
Acoustooptic Interaction in Barium Beta-Borate Crystals

Martynyuk-Lototska I., Dudok T., Dyachok Ya., Burak Ya. and Vlokh R.

Institute of Physical Optics, 23 Dragomanov Str., 79005 L'viv, Ukraine

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Abstract

Basing on the measurements of photoelastic coefficients, acoustic waves velocities and the refractive indices, the possible geometries for acoustooptic interaction in β -BaB₂O₄ crystals have been analysed. It has been shown that the acoustooptic figure of merit achieves its maximum value when the transverse acoustic wave v_{13} with the velocity 817m/s is propagated in YZ-plane. In this case $M_2=95.35\times 10^{-15}\text{s}^3/\text{kg}$.

Key words: acoustooptic effect, borate crystals

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It has been shown in our previous paper [1] that the acoustooptic figure of merit (AOFM) for α -BaB₂O₄ and Li₂B₄O₇ crystals can be as high as $M_2=243.4\times 10^{-15}\text{s}^3/\text{kg}$ and $M_2=2.57\times 10^{-15}\text{s}^3/\text{kg}$ in case of the optimised geometry for acoustooptic (AO) interaction. Such the magnitudes of AOFM appear due to AO interaction with the slowest acoustic waves. The direction of propagation of these waves does not coincide with the principle (crystallophysical) directions but is determined by anisotropy of the ultrasonic wave velocities. The crystals of β -BaB₂O₄ exhibit rather high values of AOFM, too [2]. Therefore the goal of the present paper is to analyse all the possible geometries for the AO interactions in β -BaB₂O₄ crystals on the basis of construction of indicative surfaces for the acoustic wave velocities.

The measured velocities of the longitudinal and transverse ultrasonic waves in β -BaB₂O₄ crystals and the possible geometries satisfying the Bragg condition are collected in Table 1.

Using the experimental data for the ultrasonic velocity, piezooptic coefficients and the refractive indices, the AOFM $M_2=p_{ef}^2 n^6 / \rho v^3$ may be calculated for the cases when the optical

beam and the acoustic wave propagate along the principal directions (see Table 1). Let us take into account that the measured value of the velocity for one of the slowest transverse acoustic wave manifesting bearable attenuation is $v_{13}= 880$ m/s and the effective elasto optic coefficient is equal to $p_{ef}=p_{44}=-0.078$ for the direction of light wave [010]. Then the calculated value of AOFM amounts to $M_2=49.95\times 10^{-15}\text{s}^3/\text{kg}$, exceeding the corresponding coefficients for the fused quartz and KDP crystals. Besides, a small light absorption throughout the wide wavelength range, a high radiation threshold stability and a possibility for growing large samples with a high optical quality facilitate a practical choice of β -BaB₂O₄ crystals as an efficient AO material [3].

Constructing the indicative surface of the ultrasonic velocity for the v_{13} transverse acoustic wave in XY plane (Figure 1) demonstrates that the velocity achieves its lowest value ($v=777\text{m/s}$) when the k vector lies in XY plane and makes the angle of $\alpha=57^\circ$ with respect to X axis and the projections of the unit displacement vector are $X_x=-0.142$, $X_y=0.115$ and $X_z=0.983$ (Figure 1,b). The equation of the optical

indicatrix in such a case reads as

$$\begin{aligned}
 &(B_1 + p_{11}e_1 + p_{12}e_2 + p_{13}e_3 + p_{14}e_4)X^2 + \\
 &+(B_1 + p_{12}e_1 + p_{11}e_2 + p_{13}e_3 - p_{14}e_4)Y^2 + \\
 &(B_3 + p_{31}e_1 + p_{31}e_2 + p_{33}e_3)Z^2 + \\
 &+2p_{41}(e_1 - e_2)ZY + 2p_{44}(e_4YZ + e_5XZ) = 1
 \end{aligned} \quad (1)$$

One can neglect the terms that describe the optical indicatrix rotation as it has only a minor effect on the changes in the principal refractive indices and take into account that the incident optical wave is polarized parallel to Z axis. Then

the value of p_{ef} should be determined by the change in the refractive index n_3 , which is as follows:

$$\begin{aligned}
 \Delta n_3 &\approx \frac{1}{2}n_3^3 \{p_{31}e_1 + p_{31}e_2 + p_{33}e_3\} = \\
 &= \frac{1}{2}n_3^3 \{-0.142p_{31} + 0.115p_{31} + 0.983p_{33}\}e
 \end{aligned} \quad (2)$$

Taking the values of $p_{31}=-0.112$ and $p_{33}=0.039$, one can finally obtain $p_{ef}=0.04$ and $M_2=12.32 \times 10^{-15} \text{ s}^3/\text{kg}$. The decrease in M_2 in the specific latter case is related to the fact that the

Table 1. AO parameters of β -BaB₂O₄ crystals ($\rho=3840\text{kg/m}^3$, $n_o=1.6673$ and $n_e=1.5506$ for $\lambda=632.8\text{nm}$).

Acoustic wave		p	p _{eff}	n	Light		M ₂ , 10 ⁻¹⁵ s ³ /kg or possibility for matching the Bragg conditions
V, m/s	Propagation direction, Polarization				Direc- tion	Polarization	
5410	[100], [100]	p ₁₁	0,195	n _e	[010]	[100]	not
		p ₃₁	0,112	n _o		[001]	not
		p ₂₁	0,197	n _o	[001]	[010]	not
		p ₁₁	0,195	n _o		[100]	not
5805	[010], [010]	p ₁₁	0,195	n _e	[100]	[010]	not
		p ₄₂ =-p ₄₁	0,007	n _o		[001], [010]	0.0014
		p ₃₁	0,112	n _o		[001]	not
		p ₄₂ =-p ₄₁	0,007	n _e		[010], [001]	0.0009
		p ₁₂	0,197	n _o	[001]	[100]	not
		p ₂₂ =p ₁₁	0,195	n _o		[010]	not
3500	[001], [001]	p ₂₃ =p ₁₃	0,059	n _e	[100]	[010]	not
		p ₃₃	0,039	n _o		[001]	not
		p ₁₃	0,059	n _e	[010]	[100]	not
		p ₃₃	0,039	n _o		[001]	not
2900	[100], [010]	p ₅₆ =p ₄₁	0,007	n _o	[010]	[001], [100]	0.01124
		p ₄₁ =p ₅₆	0,007	n _e		[100], [001]	0.00726
		p ₆₆	0.001	n _o	[001]	[010], [100]	not
		p ₆₆	0.001	n _o		[100], [010]	not
880	[100], [001]	p ₅₅ =p ₄₄	0,078	n _o	[010]	[001], [100]	49.945
		p ₅₅ =p ₄₄	0,078	n _e		[100], [001]	32.538
		p ₆₅ =p ₁₄	0,005	n _o	[001]	[010], [100]	not
		p ₆₅ =p ₁₄	0,005	n _o		[100], [010]	not
940	[010], [001]	p ₂₄ =-p ₁₄	0,005	n _e	[100]	[010]	not
		p ₄₄	0,078	n _o		[001], [010]	40.979
		p ₄₄	0,078	n _e		[010], [001]	26.452
		p ₁₄	0,005	n _o	[001]	[100]	not

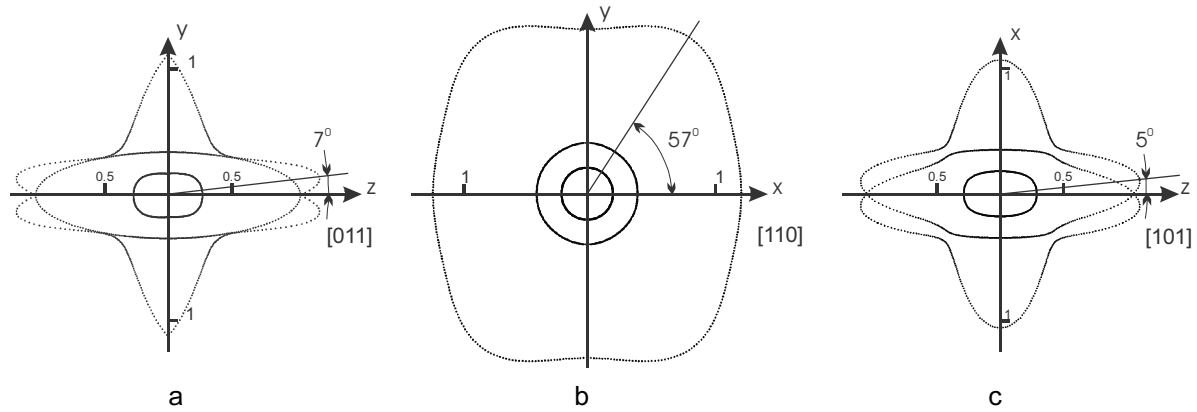


Fig. 1. Indicative surfaces of the inverse transverse acoustic wave velocity for β -BaB₂O₄ crystals (in the units $s \times km^{-1}$).

anisotropy of ultrasonic velocity is quite small (approximately 10%) and the other parameters, such as p_{ef} and n , influence the M_2 value.

From other side, when the acoustic wave is propagate in YZ -plane with the direction of propagation which make the angle 7° with Z -axis and the projections of displacement vector $X_x=0$, $X_y=-0.99$, $X_z=0.125$ (Figure 1,a) the change of refractive index n_3 can be written as

$$\begin{aligned} \Delta n_3 &\approx \frac{1}{2} n_3^3 \{ p_{31} e_2 + p_{33} e_3 \} = \\ &= \frac{1}{2} n_3^3 \{ -0.112 p_{31} + 0.039 p_{33} \} e \end{aligned} \quad (3)$$

The value of effective photoelastic coefficient is equal $p_{ef}=0.12$, acoustic wave velocity – $v_{13}=817m/s$ and AOFM – $M_2=95.35 \times 10^{-15} s^3/kg$. For the case of acoustic wave propagation in the XZ -plane (Figure 1, c) AOFM achieve only $M_2=2 \times 10^{-15} s^3/kg$.

Thus, the best geometry for the AO interaction in β -BaB₂O₄ crystals is that when the transverse acoustic wave v_{13} with the velocity

$v_{13}=817m/s$ is propagated YZ -plane. AOFM in this case achieve value $M_2=95.35 \times 10^{-15} s^3/kg$.

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