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Laser- Various Tissue Interaction: Absorption and Scattering of Laser Near- Infrared Radiation (860 nm)

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ABSTRACT

Since 1988, we have been using various types of laser radiation in dealing with different diseases. Generally, several types of laser radiation are used in the treatment program, where the ones corresponding to the near-IR (850-910 nm) and the red region (630-640 nm). For a series of publications revealing the use of intravenous laser blood irradiation, an international award was received (Ming Chien Kao Awards). The obtained results forced us to reconsider the existing views on the work of the cardiovascular and nervous systems. Was discovered the new principle of the cardiovascular systems development and structure.The main range (850 -910 nm) is used for the treatment of pathology of internal organs. Initially were used, a power of 5-10 watts per pulse and a time from 5 to 20 minutes. By now, the power has increased up to 100 watts per pulse and the irradiation time has become several hours. This made it possible to improve the results of treatment. Especially with regard to oncology. We have not found studies how this wave range penetrates and how it is dispersed by various tissues and internal organs. Therefore, we conducted an experimental study on pig tissues to examine these factors. The main purpose of the experiment were to determine the scattering and absorption capacity of the main tissues and organs - skin of various thicknesses, adipose tissue, muscle tissue, liver, heart, lung, kidneys, cardiac septum, bones (flat and tubular). Based on these obtained results was created a computer program. This program, using ultrasound and MRI data, allows us to determine what dose reaches the affected target. This takes into account which tissues and the distance the laser beam passes through. This allows to use of multiple lasers, conducting training at different angles. Without damaging normal tissues, the necessary dose is applied to obtain the maximum therapeutic effect.

Introduction

High effectiveness of laser radiation in treating various diseases has been proved in 35 years of its application in medicine. One of the problematic issues in the treatment of internal diseases consists in the inability to determine the most effective dose to treat various lesions of internal organs. In this field of application, laser is used in a near-infrared radiation range due to the greatest penetration depth into the human body. During the entire period of laser therapy use, studies on penetrating and reflective ability of biological tissues were carried out at a limited wavelength range. The purpose in conducting this study was to gain insights and to experimentally determine the penetrating and reflective capacity of various tissues. The experiment was carried out with the use of laser radiation at the operating wavelength equal to 860 nm of the Mustang-2000 laser therapeutic device. The results obtained made it possible to calculate the dose of laser radiation suited to the organs at different depths from the surface of the body to absorb it. This solves one of the main problems of laser therapy, dose determination of laser radiation required to treat various diseases. Since 1988, we have been using various types of laser radiation in dealing with different diseases [1]. As a rule, several types of laser radiation are used in the treatment program, where the ones corresponding to the near-IR (850-910 nm) and the red region (630-640 nm) of the visible wavelength range [2-4] are most frequently exploited. When using the red range of laser radiation (630-640 nm), the mechanisms of its effect on tissue and blood have been fully studied. Indications and contraindications for the use of the method have been compiled [2,5].

Moreover, the accumulated vast practical experience has made it possible to reconsider the existing views on the functioning of cardiovascular and nervous systems [6-13]. The experimental inquiry resulted in the international Award in Medicine in 2016 [14]. Due to its high penetrating ability, the use of the near-infrared range (850-890 ppm) has made it possible to effectively treat the pathology of many internal organs [15-25]. Overall, we can confirm that the most interesting results were evident in cancerous diseases treatment. We have studied the mechanisms of the impact this type of radiation has on the oncological process, and it helped us to further work out the basic principles of using this wavelength in the treatment of cancer [26-30]. Experimental studies were conducted on several models of oncological tissues (Walker's carcinosarcoma and breast cancer in rats and spontaneous breast cancer in mice). Along with testing and studying the most effective doses of laser radiation and its combination with various groups of chemotherapy drugs, the possibility of combination with photodynamic therapy has been also approached [31-34]. The application of this method in clinical practice began in 1988. Initially, laser therapy was used prior to surgery [1]. Then it was implemented both as an independent method and in combination with radiation and chemotherapy [35-50]. The results got in the treatment for mastopathy proved to be most interesting [51].

One of the important practical outcomes of the study is differential choice of the absorbed dose for various organs according to the formula 1 :

$$W\ ads. = \left(Jx.T.\left[1-\rho(\lambda)\right].f\left(t\_0.5\right)\right)/\left(S.x\right) \quad (1)$$

W- Absorbed dose of energy, $J/cm2$,

X - Depth of the target for irradiation, cm

Jx- Power of irradiation on the 'X' depth (W); determined according to special tables.

T – Exposure time, sec

$\rho(\lambda)$ - Reflection coefficient (for skin approximately -0.38)

F - Pulse repetition frequency, Hz

t0.5 - Duration of laser impulse (70x 10-8 sec.).

S -Area of impact on the surface of biological tissue, cm.

$1-\rho(\lambda)$ – since a mirror emitter was applied, it can be taken as 1

In synthesizing the data obtained, the most interesting results were evident in cancer treatment. The mechanisms of the effect this type of radiation has on oncological process were studied and the basic principles of using this wave range in the treatment of cancer have been formed [26-30]. During the research our team carried out experimental studies on several models (Walker's carcinosarcoma and mammary cancer in rats and spontaneous mammary cancer in mice) to examine and choose the most effective doses of laser radiation and its combination with various groups of chemotherapeutic drugs. We also approached the possibility of combination of the method with photodynamic [31-34]. The use of this method in clinical practice began in 1988. Initially, laser therapy was used prior to surgery [1]. It was then implemented both as an independent method and in combination with radiation and chemotherapy [35-50]. The results got in the treatment for mastopathy proved to be interesting [51]. We found the results of the treatment satisfactory. They demonstrated the high effectiveness of this type of radiation for the treatment of cancer in patients. Therefore, this absorbed dose calculation formula has been in use for quite a long period of time [52]. During accumulation of clinical experience and practical application of the method , it turned clear that this calculation method does not take many factors that affect the absorbed dose into account.

Such factors as blood supply to organs [53,54] and alveoli oxygenation were not considered. Compared to a power of 5-10 W per pulse and a time of 5 to 20 minutes used in 1988, current indicator for a power of up to 100 W per pulse is used and the irradiation time is several hours. These observations demonstrated the need for research to consider the spectral features of all tissues through which laser radiation passes and the dose which reaches the pathological focus.

Purpose and Objectives of the Study

The purpose of this study was to learn how various pig tissues and organs absorb and scatter laser radiation (860nm). According to their histological structure, they are most like human tissues. All the studies were carried out based on the Faculty of Basic Sciences at Bauman Moscow State Technical University. The objectives of the experiment were to determine the scattering and absorption capacity of the main tissues and organs - skin of various thicknesses, adipose tissue, muscle tissue, liver, heart, lung, kidneys, cardiac septum, bones (flat and tubular). It was necessary to create a special stand, which was supposed to consist of a laser diode of a certain wavelength (860nm), a device for fixing tissue through which laser radiation was supposed to pass, and a device for recording the radiation was to pass through the tissue. The results obtained after processing made it possible to calculate the reflective and absorptive capacity of various tissues.

Theoretical Studies

Laser radiation of different wavelengths penetrates biological tissues differently. Experiments revealed that near-infrared range (IR) of wavelength has the most penetrating capacity (Figure 1). During the experiment, we found out the following: when laser radiation passes through biological tissue, change in radiation intensity is observed, and further gets decomposed into three components - reflected, absorbed, and transmitted ones (Figure 2). Under normal incidence of a collimated laser beam along the z axis on biological tissue, because of reflection from its surface, scattering and absorption by tissue, a change in radiation intensity is observed in accordance with an exponential law,

$$I(z) = (1 - R)I_0 \exp(\beta_t z) \quad (2)$$

where :

I_0 - Intensity of the incoming irradiation on the tissue

R - Coefficient of Fresnel reflection at normal incidence

β_t - Elimination (attenuation) coefficient

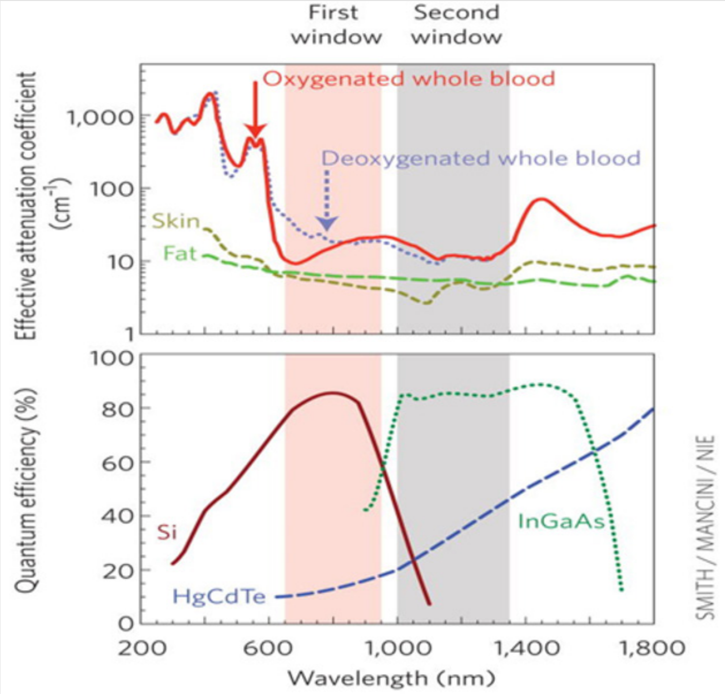


Figure 1: Penetrating ability of different wavelengths.

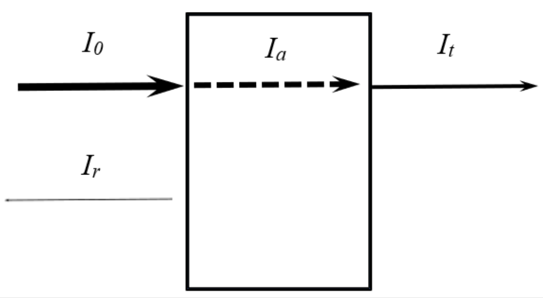


Figure 2: The flow of laser radiation through biological tissue.

Elimination rate is the sum of absorption β_a and dissipation β_s coefficients.

Attenuation coefficient is equal to the sum of absorption β_a □a and scattering β_s coefficients.

$$\beta_t = \beta_s + \beta_a \quad (3)$$

The link between the normally oriented intensity of irradiation is expresses as follows:

$$I_0 = I_r + I_a + I_t \quad (4)$$

Where:

$I_r = I_r R$ – Intensity of reflected radiation,

I_a –Change in intensity at propagation through a sample of biological tissue,

I_t - the intensity of radiation transmitted through the tissue.

For sample of tissue with the thickness x

$$I_t = (1-R) I_0 exp(-\beta_t x) \qquad (5)$$

Then , from equations (3) and (4) it follows.

$$I_0 = I_t exp(-\beta_t x) + I_r \qquad (6)$$

For two tissue samples we can write a system of equations

$$I_0 = I_{t1} exp(-\beta_t x_1) + I_{r1} \qquad (7)$$
$$I_0 = I_{t2} exp(-\beta_t \ x_2) + I_{r2} \qquad (8)$$

When measurements for two identical (Ir1=Ir2) tissue samples of different thicknesses are carried out, attenuation coefficient and reflection coefficient are found

$$\beta_t = \frac{\ln(\frac{I_{t1}}{I_{t2}})}{x_1 - x_2} \qquad (9)$$

$$R = 1 - \frac{I_t}{I_0} \exp(\beta_t x) \qquad (10)$$

Thus, the passage of laser radiation through biological tissue is characterized by significant scattering by inhomogeneities (in inhomogeneous media). The scattered radiation pattern usually has a uniform angular intensity distribution.

Materials and Methods

The choice of the working wavelength corresponds to the parameters of the pulse emitting head of the certified laser therapeutic device "Mustang 2000" (Company "Technika"), the characteristics of this device were taken as input radiation parameters. All the work was done based on the Bauman Faculty of Basic Sciences on personal initiative (Head - Prof. Gladyshev V.O.) To carry out the research, a special stand was developed (Gladyshev V.O., Sharandin E.A.), which made it possible to calculate the incident and transmit radiation power.

The Stand Consisted of the Following Components

A. A photodetector with a wide dynamic range. An Avesta ASP-100MF spectrometer was used as a photodetector with a wide dynamic range.

B. A special device in which the materials being studied were recorded.

C. Laser diode (Figure 3).

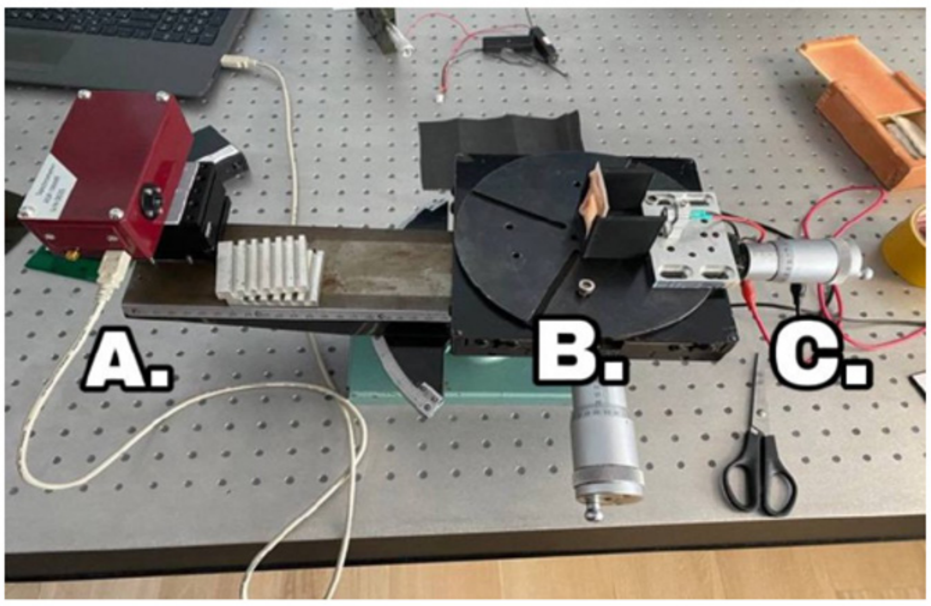


Figure 3: Measuring stand.

Due to the rotating mechanism the stand allows for measuring the radiation patterns passed through the sample in the region from -90 to +90 degrees. Various pig tissues and organs were used for the research. Since they are like human ones in their structure and optical properties. The experimental material was obtained at stages 3-5 hours after killing the animal. To preserve the biological structure of the tissues as much as possible during transportation, a special medical container was used. All samples were brought to the same size $(2x2\ cm)$ and thickness $(0.1-1\ cm)$. They were rigidly fixed in the device, which made it possible to minimize the change in the thickness of the tissue across the cross-section and its deformation during the measurement process. The following animal tissues were studied: pieces of skin of various thicknesses, adipose tissue, muscle tissue, liver, heart, lung, kidneys, cardiac septum, bones (flat and tubular). An example of organ fixation is shown in Figure 4. After this, the material was inserted into a special device and fixed rigidly (Figure 5). Laser radiation passed through the tissue and was recorded in a spectrometer (Figure 6). We used at least two samples of different thicknesses, which made it possible to determine absorption and reflection coefficients for axial radiation beams by using formulas (8) and (9). The radiation at the input to the photodetector is recorded in relative units of measurement. The results were monitored by measuring laser radiation intensity distribution through a reference matte plate with a scattering pattern close to the Lambert distribution.

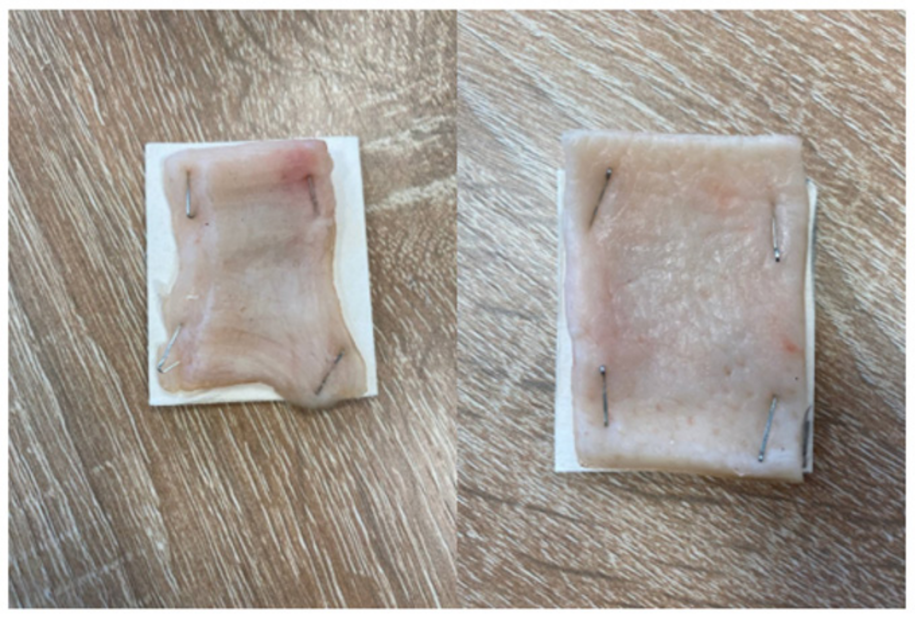


Figure 4: Fixed skin material on solid carrier.

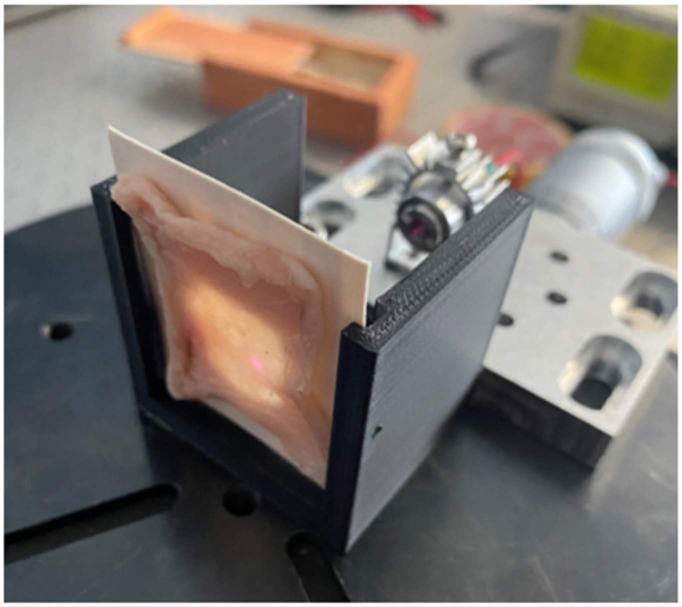


Figure 5: The examined material is rigidly fixed in a special device.

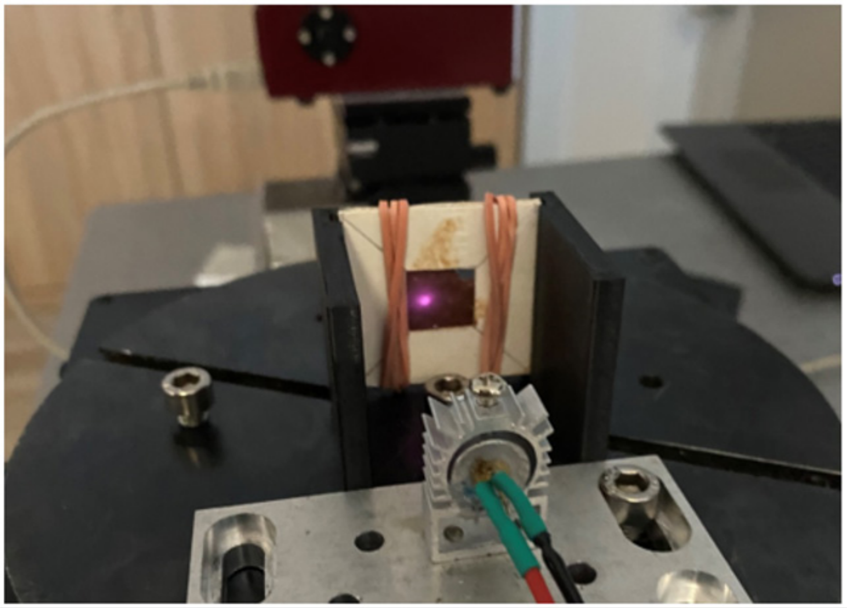


Figure 6: The passage of laser radiation through the fabric.

Results

The results obtained were tabulated for further data processing and program development (Table 1).

Table 1: Results of measurements of the passage of laser radiation (at all angles of direction) through various tissues.

Angle, Degree	Skin			Liver		Muscle tissue				Adipose tissue	
	1 mm	3 mm	4 mm	1 mm	5 mm	1.5 mm (S)	1.5 mm (B)	8.5 mm (Г)	8.5 mm (B)	2 mm	4 mm
-80	1100	1500	500	0	0	0	0	0	0	1000	1000
-75	2400	2000	1500	1000	700	1000	800	700	800	2300	2000
-70	3000	3000	2100	2000	900	1400	1400	1200	1200	3500	3000
-65	3500	3700	2700	2500	1200	1800	2200	1800	1600	4700	3800
-60	5000	4500	3500	3200	1500	2300	3000	2600	2000	5500	4200
-55	6000	5000	4000	4500	1800	2600	3200	3300	2400	7000	5200
-50	7000	6000	5000	4500	2000	3300	4300	4300	3000	7500	5400
-45	7500	6700	5200	6000	2200	3800	4500	4600	3400	8000	6000
-40	8000	7000	5700	6500	2400	4000	5000	5900	3800	9000	6000
-35	8500	7800	6500	7500	2600	4200	4500	5800	4400	9000	6400
-30	11500	9000	7500	8500	2800	5500	7500	6200	4800	9500	6600
-25	10000	9500	7800	10500	3000	7500	7000	6600	5200	9500	6800
-20	9500	10000	8000	11000	3200	8000	10000	7200	6000	10500	6800
-15	12000	10000	8500	12000	3200	8700	13000	7500	6200	10500	6800
-10	11500	9500	9000	11500	3300	11500	12000	7800	6600	11000	7200
-5	13500	10000	9000	11500	3400	14500	15500	7800	6600	11000	7000
0	12500	10500	9000	12000	3400	17000	13000	8000	7000	10500	7200

5	12000	10500	9000	11000	3200	17000	16500	7800	7000	10500	7000
10	12000	10000	9000	12000	3200	13500	15500	7800	7000	10500	6500
15	13500	10000	9000	11500	3100	9500	16500	7600	6800	10000	6600
20	12000	10000	9500	10500	3000	8700	14000	7400	6800	9500	6000
25	11500	9500	8500	9500	2800	5500	12200	7200	6700	9000	5800
30	11500	9000	8500	9500	2700	5300	10500	7000	6800	8500	5400
35	10500	9000	8000	7000	2500	5000	6000	6700	6400	7500	5000
40	10000	8000	8000	7000	2200	3400	4800	6500	6200	7500	4400
45	8500	7500	7500	6500	1800	2800	5000	5800	6000	7000	4200
50	8000	7000	7000	6000	1600	2800	3200	5200	5400	6500	3600
55	8000	6500	6500	5500	1300	2000	3200	5000	5000	5500	2800
60	6500	5300	5500	4200	800	1600	2200	4200	4600	4500	2000
65	5500	4500	4500	3500	500	1200	2200	3900	3000	3500	1200
70	4500	3500	3500	2500	0	900	1400	3000	2800	2000	600
75	3000	2200	2700	1500	0	400	0	2500	1800	500	0
80	1000	1000	1000	0	0	0	0	1500	800	0	0

Angle, Degree	Heart		Bone tissue		Omentum	Lung		Kidney		Heart Septum	
	1.5 mm	7 mm	spinal canal	4 (9) mm	1 mm + 21.7 times coefficient glass	1.5 mm	5 mm	1.5 mm	3 mm	2 mm	5 mm
-80	0	0	0	0		300	0	0	0	0	0
-75	1200	0	0	0		600	0	1500	1600	2500	800
-70	2200	150	0	0		800	0	2500	2400	3500	1000
-65	2800	210	100	0		1100	0	3500	3400	4500	1400
-60	3400	350	200	100		1400	50	5000	3800	5500	1700
-55	3800	500	350	300		1600	70	5500	4600	6800	2000
-50	4600	600	500	500	0	1700	90	7000	5200	6800	2200
-45	5000	700	600	600	0	1800	100	8000	5600	8000	2400
-40	5000	900	700	780	400	2000	110	10000	5800	9500	2500
-35	5200	1050	900	1000	600	2100	115	10000	6000	10000	2800
-30	6200	1200	1400	2800	800	2200	120	11000	6000	11500	3000
-25	6800	1400	2200	8500	1000	2300	130	13000	6500	11500	3200
-20	7200	1600	2700	1200	1600	2300	140	14000	7000	11500	3300
-15	7200	1800	3400	5000	2400	2400	140	15500	7000	12000	3400
-10	7400	1900	4600	6000	5600	2400	180	14500	7000	14000	3400
-5	7200	2100	5200	6800	4500	2400	150	15500	6600	11500	3400
0	7600	2200	6000	8000	6800	2300	150	15000	7000	13000	3600
5	7200	2200	7000	8700	7000	2300	150	15500	6600	14000	3600
10	7200	2300	8000	10000	3500	2200	130	14500	6400	11500	3400
15	6900	2300	8500	11000	2500	2100	120	15000	6200	11500	3300
20	6400	2300	10000	11000	1800	2000	110	12500	5800	9500	3200
25	6800	2200	10000	10500	1200	1800	110	13500	5600	12000	3000

30	6200	2200	9500	9500	600	1700	100	12000	5400	11000	2800
35	6000	2100	9000	8500	400	1600	90	8500	5000	10500	2600
40	5200	2000	8500	7500	0	1500	85	8500	4600	9500	2400
45	4800	1800	8000	7000	0	1300	80	8500	4400	9000	2200
50	4000	1600	7500	6000	0	1200	70	8000	4000	7500	2000
55	2400	1300	6500	4500	0	900	65	6000	3800	7000	1600
60	1200	1000	5200	3200	0	700	50	5000	3000	6000	1400
65	400	600	4200	2300	0	600	0	4000	2400	4000	900
70	0	300	3200	1900	0	400	0	3500	1200	2500	600
75	0	100	2200	1700	0	0	0	2000	0	0	0
80	0	0	1000	1500	0	0	0	0	0	0	0

Tissue Absorption Coefficient Calculation

Calculation of Fat Absorption Coefficient: The results of the normal measurement of the radiation intensity through 2 and 4mm fat tissue and the estimated absorption coefficient are presented in Table 2. Substituting values in formulas (9) and (10), we get:

$$\beta_t \approx \frac{ln\left(\frac{10500}{7200}\right)}{4-2} = 0{,}19\ ì\ ì^{-1}$$

Absorption coefficient value for adipose tissue is 1 millimeter (for working wavelength, 860nm) Similarly, we calculate absorption coefficients for other tissues:

β_t skin $-$ 0.13 mm^{-1}

β_t liver $-$ 0.23 mm^{-1}

β_t muscle tissue $-$ 0.22 mm^{-1}

β_t fat $-$ 0.19 mm^{-1}

β_t heart $-$ 0.32 mm^{-1}

β_t bone tissue $-$ 0.5 mm^{-1}

β_t lung $-$ 0.79 mm^{-1}

β_t kidney $-$ 0.53 mm^{-1}

β_t of the cardiac septum $-$ 0.44 mm^{-1}

Table 2: Results of measurements of radiation intensity through adipose tissue.

Angle, Degree	Adipose tissue	
	2 mm	4 mm
0	10500	7200

Tissue Scatter Diagrams

Below are the maximum angular intensity distributions (scattering diagrams) of collimated laser radiation passed through tissue samples with a wavelength of 860 nm. The sample radiation directional data in the range of -90 to +90 degrees (Table 1) are used to draw laser dissipation diagrams for each type of tissue.

Skin Tissue

Skin tissue, pieces of various thicknesses (1 and 3 mm) were used for the study. Skin scatter diagram (Figure 7). The graph shows that the main radiation dose (more than 50%) falls on a wide angle of exposure (±50O..60O). It is very important to note the good transmittance of the skin (up to 80% or more) for this type of radiation.

Liver Tissue

Diagram of radiation scattering in liver tissue (Figure 8).

Muscle

Diagram of radiation scattering in muscle tissue (Figure 9).

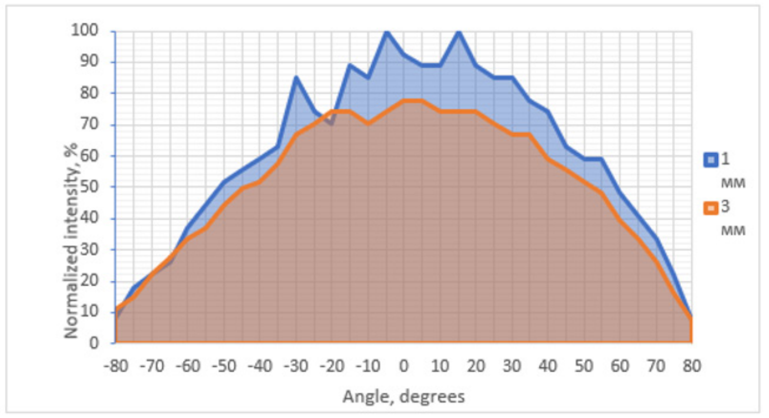


Figure 7: Radiation dissipation diagram in skin tissue.

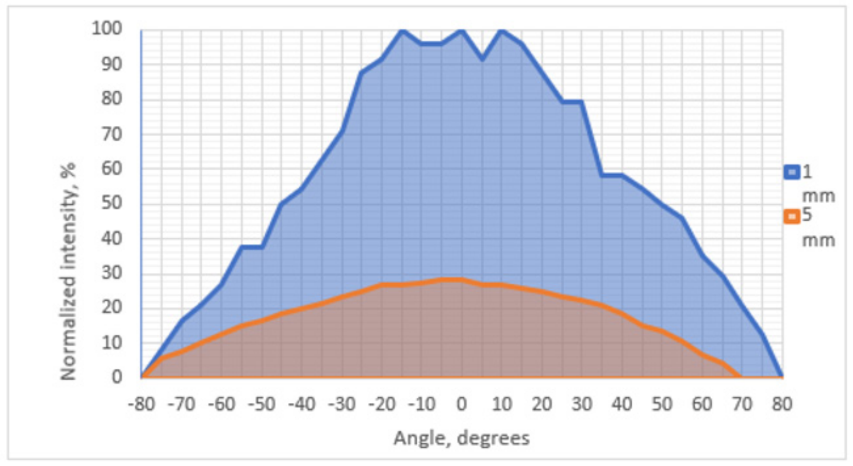


Figure 8: Radiation dissipation diagram in liver tissue.

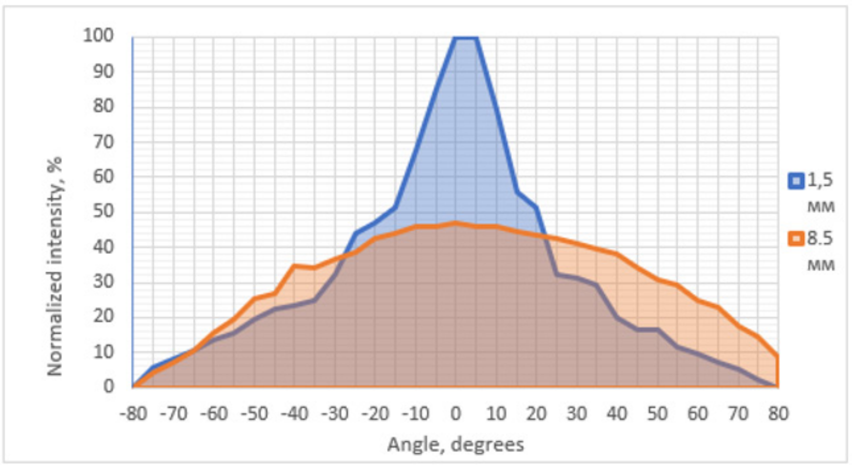


Figure 9: Diagram of radiation dissipation in muscle tissue.

Adipose Tissue

Diagram of radiation scattering in adipose tissue (Figure 10).

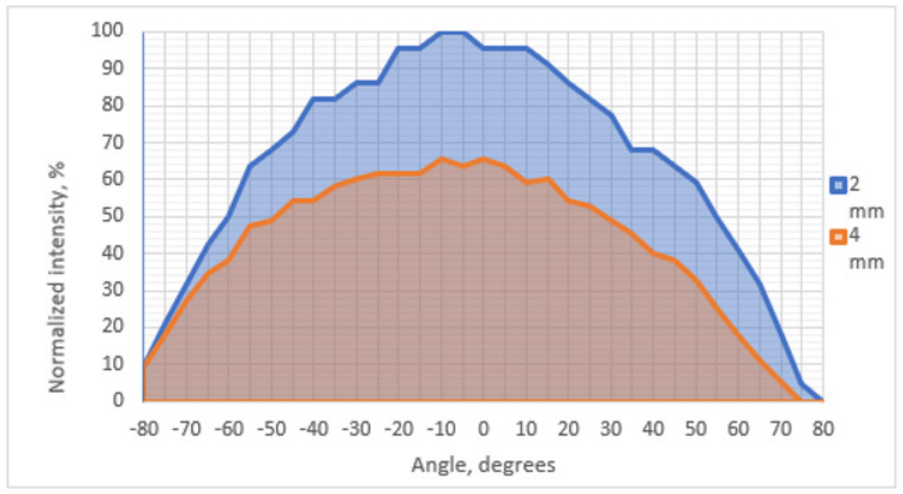


Figure 10: Radiation dissipation diagram in adipose tissue.

Heart Tissue

Diagram of radiation scattering in cardiac tissue (Figure 11).

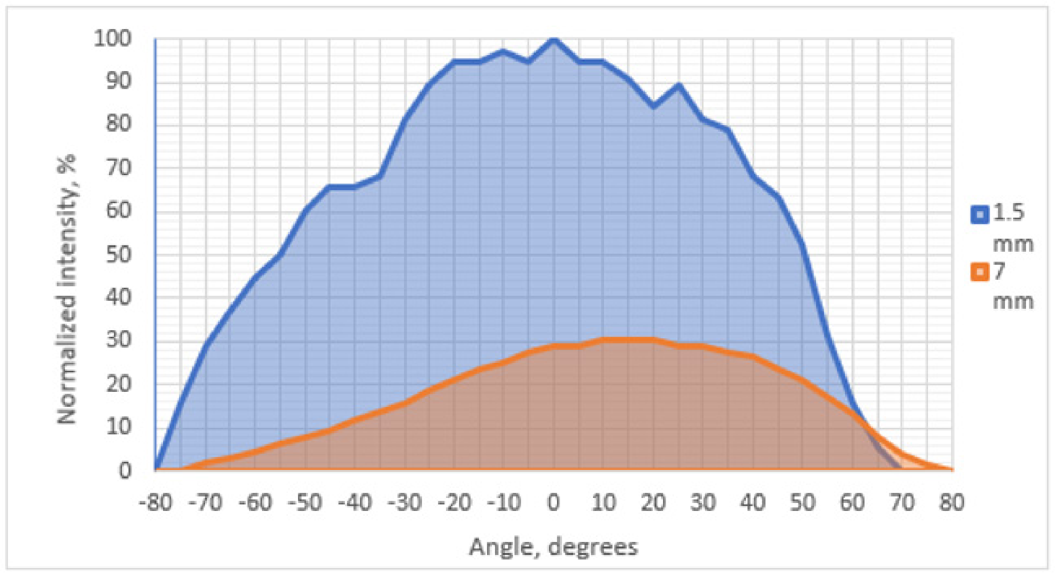


Figure 11: The pattern of radiation dissipation in the heart tissue.

Heart Septum Tissue

Scatter diagram of cardiac septum (Figure 12).

Bone Tissue of the Spinal Canal

Radiation scattering diagram in the spinal canal (Figure 13).

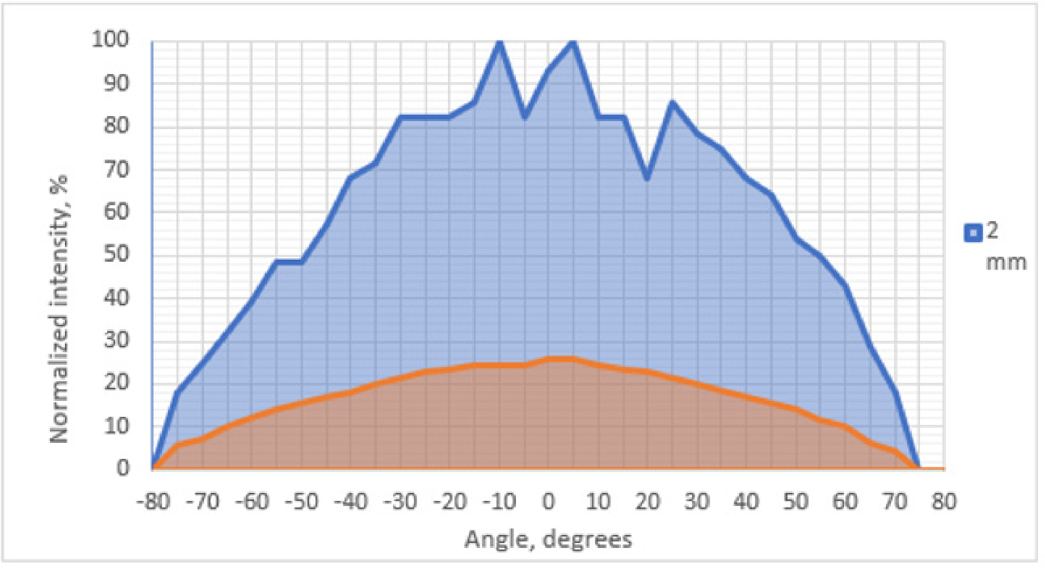


Figure 12: The diagram of the dispersion in the cardiac septum.

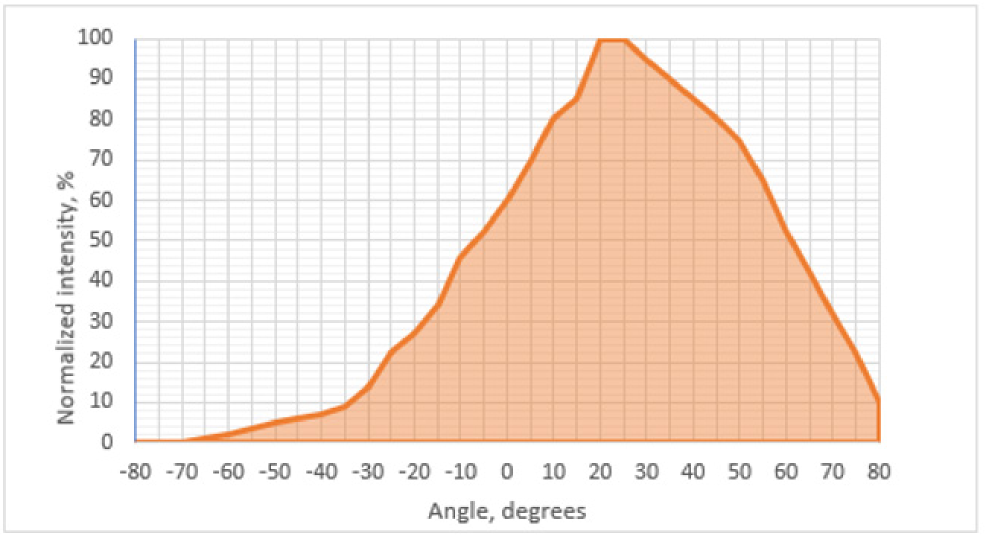


Figure 13: Radiation dissipation diagram in the spinal canal.

Bone

Diagram of radiation scattering in bone tissue (Figure 14).

Lung Tissue

Diagram of radiation scattering in lung tissue (Figure 15).

Kidney Tissue

Diagram of radiation scattering in kidney tissue (Figure 16).

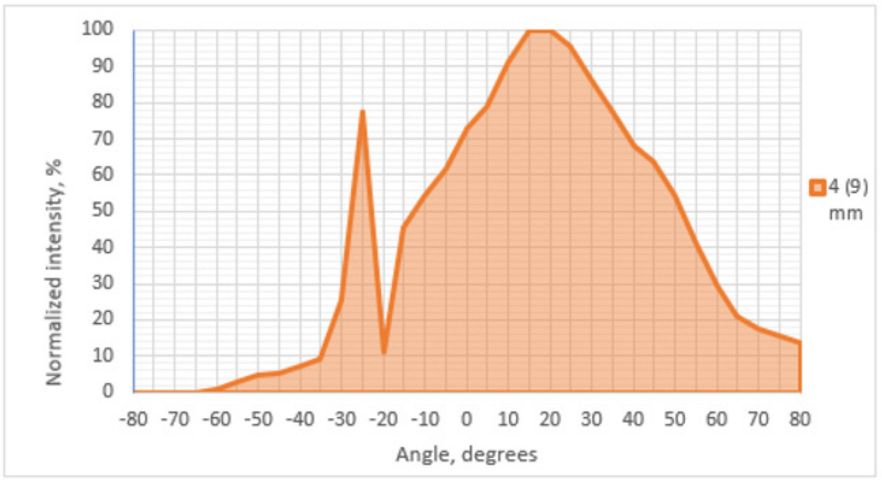


Figure 14: Radiation dissipation diagram of the bone tissue.

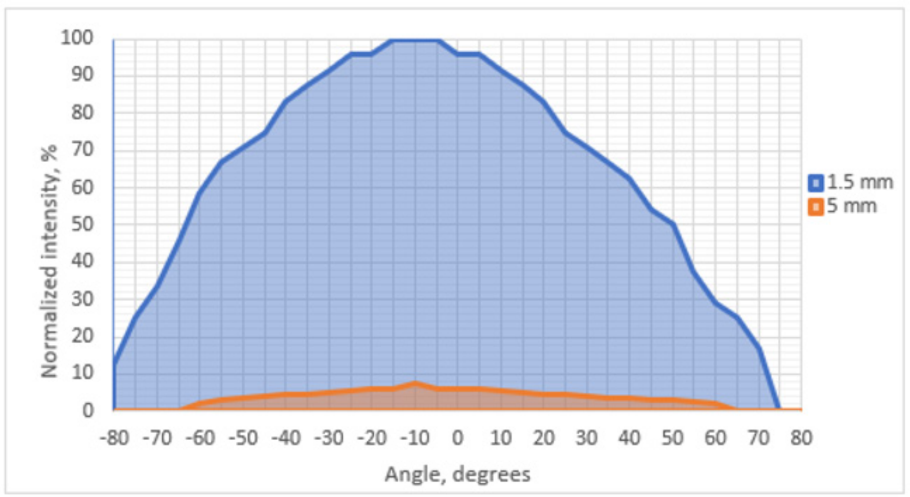


Figure 15: Radiation dissipation diagram in lung tissue.

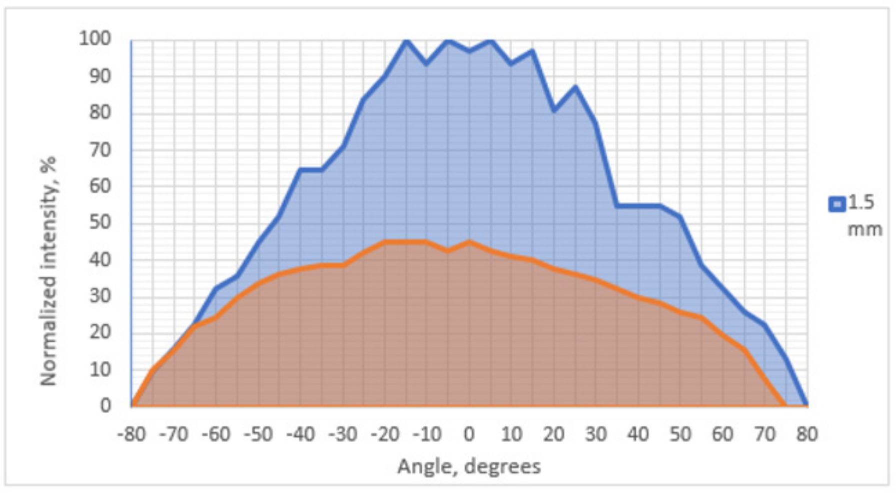


Figure 16: Radiation dissipation diagram in renal tissue.

Calculation of the Absorbed Radiation Dose by Different Organs Located at Different Distances from the Body Surface

The study allows us to calculate the radiation dose to obtain the necessary therapeutic effect in the affected organ. Knowing the reflectivity of radiation from the skin and the absorption coefficients of all tissue types under study, it became possible to calculate the radiation dose that a certain area should receive. For this purpose, a program that allows to calculate an algorithm for using laser therapy to treat various pathologies was compiled. The input parameters for calculating the program are:

1. Radiation power.
2. Power level.
3. Pulse frequency.
4. Irradiation time.
5. Radiation angle,
6. Thickness of fabrics.

The total energy exposure $(J/cm2)$ is calculated according to the formula:

$$E = \frac{P \cdot \tau \cdot F \cdot t}{s}, \qquad (11)$$

Where:

P - radiation power (W),

τ - unit pulse duration (s),

t - Radiation exposure time (c),

S - laser impact area (cm^2),

F - pulse frequency (Hz).

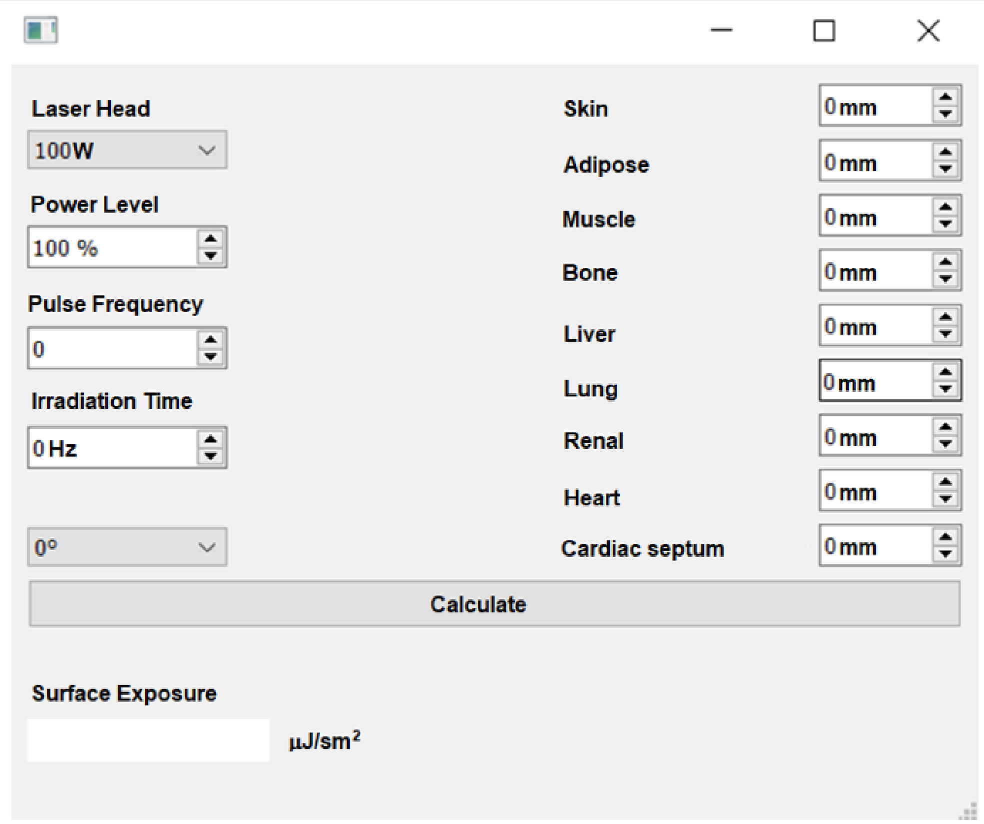
The laser impact area for the Mustang 2000 device is selected according to the parameters of the laser head beam, 5 mm in diameter. The formula provides for [11], finding out energy exposure at the output of the laser head. To obtain the final exposure, it is necessary to consider the radiation lost because of reflection and absorption in tissues. When carrying out calculations, radiation absorption was found for each layer independently. The number, type and thickness of each layer were specified as initial data. Loss of laser radiation energy due to reflection, with the assumption of similar refractive indices of different types of tissue, was calculated only for the first layer - skin. Processing of experimental data made it possible to establish that about 45% of the radiation is reflected from the skin tissue sample. Such a high value can be explained by a combination of the processes of both reflection and backscattering of radiation in the samples. The reflectance value directly depends on the degree of pigmentation and wrinkling of the skin, the presence of fat and moisture, and, most importantly, the wavelength of the emitter. According to the data given in [55-57], the reflectance of human skin in the IR range can vary from 10 to 55%. Calculation of the dose of radiation that has sequentially passed through various biological tissues may serve as an example. The formula for finding the total energy exposure of radiation with a wavelength of 850nm passing through skin, muscle and fat tissue is following:

$$E_{\hat{a}\hat{u}\ \tilde{o}} = \frac{P \cdot \tau \cdot F \cdot t}{S} \cdot (1-\beta) \cdot \exp^{-\alpha_{\lambda 1} \cdot x_1} \cdot \exp^{-\alpha_{\lambda 2} \cdot x_2} \cdot \exp^{-\alpha_{\lambda 3} \cdot x_3} \qquad (12)$$

where $\alpha\_\lambda 1$, $\alpha\_\lambda 2$ and $\alpha\_\lambda 3$ are the absorption coefficients of skin, muscle and adipose tissue, respectively, and x_1, x_2 and x_3 are thickness.

Considering the outcomes we may claim that the study made it possible to determine the radiation dose at different angles of incidence. Moreover, reflection and absorption parameters of all tissues studied have been determined. This made it possible to determine the total absorption dose of laser radiation at passing through all tissues from the surface of the skin to the pathological focus. Based on these results, a program was developed making it possible to determine the dose of laser radiation that the target organ and the tissues around receive. The program allows to calculate the total energy exposure of laser radiation passed through various types of biological tissues, starting from the skin and to the required irradiation zone (Figure 16). The program window for calculating the absorbed dose by the organs under study for a wave of 850mn (Figure. 17).

The program allows to calculate the total energy exposure of laser radiation passing through various types of biological tissues, starting from the skin and to the required irradiation zone (Figure 17).



Laser Head: 100W
Power Level: 100 %
Pulse Frequency: 0
Irradiation Time: 0 Hz
0°
Skin: 0 mm
Adipose: 0 mm
Muscle: 0 mm
Bone: 0 mm
Liver: 0 mm
Lung: 0 mm
Renal: 0 mm
Heart: 0 mm
Cardiac septum: 0 mm
Surface Exposure: µJ/sm²

Figure 17: Program window for calculating the absorbed dose by the examined organs for 850mn wave.

Discussion of the Results Obtained

Pig tissues were used as an experimental model. Of all experimental models available, pig tissues are most similar to human tissue. Analyzing the results obtained, it can be assumed that similar human tissues have similar absorption capacity. At least it proved possible to reliably estimate the radiation dose to various tissues and organs when exposed to laser radiation with a wavelength of 860 nm. For this purpose, a special program was created (Gladyshev V.O., Sharandin E.A.). It made it possible to calculate the absorbed dose based on the total absorption coefficient of the organs the laser beam is supposed to pass thought. Of course, the absorption capacity of the organs being studied differs from the normal state of the tissues of a living organism. In the samples studied, there was no sufficient volume of blood that could be found in the tissue of a living organism. At lungs testing, besides the absence of blood, there was no air in the alveoli and bronchi. Therefore, absorption and reflection coefficients in organs under study are, of course, different from living tissues. In further research, we are to consider the reflective and absorptive ability of all blood components for a wavelength of 860 nm. In those organs where blood volume was not considered, these coefficients should be approximately equal. In lungs such differences will be significant. Since blood supply and the volume of lungs filled with air were not considered, it is possible to calculate the absorbed dose in different segments of lungs only approximately. In organs such as bones, tendons, ligaments, where blood supply is lower than in parenchymal organs, these coefficients are almost equal.

Conclusion

It follows from what has been discussed that it was the first time the way different tissues influence the passage of laser radiation with a wavelength of 860 nm was approached in a study . Absorption coefficients and scattering diagrams have been experimentally worked out for major types of biological tissues. A program to determine the radiation dose most optimal to obtain the maximum effect in treatment for various pathologies of internal organs has been developed. The developed methodology will serve subsequent in-depth study of the effect IR radiation has on the human body and is going to be of good use for further improvement and development of laser therapy and laser medicine in general.

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