Article

Polarization-Holographic Processes in Biosystems

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ABSTRACT

A proposed physical-mathematical model that describes a version of the polarization-holographic vector-shaped calibration of potential spatio-temporal dynamic processes of higher biosystems in their development and in adulthood.

Keywords: DNA, light radiation, chromosomal continuum, polarization, hologram.

Let's record a vector diffraction Kirchhoff's integral in paraxial approximation [10], which describes wave field, for instance photon field, formed by a non-stationary fragment of a biosystem. These coherent photon fields may radiate from the liquid crystal continuum of a chromosome (LCCC) *in vivo* [27]. This type of radiation may be expressed by the following equation:

$$E_{ob}(x,y,z,\omega,t) \approx \frac{i}{2\pi c}\int_{S_0}\int_{T_0}\frac{\omega}{r}E_{ob}(x_0,y_0,z_0,t_0)\exp i\omega[(t-t_0)-\frac{1}{c}r]dt_0 dS_0 \qquad (1)$$

where ***c*** — speed of light; ***ω*** — frequency; ***x0, y0, z0, t0*** и ***x, y, z, t*** – space-time coordinates of a LCCC's point and an observation point, respectively; ***r*** -distance between these points; ***S0, T0*** - time-space interval, occupied by LCCC; ***dS=dx0, dy0***

In the equation (1), ***Eob (x0, y0, z0, t0)*** represents distribution of field amplitude of LCCC. This field is present for every polarization mode which are orthogonal and are independent until a turn occurs in their planes from their initial positions of vectors of median frequency waves of ***ω0*** (which are polarized mono-frequency waves, slightly shifted by frequency in relation to one another), propagating along ***z*** axis with Jones vector [11]. Remember, chromosomes are characterized by high optical activity, expressed by optical spin dispersion and spherical dichroism that is a prerequisite for formalism.

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$$E_0 = E_{0x} \exp - \frac{i\omega_0 z}{c} \begin{pmatrix} 1 \\ \iota\varepsilon \end{pmatrix}, \quad 0 \le \varepsilon = \frac{E_{0y}}{E_{0x}} \le 1 \qquad (2)$$

Field ***E0*** passes via non-stationary fragment of LCCC with Jones matrix.

$$M_{ob}(x_0, y_0, z_0, t_0) = \begin{pmatrix} m_{11}(x_0, y_0, z_0, t_0) & m_{12}(x_0, y_0, z_0, t_0) \\ m_{21}(x_0, y_0, z_0, t_0) & m_{22}(x_0, y_0, z_0, t_0) \end{pmatrix}$$

For simplification we will consider that non-stationary LCCC is not a function of the frequency of translucent light [12, 13].

Both polarization modes of coherent light are depolarized by gene-sign non-stationary nature of LCCC (discussed above [22]) and are partially elliptically polarized. At the same time, they may interfere with formation of speckle patterns, and their total intensity is transferred from one mode to another by means of an earlier postulated way [25]. This in turn, leads to modulation of radio waves, formed from chromosomal photons by the mechanism of their delocalization [24].

According to [14], immediately behind the object, modified Johns' vector of orthogonally polarized passed waves may be represented in a form of partially coherent orthogonal components of elliptical polarization

$$E_{ob}(x_0, y_0, z_0, t_0) = [E_{Ax} M_{ob}(x_0, y_0, z_0, t_0) \begin{pmatrix} 1 \\ i\varepsilon \end{pmatrix} \oplus$$
$$\oplus E_{By} M_{ob}(x_0, y_0, z_0, t_0) \begin{pmatrix} i\varepsilon \\ 1 \end{pmatrix}] \exp i\omega t_0, \qquad (3)$$

where $\varepsilon = E_{Ay} / E_{Ax} = E_{Bx} / E_{By}$; $0 \le \varepsilon \le 1$; $\oplus$ – a sign of non-coherent sum of amplitudes, which [14] is introduced for partially polarized light; ***EA*** – complex amplitude of one basis component; ***EB*** – complex amplitude of another basis component, orthogonal to the previous one and non-coherent.

In a biosystem in the composition of LCCC (with only one polarization component) as a hypothetical we use a carrying wave, which passed, for instance, through an infinitely narrow time shutter lock, possessing ***δ*** - like characteristic of time transmission. Such a shutter lock

completely depolarizes the initially polarized wave [14]. The resulting wave, passed behind the shutter lock, is characterized by a continuous spectrum in the whole range with evenly distributed spectral density, and the modified vector of the carrying wave has a form of orthogonal basis of elliptical polarization:

$$E_{\text{ОП}} = [E_{0x}\exp i\varphi\begin{pmatrix}1\\ \iota\varepsilon\end{pmatrix}\oplus \\ \oplus E_{0x}\exp i\left(\phi-\frac{\pi}{2}\right)\begin{pmatrix}\iota\varepsilon\\ 1\end{pmatrix}]\exp i\omega\left(t-\frac{1}{c}z\right) \tag{4}$$

where $\varepsilon = E_{0y}/E_{0x}$, E_{0x}, E_{0y} – amplitudes; ϕ, φ – initial phases of two mutually non-coherent components.

For our case, where sometimes both polarization components are employed, the above assumption about the infinitely narrow time shutter lock is not necessary, and the sum of the field in the plane of the polarized hologram has the following form:

$$E_{\Sigma}(x,y,z,t) = E_{ip} + E_{ob} \tag{5}$$

$$E_{\Sigma}(x,y,z,t) = \{E_{0x}\exp i\varphi\exp i\omega\left(t-\frac{1}{c}z\right) + \frac{i}{2\pi c}\iint\limits_{S_0T_0}\frac{\omega}{r} \\ E_{Ax}M_{ob}(x_0,y_0,z_0,t_0)\exp i\omega\left[(t-t_0)-\frac{1}{c}r\right]dS_0dt_0\}\begin{pmatrix}1\\ i\varepsilon\end{pmatrix}\oplus \\ \left\{E_{0x}\exp i\left(\phi-\frac{\pi}{2}\right)\exp i\omega\left(t-\frac{1}{c}z\right) + \frac{i}{2\pi c}\iint\limits_{S_0T_0}\frac{\omega}{r}E_{By}\cdot\right. \\ \left.\cdot M_{ob}(x_0,y_0,z_0,t_0)\exp i\omega\left[(t-t_0)-\frac{1}{c}r\right]dS_{0_0}dt_0\right\}\begin{pmatrix}i\varepsilon\\ 1\end{pmatrix}$$

The real part of equation (5) represents the tension of electrical vector of the aggregate wave [16].

$$\mathrm{Re}(E_{\Sigma}) = p\cos\omega t + g\sin\omega t \qquad (6)$$

Parameters of the ellipse ***p*** and ***g*** are defined via ellipse components of polarization of each basis ***A*** and ***B***, as in paper [14]

$$\begin{aligned} p &= \mathrm{Re}(E_{\Sigma})_A \oplus \mathrm{Re}(E_{\Sigma})_B = p_A \oplus p_B \\ g &= \mathrm{Im}(E_{\Sigma})_A \oplus \mathrm{Im}(E_{\Sigma})_B = g_A \oplus g_B \end{aligned} \qquad (7)$$

Endogenous biological registration of the aggregate wave field (5) pertaining to LCCC as a basic element of DNA-wave bio-computer [26], implies the presence of polarization-sensitive medium in organisms [17,18], which is spectrally non-selective across the whole range of active frequencies (like non-stationary fragments of a biological object, for instance LCCC).

The polarization characteristics of the inducing light [19, 20] in the light-sensitive registering medium of LCCC allow photo-anisotropy and photo-gyrotropy. To describe the vector photo-response of polarized-sensitive media in the papers [19, 20, 21] functions of isotropic ***s***, anisotropic ***vL*** and gyrotropic ***vG*** reactions are introduced, which are constant for all frequencies of active radiation. Using Johns' matrices [8, 11] and rules of their formation [20] for cases of partially polarized inducing radiation, for the resulting Johns' matrix we get:

$$M = \exp(-2i\chi dn_0).\begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix}, \qquad (8)$$

where

$$M_{11,22} = 1 - \frac{i\chi d}{2n_0}\left[s(I_1 + I_2)_A + s(I_1 + I_2)_B \pm v_L \cos 2\theta_A \cdot \right.$$
$$\left.\cdot(I_1 - I_2)_A \pm v_L \cos 2\theta_B .(I_1 - I_2)_B\right]$$
$$M_{12,21} = -\frac{i\chi d}{2n_0}\left[v_L \sin 2\theta_{A..}(I_1 - I_2)_A + v_L \sin 2\theta_B \cdot \right.$$
$$\left.\cdot(I_1 - I_2)_B \mp iv_G(I_{\pm} - I_{\mp})_A \mp iv_G(I_{\pm} - I_{\mp})_B\right]$$

In (8) $\chi = {}^{2\pi}\!/_{\lambda}, \lambda$ – the length of the initial translucent endogenous wave (for instance, photonic radiation of chromosomes *in vivo*); ***d*** – thickness of registering LCCC; ***n0*** – complex coefficient of diffraction of LCCC in its original, non-irradiated state; ***(I1+I2)A*** и ***(I1+I2)B*** – first Stokes' parameter; ***(I1-I2)A*** and ***(I1-I2)B*** – second Stokes' parameter; ***(I±-I±)A*** and ***(I±-I±)B*** – fourth Stokes' parameter for ***A*** and ***B*** components; ***θA*** and ***θB*** – orientational angles of the large ellipse's polarization axis for ***A***- and ***B***- components, respectively measured counter-clockwise in relation to ***x*** axis.

Expressing in (8) Stokes' parameters via ***pA, pB, gA ,gB*** [8], for holograms' matrix represented as a sum of the three matrices, in the whole range of active frequencies we will get:

$$M = M_0 + M_{-1} + M_{+1}, \tag{9}$$

where ***M0*** – matrix describing non-diffracted beams;

$$M_0 \approx \exp(-2i\chi dn_0)\left[1 - \frac{i\chi ds}{n_0}\left(1 + \varepsilon^2\right)E_{0x}^2\right]\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix}; \tag{10}$$

M-1 – matrix describing virtual image;

$$M_{-1} \approx \frac{\chi d}{4\pi c n_0}\exp(-2i\chi dn_0)\begin{pmatrix}(M_{-1})_{11} & (M_{-1})_{12}\\ (M_{-1})_{21} & (M_{-1})_{22}\end{pmatrix} \tag{11}$$

with matrix elements

$$(M_{-1})_{11,22} = \iiint\limits_{S_0T_0\Omega} \frac{\omega}{r}\{E_{Ax}[(s \pm v_L)(m_{11} + i\varepsilon m_{12}) - i\varepsilon(s \mp v_L)(m_{21} + i\varepsilon m_{22})]E_{0x}\exp -i\varphi + E_{By}$$

$$\times[(s \mp v_L)(m_{22} + i\varepsilon m_{21}) - i\varepsilon(s \pm v_L)(m_{12} + i\varepsilon m_{11})]E_{0x}\exp -i(\phi - \frac{\pi}{2})\}$$

$$\exp i\frac{\omega}{c}z\exp -i\omega(t_0 + \frac{1}{c}r)d\omega dt_0 dS_0,$$

$$(M_{-1})_{12,21} = \iiint\limits_{S_0T_0\Omega} \frac{\omega}{r}\{E_{Ax}[(v_L \pm v_G)(m_{21} + i\varepsilon m_{22}) - i\varepsilon(v_L \mp v_G)(m_{11} + i\varepsilon m_{12})]$$

$$\times E_{0x}\exp -i\varphi + E_{By}[(v_L \mp v_G)(m_{12} + i\varepsilon m_{11}) - i\varepsilon(v_L \pm v_G)(m_{22} + i\varepsilon m_{21})]$$

$$\times E_{0x}\exp -i(\phi - \frac{\pi}{2})\}\exp i\frac{\omega}{c}z\exp -i\omega(t_0 + \frac{1}{c}r)d\omega dt_0 dS_0;$$

M+1 – matrix describing real image

$$M_{+1} \approx -\frac{\chi d}{4\pi c n_0}\exp(-2i\chi d n_0)\begin{pmatrix}(M_{+1})_{11} & (M_{+1})_{12}\\ (M_{+1})_{21} & (M_{+1})_{22}\end{pmatrix} \qquad (12)$$

with matrix elements

$$(M_{+1})_{11,22} = \iiint\limits_{S_0T_0\Omega} \frac{\omega}{r}\{E^*_{Ax}[(s \pm v_L)(m^*_{11} - i\varepsilon m^*_{12}) + i\varepsilon(s \mp v_L)(m^*_{21} - i\varepsilon m^*_{22})]E_{0x}\exp i\varphi + E^*_{By}$$

$$\times[(s \mp v_L)(m^*_{22} - i\varepsilon m^*_{21}) + i\varepsilon(s \pm v_L)(m^*_{12} - i\varepsilon m^*_{11})]$$

$$\times E_{0x}\exp i(\phi - \frac{\pi}{2})\}\exp -i\frac{\omega}{c}z\exp i\omega(t_0 + \frac{1}{c}r)d\omega dt_0 dS_0,$$

$$(M_{+1})_{12,21} = \iiint\limits_{S_0T_0\Omega} \frac{\omega}{r}\{E^*_{Ax}[(v_L \pm v_G)(m^*_{21} - i\varepsilon m^*_{22}) +$$

$$i\varepsilon(v_L \pm v_G)(m^*_{11} - i\varepsilon m^*_{12})]E_{0x}\exp i\varphi + E^*_{By}[(v_L \pm v_G)(m^*_{12} - i\varepsilon m^*_{11}) + i\varepsilon(v_L \mp v_G)(m^*_{22} - i\varepsilon m^*_{21})]$$

$$\times E_{0x}\exp i(\phi - \frac{\pi}{2})\}\exp -i\frac{\omega}{c}z\exp i\omega(t_0 + \frac{1}{c}r)d\omega dt_0 dS_0.$$

Here ***mij≡mij(x0,y0,z0,t0)*** – elements, depending on coordinates and time of the 2D matrix of non-stationary LCCC fragment. Under the condition of rationality in biological objects, interrelation between functions of media reaction may be the following:

$$s = v_L \qquad v_L = -v_{G'} \tag{13}$$

and expressions (11) and (12) can be simplified. In publication [8] is noted, that conditions in (13) are met with a high precision for a very large class of polarized-sensitive media.

Provided that conditions in (13) are met, ***M-1*** and ***M+1*** matrices take the following form:

$$M_{-1} \approx \frac{\chi dv_L}{2\pi c n_0} \exp(-2i\chi dn_0) \iiint_{S_0 T_0 \Omega} \frac{\omega}{r} M_{ob} P \exp - i\omega[t_0 + \frac{1}{c}(r - z)] d\omega dt_0 dS_0, \tag{14}$$

$$M_{+1} \approx \frac{\chi dv_L}{2\pi c n_0} \exp(-2i\chi dn_0) \iiint_{S_0 T_0 \Omega} \frac{\omega}{r} P^* M_{ob}^* \exp i\omega[t_0 + \frac{1}{c}(r - z)] d\omega dt_0 dS_0, \tag{15}$$

In (14) and (15) LCCC matrix ***Mob*** is marked, and ***P*** represents the following matrix

$$P = \begin{pmatrix} a + \varepsilon^2 b & -i\varepsilon(a-b) \\ i\varepsilon(a-b) & \varepsilon^2 a + b \end{pmatrix},$$

where

$$a = E_{Ax} E_{0x} \exp - i\varphi$$

$$b = E_{By} E_{0x} \exp - i(\phi - \frac{\pi}{2});$$

P* Mob* – Hermitian adjoint matrices.

Publication [21] should be noted for the original approach to the solution of the image reconstruction problem, which we will be glad to use in relation to morphogenetic modelling.

Under condition of endogenous illumination of the received hologram by reconstructing non-polarized waves with complex amplitudes

$$E'_{0x} \exp i\varphi', E'_{0y} \exp i\phi' (\varepsilon' = E'_{0y} / E'_{0x})$$

endogenous or exogenous in relation to the biosystem, and frequency ***ω'***

$$E_{rec} = [E'_{0x} \exp i\varphi' \begin{pmatrix} 1 \\ i\varepsilon' \end{pmatrix} \oplus E'_{0x} \exp i(\phi' - \frac{\pi}{2}) \begin{pmatrix} i\varepsilon' \\ 1 \end{pmatrix}] \exp i\omega'(t' - \frac{1}{c}z) \qquad (16)$$

the wave passed through the biological hologram is formed as follows:

$$E(x', y', z', t') = \frac{i}{2\pi c} \int_S \frac{\omega'}{r'} M E_{rec} \exp - i\frac{\omega'}{c} r' dS, \qquad (17)$$

where ***S*** – fragment size of LCCC's hologram; ***r'*** – distance between the point on the hologram surface and observation point.

Then, successively substituting in (17) expressions for matrices (10), (14) and (15), let's define null, virtual and real images, formed by the hologram. And only now determine, what endogenous or/and exogenous wave is necessary for the organism to utilize as to reconstruct the required fragment of the wave image in a virtual form. To achieve this, it is necessary to determine their own vectors and corresponding to them values of ***P*** matrix. It turns out that with a precision of up to a constant multiplier, the vectors of ***P*** matrix are in essence

$\begin{pmatrix} 1 \\ i\varepsilon \end{pmatrix}$ and $\begin{pmatrix} i\varepsilon \\ 1 \end{pmatrix}$ with their respective values

$(1 + \varepsilon^2)a$ and $(1 + \varepsilon^2)b$.

It follows that reconstruction should be performed by a wave identical to the one used during recording by the carrying wave. As apparently, in biosystems at LCCC level recording and reconstruction happen either simultaneously or in accordance with the last condition, then the reconstructed virtual image depiction corresponds to the real one and is not subject to any distortions. The latter is of principle importance for preservation of the wave image-vectors of morphogenesis, despite of the biosystem mobility in general as well as its LCCC in particular. Nonetheless, the non-stationary nature of images will appear, though over long time periods during organism aging and its pathological states, for instance in the case of carcinogenesis.

For a wave passed without diffraction [21], the null image has the following form:

$$E_0 \approx \exp(-2idn_0\chi)[1-\frac{ids\chi}{n_0}(1+\varepsilon^2){E_{0x}}^2][E_{0x}\exp i\varphi\begin{pmatrix}1\\ i\varepsilon\end{pmatrix} \oplus E_{0x}\exp i(\phi-\frac{\pi}{2})\begin{pmatrix}i\varepsilon\\ 1\end{pmatrix}]\exp i\omega(t'-\frac{1}{c}z'), \quad (18)$$

where the virtual and real images are presented as:

$$E_{-1}(x',y',z',t') \approx \frac{idv_L\chi}{(2\pi c)^2 n_0}\exp(-2idn_0\chi)E_{0x}^2(1+\varepsilon^2) \int_S\int_{S_0}\int_{T_0}\int_\Omega \frac{\omega^2}{r'r}[E_{Ax}M_{ob}(x_0,y_0,z_0,t_0)\begin{pmatrix}1\\ i\varepsilon\end{pmatrix} \oplus E_{By}M_{ob}(x_0,y_0,z_0,t_0)\begin{pmatrix}i\varepsilon\\ 1\end{pmatrix}]\times \times\exp i\omega[(t'-t_0)-\frac{1}{c}(r'+r)]d\omega dt_0 dS_0 dS, \quad (19)$$

$$E_{+1}(x',y',z',t') \approx -\frac{idv_L\chi}{(2\pi c)^2 n_0}\exp(-2idn_0\chi)E_{0x}^2\int_S\int_{S_0}\int_{T_0}\int_\Omega \frac{\omega^2}{r'r}[P_A^*M_{ob}^*(x_0,y_0,z_0,t_0)\begin{pmatrix}1\\ i\varepsilon\end{pmatrix} \oplus P_B^* \times M_{ob}^*(x_0,y_0,z_0,t_0)\begin{pmatrix}i\varepsilon\\ 1\end{pmatrix}]\exp i\omega[(t'+t_0)-\frac{1}{c}(r'-r+2z)]d\omega dt_0 dS_0 dS, \quad (20)$$

where

$$P_A^* = \exp i\varphi P^*,$$

$$P_B^* = \exp i(\phi-\frac{\pi}{2})P^*$$

Integrals, pertaining to (19) and (20), as in paper [21] are solved in a linear approximation for distances ***r*** and ***r***' and for infinitely large areas of integration ***S, S0, T0, Ω***. Integrals ***S*** and ***Ω*** have a character of spatial and time ***δ***- function respectively. The final expressions executed in a similar way as in paper [6], lead to the following equations for the formed space-time polarized hologram. For the formed virtual image under condition of $z' = z_0$ from (19) we have:

$$E_{-1}(x',y',z',t') \approx -\frac{2\pi i\chi dv_L}{n_0}\exp(-2i\chi dn_0)E_{0x}^2(1+\varepsilon^2)[E_{Ax}M_{ob}(x',y',z',t') \times\begin{pmatrix}1\\ i\varepsilon\end{pmatrix} \oplus E_{By}M_{ob}(x',y',z',t')\begin{pmatrix}i\varepsilon\\ 1\end{pmatrix}]. \quad (21)$$

An analysis of the last equation shows that with precision up to the multiplier it depicts complete reconstruction of space-time structure as well as polarization characteristics of the field of its non-stationary object wave for example, via LCCC. It is convenient for the biosystem to use this structure-image to organize itself in time and space, as this structure-image fully preserves the original calibrating scale without any distortions imposed by the dynamic nature of the biosystem and reproduces it in adequate dimensions for a developing or an adult organism.

Four dimensional organization of metabolic flows and morphogenetic movement of cells and tissues during embryogenesis additionally partial regeneration of biosystems in case of damage occurs in accordance with reconstructed wave gradients of scanned polarization holograms (calibration of the potential space-time of the biosystem), and proven by us [22].

In application of equation (20) for the real image where $z' = 2z - z_0$ we have:

$$E_{+1}(x',y',z',t') \approx -\frac{2\pi i\chi dv_L}{n_0}\exp(-2i\chi dn_0)E_{0x}^2[P_A^* M_{ob}^*(x',y',z',\frac{2z}{c}-t') \times\begin{pmatrix}1\\ i\varepsilon\end{pmatrix}\oplus P_B^* M_{ob}^*(x',y',z',\frac{2z}{c}-t')\begin{pmatrix}i\varepsilon\\ 1\end{pmatrix}] \quad (22)$$

From equation (22) it follows that the image with pseudoscopic spatial structure of the objective fragment of the LCCC field is formed of distance $z' = 2z - z_0$, symmetrically to the virtual image (19) in relation to the hologram. Wherein its circulation time profile occurs with a delay, caused by the light passing the distance of $2z = z' + z_0$, equal to the distance from the point of observation to the point on the surface of the real image, with conversion of polarization state, determined by ***PA**** and ***PB**** types of matrices.

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