Check Your Eyes

As a second example I would like to describe how laser light may be used to check the eyesight of an individual. While working with an expanded laser beam, we explored some of the many fascinating phenomena that occur with coherent light. One was particularly intriguing and has become a delight for visitors and staff alike. When laser light is reflected from a diffuse surface it appears grainy, much like sandpaper. The grainy texture results from the interference of light coming from different parts of the diffuse surface. The position of the eye, more specifically the retina, determines whether the interference is constructive or destructive, resulting in bright or dark spots respectively.

The practical experiment: A laser beam is expanded and pointed toward a piece of paper to make a spot several centimeters in diameter. The spot is observed from a distance in excess of 1 m. The grainy texture, resulting from interference, will be easily visible regardless of eyesight. A sideways swaying motion of the observer will cause the interference pattern to move across the retina. It is best to observe with each eye individually, cupping the other eye carefully to avoid distorting the lens. If the grains appear to be moving in a direction opposite to the swaying motion, the observing eye is nearsighted and visa versa for a farsighted eye. Should the vision be correct for the color of the laser, the grains will appear to be moving randomly. For an astigmatic eye, the grains will move diagonally across the retina in response to a horizontal swaying motion.

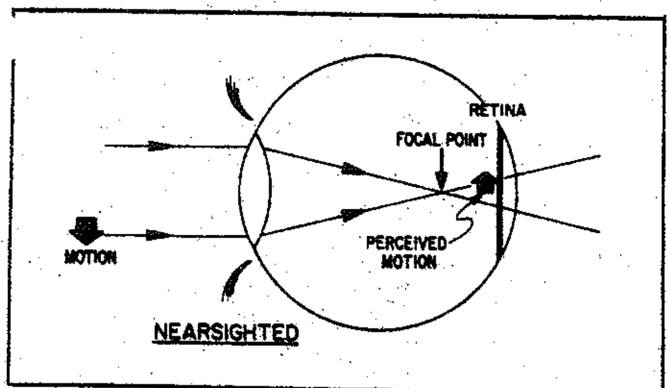

Fig. 6. A nearsighted eye is shown with the focal point between the lens and the retina. The sense of motion is reversed on opposite sides of the focal point.

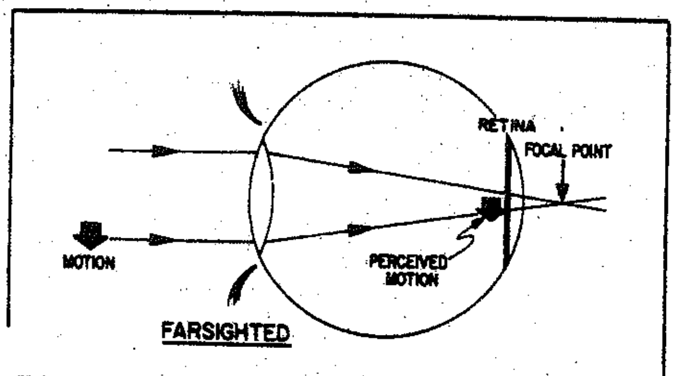

Fig. 7. A farsighted eye is shown with the focal point behind the retina. Since the retina and the source of motion are on the same side of the focal point, there is no reversal.

Figures 6, 7, and 8 illustrate the reason for the above described behavior. In the case of nearsightedness, the focal point is in front of the retina and any sense of motion is reversed. The reverse applies for farsightedness. In the case of astigmatism the eye is radially not symmetric and thus does not preserve the plane in which the motion takes place. This translates a horizontal motion into one which includes a vertical component.

The eye, like other lenses, suffers from chromatic aberration (see Fig. 9) and will focus blue light closest to the lens and red furthest from it. If a red laser is used for the examination and the subject

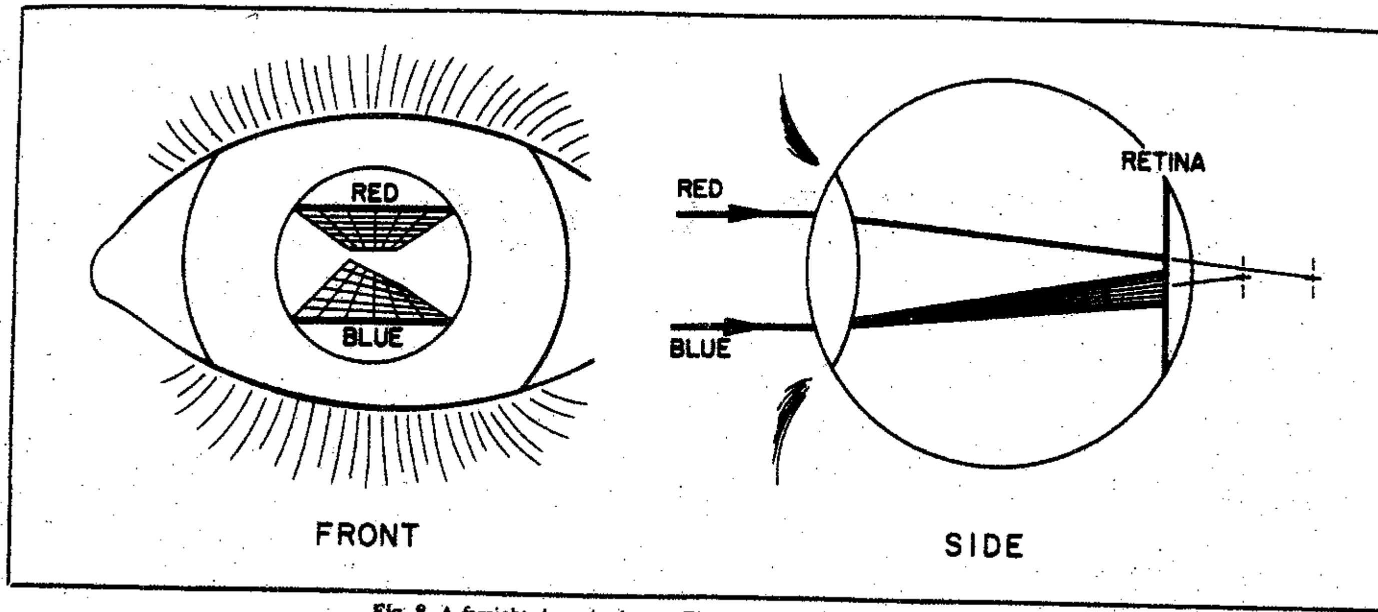

Fig. 8. A farsighted eye is shown. The chromatic aberration is evident by the different focal point for the blue and red light rays. The figure also illustrates astigmatism for blue light but not for red light, as was implied for some observers.

has correct vision, the test will indicate farsightedness. The examination should of course be performed with and without corrective lenses to ascertain if the correction is sufficient. If several colors of laser light, preferably blue, green, and red, are available, the eye tests become more interesting and precise. In that case blue and red should indicate near and farsightedness respectively, green should be correct vision. In addition to the chromatic aberration of the eye, the asymmetry can also be color sensitive. On several occasions we have found a person with glasses that were corrected for astigmatism, but by testing them without their glasses, we found that the person did not have astigmatism in the red. Further testing with their corrective lenses on would show astigmatism in the red. Retesting by their opticians confirmed their astigmatism in the center of the visible spectrum and their need for lenses with correction for astigmatism. We have also found people that were clearly astigmatic in the red, but according to their opticians they needed no correction for astigmatism. We conclude that optical asymmetry of the eye can be quite different in different parts of the spectrum (Fig. 8). In the vast majority of cases, however, our diagnosis in the red agrees with the prescription obtained from opticians who test in the center of the optical spectrum. □

References

1. Rock Physics Laboratory, CIRES Campus Box 449, Univ. of Colorado, Boulder, CO 80309.
2. Charles M. Vest, *Holographic Interferometry*, (Wiley, New York, 1979).
3. Yue-Pyng Hwu, "*Holographic Interference Fringes by Thermal Deformation*." Phys. Teach., 18, 295 (1980).
4. Philip F. Schewe, *Phys. Teach.*, 19, 534, (1981).
5. K. Kurita, P. L. Swanson, I. C. Getting and H. Spetzler, *Geophys. Res. Lett.*, 10, No. 1, (1983), p. 75.
6. M. D. Meyer and H. Spetzler, *Experimental Mechanics*, Vol. 16, No. 11, (1976), p. 434.
7. H. Spetzler, I. C. Getting and R. J. Martin, III, *High-Pressure Science and Technology*, Vol. 1, 1979 (Plenum Publish. Co., New York, NY) pp. 883-889.
8. R. F. Spetzler and H. Spetzler, *Journal of Neurosurgery*, Vol. 52, No. 6, (1980).

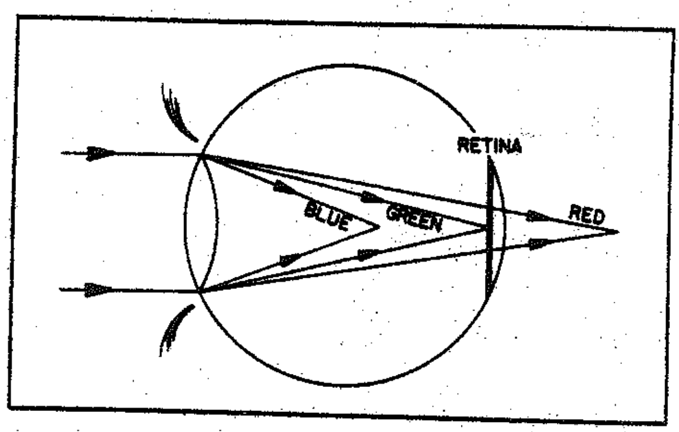

Fig. 9. The focal points for this eye are placed to show their relative positions in an eye needing no correction for perfect vision. Light from the middle of the spectrum is green and focuses on the retina, while blue and red focus in front of and behind the retina, respectively.