Optical Memory and Neural Networks
October 2012, Volume 21, Issue 4, pp 233-241

Fourier-Stokes polarimetry of fields scattered by birefringent biological networks

Abstract

This work presents the results of Stokes vector coordinate distributions determination of biological tissues laser images in Fourier plane. The description of experimental setup — Fourier Stokespolarimeter is provided. The optical model of polycrystalline networks of histological sections of rectum wall is suggested. The results of investigating the interrelation between the values of statistical (statistical moments of the 1st–4th order) parameters are presented. They characterize the coordinate distributions of the fourth parameter of Stokes vector of Fourier transforms of laser images of rectum wall histological sections and oncological changes. The diagnostic criteria of rectum cancer are determined.

Page %P

Page 1

ISSN 1060-992X, Optical Memory and Neural Networks (Information Optics), 2012, Vol. 21, No. 4, pp. 233–241. © Allerton Press, Inc., 2012.

Fourier-Stokes Polarimetry of Fields Scattered by Birefringent Biological Networks

P. O. Angelsky[a], L. B. Bodnar[b], M. P. Gorskii[a], and L. Ya. Kushnerick[a]

[a]*Optics and Spectroscopy Department, Chernivtsi National University, Chernivtsi, Ukraine*

[b]*Bucovinian State Medical University, Department of pediatric and medical genetic, Ukraine*

e-mail: ushenko@itf.cv.ua

Received April 14, 2012; in final form, July 15, 2012

Abstract—This work presents the results of Stokes vector coordinate distributions determination of biological tissues laser images in Fourier plane. The description of experimental setup – Fourier Stokes-polarimeter is provided. The optical model of polycrystalline networks of histological sections of rectum wall is suggested. The results of investigating the interrelation between the values of statistical (statistical moments of the 1st-4th order) parameters are presented. They characterize the coordinate distributions of the fourth parameter of Stokes vector of Fourier transforms of laser images of rectum wall histological sections and oncological changes. The diagnostic criteria of rectum cancer are determined.

Keywords: polarization, birefringence, anisotropy, phase, laser polarimetry

DOI: 10.3103/S1060992X12040029

1. INTRODUCTION

A new direction of optical physical diagnostics [1–8]—laser polarimetry of microscopic images of polycrystalline networks of biological tissues histological sections [9–12] has been developed in recent years. This approach is focused on in vitro measurements of coordinate distributions of Stokes vector parameters of biological tissues laser images with further complex (statistical, correlation, fractal, singular, wavelet, etc.) analysis on the basis of the obtained data arrays [13–24].

Another diagnostic biomedical laser technique—polarizationally sensitive optical coherent tomography—also became widely spread [25–29]. It is based on measuring the parameters of Stokes vector in the remote (Fourier) diffraction zone of the field of scattered laser radiation.

That is why the task of combining the information potentiality of the above mentioned techniques of optical diagnostics basing on the development of new methods of analysis and processing of polarizationally inhomogeneous images of biological tissues in the Fourier plane [30–34] of scattered radiation field proves to be topical.

This research is focused on the development of experimental technique of polarization investigation of coordinate distributions of Stokes vector parameters of the laser field in the Fourier plane for diagnostics and differentiation of the severity of pathological changes in rectum tissue biopsy.

2. BASIC ANALYTICAL RELATIONS

It was determined for the fields of scattered laser radiation that polarization state in every point with (n, m) coordinates is formed by the mechanisms of statistical interference and is determined using the following relations [15, 19, 31]

$$\alpha(n,m) = 0.5\arcsin\left[\frac{\sin 2\Theta(n,m)}{\cos\delta(n,m)}\right]; \quad (1)$$

$$\beta(n,m) = 0.5\arctan\left[\frac{\sin\delta(n,m)}{\cos 2\Theta(n,m)}\right], \quad (2)$$

where $\Theta = \arctan\frac{E_y}{E_x}$—the phase angle, δ—phase shift between the orthogonal components E_x, E_y of

No Body Text -- translate me!
Page 2

laser radiation amplitude determined from relations [26]

$$E_x e^{i\delta_x} = e^{i\delta_{0x}} E_{0x}\left[\left(\cos^2\rho + e^{-i\phi}\sin^2\rho\right)\sin^2\theta\right] + e^{i\delta_{0y}} E_{0y}\left[\cos\rho\sin\rho\left(1 - e^{-i\phi}\right)\cos^2\theta\right]; \quad (3)$$

$$E_y e^{i\delta_y} = e^{i\delta_{0x}} E_{0x}\left[\cos\rho\sin\rho\left(1 - e^{-i\phi}\right)\sin^2\theta\right] + e^{i\delta_{0y}} E_{0y}\left[\left(\cos^2\rho + e^{-i\phi}\sin^2\rho\right)\cos^2\theta\right]. \quad (4)$$

Here δ_{0x}, δ_{0x}—phases of orthogonal components (E_{0x}, E_{0y}) of the amplitude of the laser image probing polycrystalline network; $\rho\ \varphi\ \theta\ \delta = \delta_x - \delta_y = \varphi + \theta$.

Expressions (3) and (4) are "input" parameters for diffraction integrals [31] determining further diffraction-interferential process of evolution of amplitude-phase distributions of object field.

For the case of finding the biological tissue layer in the focal plane of the objective the following can be written

$$U_x(m^*, n^*) = \frac{A}{i\lambda f}\int_{-\infty}^{+\infty} E_x(m,n)\exp\left[-i\frac{2\pi}{\lambda f}(nn^* + mm^*)\,dndm\right]; \quad (5)$$

$$U_y(m^*, n^*) = \frac{A}{i\lambda f}\int_{-\infty}^{+\infty} E_y(m,n)\exp\left[-i\frac{2\pi}{\lambda f}(nn^* + mm^*)\,dndm\right]. \quad (6)$$

Here f—focus distance of the objective; λ—wave length of laser radiation; n, m and n^*, m^*—coordinates of the points in the image plane and Fourier plane respectively.

Diffraction integrals (5) and (6) enable to determine the asymmetry degree of Fourier spectrum in two mutually transverse directions

$$\Delta(\nu) = \frac{U_x(m^*) + U_y(m^*)}{U_x(n^*) + U_y(n^*)}, \quad (7)$$

where

$$U_x\left(m^*\right) = \frac{A}{i\lambda f}\int_{-\infty}^{+\infty} E_x(m)\exp\left[-i\frac{2\pi}{\lambda f}mm^*\right]dm = \frac{A}{i\lambda f}\int_{-\infty}^{+\infty} E_x(m)\exp\left[-i2\pi m\nu_m\right]dm; \quad (9)$$

$$U_x(n^*) = \frac{A}{i\lambda f}\int_{-\infty}^{+\infty} E_x(m)\exp\left[-i\frac{2\pi}{\lambda f}nn^*\right]dn = \frac{A}{i\lambda f}\int_{-\infty}^{+\infty} E_x(m)\exp\left[-i2\pi n\nu_n\right]dn; \quad (10)$$

$$U_y(m^*) = \frac{A}{i\lambda f}\int_{-\infty}^{+\infty} E_y(m)\exp\left[-i\frac{2\pi}{\lambda f}mm^*\right]dm = \frac{A}{i\lambda f}\int_{-\infty}^{+\infty} E_y(m)\exp\left[-i2\pi m\nu_m\right]dm; \quad (11)$$

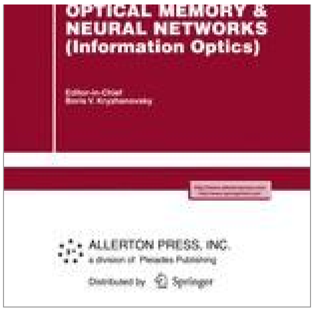
$$U_y(n^*) = \frac{A}{i\lambda f}\int_{-\infty}^{+\infty} E_y(n)\exp\left[-i\frac{2\pi}{\lambda f}nn^*\right]dn = \frac{A}{i\lambda f}\int_{-\infty}^{+\infty} E_y(n)\exp\left[-i2\pi n\nu_n\right]dn. \quad (12)$$

Thus, taking into account relations (1)–(6) the following expressions for the Stokes vector parameters can be written [32]

$$\begin{aligned} S_1(m^*, n^*) &= E_x E_x^* + E_y E_y^*; \\ S_2(m^*, n^*) &= E_x E_x^* - E_y E_y^*; \\ S_3(m^*, n^*) &= E_x E_y^* - E_y E_x^*; \\ S_4(m^*, n^*) &= i\left(E_y E_x^* - E_x E_y^*\right), \end{aligned} \quad (13)$$

and asymmetry degree of $S_{k=1;2;3;4}(m^*, n^*)$ distributions can help to determine the degree of asymmetry (relations (7)–(12)).

For objective (quantitative) estimation of distributions $S_{k=1;2;3;4}(m^*, n^*)$ the statistical, correlation and spectral approaches were used.


OPTICAL MEMORY &
NEURAL NETWORKS
(Information Optics)
Editor-in-Chief
Boris V. Kryzhanovsky
ALLERTON PRESS, INC.
a division of Pleiades Publishing
Distributed by Springer

Related Content

References (34)

About this Article

Title
Fourier-Stokes polarimetry of fields scattered by birefringent biological networks

Journal
Optical Memory and Neural Networks
Volume 21, Issue 4 , pp 233-241
Cover Date
2012-10-01
DOI
10.3103/S1060992X12040029
Print ISSN
1060-992X
Online ISSN
1934-7898
Publisher
Allerton Press, Inc.

Additional Links

- Register for Journal Updates
- Editorial Board
- About This Journal
- Manuscript Submission

Topics

- Information Storage and Retrieval
- Complexity

Keywords

- polarization
- birefringence
- anisotropy
- phase
- laser polarimetry

Authors

- P. O. Angelsky [(1)]
- L. B. Bodnar [(2)]

- M. P. Gorskii [(1)]
- L. Ya. Kushnerick [(1)]

Author Affiliations

- 1. Optics and Spectroscopy Department, Chernivtsi National University, Chernivtsi, Ukraine
- 2. Department of pediatric and medical genetic, Bucovinian State Medical University, Chernivtsi, Ukraine

Continue reading...

To view the rest of this content please follow the download PDF link above.