G. A. **Askar'yan.** *Possibilities for enhancement of the transmission of light and other forms of radiation through soft turbid physical and biological media.* The problem of light scattering in turbid media has acquired new interest with the discovery of the biostimulated action of low intensity laser and narrowband radiation. It has been found, in particular,[1-3] that radiation from a helium-neon laser at $\lambda \approx 0.63$ μm and power no greater than 10 mW is capable of initiating and accelerating healing of trophic ulcers, festering wounds, stomach ulcers, etc. However, the small depth of attenuation of this radiation in the tissues ($z_s \approx 1-2$ mm) means that such treatment can be used effectively only for superficial or intracavity irradiation at small depths.

An essential characteristic of these media—their softness or compliance under pressure—has not been taken into account in penetration estimates. This paper is devoted to possible ways of increasing the penetration of light through soft turbid physical and biological media (for details see Ref. 4).

Porolon was chosen as a first model of a soft turbid physical medium. The transmission of light from an LG-75 helium-neon laser with a power of 10–15 mW through a layer of Porolon with an initial thickness $z_0 \approx 25$ mm was investigated with the material pressed between a glass plate and a Plexiglas cylinder, through which the laser beam was passed. The patch of scattered light was observed to shrink and its intensity to increase under compression. This improvement in transmission was measured by a photomultiplier onto the photocathode of which light from the center of the spot was directed through a hole in the end of the PM case or through a lightguide. Figure 1a shows the increase of the intensity I at the center of the spot as a function of the thickness z of the compressed layer, and Fig. 1b the decrease in the dimensions of the spot on compression, (exposure 1/500 sec). A 30–40-fold brightness increase was registered when the Porolon layer was compressed to one-tenth of its original thickness. A relation of the form $I \sim z^{-\alpha}$ gave $\alpha \approx 1.2$.

The intensity increases on compression of the layer were estimated for various models: multiple scattering at small angles ($\theta_s^2 \approx z/z_s$, $z_s \sim 1/n\sigma_s$, where n is the concentration of scattering centers. For $nz \simeq$ const, the area of the spot $s \approx (z\theta_s)^2 \sim z^2$ i.e., $\alpha \simeq 2$) for strong diffuse spreading, etc. The exponent α could vary from 1 to 2, depending on the variant. Typically, strong compression is required to obtain a significant intensity increase in physical media, and this would hardly be acceptable for biological tissues.

However, investigation of biological tissues (the palm of the hand, soft tissues) indicated a much stronger effect—a 30–50-fold intensity increase was observed even under mildly uncomfortable pressure reducing the thickness of the hand at the center from 2.5 to 2 cm. The photographs in Fig. 2 show the increased transmis-

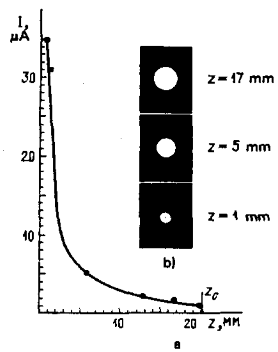

FIG. 1. Increase of intensity of light on compression of Porolon layer. a) Intensity I at center of spot as a function of the thickness z of compressed medium; b) photograph of scattered-light spot with Porolon compressed between glass and Plexiglas cylinder 10 mm in diameter. The diameter of the lower, small spot is 15 mm; exposure 1/500 sec.

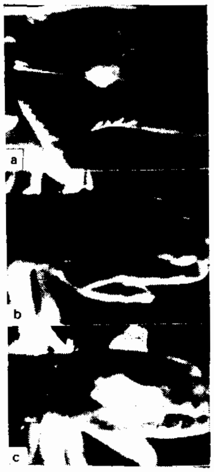

FIG. 2. Transmission of light with pressure exerted on palm of hand. a) transmission of light with glass rod pressed against palm (laser light from dorsal side of hand); b) hand without pressure (laser light from palm side); c) same, but with palm pressed against Plexiglas-cylinder lightguide. Exposure 30 sec.

sion of the palm when a glass rod is pressed into it (the beam is being projected onto the dorsal surface of the hand) (Fig. 2a) and when the palm is pressed against a lightguide (Fig. 2c) (exposure times 30 sec). It was found that the enhanced transmission persists for 2–3 sec after removal of the pressure. This sharp increase in the transparency is apparently due to the heterogeneity of the tissues—by displacement of tissues and blood from the tissue in the region under pressure. This displacement, which is not uniform over volume is similar to what causes whitening of the palms, nose, or cheeks when they are pressed against glass. It is possible to modulate the pressure in such a way as to obtain transmission increase and normal functioning of the tissues by turns.

The transmission enhancement under pressure enables us to increase the intensity of radiation at depth and to apply the doses necessary for therapeutic effects deep in the body.

It may be possible to conduct radiation into deep tissues by an even more radical and effective method: by the use of "light syringes" that guide the light through a channel in the needle by reflection from the walls of the channel or from the walls of the central filament of a length of lightguide inserted into the needle. A liquid can be injected to move the tissues away from the tip of needle, thus making it possible for the light to spread out and preventing concentrated light from contacting the tissues.

Clearly, all the above applies not only to laser, but also to any other type of optical radiation; however, transport through the needle is more effective in the case of laser beams because of their good focusability. Similar procedures can also be applied with ionizing radiation (charged particles, beams), ultraviolet, x-ray, and gamma photons, and radio emission, since the techniques used not only reduce the size of the scattering spot, but also lower absorption by displacing some of the matter from the path of the radiation.

The effects described above can be used for deep treatment of internal diseases (for example, neuroinfective diseases of the spinal cord) when it is desirable to increase the resistance and activity of cells and for mytogenetic and bactericidal effects, especially in cases when the area to be irradiated is known from the symptoms of the disease or from diagnostic procedures.

The described phenomena may be useful for intrascopy and the optics of strongly scattering media. We note that transmission by media may be enhanced by various mechanisms under pressure, mechanisms that involve for example, not only shortening of the path of the radiation but also tight packing of the scattering centers (when many of them are squeezed into each wavelength and the medium comes to resemble a homogeneous medium with an averaged dielectric permittivity), as well as changes in the scattering characteristics that result from changes in the shape and orientation of the scattering centers. All these processes are different in different regions of the spectrum and must be investigated.

[1]Elektronnaya promyshlennost', 1979, No. 8–9: V. P. Vyzhelevskiĭ *et al.*, Low-power laser for treatment of trophic ulcers, festering wounds, and bond fractures (p. 72); G. V. Boyarskiĭ *et al.*, The mechanism of the biological effects of laser radiation (p. 77); I. I. Kosarev *et al.*, Use of low-intensity red laser in surgery, and other articles in this issue.

[2]Elektronnaya promyshlennost', 1981, No. 5–6: A. P. Gushcha *et al.*, Use of laser radiation to stimulate regeneration processes. . . (p. 150) and other articles in this issue.

[3]Lasers in Photomedicine and Photobiology/Editors R. Pratesi and C. A. Sacchi. Springer-Verlag, Berlin; Heidelberg; New York, 1980. (Optic Sciences. Vol. 22).

[4]G. A. Askar'yan, Transmission of optical and laser radiation through turbid physical and biological media. Possibility of intensifying transmission through soft media: FIAN SSSR Preprint No. 55, Moscow, March 1982; Kvantovaya Elektron. (Moscow) **9**, 1379 (1982) [Sov. J. Quantum Electron. **12**, 877 (1982)].