Optical Power Control Module

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***Abstract* – This article describes the optical power control module, of laser diodes, which is included in the therapy installation using local hyperthermia. The function of this module is to produce and maintain, during the entire duration of the therapy procedure, the stable optical power, which has an enormous significance in efficiency of therapy using local hyperthermia.**

Also the module obligations are: monitoring the laser diodes performance, which also plays an important role in proper functioning of the entire system. This module can serve up to four laser diodes simultaneously, is equipped with RS232 serial interface, necessary to control module via computer. For this purpose, was prepared a computer program that allows the operator to install optical power level for each of the four laser diodes and to monitor laser diodes efficiency.

The main element of this module is the microcontroller ATmega16, equipped with a periphery, corresponding the requirements of given module

I. INTRODUCTION

The principle of local hyperthermia is to create inside the human body at a certain depth of temperature (accurate), necessary to destroy tumor tissue (~ 43.5 ° C).Temperature excess or insufficiency may even harder aggravate the situation.

In this project, the primary concept, was to develop the device would allow the therapy of cancer, infectious diseases with high energy infrared radiation, which practical has no harmful effects on humans when compared with traditional therapy with roentgen rays (after which the patient passes a rehabilitation period). Another advantage is that the device does not need a specialized room (concrete walls, special clothing, dosimeters) and can be easily moved from one place to another (it is quite mobile). Also construction of the device was designed so, that each module in case of damage to be changed in a short period of time and without great expense.

The installation is equipped with a set of high optical power laser diodes (full power ~ 4W), based on heterojunctions InAlGaAs, with wavelength of emitted radiation equal to 808nm. Each diode laser is also equipped with an optical collimator to create a parallel flux, with minimal divergences. In order to avoid, due to overheating, the damage of the intermediate tissues during the radiation penetration through the body and to focus all energy on the tumor, was designed a division of the needed flow in a smaller flows, which in the sum will have the same effect on the tumor. For this, the laser diodes must be placed at certain angles, chosen by the doctor, depending on tumor location and state (depth, the distance to vital organs, the dose required, etc.).

The installation is also equipped with RS232 serial interface for data exchange with the computer. Through this interface and main program, is handled the optical power of the laser diodes, monitoring the heat fields (temperature distribution in the tumor area), monitoring the efficiency of the laser diodes (laser diodes operates in the normal mode or begins to degrade). The program also records all thermal field variations in a file for future analysis.

Installation for therapy using local hyperthermia can be divided into the following sub modules:
- thermal field monitoring module (the basic functions is to collect information about the temperature in the tumor region).
- optical power control module of the laser diodes.
- cooling system (its function is to evacuate the excess heat produced from laser diode operation)
- power supply module (electric power for all sub modules of installation)

Each of these sub modules meet the vital functions for the normal functioning of the entire device.

II. THE DESCRIPTION OF THE OPTICAL POWER CONTROL MODULE OF THE LASER DIODES

The main function of this module is to create and maintain a certain level (set by the operator via computer) of the optical power for laser diodes. The precision of the installed level has a huge significance in terms of efficiency of the therapy using local hyperthermia, so the module is equipped with an optical power monitoring loop, which continuously checking the actual optical power with the necessary optical power (installed by operator) and in case of deviation – introduce the necessary correction.
Also one of the functions of the module is to monitor the effectiveness of the laser diodes to prevent they're damage. These effects can occur in case, when the heating speed of the laser diode exceeds the speed of the heat surplus evacuation by the cooling system, which leads to lower optical power of emitted flow by the laser diode. Therefore, the optical power monitoring loop (which role is to maintain a constant optical power), is to detect the decreasing of the optical power level, and if this occurs, to increases the intensity of electric current which flows through the diode laser, in order to restore the installed level of the optical power.

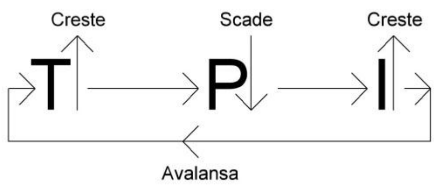

Fig.1 Laser diode thermal loop

The increase of the electric current intensity, therefore, leads to further warming of the laser diodes (in case when cooling system fails to evacuate the exceeded heat) and respectively decreases the efficiency of the laser diode. A such situation can be characterized as a "thermal loop".

It is very important to avoid the entering of the laser diode in the "thermal loop" for several reasons: first of all to ensure an effective therapy, and secondly - to avoid the damage of the laser diodes (rather expensive). Therefore the monitoring function of the laser diode efficiency (went in the thermal loop or is functioning in normal mode) has a great significance in the normal functioning of the entire installation for therapy using local hyperthermia.

$$T_D \sim A \cdot P_o \cdot \Delta t \qquad (1)$$

where:

- T_D - laser diode temperature, during time interval Δt
- A - parameter that depends by the nature of the laser diode
- P_o - optical power of emitted flux of laser diode
- Δt - time interval, during which the laser diode emits radiation with optical power P_o

As shown in relation (1), since the optical power level, at which operate the laser diode, is higher, then the work time should be less, to keep the diode at a temperature at which the cooling system can serve it. Solving this problem can be: equipping every laser diode with a powerful cooling system, able to serve any heating level, but such a system is quite expensive. Another method - use a large number of laser diodes, which have the same thermal effect on the tumor, but which will operate at a lower level of optical power, which would allow a longer period of operation of laser diodes.

As shown in Fig.2, the module can be divided into three functional blocks: digital block, analog block and photo sensor.

Digital block provides the connection between computer and optical power control module, via the RS232 serial interface. Data frame transmitted to the control module contains the information about the optical power, laser diode address, however data transmitted to the computer (collected from the analog block) contains the information about the electric currents flowing through the laser diode (required for monitoring effectiveness of the laser diode). The software running on the computer analyzes the received data and operates according to the obtained results. Data received by the digital block (from the computer) are processed and sent to the analog block, through the 3-wire interface, which will be converted into an analog signal that will control the laser diode optical power.

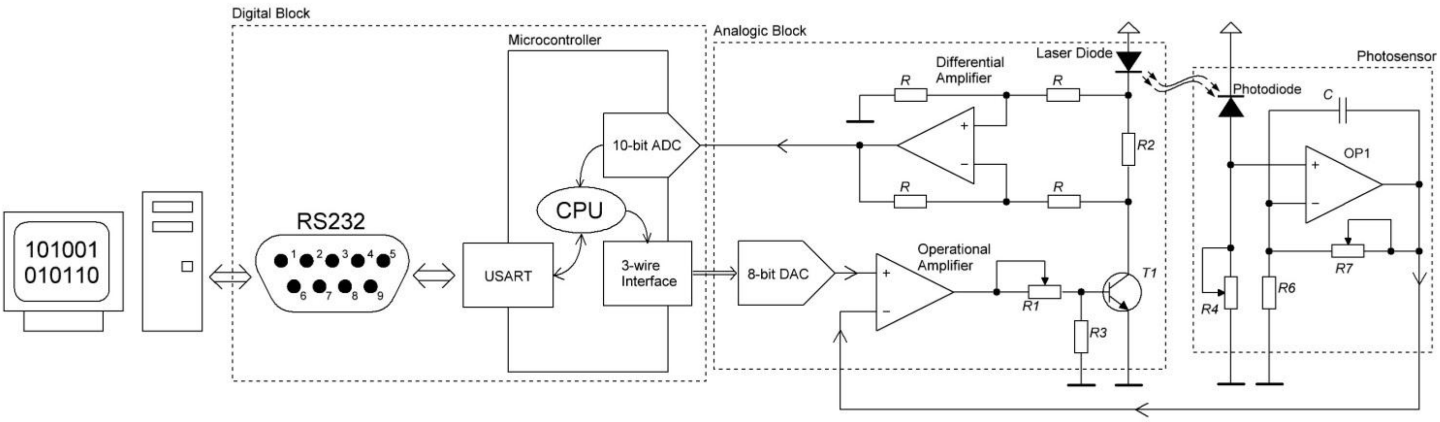

Fig.2. Scheme - Block of laser diode optical power control module

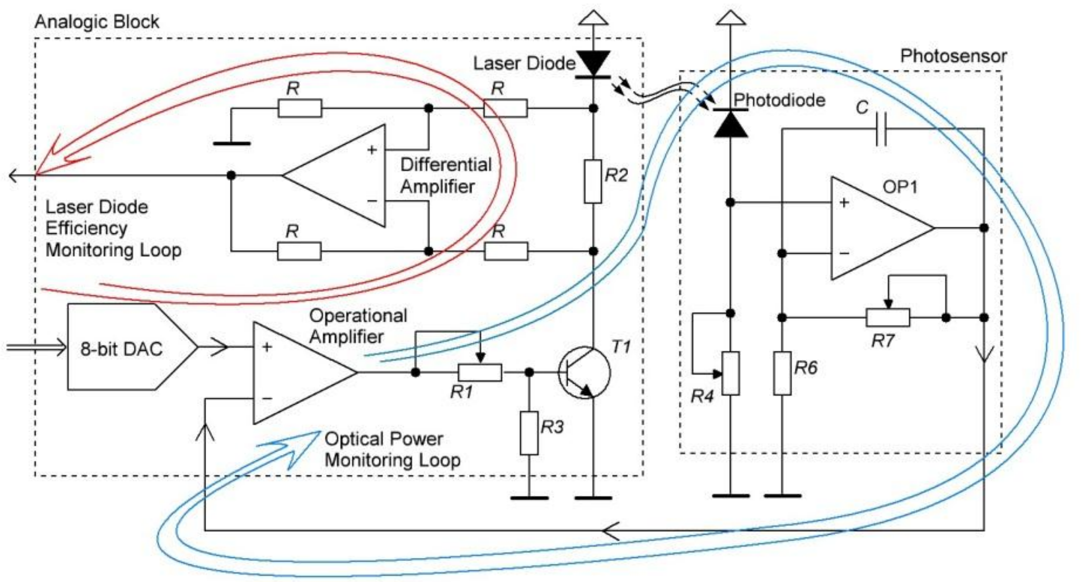

Fig.3 Optical power monitoring loop and laser diode efficiency monitoring loop

Functions of analog block are based on creating and maintaining the optical power level introduced by the operator. Optical power level is transmitted via 3-wire interface by the digital block to the digital-analog converter (DAC, component present in the analog block). DAC converts the digital signal into an analog signal that is applied to non-inverting input of the operational amplifier (OA). OA, together with the power transistor T1, controls the current flowing through the laser diode (directly proportional to the optical power of emitted radiation, see Fig.4). OA, depending on the received electric signal at the inverting input (from photo sensor), increases / decreases the intensity of the electric current flowing through the laser diode, therefore acting on optical power of the emitted radiation. The differential amplifier, measures the voltage drop on resistor R2, which is directly proportional to the electric currents flowing through the laser diode. This voltage is applied to the ADC input (component present in the digital block).

So analog block, together with photo senor forms two monitoring loops: optical power monitoring loop and laser diode efficiency monitoring loop.

Optical power monitoring loop, continuously check the laser diode optical power level through an operational amplifier and photo sensor. Part of this loop are the power transistor T1, which operates as the current supply for the diode laser and laser diode itself, which according to the electric current intensity flowing through it, produces a coherent stream of infrared radiation with an optical power well known. Dependence between the emitted radiation optical power and the electric currents flowing through the diode laser is linear and direct proportional.

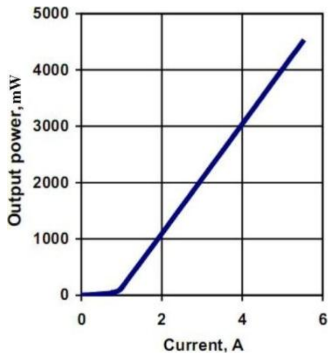

Fig.4 Dependence of the laser diode optical power of the electric current

The laser diode efficiency monitoring loop, as previously mentioned, is intended to prevent the entry of the laser diode into "thermal loop", which can damage it. The loop continuously monitors the electric currents, flowing through the laser diode. Measured by the differential amplifier, the voltage drop on the resistor R2, is directly proportional to the electric currents flowing through the laser diode and respectively with its optical power. The signal obtained at the differential amplifier output is applied to the ADC input (component present in the digital block). The binary data, obtained after analog to digital conversion, are transmitted via RS232 serial interface to the computer, where they are processed and displayed by the optical power control module software. If the software detects a situation when the laser diode has entered into "thermal loop" – stops local hyperthermia therapy procedure.

In Fig.5 is presented the photo sensor block – scheme, a basic element of the optical power monitoring module. Photo sensor main function is to monitor the optical power of the laser diode (together with op-amp). The photodiode, which is a part of the photo sensor, is connected in a photoconductive mode, which reduces it parasitic capacity and increases the optical sensitivity, which, in this case, is very important. The R4 resistor also regulates the photo sensor sensitivity. The signal produced by the photodiode and the resistor R4 is applied to the non-inverting input of the operational amplifier, component present in photo sensor. Resistors R6 and R7 regulates the signal amplification factor. Capacitor C performs the function of filtering various oscillatory signals which are produced by parasitic capacity of the photodiodes or other devices in the same room (network noise: ~(50 – 60)Hz). The signal produced by the photo sensor is applied to the operational amplifier inverting input.

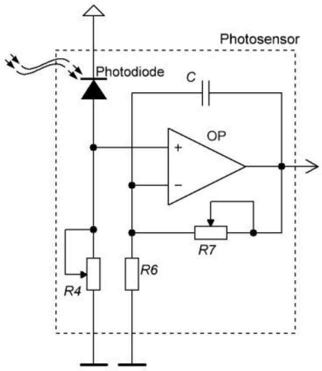

Fig.5 Photosensor's scheme – block

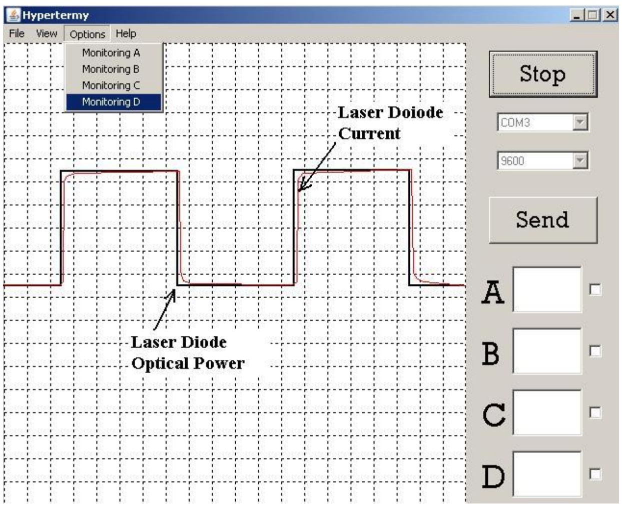

Fig. 6 Monitoring laser diode efficiency

To achieve communication between the computer and optical power control module, was developed a protocol that provides, together with RS232 standard, data transmission without distortions and losses. One function of the software running on computer (except for data transmission and reception) is to process the received data, regarding the laser diodes efficiency, with the following graphical display of the dependence between the laser diode optical power and efficiency

III. CONCLUSIONS

Within the installation for therapy using local hyperthermia, was developed, optical power laser diodes control module, able to monitor up to four laser diodes at the same time. Module operation was tested within the installation, obtaining accurate results in maintaining the level of optical power, responsiveness (for switching power transistors rather than ~ 25us) and high sensitivity. As mentioned previously, to avoid laser diodes entering into the "thermal loop" is proposed to provide them with more powerful cooling system and also increasing the number of laser diodes, which would increase the overall safety of the installation for therapy using local hyperthermia.

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