# Optoelectronic multispectral device for determining the state of peripheral blood circulation

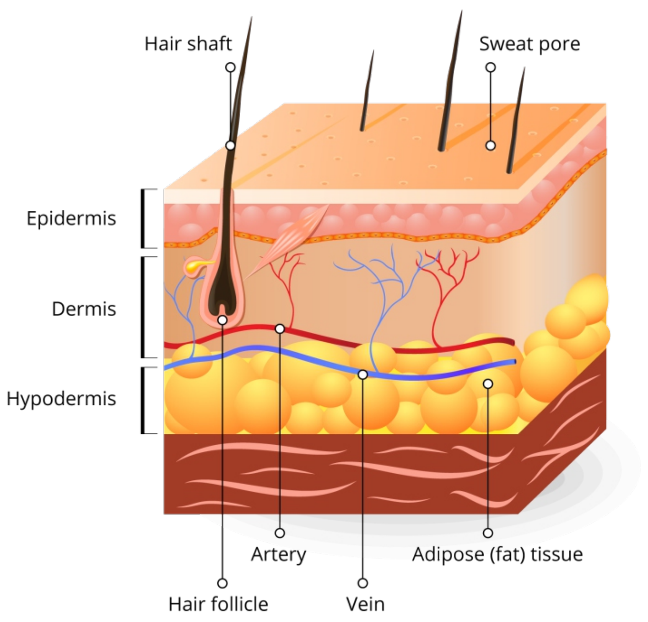
Tatiana I. Kozlovska[a], Sergii M. Zlepko[a], Petro F. Kolesnic[b], Volodymyr S. Pavlov[a], Anatolii V. Poplavskyy[a], Waldemar Wójcik[c], Marzhan Spabekovad, Serzhan Mirzabayev[d]

[a]Vinnitsa National Technical University, Ukraine; [b]Vinnytsia National Medical University, Ukraine, 21018; [c]Lublin University of Technology, Poland; [d]Kazakh Academy of Transport & Communication, Kazakhstan

Today the problem of peripheral blood circulation disorders is very actual. The modern scientific and technological progress causes a negative influence on the environment, and accordingly on the human health, that is one of the reasons of decreasing the age of many diseases associated with peripheral blood circulation disorders. The basis of successful treatment of a particular disease is the correct and timely diagnosis, because identifying of certain problems at an early stage significantly increases the probability of a complete recovery of the patient. Therefore, the development of new diagnostic devices makes an important contribution to the development of modern medicine.

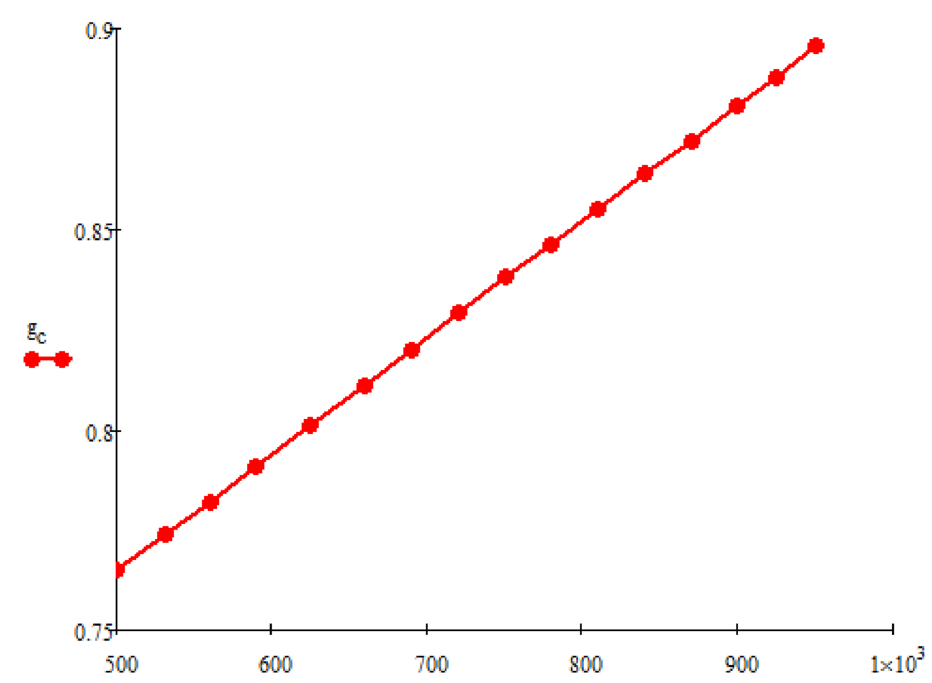
The promising direction of early diagnosis of peripheral blood circulation disorders is the optical methods that allow conducting painless and non-destructive control of affected areas. Among them takes an important place the photoplethysmographic method, which based on irradiation of biological tissue by infrared light and registration of reflected from investigated area light by photodetector. In the cases of studying of the thin tissues uses not reflected but passed light. But there are many factors affected on the results of investigations, so in the cases of construction such devices, based on the method of photoplethysmography it must be taken into account. First of all it is necessary to choose the optimal wavelength of the irradiation source, for this need to study the specifics of the human skin and interaction of the optical radiation with the skin layers. The human skin consists of three layers: epidermis, dermis and subcutaneous fat (hypoderms). Each of them, in turn, also consists of several layers.
The thickness of the epidermis is different, it takes from 0.01 to 0.2 mm. The epidermis is a multi-layered epithelium, the outer layer of which is called cornea. Due to its special optical properties, the horn layer is sometimes considered a separate part of the skin. The horn layer differs from other layers by density, elasticity, poor conductivity of heat and electricity. The lower layer of the epidermis is called basal, it shares epidermis and dermis. Cells of this layer (melanocytes) produce a pigment of melanin, whose granules are in diameter from 30 to 400 nm. The average thickness of the dermis is about 1500-2000 µm. Actually, the skin or dermis consists of connective tissue, cellular elements and a basic amorphous substance. In the interaction of light with the skin due to the difference in the refractive index of air and the stratum corneum, there is a partial reflection of the incident radiation. In this case, the reflected light is reversed in different directions and becomes diffuse, and a significant part of the beam of light (93-95%) is included in the skin

## METHODOLOGY



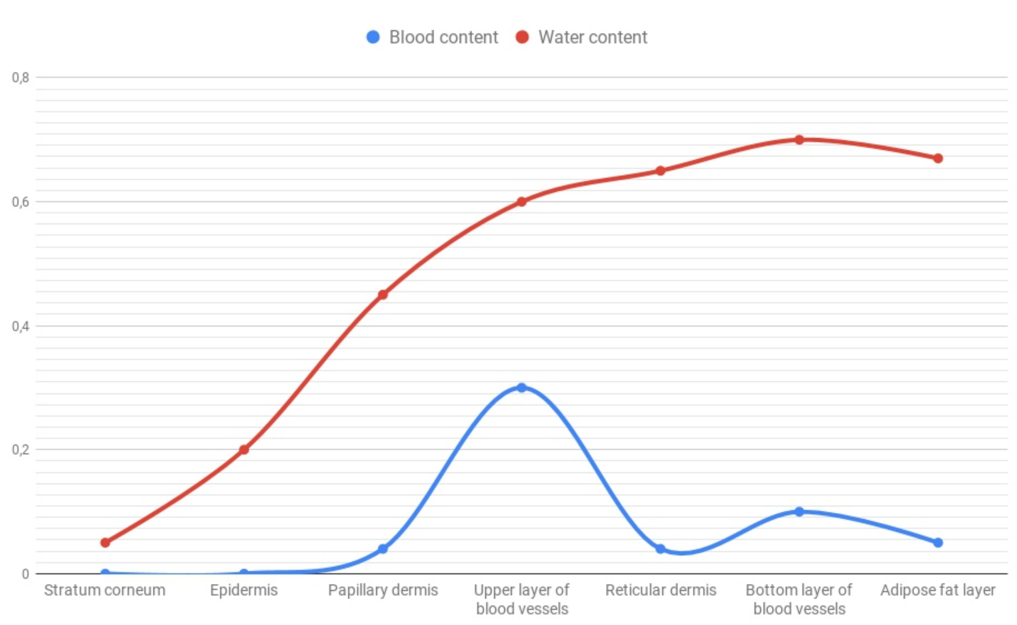

The structure of the human skin

One of the parameters that affects absorption and scattering is the thickness of the skin. The thickness of a human skin depends on age, skin color, sex, health and localization. At different parts of the body the skin has a different thickness. Absorption of light is one of the characteristics of the interaction of light with the skin. Absorption in the epidermis is mainly determined by the pigment melanin. The dermis of the skin is strongly infiltrated by the blood vessels in which hemoglobin is present. The absorption spectrum of hemoglobin has an absorption band of about 405 nm and is characterized by a double absorption peak in the region of 545-575 nm, hemoglobin also strongly absorbs near 430 nm and is weaker near 550 nm. In the infrared region of the spectrum, all biomolecules have rather intense oscillatory absorption bands. Starting from λ = 1500 nm and above, the absorption spectrum of the skin is largely determined by the absorption spectrum of water.

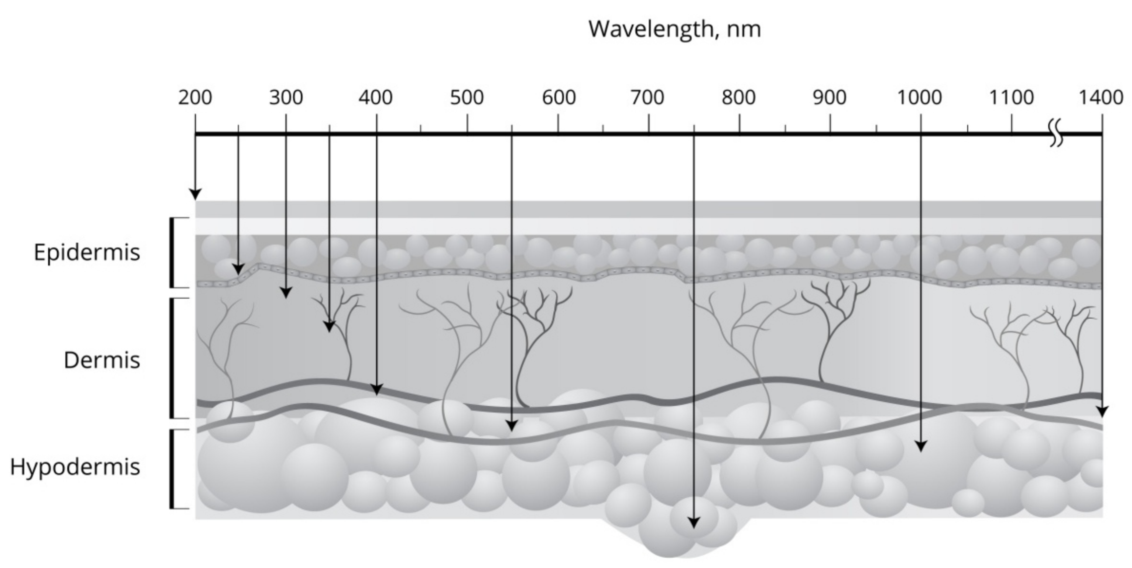



Dependence of the anisotropy factor on the scattering of the epidermis and the dermis from the wavelength

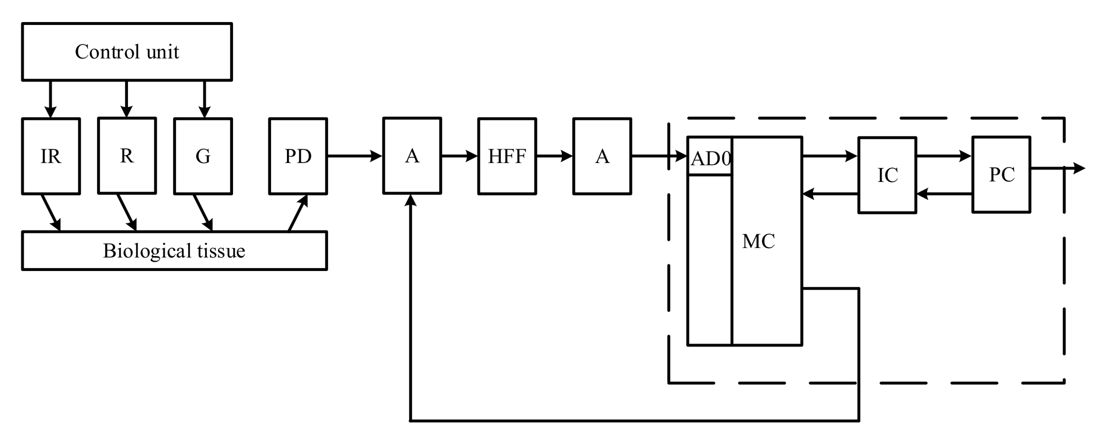
## RESEARCH RESULTS




Content of water and blood in different layers of the skin




Depth of light penetration on different wavelengths




Structural diagram of optoelectronic multispectral device for determining the state of the peripheral blood circulation

- The control unit makes a consistent choice of the source of radiation.
- The selected source of radiation emits a light flux, which is partially absorbed and partially scattered by the biological tissues of the study area of the body (biological tissue), is sent to the photodetector (PD).
- The pulsations of peripheral vessels that arise due to the passage of the pulse wave cause fluctuations in the optical density of living tissue.
- The signal from the photodetector (PD) goes to the amplifier (A), and after to the filter of high frequencies (HFF), and then again intensifies by next amplifier (A).
- The signal amplification is determined by the MC. MC is connected to USB interface chip with galvanic isolation (IC).

The intensity of the optical radiation that is registered by the photodetector:

$$I = I_0 \cdot \left(1 - \left(\left(1 - \frac{\tau_{opt.} \cdot \pi \cdot r^2}{L^2} \cdot \cos\alpha \cdot \cos\beta\right) + \left(1 - \exp\left(-\left(\mu_{t_1}(\lambda) + \mu_{t_2}(\lambda) + \ldots + \mu_{t_n}(\lambda)\right) \cdot z\right)\right)\right)\right)$$

$I_0$ – the intensity of the incident radiation on the biological tissue; ($I_0 = J/l^2$, where $J$ – is candle power, $l$ – distance between the light source and the surface of biological tissue); $\tau$opt – coefficient that characterizes the light passage through the optical system (0,9 – 0,95); $L$ – distance between biological tissue and photodetector; $\alpha$ – angle of the incident light on the photodetector area; $\beta$ – the angle between the normal to a surface and an incoming light ray; $\mu_{t1}(\lambda)\ldots\mu_{tn}(\lambda)$ – extinction coefficients for different skin layers, where $\mu_t(\lambda) = \mu_s(\lambda) + \mu_a(\lambda)$.

## CONLUSIONS

The developed optoelectronic multispectral device for determining the state of peripheral blood circulation allows conducting research on several wavelengths (infrared, red, and green). The combination of these wavelengths allows not only to effectively investigate vascular blood flow or to determine the saturation of blood with oxygen, but also opens up new diagnostic possibilities. Because the use of green light allows to effectively investigate the surface layers of the skin, which is very important in diagnosing skin cancer.