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Acoustic and elastic properties of $Sn_2P_2S_6$ crystals

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Abstract
We present the results concerned with acoustic and elastic properties of $Sn_2P_2S_6$ crystals. The complete matrices of elastic stiffness and compliance coefficients are determined in both the crystallographic coordinate system and the system associated with eigenvectors of the elastic stiffness tensor. The acoustic slowness surfaces are constructed and the propagation and polarization directions of the slowest acoustic waves promising for acousto-optic interactions are determined on this basis. The acoustic obliquity angle and the deviation of polarization of the acoustic waves from purely transverse or longitudinal states are quantitatively analysed.

1. Introduction

Tin thiohypodiphosphate ($Sn_2P_2S_6$) crystals belong to a broad family of compounds with the general chemical formula $Pb_xSn_{(1-x)}P_2S_{6y}Se_{6(1-y)}$ [1]. They manifest a proper ferroelectric phase transition with the point symmetry change $2/m \leftrightarrow m$ at $T_c = 337$ K [1] and are transparent in a wide spectral range limited by the light wavelengths $\lambda = 0.53$–8.0 μm [2]. These crystals are known to have very good electro-optic characteristics (e.g., the electro-optic coefficient r_{11} is as high as $r_{11} = 1.74 \times 10^{-10}$ m V^{-1} for room temperature and the wavelength of $\lambda = 632.8$ nm [3, 4]). Moreover, tin thiohypodiphosphate represents a promising magneto-optic material (the Verdet constant 115 rad T^{-1} m^{-1} [5]) and manifests notable photorefractive properties [6, 7].

Recently, we have shown that the crystals under analysis reveal a high enough acousto-optic (AO) figure of merit (AOFM): $M_2 = (1.7 \pm 0.4) \times 10^{-12}$ kg s^{-3} [8], where the AOFM is defined as

$$M_2 = \frac{n^6 p_{ef}^2}{\rho v^3}. \quad (1)$$

In formula (1) ρ stands for the material density, v the acoustic wave velocity, n the refractive index and p_{ef} the effective photoelastic coefficient. To our knowledge, this is one of the highest AOFM ever known for AO materials operating in the visible spectral range. A direct consequence is that the acoustic powers as low as $P_a = 6.7 \times 10^{-4}$ W would be enough for gaining high diffraction efficiencies (e.g., $\eta = 16\%$ [8]). It is worth noticing that the AOFM value quoted above has been obtained for a particular case of AO interaction with the acoustic waves propagating along the principal crystallographic directions and having the velocities $v_{21} = 2100$ m s^{-1} and $v_{23} = 2610$ m s^{-1} [9].

Of course, these waves may turn out to be not the slowest. At the same time, it is obvious that the interaction with the slowest acoustic wave could, in principle, provide an increase in the AOFM as large as some orders of magnitude. For example, it has been shown by us [10, 11] that the corresponding parameter for α-BaB_2O_4 crystals increases from the value of $M_2 = (54.5 \pm 7.4) \times 10^{-15}$ s^3 kg^{-1} for the case of AO interaction with a transverse acoustic wave propagated along one of the principal crystallographic directions up to $M_2 = (270 \pm 70) \times 10^{-15}$ s^3 kg^{-1} for the case of interaction with the slowest wave.

In order to analyse thoroughly the AO interaction in $Sn_2P_2S_6$ crystals, one needs to acquire comprehensive data on the acoustic wave velocities enough to construct the so-called acoustic slowness surfaces, determine obliquity parameter defining deviation of the acoustic energy flow from the acoustic wavevector and find deviation of the polarization vector from its purely transverse or longitudinal orientation. Some preliminary results concerned with the elastic properties of these crystals have already been reported in our recent works [9, 12]. However, the corresponding data are not sufficient for the complete analysis of AO interactions in $Sn_2P_2S_6$ crystals. Moreover, these crystals represent a material which is rather difficult to deal with, since it is characterized by a low symmetry.

The aim of the present work is to study the acoustic properties of $Sn_2P_2S_6$ crystals in order to determine the propagation and polarization directions that are typical for the slowest acoustic waves.

2. Experimental details

The velocities of longitudinal and transverse ultrasonic waves have been measured with a standard pulse-echo overlap method [13]. We have excited the acoustic waves in the samples using $LiNbO_3$ transducers (the resonance frequency $f = 10$ MHz, the bandwidth $\Delta f = 0.1$ MHz and the acoustic power $P_a = 1$–2 W). We have used four samples obtained from different growth processes. Only the results obtained for one of them somewhat differ from those for the other samples. This difference is probably caused by comparatively larger error in its crystallographic orientation and has been included in the general experimental error.

The elastic constants have been measured with respect to crystallographic axes $a = 1$, $b = 2$ and $c = 3$. Here we report on a complete determination of the matrix $C_{klmn} = C_{ij}$ of elastic constants (where $i, j = 1$–6; $1 = 11$, $2 = 22$, $3 = 33$, $4 = 23$, $5 = 13$ and $6 = 12$), via the measurements of phase ultrasonic velocities along different crystallographic directions. It is known that the $Sn_2P_2S_6$ crystals belong to the monoclinic point group m. There are 13 independent nonzero elastic coefficients for the monoclinic crystals (C_{11}, C_{22}, C_{33}, C_{44}, C_{55}, C_{66}, C_{12}, C_{13}, C_{23}, C_{15}, C_{25}, C_{35} and C_{46}). Direct and simple relations relating the velocities measured and the elastic coefficients exist only for the four of the elastic stiffness matrix components ($C_{22} = \rho v_2^2$, $C_{44} = \rho v_{32}^2$, $C_{66} = \rho v_{12}^2$ and $C_{46} = \frac{1}{2}\sqrt{(\rho v_{21}^2 - \rho v_{23}^2)^2 - (C_{44} - C_{66})^2}$). All the other coefficients are linked by more complicated relations. Therefore cumbersome, both in experimental and computational aspects, procedures for deriving the remaining nine elastic coefficients are required for the monoclinic system [14, 15]. To determine these coefficients, one should measure the velocities of quasi-longitudinal (QL) and quasi-transverse (QT) ultrasonic waves for at least six different directions ([100], [010], [001], [110], [101] and [011]).

The elastic compliances S_{ij} have been determined following from the matrix C_{ij} of elastic constants, using the relations

$$
\begin{aligned}
S_{12} &= [-(C_{35}^2 C_{12} - C_{35}C_{15}C_{23} - C_{35}C_{13}C_{25} + C_{55}C_{23}C_{13} \\
&\quad + C_{33}C_{25}C_{15} - C_{33}C_{55}C_{12})][A]^{-1}, \\
S_{11} &= \frac{(C_{35}^2 C_{22} - 2C_{35}C_{25}C_{23} - C_{33}C_{55}C_{22} + C_{33}C_{25}^2 + C_{23}^2 C_{55})}{A}, \\
S_{13} &= [(-C_{22}C_{35}C_{15} + C_{35}C_{12}C_{25} + C_{22}C_{13}C_{55} \\
&\quad + C_{25}C_{23}C_{15} - C_{55}C_{12}C_{23} - C_{25}^2 C_{13})][A]^{-1}, \\
S_{15} &= [(C_{33}C_{15}C_{22} - C_{33}C_{12}C_{25} - C_{22}C_{13}C_{35} + C_{25}C_{23}C_{13} \\
&\quad + C_{35}C_{12}C_{23} - C_{23}^2 C_{15})][A]^{-1}, \\
S_{22} &= \frac{(C_{11}C_{35}^2 - 2C_{35}C_{13}C_{15} - C_{33}C_{11}C_{55} + C_{33}C_{15}^2 + C_{55}C_{13}^2)}{A}, \\
S_{23} &= [-(C_{11}C_{35}C_{25} - C_{35}C_{12}C_{15} - C_{11}C_{23}C_{55} \\
&\quad + C_{55}C_{12}C_{13} - C_{13}C_{15}C_{25} + C_{15}^2 C_{23})][A]^{-1}, \\
S_{25} &= [-(C_{11}C_{35}C_{23} - C_{35}C_{12}C_{13} - C_{11}C_{33}C_{25} \\
&\quad - C_{13}C_{23}C_{15} + C_{33}C_{12}C_{15} + C_{13}^2 C_{25})][A]^{-1}, \\
S_{33} &= [(-2C_{25}C_{12}C_{15} + C_{55}C_{12}^2 + C_{22}C_{15}^2 \\
&\quad - C_{22}C_{11}C_{55} + C_{25}^2 C_{11})][A]^{-1}, \\
S_{35} &= [(C_{22}C_{35}C_{11} - C_{35}C_{12}^2 - C_{22}C_{13}C_{15} - C_{11}C_{23}C_{25} \\
&\quad + C_{25}C_{12}C_{13} - C_{23}C_{12}C_{15})][A]^{-1}, \\
S_{44} &= \frac{C_{66}}{-C_{46}^2 + C_{44}C_{66}}, \qquad S_{66} = \frac{C_{44}}{-C_{46}^2 + C_{44}C_{66}}, \\
S_{46} &= \frac{-C_{46}}{-C_{46}^2 + C_{44}C_{66}}, \\
S_{55} &= [-(C_{22}C_{33}C_{11} - C_{22}C_{13}^2 - C_{11}C_{23}^2 - C_{33}C_{12}^2 \\
&\quad + 2C_{23}C_{12}C_{13})][A]^{-1},
\end{aligned} \tag{2}
$$

where

$$
\begin{aligned}
A &= C_{11}C_{23}^2 C_{55} - 2C_{11}C_{23}C_{25}C_{35} - C_{23}^2 C_{15}^2 \\
&\quad - 2C_{23}C_{12}C_{13}C_{55} - C_{13}^2 C_{25}^2 + 2C_{23}C_{25}C_{13}C_{15} \\
&\quad + 2C_{35}C_{12}C_{13}C_{25} + 2C_{35}C_{23}C_{12}C_{15} - C_{35}^2 C_{12}^2 \\
&\quad - 2C_{33}C_{25}C_{12}C_{15} + C_{33}C_{12}^2 C_{55} + C_{22}C_{33}C_{15}^2 \\
&\quad - C_{22}C_{11}C_{33}C_{55} + C_{11}C_{33}C_{25}^2 - 2C_{22}C_{35}C_{13}C_{15} \\
&\quad + C_{22}C_{13}^2 C_{55} + C_{22}C_{11}C_{35}^2.
\end{aligned} \tag{3}
$$

Finally, let us take into consideration that for the crystals under test the eigen-coordinate system XYZ of the elastic stiffness tensor (for conciseness referred hereafter to as the elastic eigen-coordinate system) differs from the crystallographic system, abc (see figure 1), thus making the analysis even more complicated.

3. Results and discussion

3.1. Acoustic wave velocities

The acoustic wave velocities for $Sn_2P_2S_6$ crystals referred to the crystallographic system are presented in table 1. As one can see, the lowest velocities 2100 ± 70 m s^{-1} (or 2115 ± 20 m s^{-1}) are peculiar to the quasi-transverse wave that propagates along the direction $\langle 010 \rangle$ (or $\langle 001 \rangle$) and has its polarization parallel to $\langle 001 \rangle$ (or $\langle 010 \rangle$).

Let us stress here an important aspect of searching directions of propagation and polarization of the slowest acoustic waves. The direction of the slowest wave may, in principle, be obtained by searching for a minimum of the acoustic velocity function defined by the Christoffel equation and written in the spherical coordinate system. However, this high power equation is difficult to solve analytically and, moreover, the corresponding results have to include large

Table 1. Ultrasonic wave velocities for $Sn_2P_2S_6$ crystals referred to the crystallographic system *abc*.

Direction of the wavevector	Direction of polarization	Velocity ($m\ s^{-1}$)	Direction of the wavevector	Direction of polarization	Velocity ($m\ s^{-1}$)
$\langle 100\rangle$	$\langle 100\rangle$	3550 ± 40	$\langle 010\rangle$	$\langle 100\rangle$	2480 ± 50
$\langle 010\rangle$	$\langle 010\rangle$	3210 ± 20	$\langle 001\rangle$	$\langle 100\rangle$	2420 ± 20
$\langle 001\rangle$	$\langle 001\rangle$	3635 ± 50	$\langle 010\rangle$	$\langle 001\rangle$	2100 ± 70
$\langle 100\rangle$	$\langle 010\rangle$	2500 ± 50	$\langle 001\rangle$	$\langle 010\rangle$	2115 ± 20
$\langle 100\rangle$	$\langle 001\rangle$	2335 ± 20	$\langle 101\rangle$	$\langle 101\rangle$	3800 ± 70
			$\langle 101\rangle$	$\langle \bar{1}0\bar{1}\rangle$	2260 ± 20

Table 2. Components of elastic stiffness and elastic compliance tensors for $Sn_2P_2S_6$ crystals referred to the crystallographic coordinate system *abc*.

Indices	C_{ij} ($10^9\ N\ m^{-2}$)	S_{kl} ($10^{-11}\ m^2\ N^{-1}$)	Indices	C_{ij} ($10^9\ N\ m^{-2}$)	S_{kl} ($10^{-11}\ m^2\ N^{-1}$)
11	43 ± 2	4 ± 2	15	-7 ± 1	1.1 ± 0.8
22	36 ± 4	4.2 ± 1.5	25	-5 ± 3	0.4 ± 0.8
33	46 ± 3	2.8 ± 1.0	35	3.9 ± 1.5	-1.0 ± 0.6
12	23 ± 8	-2.1 ± 1.7	44	16.0 ± 0.3	6.3 ± 0.1
13	20 ± 14	-1.3 ± 1.5	55	21 ± 1	5.3 ± 0.5
23	12 ± 7	-0.3 ± 1.0	66	22.1 ± 0.2	4.54 ± 0.04
			46	1.2 ± 0.8	-0.34 ± 0.19

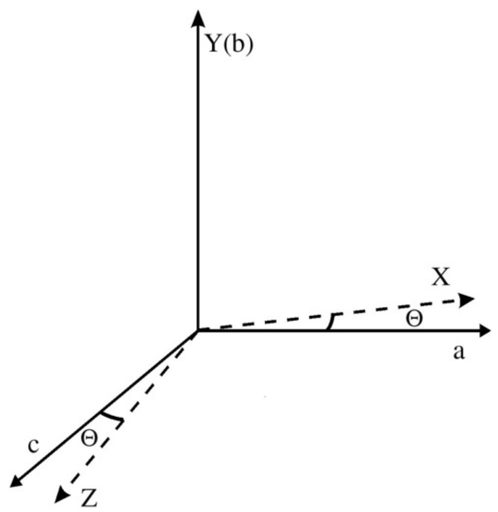

Figure 1. Schematic representation of crystallographic (*abc*) and eigen-acoustic (*XYZ*) coordinate systems.

errors. In practice the most convenient way is to study sections of the acoustic slowness surfaces by the crystallographic coordinate planes. However this method cannot ensure that a global minimum for the velocity is not missed, since the orientation of the latter can, in principle, be different from the principal eigenplanes. Then the only way out is to construct the acoustic slowness surfaces in the eigen-acoustic coordinate system, in which the extremum points of those surfaces should lie in the principal planes, according to the general symmetry considerations. In other words, reliable determination of the absolute minima of acoustic velocities should preliminarily include finding out of all the components of the elastic stiffness tensor and transforming them to the eigen-acoustic coordinate system.

Tensor components of the elastic stiffnesses and elastic compliances written in the crystallographic system are listed in table 2, while those referred to the eigen-acoustic system are gathered in table 3. It is seen from table 2 that some of the elastic compliance components (S_{12}, S_{13}, S_{23}, S_{15}, S_{25}, and S_{35}) are determined with relatively large errors. The latter ones originate from intricate recalculations that involve many elastic stiffness coefficients.

Table 3. Components of elastic stiffness tensor for $Sn_2P_2S_6$ crystals referred to the eigen-acoustic coordinate system XYZ.

Indices	C'_{ij} ($10^9\ N\ m^{-2}$)	Indices	C'_{ij} ($10^9\ N\ m^{-2}$)
11	39 ± 4	23	14 ± 9
22	36 ± 4	44	16 ± 1
33	45 ± 6	55	27 ± 4
12	21 ± 8	66	27 ± 5
13	22 ± 13		

The rotation angle of the eigen-acoustic coordinate system around the b axis with respect to the crystallographic system could be found using the condition that some of the elastic stiffness coefficients in the eigen-acoustic system are equal to zero. Namely, we have

$$C'_{46} = C'_{15} = C'_{25} = C'_{35} = 0. \quad (4)$$

Then the angle mentioned above is given by

$$\theta = \frac{1}{2} \arctan \frac{2C_{46}}{C_{66} - C_{44}}. \quad (5)$$

Using the specific values of the parameters, one finds $\theta = -(16 \pm 5)^\circ$, where the sign '−' corresponds to anti-clockwise rotation.

The cross sections of the acoustic slowness surfaces by the coordinate planes $X = 0$, $Y = 0$ and $Z = 0$ are presented in figure 2. It is easily seen that the lowest acoustic velocity for the $Y = 0$ plane corresponds to a quasi-transverse acoustic wave (QT_2) propagating in the XZ plane along the

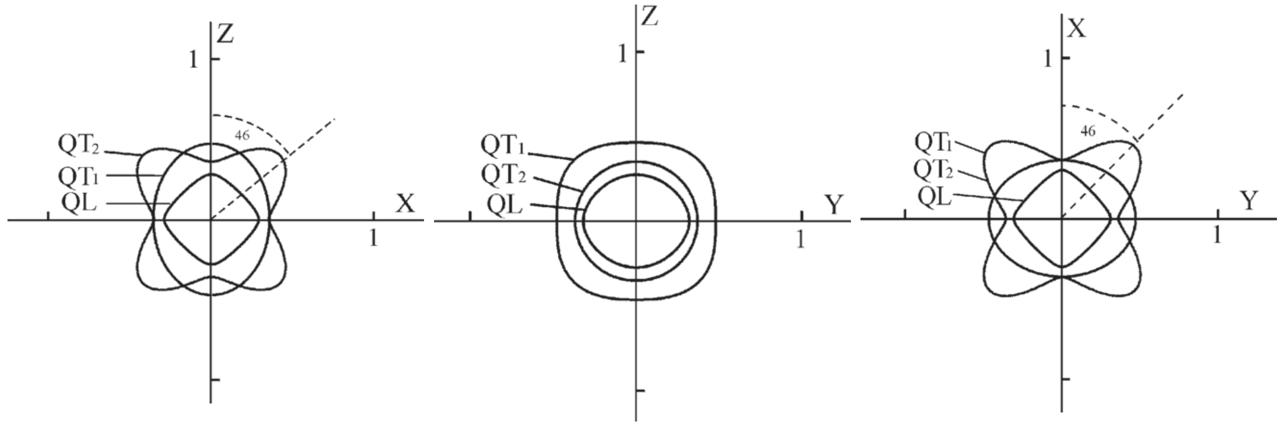

Figure 2. Acoustic slowness surfaces for $Sn_2P_2S_6$ crystals referred to the eigen-acoustic coordinate system (in 10^{-3} s m^{-1}).

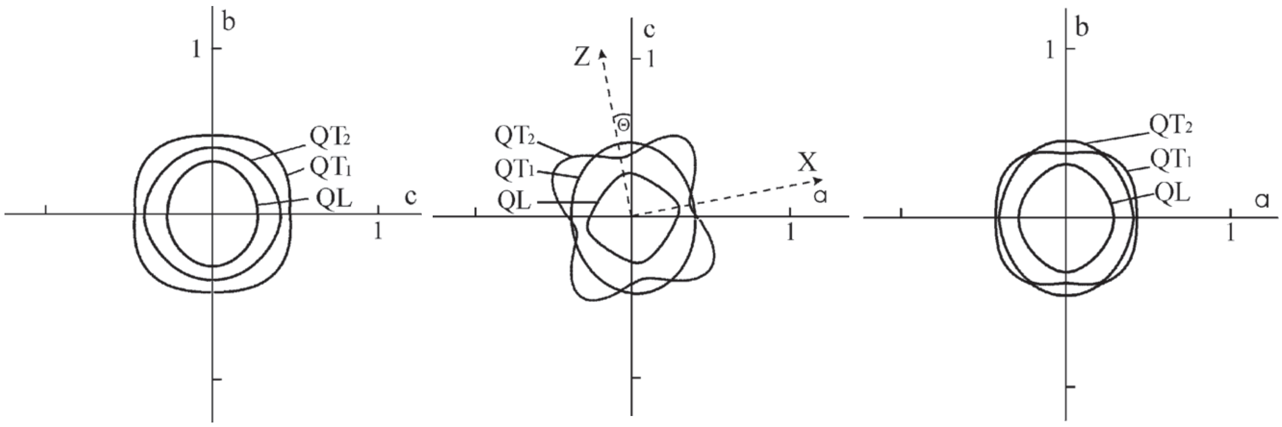

Figure 3. Acoustic slowness surfaces for $Sn_2P_2S_6$ crystals referred to the crystallographic coordinate system (in 10^{-3} s m^{-1}).

direction defined by the angle 46° with respect to the Z axis. Its polarization is almost parallel to the direction defined by the same angle, 46°, with respect to the X axis. In the crystallographic coordinate system the propagation direction of this wave is rotated in the ac plane by $30 \pm 5°$ around the c axis (see figure 3). The velocity of this wave is equal to 1710 ± 560 m s^{-1}. In this plane there exists a velocity minimum for another quasi-transverse wave (QT_1): one finds the value $v = 2110 \pm 110$ m s^{-1} for the QT_1 wave propagating along the Z axis, with the polarization parallel to the Y axis. In the crystallographic system the propagation direction of this wave is rotated by $-(16 \pm 5)°$ around the c axis in the ac plane. The velocity of quasi-longitudinal waves acquires its minimum (3360 ± 170 m s^{-1}) for the wave normal directed along the X axis or, which is the same, for the direction defined by the angle $-(16 \pm 5)°$ with respect to the a axis.

In the case of the other crystallographic plane ($X = 0$) we have the lowest velocity for the QT_1 wave ($v = 1920 \pm 340$ m s^{-1}) propagating in the ZY plane along the direction deviated by 42° from the Z axis. Its polarization is almost parallel to the direction defined by the angle 42° with respect to the Y axis. In the crystallographic system the propagation direction of this acoustic wave is determined by the directional cosines $\cos\alpha = 0.2048$, $\cos\beta = 0.6691$ and $\cos\gamma = 0.7151$ with respect to the a, b and c axes, respectively. The corresponding polarization is given by the cosines $\cos\alpha = -0.1844$, $\cos\beta = 0.7431$ and $\cos\gamma = -0, 6432$.

The acoustic QT_2 wave acquires its minimum velocity ($v = 2840 \pm 120$ m s^{-1}) when propagating along the Y (or b) axis, its polarization being parallel to the X axis ($-(16 \pm 5)°$ with respect to the a axis in the ac plane). For the quasi-longitudinal wave the minimum velocity (3180 ± 100 m s^{-1}) corresponds to the propagation direction along the Y (or b) axis.

Finally, in the $Z = 0$ plane the minimum velocity for the QT_1 wave is equal to $v = 1550 \pm 120$ m s^{-1}. This corresponds to the propagation direction inclined by 46° with respect to the X axis and the polarization vector that belongs to the XY plane and is almost perpendicular to the wavevector. The direction of propagation of this wave in the crystallographic system is determined by the directional cosines $\cos\alpha = 0.6678$, $\cos\beta = 0.7193$ and $\cos\gamma = -0.1915$, while the polarization is characterized by $\cos\alpha = -0.6914$, $\cos\beta = 0.6947$ and $\cos\gamma = 0.1983$. The QT_2 wave has its minimum velocity equal to $v = 2110 \pm 110$ m s^{-1} when propagating along the Y (or b) axis and being polarized along the Z axis. The latter direction in the crystallographic system lies in the ac plane and deviates by $-(16 \pm 5)°$ from the c axis. At the same

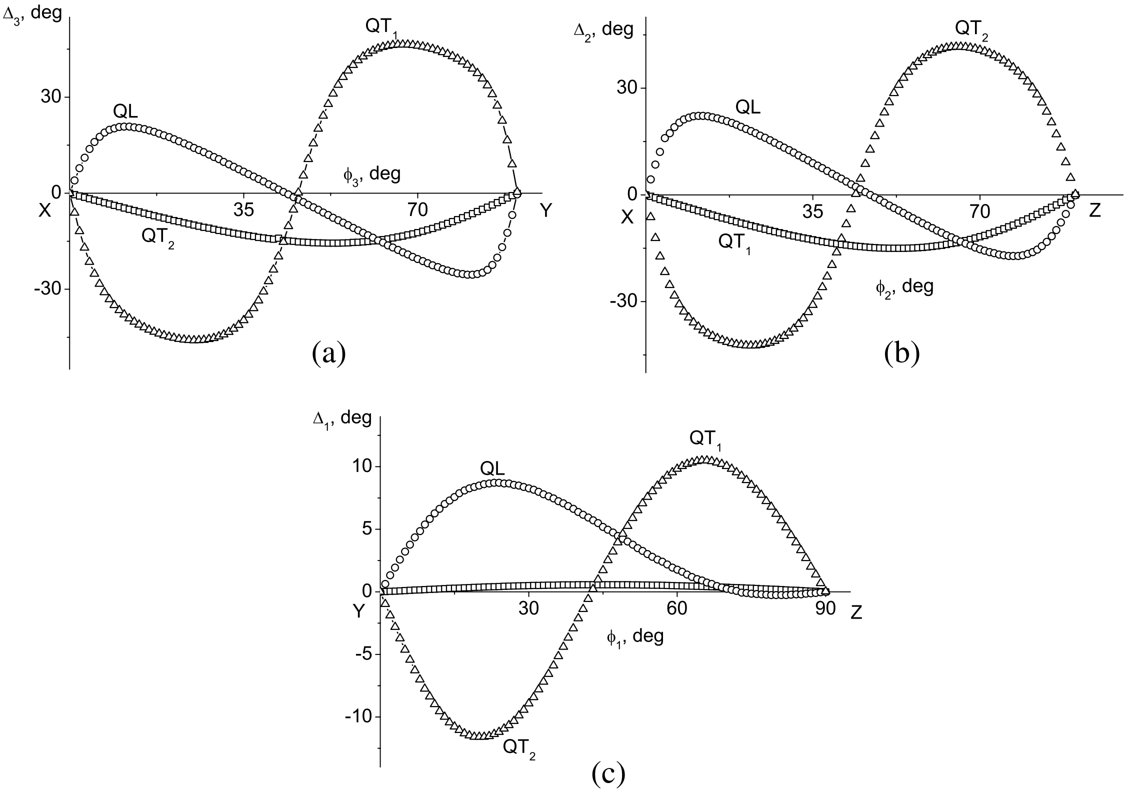

Figure 4. Acoustic obliquity for $Sn_2P_2S_6$ crystals represented in different planes of the eigen-acoustic coordinate system: (a) XY, (b) XZ and (c) YZ.

time, the quasi-longitudinal wave reveals its minimum velocity (3180 ± 100 m s^{-1}) while propagating along the Y (or b) axis.

Hence, we have three different acoustic waves in the $Sn_2P_2S_6$ crystals that reveal the lowest velocities, though only one of them corresponds to the principal crystallographic axis b. The latter coincides with the propagation direction of the quasi-longitudinal wave having the velocity 3180 ± 100 m s^{-1}. Based on the analysis performed above one can conclude that the absolute minimum velocity ($v = 1550 \pm 120$ m s^{-1}) for the $Sn_2P_2S_6$ crystals is peculiar for the acoustic wave QT_1.

While determining precisely the polarization and propagation directions of the three waves mentioned above, one should know their obliquity and deviation of their polarization states from purely transverse or longitudinal ones. Relevant consideration is given below.

3.2. Obliquity of the acoustic waves and deviation of their polarization from purely longitudinal or transverse types

The obliquity angle for the acoustic waves may be calculated using the relation (see [16])

$$\Delta_i = \arctan \frac{1}{v(\phi_i)} \frac{\partial v(\phi_i)}{\partial \phi_i} + \phi_i, \qquad (6)$$

where $v(\phi_i)$ denotes a function of acoustic velocity that depends upon the angle ϕ_i between the wavevector and the corresponding axis of the eigen-coordinate system. Here i is the axis perpendicular to the geometric plane under consideration. As seen from figure 4, the maximum obliquity for the QL waves amounts to $\Delta_2 = 22.3°$ and corresponds to the angle of $\phi_2 = 11°$ with respect to the X axis in the XZ plane. For the QT_2 and QT_1 waves we have respectively $\Delta_2 = 41.6°$ (XZ plane; $\phi_2 = 65°$ with respect to the X axis) and $\Delta_3 = 46.4°$ (XY plane; $\phi_3 = 67°$ with respect to the X axis). Moreover, the obliquity angle is equal to zero for the propagation directions of the slowest waves, which are collected in table 4.

The angle of deviation of polarization from the purely longitudinal type has been calculated on the basis of the Christoffel equation using the formulae [16]

$$\zeta_1 = \phi_1 - \frac{1}{2} \arctan \frac{(C_{23} + C_{44}) \sin 2\phi_1}{(C_{22} - C_{44}) \cos^2 \phi_1 + (C_{44} - C_{33}) \sin^2 \phi_1} \qquad (7)$$

$$\zeta_2 = \phi_2 - \frac{1}{2} \arctan \frac{(C_{31} + C_{55}) \sin 2\phi_2}{(C_{55} - C_{11}) \cos^2 \phi_2 + (C_{33} - C_{55}) \sin^2 \phi_2} \qquad (8)$$

$$\zeta_3 = \phi_3 - \frac{1}{2} \arctan \frac{(C_{11} + C_{66}) \sin 2\phi_3}{(C_{11} - C_{66}) \cos^2 \phi_3 + (C_{66} - C_{22}) \sin^2 \phi_3} \qquad (9)$$

which concern respectively YZ, XZ and XY planes. Here ϕ_1, ϕ_2 and ϕ_3 are the angles between the wavevector and the Y, X and X axes, respectively. The corresponding non-orthogonality of the quasi-transverse waves may be, in principle, calculated with the same formulae. The only difference is that the angle 90° should be added to the rhs of relations (7)–(9).

Following from the analysis of our experimental data (see figure 5), we have found that the non-orthogonality of the

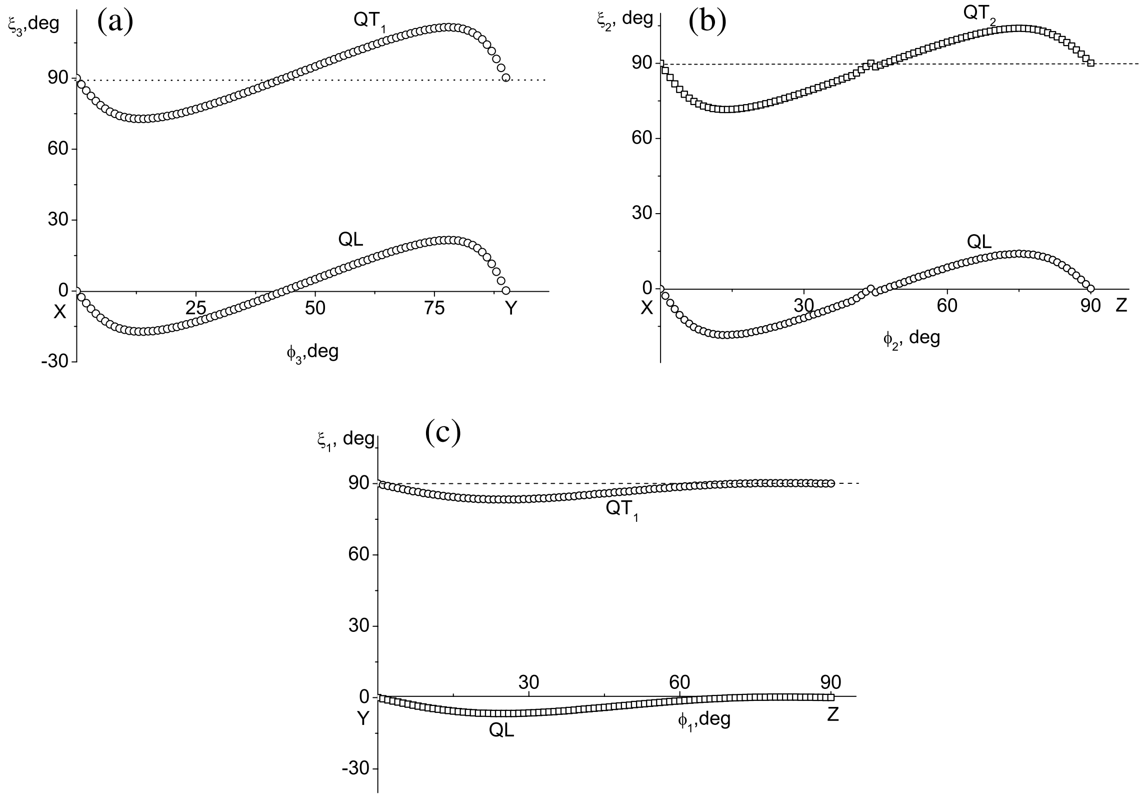

Figure 5. Dependences of deviation of the polarization from the wavevector direction on the wavevector direction represented in different planes of the eigen-acoustic coordinate system for $Sn_2P_2S_6$ crystals: (a) XY, (b) XZ and (c) YZ.

Table 4. Velocities of the slowest acoustic waves in $Sn_2P_2S_6$ crystals and their propagation and polarization directions referred to different coordinate systems.

		Propagation and polarization directions in the eigen-acoustic coordinate system		Propagation and polarization directions in the crystallographic coordinate system	
Type of acoustic wave	Acoustic wave velocity (m s^{-1})	Propagation direction	Polarization direction	Propagation direction	Polarization direction
QT$_1$	1550 ± 120	46° with respect to X axis in XY plane	Located in XY plane; almost perpendicular to the wavevector	$\cos\alpha = 0.6678$, $\cos\beta = 0.7193$, $\cos\gamma = -0.1915$	$\cos\alpha = -0.6914$, $\cos\beta = 0.6947$, $\cos\gamma = 0.1983$
QT$_2$	1710 ± 560	46° with respect to Z axis in XZ plane	Located in XZ-plane; almost perpendicular to the wavevector	$\cos\alpha = 0.8829$, $\cos\beta = 0$, $\cos\gamma = 0.4695$	$\cos\alpha = -0.4695$, $\cos\beta = 0$, $\cos\gamma = 0.8829$
QL	3180 ± 100	Parallel to Y axis	Parallel to Y axis	Parallel to b axis	Parallel to b axis

polarization and wavevectors for the QT$_1$ wave is equal to $\sim$1.9° (under the condition of propagation in the XY plane at the angle $\phi_3 = 46°$ with respect to the X axis). The above non-orthogonality for the QT$_2$ wave is approximately equal to zero (the case of propagation in the XZ plane at the angle of $\phi_2 = 46°$ with respect to the Z axis). Finally, the deviation of the polarization vector of the quasi-longitudinal wave propagating along the Y axis from its wavevector is also equal to zero.

The latter facts should be properly taken into account when quantitatively analysing the conditions of AO interactions in $Sn_2P_2S_6$ crystals. In particular, they are of primary importance when deriving the exact relation that determines the effective photoelastic coefficient.

4. Conclusions

In the present work we have determined for the first time all the acoustic wave velocities for the promising acousto-optic material, $Sn_2P_2S_6$ crystals, and have constructed on this basis the acoustic slowness surfaces in both the crystallographic system and the eigen-coordinate system of their elastic stiffness tensor. It has been found that the eigen-acoustic coordinate system is rotated by $\theta = -(16 \pm 5)°$ with respect to the crystallographic one. The complete matrices of the elastic stiffness and compliance coefficients have been determined.

Following from the quantitative analysis of the acoustic and elastic properties of these crystals, we have determined the directions of propagation and polarization of the slowest eigen-acoustic waves, accounting consistently for the acoustic obliquity and the deviation of acoustic polarization direction from the states corresponding to purely transverse and longitudinal ones. The velocities of the waves of greatest interest are 1550 ± 120 m s^{-1} (the QT_1 wave), 1710 ± 560 m s^{-1} (the QT_2 wave) and 3180 ± 100 m s^{-1} (the QL wave). In the directions of propagation of the latter waves there is no acoustic obliquity, while the deviation of their polarizations from the purely transverse and purely longitudinal types is negligibly small. The AO interaction with these acoustic waves should be most efficient, when compared with that typical for any other waves, owing to essentially increased AOFM.

For complete analysis of AO interactions in the $Sn_2P_2S_6$ crystals it would be necessary to have additionally the complete matrix of photoelastic coefficients. The results of studies for the photoelastic effect and the AO diffraction for the cumbersome case of low-symmetry $Sn_2P_2S_6$ crystals will be presented in a forthcoming paper.

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