Refractometry

The main directions of using light refraction in biomedical research in medicine:

- Performing quantitative measurements of the refractive index of the substances under study - refractometry: a refractometer is used to quickly determine the concentration of aqueous, alcoholic, ethereal and other solutions by refractive index (in medicine, these devices are used to determine the total amount of protein in the blood and its individual fractions in the analysis of gastric juice, urine and other substances);
- Transmission of light fluxes with the help of fiber optics to the patient;
- Illumination of hard-to-reach areas when performing manipulations (for example, when intubating patients for artificial respiration during surgery);
- Intravascular blood irradiation with laser light in the treatment of patients with myocardial infarction, intrapulmonary ultraviolet irradiation in the treatment of tuberculosis;
- Transmission of images of internal organs (fiber endoscopy): for visual diagnostics of the state of tissues of internal organs by introducing an endoscope (fibrogastroscopy); through a skin incision (laparoscopy); when taking biopsy material in selected areas; during treatment with laser irradiation of certain areas of internal organs.

A light wave, reaching the interface between two media, excites forced vibrations of electrons with a frequency equal to the frequency of the incoming wave in atoms, ions, molecules of the substance; these vibrations are coherent both with each other and with the incident wave. As a result of the superposition of the primary and secondary waves (Fig. 1), a reflected wave Φ_{refl} and a refracted wave Φ_{refr} are formed, propagating in the second medium.

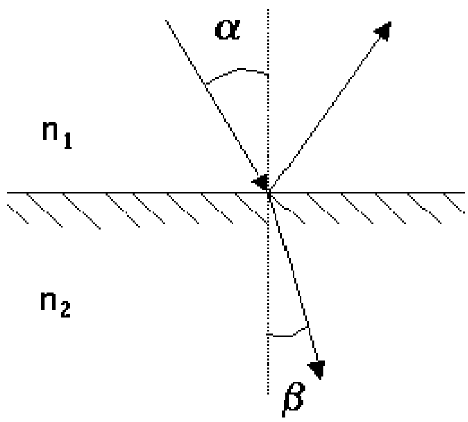

Fig. 1. Propagation of the light flux at the interface between the two media.

Refraction of a ray of light during the transition from one medium to another is due to a change in the speed of the light wave. The speed of light will be maximum under vacuum conditions (υ_{max} = c = 300,000 km / s).

The higher the density of the medium, the lower the speed of light in it. The absolute refractive index of a medium n_{abs} shows how many times the speed of light in a vacuum is greater than the speed of light in a given medium.

$$n_{абс} = \frac{c}{\upsilon} \quad (1)$$

Along with the absolute refractive index, the relative refractive index is used as a characteristic of the optical density of the media, which is equal to the ratio of the absolute refractive indices of the media under study:

$$n_{отн} = \frac{n_2}{n_1} = \frac{c \cdot \upsilon_1}{c \cdot \upsilon_2} = \frac{\upsilon_1}{\upsilon_2}, \quad (2)$$

Where $n_1 = \frac{c}{\upsilon_1}$ is the absolute refractive index of the first medium,

$n_2 = \frac{c}{\upsilon_2}$ is the absolute refractive index of the second medium.

The path of the rays in Fig. 1 illustrates the following laws of light refraction:

1. A ray incident on the interface between two media, perpendicular to the surface at the point of incidence of the ray, and the refracted ray lie in the same plane.
2. The ratio of the sine of the angle of incidence α to the sine of the angle of refraction β of the rays for these two media is a constant value equal to the relative refractive index of the second medium relative to the first:

$$\frac{\sin\alpha}{\sin\beta} = n_{21} \quad (3)$$

Media with a higher refractive index are called optically denser.

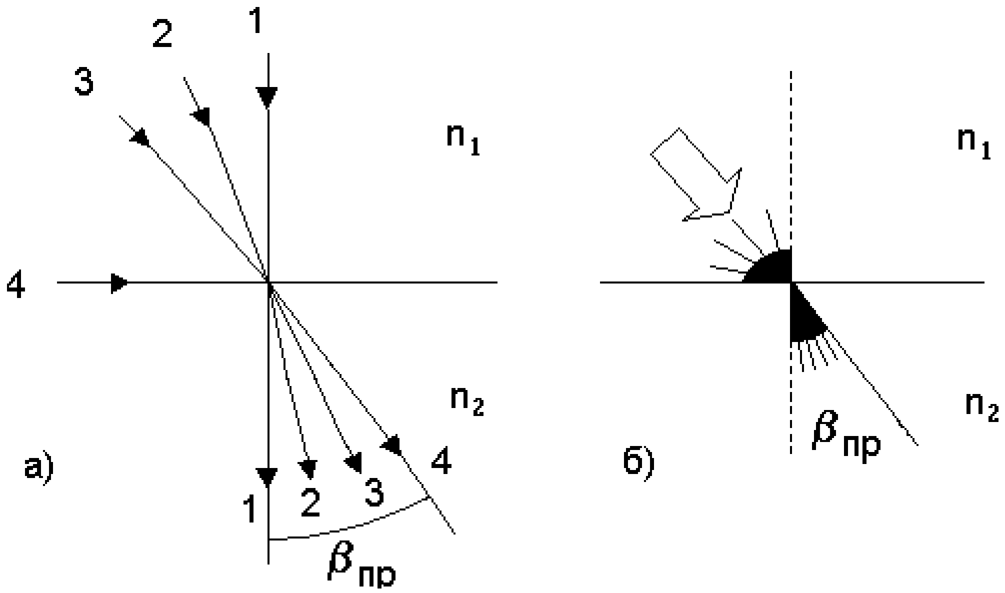

Fig. 2. Refraction of light during the transition from a less dense medium to a denser one (n_1 <n_2); a - for individual rays; b - for
flux of rays with angles of incidence from 0 to 90^0.

If light passes from an optically less dense medium to an optically denser medium (Fig. 2), then the angle of refraction is less than the angle of incidence (ray 2 - 2, 3 - 3). With an increase in the angle of incidence to 90^0 (beam 4 - 4), light in the second medium will propagate only within the angle β, called the limiting angle of refraction.

The limiting angle of refraction can be determined from the condition:

$$\frac{\sin 90^0}{\sin\beta_{refr}} = \frac{n_2}{n_1}, \qquad (4)$$

since $\sin 90^0 = 1$, then $\sin\beta_{пр} = \dfrac{n_1}{n_2}$ ... (5)

If the beam passes from an optically denser medium to an optically less dense medium (Fig. 3), then the angle of refraction is greater than the angle of incidence. With an increase in the angle of incidence, the refracted ray comes closer and closer to the interface between the media and slides along it at α_{lim} (ray 3 - 3). This phenomenon is called total internal reflection, and the angle of incidence α_{lim} is the limiting angle of total internal reflection.

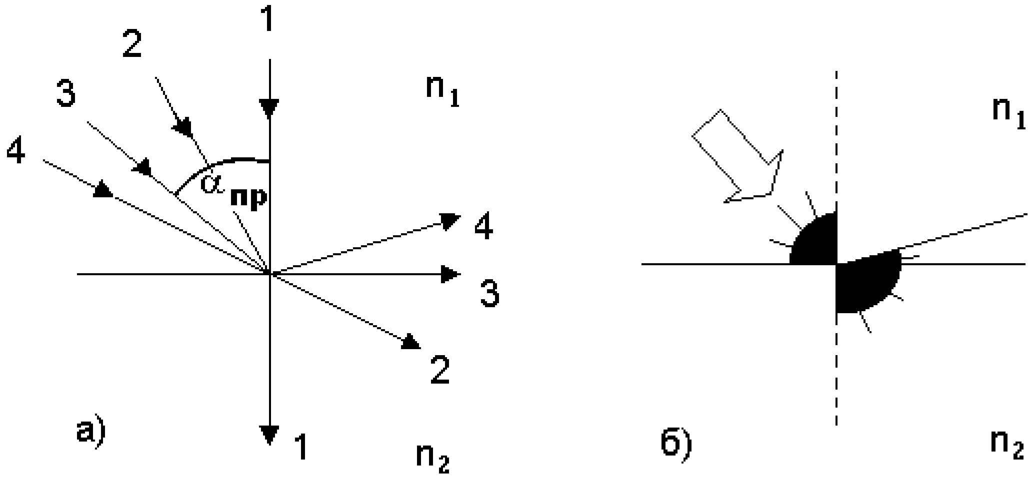

Fig. 3. Refraction of light during the transition from a denser medium to a less dense one (n1> n2); a - for individual rays; b - for a stream of rays with angles of incidence from 0 to 90^0.

This angle can be found from the condition:

$$\frac{\sin\alpha_{пр}}{\sin 90^{0}} = \frac{n_2}{n_1}, \qquad (6)$$

since $\sin 90^0 = 1$, then $\sin\alpha_{lim} = \frac{n_2}{n_1}$ ... (7)

For these two media, due to the reversibility of the ray path, the limiting angle of refraction of the first medium is equal to the limiting angle of reflection of the second medium.

Fiber optics widely used in medicine is based on the phenomenon of total internal reflection. Fiber optics refers to the branch of optics that deals with the transmission of light and images through optical fibers. Light falling inside a transparent fiber surrounded by a substance with a lower refractive index is repeatedly reflected and propagated along this fiber.

To transmit the image, the fibers are formed into beams in a strict sequence (the order of the fibers at the input and output of the fiber must be the same). The principle of image acquisition is that each fiber transmits only a fragment (light or dark point at the end of the fiberglass) of the entire picture. The complete image is "collected" at the end of the beam from points such as a mosaic. Therefore, the smaller the diameter of the light guides entering the fiber endoscope, the higher the image clarity.