

POLARIZATION

Mueller Matrix Approach for Discriminating Optical Rotation

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The effective management of diabetes requires regular monitoring of the concentration of glucose in blood. Measurement of the degree of rotation of the plane of polarization of a linearly polarized light by the glucose present in blood provides an attractive approach for this purpose.¹

One serious problem with this approach, however, is that the incident polarized light becomes depolarized due to multiple scattering in a turbid medium such as human tissue. The use of polarization modulation and synchronous detection has therefore been investigated to extract the polarization-retaining fraction of the backscattered light and use it to quantify optical rotation. However, recent studies have shown that, even when depolarization due to multiple scattering is addressed, the relatively small rotation of the polarization vector arising from the optical activity in the medium gets

swamped by the much larger changes in the orientation angle of the polarization vector due to single scattering.²

Our studies show that the scattering-induced change in the orientation angle of the polarization vector arises from the combined effect of linear diattenuation (the difference in attenuation coefficients for two orthogonal linear polarizations) and linear retardance (the difference in phase between two orthogonal linear polarizations).³ We have therefore extended the methodology available⁴ for decomposition of the Mueller matrix of a scattering medium into matrices corresponding to diattenuation, retardance and depolarization to further separate out the linear component of retardance from the circular.

This approach helps separate the rotation of the polarization vector arising from the optical activity of the medium from that due to scattering, and may thus

facilitate more sensitive determination of the concentration of chiral substances in a turbid medium (e.g., glucose in blood).

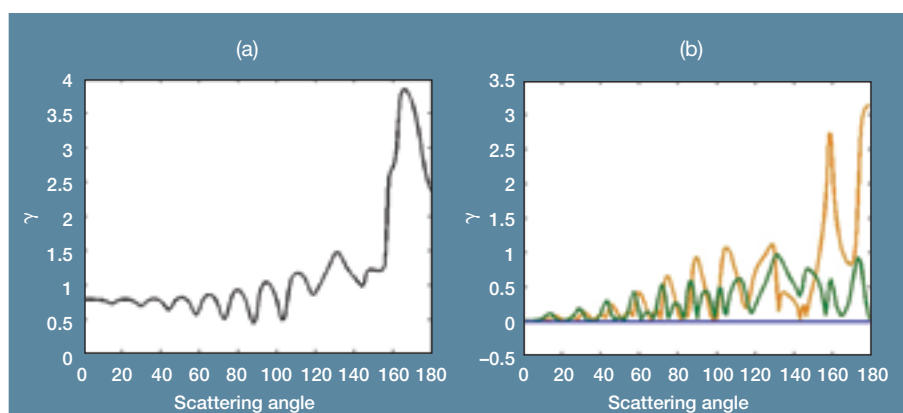
In the figure, we show the variation in the value for the orientation angle (γ) of the linear polarization vector as a function of the scattering angle (Θ) for a spherical scatterer embedded in an achiral medium (a). The value for γ is observed to increase with an increasing value of Θ , even in the absence of any optical activity of the medium.

In the case of single scattering, there is no depolarization, and the angular variation of diattenuation, linear retardance and optical rotation obtained using the computed Mueller matrix is shown in (b). The results confirm that the increasing rotation of the linear polarization vector with scattering angle in this case is solely due to scattering. This finding establishes the validity of our approach for discriminating between rotation arising due to chirality and that due to scattering. Muller matrix measurements on turbid media (prepared using aqueous suspension of polystyrene microspheres) containing a known concentration of glucose molecules further validated this strategy—which may soon prove to be a useful tool for non-invasive monitoring of glucose levels in the blood. \blacktriangle

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(a) The variation of the orientation angle of the linear polarization vector (γ) as a function of the scattering angle Θ for 632.8 nm light scattered from a spherical scatterer embedded in an achiral medium. The diameter of the scatterer is 2.0 μm , and the refractive index of the scatterer and the surrounding medium are 1.59 and 1.33, respectively. (b) The angular variation of linear retardance (orange line), diattenuation (green line) and optical rotation (blue line) obtained from decomposition of single scattering Mueller matrix.