NATIONAL TECHNICAL UNIVERSITY OF UKRAINE
"KYIV POLYTECHNIC INSTITUTE
NAMED AFTER IHORY SIKORSKY"
FACULTY OF BIOMEDICAL ENGINEERING
DEPARTMENT OF BIOMEDICAL ENGINEERING

« Approved for defense»
Head of the Department of BMI
___________ Vladyslav SHLYKOV
(signature) (initials, surname)
“ ___ ” _______________2023

Graduate work

to obtain a bachelor's degree

under the educational and professional program "Medical Engineering"

specialty 163 "Biomedical engineering"

on the topic: The complex of software and technical tools for managing the process of photodynamic laser therapy

Completed:
IV year student, group BM-93
Amirhossein Saedigordnejad ______________

Supervisor:
senior lecturer dep. BMI,
Ph.D., M. Delavar-Kasmai ______________

Adviser for the labor protection:
Lecturer at the OPCB, Senior Lecturer Ph.D.
Kalinchyk V.V. ______________

Reviewer:
assistant of the biosafety and human health department
Grishin Ivan Leonidovych ______________

I certify that in this bachelor thesis there are no borrowings from the works of other authors without appropriate references.

Student _____________

Kyiv –2023

НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ УНІВЕРСИТЕТ УКРАЇНИ
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

ФАКУЛЬТЕТ БІОМЕДИЧНОЇ ІНЖЕНЕРІЇ

КАФЕДРА БІОМЕДИЧНОЇ ІНЖЕНЕРІЇ

До захисту допущено:

Завідувач кафедри

________ Владислав ШЛИКОВ

«___»____________20__ р.

Дипломна робота

на здобуття ступеня бакалавра

за освітньо-професійною програмою «Медична інженерія»

спеціальності 163 «Біомедична інженерія»

на тему: Комплекс програмно-технічних засобів для управління процесом фотодинамічної лазерної терапії

Виконав:
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Керівник:
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доц. каф. ОПЦБ, к.т.н.
Калінчик Віктор Васильович ___________

Рецензент:
асистент кафедри ББЗЛ
Гришин Іван Леонідович___ ___________

Засвідчую, що у цій дипломній роботі немає запозичень з праць інших авторів без відповідних посилань.
Студент ______________________

Київ – 2023

National Technical University of Ukraine
"Kyiv Polytechnic Institute named after Igor Sikorsky"
Faculty of Biomedical Engineering
Department of biomedical engineering

Level of higher education - first (bachelor's)

Specialty - 163 "Biomedical Engineering"

Educational and professional program "Medical engineering"

I APPROVE

Head of Department

_______ Vladyslav SHLYKOV

"___"_____________20__ year.

TASK

for a diploma work for a student

Amirhossein Saedigordnejad

1. The topic of the work " The complex of software and technical tools for managing the process of photodynamic laser therapy", head of the work M. Delavar Kasmai, Senior lecturer of the faculty BMI, Ph.D in technical science, approved by order of the university dated May 26; 2023 No. 52/23-si

2. Deadline for student submission of work: 9 June

3. Initial data for work: scientific and technical literature, software NI LABVIEW.

4. The content of the work: review a literature analysis of the latest research according to the chosen topic, create an algorithm for obtaining feedback, build an algorithm for controlling the laser installation based on the generated feedback, propose a hardware complex for implementing the control algorithm.

5. A list of illustrative material (with an indication of posters, presentations, etc.): 21 illustrations, 1 presentation

6. Adviser of work sections

7.

Department	Surname, initials and position adviser	Signature, date	
		task published	task accepted
Labor protection	Kalinchyk V.V Assoc. prof. dep. Safety of labor, industrial and of civil security"		

Issue date of the assignment____________________

Calendar plan

№ by number	The name of the execution stages thesis	Deadline stages of work	Note
1.	Literature review	date	
2.	Development and setting of tasks according to the topic of the thesis	date	
3.	Development of the theoretical part of the thesis	date	
4.	Development of the practical part and obtaining results	date	
5.	Writing conclusions on the work	date	
6.	Completion of the "Labor Protection" section	date	
7.	Completion of an explanatory note to the thesis	date	
8.	Submission of work for regulatory control	date	
9.	Receiving reviews and feedback from the manager	date	
10.	Submission of a package of documents for the thesis for the defense (Preparation for the defense)	date	
11.	Defense of the thesis	date	

Student Amirhossein Saedigordnejad

Supervisor: M. Delavar Kasmai

Національний технічний університет України

«Київський політехнічний інститут імені Ігоря Сікорського»

Факультет біомедичної інженерії

Кафедра біомедичної інженерії

Рівень вищої освіти – перший (бакалаврський)

Спеціальність – 163 «Біомедична інженерія»

Освітньо-професійна програма «Медична інженерія»

ЗАТВЕРДЖУЮ

Завідувач кафедри

_______ Владислав ШЛИКОВ

«___»____________20__ р.

ЗАВДАННЯ

на дипломну роботу студенту

Амірхоссейн Саедігорднеджад

1. Тема роботи "Комплекс програмно-технічних засобів для управління процесом фотодинамічної лазерної терапії", керівник роботи М. Делавар-Касмаі, ст. викл. каф. БМІ, к.т.н., затверджені наказом по університету від **" 26 " травня 2023 р. № 52/23-si**

2. Термін подання студентом роботи: 09 червня 2023 року.

3. технічна документація та навчальна література, друковані та електронні видання, наукові статті, середовище програмування NI LABVIEW.

4. Зміст роботи: провести літературний аналіз останніх досліджень згідно з обраною тематикою, сформувати алгоритм отримання зворотного зв'язку, побудувати алгоритм керування лазерною установкою на основі сформованого зворотного зв'язку, запропонувати апаратний комплекс для реалізації алгоритму керування.

5. Перелік ілюстративного матеріалу (із зазначенням плакатів, презентацій тощо): 21 ілюстрація, 1 презентація

6. Консультанти розділів роботи

Розділ	Прізвище, ініціали та посада консультанта	Підпис, дата	
		завдання видав	завдання прийняв
Охорона праці	Калічік В.В. Старший викладач кафедри «Охорона праці, промислової та цивільної безпеки»		

7. Дата видачі завдання ____

Календарний план

№ з/п	Назва етапів виконання дипломної роботи	Термін виконання етапів роботи	Примітка
1.	Огляд літератури	дата	
2.	Розробка та постановка задач згідно з темою дипломної роботи	дата	
3.	Розробка теоретичної частини дипломної роботи	дата	
4.	Розробка практичної частини та отримання результатів	дата	
5.	Аналіз отриманих результатів	дата	
6.	Оформлення розділу з «Охорони праці»	дата	
7.	Оформлення пояснювальної записки до дипломної роботи	дата	
8.	Здача роботи на нормконтроль	дата	
9.	Отримання рецензії та відгуку керівника	дата	
10.	Подання пакету документів по дипломній роботі до захисту (Підготовка до захисту)	дата	
11.	Захист дипломної роботи	дата	

Студент Аміρхоссейн Саедігорднеджад

Керівник М. Делавар-Касмаі

CNONTENT

SECTION1:

SECTION2:

SECTION 3:

PRACTICAL PART

SECTION4:

ABSTRACT

Topic of the thesis: "A complex of software and technical tools for managing the process of photodynamic laser therapy".

The volume of the report is 58 pages, contains 21 illustrations, 20 tables, 19 formulas. In total, sources, 3 applications were developed.

The diploma work was completed on the basis of NTUU "KPI" named after Igor Sikorsky", FBMI, BMI. The thesis supervisor is M. Delavar Kasmai, Senior lecturer of the faculty.

Relevance: Photodynamic laser therapy (PDT) is an effective clinically approved method of cancer treatment, however, it has several limitations. Therefore, for the first time, it was proposed to create a software and hardware complex that would ensure optimal management of the PDT process, taking into account the existing shortcomings.

Objective: to create a control algorithm to improve the efficiency of the PDT procedure based on real-time feedback.

Task: to research literary sources regarding the current state and prospects of PDT; justify the use of the thermography method as feedback, the polynomial regression method for processing thermographic data; justify the use of the NI LabVIEW software environment; build an optimal control algorithm and implement it in the chosen environment; to develop the concept of a hardware complex for the implementation of the constructed control algorithm.

The main results: simulation of the process of heating biological tissue with accumulated photosensitizer was carried out, a control algorithm based on feedback was built, technical means for implementing the control algorithm were proposed

Key words: photodynamic laser therapy, optimal control

LIST OF ABBREVIATIONS

PDT - photodynamic laser therapy

RK - reactive oxygen

FS is a photosensitizer

OCT is optical coherence tomography

ICT - infrared thermography

IR is infrared radiation

INTRODUCTION

- Photodynamic laser therapy (PDT) is a treatment procedure for various types of oncological diseases based on the principle of generating cytotoxic reactive oxygen (ROS) with the aim of activating cell apoptosis and tissue destruction under the selective action of photosensitizers (PS) . Compared to traditional cancer treatments (such as chemotherapy and radiotherapy), PDT causes low-level non-specific toxicity to healthy tissues and organs, as RC is only produced by certain wavelengths (non-ionizing and harmless)PDT is considered an effective medical and clinically approved method of treatment for bladder cancer, lung cancer, esophageal cancer, head and neck skin cancer, etc. .
- PDT is currently the subject of extensive research, however, despite significant progress, it has a number of limitations:.standard values of the duration of the procedure, which do not take into account the physiological characteristics of the patient and do not guarantee the effectiveness of the results;
- • sensitivity of photosensitizers to temperature;
- • dependence of the course of the procedure on the level of qualification of the doctor[4].
- The relevance of the work lies in the fact that, for the first time, the creation of a software and hardware complex is proposed, which will ensure optimal control of the PDT process, taking into account the above-mentioned shortcomings.
- The aim of the thesis is to create a control algorithm for increasing the efficiency of the PDT procedure based on feedback received from the patient during PDT in real time.
- To achieve the goal of the thesis, the following tasks were set:research literary sources regarding the process of conducting the procedure and the current state of PDT;
- • justify the use of the thermography method as feedback;
- • justify the use of the polynomial regression method for processing thermographic data;
- • build an optimal control algorithm;
- • justify the use of the NI LabVIEW software environment;

- • simulate the process of heating biological tissue with accumulated FS;
- implement the control algorithm in the selected software environment;to develop the concept of a hardware complex for the implementation of the constructed control algorithm.

The object of research is a model of heating biological tissue with accumulated FS.

The subject of the study is a control algorithm for increasing the efficiency of PDT results.

The methods of research for building an algorithm with feedback are the method of regression analysis, as well as the method of thermography.

The scientific novelty lies in the absence of similar control algorithms for improving the efficiency of the PDT procedure based on real-time feedback.The practical significance of the obtained results is the use of this development to optimize and increase the efficiency of the PDT procedure, as well as to build a commercial product and bring it to the market.

CHAPTER 1

CUROverview of the mechanism and physical basis of the PDT procedureRENT STATUS AND PROSPECTS OF PDT

Malignant tumors (primary cancer of the brain and spinal cord, pancreas and thyroid gland, metastases of liver cancer, etc.) are able to accumulate molecules of highly specific chemical photosensitive substances - photosensitizers (PS), which are previously introduced through blood vessels.

When the FS is irradiated with laser radiation, the wavelength of which coincides with the region of strong absorption of the FS, its disintegration occurs. At the same time, free radicals (RC) are released, which are toxic to living cells. As a result, the cells of the malignant tumor die, and the surrounding healthy cells remain alive.

Most of the modern FS used in oncotherapy have a tetrapyrrole chemical structure, which is similar to the structure of photoporphyrin, which is contained in hemoglobin molecules. FS molecules should have a high level of absorption at wavelengths of 600-800 nm, since photons with a wavelength longer than 800 nm do not have enough energy to transfer oxygen from the singlet state to the form of an excited reactive state.

In addition, the process of formation of free radicals is possible only if the optimal temperature regime is observed (no more than 37°C), otherwise the FS molecule is destroyed without releasing RK (the oxygen molecule returns to the singlet state, producing energy only in the form of photons), i.e., a radiation process occurs (known as fluorescence) without the correspondingly necessary chemical photodynamic reaction)[5].

Modern types of FS used for the PDT procedure are listed in the table. 1.1.

Table 1.1 Types of modern FS used for PDT

FS name	Chemical structure in the basis	Absorption wavelength, nm	The type of cancer it is used for
Photofrin (HPD)	Porphyrin	630	Cancer of the lungs, esophagus, bile ducts, bladder, brain, ovaries
ALA	Porphyrin	635	Cancer of the skin, bladder, brain, esophagus
Temoporfin (Foscan)	Chlorine	652	Cancer of the head and neck, lungs, brain, bile ducts
Verteporfin	Chlorine	690	Cancer of organs of vision, pancreas, skin
HPPH	Chlorine	665	Head and neck, lung, esophagus cancer
Purlitin	Chlorine	665	Skin cancer, breast cancer
Talaporfin	Chlorine	660	Liver, colon, and brain cancer
Silicon phthalocyanine	Phthalocyanine	675	Cutaneous T-cell lymphoma
Padoporfin	Bacteriochlorin	762	Prostate cancer

Table1.1

- The nature and intensity of exposure depend on the properties of laser radiation, such as:
- • wavelength,

- • radiation power density,
- • duration of exposure,
- • frequency of exposure repetition

Today, the clinically approved and most effective type of irradiation during the PDT procedure is considered to be irradiation of altered pathological cancer tissues with laser radiation lasting up to 20 minutes. with a power density of laser radiation of the order of 100 – 800 mW/cm2 [6].

The main types of modern laser installations that are currently traditionally used for the PDT procedure are listed in table. 1.2.

Table 1.2 – Main types of lasers for PDT [6]

Laser type	Wavelength		Note
	The main one	Others are possible	
He-Ne	633 nm	9,6 мкм	P_{max} : 100 мВт
Kr	530 nm is green 568 nm – yellow-green 676 nm - red	A number of discrete lines in the range of 350 – 800 nm (UV – IR	P_{max} : 10 Вт
On the dye	400 – 900 nm, tunable in a 500 – 100 nm wide range for each laser		
Diode	635 – 808 nm		P_{max} : 2 кВт

Table1.2

- When a beam of laser radiation falls on the surface of biological tissue, two sets of tissue properties are fundamentally important:

• optical (reflection, absorption, scattering, as well as transmission),

• thermal-physical (related to an increase in temperature).

Examples of thermal reactions are given in table. 1.3

Table 1.3 – Thermal reactions and changes in tissue properties associated with laser irradiation [6]

Temperature, °C	37 - 60	60 - 65	90 - 100	>100	Several hundred
Process	heating	protein denaturation	dehydration	carbonization	ablation, burning
Optical changes	missing	gray color, increased scattering	constant scattering	black color, increased absorption	smoke and gas formation
Mechanical changes	missing	loosening	shrinkage, fluid outflow	severe mechanical damage	tissue removal

Table 1.3

The process of heating the fabric, i.e. the temperature to which it heats up depends on:

- power densities of absorbed radiation;
- irradiation time;
- speed of heat removal by blood flow;
- efficiency of converting absorbed energy into heat [6].

1.1 Modern methods of optimization of the PDT process

Method of fluorescence diagnostics

One of the currently known mechanisms for optimizing the PDT process is fluorescence, since it is possible to restore the oxygen of the FS to the singlet state, in which photons are extinguished.

In this state, FS serve as agents for visualization (an example of the results of digital processing of images obtained during fluorescence diagnostics is shown in

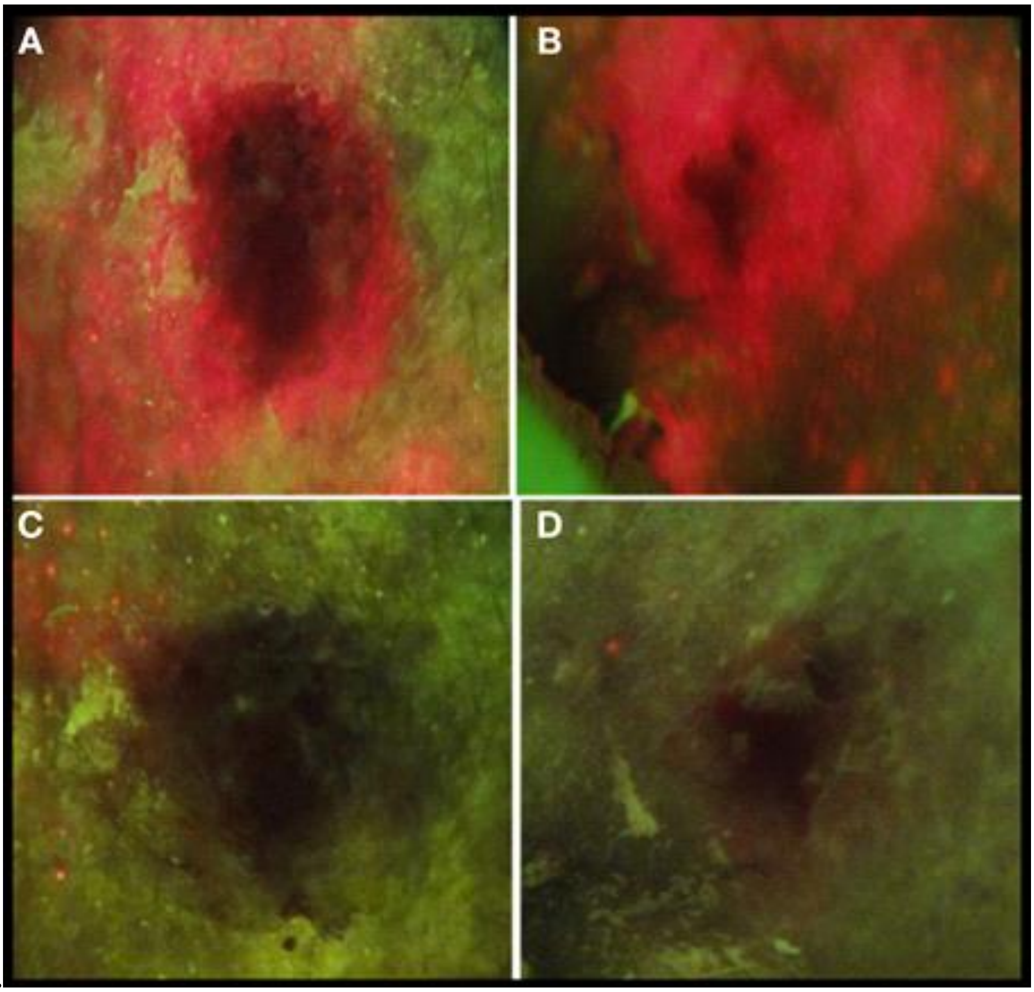

Fig. 1.1).

Figure 1.1 – Fluorescent image for comparing the processes of FS accumulation (A, C – before PDT) and FS degradation (B, D – after PDT) in different cancer formations of one patient during one irradiation session

It is known that the intensity of fluorescence indicates the concentration of FS in the tumor. That is, the effectiveness of PDT is evaluated by the quantitative composition of FS before and after irradiation

Images obtained in the course of fluorescent diagnostics are subjected to digitization with the aim of primary selection of RGB channels, which correlate with the fluorescence of FS [7].

Subsequently, only R (red) channels correlating with PS fluorescence are isolated from the entire obtained mass of channels. Based on the results of digital processing and counting (Fig. 1.1), if the fluorescence level has

Modern thermal imaging systems record body temperature deviations with an accuracy of 0.05 °C and less [12].

The method of regression analysis

Regression analysis is a method of modeling measured data and studying their properties, where the data consists of pairs of values of the dependent variable (response variable) and the independent variable (explanatory variable).

The parameters of the regression model (the function of the independent variable and the parameters to which the random variable is added) are adjusted in such a way that the model best approximates the data.] the approximation (objective function) is usually the root mean square error: the sum of squares of the difference between the values of the model and the dependent variable for all values of the independent variable as an argument.

It is assumed that the dependent variable is the sum of the values of some model and a random variable. Assumptions are made about the nature of the distribution of this value, called the data generation hypothesis. Statistical tests called analysis of residuals are performed to confirm or refute this hypothesis. At the same time, it is assumed that the independent variable does not contain errors. The following types of regression are known:

1. simple linear,
2. multiple linear,
3. polynomial,
4. non-linear,
5. binary logistic,
6. multinomial logistic,

ordinal regression, etc. It is advisable to analyze the received thermographic data using the polynomial statistical method regressive analysis linking quantitative and predictive variables. During the analysis of the polynomial regression function, the correspondence between the variables of two groups is established and parameter estimates are obtained, which allow the prediction of the value of the dependent variable using the independent one [12].

Polynomial regression means approximating the data with a k-degree polynomial:

$$y_i = \sum_{j=1}^{k} \omega_j \cdot x_i^{j-1} + \varepsilon_i$$

(2.1)

where y_i is the set of values of the dependent variable,

x_i is the set of values of the independent variable,

ω is the desired vector of parameters according to the method of least squares (LSM),

ε is an additive random variable [13].

According to the MNC, the vector ω = (ω1, ω2)T is a solution of the normal equation:

$$\omega = (A^T A)^{-1} \cdot A^T \cdot y$$

(2.2)

where A^T is the Vandermonde matrix [14].

The Vandermonde matrix will have the following form:

$$A = \begin{pmatrix} 1 & x_1 & x_1^2 & \dots & x_1^k \\ 1 & x_2 & x_2^2 & \dots & x_2^k \\ 1 & x_m & x_m^2 & \dots & x_m^k \end{pmatrix}$$

(2.3)

where x_i is the set of values of the independent variable.

The sought variable y^* is restored using the found vector and the set values of the independent variable:

$$y^* = A \cdot \omega.$$

(2.4)

The criterion of the sum of squares of the regression residuals (2.5) and the mean square error, or the variance of the residuals (2.6) [13] are used to assess the quality:

$$SSE = \sum_{i=1}^{m} (y_i - y_i^*)^2,$$

(2.5)

$$MSE = \frac{SSE}{\mathrm{m}-2} \quad .$$

(2.6)

\

In practice, k<5 is used.

To construct a regression with a k-degree polynomial, the presence of (k+1) data points is necessary [13].

Conclusions to section 2

This section presents methods of infrared thermography and regression analysis, with the help of which it is possible to obtain and analyze feedback data, that is, methods that allow optimization of the PDT procedure in real time.

decreased significantly, this indicates an active process of absorption of PS during the photodynamic reaction.

fig1.2

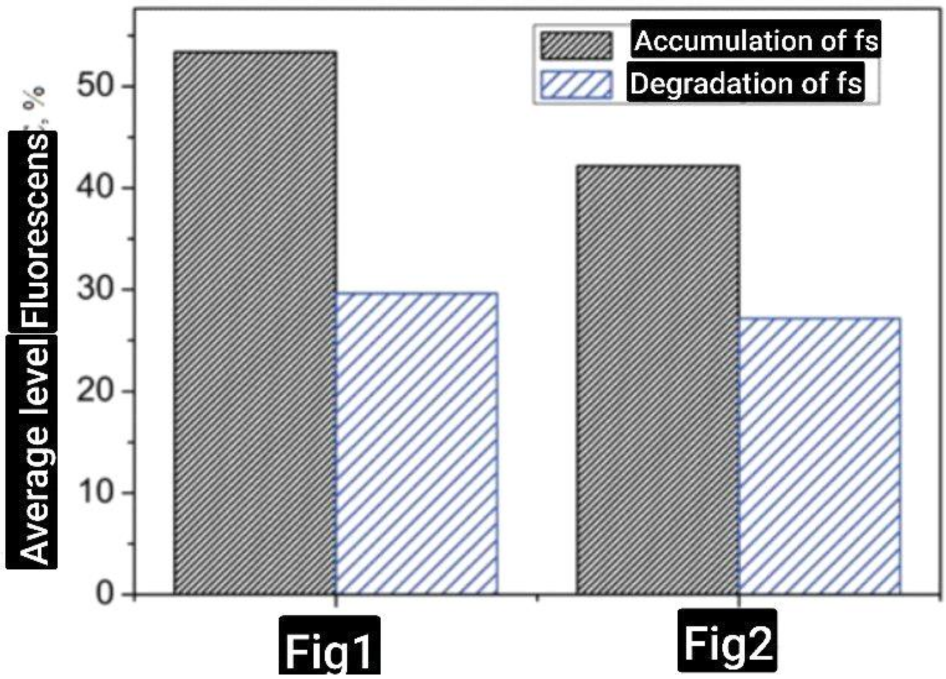

Figure 1.2. – The average value of the fluorescence level by the number of R-channels in different cancer formations of one patient during one irradiation session

Fluorescent diagnostics allows you to separate pathological cancer cells from healthy ones, and also allows you to detect multiple surface lesions that may not be noticed during visual diagnostics, which is previously performed by a specialist doctor [8].

Figure 1.2. – The average value of the fluorescence level by the number of R-channels in different cancer formations of one patient during one irradiation session

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fig1.3

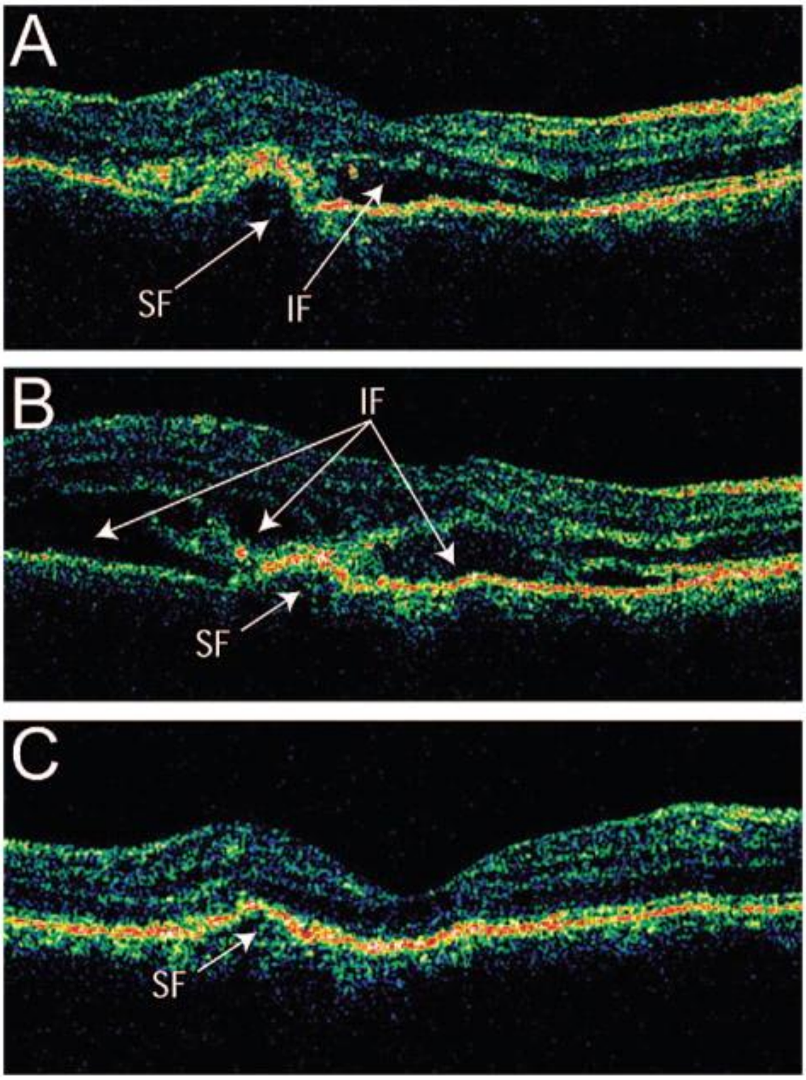

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Figure 1.3 – OCT images of a patient with cancerous pathology of vascular walls, where SF and IF are intra- and subretinal fluids, the volume of which changes as a result of the intro

duction, activation and degradation of FS (A – before PDT and before FS introduction, B – before conducting PDT, after introduction of FS, C – after conducting PDT)

According to the principle of its action, OCT is a light analogue of ultrasound. In the process of OCT diagnostics, the time delay of photons reflected from the surface of biological tissue is measured.

The light reflected from the surface of the sample is collected and focused on the interferometer, as a result of which an interferometric picture is formed, containing information about the depth of penetration of light streams. Spectral interferograms are calculated using Fourier transforms at each point of the interferometric pattern.

In the course of OCT diagnostics, a detailed anatomical structure of the tumor is created at the microscopic level at a depth of several mm from the surface of the biological tissue, and the destructive processes of tumor vascularization are visualized during PDT [9].

1.3. Optical-acoustic method

The development of an optical-acoustic method, which combines the advantages of optical and acoustic methods of diagnosis and optimization of the PDT procedure, is promising, but insufficiently researched.

The optical-acoustic method is based on the generation of a nanosecond laser pulse in the near-infrared region of the wavelength spectrum. Thermal elastic expansion of molecules occurs as a result of the absorption of photons of light. This short-term expansion leads to the formation of a pressure wave, which is registered by an ultrasonic transducer and converted into a digital image.

Anatomical images of the generated pressure wave under the influence of a single pulse at different levels of anatomical structures are combined into a single image, which illustrates the dependence of the level of photon absorption by different tissue structures.

Thus, multispectral images, based on absorption levels, can provide information on the level of oxygenation and deoxygenation of pathological cancer formations (Fig. 1.4)

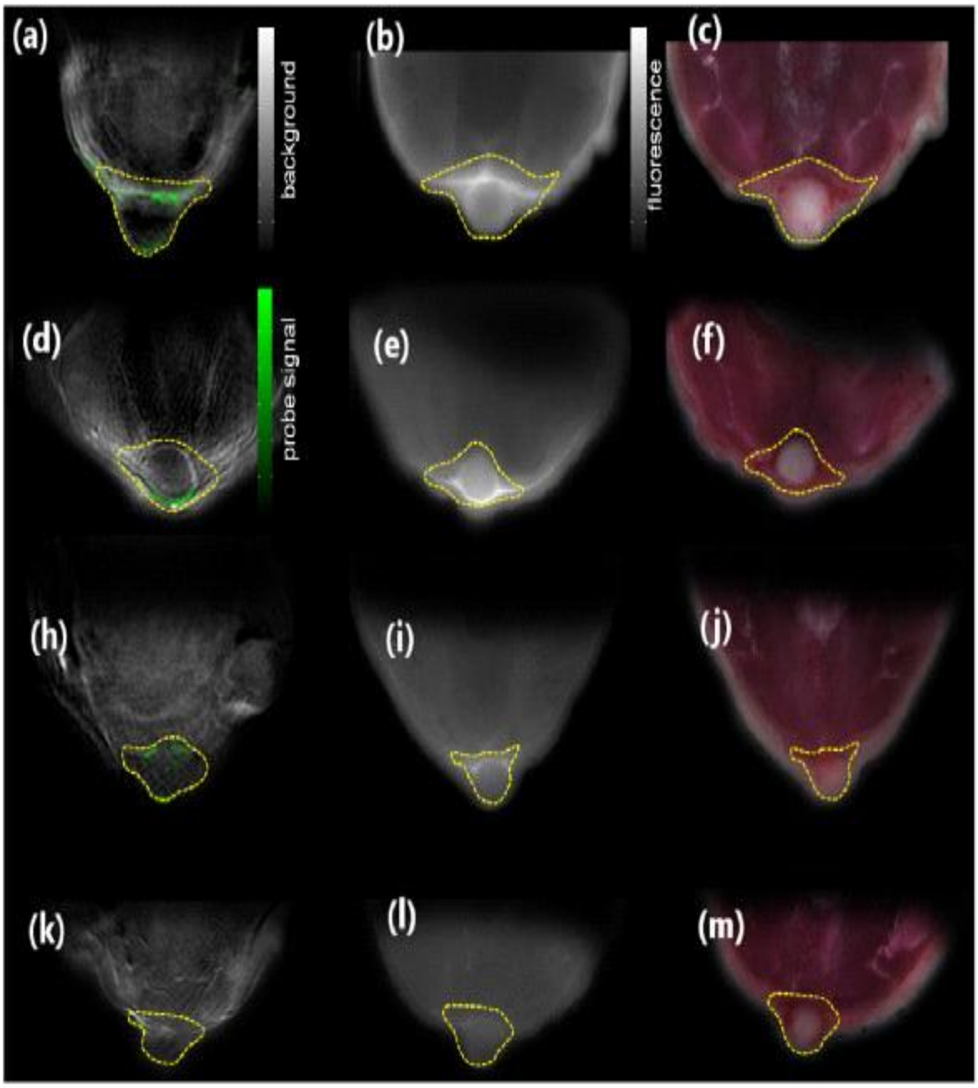

Figure 1.4 – Apoptosis markers of mouse tumor formations

(a and d – superposition of the anatomical image under the influence of a single wave pulse and the image of the accumulated FS 24 hours after injection, h and k – 3 hours after injection)

Therefore, the first studies in this direction indicate the possibility of assessing the architecture of the vascular network of a cancerous formation along with monitoring the level of tumor oxygenation [8].

1.4.Conclusions to section 1

In this section, modern analytical sources regarding the mechanism and physical foundations of the PDT procedure are considered.

In addition, modern methods of diagnosis and optimization of the PDT procedure are also considered.

As a result of the review, it was found that modern methods offer diagnostics and optimization of the PDT procedure only before and after irradiation and do not provide regulation of the procedure in real time, which leads to the limitation of the effectiveness of the procedure results and puts the control and regulation of the PDT process on the qualification of a specialist doctor and his assistants.

SECTION 2

APPLICATION OF THERMOGRAPHY AND REGRESSION ANALYSIS METHODS FOR OPTIMIZATION OF THE PDT PROCEDURE

2.1Method of infrared thermography

Since during the process of irradiation of biological tissue with laser radiation, it is heated, receiving feedback from the patient during the PDT procedure, in addition to the methods discussed in section 1, is possible using the infrared thermography (IRT) method [10-11].

ICT is a method of examining patients that allows recording infrared radiation (IR) and converting it into an image - a thermogram that illustrates the distribution of temperature fields on the surface of the body. The temperature of biological coatings is an integral indicator and is formed by such factors as the vascular network (arteries, veins, lymphatic system), the level of metabolism in organs, and the thermal conductivity of biological tissue. ICH is based on the ICH of a body whose temperature is greater than absolute zero.

Measurements are carried out using a special device - a thermal imager. The structural diagram of the thermal imager is shown in Fig. 2.1.

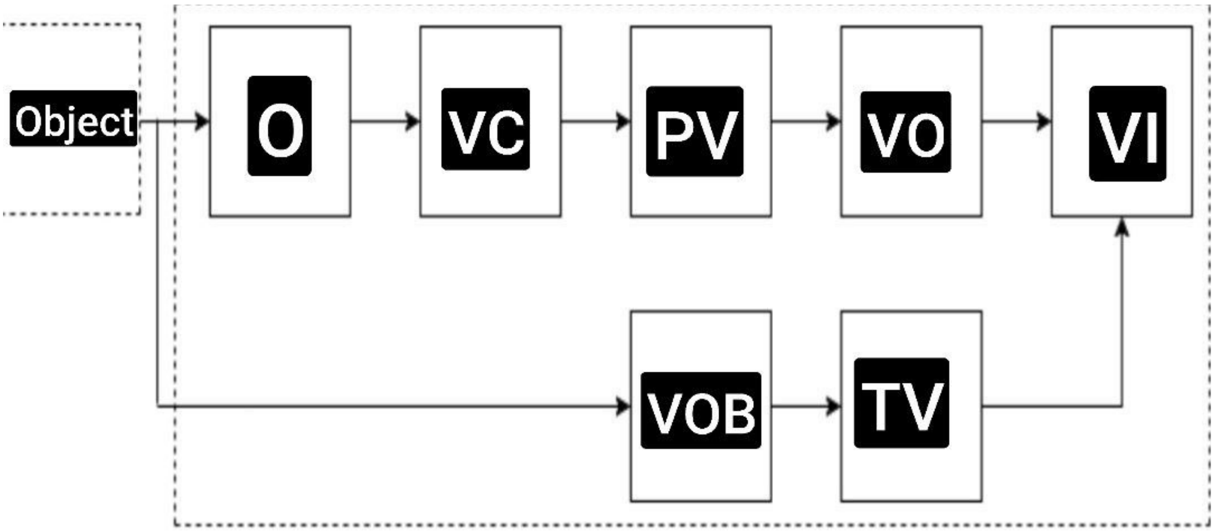

Figure 2.1 – Structural diagram of a thermal imager

The IR stream from the biological object falls on the O lens, is reflected by the mirror of the VS scanning unit and falls on the PV radiation receiver (IR matrix or point receiver). The PV radiation receiver converts the energy of the IRV flow into electrical voltage. The VO processing node converts the receiver signal into an array of temperature values in accordance with the individual grading characteristics of the device and the indicators of the built-in temperature sensors and displays this array on the monitor.

Simultaneously with the output of the temperature distribution graph, an image of the object in the visible spectral range formed by the television channel (consisting of a TV camera and a VOB vario lens) is additionally supplied to the VI display node. By means of software, the temperature is displayed on the monitor in digital form and can be adjusted taking into account the radiation coefficient of the object and the ambient temperature [18].

An example of the received thermal imaging image is shown in Fig. 2.2.

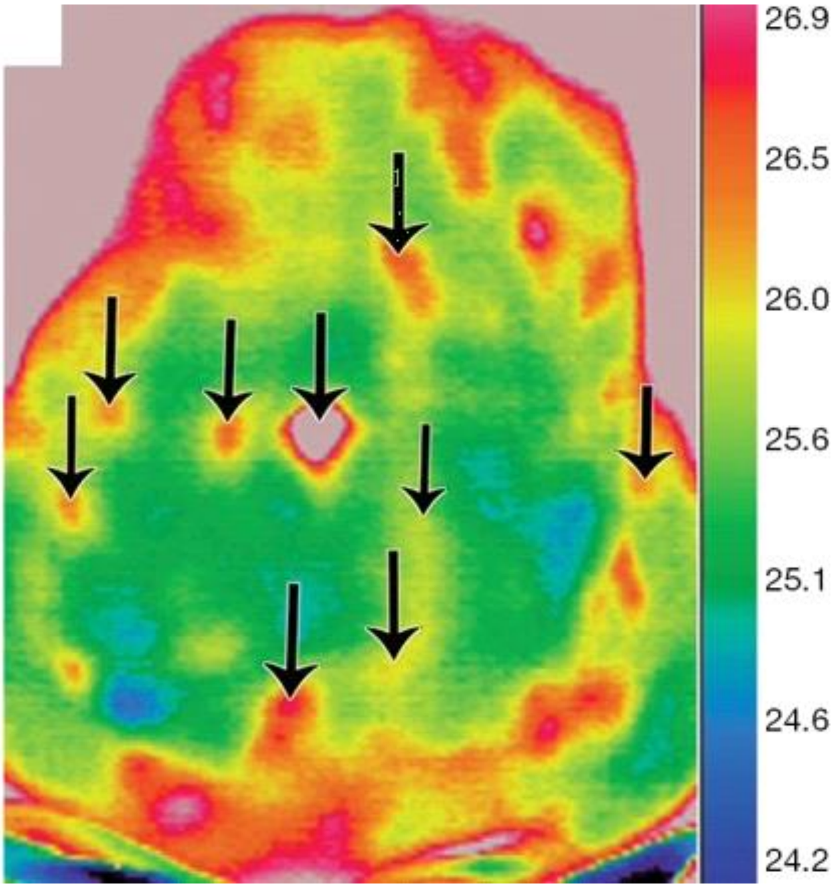

Figure 2.2 – Thermogram of vascularization of the abdominal wall after oncotherapy (arrows indicate the places of removal of pathological formations)

Modern thermal imaging systems record body temperature deviations with an accuracy of 0.05 °C and less .

2.2.The method of regression analysis

Regression analysis is a method of modeling measured data and studying their properties, where the data consists of pairs of values of the dependent variable (response variable) and the independent variable (explanatory variable).

The parameters of the regression model (the function of the independent variable and the parameters to which the random variable is added) are adjusted in such a way that the model best approximates the data.

The criterion of the quality of the approximation (objective function) is usually the root mean square error: the sum of squares of the difference between the values of the model and the dependent variable for all values of the independent variable as an argument.

It is assumed that the dependent variable is the sum of the values of some model and a random variable. Assumptions are made about the nature of the distribution of this value, called the data generation hypothesis. Statistical tests called analysis of residuals are performed to confirm or refute this hypothesis. At the same time, it is assumed that the independent variable does not contain errors.

The following types of regression are known:

- simple linear,
- multiple linear,
- polynomial,
- non-linear,
- binary logistic,
- multinomial logistic,
- ordinal regression, etc. The analysis of the obtained thermographic data should be carried out using the statistical method of polynomial regression analysis, which connects quantitative and predictive variables. During the analysis of the polynomial regression function, the correspondence between the variables of two groups is established and parameter estimates are obtained, which allow the prediction of the value of the dependent variable using the independent one .

Polynomial regression means approximating the data with a k-degree polynomial:

,

where is the set of values of the dependent variable,

is the set of values of the independent variable,

ω is the desired vector of parameters according to the method of least squares (LSM),

ε is an additive random variable .

According to the MNC, the vector ω = (ω1, ω2)T is a solution of the normal equation:

where is the Vandermonde matrix [14].

The Vandermonde matrix will have the following form:

where is the set of values of the independent variable.

The searched variable is restored using the found vector and the given values of the independent variable: . (2.2)

The criterion of the sum of squares of the regression residuals and the mean square error, or the variance of the residuals are used to assess the quality: ,

In practice, k<5 is used.

To construct a regression with a k-degree polynomial, the presence of (k+1) data points is necessary .

2.3. Conclusions to section 2

This section presents methods of infrared thermography and regression analysis, with the help of which it is possible to obtain and analyze feedback data, that is, methods that allow optimization of the PDT procedure in real time.

SECTION 3

PRACTICAL PART

3.1 Construction of the functional algorithm of the PDT control system:

The control algorithm for increasing the efficiency of the PDT procedure was built using the ICH method to organize feedback and using the polynomial regression analysis method to organize the analysis of the data received from the patient.

During the analysis of the regression function, the correspondence between the variables of the two groups (temperature and the duration of exposure to laser radiation generated by the laser installation) is established and the value of the temperature of the biological tissue is predicted after a certain amount of time [14-15].

The algorithm for calculating polynomial regression is shown in Fig.

3.1.

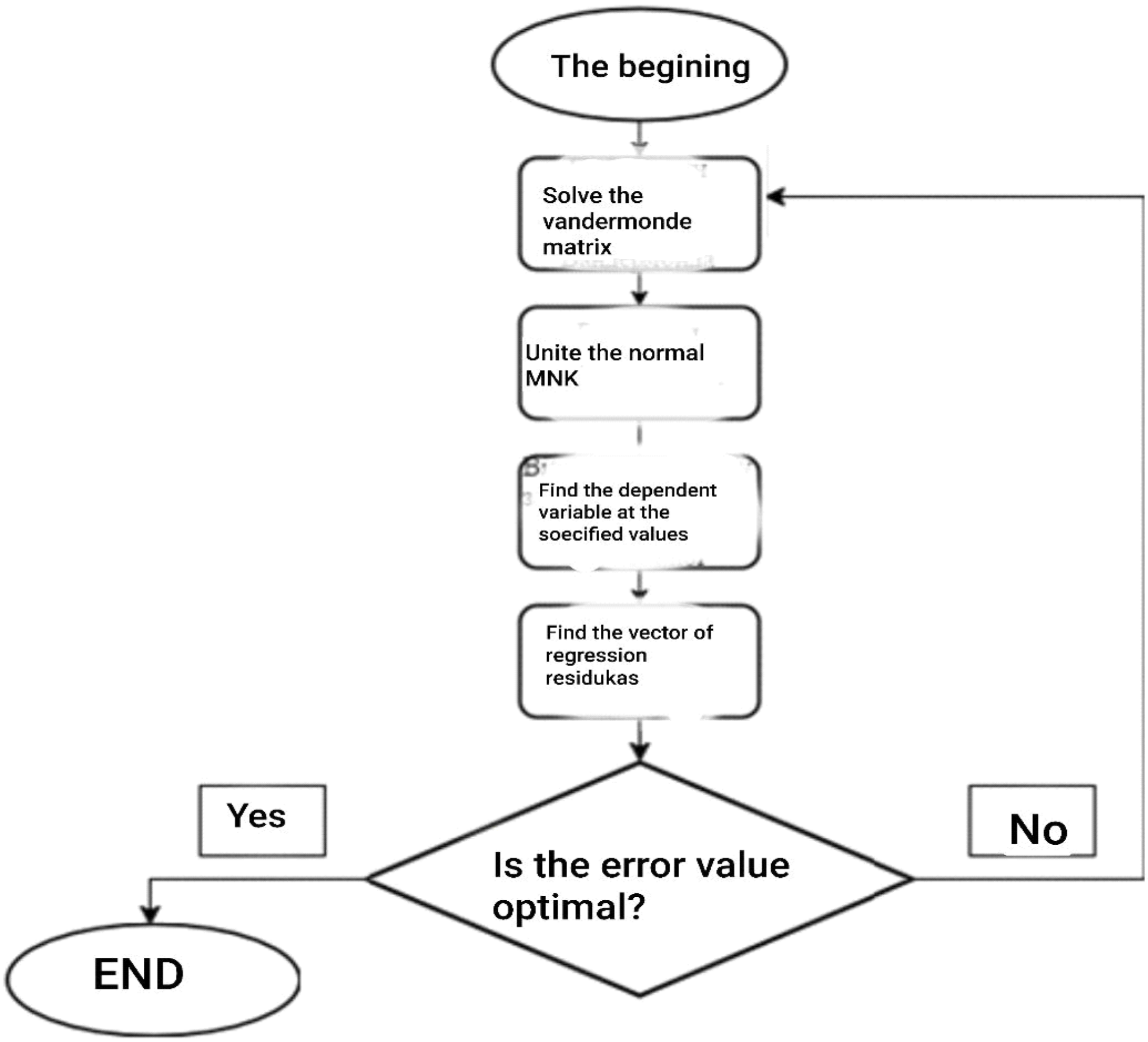

Figure 3.1 – Block diagram of the polynomial regression calculation algorithm

The software calculation of polynomial regression takes place according to the formulas (2.1 - 2.6) given in section 2.

The general algorithm for controlling the laser installation based on statistical feedback is shown in Fig. 3.2.

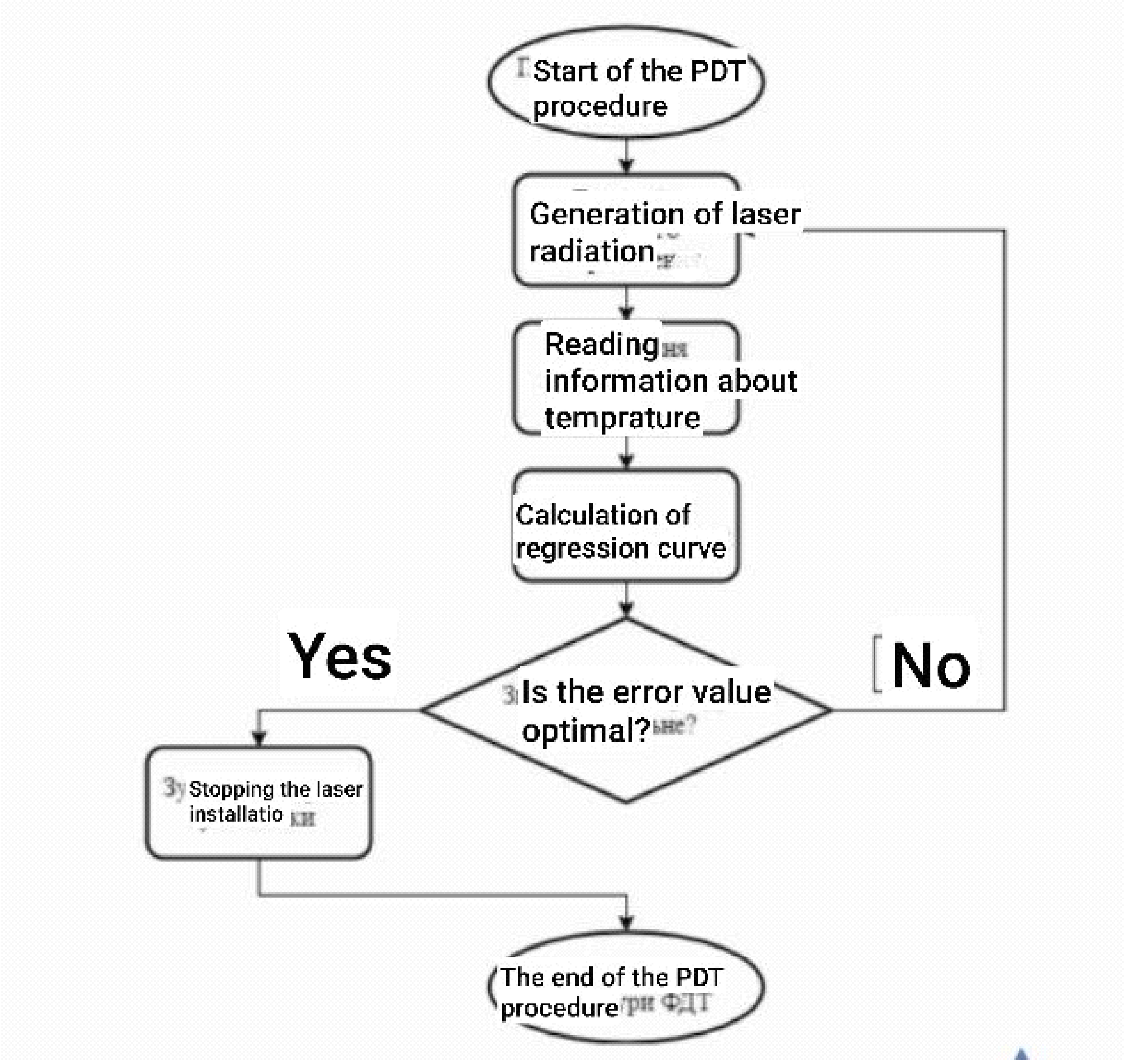

Figure 3.2 – Block diagram of the algorithm for controlling the laser installation in order to increase the efficiency of the PDT procedure

- Management of the PDT procedure according to the algorithm will take place as follows:
- • The PDT procedure begins with the generation of laser radiation. A beam of laser light is focused on the irradiated surface, which causes biochemical reactions in biological tissues and, in particular, their gradual thermal heating.

• • Data on the degree of heating for a certain time are read from the surface using a registration device (thermal imager).

• The obtained quantitative variables are subjected to polynomial regression analysis, as a result of which we get a forecast of the process of changing the curve of temperature dependence on the duration of the procedure.

• If the optimal value of the temperature regime is reached, a signal is sent to the laser installation to stop the generation of laser radiation, otherwise, a signal is sent to continue generating the laser beam until the temperature reaches the optimal value.

• After the laser installation receives a signal to stop the generation of laser radiation, the PDT procedure is completed.

3.2 Selection of the control system implementation environment

The software environment National Instruments LabVIEW was chosen to implement the PDT control system.

NI LabVIEW significantly increases design productivity by scaling low-level complexity and integrating the necessary technological calculations into a single, unified environment. This allows you to use any measurement and control hardware in a single development environment, as well as to integrate various desktop and modular devices and data collection devices .

In addition, a wide collection of control and indication elements can be used to create a simple, convenient and flexible user interface, implement operator input, and a wide selection of integrated mathematical functions and signal processing models allow real-time data acquisition, analysis and visualization.

Using NI LabVIEW provides the ability to install software on the laser setup, and thus the ability to provide control of the laser generation process.

Also, the use of NI LabVIEW provides an opportunity to connect a thermal imager to a software-hardware complex in order to obtain data on the temperature of biological tissue in the PDT process, and therefore makes it possible to organize feedback [11].

3.2 Designing a laser installation control algorithm in the NI LabVIEW environment

3.2 Modeling the process of heating biological tissue

In the course of clinical research, it was established that the process of heating pathological tissue, in which highly specific FS is accumulated, has the form of a curve with saturation. The process of heating pathological biological tissue is shown in fig. 3.3).

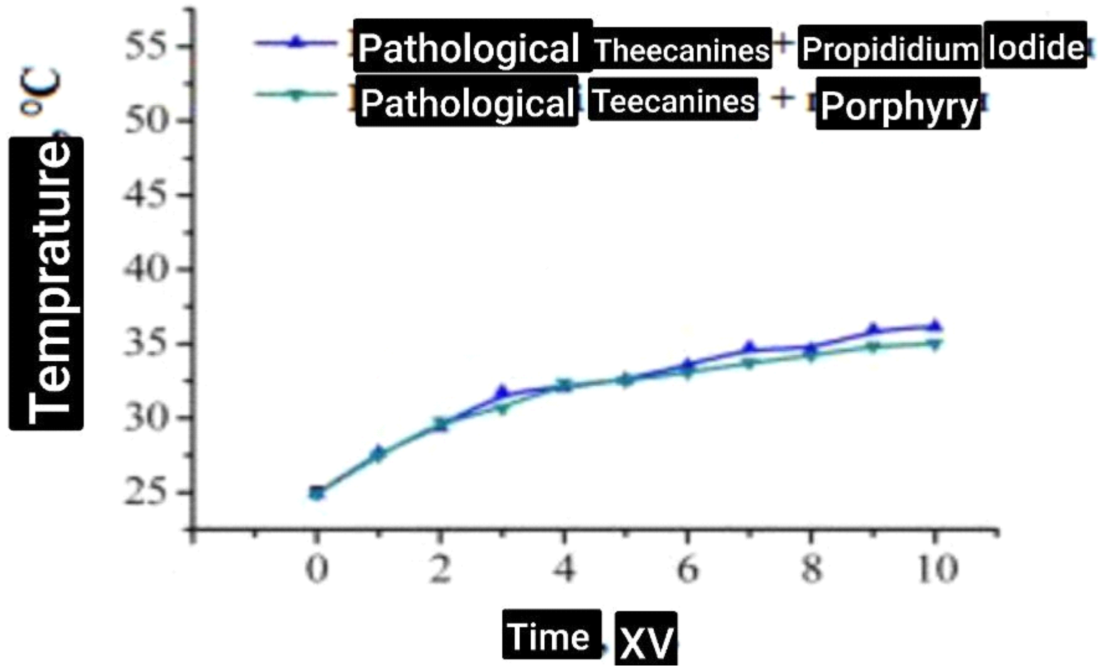

Figure 3.3 – Heating curve of pathological tissues [11]

Propidium iodide and porphyrin were used as chemically active light-sensitive PS in clinical studies.

Research was conducted using laser radiation with a wavelength of 662 nm and a power of 100 mW.

The temperature change of leukemic cells was established by measuring fluorescence spectra before and immediately after irradiation [12].

We digitize the graph of the dependence of the heating of the pathological tissue, in which the highly specific PS is accumulated, on the duration of the laser irradiation and obtain an array of relevant data. We have timers from 0 to 10 minutes. and time-dependent temperature values from 25 to 34.7 °C, respectively.

The program model of tissue heating is set by an array of corresponding pre-digitized data according to established real measurements (Fig. 3.4).

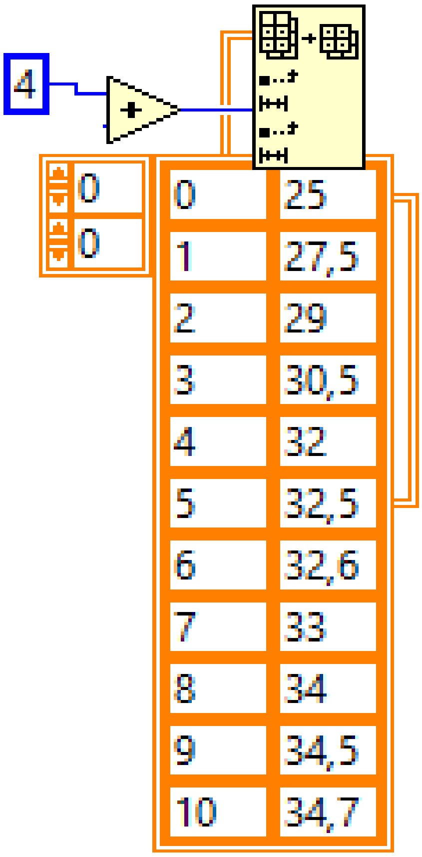

Figure 3.4 – Software model of the process of heating biological tissue, given by an array of digitized clinical research data

In the real device, we will have the value of temperature measurements taken by a thermal imager during the PDT procedure for each individual patient in real time.

- 3.4 Implementation of regression analysis
-
- Polynomial regression in the NI LabVIEW environment is implemented using the integrated function General Polynomial Fit VI (Fig. 3.5).
- We apply to the function input:

- • array of X values (independent variables – procedure duration in minutes);
- • Y (dependent variables – temperature of biological tissue in degrees Celsius);
- • polynomial order (polynomial order), equal to 3 in order to obtain the optimal level of accuracy of program approximation of the curve;
- • calculation method (method), in particular, the method of least squares for software implementation of polynomial regression.

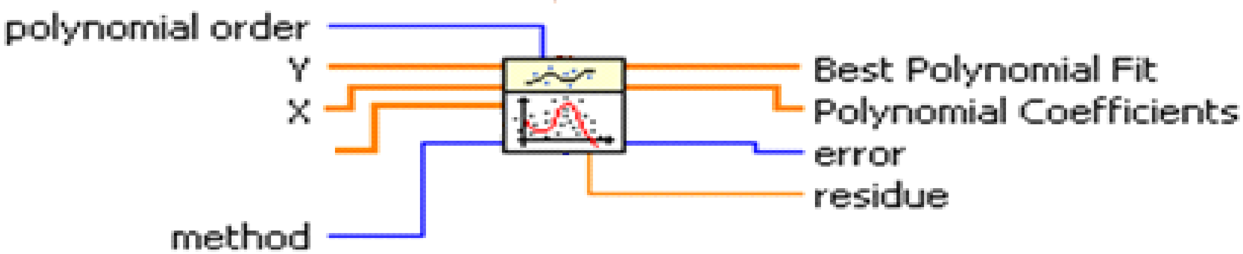

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Figure 3.5 – Block diagram of the General Polynomial Fit VI polynomial regression calculation function [14]

At the output of the function, we get the calculated optimal coefficients of the regression equation (Polynomial Coefficients), the own regression equation (Best Polynomial Fit), the calculated error (error), which is satisfactory in terms of accuracy, and the residues (residue), which we will display on the front panel for the convenience of the operator-user .

3.3. Construction of a complex scheme

- The block diagram of the system of optimal control of the laser installation using statistical feedback based on polynomial regression is given in the appendix. AND.
- As part of the block diagram of the control system, the following main nodes can be distinguished:
- • model of the process of heating biological tissues;

- • device for calculating the regression equation and its coefficients;
- • curve extrapolation device using the obtained regression equation;
- • a device for dynamic indication of the results of calculation of the regression equation and extrapolation of the curve;
- • indicator of the remaining duration until the required temperature is reached;

• device for stopping the laser installation.

The optimal temperature value for PDT is 37 °C [21], therefore, in the corresponding cycle of the program, a numerical limit of 37 is set, after reaching which, the system stops automatically.

From the array, in each iteration of the large cycle, a subarray is read, starting with 4 points (in the case of a smaller number of points, it is not possible to calculate the regression equation of the third order of the polynomial). In each iteration, one more point is added for the next calculation.

In the small cycle, for each iteration of the large cycle, a regression curve is calculated using the formula. In each subsequent iteration, this curve is changed (refined), as the duration of laser irradiation, which is necessary to reach the optimal temperature value, is calculated.

The output indicators in each iteration show how much time is needed in minutes and how much time is left until the optimal temperature value is reached.

In the process of functioning, these data change, as the regression curve is refined each time. When the required temperature value is reached, the device stops.

3.4 .Results of simulation and design of the PDT control system in the NI LabVIEW environment

For the given array of data, the coefficients (3.1 – 3.4) of the regression equation, equal to:

(3.1)

(3.2)

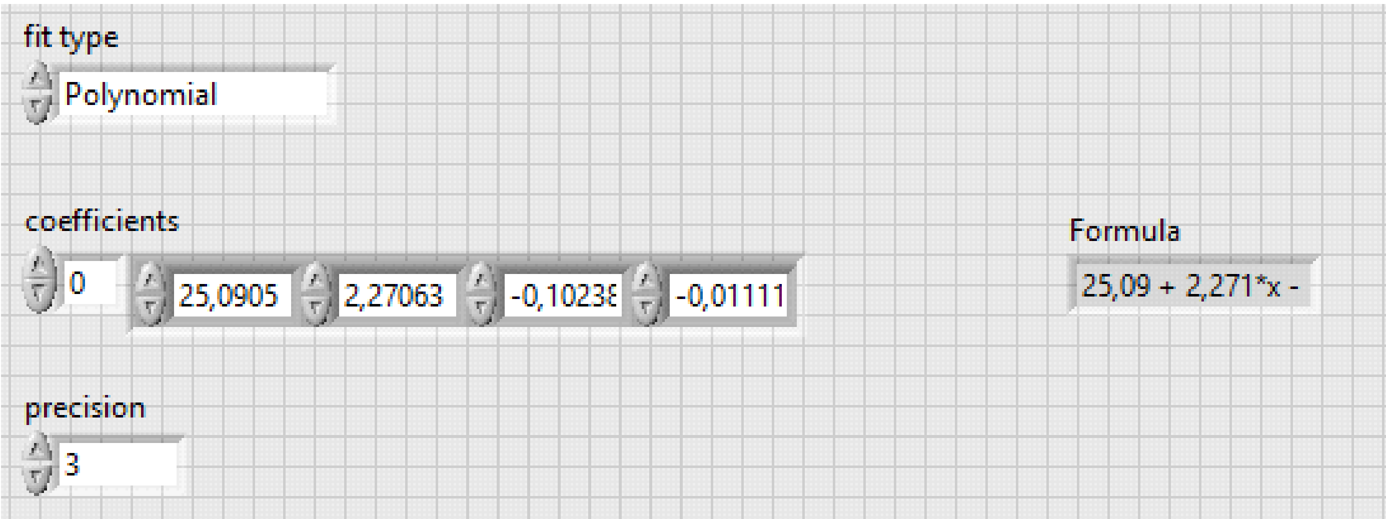
(3.3)

(3.4)

The regression equation for the given array, taking into account the calculated coefficients, looks like this:

(3.5)

The results of the created system with regard to the calculation of polynomial regression control are shown in fig. 3.6.



- Figure 3.6 – Results of the function of polynomial regression analysis
-
- Since the work of the algorithm is organized in several stages:
- • reading the subarray starting from 4 points in the first iteration of the big loop
- • calculation of the polynomial regression curve in a small cycle
- • adding a new point in the second iteration of the big loop for the next calculation

• calculation (refinement) of the polynomial regression curve in the second iteration of the small cycle and so on, until obtaining the optimal value of the temperature regime, then the results of the algorithm of controlling the laser installation in order to increase the efficiency of the PDT procedure are respectively illustrated in several figures.

The results of the algorithm at the stage of execution of the first iterations of large and small cycles are shown in fig. 3.7

According to the first calculations, based on the thermographic data of 4 points of the temperature dependence on the time of the procedure calculated by the algorithm, we get the duration of laser irradiation during the PDT procedure in 5 minutes.

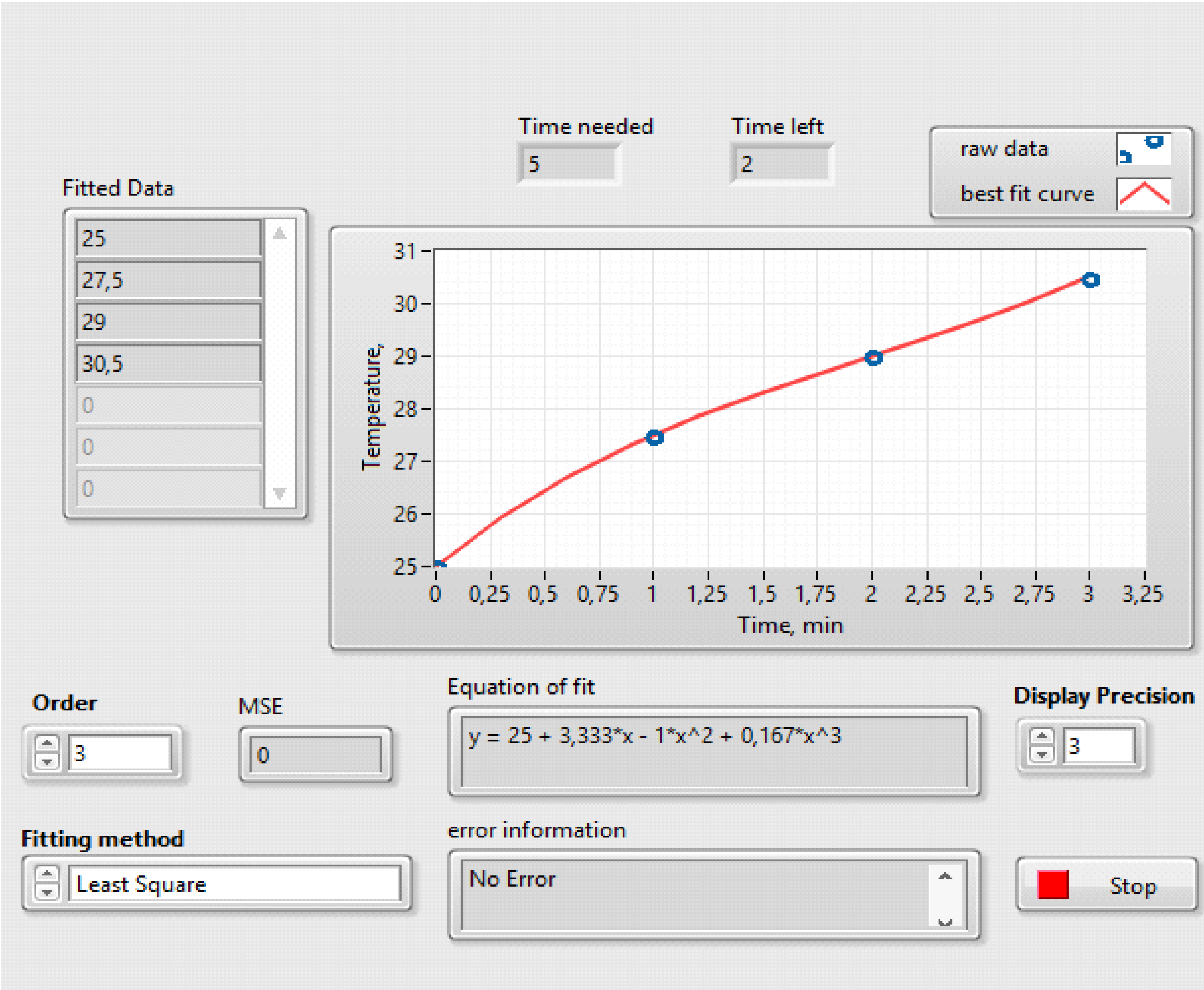


Figure 3.7 - Algorithm operation at the stage of execution of the first iterations of large and small cycles

The results of the algorithm at the stage of execution of the second iterations of the large and small cycles are shown in Fig. 3.8.

During the further operation of the algorithm, we observe a change in the curve, which is associated with the addition of the data array and, accordingly, the refinement of calculations during the operation of the algorithm.

During the second stage of calculations, based on the thermographic data of 5 points read by the algorithm (the next additional 1 point is added to the subarray of 4 points) of the dependence of the temperature on the time of the procedure, we get a different duration of laser irradiation during the PDT procedure.

The resulting duration is refined and supplemented and is 6 minutes, which is 1 minute more compared to previous calculations.

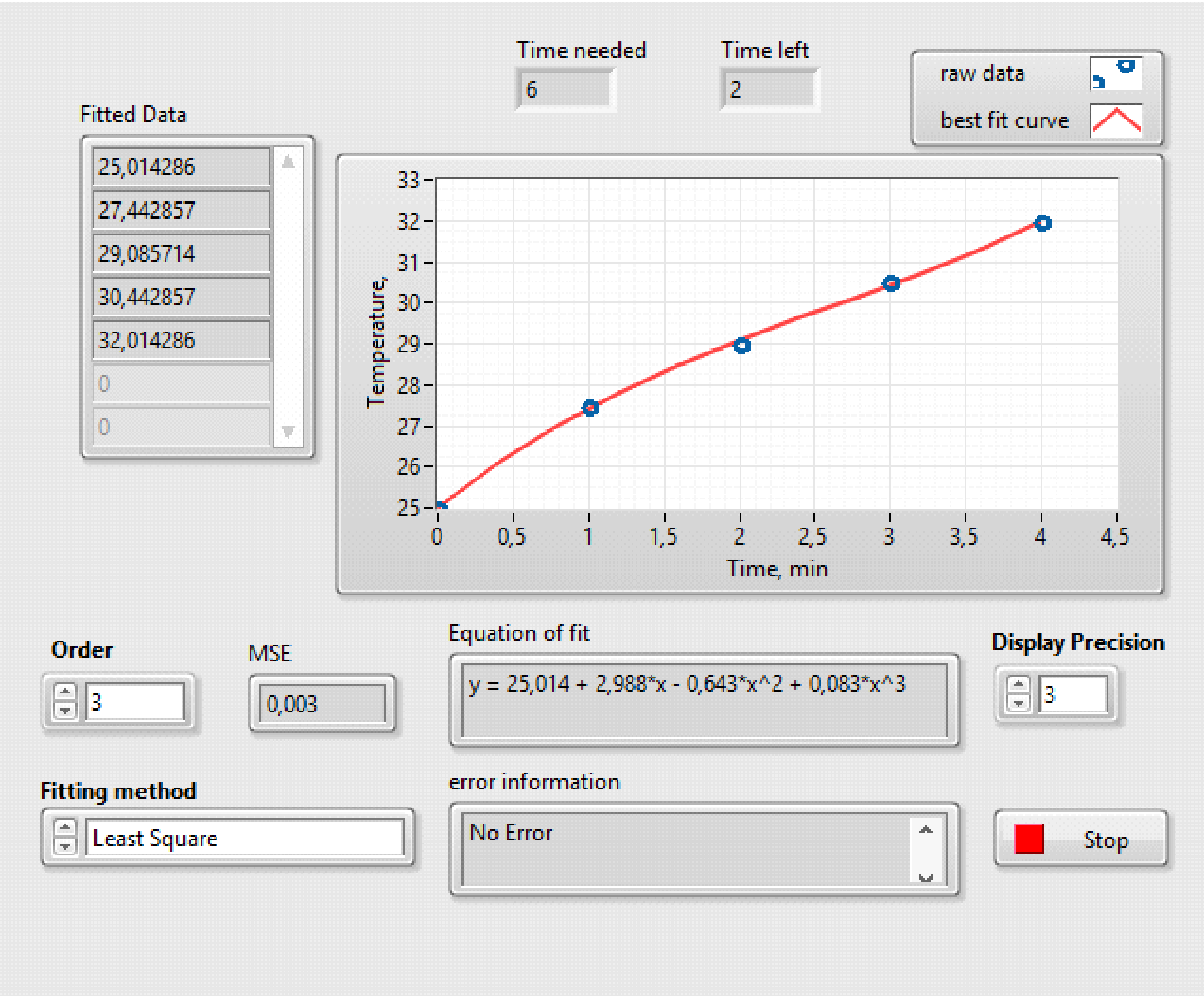


Figure 3.8 – Algorithm operation at the stage of execution of the second iterations of large and small cycles

The results of the algorithm at the stage of execution of the third iterations of the large and small cycles are shown in Fig. 3.9.

Similarly to the previous stages, during the further operation of the algorithm, at the third stage, we also observe a change in the curve, which is associated with the further addition of the data array and, accordingly, further refinement of the calculations during the operation of the algorithm.

During the third stage of calculations, based on the thermographic data of the 6 points already read by the algorithm (the following additional 1 point is added to the previous subarray of 5 points) of the dependence of the temperature on the time of the procedure, we get a duration of laser irradiation of 7 minutes, which is 2 minutes more compared to the very first stage of calculations.

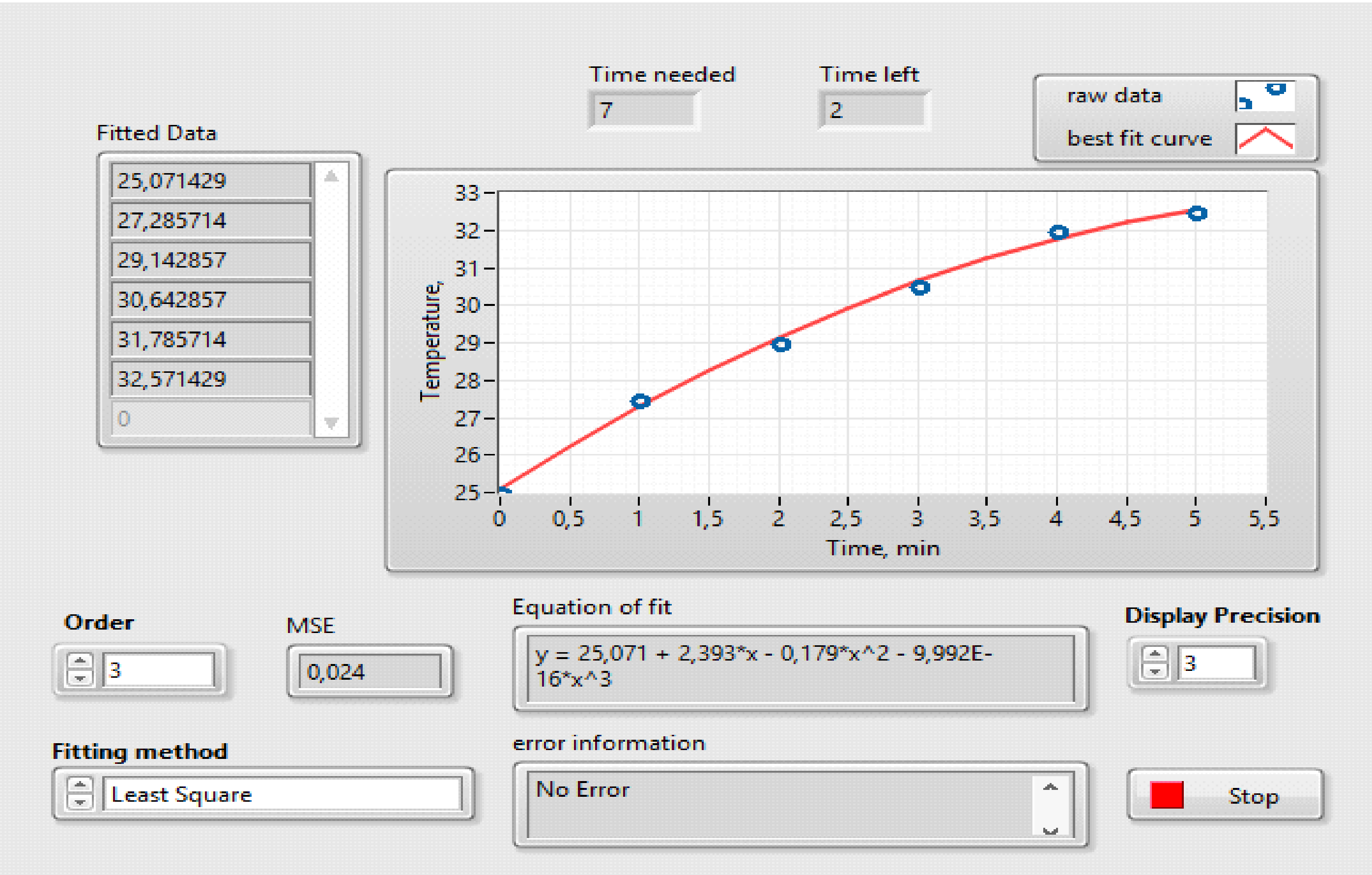


Figure 3.9 – Algorithm operation at the stage of execution of the third iterations of large and small cycles

In addition, we also observe a change in the coefficients of the regression equation. So, at the first stage, they are equal to:

(3.6)

(3.7)

(3.8)

(3.9)

Then, as at the third stage, they are equal to:

(3.10)

(3.12)

(3.13)

(3.14)

The results of the final calculation of polynomial regression coefficients are given in formulas 3.1 - 3.4The results of the final stage of the constructed algorithm for controlling the laser installation in order to increase the efficiency of the PDT procedure are shown in fig. 3.10.

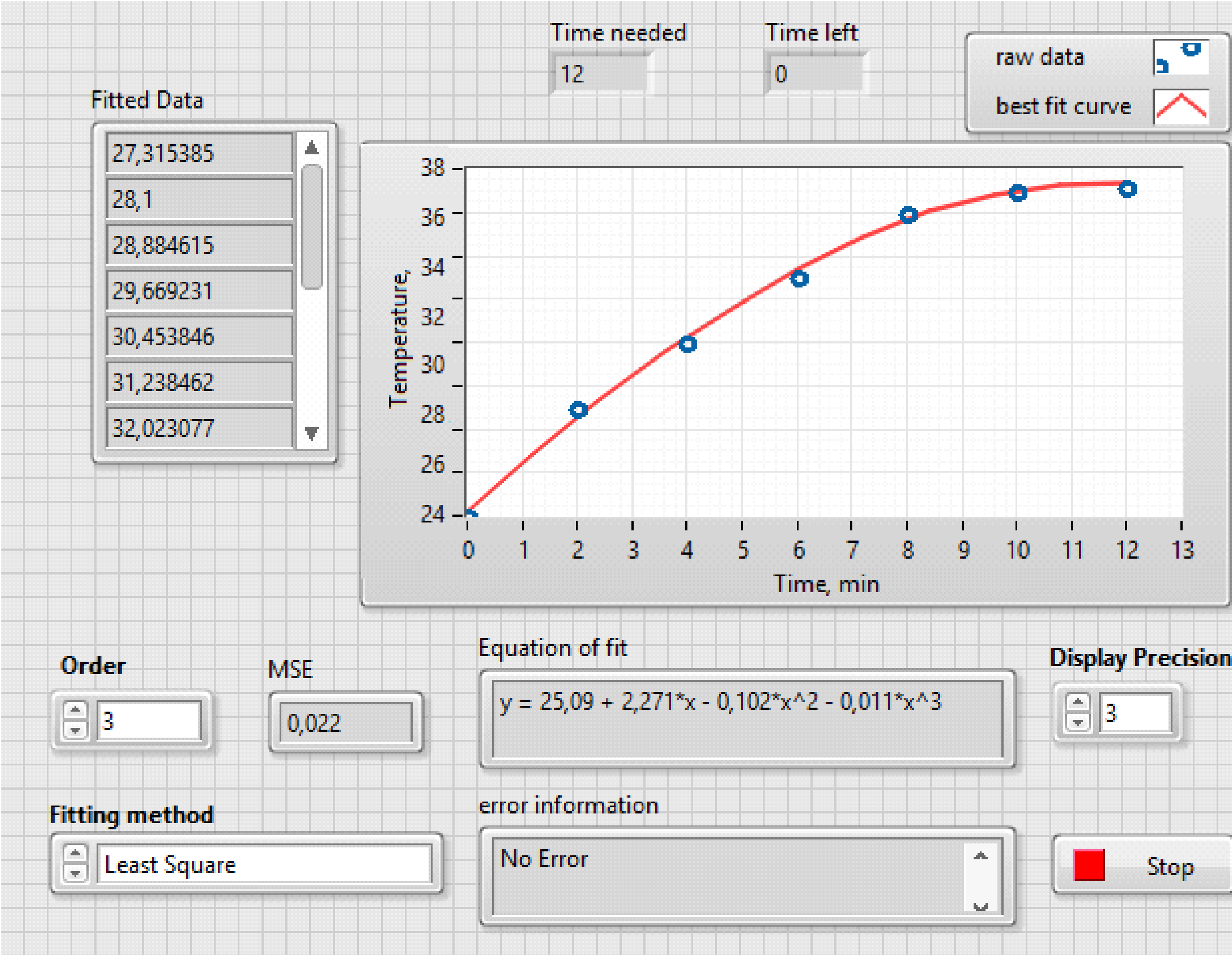


Figure 3.10 - Final results of the PDT procedure management algorithm

On the graph, we get simulated readings (from 0 to 10 min) and extrapolated readings (from 10 to 12 min), through which the value of 37°C will be reached, after which the laser installation will automatically stop.

In addition, the total duration of the procedure, which is 12 minutes, is displayed on the front panel.

3.5 Technical characteristics of control system elements

Laser installation

The LAHTA-MILON diode laser device (Fig. 3.11), the technical characteristics of which are given in the appendix, was chosen as the laser installation for implementing the hardware part of the software-hardware complex for controlling

the PDT procedure. B.

Figure 3.11 – LAHTA-MILON laser device [19]

In one device, two wavelengths from the range of 635 nm, 662 nm, 675 nm, 810 nm, 970 nm, 1060 nm, 1470 nm, 1560 nm can be combined. , thermotherapy, laser ablation, etc.) [16].The optical connectors of the laser unit are made according to the international standard SMA-905 with a minimum diameter of the optical fiber of 300 μm, which allows its introduction into the instrument channels of flexible and rigid endoscopes and puncture needles.The "LAHTA-MILON" laser installation also has an additional output that provides the possibility of connecting a stopping stop signal, which is supplied by the algorithm to the laser installation in order to stop the procedure.The technical characteristics of the device meet the requirements of the control algorithm.

3.5. Thermal imager

The PergaMed thermal imager (Fig. 3.12), the technical characteristics of which are given in the appendix, was chosen as the registration device for the organization of feedback. IN.

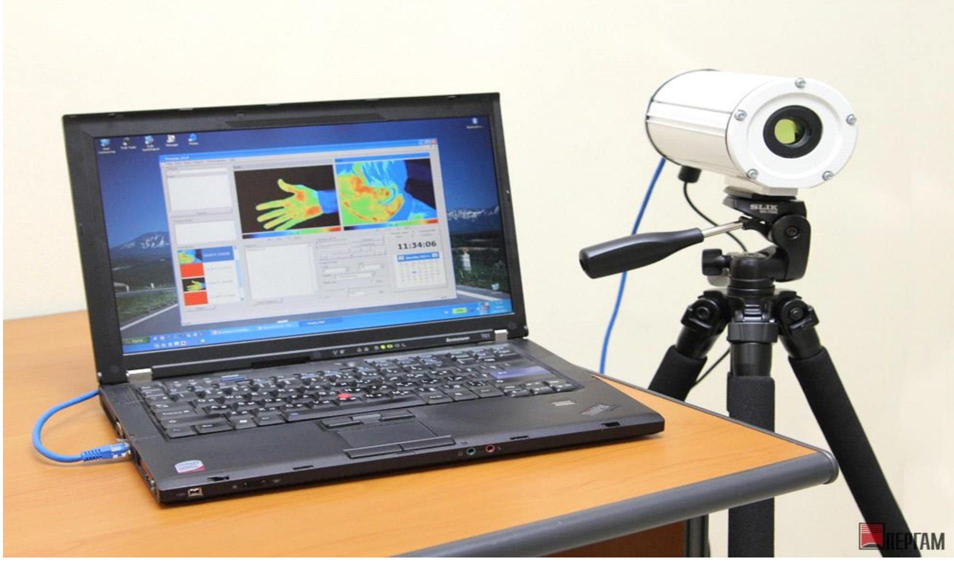


Figure 3.2 – PergaMed thermal imager connected to a computer [16]

Thermal imager "PergaMed" is a certified medical thermal imager widely used in medical diagnostics. The technical characteristics of the device meet the requirements of the control system [16].

Conclusions to section 3

This section presents the results of the design process of the PDT control algorithm in the NI LabVIEW software environment.

In particular, the process of heating biological tissue was simulated, a polynomial regression analysis was implemented with the prediction of the duration of the procedure using the integrated function General Polynomial Fit VI, a complex control system of the laser installation with statistical feedback processing was obtained, and its functioning was checked.

For the hardware implementation of the control algorithm, the LAHTA-MILON laser installation and the PergaMed thermal imager, the technical characteristics of which satisfy the control algorithm, are proposed.

SECTION 4

OCCUPATIONAL HEALTH

In the work, the algorithm for controlling the laser installation is designed in order to increase the efficiency of the PDT procedure, which, together with the proposed laser installation and the thermal imager, is considered as a software and hardware complex. The section examines the operation of the design object, the necessary means of labor protection and the means of optimizing the parameters known by the regulatory requirements for the safe functioning of the hardware and software complex in the medical office.

4.1 General characteristics of the medical office premises

The plan of the medical office is presented in Fig. 4.1. The parameters and main components of the cabinet are listed in the table. 4.1 and 4.2

Table 4.1 - Characteristics of the medical office premises

Parameter	Characteristic/meaning
Area of the premises	6000×6000 = 36 (м^2)
The volume of the room	6000×6000×3000=108 (м^3)
Number of employees	2
Floor	Antistatic coating
The walls	Light anti-reflective whitewash
Natural lighting	1 window, facing west
Lamplight	CPW 2.58 IP65 fluorescent lamp built into the ceiling; the number of lamps is 2, the power is 58 W
Heating	Radiator NOVA B3, 6 sections

Table 4.2 – Characteristics of medical office equipment

Name	Number	Characteristic	No. in the picture
Laser installation	1 pc.	"LAHTA-MILON", 245180305mm, 220 V, 200 W, 5 kg	1
Тепловізор	1 pc.	"PergaMed", 200107109mm, 12 V, less than 6 W, 1.83 kg	2

Continuation of table 4.2

Name	Number	Characteristic	No. in the picture
Laptop	1 шт.	Asus UX306UA, screen 13.3" IPS (3200x1800) QHD+ / Intel Core i5-6200U (2.3 - 2.8 GHz) / RAM 8 GB / SSD 256 GB / Intel HD Graphics 520	3
Air conditioning	1 шт.	Leberg, split system, 600800320, 1 kW, cooling capacity 3.52 kW	4
Doctor's desk	1 шт.	1132630750	5
Work chair	2 шт.	530570850	6
Medical couch	1 шт.	1970670520	7
Protective curtain	2 шт.	29003000	8
Medical cabinet	1 шт.	6004001500	9
Cabinet for documents	1 шт.	7734101985	10
Lighting	2 шт.	1051560155	11
Heating	1 шт.	Radiator, 6 sections, 550480	12
Hanger	1 шт.	600120	13
A bucket with a pedal	1 шт.	372315	14

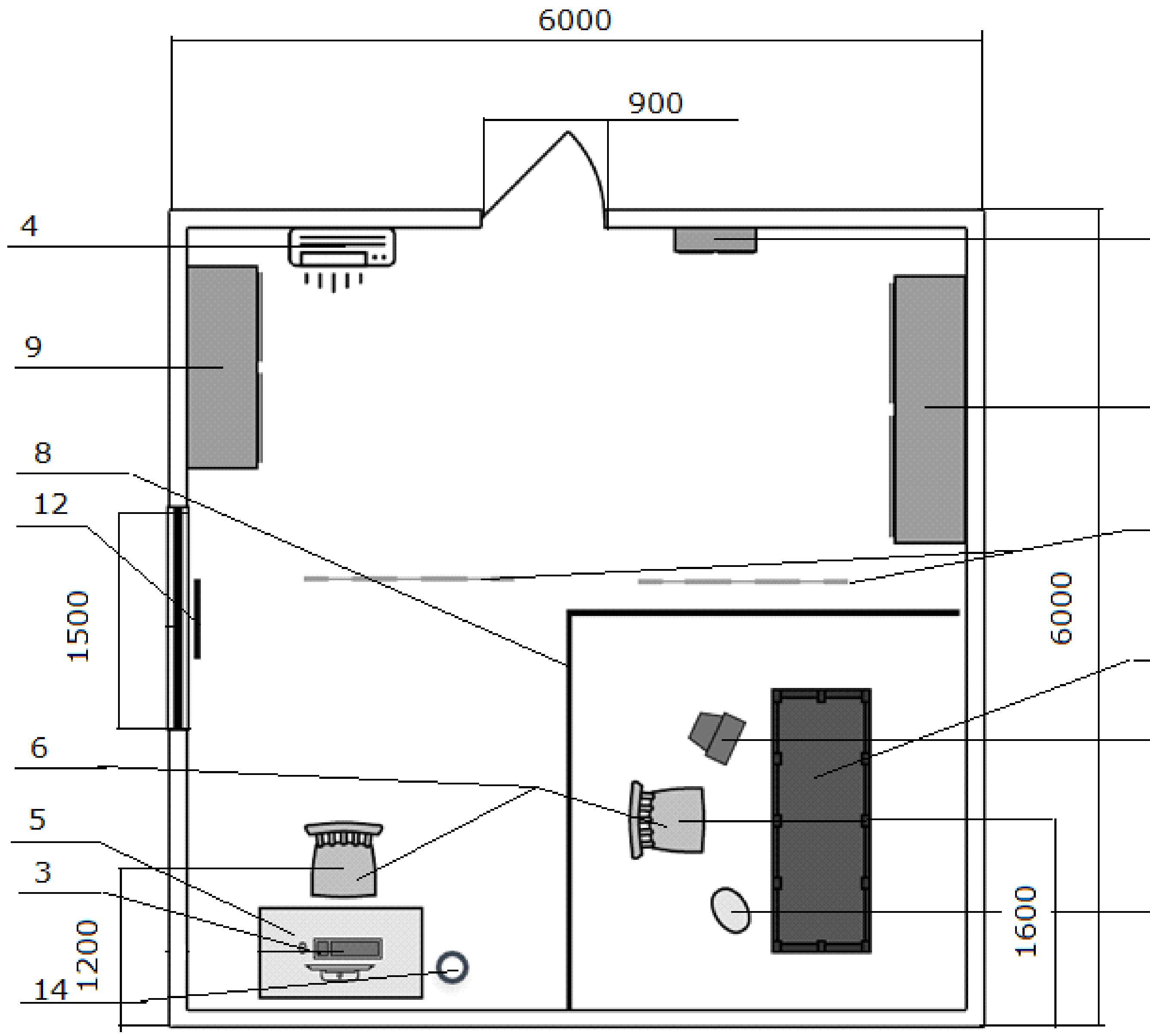


Figure 4.1 – Plan of the medical office

The comparative characteristics of the actual and normative values of the requirements for the premises of the medical office in accordance with DBN A.3.1-5:2016 are given in the table. 4.3

Table 4.3 – Comparative characteristics of the parameters of the medical office premises

Parameter	Normalized value	Actual value
Розмір дверей, м	20,8	20,9
Area, m2	At least 6	36
Volume, m3	At least 20	108
Room height	3 – 3,5	3
Distance from workplaces to walls, m	1	1-1,2

The actual values of the parameters meet the requirements of the regulatory document.

4.2 Assessment of dangerous and harmful production factors

Dangerous and harmful production factors present in the premises of the medical office are listed in the table. 4.4.

Table 4.4 - Dangerous and harmful production factors in the medical office

Physical	Laser radiation
	Thermal hazards of the laser installation
	Risk of electric shock
	Danger of fire

4.2Laser radiation

Laser installation "LAHTA-MILON" refers to lasers of class III subclass B in accordance with GOST standard 12.1.040-83.

The characteristics of laser radiation generated by the LAHTA-MILON laser installation are given in table. 4.2.1.

Table 4.2.1 – Characteristics of laser radiation

parametr	Impact on the human body
Monochromatic coherent laser radiation of the visible spectrum, parasitic reflected and scattered laser radiation of the visible spectrum	Focusing of the laser beam on the retina, tension and discomfort of the organs of vision, blood pressure instability, headache, increased excitement

The characteristics of laser radiation, which are normalized, are given in the table. 4.2.2.

Table 4.2.2 – Normative characteristics of laser radiation in accordance with "Sanitary norms and rules for the installation and operation of lasers" No. 2392-81

parametr	Normative value	Real value
Radiation power	1 Вт	0,1 – 0,9 Вт
Pulse length	min 0,01 c	0,01 – 1c
Duration of exposure	$1 – 2{,}2·10^3$ c	$6·10^2 – 1{,}2·10^3$ c

Measures to ensure the safety of operation of the laser installation that will generate laser radiation in the medical office are listed in table. 4.2.3

Table 4.2.3 – Safety measures to minimize the hazardous effects of laser radiation

Activities	Means
Technical	1) Shielding and channeling of the laser beam using optical fibers, as shown in fig. 4.2 2) Installation of protective diaphragms 3) Installation of radiation traps at the end of the beam Indoors: 1) Protective curtain made of light-absorbing fire-resistant material 2) Signal plate with a yellow background with a sign and a black edging 3) Matte whitewash of walls with reflection coefficients of no more than 0.4 4) location of the laser installation in a fenced-off part of the room
Organizational	Briefings; carrying out dosimetric control; timely inspection and preventive actions; strict compliance with the rules and norms defined by current regulatory documents; compliance with all special instructions that are established for med. equipment and procedures carried out in this medical institution
ЗІЗ	Safety glasses, protective gloves, gowns and masks of cotton-paper fabric, protective diapers for non-irradiated patient areas

Figure 4.2 – Light guide for shielding laser radiation

4.3Thermal hazards of the laser installation

The characteristics of the thermal effects present in the LAHTA-MILON laser installation are given in table. 4.2.4.

Table 4.3.1 – Characteristics of the thermal effects of the laser installation

parametr	Impact on the human body
Heat release from heated surfaces of capacitors	Damage to the skin surfaces of the specialist doctor and the patient (burns)

The normalized characteristics are given in table. 4.2.5.

Table 4.3.2 – Normative characteristics of the laser installation in accordance with "Sanitary norms and rules for the installation and operation of lasers" No. 2392-81

parametr	Нормативне значення	Real value
Surface heating temperature	70° C	65 °C

Measures to ensure the safety of operation of the laser installation that will generate laser radiation in the medical office are listed in table. 4.2.6

Table 4.3.3 - Safety measures to minimize thermal hazards

Activities	Means
Technical	1) Installation of the air cooling mechanism of the capacitors of the laser installation

Continuation of the table. 4.3.4

Activities	Means
Technical	Indoors: 1) location of the laser installation in a fenced-off part of the room
Organizational	Briefings; timely inspection and preventive actions; strict compliance with the rules and norms defined by current regulatory documents; compliance with all special instructions that are established for med. equipment and procedures carried out in this medical institution
ЗІЗ	Protective gloves made of cotton-paper fabric,

4.4.Danger of electrocution

According to ONTP24-86 and PUE-87, the premises belong to the class of premises without an increased risk of electric shock to workers. The characteristics of the electrical network of the premises are given in table. 4.4.1

Table 4.4.1- Characteristics of the electrical network in the room

Supply voltage from the mains	Frequency	The operating current of the load of electrical appliances	Electricity consumers
220 B	50 ± 0,5 Hz	To 5 A	Laser installation, air conditioner, thermal imager, laptop, lighting sources

The impact of sharp fluctuations in the network voltage, which can be caused by the switching on of other consumers of the transformer substation, is minimized by the implementation of power supply from a powerful substation. The main technical characteristics of the LAHTA-MILON laser installation according to GOST R MEK 601-1-1-96 are given in table 4.2.8.

Table 4.4.2 – Electronic safety parameters of the LAHTA-MILON laser installation

Parameter	Value
Electrical safety class	II - a device that, in addition to the main one, also contains additional insulation

Continuation of the table. 4.4.3

Parameter	Value
Degree of protection against electric shock	BF – increased degree of protection and isolated working part
BF - increased degree of protection and isolated working part	Polystyrene
PC connection	RS232, signal, maximum current 10mA
Power	100 vt
Voltage/ Frequency	220 B, 50 HY

Table 4.4.5 – Evaluation of the criteria for protection against electric shock according to DSTU 3798-98. Medical electrical products.

Criterion		Device	GDR
Earth leakage current	Under normal conditions	0,35 мA	0,5 мA
	Under the conditions of a single violation	0,7 мA	1 мA
Leakage current per patient	Under normal conditions	0,075 мA	0,1 мA
	Under the conditions of a single violation	0,3 мA	0,5 мA

Table .4..4.4 - Means of protection against electric shock

Activities	Means

Technical	Normal mode of operation	1) inaccessibility and rubber insulation of current-carrying parts; 2) turning on the devices in the socket through special sockets with grounding; 3) rubber insulation of the network cord of the measuring equipment, the presence of a plug with grounding contacts;
	Emergency mode of operation	1) the use of special separate wires for grounding along the entire contour of the walls; 2) puncture automatic fuse VPB 6-10;
	In the production room	1) protective grounding of equipment, as well as couches; 2) antistatic linoleum floor covering; 3) laying hidden wiring in floor recesses; 4) lamps at a height of 2.8 m (at least 2.5 m); 5) location of the office outside the zone of influence of electromagnetic fields, away from x-ray diagnostic offices and electrophototherapy offices
Organizational	Briefings; control of electric current parameters; timely inspection and preventive actions; strict compliance with the rules and norms defined by current regulatory documents; compliance with all special instructions that are established for a certain med. equipment and procedures carried out in this medical institution	
PPE	Dielectric mats; insulating stands on the ground; replaceable rubber shoes.	

The requirements of DNAOP 0.00-1.21-98 and DNAOP 1.1.10-1.07-01 regarding electrical safety are fully met.

• Fire hazard

The reasons for the possible occurrence of a fire in the given premises are as follows:

• malfunction of electrical equipment,

• ignition of the laser installation due to overheating of its structural elements

• violation of the fire safety regime (for example, smoking).

Characteristics of explosiveness and fire safety are given in the table. 4.4.4.

Table 4.4.5 - Characteristics of explosiveness and fire safety

Flammable materials in the medical office	fibrous - paper, solid - wood, electrical equipment
Category of medical office according to fire safety	II-IIa - there are solid combustible substances and materials in the room

Fire class	A - burning of solid substances
Fire subclass	A1 – accompanied by decay, A2 – not accompanied by decay, E - burning of electrical installations under voltage
Category of medical office according to explosiveness	B – fire hazard

Fire safety measures used in the medical office to avoid emergency situations are listed in the table. 4.4.5.

Table 4.4.5 – Fire safety measures

Activities		Means
Technical	Emergency mode of operation	1) carbon dioxide fire extinguisher BB-5 2) DTL type sensor, operating temperature 72 C, operating inertia 120s, monitored area 25 m2
Organizational		Briefings; control of electric current parameters; timely inspection and preventive actions; strict compliance with the rules and norms defined by current regulatory documents;

Continuation of the table. 4.4.5

Activities	Means
Organizational	compliance with all special instructions that are established for a certain med. equipment and procedures carried out in this medical institution.
ЗІЗ	Gas masks, respirators, masks

4,5 Conclusions to section 4

In this section, safety measures against the harmful effects of laser radiation, the effects of thermal hazards of the laser installation are considered, as well as safety measures against electric shock and fire safety measures when working in a medical office are considered.

The area and height of the medical office have optimal indicators.

In general, the equipment of the premises meets all requirements and provides the possibility of a comfortable and safe working regime.

CONCLUSIONS

In this work, the modern literature on the general state of PDT and prospects for its further development, conditions and parameters of the procedure, equipment and optimization methods used for PDT was investigated and analyzed. As a result, it was found that modern methods of optimization and diagnosis do not take into account the biological characteristics of the patient, since the value of the duration of the procedure is standard, and do not provide the possibility of optimizing the PDT procedure in real time, and therefore put the regulation and control of the procedure on the level of the doctor's qualification - specialist.

Modern medical literature on the effect of laser radiation on the surface of biological tissue, the effect of the duration of the procedure on the temperature of pathological tissue with accumulated FS during laser irradiation of a given wavelength and power density was also investigated. As a result, a model of the process of heating pathological tissue with accumulated FS during laser irradiation of a given wavelength and power density was found.

The paper proposes and theoretically substantiates the use of the thermography method for building a control algorithm using feedback, and also proposes and theoretically substantiates the use of the statistical method of polynomial regression for processing thermographic data.

The paper substantiates the use of the NI LabVIEW software environment and creates a control algorithm in this environment.

As a result of the design in the NI LabVIEW software environment, a software model of the process of heating biological tissue was created, a polynomial regression analysis was implemented with by predicting the duration of the procedure until the optimal temperature value is reached, an algorithm for controlling the laser installation with statistical feedback processing was obtained in order to increase the efficiency of the PDT procedure.

For the hardware implementation of the control algorithm, the LAHTA-MILON laser installation and the PergaMed medical thermal imager are proposed.

A promising direction of research is supplementing the developed system with a database for saving regression coefficients, and therefore the type of regression curve, for each patient along with other characteristics (gender, age, skin type, etc.) to search for regularities.

APPENDIX A

BLOCK DIAGRAM OF THE PDT CONTROL ALGORITHM

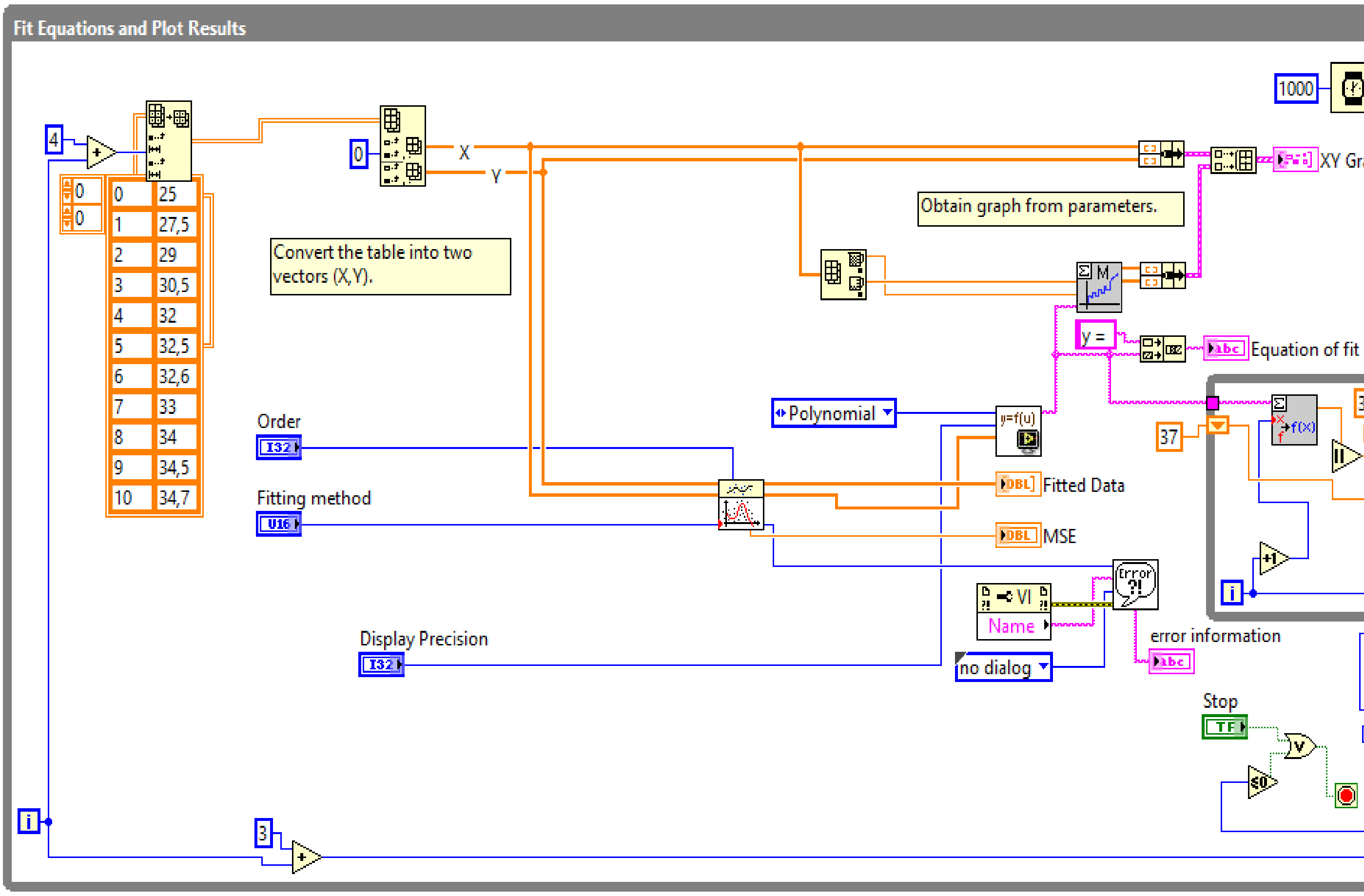


Figure A.1 – Block diagram of a virtual device for implementing the algorithm control of a laser installation with statistical feedback processing

APPENDIX B

TECHNICAL CHARACTERISTICS OF THE LAHTA-MILON APPARATUS

Table B.1 – Technical characteristics of the "LAHTA-MILON" device [17]

parametr	Value		
Display type	Color graphic display (TFT LCD) with a diagonal of 5.7´´		
Selection of parameters	Color indicator with a touch screen panel		
Radiation wavelength, nm	635	662	675
Maximum radiation power, W	0,1 – 1	0,01 – 0,6	
Exposure time	0,01 с – 6 год		
Time mode of operation	Continuous, pulse, pulse-periodic		

Digital and graphic display	• • power of laser radiation • • duration of the radiation pulse • • interval between pulses • • exposure to laser radiation • • total time of laser radiation • • total energy dose • • momentum energy • • pulse counter
Supply voltage (from the AC network)	220 В
Power consumption	200 Вт
Overall dimensions of the single-wave device, mm (W	245180305
Overall dimensions of the two-wave apparatus, mm (W	
Mass of single-wave apparatus, kg	5
Weight of the two-wave device, kg	

APPENDIX B

TECHNICAL CHARACTERISTICS OF THERMAL VISOR "PERGAMED"

Table B.1 – Technical characteristics of the PergaMed device [18]

parametr	Value
Detector type	Focal plane array (FPA)
Frequency of staff turnover	60 Гц
Temperature range	-20 °C … +100°C
Electronic zoom	2x, 4x
Viewing angle (lens)	22, 6° 16,9°
Focusing	Manual
Weight	1,83 kg
Dimensions	200mm 107mm 109 mm
Feeding	12 В
Power consumption	<6 vt

Computer requirements for software operation:

• computer IBM PC

• Pentium 1000MHz processor (or analogues) and higher

• RAM 512 MB

• CD-ROM 4-x speed and higher

• video card 64 MB memory, 16-bit color, 800600, 96 dots/inch

• The USB port is compatible with USB 1.1 and USB 2.0

• Ethernet port

• printer with photo printing function

• operating system (OS) Windows XP, Windows 7, Windows 8

• Microsoft Office 2000 and higher

• The amount of memory on the hard disk is 200 MB for the program and at least 500 MB for databases.

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