

# ФІЗИКА

UDC 681.784

## EXPERIMENTAL MODEL OF TRAINING INSTRUMENT FOR REAL TIME VISUALIZATION OF OPTICAL DISK OF THE RETINA

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*An experimental instrument has been developed which makes it possible to realize the visualization of optical disk of the retina by using transscleral methods of illumination. The indirect illumination of eye fundus through the sclera and skin covers the sclera (not through a pupil) in infrared spectral range will allow to expand opportunities of visualization of optical disk for practical illustration of structure of retina.*

**Keywords:** sclera, retina, diagnostics, fundus, medical equipment, training equipment.

*Розроблено експериментальний прилад, який дозволяє реалізувати візуалізацію оптичного диска сітківки з використанням методів трансклерального освітлення. Непряме освітлення очного дна крізь склеру та шкіряні покриви прилегли до склери (не скрізь зіницю) в інфрачервоній ділянці спектру дозволить розширити можливості візуалізації опричного диску для практичної ілюстрації структури сітківки*

Ключові слова: склера, сітківка, очне дно, діагностика, медичне обладнання, учбове обладнання.

### Abstract

At present, specialists use stationary and portable instruments that enable them to do examination (photographing) of the optical disk of the retina of fundus of eye in the white light or in the light of various spectral compositions in the visual range of radiation. The various models of fundus cameras are applied to research with use of a fluorescein angiography method. Recently actively develop video angiography researches and systems of digital processing of the images with use of new generation of devices produced by various firms: "Opton", "Topcon", "Meditec AG", "Canon" etc. Unfortunately, fluorescein angiography is the invasive method and cannot be used by students for visualization of optical disk as practical illustration of structure of retina. In the series of publications [1–4] the innovative conception and instruments for near-infrared (NIR) transillumination photography of intraocular structures of eye (tumours) are developing. The technique for near-infrared transillumination imaging of intraocular tumours based on the modifications of a conventional digital slit lamp camera system (the Haag-Streit Photo-Slit Lamp BX 900, Haag-Streit AG) was used for transillumination photography of the eye.

The modification for near-infrared photography was done by replacing the original camera with a Canon EOS 30D (Canon Inc) converted by Advanced Camera Services Ltd. In the camera the infrared blocking filter was exchanged for a 720 nm long-pass filter. The near-infrared part of the spectrum was recorded by the sensor. The technique was applied for the patients and the good diagnostic quality of the photographs made it possible to evaluate the exact location of the tumor [1–3]. In a series of the devices [4; 5] (Technical Center of the National Academy of Sciences of Ukraine, Department of Spectroscopy of Solid Surface of Institute of Metal Physics of the National Academy of Sciences of Ukraine) the research can be made with use of the traditional methods of illumination of the fundus of eye (through a pupil) and the methods of indirect illumination of eye fundus not through a pupil (transskin transillumination or transcleral illumination without direct contact of light source to sclera). During the research was proposed the close packing model of eye biological media, which contain collagen fibers, simulated the spectral properties of eye membranes (cornea, sclera, suprachoroid lamina, lens capsule) and proved the save using of transcleral illumination based on ICNIRP [6–8].

The progress in the given direction was reached after the beginning of teamwork under the cooperation agreements between Technical Center of the National Academy of Sciences of Ukraine, Institute of Metal Physics of the National Academy of Sciences of Ukraine (Kiev, Ukraine), Institute of Eye Diseases and Tissue Therapy of the Academy of the Medical Sciences of Ukraine (Odessa, Ukraine) and Ocular Microsurgery Center (Kiev, Ukraine). At present time, the transillumination method and technique (fundus system FS 11) is recommended for medical using in Ukraine.

The main goal of the present work is the analysis of theoretical and experimental opportunities for development of the simple method and experimental instrument for visualization of optical disk as practical illustration of structure of retina for students.

**Material and methods**

The original devices developed in the National Academy of Sciences of Ukraine makes it possible to conduct medical inspection of the front part of an

eye and to do examination of the fundus of eye in infrared radiation (not polarized or polarized), and the visualization of the image is carried out with use of the electron-optical transducer.

The ophthalmoscopic research can be made in the reflected radiation of the visible and infrared range up to 1200 nm (not polarized or polarized) with use as traditional methods of illumination of the fundus of eye (through a pupil), and with use of a set of original devices realizing a method of indirect illumination of eye fundus through the sclera and skin covers the sclera (not through a pupil).

In the recent devices the electron-optical transducer is replaced by camera with a CCD-matrix. It has allowed to carry out inspection and record on the computer of process of survey of an eye in a real time mode. The modified optical head of the OAIp-03 ophthalmoscope is used as one of constructive elements. The device and principle of operation of the instrument with use of traditional methods of illumination of the fundus of eye (through a pupil) is illustrated in Fig. 1.

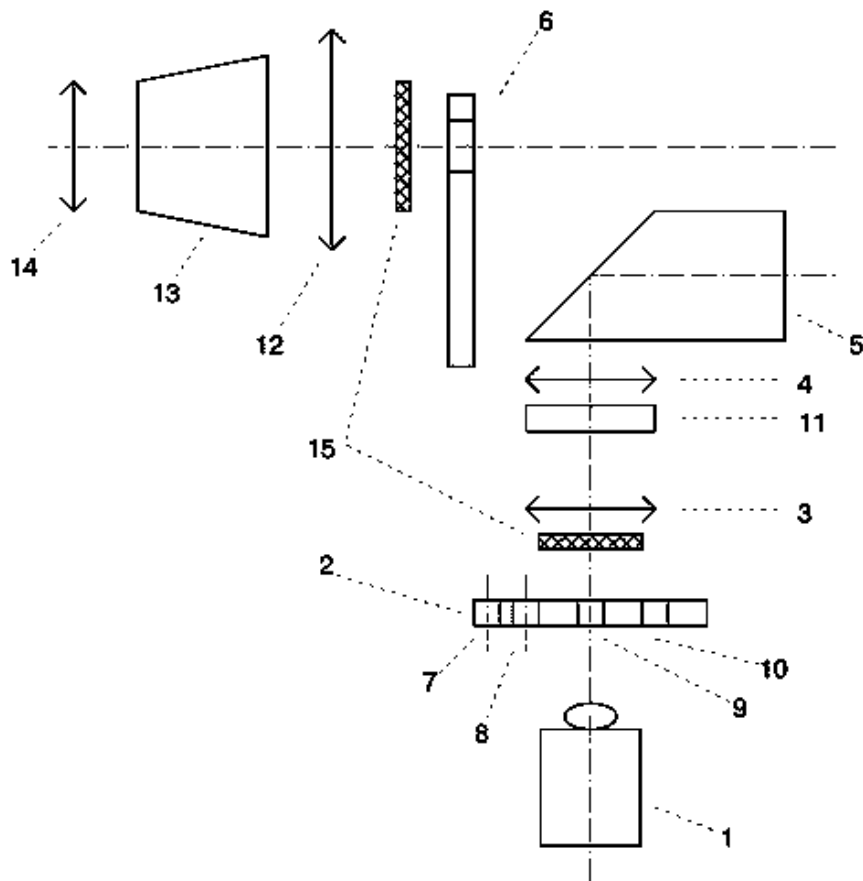


Fig. 1. Optical system of the instrument:

- 1 — halogen lamp or LED; 2 — control unit for projection on the fundus of eye;
- 3 — two-element condenser; 4 — objective; 5 — prism; 6 — correcting lenses;
- 7 — diaphragm 3.2 mm in dia. with a net; 8 — diaphragm 2.5 mm in dia.;
- 9 — diaphragm 0.5 mm in dia.; 10 — slit; 11 — filter; 12 — objective;
- 13 — CCD-camera or electrooptical transducer; 14 — ocular; 15 — polarizing filters

The optical system of the instrument consists of light source 1 (halogen lamp 3,5/2,5, in a centering lamp-holder or LED of a various spectral range); control unit 2 for projection on the fundus of eye; two-element condenser 3; light filter 11; objective 4; reflecting prism 5; correcting lenses 6 with  $-1, -2, -3, -4, -5, -6, -8, -12, -20, -25, +1, +2, +3, +5, +8, +15, +20$  diopters; objective 12; CCD-camera or electrooptical transducer 13; ocular 14 with dioptric adjustment for sharpness within  $\pm 4$ . Control unit 2 for projection on the fundus of eye has the form of a slider in which there is a diaphragm 3.2 mm in diameter with a net (the least division of the net is 0.25 mm; in the centre of the net there is an asterisk 0.3 mm wide), a diaphragm 2.5 mm in diameter, a diaphragm 0.5 mm in diameter, and a slit 0.1 mm wide. For the purpose of effecting polarized light ophthalmoscopy the instrument is fitted with additional polarizing filters 15.

*Method of direct illumination of the fundus of eye (through a pupil).* The condenser, objective, and prism form an image of the luminous lamp filament or LED crystal. The prism reflects the light flux in the direction perpendicular to the optical axis, so that the illuminating light flux enters the eye of a patient and illuminates the fundus of the eye through the optical system of the eye under investigation. An image of the diaphragms, net, and slit of the control unit 2 is formed at infinity and projected on the fundus of the eye with the optical system of the investigated eye itself. The image of the fundus of the eye is projected in the reflected light by the optical system of the eye and objective 12 on the CCD matrix or photocathode of the electrooptical transducer, is reproduced on the screen of the monitor (or on the electrooptical transducer screen, and observed through the ocular).

The optical light filters are chosen in the way to provide the need spectral range of light illumination. In case of need, one of the correcting lenses 6 is added to bring the picture of the examined portion of the fundus of eye into sharp focus.

To do the examination of the front part of an eye it is necessary to use correcting lenses  $+15$  or  $+20$  diopters.

The observation angle is low (about 6 degree). That fact is the limitation factor for using of such traditional optical system for realization of our goal for development of the experimental instrument for visualization of optical disk as practical illustration of structure of retina for students.

*The method of indirect illumination of eye fundus through the sclera and skin covers the sclera (not through a pupil).*

The given method is realized with use of a set of original devices: ring and cylindrical light sources (LED or halogen lamp) of a visible and infra-red range up to 1200 nm.

The fundus system for eye observation FS 11 is the hand-held non-invasive video fundus camera for eye observation which can be used for eye observation on the base of transscleral illumination technology. The absorption coefficient in the range of 400–1200 nm varieties from 10 % up to 70 % according to the various experimental and theoretical data).

Calculations of the transmission spectra of the sclera in the visible and near-infrared (0.6–1.1  $\mu\text{m}$ ) without interference effects caused by the short-range order scattering particles within the model of Hart-Farrell taken into account, is shown in Fig. 2 (the sclera is modeled as a monodisperse system of ordered and oriented along the surface long non-absorbing dielectric cylinders) [5].

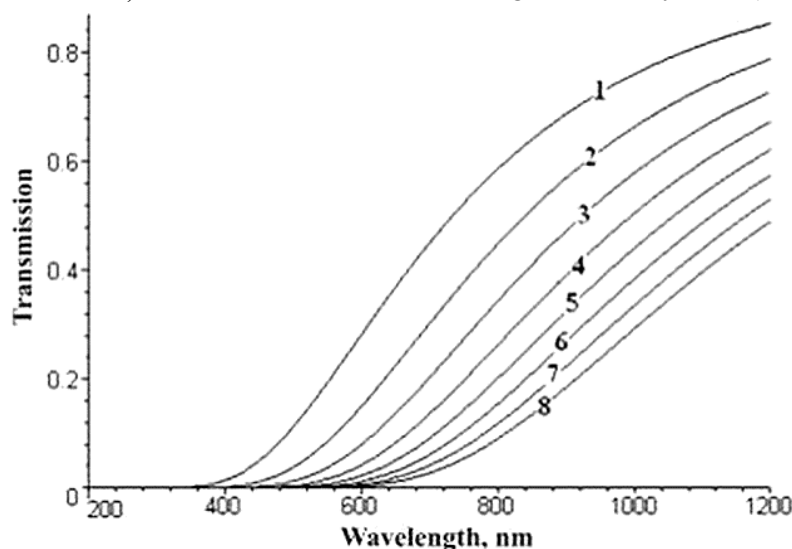


Fig. 2. Transmission spectra of the sclera in the range 200–1200 nm for different thickness of the sclera: 1 — 0.4; 2 — 0.6; 3 — 0.8; 4 — 1.0; 5 — 1.2; 6 — 1.4; 7 — 1.6; 8 — 1.8 mm (collagen fibers diameter  $2a = 26$  nm) [5]

The method of indirect illumination of eye fundus through the sclera and skin covers the sclera (not through a pupil) allows essentially to expand a field of a review eye fundus with complete absence of reflexes from a cornea.

The transmission coefficient of the sclera in the IR region is much larger than in the visible range, and can exceed 10 %, which is sufficient for transillumination and obtaining optical disk images with illumination not through the pupil.

The method allows visualizing tumors hidden under the serous retinal detachment without contrasting vessels, and can be used for early diagnostics of pigmented lesions (nevi), tumors, and pigmentation anomalies of the fundus.

Thus, the transmission in infrared region is much larger than in visible range. That feature is the base for visualization of optical disk for practical illustration of structure of retina.

The main features of the method are: ability to examine mydriasis with a wide field of view and ability to obtain different images of fundus structures with selective change in the wavelength of the radiation source. Thus, the main advantage of indirect (transscleral) illumination technology is the absence of reflected light from cornea and as the result — large viewing angle (more than 45 degrees).

The experimental model of the system on the base of fundus systems for eye observation FS 11 and IRIS is shown in Fig. 3.

The experimental system consists of the video camera (IRIS), monitor and led transilluminator (fundus system FS11). Radiation of LED transilluminator (visible and NIR range) is directed

at the edge of the lower or upper eyelid with the temporal side and diffusely illuminates the fundus through the tissue and the medium adjacent to the sclera. Even and diffuse illumination of the eye tissue occurs due to the effects of multiple scattering and reflection of internal biological tissues (retrobulbar tissue, sclera, etc.) from the posterior pole of the eye, and in part due to the electromagnetic radiation passing through the sclera and vitreous body and falling on fundus at different angles (front side light). From the scattered and reflected radiation on the fundus structures the optical system builds an actual image in the matrix of a receiver and displays the resulting image on the monitor in real time. The developed instrument can be used in a future in the course of Physics (Optical systems) for practical using of students. One of the main features of the present instrument is that during infrared light scoping there is no narrowing myosis and flash blinding from the bright light of the visual range (Fig. 4–5).

Besides, the images received in infrared light can provide information about the structure of retina and can be used in a future in the course of Physics (Optical systems).

Also it is perspective for using in education process the new innovative technology for self-visualization of retina vessels (Fig. 6–7) and central part of retina (macula — the most important area for vision), which can be realized using fundus system FS 11 (Led auto-ophthalmoscope Pluto).

The characteristics of instrument was developed for realization of maximum contrast of retina vessels and in the perspective will be used by students of medical and biophysics specialties.



Fig. 3. The experimental model of the system for visualization of optical disk for practical illustration of structure of retina on the base of fundus system for eye observation FS 11

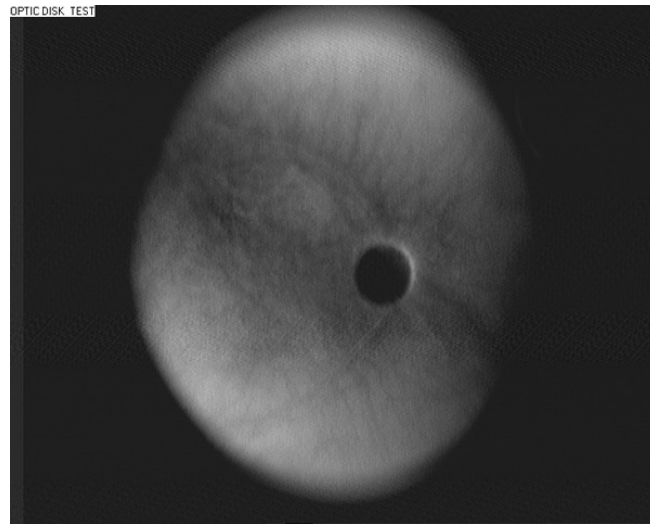


Fig. 4. Image of the optical disk (blind spot) eye using the method of indirect illumination eye fundus through the sclera and skin covers the sclera (infrared Led transilluminator of the fundus system FS11 — 940 nm)

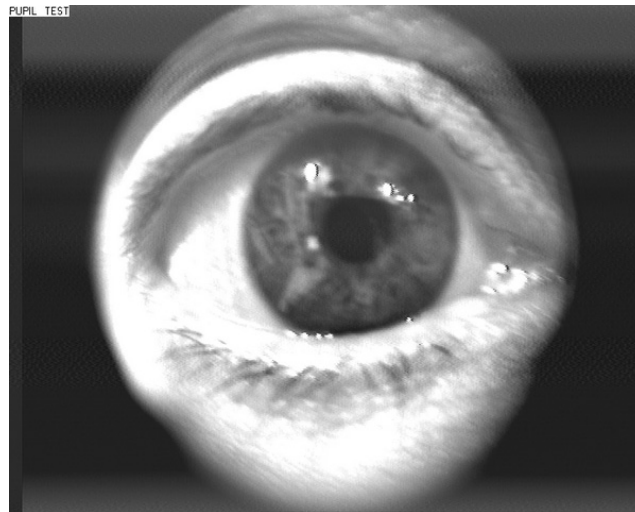


Fig. 5. Image of the pupil of eye by using of the experimental model of the system



Fig. 6. Self-visualization of retina vessels and central part of retina (macula – the most important area for vision), which can be realized using system FS 11 (Led auto-ophthalmoscope Pluto)

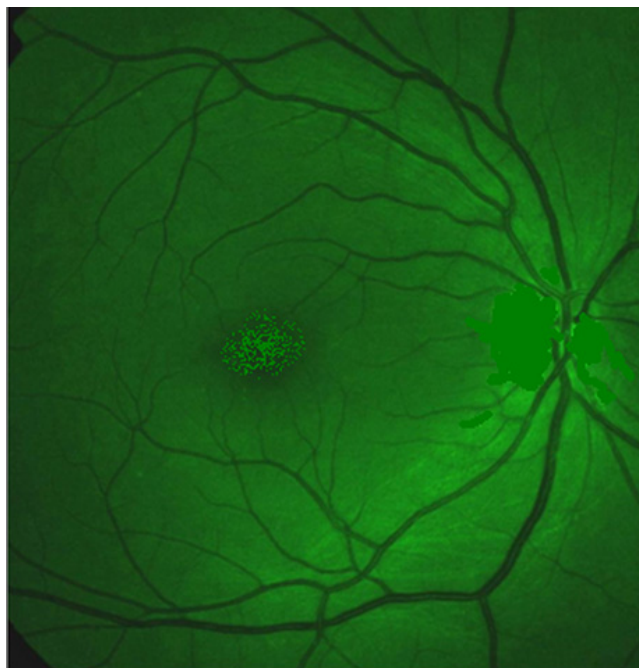


Fig. 7. The pattern of retina vessels and central part of retina (normal eye)

### Conclusion

The indirect illumination of eye fundus through the sclera and skin covers the sclera (not through a pupil) in infrared spectral range will allow to expand opportunities of visualization of optical disk for practical illustration of structure of retina. The developed model of the instrument can be used for practical using of students in the course of Physics (Optical systems). The aim of the next step of investigations is to develop technology for visualization in natural (usually used) conditions of illumination.

### Acknowledgements

The authors thank prof. Igor Zozulenko for useful advice and support of the project.

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Стаття надійшла до редакції 11.03.16