Monte Carlo model for coherent microscopic imaging through turbid media

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Abstract

Monte Carlo simulation methods are considered as an effective method to simulate the light transport in tissue. In recent years, we have developed Monte Carlo simulation models for transmission and reflection microscopes, fluorescence microscopes (including single-photon, two-photon, and three-photon excitation). Image formation has been investigated under different optical gating mechanisms such as temporal gating, confocal gating and polarization gating methods. We have also extended our simulation models to deal with complex tissue structures such as multi-layer structures, multiple size composition, and fractal aggregate. In addition, we have developed image reconstruction methods based on the concept of effective point spread function. Due to the fact that Monte Carlo methods are based on ray optics approximation, the wave properties of light are omitted, and the simulation models are only suitable for incoherent imaging.

Coherent imaging methods such as optical coherent tomography (OCT) and second harmonic generation (SHG) imaging have attracted many research interests because of their potential application in biological imaging in vivo. The conventional Monte Carlo simulation models have the difficulty in subtracting coherent information in imaging through turbid media. Although there are some early research works on theoretical analysis of coherence feature of light propagating through turbid media, only the effect induced by path variations in photon migration has been considered. In this paper, we have developed a novel Monte Carlo simulation model, in which phase variations in the event of scattering have been taken into consideration. In order to achieve this, wave properties at each single scattering event are calculated based on Mie theory prior to the simulation. The phase variation due to multiple scattering are investigated in details as functions of various physical parameters such as the wavelengths of light and the sizes of scatterers. This development lays a solid foundation for future developments of Monte Carlo simulation models for studying coherent image formation and reconstruction.