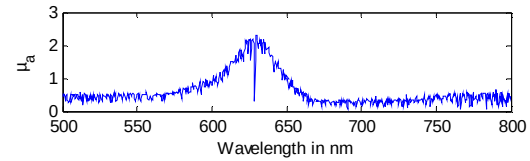
μs’

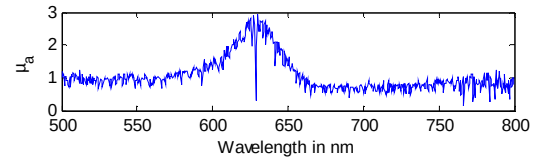


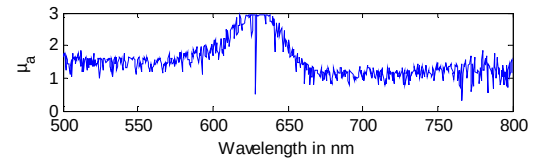


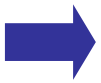


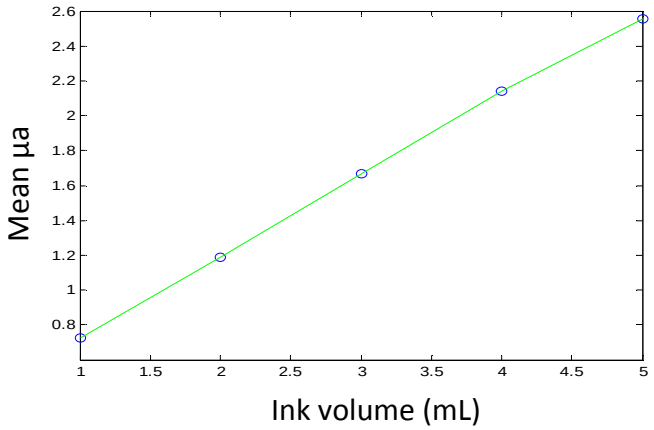
μa











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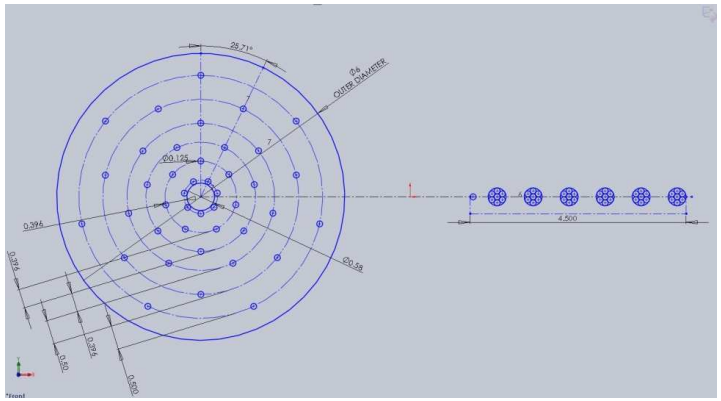
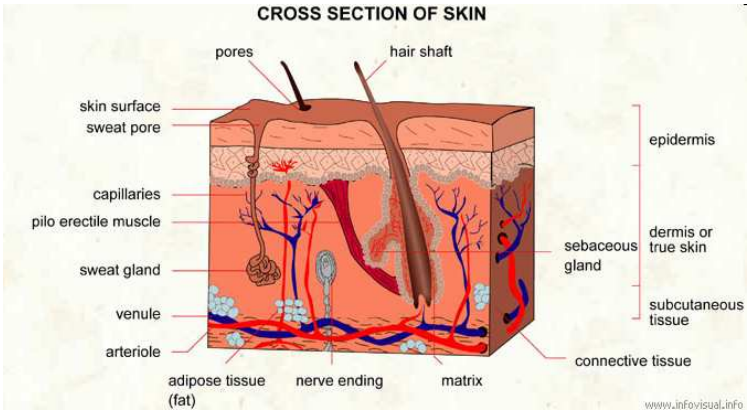
On-going work

- Chromophore sepration
- New probe design for optimized resolution and sensitivity
- Multilayer Monte Carlo simulation (skin model)
- Clinical study for tuberculosis detection





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