Acoustical Physics, Vol. 50, No. 6, 2004, pp. 670–676. Translated from Akusticheskiĭ Zhurnal, Vol. 50, No. 6, 2004, pp. 776–782.

Numerical Analysis of the Properties of Slit Electroacoustic Waves

M. Yu. Dvoesherstov, V. I. Cherednik, S. G. Petrov, and A. P. Chirimanov

Lobachevsky State University, pr. Gagarina 23, Nizhni Novgorod, 603950 Russia

e-mail: dvoesh@rf.unn.ru

Received March 17, 2003

Abstract—The properties of slit electroacoustic waves that propagate in a system of two semi-infinite piezoelectric media separated by a vacuum gap, in a system consisting of a thin piezoelectric plate and a semi-infinite piezoelectric medium separated by a gap, and in a system consisting of two thin piezoelectric plates separated by a vacuum gap are studied. The process of transformation of slit electroacoustic waves to generalized surface acoustic waves or to Lamb waves is considered. © *2004 MAIK "Nauka/Interperiodica".*

As is known [1–4], slit electroacoustic waves (SEAWs) may propagate in a system of two semi-infinite piezoelectric crystalline media separated by a thin air gap. The energy of these waves is localized near the boundaries of the piezoelectric half-spaces and exponentially decays on both sides of the gap toward the depth of both piezoelectric media. Mechanical displacements in the two piezoelectric media are related to each other through the air gap by the electrostatic field accompanying the wave. It should be noted that an SEAW can also propagate in more complex configurations of piezoelectric media. These include, for example, a system consisting of a thin piezoelectric plate and a piezoelectric half-space with a gap between them or a system of two thin piezoelectric plates separated by a gap (when the plate thickness is $H \approx \lambda$, where λ is the wavelength). The interest in studying this type of waves arises from the fact that the SEAWs can be used in designing various kinds of acoustoelectronic pressure and temperature sensors or liquid and gas analyzers [4, 5].

An analytical calculation of the properties of SEAWs propagating in a system of two identical piezoelectric half-spaces separated by a gap was first carried out in [1–3]. In these publications, transverse slit acoustic waves with displacements u_2 in the boundary plane were studied, because the piezoelectric crystal cuts considered there satisfied the crystallographic symmetry conditions [6]. From the theory of surface acoustic waves (SAWs), it is known that, if the X_1X_3 saggital plane is perpendicular to the axis of twofold rotation of the crystal about one of the crystallographic axes of the crystal, i.e., the X, Y, or Z axis, then, X_1 is the direction of propagation of the "pure" acoustic mode (the Gulyaev–Bleustein mode) characterized by only one purely transverse component of mechanical displacement u_2 and an accompanying electric potential φ. If the saggital plane is a mirror symmetry plane of the crystal, the X_1 axis is the direction of propagation of the "pure" acoustic mode characterized by two components of mechanical displacement, u_1 and u_3, and an accompanying electric potential φ (the pure Rayleigh mode). In all other cases, a SAW has all three components of mechanical displacement, namely, u_1, u_2, and u_3, and an electric potential (φ). The same crystallographic symmetry conditions can be applied to SEAWs.

In this paper, we theoretically study the properties of the general type of SEAWs propagating in a system of two piezoelectric crystals of any crystallographic symmetry. In the most general case, in both media the SEAWs will have not one transverse u_2 but rather all three components of mechanical displacement u_i, where $i = 1, 2, 3$. We also study the properties of more complex SEAWs that propagate in a system of two different semi-infinite piezoelectric media separated by an air gap, in a system consisting of a thin piezoelectric plate and a semi-infinite piezoelectric medium with a gap between them, and in a system of two thin piezoelectric plates separated by a gap. We theoretically calculate the basic parameters of different modes of the SEAWs (the phase velocity V, the electromechanical coupling coefficient K^2, and the temperature coefficient of delay TCD).

Let us first consider a system that consists of two semi-infinite piezoelectric media separated by a vacuum gap whose width H is smaller than the wavelength λ (Fig. 1). Let the plane $X_3 = 0$ lie in the middle of the gap. The X_1 axis is the direction of propagation of a SEAW with a wave number $K = 2\pi/\lambda$. The electric energy of the SEAW is localized within the gap, and the mechanical displacements reach their maxima at the boundaries of the piezoelectric media, $X_3 = \pm H/2$, and exponentially decay on both sides of the gap in the depths of the two media. If the two piezoelectric media are identical and have the same orientation, the distribution of the electric potential φ in the gap may be sym-

1063-7710/06/5006-0670$26.00 © 2004 MAIK "Nauka/Interperiodica"

metric or antisymmetric and, hence, in this case, both symmetric and antisymmetric modes of the SEAW may propagate in the system under consideration. Unlike the classical SAW propagating over a free surface of the crystal, the velocity V of the SEAW depends on the wavelength λ. This spatial dispersion is related to the presence of a finite size (the gap width H) in the given structure and is analogous to the dispersion of waves in waveguides [3].

The general solution for such a wave can be obtained by solving the equations of the elasticity theory and electrostatics for both media [6, 7]. In addition, it is necessary to use ten boundary conditions. The mechanical and electric boundary conditions at the boundaries of piezoelectric media 1 and 2 ($X_3 = \pm H/2$) with a gap are as follows:

the zero values of the normal components of the stress tensor T_{3i} are

$$T^1_{31} = 0, \quad T^1_{32} = 0, \quad T^1_{33} = 0 \text{ at } X_3 = H/2,$$
$$T^2_{31} = 0, \quad T^2_{32} = 0, \quad T^2_{33} = 0 \text{ at } X_3 = -H/2, \tag{1}$$

and the continuity of the electric potential φ and the normal component of the electric induction D_3 are

$$\varphi^V = \varphi^1, \quad D^1_3 = D^V_3 \text{ at } X_3 = H/2,$$
$$\varphi^V = \varphi^2, \quad D^2_3 = D^V_3 \text{ at } X_3 = -H/2. \tag{2}$$

In the general form, the displacements u_i and the potential φ in each piezoelectric medium (media 1 and 2) can be represented as a sum of four partial waves ($u_4 = \varphi$):

$$u^1_i = A_m C_{im} \exp(jK\beta^1_m X_3)\exp[jK(X_1 - Vt)],$$
$$u^2_i = B_m D_{im} \exp(jK\beta^2_m X_3)\exp[jK(X_1 - Vt)]. \tag{3}$$

Here, A_m, C_{im}, B_m, and D_{im} are the amplitude factors, $\beta^{1,2}_m$ are the coefficients of attenuation along the X_3 axis, V is the wave velocity, and i and m are the indices: i = 1–4 (coordinates and potential) and m = 1–4 (partial mode number), where a summation is implied over repeated indices m.

Substituting these solutions into the set of equations of the elasticity theory, we obtain the Christoffel equations, from which we can calculate the partial wave amplitudes C_{im} and D_{im} and the coefficients $\beta^{1,2}_m$. Since the displacement amplitudes should decay in the depths of the media, from the complex attenuation coefficients $\beta^{1,2}_m$ found for the first and second media it is necessary to chose the coefficients that have a physical meaning, i.e., that comply with the condition of the wave localization near the surfaces of the two crystals.

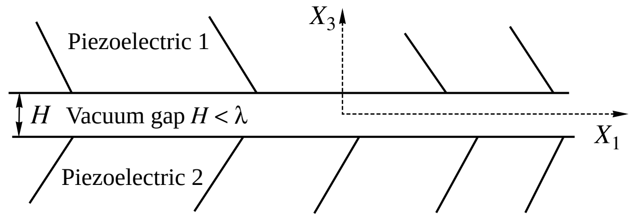

Fig. 1. System of two semi-infinite piezoelectric media separated by a gap.

The electric potential inside the vacuum gap, φ^V, is determined from the solution to the Laplace equation and can be represented in the form

$$\varphi^V = (\Phi_s \cosh(KX_3) + \Phi_a \sinh(KX_3)) \times \exp(jK(X_1 - Vt)). \tag{4}$$

The unknown coefficients Φ_s, Φ_a, A_m, and B_m are determined from the set of ten complex homogeneous equations that are obtained from the boundary conditions formulated above.

The number of unknowns and the number of equations can be reduced to eight if we preliminarily express the coefficients Φ_s and Φ_a in terms of the potentials of both media at their boundaries. The two ways of determining the coefficients Φ_s, Φ_a, A_m, and B_m are fully equivalent. Then, using the Farnell–Jones approach [6], we can determine the phase velocity V of the SEAW by solving the set of linear homogeneous boundary equations obtained from conditions (1) and (2).

As an example, in Fig. 2 we present the calculated dependences of the phase velocity V on the normalized width of the vacuum gap H/λ for the antisymmetric (curve A) and symmetric (curve S) modes of the SEAW propagating in a system of two identical lithium niobate piezoelectric crystals specified as YX-cut $LiNbO_3$ with the Eulerian angles $\phi = 0°$, $\theta = 90°$, and $\Psi = 0°$ [8]. From Fig. 2, one can see that the velocity of the modes of the SEAW exhibits a dispersion and, when $H/\lambda >$ 0.01, the modes of the SEAW transform to a common SAW (V_{SAW} = 3.7178 km/s) propagating in the given direction of the piezoelectric crystal.

If two different piezoelectric crystals or identical piezoelectric crystals of different cuts are used, the very structure of the wave becomes asymmetric with respect to the center of the gap. In this case, the existence of purely symmetric and purely antisymmetric modes of the SEAW is impossible. However, solutions exist for the distorted quasi-symmetric and quasi-antisymmetric modes of the SEAW. The greater the difference between the piezoelectric crystals in their material properties and crystallographic symmetry, the stronger the distortions of the SEAW modes are. As an example, Fig. 3 presents the calculated values of the phase velocity of the SEAW modes propagating in a system of two identical piezoelectric media of different crystal cuts, namely, YX-cut $LiNbO_3$(0°, 90°, 0°) and XY-cut

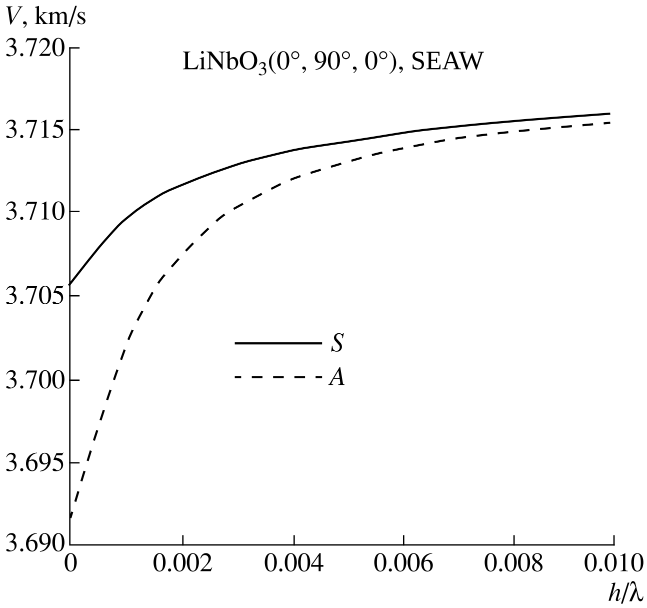

Fig. 2. Dependence of the phase velocity V on H/λ for the (A) antisymmetric and (S) symmetric modes of the SEAW in a system of two identical piezoelectric media, YX-cut $LiNbO_3$.

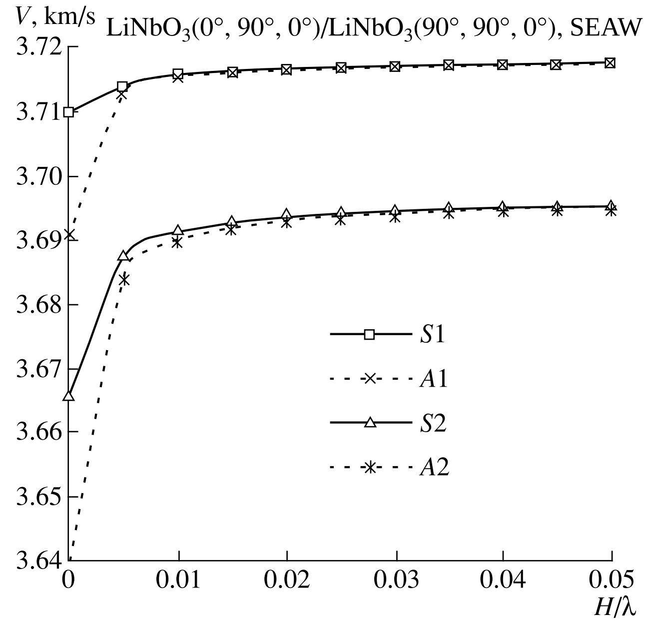

Fig. 3. Dependence of the phase velocity of the SEAW modes on H/λ in a system of two piezoelectric media: YX-cut $LiNbO_3$ and XY-cut $LiNbO_3$ with a gap between them.

$LiNbO_3$(90°, 90°, 0°), separated by a gap. For these crystal cuts, the crystallographic symmetry conditions [6] are not satisfied. From Fig. 3, one can see that solutions exist for two quasi-symmetric modes (curves $S1$ and $S2$) and two quasi-antisymmetric modes (curves $A1$ and $A2$) of the SEAW. As the gap width increases ($H/\lambda > 0.01$), these modes are transformed to SAWs propagating in the YX-cut (V_{SAW} = 3.7178 km/s) and XY-cut lithium niobate (V_{SAW} = 3.696 km/s), respectively.

An analysis of the properties of SEAWs propagating in a system that consists of a thin piezoelectric plate and a semi-infinite piezoelectric medium with a gap between them is of special interest, because precisely this type of structure seems to be promising for the development of acoustoelectronic sensors. To find the solutions, one can use the method described above. However, if the thickness of the piezoelectric plate $H2$ is comparable with the wavelength λ, the energy of the wave will be distributed over the whole thickness of the plate and, therefore, the solution for u_i in the plate should be represented as a sum of eight partial waves with allowance for all eight attenuation coefficients β_m ($m = 1, 2, \ldots, 8$) along the X_3 axis. It is also necessary to add four boundary conditions for the upper free boundary of the piezoelectric plate: the zero values of the normal components of the stress tensor T_{3i} and the continuity of the normal component of the electric induction. Then, one has to solve a set of 14 complex homogeneous boundary equations (or 12 equations, if the coefficients Φ_s and Φ_a are preliminarily determined).

Figure 4 shows a family of curves representing the calculated phase velocities of the symmetric mode of the SEAW versus the normalized gap width H/λ in a system consisting of a piezoelectric plate made of YX-cut quartz SiO_2(0°, 90°, 0°), a vacuum gap, and a semi-infinite piezoelectric crystal of YX-cut quartz SiO_2(0°, 90°, 0°) for different values of the thickness of the upper plate: $H2/\lambda$ = 0.2, 5, 6, 7, and 10 (curves denoted as $H2$ = 0.2, $H2$ = 5, $H2$ = 6, $H2$ = 7, and $H2$ = 10). From this figure one can see that, as the thickness of the upper plate $H2/\lambda$ decreases, the phase velocity of the SEAW mode also decreases. When the gap width increases to $H > 0.1\lambda$, the SEAW mode transforms to a SAW propagating in the YX-cut quartz (V_{SAW} = 3.1605 km/s). In addition, two solutions exist simultaneously for electroacoustic symmetric and antisymmetric Lamb modes [9, 10] propagating in the upper piezoelectric quartz plate. These Lamb modes exhibit a velocity dispersion. Unlike the case of a single free piezoelectric plate, in the system under consideration the values of the Lamb mode velocities depend on both the plate thickness $H2$ and the gap width H. Figure 5 shows the calculated dependences of the velocity of the antisymmetric Lamb mode on the gap width H/λ for two different values of the thickness of the YX-cut quartz plate: $H2/\lambda$ = 0.2 with the Lamb mode velocity V = 1.657 km/s (curve $H2$ = 0.2), and $H2/\lambda$ = 1 with the Lamb mode velocity V = 2.97898 km/s (curve $H2$ = 1).

Note that the structure considered above is fundamentally asymmetric with respect to the center of the gap. Therefore, even if the piezoelectric plate and the medium are made of the same material and have identical orientations, the SEAW modes will also be quasi-symmetric or quasi-antisymmetric. When the gap width increases, one mode transforms to a SAW propagating along the surface of the half-space and the other mode transforms to a Lamb mode propagating in the upper piezoelectric plate.

In a system consisting of two thin piezoelectric plates separated by a gap, the propagation of piezoelectrically active modes of the SEAW is also possible. Let us consider the system shown in Fig. 6. Here, $H1$ and $H2$ are the thicknesses of the upper and lower piezoelectric plates and H is the width of the gap between them. This kind of system is of interest because it allows one to study the process of transformation of the SEAW modes. For example, if the thicknesses of the two plates are $H1$, $H2 \gg \lambda$, in the general case we obtain two classical modes of the SEAW that propagate in a system of two piezoelectric half-spaces separated by a gap. As the gap width increases, the SEAW transforms to the common SAWs propagating along the surfaces of the two piezoelectric media. If the thicknesses of the two plates are $H1$, $H2 \approx \lambda$, an increase in the gap width will lead to a transformation of the SEAW to electroacoustic Lamb modes propagating in the piezoelectric plates. When the thickness of one plate is comparable to the wavelength λ and the thickness of the other plate is much greater than λ, the SEAW will transform to a common SAW propagating in the piezoelectric medium and to Lamb modes propagating in the piezoelectric plate.

A general solution for the SEAW in such a system can be obtained by representing the corresponding solutions for the mechanical displacements and the electric potential in the form of eight partial waves propagating in each of the plates. In this case, the number of boundary conditions will be greater, and it is necessary to find a solution to a set of 18 complex homogeneous boundary equations (or 16 equations).

As an example, Fig. 7 shows the calculated velocities of the symmetric and antisymmetric modes of the SEAW (the curves marked as mode *1* and mode *2*) propagating in the system of two identical piezoelectric plates made of langasite (LGS) with the (0°, 140°, 25°) orientation and with the thickness $H2 = H1 = \lambda$ versus the gap width H/λ. As the gap width increases to $H/\lambda >$ 0.1, the velocities of these modes tend to the velocities of the Lamb modes propagating in the piezoelectric plates. This means that the SEAW modes transform to the corresponding Lamb modes. Figure 8 displays the calculated velocities of the fundamental symmetric and antisymmetric Lamb modes (curves *S* and *A*) versus the plate thickness $H1/\lambda$. It should be noted that, in a single plate, an increase in its thickness to $H1 > 0.5\lambda$ leads to the appearance of a family of electroacoustic Lamb modes of higher orders [9, 10] (not shown in the figure), which transform to common SAWs as the plate thickness increases. In a system of two piezoelectric plates separated by a gap, symmetric (V_S = 2.8153 km/s) and

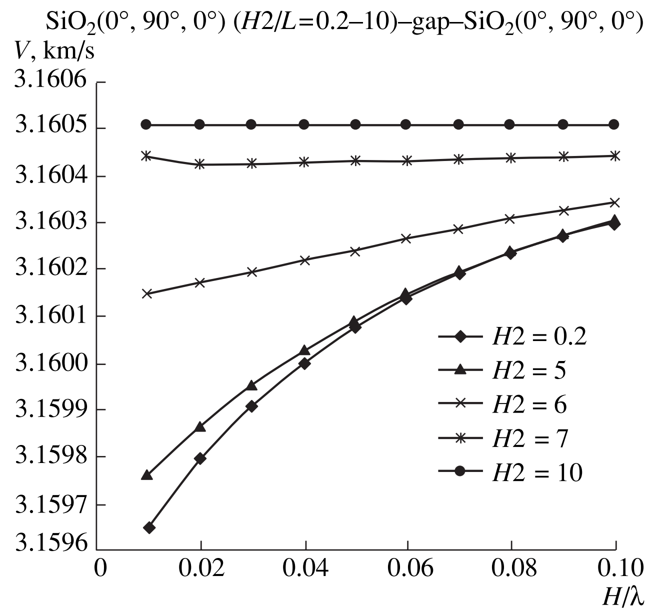

Fig. 4. Dependence of the phase velocity of the SEAW on H/λ in a system consisting of a *YX*-cut SiO_2 piezoelectric plate and a *YX*-cut SiO_2 piezoelectric medium with a gap between them for different values of the plate thickness: $H2$ = 0.2, 5, 6, 7, and 10.

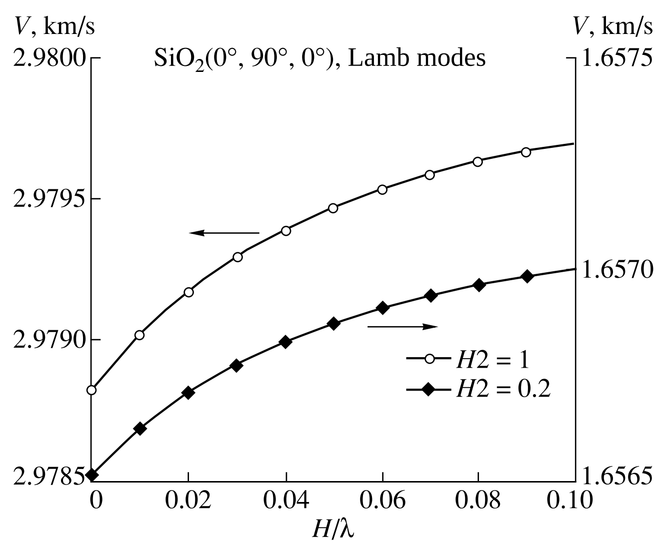

Fig. 5. Dependence of the velocity of the antisymmetric Lamb mode on the gap width H/λ for two different values of the *YX*-cut quartz plate thickness: $H2$ = 0.2 and 1.

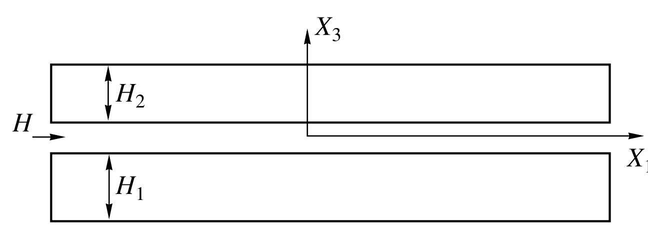

Fig. 6. System of two piezoelectric plates separated by a gap.

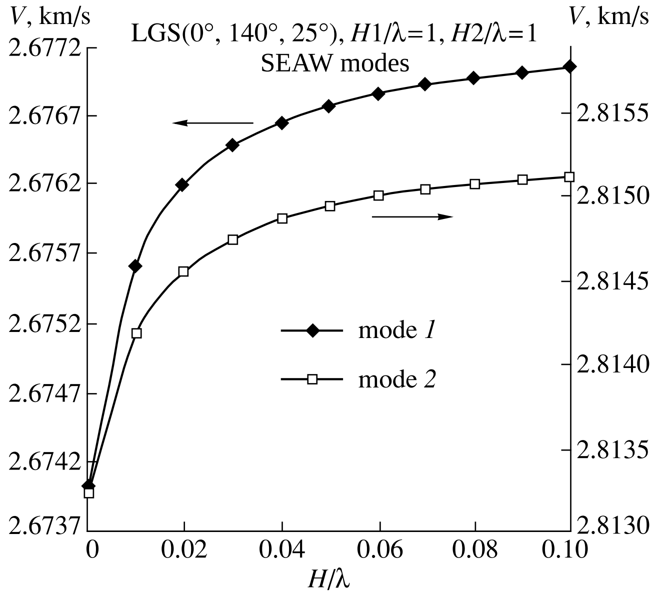

Fig. 7. Dependences of the velocities of the symmetric and antisymmetric modes of SEAW (modes *1* and *2*) on H/λ in a system of two piezoelectric plates made of langasite (LGS) with the orientation (0°, 140°, 25°).

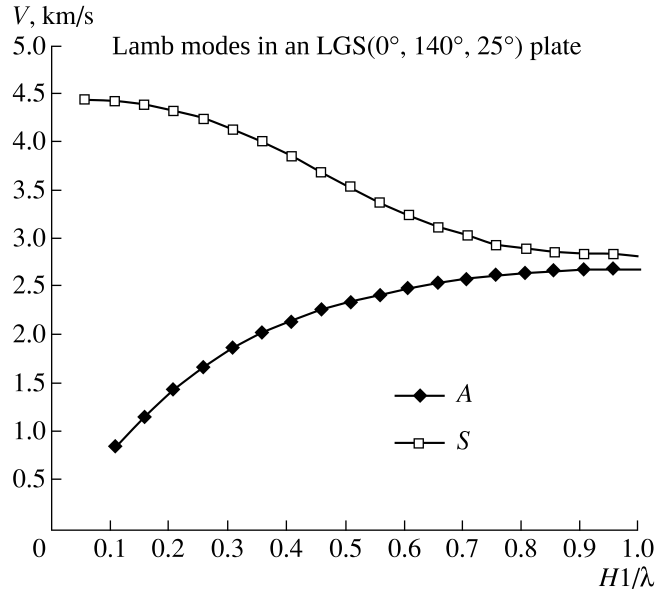

Fig. 8. Dependences of the velocities of the fundamental (*S*) symmetric and (*A*) antisymmetric Lamb modes on H/λ in an LGS(0°, 140°, 25°) piezoelectric plate.

antisymmetric (V_A = 2.6773 km/s) modes of the SEAW (see Fig. 7) transform to Lamb modes with an increase in the gap width (see Fig. 8). Finally, when the thicknesses of the two langasite plates are $H2$, $H1 > 5\lambda$, an increase in the gap width to $H > 0.1\lambda$ leads to the transformation of the SEAW to a common SAW propagating over the free surface of the langasite (V_{SAW} = 2.744 km/s).

It should be noted that one of the difficulties in solving the equations described above is that, in such complex piezoelectric crystal structures, several solutions simultaneously exist for one or another type of wave. Therefore, when searching for a specific mode, it is necessary to chose a sufficiently narrow interval of velocities, because, according to the Farnell–Jones approach, the phase velocity of the wave V is the parameter of the problem that is scanned to find the zero determinant of the boundary conditions [6, 11].

After calculating the phase velocity of the wave, it is possible to determine all other parameters of the wave. As is known [6], the electromechanical coupling coefficient K^2 for a SAW, which determines the efficiency of the wave excitation by an interdigital transducer positioned on the surface of the piezoelectric crystal, is calculated by the formula $K^2 = 2(V_0 - V_S)/V_0$, where V_0 and V_S are the SAW velocities along the open and metallized surfaces of the piezoelectric crystal.

Unlike SAWs, SEAWs propagate in a system of two piezoelectric crystals separated by a gap. If one of the piezoelectric crystal surfaces is metallized, the SEAW itself disappears, because the electric field connecting the oscillations in the two piezoelectric media proves to be shorted out, and the two half-spaces become completely isolated. However, to estimate the efficiency of excitation of the SEAW, it is possible to determine the electromechanical coupling coefficient K2 in a similar way. For example, if the SEAW is excited by an interdigital transducer positioned on the surface of the upper piezoelectric crystal, we have

$$K_U^2 = 2(V_0 - V_S)/V_0, \quad (5)$$

where V_0 is the velocity of the SEAW and V_S is the SAW velocity along the metallized surface of the upper piezoelectric crystal. If the SEAW is excited by an interdigital transducer placed on the surface of the lower piezoelectric crystal, we have $K_l^2 = 2(V_0 - V_S)/V_0$, where V_0 is the velocity of the SEAW and V_S is the SAW velocity along the metallized surface of the lower piezoelectric crystal.

For a system of two thin piezoelectric plates separated by a gap, the value of K^2 for SEAWs can be determined for a greater number of variants, depending on the positions of the interdigital transducers (four variants of positioning on one of the four surfaces) and on the state of each of the outer surfaces (metallized or free) that carries no interdigital transducer.

We used formula (5) to calculate the value of K_U^2 for the SEAW as a function of the normalized gap width H/λ in a system of two piezoelectric media consisting of langasite LGS with the orientation (0°, 140°, 25°). The calculations showed that the value of K_U^2 drastically decreases with increasing gap width. For example, for the gap width $H = 0.0001\lambda$, we obtain K_U^2 = 0.22%, and for $H = 0.05\lambda$, K_U^2 = 0.0046%. This means that the efficiency of the excitation of SEAWs drastically decreases as the gap width increases.

It is well known [12, 13] that, in a single thin piezoelectric plate made of lithium niobate (lithium tantalate, etc.) of a given orientation (an *XY*-cut, *YX*-cut, or *ZX*-cut plate), the propagation of a quasi-*SH*-wave is also possible, and this wave has a very high value of K^2 (up to 33%) at a certain plate thickness. For example, for an *XY*-cut $LiNbO_3$ plate with the thickness $H = 0.1\lambda$, the value of K^2 is $K^2 \approx 36\%$ and the phase velocity is V = 4.372 km/s [12, 13]. In fact, this is a fast transverse shear-horizontal wave propagating in the piezoelectric plate and containing almost no mechanical displacement component u_3 normal to the surface. Hence, the *SH* wave can propagate in a plate that is in contact with a liquid without any radiation loss caused by the energy transfer from the wave to the liquid medium.

In a system of two thin piezoelectric plates separated by a gap, the propagation of a fast *SH* mode of the SEAW is possible, and this mode has a high value of K^2 and a velocity V equal to that of the *SH* wave propagating in a single plate. Figure 9 shows the calculated velocities V_0 of the fast *SH* mode of the SEAW (curves $V(0.1)$, $V(0.2)$, and $V(0.5)$) and the values of K^2 (curves $K(0.1)$, $K(0.2)$, and $K(0.5)$) for three values of the thickness of both piezoelectric plates made of *XY*-cut $LiNbO_3$ ($H1/\lambda = H2/\lambda$ = 0.1, 0.2, and 0.5) versus the gap width H/λ. The value of K^2 was calculated in this case under the condition that the interdigital transducers are placed on the outer surface of the upper plate (i.e., V_S and V_0 in formula (5) refer to this surface) while other three surfaces are free. From Fig. 9, one can see that, as in the case of a single plate, the maximal value of K^2 calculated from Eq. (5) is obtained for the *SH* mode of the SEAW when the thickness of both plates is $H1/\lambda = H2/\lambda = 0.1$. For example, when the gap width is $H/\lambda = 0.01$, we have $K^2 \approx 9\%$, which is noticeably greater than the value of K^2 for a SAW in lithium niobate ($K_{SAW}^2 \approx 5.5\%$).

In a system of two plates separated by a thin gap, as well as in a single plate, many solutions and many modes are possible. In addition to the solutions shown in Fig. 9, there are modes with lower and higher velocities. For example, for the same conditions as in Fig. 9, for $H1/\lambda = H2/\lambda = 0.1$ (plates) and $H/\lambda = 0.01$ (gap), there is a wave with a lower velocity $V_0 = 4.04727$ km/s and $K^2 \approx 20.7\%$ and a wave with a higher velocity V_0 = 6.4753 km/s and $K^2 \approx 4.83\%$.

Another important parameter of the wave is the temperature coefficient of delay (TCD). For a SAW in a single medium, $\mathrm{TCD} = \alpha - \mathrm{TCV} = \alpha - 1/V \times (\partial V/\partial t)$, where α is the coefficient of linear thermal expansion of the medium, TCV is the temperature coefficient of

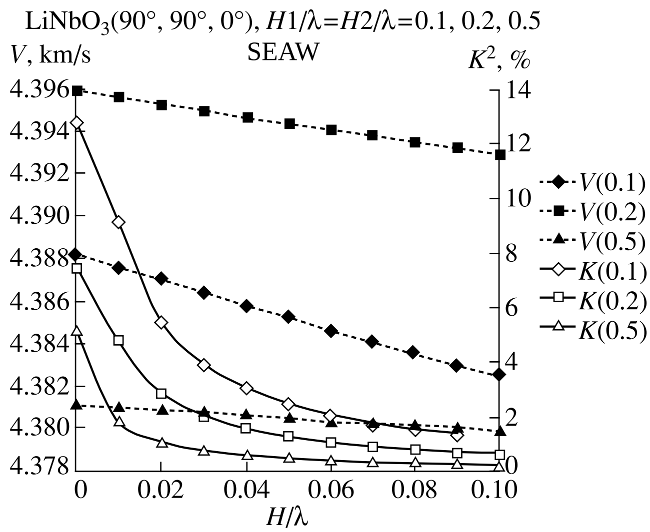

Fig. 9. Velocity V of the fast mode of the SEAW (curves $V(0.1)$, $V(0.2)$, and $V(0.5)$) and the electromechanical coupling coefficient K^2 (curves $K(0.1)$, $K(0.2)$, and $K(0.5)$) as functions of the gap width H/λ for three values of the piezoelectric plate thickness: $H1/\lambda$ = 0.1, 0.2, and 0.5.

velocity of the SEAW, and t is the temperature. In the case of the SEAW, the value of TCV for the SEAW is uniquely determined. However, since we have a system of two different piezoelectric media, an ambiguity arises in the determination of the TCD for the SEAW, because the value of α may be different in different media. Hence, we can determine two values of the TCD for the SEAW: one for the upper and one for the lower piezoelectric media with respective coefficients of linear expansion. The TCD of a real device will be determined by the coefficient of linear thermal expansion of the medium on which the interdigital transducers are placed, because the thermal expansion of the other medium will have no effect on them in this case.

Our calculations showed that, even in the case of two identical piezoelectric media with the same orientation, the values of TCD for SEAW somewhat differ from the value of TCD calculated for common SAWs. For example, in a system of two piezoelectric media thermally stable for SAWs, namely, LGS(0°, 140°, 25°) ($\mathrm{TCD_{SAW}} = -0.09 \times 10^{-6}$/K), with a gap $H = 0.5\lambda$ between them, the value of TCD for the SEAW is equal to -1.5×10^{-6}/K and depends on the width of the gap.

The materials constants for $LiNbO_3$, SiO_2, and LGS were taken from [14–16].

Thus, in this paper we described the method for a numerical calculation of the parameters of various kinds of SEAWs that propagate in piezoelectric media of any crystallographic symmetry class and their configurations. We considered the processes of transformation of SEAWs to SAWs in the case of two half-spaces or to electroacoustic Lamb modes in the case of a system of two thin piezoelectric plates separated by a gap. We showed that the velocity of SEAW modes is determined by the properties of both piezoelectric media and depends on the width of the gap. We proposed a system of two thin piezoelectric plates made of *XY*-cut (or *YX*-cut) lithium niobate with a gap between them, for which the slit electroacoustic wave has a high value of the electromechanical coupling coefficient. This structure can be used in the design of high-efficiency acoustoelectronic pressure sensors and gas and liquid analyzers.

REFERENCES

1. N. V. Gulyaev and V. P. Plesskiĭ, Akust. Zh. **23**, 716 (1977) [Sov. Phys. Acoust. **23**, 410 (1977)].
2. M. K. Balakirev, S. V. Bogdanov, and A. V. Gorchakov, Fiz. Tverd. Tela (Leningrad) **21**, 2508 (1979) [Sov. Phys. Solid State **21**, 1448 (1979)].
3. M. K. Balakirev and I. A. Gilinskiĭ, *Waves in Piezoelectric Crystals* (Nauka, Novosibirsk, 1982), p. 240 [in Russian].
4. P. A. Pyatakov, Akust. Zh. **47**, 836 (2001) [Acoust. Phys. **47**, 739 (2001)].
5. M. Veleekoop, Ultrasonics **36**, 7 (1998).
6. *Surface Wave Filters: Design, Construction, and Use*, Ed. by H. Mathews (Wiley, New York, 1977; Radio i Svyaz', Moscow, 1981).
7. *Acoustic Surface Waves*, Ed. by A. A. Oliner (Springer, New York, 1978; Mir, Moscow, 1981).
8. M. P. Shaskol'skaya, *Acoustic Crystals* (Nauka, Moscow, 1982), p. 632 [in Russian].
9. S. Tonami, A. Nishikata, and Y. Shimizu, Jpn. J. Appl. Phys., Part 1 **35** (5b), 3002 (1996).
10. M. Yu. Dvoesherstov, V. I. Cherednick, and A. P. Chirimanov, in *Proceedings of IV International Conference on Wave Electronics and Its Applications* (St. Petersburg, 2001), ISBN 5-8088-0059-5, p. 32.
11. M. Yu. Dvoesherstov, V. I. Cherednik, and A. P. Chirimanov, Izv. Vyssh. Uchebn. Zaved., Radiofiz. **43**, 801 (2000).
12. B. D. Zaitsev, S. G. Joshi, and I. E. Kuznetsova, in *Proceedings of IEEE Ultrasonics Symposium* (1998), p. 419.
13. S. G. Joshi, B. D. Zaĭtsev, and I. E. Kuznetsova, Akust. Zh. **47**, 336 (2001) [Acoust. Phys. **47**, 282 (2001)].
14. G. Kovacs, M. Anhorn, H. Engan, *et al.*, in *Proceedings of IEEE Ultrasonics Symposium* (1990), p. 435.
15. Y. Shimizu and Y. Yamamoto, in *Proceedings of IEEE Ultrasonics Symposium* (1980), p. 420.
16. A. Bungo, C. Jian, and K. Yamaguchi, in *Proceedings of IEEE Ultrasonics Symposium* (1999), p. 333.

Translated by E. Golyamina