

Elasto-optic studies on potassium acid phthalate single crystal

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Potassium acid phthalate (KAP) belongs to the $mm2(C_{2v})$ class of orthorhombic system according to Okaya [1]. Belyaev *et al.* [2] have studied its optical, dielectric, piezoelectric and elastic properties. The acousto-optic interactions and hence the individual values of nine of the twelve strain optical constants have been determined by Belikova *et al.* [3] using the Bragg ultrasonic diffraction technique. Since the acousto-optic interaction in this crystal characterizes it as an interesting material for use in acousto-optic devices, we have studied in detail the elasto-optic behaviour of the single crystal of KAP and now present the complete set of absolute values of its stress-optical and strain-optical constants q_{ij} and p_{ij} respectively.

These constants have been obtained from the experimental measurements of relative path retardation employing the bi-refrident compensator method of Veerabhadra Rao and Narasimhamurty [4] and absolute path retardation employing a modified form of Rayleigh refractometer, when crystals of different orientations were subject to linear stresses.

The photo-elastic tensor of orthorhombic crystals is described in Pockels' scheme by its 12

stress-optical constants q_{ij} and 12 strain-optical constants p_{ij} . The complete matrices of q_{ij} and p_{ij} and also the expressions for the absolute and relative path retardations for different directions of stress and directions of observation for an orthorhombic crystal are given by Narasimhamurty [5].

The crystals of KAP were grown in the laboratory by the slow evaporation of an aqueous solution of its salt at room temperature. Large crystals of 40 mm x 30 mm x 8 mm size were obtained, by seeding, in a period of 8 to 10 weeks. The crystallographic data reported by Okaya [1] was used to identify the faces and the crystallographic axes of the crystal. The assignment of the cartesian axes x, y, z to the crystal follows that by Belyaev *et al.* [2]. The orientations of the KAP prisms were accurate to within 1°.

Observations on the differential stress bi-refrignence at mean sodium yellow light are presented in Table I and those on the absolute path retardation measurements are collected in Table II.

The values of the principal refractive indices and elastic constants used in the calculations are taken from Belyaev *et al.* [2] and are

TABLE I Observations on differential stress bi-refrignence of KAP at 589.0 nm and at room temperature

S. No.	Direction of stress*	Direction of observation†	Relative path retardation per unit stress per unit thickness	
			Expression	Value (10 ¹³ cm)
1	[100]	[010]	$(n_x^3 q_{11} - n_z^3 q_{31})$	-31.14
2	[100]	[001]	$(n_x^3 q_{11} - n_y^3 q_{21})$	-51.97
3	[010]	[001]	$(n_y^3 q_{22} - n_z^3 q_{12})$	-54.13
4	[010]	[100]	$(n_y^3 q_{22} - n_z^3 q_{32})$	-55.05
5	[001]	[100]	$(n_z^3 q_{33} - n_y^3 q_{23})$	-19.03
6	[001]	[010]	$(n_z^3 q_{33} - n_x^3 q_{13})$	-55.20
7	M	M'	$\frac{1}{8}n_y^3(q_{22} + q_{23} + q_{32} + q_{33} + 2q_{44}) - \frac{1}{4}n_x^3(q_{12} + q_{13})$	-69.72
8	L	L'	$\frac{1}{8}n_x^3(q_{11} + q_{13} + q_{31} + q_{33} + 2q_{55}) - \frac{1}{4}n_y^3(q_{21} + q_{23})$	+71.16
9	N	N'	$\frac{1}{8}n_x^3(q_{11} + q_{12} + q_{21} + q_{22} + 2q_{66}) - \frac{1}{4}n_z^3(q_{31} + q_{32})$	-32.00

*M indicates a direction in the yz plane equally inclined to the y and z axes, L indicates a direction in the xz plane equally inclined to the x and z axes and N indicates a direction in the xy plane equally inclined to the x and y axes.

†M', L', N' indicate directions perpendicular to M, L and N respectively.

TABLE II Observations on the absolute path retardation measurements on KAP at 589.0 nm and at room temperature

Sample No.	Direction of stress	Direction of observation	Direction of light vibration	Absolute path retardation per unit stress per unit thickness	
				Expression	Value (10 ¹³ cm)
1	[1 0 0]	[0 1 0]	Vertical	$n_x^3 q_{11}$	-111.15
2	[1 0 0]	[0 1 0]	Horizontal	$n_z^3 q_{31}$	-63.03
3	[0 1 0]	[0 0 1]	Vertical	$n_y^3 q_{22}$	-58.55
4	[0 1 0]	[1 0 0]	Horizontal	$n_z^3 q_{32}$	22.35
5	[0 0 1]	[1 0 0]	Vertical	$n_z^3 q_{33}$	-127.16
6	[0 0 1]	[1 0 0]	Horizontal	$n_y^3 q_{23}$	-105.89
7	[1 0 0]	[0 0 1]	Horizontal	$n_y^3 q_{21}$	-84.12

$$n_x = 1.66055, \quad n_y = 1.66301, \quad n_z = 1.49386$$

for $\lambda = 589.0$ nm, and

$$S_{11} = 10.38, \quad S_{22} = 9.9, \quad S_{33} = 9.27,$$

$$S_{44} = 20.59, \quad S_{55} = 13.18, \quad S_{66} = 16.05,$$

$$S_{12} = -3.8, \quad S_{13} = -5.22, \quad S_{23} = -0.62$$

(in units of 10^{-12} cm² dyne⁻¹ at 20° C).

A slight variation in the values of S_{12} , S_{13} and S_{23} considerably alters the values of q_{ij} arrived at from absolute path retardation measurements. Therefore, taking into consideration the relative orders of accuracy of the two methods used for the relative and absolute path retardation measurements, due weighing was given to the two sets of experimental observations obtained by these two different methods in arriving at the individual values of q_{ij} and thus p_{ij} as followed by Bhagavantam and Suryanarayana for computing the individual values of q_{ij} for potassium alum [6] and ammonium alum [7]. The values of the constants q_{ij} and p_{ij} correct to within 10%, are

$$q_{11} = -26.68, \quad q_{12} = 1.29, \quad q_{13} = -15.52$$

$$q_{21} = -15.25, \quad q_{22} = -10.48, \quad q_{23} = -23.31$$

$$q_{31} = -27.30, \quad q_{32} = 2.05, \quad q_{33} = -37.88$$

$$q_{44} = -53.83, \quad q_{55} = 83.24, \quad q_{66} = -20.68$$

(in units of 10^{-13} cm² dyne⁻¹ at $\lambda = 589.0$ nm and at room temperature).

$$p_{11} = -0.61, \quad p_{12} = -0.25, \quad p_{13} = -0.52$$

(0.21) (0.31) (0.29)

$$p_{21} = -0.58, \quad p_{22} = -0.36, \quad p_{23} = -0.60$$

(0.22) (0.16) (0.27)

$$p_{31} = -0.84, \quad p_{32} = -0.36, \quad p_{33} = -0.90$$

(0.21) (0.46) (0.28)

$$p_{44} = -0.26, \quad p_{55} = -0.63, \quad p_{66} = -0.13$$

(All at $\lambda = 589.0$ nm and at room temperature).

The values given in brackets are those reported by Belikova *et al.* [3]. Some ratios of p_{ij}/p_{kl} such as p_{11}/p_{21} and p_{11}/p_{31} are found to agree better than others. However, the individual values of p_{ij} are not in close agreement though they agree in their order of magnitude and this can be attributed to the following two factors.

(a) The order of accuracy of the ultrasonic technique employed by Belikova *et al.* [3] is different from that of our optical path retardation methods.

(b) The order of accuracy of the assumed values of S_{12} , S_{23} , and S_{13} affects the computed values of p_{ij} calculated from the optical path retardation measurements in our experimental methods.

From the results obtained on individual values of q_{ij} , we have further proceeded to deduce the effect of hydrostatic pressure on the refractive index and also double refraction of KAP in each direction of observation. While all the principal refractive indices of KAP were found to decrease

TABLE III Effect of hydrostatic pressure on principal refractive indices and double refraction of KAP at $\lambda = 589.0$ nm and at room temperature

Direction of observation	Variation of refractive index with hydrostatic pressure, P (10 ¹³)	Variation of double refraction with hydrostatic pressure, P (10 ¹³)
[1 0 0]	$\Delta n_x = -93.65 \times P$	$[(n_y - n_z) - (n_y^0 - n_z^0)] = -7.59 \times P$
[0 1 0]	$\Delta n_y = -112.80 \times P$	$[(n_z - n_x) - (n_z^0 - n_x^0)] = -11.56 \times P$
[0 0 1]	$\Delta n_z = -105.21 \times P$	$[(n_x - n_y) - (n_x^0 - n_y^0)] = 19.16 \times P$

under hydrostatic pressure, the double refraction was found to increase along [001] and decrease along [010] and [100] directions, as indicated in Table III.

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