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**Abstract**

**Full Text**

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## ROTATION OF THE PLANE OF POLARIZATION OF LIGHT BY CRYSTALS UNDER THE ACTION OF AN ELECTRIC FIELD

*(Presented by Academician A. V. Shubnikov, 8 VI 1964)*

In a plane-parallel  $z$ -cut plate of a tetragonal crystal of symmetry class  $\bar{4} \cdot m$  (of the ADP type), when it is acted upon by an electric field directed along the optical axis  $z$ , one can observe the phenomenon of rotation of the plane of polarization of light in directions parallel to the coordinate planes  $xz$  and  $yz$ , and making such angles with the optical axis  $z$  of the crystal that the path difference of the rays in the plate is equal to an odd number of half-waves. In practice this phenomenon can be detected by considering the conoscopic pattern (Fig. 1a) formed by such a plate in crossed polarizers ( $P$  and  $A$ ), with the axes  $x$  and  $y$  parallel or at an angle of  $45^\circ$  to the directions of vibration in the polarizers. The points of intersection of the circles passing through the middle of the bright rings of the conoscopic pattern and corresponding to directions of light in the plate with path differences of the rays equal to an odd number of half-waves  $\lambda/2$ , with mutually perpendicular straight lines passing through the center of the conoscopic pattern and parallel to the axes  $x$  and  $y$ , correspond to the indicated directions of the rays in the plate. When the plate is set with the axes  $x$  and  $y$  parallel to the directions of vibration in the crossed polarizers, these points will be dark and will be located on the arms of the cross of the conoscopic pattern (Fig. 1a). In the case of rotation of the plate through an angle of  $45^\circ$ , these points, on the contrary, have maximum illumination. Under the action of an increasing electric field, these points in the first case become illuminated (Fig. 1b), while in the second their illumination decreases. With a field of moderate intensity ( $E = 10 \text{ kV/cm}$ ), at which the path difference arising along the optical axis  $z$  does not exceed  $0.1\lambda$ , by rotating the analyzer through an angle within  $11^\circ 20'$  the points illuminated in the first case can practically be extinguished again, while in the second case the reduced illumination of the points can be restored to the initial one, since the ellipticity of the vibrations arising upon rotation of the plane of polarization does not exceed 0.6% for a plate thickness of 2 mm. At higher voltages, however, the ellipticity will increase rapidly, and by rotating the analyzer it is no longer possible to establish the initial darkness or maximum illumination of these points. Until now no one has paid attention to the change in illumination at the indicated points of the pattern and to the possibility of its considerable, though partial, compensation by rotating the analyzer.

Fig. 1 and Fig. 2

Figure 1: Fig. 1 and Fig. 2

In order to observe the phenomenon discovered by us more distinctly and to make it quite obvious, two  $z$ -cut plates of a KDP crystal, identical in thickness (9 mm), were used; these were cemented in a crossed position, i.e., the  $x$  axis of one plate coincided in direction with the  $y$  axis of the other. When an electric field was applied along the  $z$  axis by means of transparent electrode glasses with conducting films of tin oxide, the birefringence arising along the  $z$  axis in the plates was mutually compensated; therefore the center of the conoscopic pattern (Fig. 2) remained dark in crossed polarizers. The points of intersection of the odd dark rings with straight lines parallel to the axes  $x'$  and  $y'$  (Fig. 2), however, became illuminated to a considerably greater degree under the action of the field and could again be extinguished by rotating the analyzer. The degree of extinction, as in the preceding observation, decreased as the magnitude of the applied field increased, for the same reasons.

**Fig. 1.** Conoscopic patterns of one  $z$ -cut plate of a KDP crystal between crossed polarizers ( $P, A$ ). The points of intersection of the dashed circles with the  $x$  and  $y$  axes correspond to directions in the plate along which the phenomenon of rotation of the plane of polarization of light is observed.  $a$ —no field;  $b$ —the field acts along the  $z$  axis.

**Fig. 2.** Conoscopic pattern of two identical crossed  $z$ -cut plates of a KDP crystal between crossed polarizers ( $P, A$ ). The points of intersection of the dashed circles with the  $x, y$  and  $x', y'$  axes correspond to directions in the plates along which the phenomenon of rotation of the plane of polarization of light is observed.

In Fig.  $3b, c, d, e, f, g, h, i$  the change in the initial conoscopic pattern (Fig.  $3a$ ) is shown as the magnitude of the applied field increases. The angles of rotation of the analyzer are conventionally shown by straight lines inclined to the  $y'$  axis. In Fig.  $3i$  this angle is  $90^\circ$ , and a noticeable brightening is seen at the points of intersection of the  $y'$  axis not only with the first, but also with the third and fifth dark rings.

In Fig.  $4b, c, d, e, f, g, h, i$  the corresponding changes in the conoscopic pattern under the action of the field are shown for a pair of plates when their  $x$  and  $y$  axes are parallel to the directions of vibration in the crossed polarizers (Fig.  $4a$ ). In this case the phenomenon under consideration is observed especially clearly, and it may be interpreted in the following way. Since the odd dark rings of the conoscopic pattern correspond to those directions for which the path difference of the rays in the pair of cemented plates is equal to the corresponding odd numbers of wavelengths, in each plate the path differences along these directions will be half as large, i.e., equal to odd numbers of half-wavelengths. Under the action of the field along the  $z$  axis, the ellipses of the sections of the optical



tated through the angle at which the brightening points at the intersections of the first dark ring with the  $y$  axis again go dark, while with the  $x$  axis they become still brighter.

on the  $n$ -th ring of the conoscopic pattern, if counted from the center. In the case of an odd number  $(2n - 1)$  of plates, their greatest brightening is observed on the dark portions of the bright rings with number  $(2n - 1)$ .

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*Note: Figure translations are in progress. See original paper for figures.*

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