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Optical Anisotropy of Biological Polycrystalline Networks

Vector-Parametric Diagnostics

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Introduction

Relevance of the Topic. Biological tissues are structurally heterogeneous media that can absorb optical radiation [1–10]. In order to describe the interaction of laser radiation with such complex systems, it is necessary to use an approach that uses the formalism of Mueller matrices and of information analysis [11, 14–16, 22–26, 30–42, 44, 49–51, 53, 54]. Currently, biological and medical research uses many practical methods based on the measurement and analysis of Mueller matrices of prototypes. In recent years, biomedical optics has formed an independent direction–laser polarimetry [12–14]. Within the framework of this research area, it was possible to establish the relationship between the coordinate distributions of the values of the matrix elements (Mueller-matrix images) and the corresponding distributions of the values of the birefringence of polycrystalline networks of optically thin layers of human biological tissues. On this basis, changes in the optically anisotropic structure of biological tissues (skin dermis, epithelial tissue, etc.) are differentiated, which are caused by oncological conditions of human organs [17–20, 27–29, 31, 36, 38, 39, 43–48, 50, 57]. At the same time, laser polarimetry methods require further development and deepening. First, not all elements of the Mueller matrix are convenient for characterizing biological samples. The reason for this is the azimuthal dependence of the majority of the matrix elements—in general, 12 out of 16 elements change as the sample rotates around the sounding axis [21, 22]. In addition, there are a number of azimuthally independent combinations of elements of the Mueller matrix or Mueller-matrix invariants (MMIs). Secondly, the mechanisms of optical anisotropy of biological layers are not limited to manifestations of birefringence of spatially structured fibrillar networks. Actual on the way to expanding the arsenal of diagnostic techniques is to take into account the influence of the mechanisms of amplitude anisotropy—linear and circular dichroism [6, 8, 10]. Thirdly, there is a wide range of optically anisotropic biological objects for which laser polarimetry methods are not yet widely used. Such objects include biological fluids (blood and its plasma, urine, bile, saliva, etc.), which are easily accessible and do not require for obtain a sample of a traumatic operation biopsy. Fourth, the manifestations of

these mechanisms of optical anisotropy manifest themselves differently on different scales of the geometric dimensions of polycrystalline structures of biological layers [52–57].

Consequently, the relevance of the monograph is due to the need to develop new, information-complete and experimentally reproducible approaches to the analysis of optical anisotropy of biological tissues and fluids, to search for new azimuthally independent methods of Stokes polarimetry using algorithms of polarization reconstruction and of spatial-frequency filtering of object fields, which allows us to separate the manifestations of different mechanisms of phase and amplitude anisotropy of multiscale polycrystalline networks of biological layers in the development of objective criteria for assessing the degree of pathology and differentiation of the research samples.

The purpose of the monograph is to develop new azimuthally independent methods of Stokes polarimetry and Mueller-matrix reconstruction of the distributions of optical anisotropy parameters using spatial-frequency filtering of phase (linear and circular birefringence) and amplitude (linear and circular dichroism) anisotropy to diagnose changes in the orientation-phase structure of fibrillar networks of histological sections of biological tissues and polycrystalline films of biological fluids.

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