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BIREFRINGENCE OF MICROWAVES

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STUDENTS do not find it easy to comprehend topics in crystal optics such as circular and elliptic polarization. It may be advantageous to demonstrate these phenomena in the microwave range. Since the preparation of sufficiently large crystalline plates presents a complicated problem, we used wood as the doubly refracting material. A board cut in the usual manner (along the grain) corresponds to a crystal plate cut parallel to the optic axis. If we have, in addition, a circular piece of wood cut perpendicular to the grain and another cut at the angle 45° to the grain, we can reproduce most of the experiments that are considered in a course on crystal optics.

The experiments are performed with crossed horn antennas of a klystron transmitter and receiver, respectively ($\lambda = 3.2$ cm). For convenience the broad sides of the horns form the angle 45° with the horizontal. Voltage from the detector is fed to a 28-I amplifier and then to an EO-7 oscilloscope with its sweep switched off. With crossed antennas the received amplitude is zero. Now a pine plate about 45 mm thick is placed in the path of the wave front close to the transmitting horn; this corresponds to a $\lambda/4$ plate. When the wood grain ("the optic axis of the crystal") is parallel or perpendicular to the direction in which the electric vector of the electromagnetic wave oscillates, the reception level is still zero. The plate is then turned so that its grain is horizontal and forms an angle of 45° with the direction of oscillation. In this case the plate transmits two waves that are polarized perpendicular to each other—an ordinary and an extraordinary wave—and an appreciable amplitude reaches the receiver. By rotating the receiving horn about the ray as its axis, we prove that the resultant wave is circularly polarized since the received amplitude is identical at all angles of the antenna. By changing the angle between the grain direction and the electric vector we obtain an elliptically polarized wave. We now position one more plate 45 mm thick in the path of the wave; this is also a quarter-wave plate. By rotating the receiving horn we find that when the broad sides of the two horns are parallel the received amplitude is zero. We thus again have a linearly polarized wave oscillating perpendicular to the original electric vector direction. * In addition to the analysis of a circularly polarized wave, this experiment provides an acquaintance with the functioning of a half-wave plate ($2\times\lambda/4$).

For the analysis of an elliptically polarized wave we prepared a compensator made of two wedges obtained by cutting along the diagonal of a 500 × 200 × 100-mm wood block.† Varying the thickness of the compensator by sliding a wedge, we can transform an elliptically polarized wave into a linearly or circularly polarized wave. A plate with vertically oriented grain and a wedge having horizontally oriented grain comprise a Soleil plate (Fig. 1).

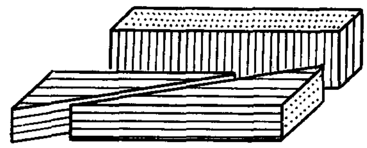

FIG. 1.

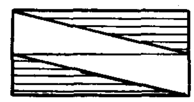

FIG. 2.

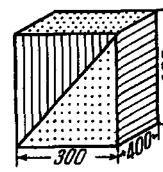

FIG. 3.

An experiment with a plate cut perpendicular to the axis of a block indicates the complete absence of birefringence as the plate is rotated around a ray that is parallel to the wood grain.

A plate ~ 200 mm thick cut at 45° to the "optic axis" yields both the ordinary and extraordinary waves when the initial wave impinges normally on it. When the wood grain is horizontal the two rays are parallel to each other in a horizontal plane, the extraordinary ray being shifted laterally. In this experiment the transmitting horn is inclined at 45° to the horizontal (the principal cross sectional plane of the plate). The receivers are now two "point" probes, oriented vertically and horizontally, respectively. The first probe is moved until it locates the point at which the ordinary wave has its maximum amplitude. With this probe remaining fixed, the second probe is moved until it detects the maximum of the extraordinary wave. The spatial separation of the two differently polarized waves is thus demonstrated visually. A greater separation is obtained with a wooden Wollaston prism (Fig. 3) oriented to yield horizontal emerging rays.

The plates must be made of dry knotfree wood; cedar, fir, or pine is suitable. When the electric vector is perpendicular to the grain even thicknesses of about 200 mm absorb very little of 3-cm radiation.

Using 45-mm thicknesses, we obtained a magnitude for the birefringence in wood:

$$(n_e - n_0)_{\text{eff}} = \frac{32}{4 \cdot 45} = 0.18.$$

Since the values for different kinds of wood can differ considerably, wedges should be prepared first and then used to determine the thickness of a quarter-wave plate.

Translated by I. Emin

*This experiment is successful only in the case of very small absorption.

†The wedges can be cemented conveniently to two boards with the arrangement shown in Fig. 2. The two wedges together then form a plane-parallel plate for any displacement of the boards along their line of contact.