Demonstrating induced birefringence in stressed glass

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A mechanical stress applied to an isotropic transparent material makes it weakly optically anisotropic with characteristic birefringent properties.[1] To spatially separate the ordinary and extraordinary components for this induced birefringence, Fresnel constructed, in 1822, a multiple glass prism that yielded a slight separation of the two images when an individual viewer observed a distant light source along the prism assembly axis.[2]

To demonstrate Fresnel's photoelastic experiment for group viewing requires significant enhancement of the angular separation of the double image. This can be achieved by the astronomical telescope method we presented in Ref. 3 for viewing Fresnel's optical activity experiment.

For the prism array, we use glass Porro prisms (90°–45°–45°) measuring 40 mm×29 mm×29 mm with thickness 20 mm. At least five prisms[4] are needed—the more the better—configured as in Fig. 1. A smeared glycerin drop helps maintain contact between adjacent prisms. Mechanical stress must be applied to the odd-numbered prisms. This is done by setting the prism array into a U-shaped rigid frame with pressure screws acting (transverse to the array axis) on triangular pieces of iron[5] on the appropriate prism faces. See Fig. 2.

The experimental layout is shown in Fig. 3. The light source is a 10- to 20-mW laser—a less powerful laser may suffice but with less clear results. The polarizer is oriented at 45° to give an equal mix of horizontal and vertical polarization and also to provide a polarization direction against which to analyze the polarization properties of the output image at the screen. The converging lens is optional—it may help in keeping the source beam narrow.

First, set up the experiment as in Fig. 3 but without applying transverse pressure on alternate prisms in the prism assembly. Adjust to obtain a clear, narrow image of the pinhole or slit on the viewing screen—for example, by changing slightly the distance between the doublet objective and the eyepiece in the telescope assembly (see Fig. 2 of Ref. 3) or by squeezing out the air bubbles in the glycerin smeared between adjacent prisms. Once the single image is clear, apply the transverse pressure via the pressure screws. Now instead of one image on the screen there appear two.

For compressed glass, the ordinary index of refraction, n_o, is slightly greater than the extraordinary index of refraction n_e. This yields a greater refractive deviation for the

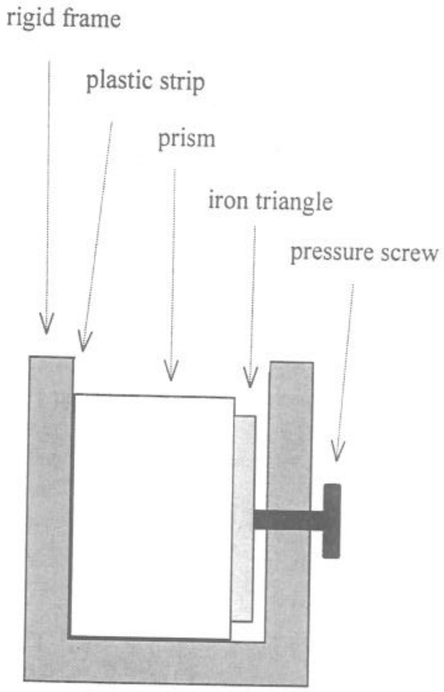

Fig. 2. Cross section of the prism assembly at a stressed prism.

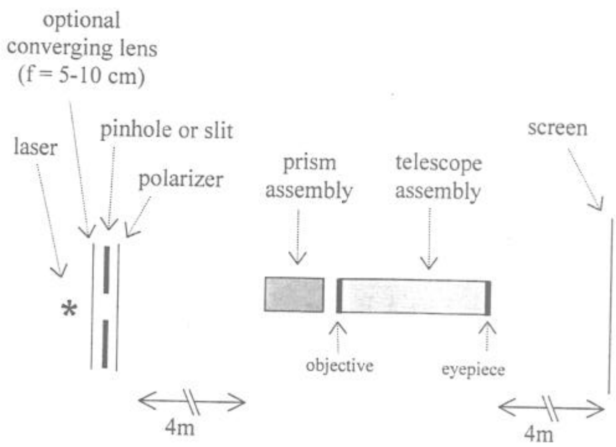

Fig. 3. Experimental layout.

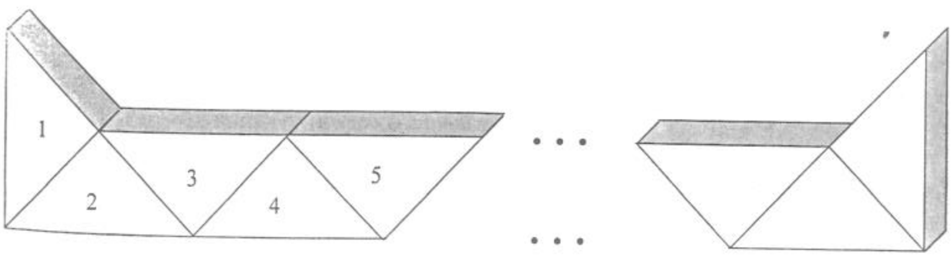

Fig. 1. Multiple Porro prism array.

ordinary wave traversing a stressed prism than for the extraordinary waves. The telescope (with an objective focal length $f_{obj}=40$ cm and an ocular focal length $f_{eye}=2$ cm) enhances the angular separation between the ordinary and extraordinary image by a factor of about $f_{obj}/f_{eye}=20$. The two images are spatially distinct on a screen 3–4 m distant from the telescope. It is now straightforward to examine the polarization properties of each image and show that they are as expected.

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[1]E. Hecht, *Optics* (Addison–Wesley, Reading, MA, 1987), p. 315.
[2]A. J. Fresnel, ''Note sur la double refraction du verre comprime,'' Ann. Chim. Phys. **XX**, 376 (1822).
[3]B. S. Perkalskis and J. R. Freeman, ''Demonstrating Fresnel's model for optical activity,'' Am. J. Phys. **66** (5), 452–453 (1998).
[4]A commercial source is: Edmund Scientific Company whose website is at http://www.edsci.com; another option for getting Porro prisms is to take apart binoculars.
[5]A triangular metal piece serves to distribute the pressure uniformly on the prism.

FITS OF EASY TRANSMISSION AND REFLECTION

When you look out into the street through a window of an evening, you will see yourself reflected in the window, and yet the passers-by can see you, too. That's quantum mechanics in action: the same causes, apparently, do not always have the same effect.

Clearly, you do not need an expensive laboratory or a huge accelerator to see quantum effects. A healthy dose of curiosity will do very well; I think that it will in fact do much better, at a fraction of the price and at a billion times the enjoyment.

Vincent Icke, *The Force of Symmetry* (Cambridge University Press, Cambridge, 1995), p. xiii.