# Simulation of Diffuse Optical Tomography using COMSOL Multiphysics®

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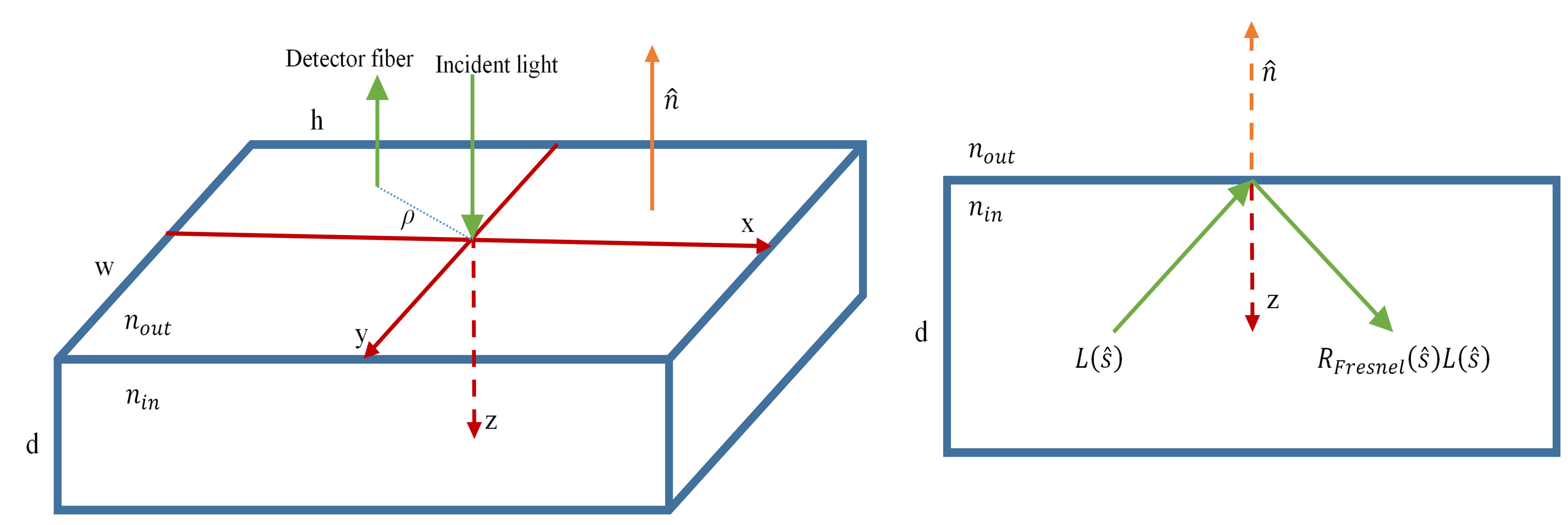
**Introduction**: Optical tomography techniques for medical diagnostic procedures have seen much progress in recent years because they employ infrared light, which is non-ionizing for biological tissues and, thus, lack the harmful effects of X-rays and other ionizing radiations. Diffuse Photon Density Waves (DPDW) methodology is a frequency domain diffuse optical tomography technique that employs intensity modulated light sources for diagnostic procedures. Here we present our results of COMSOL Multiphysics® simulation of a diffuse optical tomography system using the diffusion equation (DE) for DPDW.

**Computational Methods**: The operating principle of any optical tomography technique is the result of the interaction of light with a biological tissue. Biological tissues are turbid media, in which light propagation and light-tissue interaction is modeled analytically by the radiative transfer equation (RTE),

$$\frac{1}{v}\frac{\partial L(\vec{r},\hat{s},t)}{\partial t} = -\hat{s}\cdot\nabla L(\vec{r},\hat{s},t) - \mu_t L(\vec{r},\hat{s},t) + \mu_s \int_{4\pi} L(\vec{r},\hat{s}',t)\, p(\hat{s},\hat{s}')\, d\hat{s}' + S(\vec{r},\hat{s},t)$$

Since the RTE is numerically costly to solve, it is often approximated by the diffusion equation (DE). We have used the Helmholtz Equation model in COMSOL Multiphysics® to solve the DE for DPDW.

$$-\nabla\cdot\big(\mathrm{D}(\vec{r})\nabla U(\vec{r})\big) + \left(\mu_a(\vec{r}) - \frac{i\omega}{v}\right) U(\vec{r}) = \mathrm{S}_{ac}(\vec{r})$$




(a) (b)

**Figure 1**. (a) Geometrical model of the tissue (b) Tissue cross-section.

**Results**: We measured DPDW phase (Figure 2) and intensity attenuation (Figure 3) at a wide range of source - detector separation distances. In Figure 2 plot (a) is obtained for 0.5% and plot (b) is obtained for 2% concentration of intralipid – water solution. Figure 3 is plotted for 0.5% concentration of intralipid – water solution.

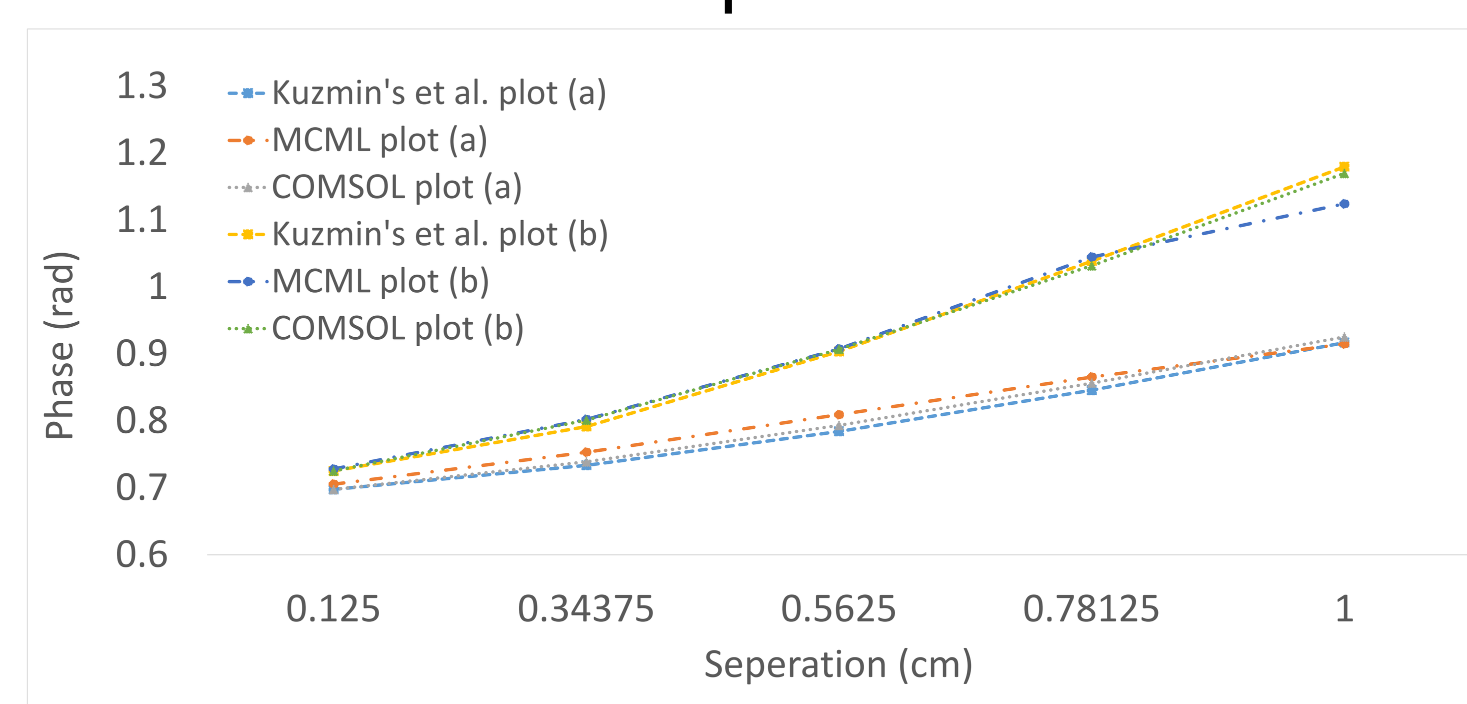



**Figure 2**. DPDW phase against source – detector separations for two different concentrations of aqueous intralipid solution

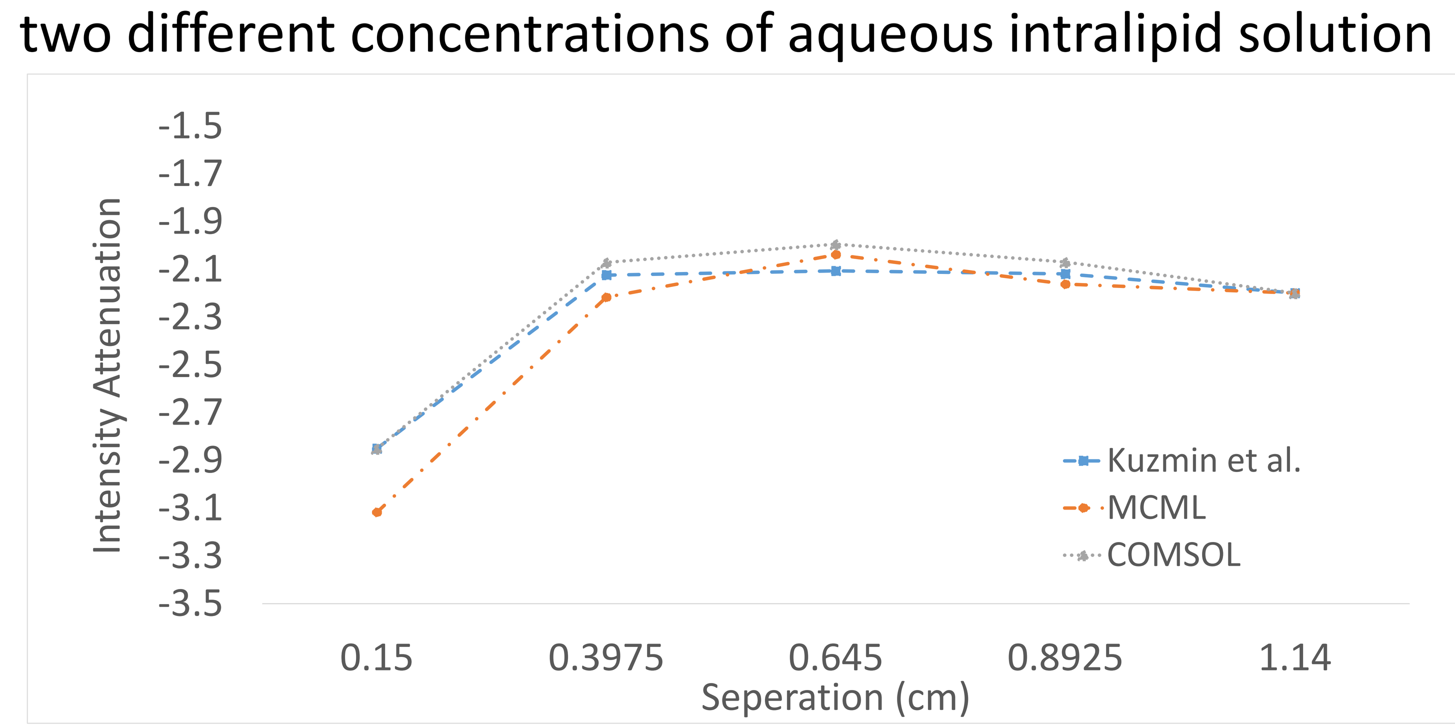



**Figure 3**. DPDW intensity attenuation against source – detector separation

**Conclusions**: Our simulations produce accurate results two orders of magnitude faster than the standard Monte Carlo method of light transport in tissues. Therefore, COMSOL is a practical tool in the simulation of DPDW in optical tomography systems for biomedical applications, such as the diagnosis of cutaneous and subcutaneous skin damage.

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