Elastical, Piezooptical and Acoustooptical Properties of Lithium Tetra Borate Crystals

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Abstract

The refractive, elastical and piezooptical properties of the lithium tetra borate crystals have been investigated. The dispersions of the refractive indexes of $Li_2B_4O_7$ crystals have been measured in the wavelength range 350-650 nm. The results of the measurement of velocity of the longitudinal and transverse ultrasonic waves in lithium borate crystals are presented. On the base of ultrasonic velocity measurements the components of the elastic matrix C_{mn} of these crystals have been calculated. Using the determined values of the refractive, elastical and elastooptical tensor components the acoustooptical quality M_2 of $Li_2B_4O_7$ crystals has been calculated.

Key words: borate crystals, piezooptical effect, acoustooptical effect, sound velocity.

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Introduction

Such crystals as $Li_2B_4O_7$ (LTB, point group of symmetry 4mm) are known as material for the acoustoelectronic technique applications [1]. The advantage of borate crystals is also their high radiation threshold stability and wide transparency region. These properties could be useful in other optoelectronic applications of borate crystals. In [2] it was shown that barium borate crystals can be used as acoustooptical material. In the present paper we continue the investigation of the optical properties of the borate crystal family that effect the value of the acoustooptical figure of merit, i.e this report is devoted to the study of refractive, elastical and piezooptical properties of lithium tetra borate crystals.

Experimental

The optically qualitative single crystals of LTB were grown by the Czochralsky technique. The crystallographic axes of the crystals were determined by the X-ray diffraction method.

The refractive indices dispersion of LTB crystals have been investigated for samples, size $8\times10\times0.98$ mm^3 by the Obreimov`s diffraction method with the accuracy 2×10^{-4}.

Elastic and piezooptical investigations were performed on samples with faces parallel to the principle crystallophysical axis and samples with X/45^o and Z/45^o orientation.

Acoustic velocity measurements of the longitudinal and transverse ultrasonic waves have been performed on single LTB crystals by the pulse-echo overlap method [3]. The accuracy of the absolute velocity determination was about 0.5%. The acoustic waves in the samples were excited by $LiNbO_3$ transducers with a resonance frequency of f = 10 MHz, bandwidth Δf = 0.1 MHz and acoustic power P_a=1 to 2W.

The piezooptical tensor components π_{im} for LTB crystals have been measured using the Senarmon technique.

Results and discussion

The indices of refraction of the LTB crystals were studied in a spectral range 350-650 nm. The data are shown in Fig. 1. The obtained dependency of the refractive indices on the wavelength is in good agreement with previous data [4,5].

The elastic properties of the borate crystals were determined via measurements of the ultrasonic velocities along different crystallophysical directions. There are six independent non zero elastic constants for LTB crystals - C_{11}, C_{33}, C_{44}, C_{66}, C_{12} and C_{13}. The relations between the measured ultrasonic velocities, V_m, and the elastic constants, C_{mn}, follow from the Cristoffel equation. Direct and simple relations between measured velocities and elastic constants are possible only for diagonal components of the elastic constant matrix. All other constants are coupled in more complicated relations and must be determined from ultrasonic velocities measured in the slanting faces. The measured velocities of the longitudinal and transverse ultrasonic waves in LTB crystals are presented in Table 1.

Using ultrasonic velocity measurements the components of the elastic constants C_{mn} of the LTB crystals have been determined as C_{11}=131.0×10^{9}Pa, C_{33}=61.4×10^{9}Pa C_{44}=55×10^{9}Pa, C_{66} =47.9×10^{9}Pa, C_{12}=9.5×10^{9}Pa and C_{13}=38.5×10^{9}Pa.

For the LTB crystals we have measured the components π_{44} and π_{66} of piezooptical tensor. The piezooptical coefficient values are: π_{44}= 1.04×10^{-12} m^2/N and π_{66}=1.66×10^{-12} m^2/N, (π_{11}- π_{12}) = 0.79×10^{-12} m^2/N, 1.11×π_{13}–π_{33} =1.62×10^{-12} m^2/N, 1.11×π_{11}–π_{31} =1.43×10^{-12} m^2/N. The values of the corresponding elastooptical tensor components p_{44} =0.0916 and p_{66} =0.0498 have been calculated according to the known formula $p_{in}=\pi_{im}C_{mn}$. The acoustooptical quality of LTB crystals $M_2 = p^2_{ef.}n^6/\rho v^3$ [6] was determinated using these elastooptical coefficients (where $p_{ef.}$ - the effective value of elastooptical coefficient, n - refractive index of materials, ρ - density). For the acoustic wave with the direction of propagation [100] and polarization [010] (v=4448 m/s) and the light wave with direction of propagation [001] and polarization [100] or [010] the value of the acoustooptical quality is M_2=0.16×10^{-15}s^3/kg. For the acoustic wave with the direction of propagation [100] and polarization [001] (v=4769 m/s) and the light wave with direction of propagation [010] and polarization [100] or [001] the value of the

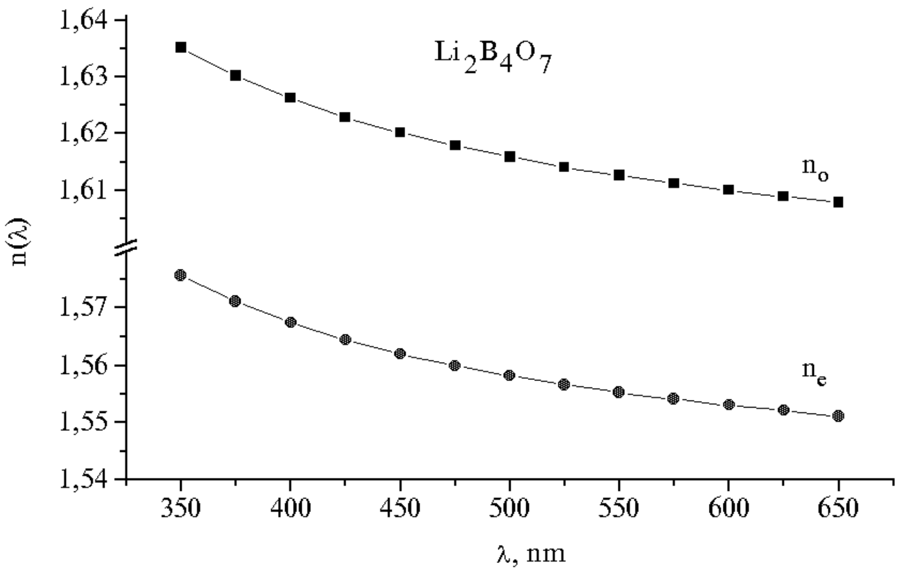

Fig. 1. Dispersion of refractive indices of LTB crystals (T=20^{o}C).

Table 1.

Ultrasonic wave velocities of LTB crystals (PT pure transverse wave, PL pure longitudinal wave, QL quasilongitudinal wave).

Direction of wave propagation	Approximate wave displacement direction	Velocity at 293 K (m/s)	Type of wave
[100]	[100]	7358	PL
[001]	[001]	5036	PL
[100]	[010]	4448	PT
[100]	[001]	4769	PT
[110]	[110]	6986	QL
[101]	[101]	7405	QL

acoustooptical quality is M_2=0.55×$10^{-15}s^3$/kg. It is necessary to note that in the case of the mentioned geometry of the acoustooptical interaction the slowest acoustical waves occur and in other cases the magnitudes of acoustooptical figures of merit should be smaller.

Conclusion

On the base of conducted measurements of the refractive, elastical and piezooptical properties of lithium borate crystals it was shown that acoustooptical figure of merit of LTB crystals is small.

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