Depolarization of light in a multiply scattering medium: Effect of the refractive index of a scatterer

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We report the results of a study carried out to investigate the influence of the refractive index and size parameter of a scatterer on the depolarization of linearly and circularly polarized light in a turbid medium. The results show that for a given refractive index of the surrounding medium, the influence of the refractive index of the scatterer on the depolarization of both linearly and circularly polarized light is rather weak for samples with smaller-sized scatterers (Rayleigh scatterers, radius \( a \ll \lambda \), anisotropy parameter \( g \approx 0.2 \)). For a given value of optical thickness (\( \tau = \mu_s \times d \), \( \mu_s \) being the scattering coefficient, \( d \) the physical thickness), the depolarization of linearly polarized light was observed to be higher than that of circularly polarized light for these samples. In contrast, for samples prepared using larger-sized scatterers (Mie scatterers, \( a \approx \lambda \), \( g \approx 0.7 \)), linearly polarized light was observed to depolarize much faster than circularly polarized light when the refractive index of scatterers was large (\( n = 1.59 \)) but no appreciable difference in depolarization of linearly and circularly polarized light was observed when the refractive index of scatterers had a lower value (\( n = 1.37 \)). Further, for scattering samples having Mie scatterers, for comparable values of \( \tau \) and \( g \), depolarization of polarized light was much higher for samples with scatterers of lower refractive index.

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I. INTRODUCTION

The promise of polarization gating for optical imaging through biological tissue [1–3] has motivated several studies on the depolarization of light in a turbid-medium-like tissue [4–8]. These studies have shown that with an increase in the value of size parameter of scatterer (\( X = 2 \pi n_{\text{medium}}/\lambda \), \( a \) being the radius of the scatterer, \( \lambda \) the wavelength, and \( n_{\text{medium}} \) the refractive index of the surrounding medium), the characteristic length of depolarization of incident polarized light increases significantly [5–7]. Further, for a medium containing smaller-sized scatterers (\( a \ll \lambda \) and anisotropy parameter—i.e., average cosine of scattering angle \( g \approx 0.2 \)), the characteristic length of depolarization for linearly polarized light is higher than that for circularly polarized light and the reverse is the case for a medium containing larger-sized scatterers (\( a \approx \lambda \), \( g \approx 0.7 \)) [5–7]. In the theoretical studies, the turbid medium has been modeled as being comprised of monodisperse spherical scatterers. For experimental studies, suspension of intralipid or aqueous suspension of polystyrene microspheres has been used to prepare tissue phantoms. The usual approach while designing tissue phantoms has been to use a chosen size of scatterers that would give a value of the anisotropy parameter (\( g \)) comparable to that of tissue. The concentration of scatterers is then adjusted to yield the value of optical thickness (\( \tau \)) or reduced optical thickness (\( \tau' = \mu'_s / d \), \( \mu'_s \) being the reduced scattering coefficient =\( \mu_s / (1 - g) \)) comparable to that of actual tissue. However, important differences have been observed in depolarization of linearly and circularly polarized light between these commonly used tissue phantoms and actual tissues [8–10]. The observed difference in depolarization between tissue and matched tissue phantoms (comparable \( \tau \) and \( g \)) may arise due to a difference in a large number of parameters like the density of scatterers or a distribution in the size and shape of the scatterers. Since it is difficult to quantify these parameters in biological tissue, elucidation of the reasons responsible for the observed differences in polarized light propagation through biologic tissue and matched tissue phantoms requires careful experiments using well-characterized tissue phantoms. Earlier studies in this direction have shown that one important reason for this discrepancy is the presence of a much wider distribution in the size of tissue scatterers as compared to commonly used tissue phantoms [11]. Another important factor that could contribute to the observed difference in depolarization in actual tissues and matched tissue...