Experimental phantom verification studies for simulations of light interactions with skin: Solid Phantoms

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Where are we from?

Outline

Motivation for the work

Phantom preparation and measurements

Computer model

Simulation

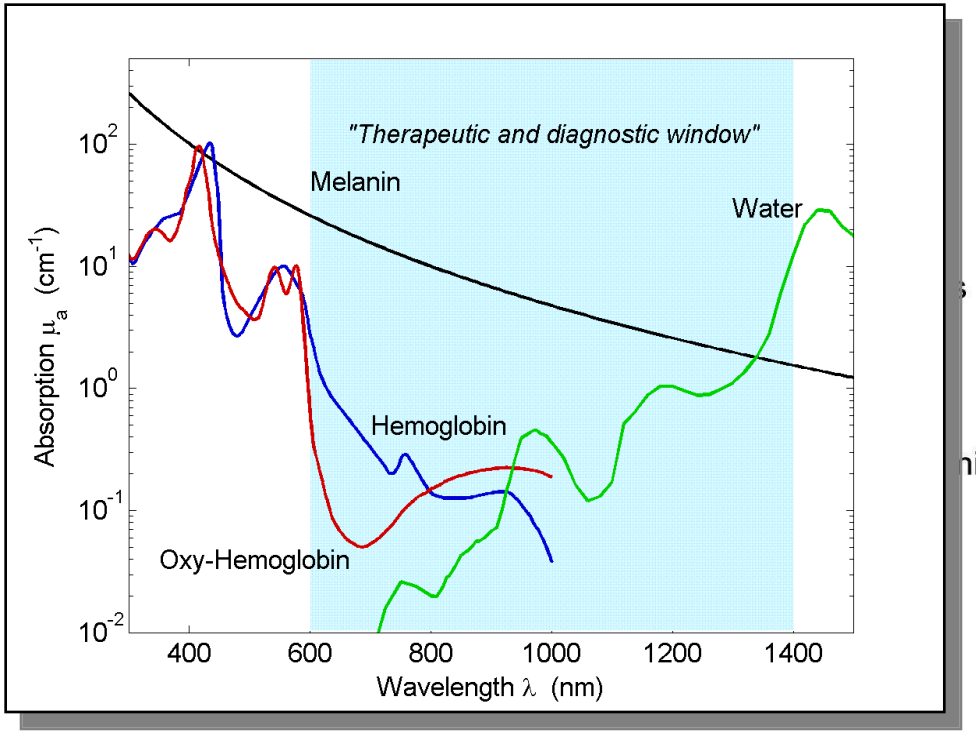
Imaging

Comparison

Conclusions

Motivation for work

- Laser or light treatment modalities are increasing
- Human skin absorbs and scatter light – skin tone important
- Melanin content in epidermis differ
- **Can the computer model be used to predict light levels at a specific depth into skin?**
- Need to verify the model
- Measurements on patients are impractical
- Use phantoms to verify model



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Verification comparison

- Layered structure of skin can be modelled
  - Solid or liquid phantoms can be used for verification
  - Solid phantoms prepared from resin, absorbing and scattering particles – advantage: multi layers possible and phantoms stable and durable for repeatability studies
  - Liquid samples made from Intralipid® and black ink – optical properties of Intralipid® is well documented in literature

- Manufacture phantoms – use phantom parameters in computer model
- Measure transmitted light through phantom and model

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Phantom preparation and measurements

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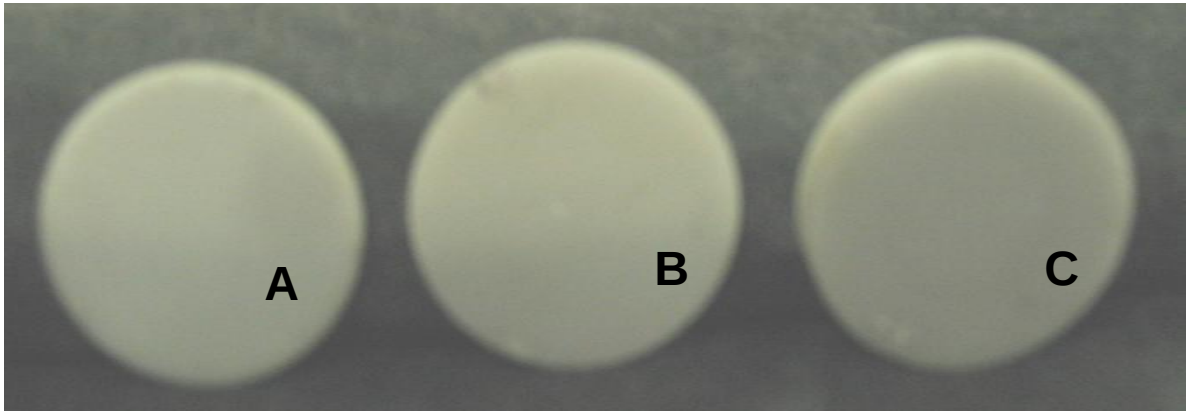
Sample preparation

- Solid phantoms prepared by mixing
  - TiO particles (particle size< 25 nm, density 3.9 g/mL) – scattering particles
  - Carbon Black – absorbing particles – different skin tones
  - Optically clear resin (Akasel)

    M Firbank, Phys. Med. Bid. 38 (1993) 847-853

  - Sample holder diameter = 30 mm
  - Samples cured for 24 hours
  - Cut in slices
  - Optical properties, total transmission and reflection measured with Integrating Sphere (IS)



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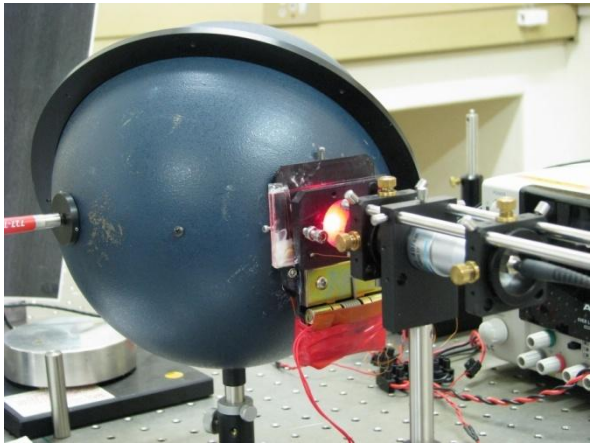
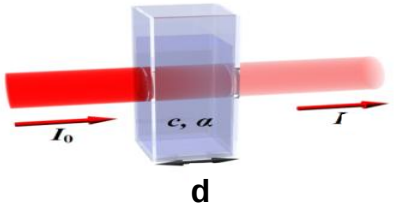
Integrating Sphere measurements

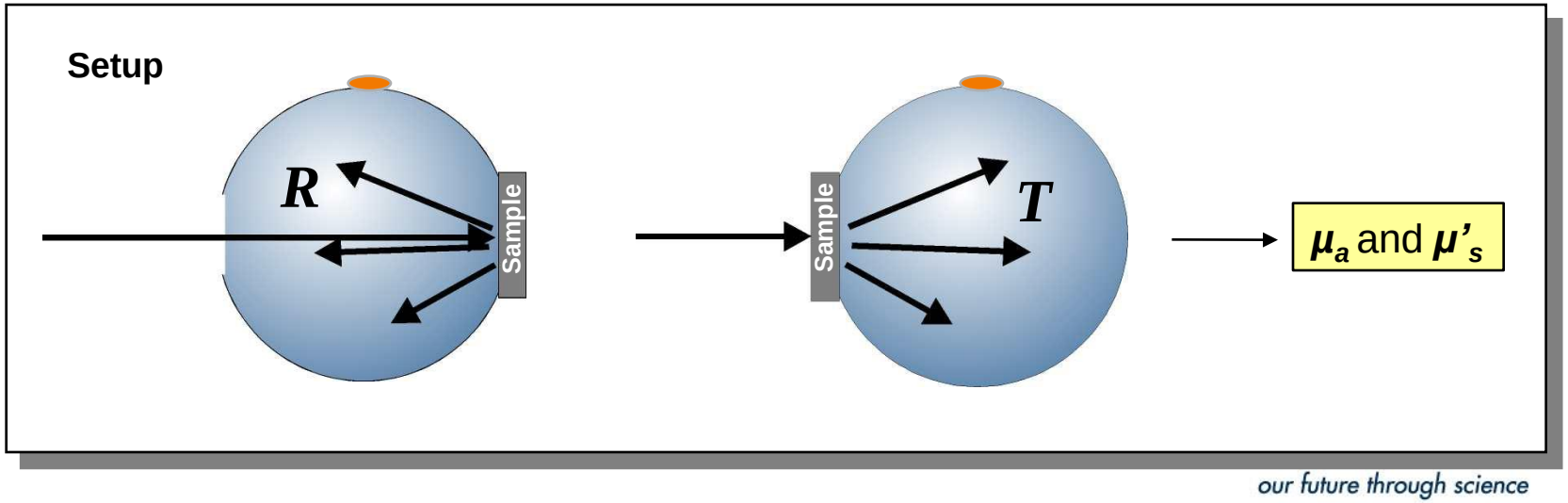


Measurements of the total transmittance and reflectance of a thin slab-shaped multiple scattering sample can yield the absorption- and the reduced scattering coefficient of the sample



$R = R_{BS}(I_R/I_{ref})$
$T = I_T/I_{ref}$

Beer-Lambert Law
$I = I_0 \exp(\mu_t d)$



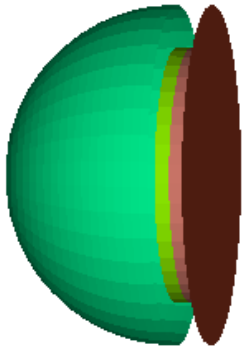
Computer Model

Computer model (I)

- **Modelling done in ASAP software**
  - Non-sequential ray tracing
  - Monte Carlo simulations
  - Rays can automatically split into reflected, refracted, diffracted, polarized, and scattered components as they propagate through the system

Computer model (II)

- **Input parameters**
  - Geometry of model – disc with 1 or 2 layers, disc diam = 30 mm
  - Light source specification – 633 nm, beam diameter 1 mm
  - Specify the optical properties (specify u_a, u_s, g and n) of each layer
  - Assume the optical properties are uniform with in each layer
  - Trace ~ 3.1 mil rays through sample
- Set up a transmission detector (absorbing disc) and a reflecting detector behind light source (absorbing semi sphere)
- Evaluation slices in model ~ 0.1 mm thick
- Voxels ~ 0.1X0.1X0.1 mm^3



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Optical parameters

- Optical properties of phantoms measured at 632.8 nm (HeNe) with integrating sphere.
- 3 different samples (diameter for all 30 mm)
  - Sample A and B – different TiO and carbon black concentrations
  - 2 Layered phantom - Sample C combination of A (d=1.7 mm) and B (d=2.2mm)
- Parameters used in model

Sample	u_a (mm^{-1})	u_s (mm^{-1})	d (mm)	n	g
A	0.268	10.38	1.66	1.4	0.79
B	0.138	4.85	2.4	1.4	0.79
C	Use A and B values	Use A and B values	3.9	1.4	0.79

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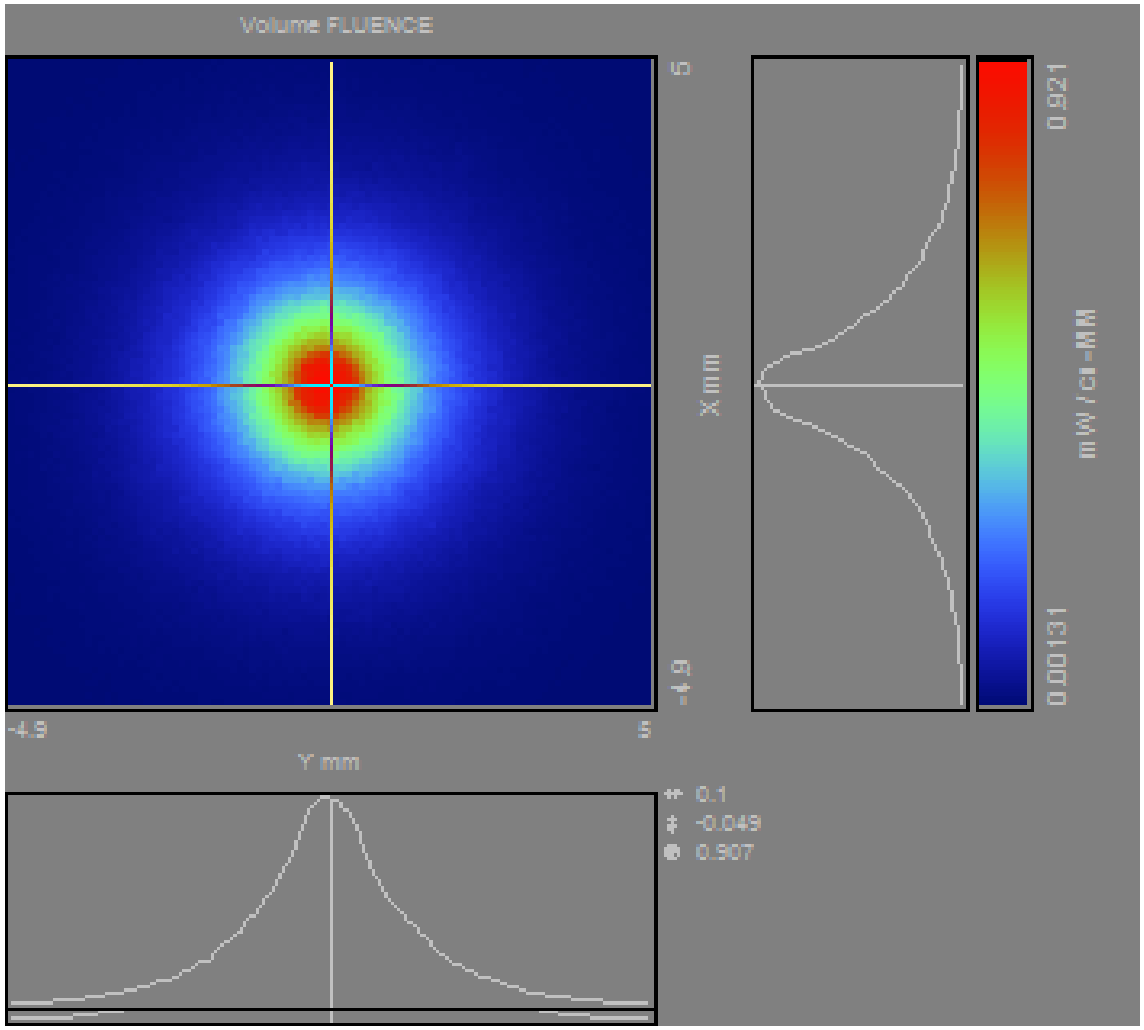
Simulation results

Propagation of beam through sample B



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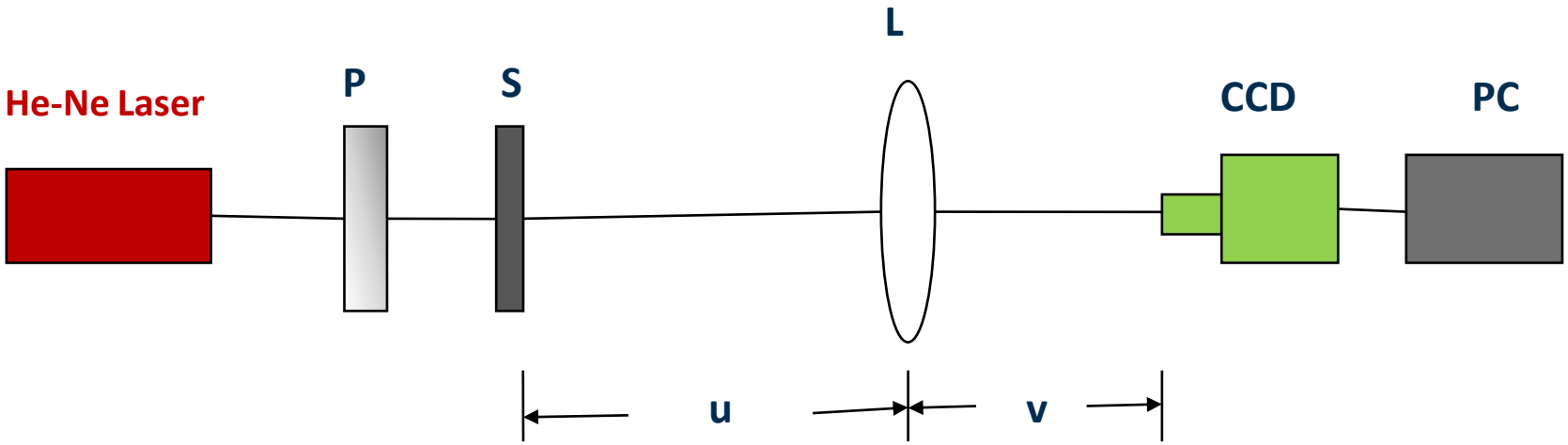
Comparing transmission, absorption and reflectance measurements (on the IS system) to simulation results

Sample	% Abs (Sim)	% Trans (IS)	% Trans (Sim)	% Refl (IS)	% Refl (Sim)
A	65	10	8.8	27	25
B	59	19	17	27	24
C	70	4	2.7	20	26

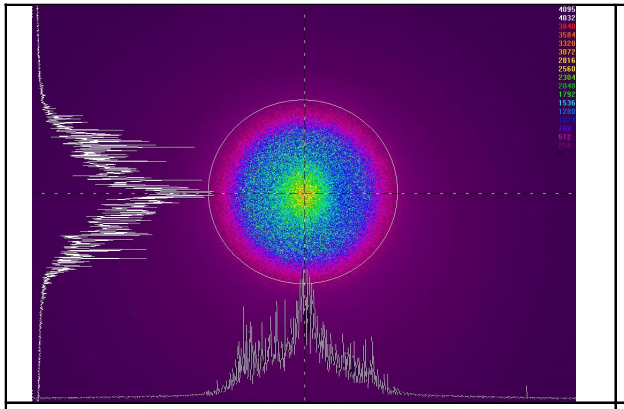
Imaging

CCD images of phantoms

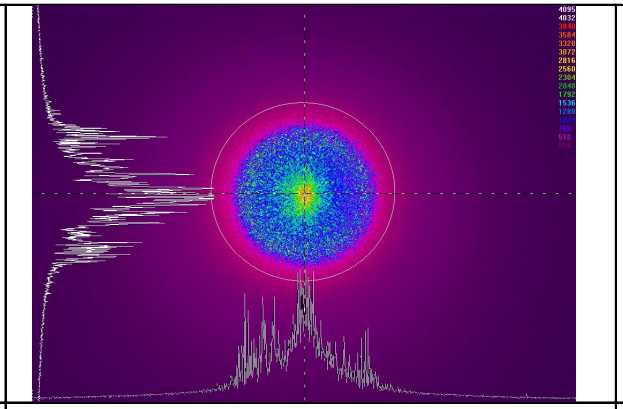


Experimental setup. P (Polarizer), S (Sample), L (Lens f= 100mm, D=50.8mm), CCD (Camera), PC (Computer), u (Object distance = 500 mm), v (Image distance = 125 mm) M= 0.25 HeNe Laser 9 mW

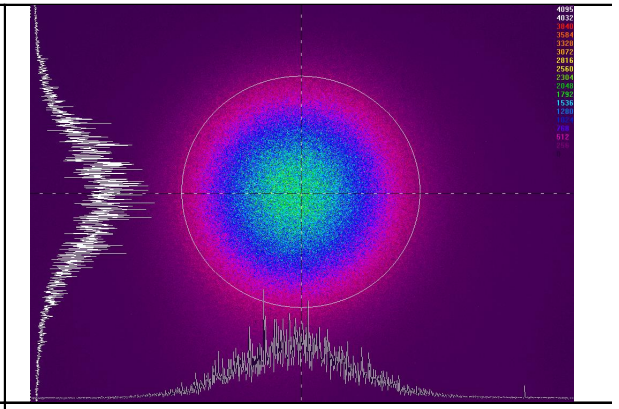
CCD images - Camera size: 7.1mm x 5.4 mm



A (Beam diam 10.1 mm)

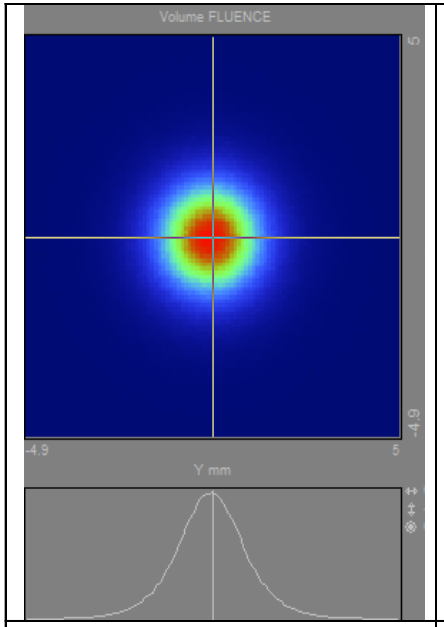


B (Beam diam 9.6 mm)

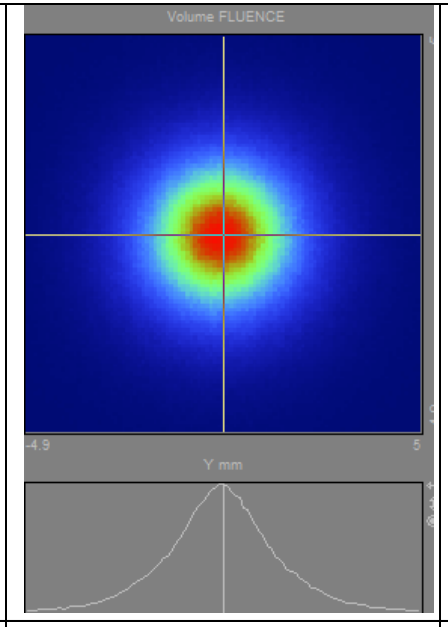


C (Beam diam 12.6 mm)

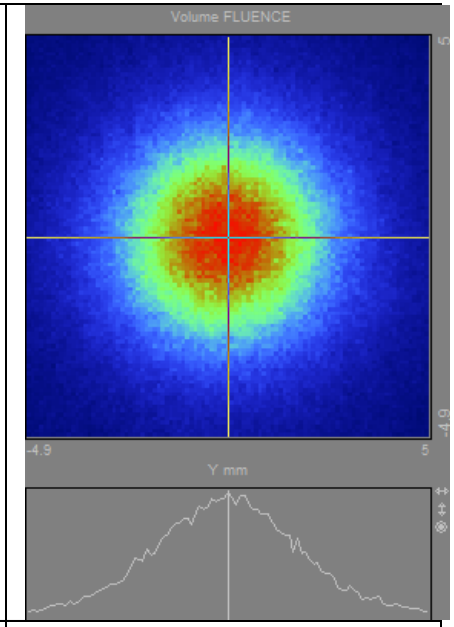
Simulation images at back of sample mages – size 5mm x 5 mm



A Fluence



B Fluence



C Fluence

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Conclusions

Conclusions

- Relatively good agreement between measured and modelled values when comparing transmitted and reflected values
- Image comparisons show good trend, but absolute values differ – maybe due to interpretation of CDD images and light settings used
  - This needs to be investigated further
- Computer model shows potential and with further refinement can be used to predict light intensities at specific distances into skin

Thank you