Effects of laser interaction with living human tissues

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Abstract. With the help of a highly sensitive laser device with the wavelength $\lambda = 0.808 \mu m$, which is optimal for deep penetration of the radiation into biological tissues, the effects associated with the appearance of uncontrolled human infrasonic vibrations of different frequencies were investigated. It was established that the observed fluctuations are associated with the vascular system which is characterized by its own respiratory movements, occurring synchronously with the movements of the respiratory muscles, the operation of the heart muscle, and the effect of compression ischemia. The effect of “enlightenment” of a tissue is observed with stopping of blood flow in vessels by applying a tourniquet on the wrist.

Introduction
It is known that during the passage of optical radiation through living human biological tissues, which are penetrated by blood vessels, there are signals related to heart operation. These periodic vibrations of volume of blood vessels are associated with heartbeat functioning due to the dynamics of blood filling during one cardiac cycle. Furthermore, in the human body mechanical vibrations of the human body surface can be generated (infrasonic waves) [1]. Own acoustic radiation is limited in the short-wave area by ultrasonic radiation. Low frequency radiation (frequencies below $10^3$ Hz) is generated by physiological processes like heartbeat, breathing movements, blood flow in blood vessels and other processes, which illustrate variations of the human body surface within the range of about $0.01 \text{–} 10^3$ Hz.

Underlying methods of registration of the human body radiation and its own physical fields are important for medical diagnostics because they are non-invasive. Therefore, the task of measuring and research of human infrasonic fields may be of a great interest.

Experimental technique
Most often, the pulse is measured using a heart rate monitor, which includes an optical radiation source and the photodetector. It is natural that we should observe the pulse signals [2] in the chosen scheme of the measuring device (figure 1).

A semiconductor laser module KLM-H808-120-5 was used as a radiation source with wavelength $\lambda = 0.808 \mu m$ (1). It was powered by a DC supply (2). The output power of the laser was 130 mW. It is possible to avoid significant absorption of the laser radiation by bones (below 80%) in some places in the palm (3). Radiation transmitted through the palm goes to the photodetector (4), and then to the amplifier (5) and digital voltmeter Tektronix TDS 1001C (6).

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Measurement results and discussion

Owing to a detailed study of pulse oscillation at a higher time sweep of the oscilloscope (~ 5 s/segment), modulation of the pulse oscillations with a frequency of 0.01–0.1 Hz was observed. The results of these studies are presented in figure 2.

![Figure 2](image)

**Figure 2.** Photodetector signal of the laser radiation transmitted through the palm (axis reamer “Y” - 10 mV/ division, “X” - 5 s/ division).

From these figures it can be seen that the infrasonic vibrations have different frequencies 0.06–0.1 Hz and have the form of sin(\(\omega\)). Presumably, this is due to the uncontrolled behavior of the nerve impulses, which are generated by the human brain. Research in this direction will be continued.

It is known[3], that any human body has different physical fields around itself – acoustic and electromagnetic, – which are characterized by the intrinsic processes, i.e. fields which are generated by the organism during its operation. Low-frequency radiation (frequencies below \(10^3\) Hz) is formed by physiological processes: heartbeat, breathing movements, blood flow in blood vessels and other processes, illustrating variations of vibrations of the human body surface within the range of about \(0.01–10^3\) Hz.

To check the connection between the observed features of the signals’ behavior and the respiratory movements, experiments with breath holding were conducted. These experiments had 3 stages: sigh for about 2 s (point A in figure 3), breath-holding for approximately 7 s, and exhalation for 2 s (point B). After this cycle, the process was repeated. The result of this experiment is shown in figure 3.
Figure 3. Signal of the laser radiation transmitted through the palm with periodic breath-holding. Point A corresponds to the breathing in, point B corresponds to the exhalation; I, II, III – periods of different wave types; upper curve is an envelope curve of waves (reamer of axis “Y” - 1V/division, “X” - 5 s/division).

As it can be seen, there are several types of waves in this case. Waves of the first type (I) are associated with the reduction of the heart (pulse), the second type (II) waves are linked to the rhythm of human breathing, and the third type waves (upper curve) are called waves of Traube-Hering (III) in the literature [4]. With the help of the “acute” experiments on the dog, Goering concluded that the vascular system is characterized by its own breathing movements, occurring synchronously with the movements of the respiratory muscles. Both of these types arise because of nerve impulses coming from the respiratory center, which is located in the medulla oblongata. Normally, these waves are practically not observed, but in a state of emotional tension, occurrence of these waves is very common. Figure 4 shows the waveform at long breath hold. Breathing stopped at the point A, and after 8 s the signal began to decrease to a point B within 25 s. As it is known [5], hemoglobin concentration increases during breath-holding, hence the absorption of laser radiation grows, and the decrease of the signal intensity is observed. After breathing resumed, the signal slowly comes back to its initial value. The figure shows that the oscillations observed in a breath-hold have higher frequency than the the oscillations during an exhalation. Oxygen does not enter the blood in the circulatory system during cessation of breathing, so the concentration of CO₂ increases leading to the fact that breathing becomes more frequent and heart rate increases.

Figure 4. The nature of the signal changes at a long breath-holding. Reamer of “X” axis: 5 s/division.
In order to clarify the influence of pulse oscillation on the effects described above, experiments were carried out to study the processes associated with blood flow in the vessels of the heart beats using the tourniquet which was superimposed on the wrist for 12.5 s. The result of this experiment is shown in figure 5.

![Figure 5](image)

**Figure 5.** Laser radiation signals from the detector. This radiation passed through the palm which was tied at the wrist. Point A corresponds to the tourniquet application, and B – to its removal (reamer “Y” axis - 2 V/division, “X” - 2.5 s/division).

At the moment of the termination of the blood flow, an increase of signal at the photodetector was observed, which corresponds to the effect of “enlightenment” of tissues. In this case enlightenment was approximately 30%. The saturation occurred over the next few seconds, i.e. signal did not change in magnitude. After removing the tourniquet, the signal decreased by 2 times in 0.5 s and then came to its normal value in about 3.5 s. As it can be seen from the waveform in figure 5, at the termination of the blood movement, the infrasonic vibrations are absent, i.e. observed waves are directly related to circulation.

Generally speaking, the effect of tissue “enlightenment” was earlier observed in article [6], where this effect was caused by the compression and puncture at the tissue area which was illuminated by light. This phenomenon was attributed to the departure of blood and squeezing the muscles of the area of compression. It was also noted that the compression layer reduces light scattering and absorption of the stain, due to the blood displacement from the area of pressing. By eliminating the pressing, enlightenment does not disappear immediately – footprint of a pressing continues to transmit the light for 1-3 s. It is noted that the thicker part of the palm, such as flesh from the edges and at the region of phalanges, tends to be more permeable and prone to light illumination by compression than the center of the palm. In our case, this effect is related to the cessation of blood flow into vessels located in the palm. Thus, besides reducing the absorption and scattering of the radiation, reduction in tissue oxygenation can also be substantial, since light is mainly absorbed by protein molecules and oxygen in the near-infrared region.

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