# Method and device used for testing of the absorbed dose of radiation during low level laser therapy

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## ABSTRACT

A method of control of the absorbed dose of radiation during low-level laser therapy is proposed. It is based on registration of both the reflected part of energy and part of energy spent on local heating of epidermis. Results of theoretical and experimental studies of heating process at pulse action are presented. As a device controlling the absorbed dose a therapeutic machine is proposed. The intensity of its action can be adjusted depending on optical and thermophysical properties of the biological tissue.
**Keywords:** LLLT, dosimetry, method of control

## 1. INTRODUCTION

At present time low level laser therapy (LLLT) is widely used for correction of functional condition of human organism due to specific qualities of laser beam. However there is still important problem as dosimetry LLLT.

Determination of optimal dose of laser influence on organism is based on correlation between clinical results and nascent under radiation measuring of various parameters, connected with influence LLLT [1]. Therefore it is necessary to include the system of control and automatic regulation of parameters of laser procedure, based on principles of biofeedback with patient [2], but the most important task is counting of as many as possible factors under dosimeter action of this procedure.

The method laser biophotometry [3], which is presently widely used, includes valuations of effectiveness of influence by optical parameters of bio-subject (the coefficient of reflection, absorption, transmission) and it is important step for solving of this problem. At meantime however it doesn't provide exact valuation of magnitude of absorbed energy by inner organs, as it doesn't count it's lost for heating of upper layers of epidermis.

The next step in order to increase the exactness of keeping of specified intensiveness of laser influence on inner organs is calculation not only optical, but also term physical properties of bio-tissue (heat conductivity, heat capacity, heat irradiation) [4].

We propose in this work to analyze the method of control of absorbed dose under low level laser therapy due to calculation both reflected and lost energy for local heating of epidermis.

## 2. THEORETICAL RESEARCH

In order to calculate lost of light energy for local heating of epidermis, as primary battery which is perceptive for laser radiation, we researched its thermophysical proprieties.

The equation of heat balance of epidermis in static conditions under switched on device LLLT is given in next way:

$$\frac{\partial^2 \Theta}{\partial r^2} + \frac{1}{r} \cdot \frac{\partial \Theta}{\partial r} + \frac{k_a + k_t}{k_{tc} \cdot h} \cdot \Theta - \frac{k_a \cdot \Theta_a + k_t \cdot \Theta_t}{k_{tc} \cdot h} = 0 , \tag{1}$$

where $\Theta$ – maximal temperature of heating of epidermis on distance $r$ from center of light spot,
$k_a$ – coefficient of heat irradiation of epidermis – air,
$k_t$ – coefficient of heat irradiation epidermis – inner layers of bio-tissue,
$k_{tc}$ – coefficient of thermal conduction of epidermis,
$h$ – thickness of epidermis,
$\Theta_a$ и $\Theta_t$ – temperature of surrounded air and inner layers of bio-tissue.

Under description of process of local heating of epidermis under corneal layer (without calculation of heat irradiation into air) as a result of influence of energetic impulses under established regime we got the next calculation

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for line of heating $\Theta_h$ and cooling $\Theta_c$ of epidermis:

$$\Theta_h = \Theta_{sur} + \frac{P_i \cdot (e^{\frac{-k_c}{C}\cdot(T-\tau)} - 1)}{k_c \cdot (1 - e^{\frac{-k_c}{C}\cdot T})} \cdot e^{\frac{-k_c}{C}\cdot t} + \frac{P_i}{k_c}; \tag{2}$$

$$\Theta_c = \Theta_{sur} + \frac{P_i \cdot (1 - e^{\frac{-k_c}{C}\cdot\tau})}{k_c \cdot (1 - e^{\frac{-k_c}{C}\cdot T})} \cdot e^{\frac{-k_c}{C}\cdot(t-\tau)}, \tag{3}$$

where $P_i$ – power in impulse**;**
$k_c$ – thermal conductivity of radiated of part epidermis
$C$ – heat capacity of radiated part epidermis
$T$ – period of impulses
$\tau$ – duration of laser impulse under level 0,5;
$\Theta_{sur}$ – temperature of surrounded bio-tissue (basic temperature before radiation).

After integration of obtained temperature impulses we get dependence of middle temperature $\Theta_m$ of local heating of epidermis from given frequency of impulses.

$$\Theta_m = \frac{1}{T} \cdot \left[ \int_0^{\tau} \Theta_h \cdot dt + \int_{\tau}^{T} \Theta_c \cdot dt \right]. \tag{4}$$

On base of obtained dependences it is possible to make a conclusion that low intensive laser therapy on cell level brings to change of temperature that on level of radiated part of epidermis to heat it, and dependence of temperature from frequency of impulses in used diapason of frequency has linear character (Fig. 1).

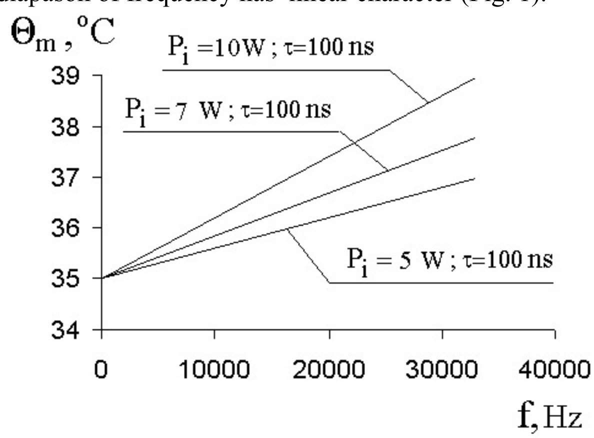


Fig. 1. The dependence of average temperature of heating epidermis from frequency of laser impulses.

## 3. METHODOLOGY

Due to conducted researches we proposed the method of control of absorbed dose by inner tissues ($D_a$). The essence of this method is in calculation of coefficient of reflection of bio-tissue ($\rho$) and maximal temperatures of heating of epidermis in 2 points of surface out of light spot ($\Theta_1$ and $\Theta_2$), which lays on the same axes of radius and nest calculation of absorbed dose by inner organs. On base of obtained meaning of temperature by method of numerical integration from equation (1) we calculate gradient of temperature $\left(\frac{\partial\Theta}{\partial r}\right)_R$ on border of light spot with radius $R$, but coefficient of thermal absorption of epidermis is calculated next way:

$$\xi = \frac{P_h}{P - P_r} \cdot 100\%\,, \tag{5}$$

where $P$ – incident average power of laser radiation established under influence.
$P_r$ – reflected average power determined due to calculation of coefficient of reflection of bio-tissue.
$P_h$ – power lost for heating of epidermis.

$$P_h = k_{tc} \cdot h \cdot 2\pi \cdot R \cdot \left( \frac{\partial \Theta}{\partial r} \right)_R. \tag{6}$$

Absorbed laser energy dose by inner tissues is calculated on base of information of meaning of incident dose $D$, coefficients $\rho$ and $\xi$ due to next calculation:

$$D_a = D \cdot \left[ 1 - (\rho + \xi) \right]. \tag{7}$$

## 4. EXPERIMENTAL DATA

The experimental researches on determination of coefficient of absorption by bio-tissues laser energy under low intensive therapy of inner organs, which counted optical and heat-transfer properties of bio-tissue, are conducted on device which includes:

– the device of magnetic- infrared- laser therapy «MILTA-F-8-01» with bio-photometer and 8 frequencies of repetition of impulse of laser radiation.

– automatic system of collection and data analysis SADT-1 with temperature probe DS1820.

The influence LLLT by contact means (illuminated terminal is placed on bio-tissue) is conducted on patient *A* (25 years old) on parts of his skin in area of group of muscles flexor forearm of left and right hand (parts 1 and 2), on patient *B* (27 years old) on parts of his skin in area of group of muscles flexor forearm of left and right hand (parts 1 and 2) and also gastronomies muscles of left and rights leg (parts 3 and 4) and on patient *C* (20 years) in area of group flexor muscles of both hands (parts 1 and 2). The parameters of influence LLLT were similar for all patients and are presented in Table 1. The number of procedures in each parts is $n = 5$.

Table 1 – The parameters of treatment LLLT

| Name of parameters | Value |
|---|---|
| Wavelength $\lambda$, nm | 890 |
| Power in impulse $P_i$, W | 6,2 |
| Pulse frequency $f$, Hz | 5000 |
| Pulse duration $\tau$, ns | 260 |
| Average output power $P$, mW | 8,1 |
| Spot size $S$, cm$^2$ | 4,5 |
| Treatment time $t$, min | 5 |
| Power density $W$, mW/cm$^2$ | 1,8 |
| Dose $D$, J/ cm$^2$ | 0,537 |

The scheme of location of temperature reformers on bio-tissue in terminal of device is presented on Fig. 2. The typical diagrams of distribution temperature on surface of epidermis in established regime for cases of radiation of patient *A* (part 1), patient *B* (part 3), patient *C* (part 1) are presented on Fig. 3. The total results of approbation of supposed method control is showed in Table 2.

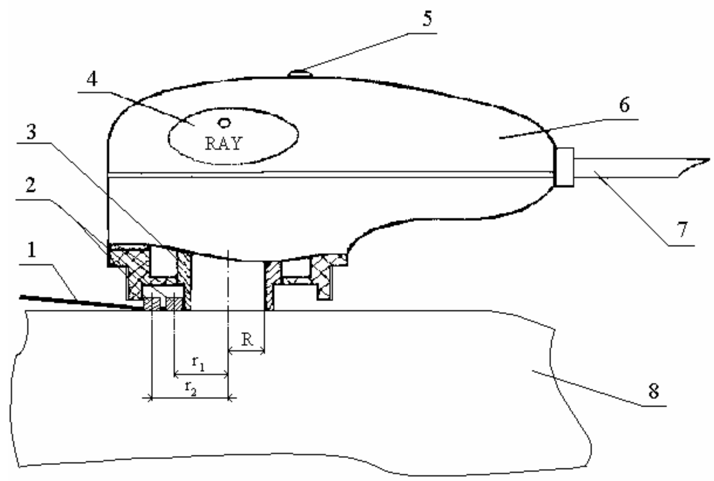


Fig. 2. The scheme of location of temperature reformer, on bio-tissue in terminal of device:
1 – connection cable of temperature reformer, 2 – temperature reformer DS1820, 3 – camera, 4 – button RAY, 5 – indicated diode of switch of laser , 6 –the body of terminal, 7 – electric cord, 8 – bio-tissue.

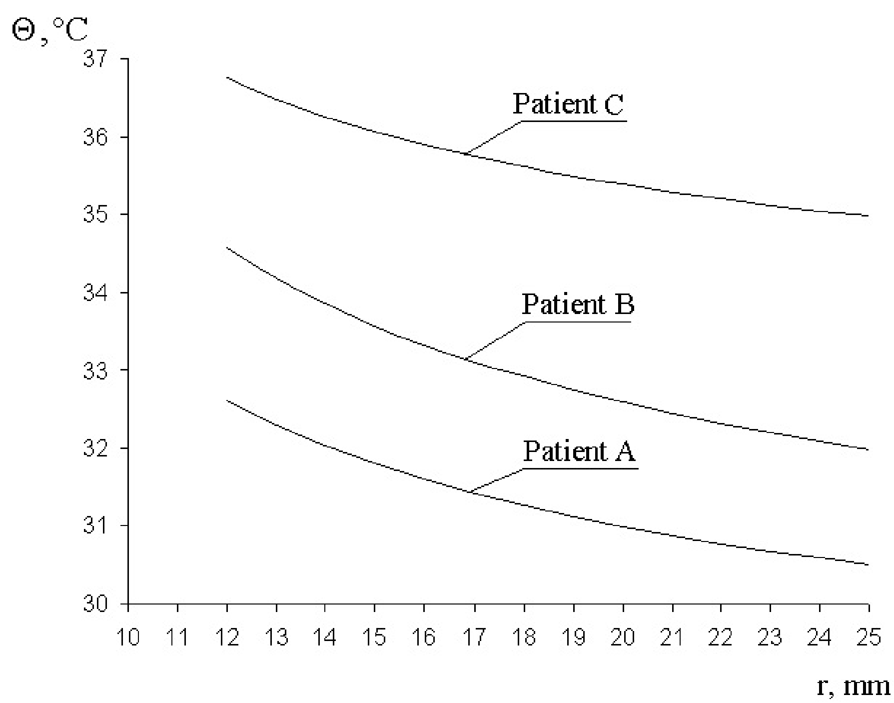


Fig. 3. The typical plots of temperature distribution on surface of epidermis due to established regime.

Table 2 – The results of approbation by control method.

| Name of parameters | Patients | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A | | B | | | | C | |
| | Treated area | | Treated area | | | | Treated area | |
| | 1 | 2 | 1 | 2 | 3 | 4 | 1 | 2 |
| Dose $D$, J/cm$^2$ | 0,537 | | 0,537 | | | | 0,537 | |
| Coefficient of reflection $\rho$, % | 40 | 39 | 38 | 37 | 41 | 42 | 39 | 39 |
| Gradient of temperature $\left(\frac{\partial \Theta}{\partial r}\right)_R$ on border of light spot with radius $R$, ˚C/m | -203 | -348 | -419 | -359 | -253 | -343 | -168 | -179 |
| Power lost for heating of epidermis $P_h$, mW | 0,4 | 0,7 | 0,8 | 0,7 | 0,5 | 0,7 | 0,3 | 0,4 |
| Coefficient of thermal absorption of epidermis $\xi$, % | 8,4 | 14,2 | 16,8 | 14,2 | 10,7 | 14,7 | 6,9 | 7,3 |
| Coefficient of absorbed by inner tissues $\kappa$, % | 51,6 | 46,8 | 45,2 | 48,8 | 48,3 | 43,3 | 54,1 | 53,7 |
| Absorbed dose by inner tissues $D_a$, J/cm$^2$ | 0,277 | 0,251 | 0,243 | 0,262 | 0,260 | 0,233 | 0,291 | 0,289 |

## 4. LASER THERAPY DEVICE

Due to proposed method of control of absorbed dose the laser therapy device is elaborated (Fig. 4), which realizes feedback on optical and heat-transfer properties of bio-tissue. The device work in next way:

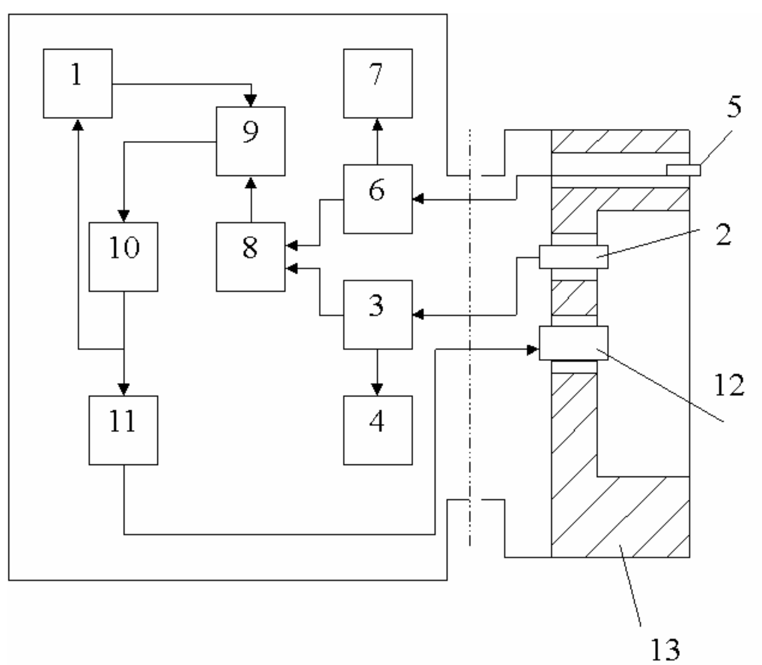


Fig. 4. The flowchart of Laser Therapy Device:
1 – master of dose, 2 – photodiode, 3 – priori intensifier, 4 – registrar of reflected radiation,
5 – temperature converters, 6 – measuring set of changing temperature, 7 – registrar of energy consumption for heating of bio-tissue, 8 – adder, 9 – differential amplifier, 10 – voltage-to-frequency transducer.

Due to master of dose 1 it is possible to determine necessary absorber dose of laser-energy by bio-tissue. The body of radiator 13 is put on bio-subject, switch on tissue temperature level channel and calculate base temperature in point of influence. The therapy procedure is conducted. Reflected from surface of bio-tissue radiation is measured by photodiode 2, prior intensifier 3 and registrar of reflected radiation 4. The radiation in upper tissue and called tissue heating is calculated by temperature converters 5, measuring set of changing temperature 6 and registrar of energy consumption for heating of bio-tissue 7. The signals from priori intensifier 3 and measuring set of changing temperature 6 incomes on adder 8. Obtained signal incomes on differential amplifier 9 and build signal, which is proportional to coefficient of absorption of laser energy by inner tissues, which incomes on voltage-to-frequency transducer 10. This block transforms voltage drive on leaving of differential amplifier 9 into frequencies movement of laser impulse given in power supply 11, whose signals incomes on laser radiator 12, located in body 13. The impulses from voltage-to-frequency transducer 10 incomes also on master of dose 1, where current dose under laser therapy is calculated, but in case of oversize devise is switched off.

In proposed devices the time of exposition, area radiation, impulse power and its length are constant, but frequency of laser radiation is calculated in depend on prescribed by operator the laser energy absorbed dose by inner organs due to next dependence:

$$f = \frac{D_a \cdot S}{P_i \cdot \tau \cdot t \cdot \left[1 - (\rho + \xi)\right]} \tag{8}$$

## 5. CONCLUSIONS

The using of this method and means of control of absorbed laser-energy by bio-tissue under LLLT thanks to measuring of maximal temperatures in two points out spot light with measuring of coefficient of reflection of bio-tissues allows to calculate the coefficient of absorption and absorbed dose of laser energy inner laser procedure with counting both optical and thermo physical properties of skin. As a result it is possible to make more precise definition of control of absorbed dose by inner tissues and therefore effectiveness of laser therapy.

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