Simulation of Diffuse Optical Tomography Using COMSOL Multiphysics®

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Abstract

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 the simulation of DPDW methodology created with the COMSOL Multiphysics® software. We have based our calculations on the 3D model of an aqueous solution of intralipid (Figure 1) that can mimic the response of human or animal tissue to light at infrared wavelengths.

Use of COMSOL Multiphysics® software

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), and can be numerically described using Monte Carlo (MC) simulations [1 - 4]. Since the RTE is numerically costly to solve, it is often approximated by the diffusion equation (DE). We have used the Helmholtz Equation interface in COMSOL Multiphysics® software to solve the DE.

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 2% and plot (b) is obtained for 0.5% concentration of intralipid - water solution. Figure 3 is plotted for 0.5% concentration of intralipid - water solution. Our results are in agreement with Monte Carlo simulations and experiment results obtained by Kuzmin et al. [5].

Conclusion

Our simulation produced accurate results in less than a minute which is about 10 times faster than the Monte Carlo simulation reported by Kuzmin et al. [5] on a commonly available personal computer. By using Application Builder of the COMSOL Multiphysics® software, our simulation can be transformed into a realtime monitoring system for biomedical applications. The ability of DPDW to determine the optical properties of tissues is critical for many biomedical applications. This can be employed to observe and analyze cutaneous and subcutaneous tissue damage, diagnosis and treatment of pressure ulcers,

skin and tissue injuries, wounds and burns.

Reference

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Figures used in the abstract

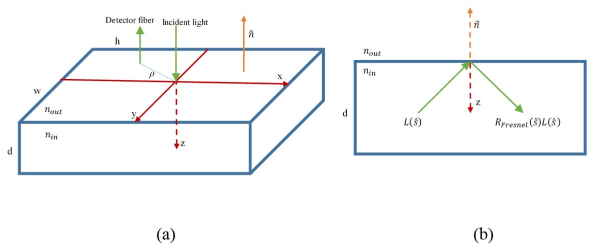

Figure 1: Figure 1: (a) Geometrical model of the tissue (b) Tissue cross-section

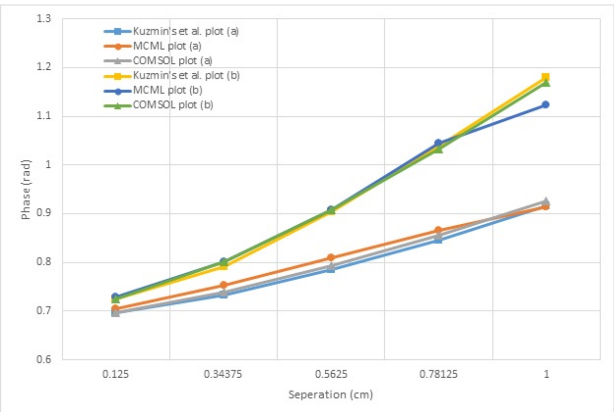

Figure 2: Figure 2: DPDW phase against source – detector separations for two different concentrations of aqueous intralipid solution

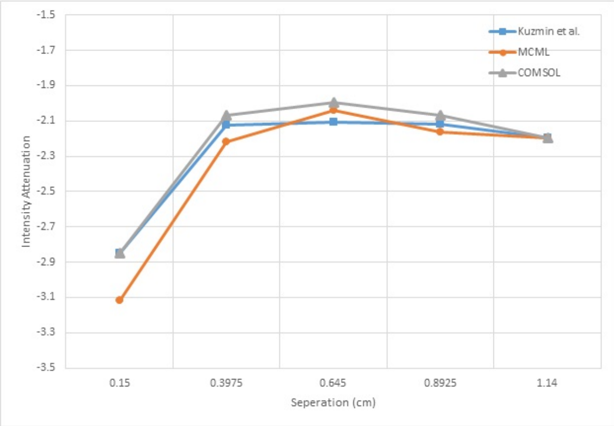

Figure 3: Figure 3: DPDW intensity attenuation against source – detector separation