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TO THE PROBLEM OF POSSIBLE DEVELOPMENT AT A BIOLASER WORKING ON FROLICH MODES

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Summary

The idea about possible development of a biological laser (BL) on Frolich modes (FM) has been stated. The two-level quantum system, simulating FM has been used as an initial model. Within the framework of the approach, using method of matrix of density, it has been shown, that in case of resonant interaction amplitude modulated electromagnetic radiation with FM the system can exist in the overexcited state. It is a necessary for creation the inverse population of the BL.

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"If you have a desire to receive results tomorrow, you should have the qualification of a shoemaker" (A.Einstein)

The idea, concerning the potential participation of the oscillatory modes of dipole structures (monomeres) of information biomacromolecules such as DNA, RNA, proteins had been put forward about 30 years ago in the parer of the English researcher H.Frolich [1,2]. Hereinafter this idea has been ddeveloped in his papers [3-8]. Subsequently, other investigators [9-14] had approached the theoretical problem from the different stand points. According to the Frolich idea [1,2]: "..The biological system is presumed to consist of

1) oscillating units of giant dipols (e.g., sections of the membrane of cells or parts of H-bonds within biological macromolecules);
2) the remainder of the biosystem which formed the heat bath;
3) an external energy source which couple to the vibratory units. Long range Coulomb interaction between the oscillatory units produced a narrow band of frequences, $\omega_i \in [\omega_0 \omega_{max} = \omega_0 + \Delta]$, corresponding to the normal modes of the electromagnetic oscillations". Real frequencies for considered biostructures lying in a spectral range $\nu = \omega_c / 2\pi \approx 10^{10} - 10^{12}$ Gc ("soft" modes). We would like note an important point in the Frolich fconcept concerning the supply of energy to these modes that leads to very strong (coherent) excitation of a single (selected) mode (having minimum frequency) provided the rate of supply of energy Is larger than a critical one, S_o , i.e. $S > S_o$ i.e. [1,2]. In the formal consideration the transition from $S < S_o$ to $S > S_o$ shows great similarity with the Bose condensation. The vibrations are considered to involve regions of biological membranes, or substantial sections of giant bio macromolecules - such as proteins, DNA, RNA, etc. Despite the long study, the role external influence on a live organisms - electromagnetic and acoustic fields, going not through specialized visual and hearing analyzers

but effecting the cellular-tissue methabolism and intermolecular information processes is not et clear. Theoretically, the non-termal microvawes effect was stated by Frolich [6]. He discusses a threshold like behaviour in the metabolic excitation of large-amplitude vibrations; this leads to a storage of energy and a resonant sensitivity to external radiation [15,16]. The direct or indirect experimental proof of this rule (influence of low-intensity millimeter waves on microbial growth and metabolism) is contained in works [15,17-21]. According to work [7], the major part of the information biomscromolecules can be simulated by a chain of dopole monomers which vibrate and interact with each other. It is essential, that such a continuum of monomers has a set of fundamental "cooperative" modes having in a narrow interval ($\Delta / \omega_0 \ll 1$).

In form Frolich oscillators we can understand such monomers as nucleotides of the DNA and RNA as well as aminoacids of the proteins. The proposed paper possibility of creation of the overexcited state of the principal (selected) Frolich mode is due to the resonant interaction of amplitude modulated electromagnetic radiation with the Frolich oscillator. Within the framework of laser physics concept it goes about creation of inverse population between quantum levels of the selected oscillatory mode and, as a result, about realization in vitro - in vivo superluminescence and laser generation with use as working bodies molecules DNA, RNA, proteins, as well as such overmolecular structures as ribosomes, polyribosomes and chromosomes.

We want to emphasize, that differ from the Frolich approach, in which the nonequilibrum state (the oscillatory temperature of a selected mode is exceeds that of thermal bath, $T_{vib} > T_{eq} > 0$, i.e. the fluctuations quasiequlibrium), in the proposed paper conditions, are being evaluated under which the system of the considered substrates is inverted ($T_{vib} < 0$, that is direct by connected with the creation of inverse poulation. So, Frolich mode is simulated by a two-level quantum system (level 1 - bottom state, 2 - upper state /see. Fig. 1/), excited by resonant amplitude - modulated electrical field, having form:

$$E(t) = E_0 g(t) \cos \omega t , \qquad (1)$$

Where (E_0 - is the amplitude of the fields intensity of fields, g(t) - is the modulating factor. $\omega = \omega_{21}$ (ω_{21} - frequency of transition $2 \rightarrow 1$). Process of excitation of the mode oscillations is described by the Boltsmann equiation for the density matrix:

$$i\hbar\left(\frac{\partial\hat{\rho}}{\partial t}+\frac{\hat{\rho}-\hat{\rho}_0}{\tau}\right)=\left[\hat{H}\hat{\rho}\right],\qquad (2)$$

Where the Hamiltonian in the dipole looks like:

$$\hat{H}=\hat{H}_0-E(t)\hat{\mu},$$

Where - $H_0=\hbar\omega_{21}\hat{\varepsilon}$ it is Hamiltonian of the isolated two-level system. The operator $\hat{\varepsilon}$ there corresponds a matrix with elements $\varepsilon_{11}=\varepsilon_{12}=\varepsilon_{21}=0$, $\varepsilon_{22}=1$, $\hat{\varepsilon}$ - operator of projection of the induced dipole oscillator moment on the direction of the field, $\hat{\rho}_0$ - equilibrum density matrix, τ - it is phenomenologically introdused time of relaxation (for the diagonal elements $\tau=T_1$, for nondiagonal elements T_2.). The Boltsman equation (2) is equivalent to the following system of equations for elements of a matrix of density (ρ_{ik}; $i,k=1,2$):

$$i\hbar\left(\dot{\rho}_{11}+(\rho_{11}-1)/T_1\right)=E(t)(\mu_{21}\rho_{12}-\mu_{12}\rho_{21})$$

$$i\hbar\left(\dot{\rho}_{12}+\rho_{12}/T_2\right)=-\hbar\omega_{21}\rho_{12}-E(t)\mu_{12}(\rho_{22}-\rho_{11})\qquad (3)$$

$$i\hbar\left(\dot{\rho}_{21}+\rho_{21}/T_2\right)=+\hbar\omega_{21}\rho_{21}+E(t)\mu_{21}(\rho_{22}-\rho_{11})$$

Accounting the normalizing level

$$\rho_{22}+\rho_{11}=1\qquad (4)$$

It is possible to show, that the system (3) can be reduced to a equation (when the second harmonics are taken into account ~exp(2iω_{21}t), naturally [22], was neglected):

$$\ddot{\rho}_{22}+\left[\frac{1}{T_1}+\frac{1}{T_2}-\frac{\dot{g}(t)}{g(t)}\right]\dot{\rho}_{22}+\left[\frac{1}{T_1}\left(\frac{1}{T_2}-\frac{\dot{g}(t)}{g(t)}\right)+\Omega_0^2g^2(t)\right]\rho_{22}=\frac{\Omega_0^2}{2}g^2(t)$$

$\rho_{22}(0)=\rho_{22}=0,$ (5)

Where $\Omega_c=E_0\mu_{21}/\hbar$ - is the Rabi frequency. Note, that the amplitude modulation of field results not only Rabi frequency, but also in modulation "friction coefficient" of the oscillator. We consider below the case $T_1=T_2=T$. It is possible to demonstrated, that equation (5) has exact solution for any arbitary function g(t):

$$\rho_{22}=1/2\left[1-G(t)\right] \quad 6)$$

$$G(t)=e^{-t/T}\cos\tau(t)+\frac{e^{-t/T}}{T}\int_0^t\cos\left[\tau(t)-\tau(t')\right]e^{t'/T}dt$$

$$\tau(t)=\Omega_0\int_0^t g(t')dt' \quad (7)$$

We consider the case of periodic modulation of amplitude of the fields,

$$g(t)=\cos\nu t\,. \quad (8)$$

If a period of modulation $T_\nu=2\pi/\nu$ is shorter than the time relaxation, for the time averaging ($T_\nu<<T$) (6) during a period T_ν gives:

$$<\rho_{22}>=1/2\left[1-I_0\left(\frac{\Omega_0}{\nu}\right)\right] \quad (9)$$

and, accordingly, (4):

$$<\rho_{11}>=1/2\left[1+I_0\left(\frac{\Omega_0}{\nu}\right)\right]$$

where I_0 - the Bessel function of the zero order, so for a difference of populations of levels 2 and 1 we will have

$$\Delta\rho = <\rho_{22}> - <\rho_{11}> = I_0\left(\frac{\Omega_0}{\nu}\right) \qquad (10)$$

It follows from (10), that in ranges of parameter $x = \Omega_0 / \nu, \Delta x_k \in (x_{2k}, x_{2k-1})$, where $k=1,2,..$ and x_{2k-1} - roots of Bessel function, probability population of the level 2 exceeds those for a level 1. In other words, we have overexcition inverted state of the oscillator, which is a necessary condition for the laser generation ($\rho_{22} > 1/2$). A situation here is analogous to the process раскачивания of a pendulum with пульсирующей by a point подвеса (of swinging a pendulum having a vibrating point of fixation (Kapitza pendium, classical consideration [23]).

For large times, t>>T, the function G(t), included in Eq (6), looks in the following way:

$$G(t)=P(t)\cos\left(\frac{\Omega_0}{\nu}\sin\nu t\right)+Q(t)\sin\left(\frac{\Omega_0}{\nu}\sin\nu t\right),$$

$$P(t)=\sum_{n=-\infty}^{\infty}\frac{I_{2n}(\Omega_0/\nu)}{\left[1+(2n\nu T)^2\right]}\left(\cos 2n\nu t+2n\nu T\sin 2n\nu t\right)$$

$$Q(t)=2\sum_{n=0}^{\infty}\frac{I_{2n+1}(\Omega_0/\nu)}{\left[1+((2n+1)\nu T)^2\right]}\left[\sin(2n+1)\nu t-(2n+1)\nu T\cos(2n+1)\nu t\right], \qquad (11)$$

where I - is the Bessel function of the corresponding order. From (11) an important conclusion follows: koherent mechanism of interaction Frolich modes with resonant amplitude-modulated field stipulates nondamping oscillations of diagonal elements of a density matrix for times t, exceeding the relaxation times of the systems, and the frequencies of pulsation are multiple the frequency of the amplitude modulation ν.

Averaging (11) during a period T_ν, we receive

$$<G(t)>=\sum_{n=-\infty}^{\infty}\frac{I_n(\Omega_0/\nu)}{\left[1+(n\nu T)^2\right]}=\frac{\pi x}{sh\pi x}I_{ix}\left(\frac{\Omega_0}{\nu}\right)I_{-ix}\left(\frac{\Omega_0}{\nu}\right), \qquad (12)$$

where $x=(\nu T)^{-1}$, $I_{\pm ix}$ - is the Bessel functions of the imaginary order (i - seeming unit). In a particular case, when a period modulation T_ν shorter than the relaxation time T, $x<<1$,

$$<\rho_{22}(\infty)>=1/2\left(1-I_o^2\left(\frac{\Omega_o}{\nu}\right)\right)$$

$$<\rho_{11}(\infty)>=1/2\left(1-I_o^2\left(\frac{\Omega_o}{\nu}\right)\right), \tag{13}$$

So,

$$<\rho_{22}(\infty)>-<\rho_{11}(\infty)>=-I_o^2(\frac{\Omega_o}{\nu})\leq 0 \tag{14}$$

In this case the effect of inversion will not be realized. We shall consider the case, when the law of modulation is set by a ratio

$$g(t)=1+\gamma\cos\nu t \tag{15}$$

By analogy with previous equation for function G(t), in the ration (eq 15), it is possible to receive ($T_\nu = 2\pi/\nu << t << T$)

$$G(t)=\sum_{n=-\infty}^{\infty} I_n\left(\gamma\frac{\Omega_o}{\nu}\right)\cos\left(\Omega_o - n\nu\right)t \tag{16}$$

From (16) it is evident, that a spectrum pulsation of diagonal matrix elements ρ_{22} and ρ_{11}. includes, except for Rabi frequency, "stocks" and "antistocks" combinational frequencies $\nu_n = \Omega_o \pm n\nu(n = 1,2,..)$. Let us accept that for certain n is fulfilled that $\Omega_o = n\nu$, I.e.

$$q_{n1} = \frac{\Omega_o}{\nu} = n, \tag{17}$$

Then, as follows from (16), constant part for the probabilities ρ_{22} and ρ_{11}. shifts. The state of equilibrium meets the following magnitudes:

$<\rho_{22}>=1/2\left(1-I_n(n\gamma)\right)$

$$<\rho_{21}>=1/2\left(1-I_n(n\gamma)\right), \tag{18}$$

So $\Delta\rho=<\rho_{22}>-<\rho_{11}>=-I_n(n\gamma)$.

Effect of inversion ($\Delta\rho>0$) is realized under the following conditions

$$I_n(n\gamma)<0 \tag{19}$$

If the parameter of modulation depth γ lies in the ranges, where the meaning of Bessel function I_n are negative, the overexcitement mode of a biomacromolecules is realized. On Fig.2 the areas of parameters of amplitude modulation $(\gamma,\Omega_o/\nu)$, at which such mode is executed, are schematically indicated.

Thus, in the present paper the idea of a principal possibility of creation biolasers working on Frolich modes in vitro, as well as initiation of such processes in a live cell in addition ally (correcting) the well-known natural liser-like processes in biosystems (see also our paper [24] has been stated). It is shown, that in certain conditions - in case koherent (resonant) interaction of amplitude modulated external electromagnetic radiation with Frolich mode - the system of information biostructures can exist in overexcited state, that is necessary condition for development of the sign-significant bearing biolasers.

It is necessary to emphasize that the described above mechanism of the DNA molecule based biolaser allows to get closer to another fundamental Frolich's hypothesis about possible repumping of the kT energy of the intracellular liquid into the energy of electric oscillations existing in the DNA molecule [28]. In accordance with this idea the stochastic modes of the kT origin can resonantly interact with the oscillatory modes of the molecule and then due to the fact that the DNA molecule as well as protein molecules represent distributed nonlinear oscillatory systems the kT energy can group in the low frequency modes ofthem. So such a molecule in the solution can get energy from it transferring partially the kT energy into the energy of its eigenmodes. Worth mentioning that even within the framework of the proposed linear approach the problem of the energy transfer can be reduced to the damping mechanism of the quantum oscillator proposed by A.Pippard [25]. According to his interpretation a complex potential is inserted into the Shrodinger equation indicating that the oscillator is giving its energy to a great number of the expanding spheric resonator modes. If the dimensions of the resonator are finite like in the case with a living cell the resonant energy exchange will take place between the kT modes of the solution and the electric modes of the DNA molecule. It also supports the idea that it can functionate as a biolaser in water liquid-cristalline electrolyte into living cells and tissues. We suppose that this hypothesis is correct (see our article about stochastic resonance [26]).

In the conclusion notes we would like to note an essential circumstance concerning a principal possibility realization of Frolich modes excitation "in vitro" along biochemical way, namely at the expense of the energy hydrolysis ATP and other nucleosid-triphosfates, as well as at the utilize of other macroergic compounds of a live cell. In this case we shall artificially replicate what evolutionally and/or other way is given to biosystems as main information or maybe energy essence.

This part of our research sets up some moral and ethetic problems of biolaser application. Here we shall our paper [27-34]. In [27,28] the idea of creation of the inverse poulation on the basis of binary systems is stated and experimentally realized. These systems include nucleohistone and DNA molecule, and [29] has been put forward a basis for real creation of biosoliton lasers. In addition we have some evidences for existance of fine mechanisms of interactions between external electromagnetic fields and information biomacromolecules, and also idea of fundamental connection between chromosomal apparatus own wave states and biosistems genetic coding functions [29-34].

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SIGNATURES To DRAWINGS

Fig.1. The two-level circuit, simulating Frolich modes; (1) - amplitude modulated koherent excitation, (2) - irradiated signal of biolaser.

Fig.2. The schematic image of the areas of parameters of peak modulation of fields $(\gamma,\Omega_0/\nu)$ excited condition of the Frolich modes; Ω_0 - Rabi frequency, ν and γ frequency and depth of peak modulation external koherent of excitation, accordingly.

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