Multiparameter Correlation Microscopy of Biological Fluids Polycrystalline Networks

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ABSTRACT

In this part the description of the basic types of human biological fluids is given. Experimentally measured coordinate divisions of Jones-matrix elements of optically thin polycrystalline networks are cited. Algorithms are provided and experimental methodology of measuring Jones-matrix imaging is analyzed. Experimental results of investigation of statistic, correlational and fractal parameters characterizing Jones-matrix imaging of polycrystalline networks of the basic types of human biological fluids are represented. The system of classification of optical anisotropic peculiarities of biological fluids' membranes based on statistic, correlational, space-frequency and spectral approach is suggested.

Keywords: correlation microscopy, biologilc fluids, polarimetry.

1. A brief characteristic of the objects

The following smears of biological fluids of a healthy human body were used as the objects of study:

- Saliva (21 samples) – group 1;
- Blood plasma (21 samples) –group 2;
- Bile (21 samples) – group 3.

This choice of biological fluids is stipulated by the following factors:

- They cover a wide range of physiological functions of a human body;
- Various biochemical structure has common optical manifestation of anisotropy (saliva – liquid albumin and globulin crystals, blood plasma – liquid fibrin crystals including amino acids of albumin and globulin and fibrin; bile – liquid and solid concretions of calcium bilirubinate and fatty acids);
- The other, physiologically important, types of biological fluids (transudates and exudates, exudation, cerebrospinal fluid, lymph, exhaled breath condensate and others) compose to a certain extent a combination of optical anisotropic peculiarities of the samples belonging to groups 1-3.

2. Jones-matrix imaging of polycrystalline networks of optically thin layers of saliva

To achieve objective criteria of classification of manifestation of optical anisotropy of polycrystalline networks of biological fluid belonging to group 1 (21 samples) we carried out the comprehensive investigation of coordinate divisions of Jones-matrix elements $\aleph_{11}(m\times n)$ i $\aleph_{12;21}(m\times n)$ mostly characterizing manifestations of orientation p and phase 8 structures of the combination of liquid crystals.

Eleventh International Conference on Correlation Optics, edited by Oleg V. Angelsky, Proc. of SPIE Vol. 9066, 90661Y · © 2013 SPIE · CCC code: 0277-786X/13/$18 · doi: 10.1117/12.2053853

Within group 1 we defined statistically averaged values and dispersion of their spread of the parameters characterizing Jones matrix imaging $\aleph_{11}(m\times n)$ i $\aleph_{12;21}(m\times n)$ of biological crystal networks forming in the membranes of human fluids:

- Statistical moments of the 1st - 4th order M; σ; A; E;
- Correlational moments of the 1st - 4th order $K_{i=1;2;3;4}$;
- Spectral moments of the 1st - 4th order $K_{i=1;2;3;4}$.

In the schemes 1, 2 there is a series of coordinate divisions of Jones matrix elements $\aleph_{11}(m\times n)$ (scheme 1) and $\aleph_{12;21}(m\times n)$ (scheme 2)of polycrystalline membranes of the layer of human saliva and corresponding histograms $H(\aleph_{11})$; $H(\aleph_{12;21})$, autocorrelational functions G_{11} (Δx); $G_{12;21}$ (Δx), logarithmic spectral dependences $LogPSD(\aleph_{11})$; $LogPSD(\aleph_{12;21})$ of such divisions [1-20].

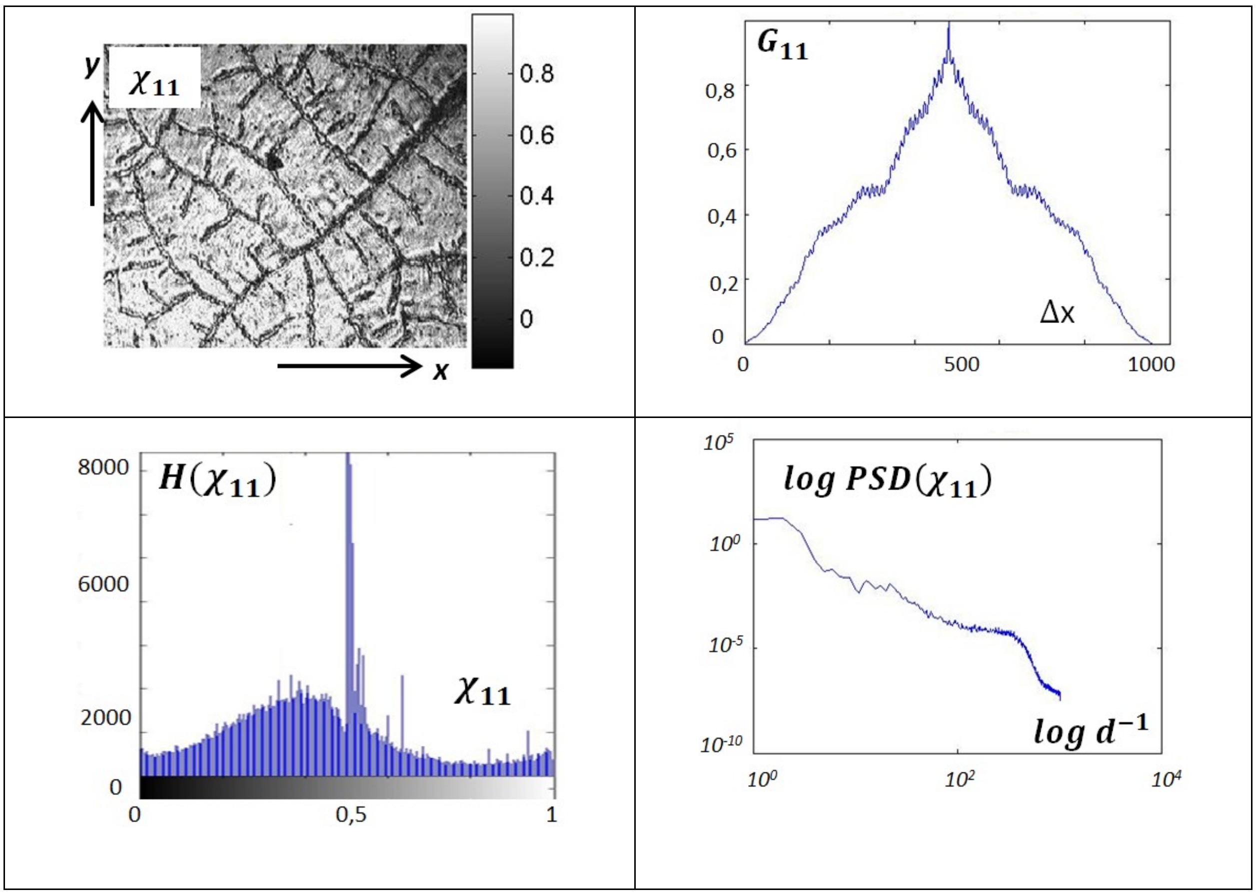


Fig. 1. Coordinate $\aleph_{11}(m\times n)$, probabilistic $H(\aleph_{11})$, correlated $G_{11}(\Delta m, \Delta n)$ and self-similar $LogPSD(\aleph_{11})$ structure of the element of John's matrix $\aleph_{11}$ of polycrystalic system of human saliva's layer.

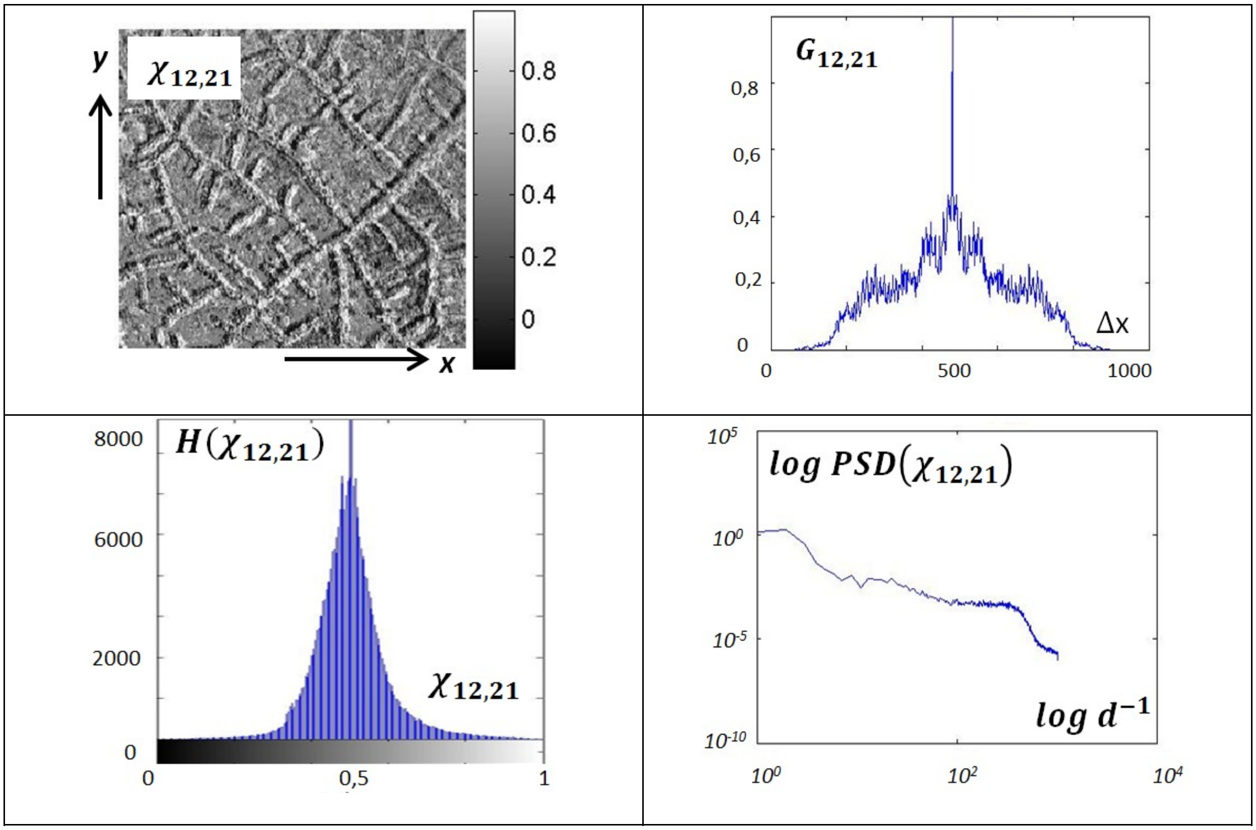


Fig. 2. Coordinate $\aleph_{12;21}$ $(m\times n)$, probabilistic $H(\aleph_{12;21})$, correlated $G_{12;21}(\Delta m, \Delta n)$ and self-similar $LogPSD(\aleph_{12;21})$ structure of the element of John's matrix $\aleph_{12;21}$ of polycrystalic system of human saliva's layer.

The results, obtained in the process of the research of the Jone's-matrix picture of the 'referential' $\aleph_{11}(m\times n)$ and 'phase's' $\aleph_{12;21}(m\times n)$ elements of polycrystal system of biological crystals of the optical-thin layer of the saliva, indicate the sufficient optical anisotropy's level. On the current fact points the wide change range ($0 \le \Delta\ \aleph_{11} \le 1$) of it's own value of the matrix element $\aleph_{11}(m\times n)$. Besides that for histogram $H(\aleph_{11})$ is typical the advantage of the possibility of values 'referential' matrix element (in 2 – 7 times) in comparison with quantities of the other extremums (Fig. 1).

Histogram $H(\aleph_{12;21})$ of the division of the values of the 'phase's' $\aleph_{12;21}(m\times n)$ element is symmetrical to the chief extremum (Fig. 2) that corroborates the supposition, that morphological structure of the optical-anisotropic polycrystal system of saliva's layer has single-type in biological composition aleuronic structures.

Correlated approach to the analysis of the obtained results showed, that autocorrelated functions $G_{11;12;21}(\Delta x)$ are similar dependencies with well-shown fluctuations of inherent meanings (fig.1 and 2).

The set of values of the 'referential' $\aleph_{11}(m\times n)$ and 'phase's' $\aleph_{12;21}(m\times n)$ elements of Jone's matrix are multifractal. The corresponding logarithmic dependencies $LogPSD(\aleph_{11})$; $LogPSD(\aleph_{12;21})$ are characterized by broken lines approximating curves with three slope angles [3,6]. To our mind the following fact can be connected with multiple discrete change of the orientations of optical axes of the partial biological crystals with simultaneous multiple change of phase period δ [2]. That is why the coordinate divisions of the elements $\aleph_{ik}\,(x,y)$ Jone's generalized matrix statement are pseudoharmonic dependencies with few main jitter frequencies, that are the reason of set formation of the self-similar of multiples $\aleph_{ik}\,(x,y)$ on different geometric scales polycrystalic net of the group 1.

3. Jones-matrix images of the polycrystalic nets of the optical-thin layers of the blood plasma

There results of the research of Jones-matrix images $\aleph_{ik}\,(x,y)$ of polycrystalic biological crystals' net of amino acids of the other type. From the biological point of view the main partial birefringence structures in blood plasma are cylindrical crystals of albumin and spherulitic crystals of globulin. From the optical-geometrical point of view such nets of blood plasma proteins form spherulitic polycrystalic nets [1]. On the Fig. 3 and 4 the series of coordinate divisions of the Jones-matrix elements $\aleph_{11}(m\times n)$ are given (fig. 3) and $\aleph_{12;21}(m\times n)$ (fig.4) spherulitic albumen-globulin net of the blood plasma and corresponding histograms $H(\aleph_{11})$; $H(\aleph_{12;21})$, autocorrelated functions $G_{11}(\Delta x)$; $G_{12;21}(\Delta x)$, logarithmic spectral dependencies $LogPSD(\aleph_{11})$; $LogPSD(\aleph_{12;21})$ of such distributions.

The results, obtained in the process of research of polarized peculiarities of polycrystalic net of albumen and globulin of the optical-thin layer of the blood plasma argue about considerable influence of the structure of coordinate divisions of 'referential' $\aleph_{11}(m\times n)$ and 'phase's' $\aleph_{12;21}(m\times n)$ elements as peculiarities of the division of optical axes of biological crystals and its substances birefringence. On the following fact points the widest range of variation ($0 \leq \Delta\,\aleph_{11} \leq 1$) of eigenvalues of distribution $\aleph_{11}$ (m×n) with similar probabilities of different values of "orientation" matrix element points out at this fact (Figure 3).

There is a structure of histogram H ($\aleph_{11}$) of the distribution of the values of Jones-matrix imaging of "orientation" element ($\aleph_{11}$) which is equally probable and typical to albumin-globulin spherulitic networks of the blood plasma.

Another dependency is a histogram for the distribution of values of "phase" $\aleph_{12;21}$ (m×n) element. As it is shown in Figure 4 $H\left(\aleph_{12;21}\right)$ is rather symmetric as to the main extremum. Comparative analysis of data on the ability of the drifting phase of dendritic polycrystalline network layer of saliva (Figure 2) showed greater dispersion, indicates a greater range of variation of geometrical sizes of partial two-beam-refracting crystals which form a particular value of the phase shift δ

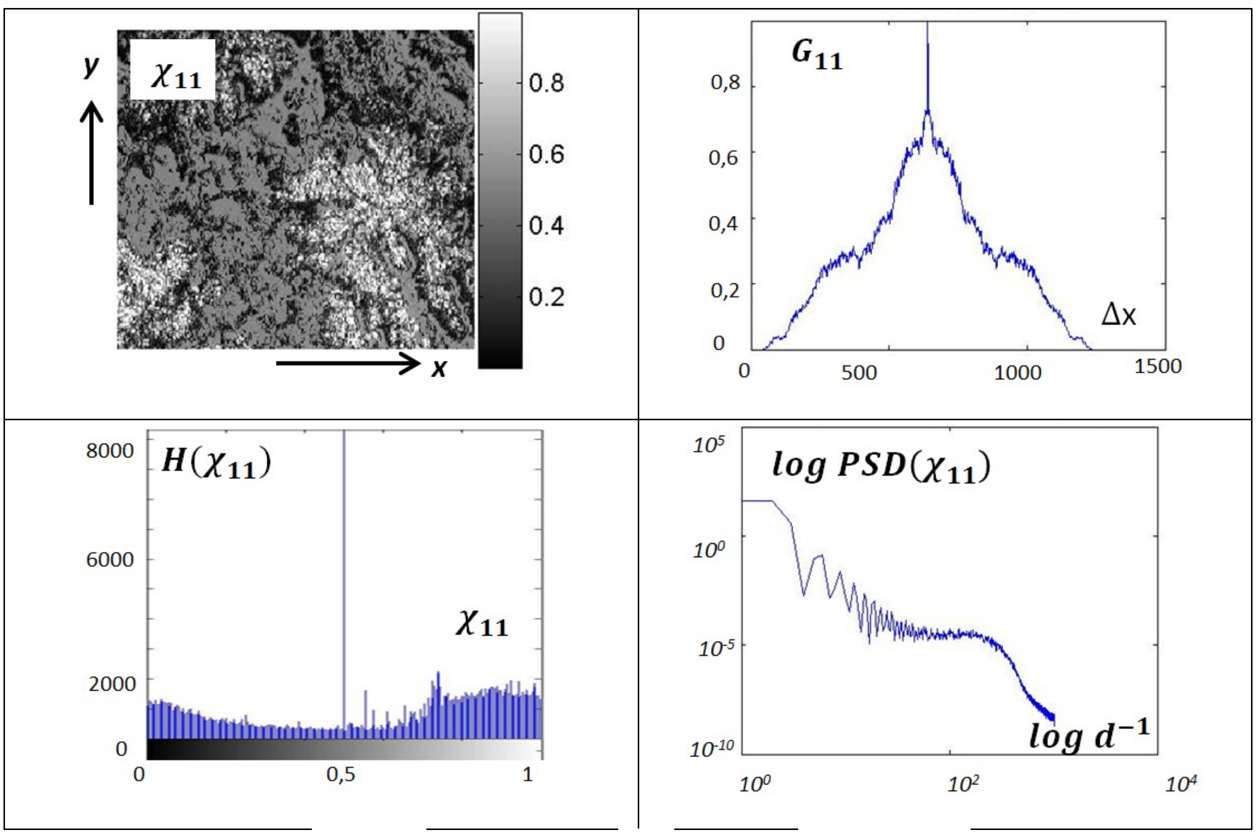


Fig. 3. Coordinate $\aleph_{11}$ (m×n), probabilistic H ($\aleph_{11}$), correlative $G_{11}(\Delta m,\ \Delta n)$ and self-similar LogPSD($\aleph_{11}$) structure of the Jones-matrix element $\aleph_{11}$ of polycrystalline network of human blood plasma.

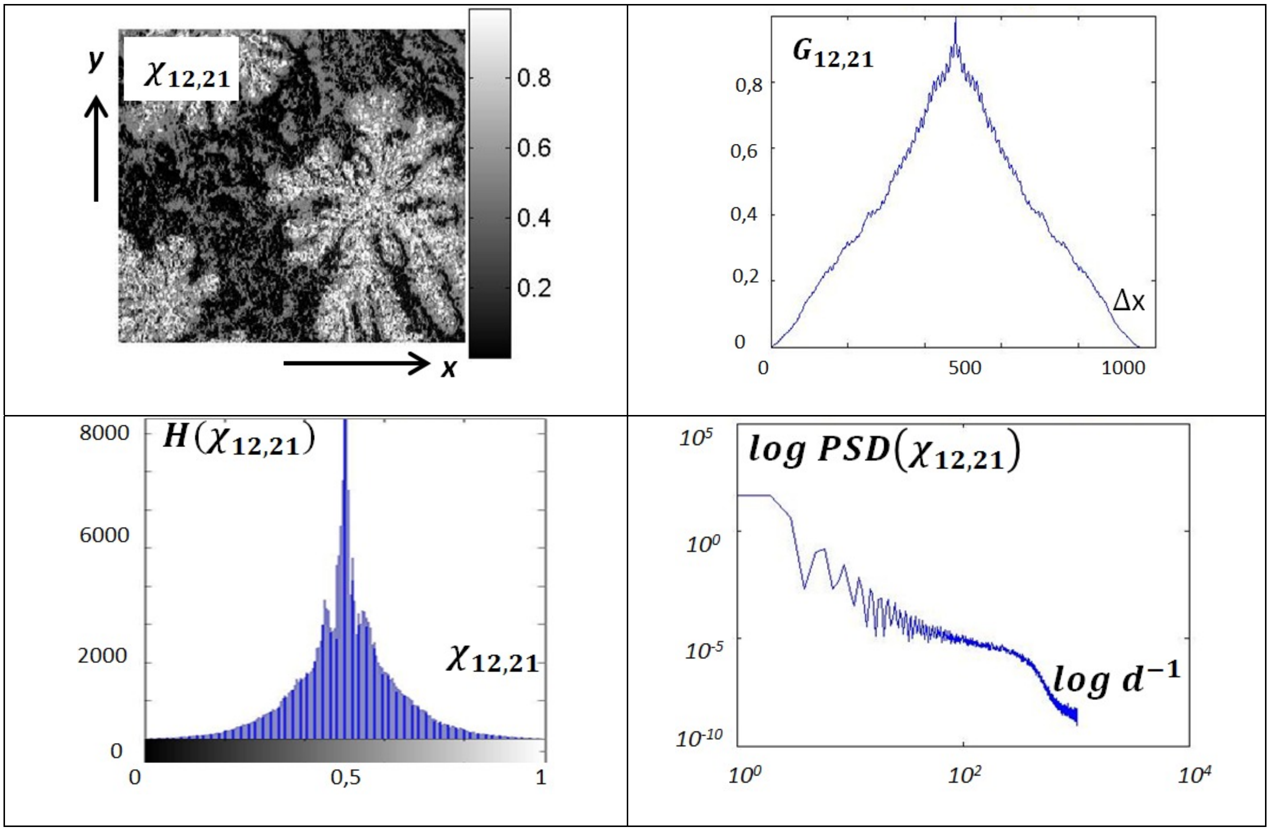


Fig. 4. Coordinate $\aleph_{12;21}$ (m×n), probabilistic H ($\aleph_{12;21}$), correlative $G_{12;21}(\Delta m,\ \Delta n)$ and self-similar LogPSD($\aleph_{12;21}$) structure of the Jones-matrix element $\aleph_{12;21}$ of polycrystalline network of human blood plasma.

Autocorrelational functions $G_{11;12;21}$ $(\Delta$ x) of Jones-matrix imaging $\aleph_{ik}$ (m×n), of the samples of blood plasma from group 2 are declining dependences with strongly pronounced fluctuations of eigenvalues (Figure 3 and 4). In addition, the discrete repetitive change of orientations of optical axes of partial biological crystals with simultaneous multiple change of the period of phase δ is the formation of self-similar sets $\aleph_{ik}$ (m×n) at different geometric scales of the polycrystalline network. As can be seen, the distributions of the values of "orientation" $\aleph_{11}$ (m×n) and "phase" $\aleph_{12;21}$ (m×n) Jones matrix elements are multifractal. The corresponding logarithmic dependences logPSD ($\aleph_{11}$); logPSD ($\aleph_{12;21}$) are characterized by broken approximating curves with three rakes.

4. Jones-matrix imaging corresponding to polycrystalline networks of optically thin layers of bile

The results of the research Jones-matrix imaging $\aleph_{ik}$ (m×n) of polycrystalline networks of biological crystals of human bile [5]. From the biochemical point of view the main partial two-beam-refracting biles' structures is optically anisotropic liquid crystal phase consisting of a combination of liquid crystals of cholesterol monohydrate and bilirubinate calcium. Moreover, there is a solid crystalline phase which is formed by dendritic and disclinational mechanisms of crystallization. From the opto-geometrical point of view such optical anisotropic formation can form an optical anisotropy cluster islands.

In Figures 5 and 6 there is a coordinate distribution of Jones matrix elements $\aleph_{11}$ (m×n) (Figure 5) and $\aleph_{12;21}$ (m×n) (Figure 6) of an optical anisotropy structure of the bile and the corresponding histograms H ($\aleph_{11}$), H ($\aleph_{12;21}$), autocorrelational functions G_{11} $(\Delta$ x); $G_{12;21}$ $(\Delta$ x), of logarithmic spectral dependences logPSD ($\aleph_{11}$); logPSD ($\aleph_{12;21}$) of these distributions.

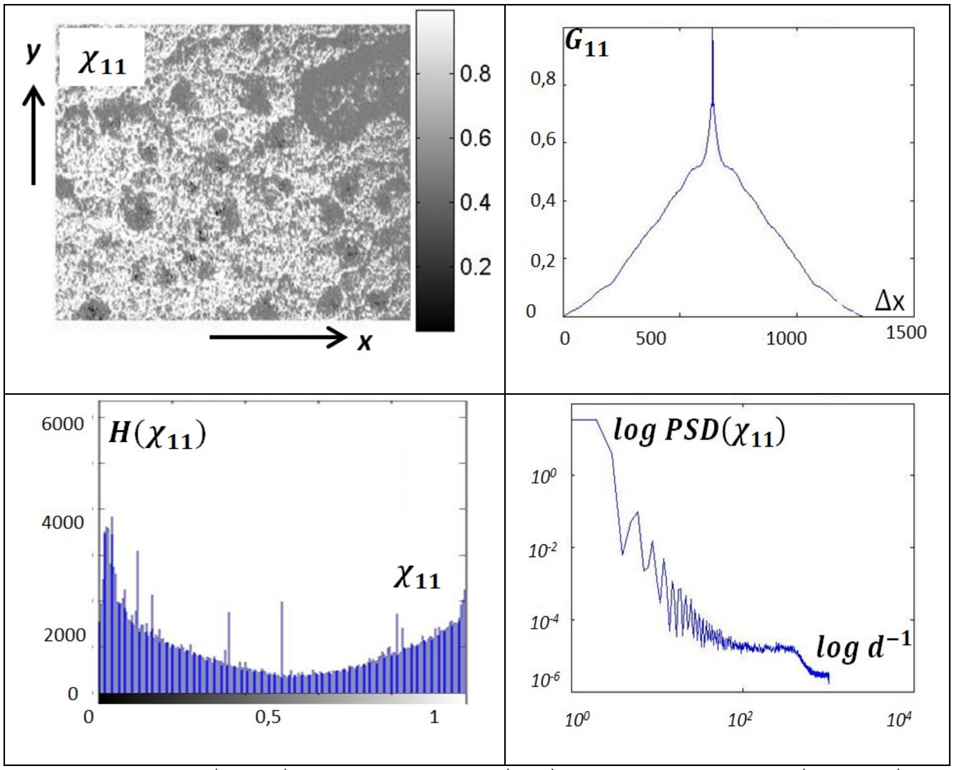
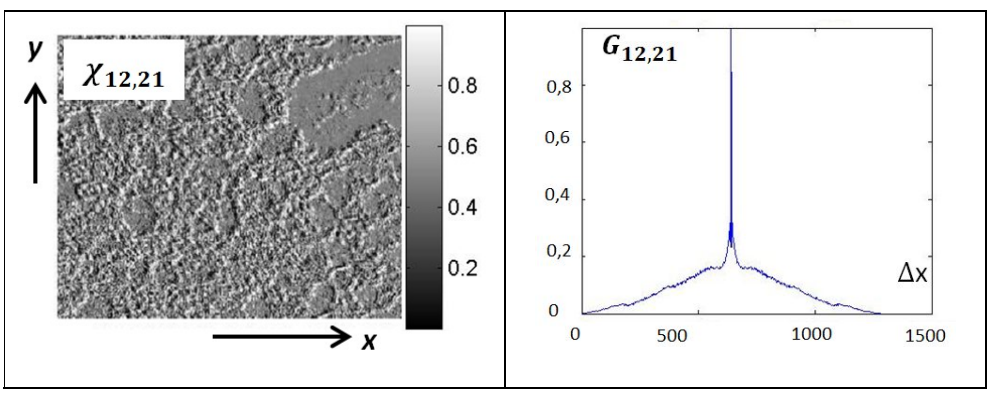


Fig. 5. Coordinate $\aleph_{11}(m \times n)$, probabilistic $H(\aleph_{11})$, correlative $G_{11}(\Delta m, \Delta n)$ and self-similar structure $LogPSD(\aleph_{11})$ of Jones matrix element of policrystallic human bile net

Cluster structure of thin optic bile layer crystal component is shown in maximum wide sufficiently equally probable change rate of "orientation" matric element division proper meanings.



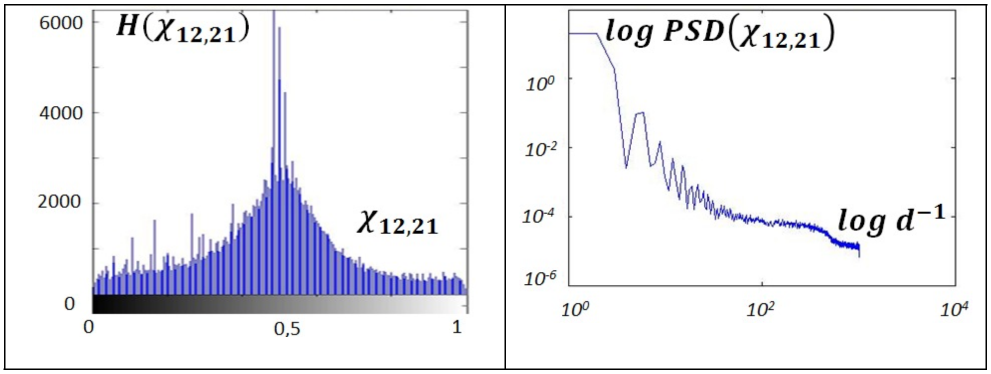


Fig. 6. Coordinate $\aleph_{12;21}(m \times n)$, probabilistic $H(\aleph_{12;21})$, correlative $G_{12;21}(\Delta m, \Delta n)$ and self-similar $LogPSD(\aleph_{12;21})$ structure of Jones matrix element $\aleph_{12;21}$ of policrystallic human bile net.

Meaning division histogram of Jones matrix "phase" element remains, as in former instances of dendritic and spherolitic biological crystal policrystallic nets, sufficiently symmetric in accordance to major extremum.

Autocorrelative functions of Jones matrix group 3 bile samples portrayal appear to be monotonously decreasing dependencies without fluctuations of their meanings (fig. 5 and fig. 6). Apart from that, scaled reoccurring change of fractioned biological crystal optic axis orientations with simultaneous multiple change of δ phase period becomes apparent in self-similar multiplicity formation on different geometric scales of cluster policrystallic net. Corresponding logarithmic dependencies $\log PSD(\aleph_{11})$; $\log PSD(\aleph_{12;21})$ are characterized by kinked approximating curved lines with three slope angles.

Analyzing the whole set of statistical, correlative and spectral parameters obtained, which characterize coordinative distribution of Jones matrix element meanings, formed by "orientative" and "phase" influences of optical-anisotropic clusters of thin optic layers of human biological fluids, individual perceptibility to geometric texture change of policrystallic net of higher rank moments may be derived.

5. CONCLUSION

In the given article the materials of research of statistical, correlative and spectral moments of the 1st and 4th order are presented which serve to describe coordinate distribution $K_{i\kappa}$ $(m$ x $n)$ of elements of John's matrix which represents various polycrystal structures of human liquids – spittle, blood plasma, bile, synovial liquid.

It was established the dimensions and ranges of all group changes of parameters of John's matrical images $\aleph_{ik}(m \times n)$ of optic-anisotropic composition for every type of biological liquid.

The criteria of objective classification of polarizable properties of polycrystal circuits of biological crystals in the liquids of human organism were set.

It was discovered that:measuring of statistical elements of the 3d and 4th order which coordinate distributions describe $\aleph_{11}(m \times n)$ of oriental elements of John's matrix which represent undiscovered biological liquid on the basis of comparative analysis with the classified maps (scheme7-9) allows to determine type of polycrystal circuit with sensitivity of 80-90%.

- measuring of correlative moments of the 3-4th order of autocorrelative dependencies $\aleph_{11}(m \times n)$ is effective with sensitivity not less than 80% in the differentiation of dendritical and spherulitical circuits of biological liquids in accordance with their belonging to group №1 and group №2.
- measuring and ranges of spectral statistical moments with changes of the 3d and 4th order which describe logarithmic dependencies of spectres representing capacity of coordinate distribution of oriental elements of John's matrix which represents undiscovered biological liquid on the basis of comparative analysis illustrated by classified maps (scheme 7-9) and it allows to determine a type polycrystal biological liquid circuit with the sensitivity of 80-90%.
- measuring of correlative moments of the 3-4th order of autocorrelative dependencies $\aleph_{11}(m \times n)$ which is effective with the sensitivity not less than 70% in the differentiation of dendritical and spherulitical circuits of biological liquids

in accordance with their belonging to group 1 and group 2.

- measuring and ranges of spectrical statistical moments of changes of the third and fourth order which describe the logarithmic dependencies of spectres representing capacities of coordinate distributions of oriental elements of John's matrix effective in the differentiation of polar properties of spherutical and clasteral optic-anisotropic circuits of biological liquids in reference to group № 2 and group №3.
- the sensitivity of statistical, correlative and fractal analysis of coordinate distribution of phasal elements $\aleph_{12;21}(m \times n)$ numbers 50-55% and cannot be used as a reliable criterion of polar properties differentiation for all three groups.

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