The device for light therapy with absorbed energy dose measuring

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Abstract. Light therapy conducting always connected with need to set optimal intensity of irradiating signal, modulation frequency and exposure. The better option is determination of dose absorbed by patient skin surface and frequency of the maximal absorption. At the same time the dose of falling signal energy is measured to protect patient from harmful effects (e.g. burns) of laser radiation. The authors developed a structural scheme of the device for light therapy and proposed an algorithm for converting and measuring signals by high-sensitive optical modulation radiometer. The scheme provides patient irradiation, measuring the dose of the absorbed energy in the irradiated areas of human body, for example, biologic active point, and determination of the maximal absorption frequencies. It increases the efficacy of the therapeutic procedure and allows to predict the result of treatment.

A number of devices and systems for light therapy with the use of the wide spectral range: ultraviolet with wavelength 180...380 nm, visible (380...780 nm) and infrared (0.78...760 microns) recently appear in medicine.

Equipment of the Korobov visible spectrum series “Barva” which uses light diodes with power from 5 to 120 mW, is widely used in Ukraine, so as various infrared range lamps, polarized light lamps by famous Swiss company Zepter, UV lamps, laser and LED devices such as UFL – 1, APL - 1, MILTA-F-01, Mustang [1,2] and oth. Typically, the power of such equipment is within 10⁻³...10⁻⁵ W.

It’s also known the method of low-intensity light therapy (LLT) which uses laser and LED irradiating sources with capacity one – tens milliwatts [3]. The feature of the LLT devices known also as photobiomodulators is transformation of the light energy into metabolic energy of the biological functioning of cells. Actions mechanisms of the low-intensity therapy are considered in details in [4].

Measurement of specified power levels is usually carried out with a built-in photodetector with a simplified scheme. However, sophisticated therapeutic systems for light therapy with feedback, radiation exposure regulation and determination of absorbed energy dose require a more sensitive measuring device based on, for example, an optical radiometer. In full, this requirement also applies to the case of scientific research on the interaction of optical radiation with tissues and other weakly transparent substances and liquids [5]. The power of the optical signals can thus be 10⁻⁹...10⁻¹² W. Such level of signals is compared to the power of the hardware noise, the effect of them during measurement can be reduced by using the modulation optical radiometer (OR) circuit. Light therapy conducting is always connected with necessity of the determination of the optimal intensity of the illuminating signal, the frequency of modulation of the light flux and its exposure. More correct is the
determination of the dose absorbed by the patient's skin, and the maximal absorption frequencies that can predict the effectiveness of the therapeutic procedure.

The efficacy of treatment depends not only on the irradiation source intensity but on absorbed dose which is proportional to biological effect manifestation. At the same time, practically there are no therapeutic devices that provide measurement of the absorbed dose of laser radiation. The dose of the falling signal energy is measured to protect the patient against harmful effect of laser radiation (e.g., burns).

The structural scheme of the device for light therapy in conjunction with optical modulating radiometer, with its help the weak reflected signals are measured is shown on fig.1 [6]. This device provides patient irradiation, absorbed energy dose in human body area, for example, biological active point (BAP), and determination of the maximal absorption frequencies.

Figure 1. Device for the light therapy with absorbed dose measuring

This device realize radar working regimen and includes: the surface of irradiation A; generator unit in the generator of impulse rectangle voltage of variable frequency 1, attenuator 2 and light emitter diode 3; high-sensitive receiver, which includes photodiode 4, load 5, standard measuring channel OR 6 and indicator 7. LED 3 and photodiode 4 are fixed at the same angles to the plane of the irradiation A.

The measuring channel of the optical radiometer consist of the consistently connected amplifier, quadratic detector, selective switching amplifier, synchronous detector and low frequencies filter. To the inputs of the switch receiving transmitters are connected. Receiving antennas are used in the radio range, and in the optical - photovoltaic converters.

Light therapy device works as follows. Rectangle impulses from generator 1 through the attenuator 2, pass to the LED 3, which periodically, with selected frequency, irradiates point A. Attenuator 2 sets necessary light flux intensity of the LED 3. Initially, in the first stage, the device is calibrated. For this the mirror should be set to point A (focus of the reflector). The signal come in to input of the photodiode and the balance of intensity can be written in the form:

$$P_1 = P_{2e} + P_3,$$

where $P_1$ – power of the emitter 3 light flux; $P_{2e}$ – power received by photodiode (reflected from mirror); $P_3$ – power of dispersion on the way laser emitter – mirror – photodiode.

When signal of power $P_{2e}$ is send to the photodiode the photocurrent $I_1$, proceeds in the circle photodiode – load 5; this photocurrent is identical to light flux intensity

$$I_1 = P_{2e},$$

The signal fed to the photodiode periodically under the action of the generator 3 impulses. At the coordination load 5, the voltage dispersion is formed during the passage of the signal

$$U_1^2 = I_1^2 R_N + U_N^2,$$
In the second half-period, when the signal does not pass, the signal voltage is absent and
\[ U_2^2 = U_N^2. \]  
\hspace{1cm} (4)

The voltage packets (3) and (4) are fed adherently to the input of the measuring channel 6. As the result of this process in the output of the measuring channel for the switching period by the analogy with the equation (5) for calibration mode we get the value:
\[ U_3^2 = S_0 \frac{(U_1^2 - U_2^2)}{2} = S_0 \frac{1}{2} I_{1N}^2 R_w = P_{2N}. \]  
\hspace{1cm} (5)

In the formula (5) the unknown part of the scattering power \( P_3 \), which physically participates intensity balance according formula (1), is not taken into consideration.

As it’s seen from (5), in the output of the OR measuring channel we receive constant voltage which is proportional to power, reflected from the mirror. Its own noises are compensated in the measuring channel by the modulation conversion algorithm.

At the second stage the measurements of the absorption dose while patient irradiated are performed. The skin area (or biological active point - BAP) is placed in the focus \( A \) of the reflector. The optical signal is fed to the photodiode and intensity balance we can write as
\[ P_1 = P_{2N} + P_3 + P_{4N}, \]  
\hspace{1cm} (6)

where \( P_{2N} \) – reflected by the skin to photodiode power; \( P_{4N} \) – absorbed by the skin power.

From the equations (1) and (6), taking into consideration the equality of falling \( P_1 \) and immutability of the scattered power \( P_3 \), by preserving the geometry of the irradiation, determine the absorption power of the area of absorption or BAP
\[ P_{abs} = P_{2N} - P_{2N}. \]  
\hspace{1cm} (7)

Or, considering the equation (5), we obtain
\[ U_4^2 = S_0 \frac{1}{2} (I_{1N}^2 - I_{2N}^2) R_w = P_{2N} - P_{2N}. \]  
\hspace{1cm} (8)

It is seen from formula (8) that power absorbed by the BAP, is proportional to the difference of the reflected power from mirror during calibration and during irradiation of the skin. The scattering power, which can be 15-20% of the total intensity of the falling light flux, does not affect the result of the measurement, which greatly increases the accuracy of the measurement of the dose of optical radiation.

The frequency of the generator 1, which determines frequency of the LED modulation is selected in the range to 100 Hz; which corresponds to the limits of biological rhythms of the human body.

**Conclusions**

The considered device can be used for light therapy and treatment of patients by irradiation of the biological active points (BAP) or zones (BAZ), as well as for different individual fractions of the human body, for example, photophoresis of blood.

Metrological determination of the absorption dose and maximal frequencies of the absorption provides the possibility of the control of light flux intensity, this is important during ultraviolet procedures. It also opens up the possibility of prediction and improves the effectiveness of the light therapy.

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