БІОМЕДИЧНІ ВИМІРЮВАННЯ І ТЕХНОЛОГІЇ

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STUDY OF EFFECT OF MODELING BIOPHYSICAL LIGHT SCATTERING IN BIOLOGICAL MEDIA

Abstract – The paper developed a method of analyzing the energy distribution in multilayer systems for evaluating the interaction of radiation in the treatment of psoriasis OED, based on the modeling of processes of light scattering in randomly inhomogeneous biological environments and the use of Monte Carlo. It has been created a block diagram of an improved control system parameters and regulation of radiation damaged skin.
Keywords. Energy, light, control system parameters.

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ИССЛЕДОВАНИЕ БИОФИЗИЧЕСКОГО ЭФФЕКТА МОДЕЛИРОВАНИЯ СВЕТОРАСПРЕДЕЛЕНИЯ В БИОЛОГИЧЕСКОЙ СРЕДЕ

В работе представлен способ анализа распределения энергии в многошаровых системах (при лечении псориаза) и оценки взаимодействия спектра ОЕП путем моделирования поглощения света в неоднородных биологических средах, применив метод Монте-Карло. Представлено схему усовершенствованной системы контроля параметров для регулирования процесса светового воздействия на пораженное место кожи.
Ключевые слова. Энергия, свет, система контроля параметров.

Introduction

In medical practice the use of new technologies become sort of controlled biological effects of UV exposure, which involve exposure of the skin Biological Objects (BO). Individual molecules that make up the cells of living organisms have the ability to absorb photons of light and cause photochemical reactions [1-2]. It has been established that the effect of radiation in the ultraviolet range is widely used in medicine to treat (eczema, psoriasis, phototherapy tumors, etc.). Therapeutic effect depends on the physical properties of the skin (thickness, its ability to absorb, temperature, terrain damaged surfaces, etc.), the quality of the exposure process, the timely detection of changes in body's response to their action, and parameters and characteristics of technology (wavelength, intensity flux , procedure duration, location area of exposure).

Problem of investigation and ways of solving the problem

To ensure the effectiveness of the therapeutic effect by ultraviolet exposure, to be posted modeling dynamic exposure using advanced pulsed radiation devices. This requires the control parameters and their optimal regulation in the application of new technologies in the treatment of skin diseases. Besides, for photomedic technologies should be considered the peculiarities of surface exposure BO and change of the depth distribution of energy in the heterogeneity of the biological environment.

As pulsed radiation sources suggested the use of semiconductor components for the construction of opto-electronic devices (OED) in the wavelength range (313 - 556) nm. Such devices are perspective for photomedic technologies because they have own efficiency and the ability to rapid regulation of the spatial distribution of radiation energy for a given range. They are characterized by small size of the operating voltage and current (up to 3.0 V, 3-50 mA), low inertia at work in pulsed mode, high reliability, low cost and so on. Unlike traditional bit of radiation sources (mercury lamps), they do not require the ballasts means, easily allow sequential and parallel connections, and provide the dynamic adjustment of the working surface of exposure BO. Reliability of OED in pulsed mode and control radiation in a given range of energy and time parameters extends the term of photomedic technologies.

The study of spatial and energy distribution characteristics of optical radiation in a biological environment. Irradiating any BO, with variable absorption μ_c and scattering characteristics μ_r will also change the energy and spatial parameters exposure [3]. In the simulation process it is necessary to know the field distribution of the radiation source, you must first determine the distribution of the radiation intensity in space to BO, and then calculate the volumetric distribution of absorbed energy in the environment. Let the function $p(\overline{r},\overline{r}')$ describes processes in biological layer protection and is a function of the density of scattering in the direction of the incident wave $\overline{r}'$, photons which are moving in a given direction of propagation of light $\overline{r}$, that it will characterize the elementary scattering. Assuming that the scattering is symmetry to the direction of the incident wave, and hence of the phase function depends only on the scattering angle θ between the directions $\overline{r}$ and $\overline{r}'$ that is, $p(\overline{r},\overline{r}') = p(\theta)$

Assuming that the process of light scattering in a heterogeneous environment is a random process, then it can be described by the following expression:

$$\int_0^{\pi} p(\theta) 2\pi \sin\theta d\theta = 1 \quad (1)$$

Thus, the biological process in the environment depends on the heterogeneity of layers (Fig.1.) with certain parameter values anisotropy *g*, then for each layer of this parameter will be different, which means that the real nature of biological media can be attributed to multiple scattering process. Therefore, the calculations must take into account the optical thickness of the individual layers, and this complicates the task of modeling random heterogeneous media and requires a time-consuming Monte Carlo's method [4]. In studies proposed a model biological environment in the form of skin layers that have different options:1- corneal layer 2 - the top layer of epidermis, the bottom layer of epidermis - 3, 4 - top layer of the dermis, 5 - the bottom layer of the dermis.

The meaning of the parameter *g* anisotropy for medium scattering of light is defined as the average meaning of the cosine of the angle. The meaning of anisotropy changes from -1> g <+1, and if g = 0 - isotropic scattering. Scattering approximation function for each use case, the phase-Greenstein function Haney [5]:

$$p(\theta) = \frac{1}{4\pi} \cdot \frac{1-g^2}{(1+g^2-2g\cos\theta)^{3/2}} \quad (2)$$

When modeling exposure in biological medium layers was used software Trace Pro 9, which is based on the method of Monte Carlo. Such approach, with using of performance PC, allowed to get results for the rays in a separate layer that characterize the uneven absorption and the scattering in randomly - inhomogeneous media by formulas (1) and (2).

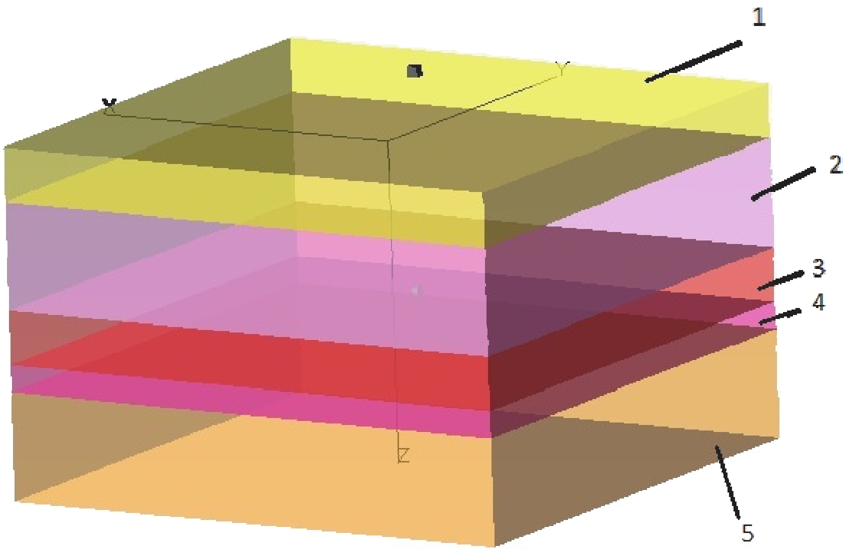

Fig. 1. Model biological environment skin

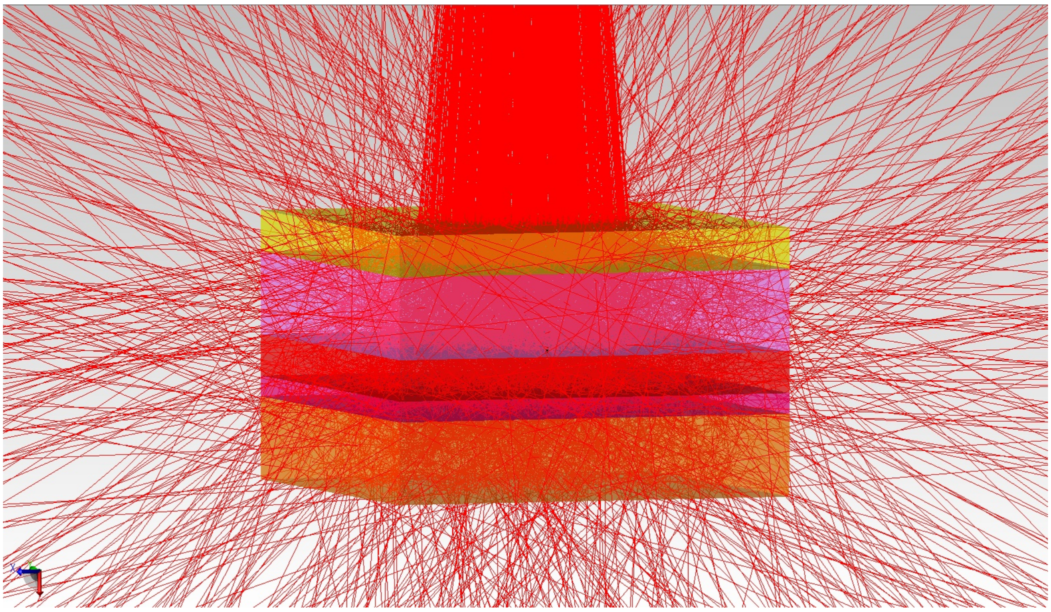

Fig. 2. Model irradiated multilayer biological environment.

The of modeling exposure show that the distribution of radiation in biological objects is due to the diffuse component of absorbing medium. Fig. 2. Shows the results of modeling irradiated multilayer randomly inhomogeneous biological environment.

It's obviously, that the penetration depth of light in a heterogeneous environment and the meaning of anisotropy parameter affect the energy dissipation in each layer (Figure 3)., So there is a need in operative process control radiation OED. We should also consider the use of dynamic radiation in pulsed mode for additional stimulating effect of damaged skin diseases in psoriasis. In this case, you need to use variables in time characteristics of modulated radiation facility for bioresonance frequencies, namely 0.4 - 4 Hz [2, 6]. Such approach requires selecting of elements for OED in the form of special matrices and diagrams of control parameters.

To evaluate the results obtained randomly inhomogeneous media with using software Trace Pro 9, we can compare the energy diagram of the horny layer skin (Fig. 4) and the lower layer dermus (Fig.6.). The simulation results show that the distribution of energy dissipation in the upper layer is more unequal than the bottom, which allows adjustment the process of treatment of skin diseases in interactive or automatic modes.

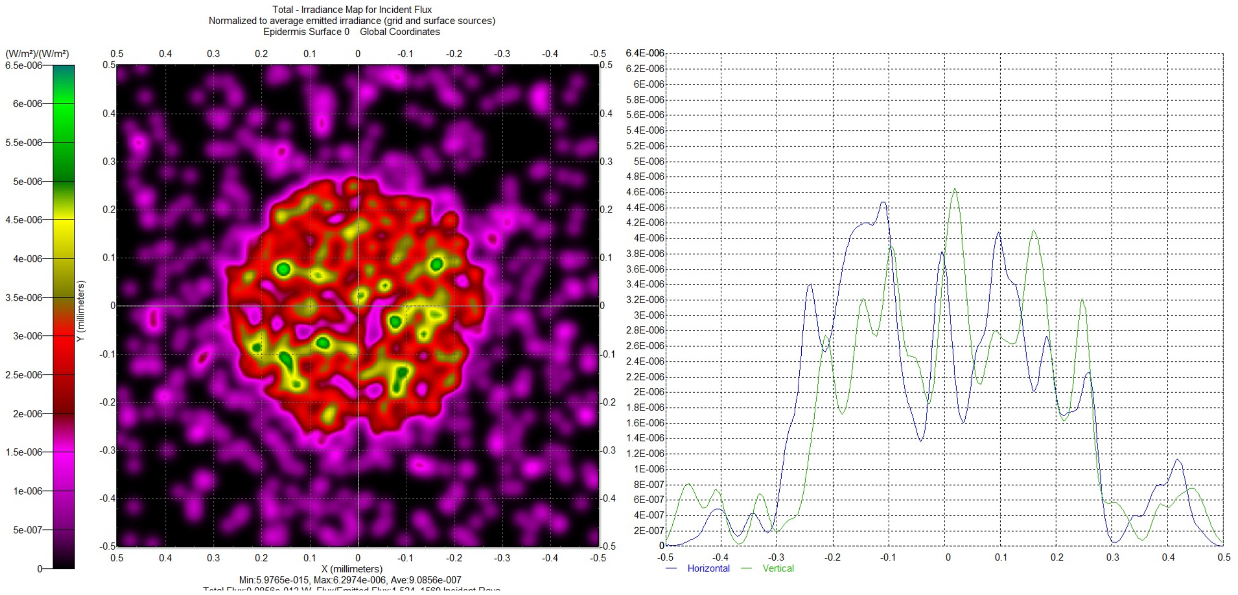

Fig.3. Diagram of point energy characteristics of the upper layer BO

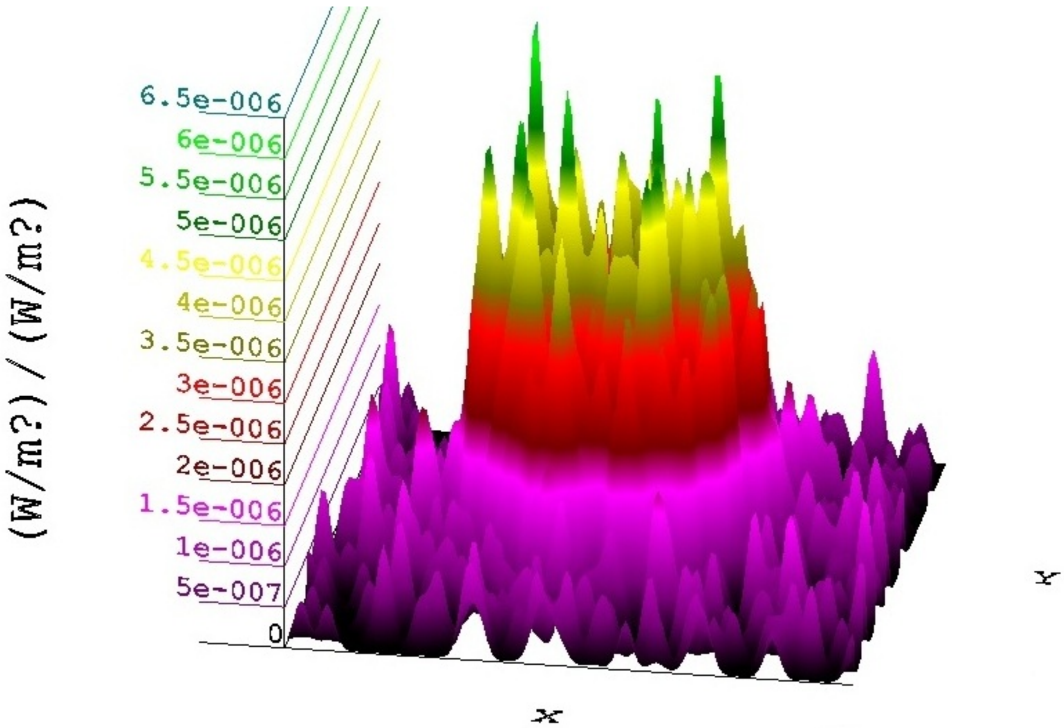

Fig. 4. Energy diagram of the upper stratum corneum of the skin

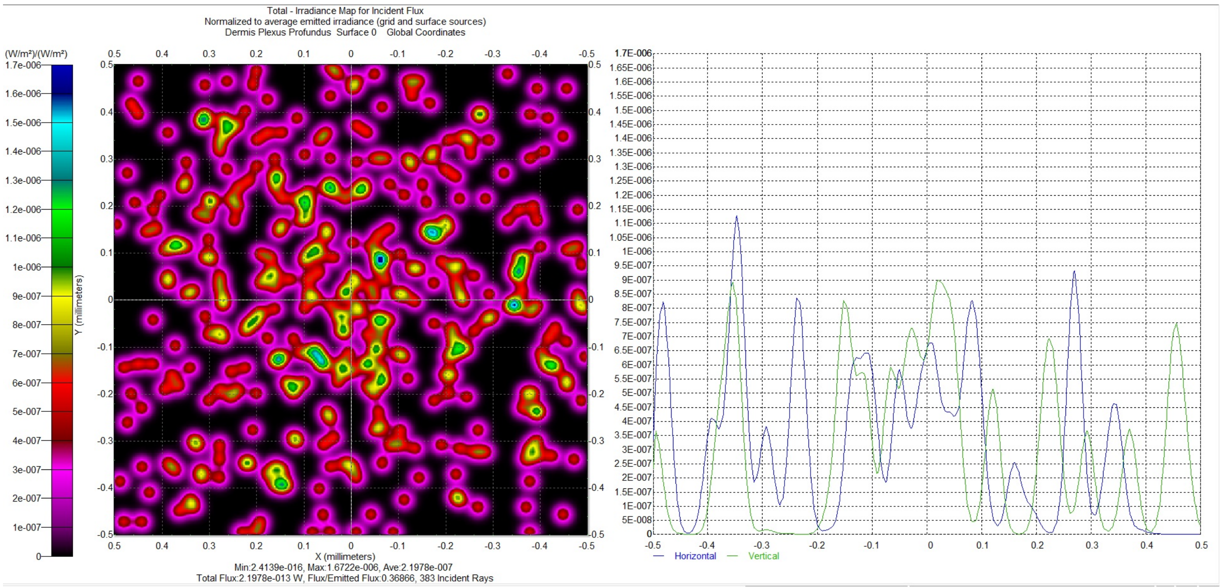

Fig. 5. Diagram of point energy characteristics of the lower layer BO

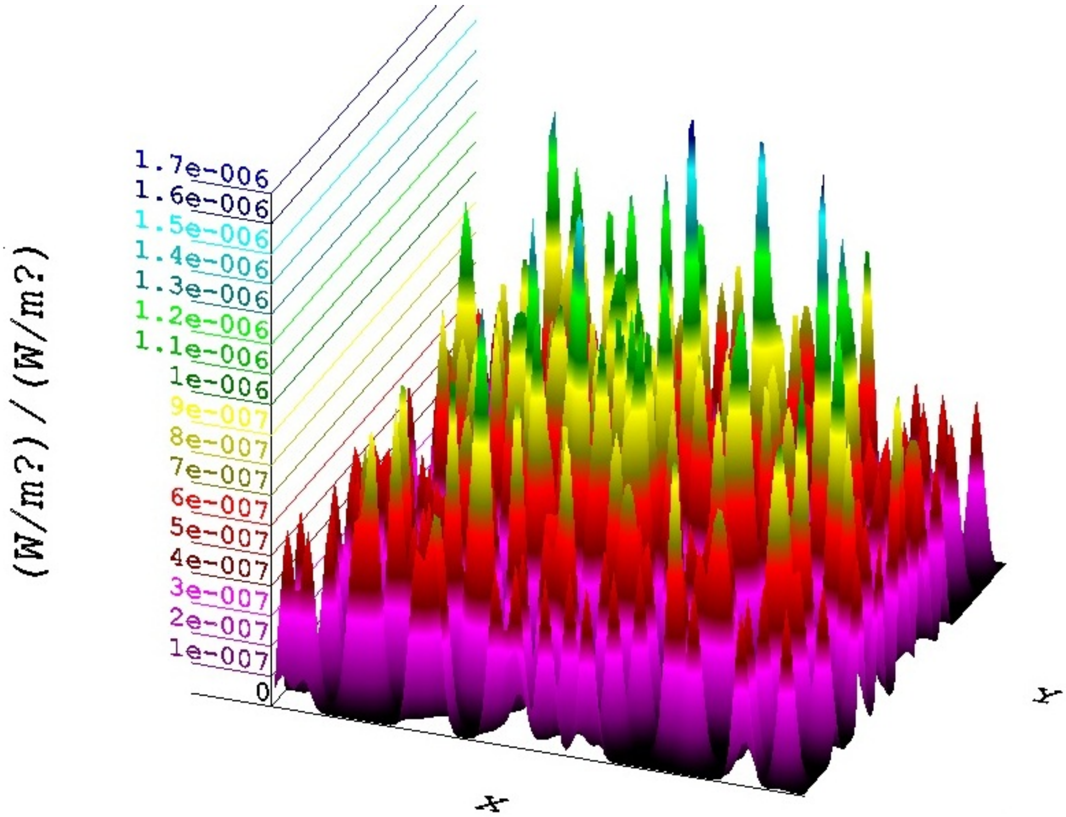

Fig. 6. Energy diagram of the lower layer of dermus

On Fig. 3 and Fig. 5 are shown a graphics of point energy characteristics of the upper and lower layer at coordinates (0, 0) the spatial values which are divided into vertical and horizontal components, allow us to accurately determine the amount of energy anywhere in the plane of the biological environment.

Based on selected types of LED L375 (385, 395) R-04 for an LED-matrix optical performance which is approaching to the UV-A range [7] is proposed a block diagram of the control advanced opto-electronic devices (Fig.7). For ease of management will apply wireless data transmission system Wi-Fi with the help of a PC or smartphone. To control the light energy that is reflected from the surface of the skin is used a type photodetector PD-299, which is located near the radiation source. The light energy reflected from the surface BO the photocurrent is used where the control unit created by the algorithm provides the necessary regulation and dynamic parameters of optical radiation OED.

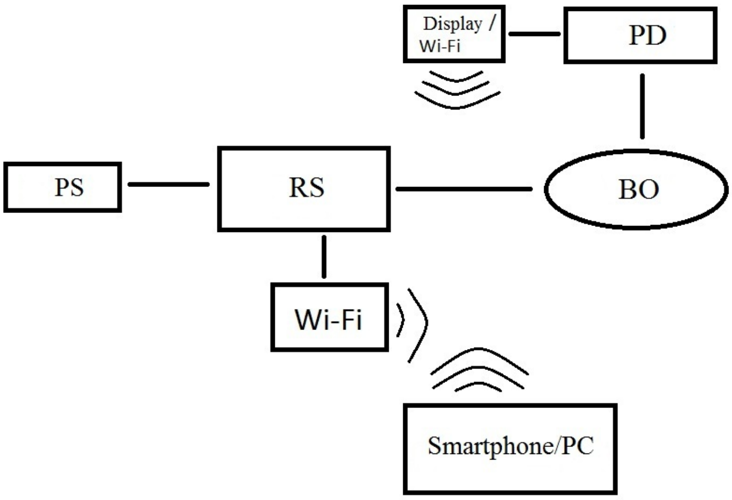

Fig. 7 Block diagram of the proposed optoelectronic device:
(PS- power supply, RS – radiation source, BO -bioobject, PD - photodetector)

The proposed regulation provides a way of automatic change the parameters of PV energy in the reflected beam deviation from the norm, and wireless transmission of control signals increases the reliability of work the devices and the culture of patients' care.

Summary

It has been experimented on the modeling process of energy dissipation in randomly heterogeneous biological environments and using the software Trace Pro 9, which is based on Monte Carlo's constructed in layers distribution of absorbed energy. A new flowchart wireless control parameters of the exposure of biological objects using wi-fi, where the transfer of data between the PC and the radiation source (LED matrix) using feedback to operative management process.

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