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Polarimetry for Biomedical Applications

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Abstract: Light scattered from the biological samples like tissue, cells etc. contain rich structural, functional and chemical information of potential biomedical importance. Most often unpolarized measurements are used. In the recent past polarized light is being explored, as polarizations measurements provide the additional diagnostic parameters which cannot be obtained from unpolarized measurements. Therefore motivated by promises of polarized light many studies were carried out for biomedical diagnostic and imaging. Different polarization parameters like depolarization, retardance and diattenuation is being explored for different applications. However confounding and overlapping effect of all these properties make it difficult to extract useful parameters by simple polarization measurements, thus required Mueller matrix measurements. A Mueller formalism is coming up as a promising technique recently for biomedical diagnosis and imaging. In this article therefore we will briefly discuss the Mueller polarimetry and its aspects for different biomedical applications.

Introduction:

The use of optical techniques for biomedical diagnosis and imaging is receiving considerable attention as these promise to provide portable and cheaper system for sensitive and non-invasive diagnosis. While most of the studies involve unpolarized light, it has been shown that polarization sensitive measurements can often provide improved contrast in tissue imaging and diagnosis [1-5]. For example, the depolarization property of scattered light has been used as convincing tool to separate out multiply scattered light and hence facilitate tissue imaging [3-5]. The increase in depolarization of light with the path traversed in a scattering medium like tissue has been used for depth resolved measurements in tissue [6]. Also the depolarization rate of incident circularly and linearly polarized light has been shown to depend on the various morphological parameters [1-3], which further can be used for quantitative diagnosis. In addition to depolarization property, many constituents of tissue are birefringent like collagen, muscle tissue and dichroic like glucose.

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Driven by Mueller polarimetry's biomedical potential it has been explored for many diagnostic applications like diabetes and cancer diagnosis etc.. In this paper we briefly discuss Mueller formalism and its applications for biomedical diagnosis.

Stokes Mueller Formalism:

In this formalism Stokes vector is used to represent the polarization state of light. When light interact with any sample, this Stokes vector (S_{in}) transformed into another S_{out}. Mathematically this transformation is described by the Mueller matrix by equation

$$S_{out} = MS_{in}$$

$$M = \begin{pmatrix} m_1 & m_2 & m_3 & m_4 \\ m_5 & m_6 & m_7 & m_8 \\ m_9 & m_{10} & m_{11} & m_{12} \\ m_{13} & m_{14} & m_{15} & m_{16} \end{pmatrix}$$

Mueller matrix have complete polarimetric response of the sample. However, polarization properties of a sample are coded in the Mueller matrix (M) elements. To extract various polarization parameters different decomposition approach have been proposed [8-9].

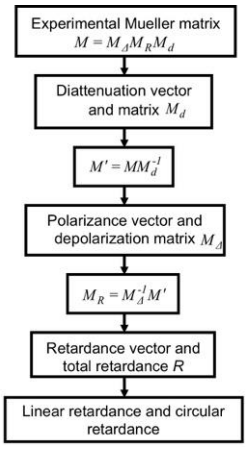

Fig.1: Different steps in Mueller matrix decomposition

Mueller polarimetry for biomedical applications:

Mueller matrix interpretation can further increase the understanding of how the different polarization properties of biological sample can be correlate with pathological features which

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can further be explored for important clinically information. Mueller polarimetry therefore have a wide range of applications.

It was shown by ex-vivo measurements taken with a multispectral Mueller polarimeter that in case of early diagnosis of colon cancer, normal tissue is more depolarizing compare to malignant one [10]. Useful contrast provided by multispectral Mueller polarimeter can be used to distinguish between different histological tumor variants. Their results revealed that in budding zones, all the light wavelength interacts mainly with the superficial layers of sample. Whereas in cancer's ulcerated zone where the layer thickness is not much, the probably light interacts mainly with healthy deeper layers, which are more depolarizing compare to superficial layers. The same setup was also explored for polarimetric contrasts between the normal and cancerous tissue on neaodjuvant treated rectum samples. Mainly depolarization was used to distinguish the different samples having different response to neaodjuvant treatment. Mueller imaging was also explored to early cervical and oral cancer diagnosis. In case of cervical cancer retardance was used to identify the normal zone from cancerous one. Normal zone shows higher retardance compare to cancerous which can be attributed to the collagen orientation in the cervical tissue. With the progression of the cancer, collagen structure degrade due to breakage of inter cross linkage between fibrils and become more randomized. Further depolarization was also used to identify the different CIN grades. Some of the research also explored partial Muller imaging to increase the contrast between cancerous and normal tissues on the basis on polarization properties like retardance and depolarization for oral cancer. Furthermore, Mueller polarimetry has been used to investigate lung tissue, liver, muscles, porcine myocardial tissue, skin including melanoma, bladders, red blood cell suspensions etc.[10-14]. Most of the studies were done on bulk tissue sample only.

Diabetes is another important problem commonly found in the human being where glucose level is increased in the blood. Mueller measurement was also explored for the non-invasive measurement of glucose level. As far non-invasive polarimetric measurements of glucose levels in actual tissues will have to be precisely investigated. Certainly, for non-invasive glucose measurements, the very low physiological glucose levels, absorption, scattering, other chiral molecules, and the various biological confounding effects like temperature, Ph etc. will pose significant challenges. to non-invasive glucose monitoring

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approach. Nevertheless, for in-vivo glucose measurements, polarimetry approaches has shown early promising results.

Conclusion:

Various polarimetric studies showed that Mueller polarimetry can be futuristic candidate for biomedical diagnosis. Mueller polarimetric imaging for diagnostics and surgical applications is a promising technique but still it is in its early stage of development, and without any doubt much research effort needs to be done. In future, it is anticipated that Mueller polarimetry has a potential to become an another important imaging modality for diagnosis and surgical applications .

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