ACOUSTIC WAVES IN CERAMICS WITH THE ELECTROINDUCED ANISOTROPY

Sergei A. Khakhomov, Sergei D. Barsukov, Igor V. Semchenko

Abstract:

The effects related with formation of induced anisotropy in natural-isotropic media, have been studied already for a long time. These phenomena interest scientists first of all due to a rare opportunity of control of artificial anisotropy of media, and also due to an opportunity of the energy transfer to a propagating acoustic or an electromagnetic wave. The idea of the nonlinear interaction of an acoustic and rotating electric field for the observation of parametrical electro-acoustic effects in crystals belongs to V.N Belyi and B.B. Sevruk, and has been ascertained more than 20 years ago [1], [2]. Then this idea has being developed by physicists of the Gomel State University [3]-[8] where F.I. Fedorov, B.V. Bokut', and A.N. Serdyukov [9]-[10] created a scientific school in the field of optics and acoustics. Until the present time the opportunity of suppression of absorption of ultrasound by rotating an electric field and amplification of ultrasonic waves in a crystal in conditions of resonant interaction of an electric field with ultrasound [11]-[14] has been predicted. In this case, media with the induced rotating spatially homogeneous acoustic anisotropy represent an acoustic analogue of spatially periodic media, showing the effects characteristic for the last.

Keywords: *ultrasound, rotating electric field, interaction, anisotropy, ceramics.*

1. Introduction

Researches in the field of interaction of acoustic waves with the electromagnetic field of an optical range extending in a crystal or an exchange by energy between an electric field and an acoustic wave are connected with necessity of application of special means of measurement having a wide spectral and dynamic range. Quite often it is necessary to deal with high and ultrahigh frequencies that demands application of the special equipment.

In particular, due the radiation of an acoustic wave with various frequencies in laboratory and a phase, it is necessary to have at the disposal of the functional generator with as much as possible wide range of frequencies, the phase shifter, the amplifier and certainly a radiating element. As a radiating element the piezoelectric element can be applied. The basic ways and the received results on the given scientific problem are shown in the article.

1.1. Development of an experimental complex

With the purpose of confirmation of theoretically predicted effects we carry out the experimental researches in this field. The experimental complex is developed for research of spatial acoustic waves in waveguide. The scheme of a setup is shown in Figure 1.

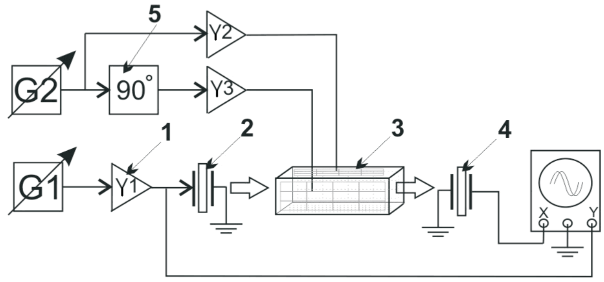

Fig. 1. The principal scheme of the setup.

The experimental setup consists of two operated generators (G1, G2), the phase shifter (5) which changes a phase on 90 degrees, two amplifiers of a high voltage (Y2, Y3), the amplifier for radiator (Y1) 1, a radiator of ultrasound (2), an acoustic waveguide (3), the receiver of ultrasound (4) and devices of indication as which the two-channel oscillograph or the analog-digital converter (ADC) is applied.

In a basis of work of a laboratory complex radiation and registration of acoustic waves by means of the piezoelectric elements connected with measuring devices under the offered block diagram. From the generator (G1) the harmonious signal affects the amplifier (Y1) with which the level of a signal necessary for normal work on facings of an acoustic radiator is provided. The generator (G1) sets frequency of the acoustic wave extending in a wave-guide. The radiator makes volumetric shift fluctuations and, that, creates cross-section fluctuations in an acoustic wave-guide. At the output of wave-guide flexible fluctuations of media are registered by means of the receiver (4), and, strengthened by an electronic part of the measuring device, accept a numerical kind. The generator (G2) sets frequency of a rotating electric field. His output is connected to the electronic phase shifter (5) and further to the high-voltage amplifier (Y3), and also directly to the high-voltage amplifier (Y2). Thus on an output of high-voltage amplifiers (Y2) and (Y3) the sine wave signal with the big amplitude and displaced on a phase between channels of amplifiers 90 degrees is formed. Submitting the received signal on the facings of an acoustic wave guide located in its mutual-orthogonal planes we form a rotating electric field where the vector of intensity of a field describes a circular trajectory with the beginning on an axis of symmetry of a wave guide and directed along an extending acoustic wave. Varying frequencies of generators and factors of amplification of amplifiers of an experimental complex in the described block diagram, it is possible to set various parameters of researches with various frequencies and levels of electric signals of control.

1.2. Experimental samples and methods of researches

In our researches we use a wave-guide, which has the rectangular form and is made from ceramics on the base of barium titanate. The general view of an acoustic wave-guide with the facings put on its sides is presented in Figure 2.

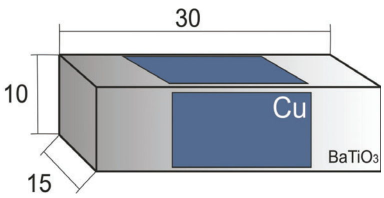

Fig. 2. The linear sizes of an acoustic wave-guide (mm).

In Figure 3 the photo of the made acoustic wave-guide with facings is presented. The variable voltage on electrodes creates a variable electric field in volume of a waveguide.

Fig. 3. A photo of an acoustic waveguide.

Transceivers and receivers of acoustic waves are presented in Figure 4. The samples of radiators of transversal acoustic waves are executed on the basis of YZ section of a plate of quartz. Control of radiators is made by a variable electric field by leading on facings of radiators of a variable voltage from the block of amplifiers. Resonant frequency of applied radiators is in the range of 28 MHz, thus measurements carry out on frequencies on the order below that allows excluding natural resonances of radiating and registering elements.

Fig. 4. Acoustic transceivers and receivers of ultrasound.

The active part of an experimental setup is presented in Figure 5. The acoustic wave-guide is fixed in special frameworks, which provide electric and acoustic isolation. The radiator and the receiver of acoustic oscillations are located at the end faces of a waveguide and have direct contact to it.

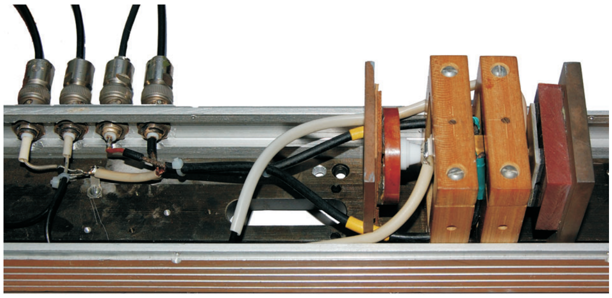

Fig. 5. An active part of an experimental setup.

2. Experimental researches

Researches carried out by us have shown good results of radiation of acoustic waves in a wave-guide and their subsequent registration. In the researched range of frequencies of resonances it was not observed.

2.1 Radiation and registration of acoustic waves

In Figure 6 the oscillograms of electric signals on a radiating element (the bottom sinusoid) and the receiver of acoustic waves (the top sinusoid) are presented.

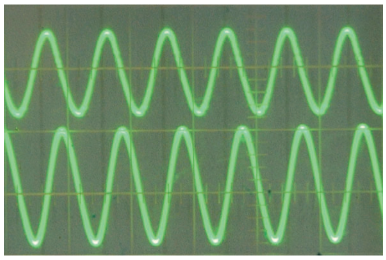

Fig. 6. Oscillograms of signals on active elements of a complexþ (The top sinusoid at 0,2V/per, bottom at 20V/per)

At equality of frequencies of a radiated acoustic wave (the bottom sinusoid in Figure 7) and frequencies of an external rotating electric field an addition of acoustic fluctuations and increase of amplitude of acoustic wave (the top sinusoid in Figure 7) is observed.

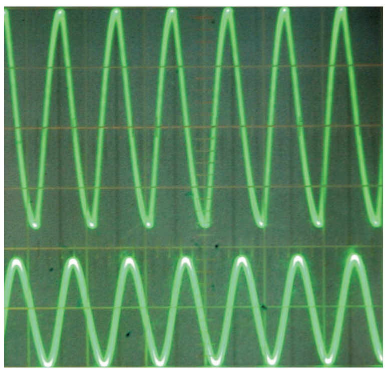

Fig. 7. Oscillograms of signals on a radiating element and the receiver of acoustic waves.

In case frequencies of acoustic waves are various, the effect of modulation of acoustic waves due to addition of mechanical fluctuations with various frequencies is observed. The effect of modulation is presented in Figure 8.

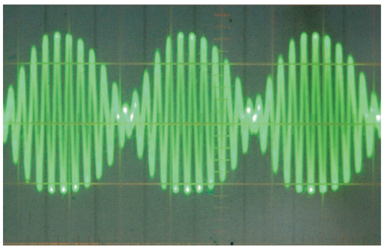

Fig. 8. Modulation of an acoustic wave by an electric field.

As results of the work the "The device for measurement of ellipticity of transversal acoustic waves" has been offered. The offered device allows measuring ellipticity of a transversal acoustic wave in a wave-guide in relative units or in percentage. The basis of work of the device is the method of measurement of the relation of amplitudes of mechanical oscillations in is mutual-perpendicular planes and their comparison. As the registering elements in the device are the piezoelectric resonators which can transform mechanical oscillations to electric, owing to piezoelectric effect. The devices of comparison are tool amplifiers with a differential input, which besides function of subtraction also provide the basic amplification of electric signals. Except for the described elements in the scheme of the device are included: filters of the bottom frequencies, peak detectors, and also potentiometer. It has allowed providing high repeatability of the device, flexible adjustment and an opportunity of work with wave-guides of any types and the linear sizes.

3. Conclusion

The received results can be applied in experimental sections of acoustics, acoustoelectronics. The basic results of work can be used at theoretical and experimental researches of environments with the structure periodically changing eventually. The developed technique can be used for definition of influence of external influences on properties of flexible waves in crystals of various dot groups of symmetry. The results received by consideration of features of creation of cross-section acoustic waves in a crystal, can be used by development of practical devices, at the decision of the broad audience of theoretical and experimental problems of physics of a firm body and the ultrasonic acoustics, connected with control of characteristics of acoustic waves (amplitude, frequency, polarization) by change of intensity and (or) frequencies of an external field.

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References

[1] Belyi V.N., Sevruk B.B. "Parametric electro-acoustic effects in crystal with rotating acoustic anisotropy induced by the external electric field", *Sov. Phys: Technical. Phys., vol.* 29, no. 2, 1987, pp. 336-340.

[2] Semchenko I.V., Sevruk B.B., Khakhomov S.A., "Acousto-electron interaction in conductor crystal of ferroelectric ceramics in the condition of inducing of piezoelectric, anisotropic and gyrotropic properties by the rotating electric field". In: *Proceedings of the "Bianisotropics'93", Gomel, Belarus*, 1993, pp. 93-96.

[3] Khakhomov S.A., Semchenko I.V., Sevruk B.B., "Electroacoustic interaction in piezoelectric semiconductors: chiral properties induced by the rotating electric field". In: *Proceedings of the "Chiral'94" Perigueux, France*, pp. 445-450, 1994.

[4] Semchenko I.V., Sevruk B.B., Khakhomov S.A., "Electroacoustic interaction in ferroelectric ceramics in presence of the rotating electric field", *Kristallografiya, vol.* 39, no. 6, 1994, pp. 1088-1091.

[5] Semchenko I.V., Khakhomov S.A., "Effect of charge-carrier drift on the resonant interaction of acoustic waves and rotating electric field in piezoelectric semiconductors", *Crystallography Reports, vol.* 42, no. 2, 1997, pp. 184-187.

[6] Fedorov F.I., *Teoriya Girotropii Theory of Gyrotropy*, Minsk: Nauka i Tekhnika, 1976, p. 456. (in Russian)

[7] Serdyukov A.N., Semchenko I.V., Tretyakov S.A., Sihvola A.H., *Electromagnetics of bi-anisotropic materials*, Gordon and Breach Sciense Publishers, 2001, p. 310.

[8] Semchenko I.V., Khakhomov S.A., *Spatial acoustic waves in crystals in the rotating electric field*, Belaruskaya navuka, Minsk, 1998. (in Russian)

[9] Semchenko I.V., Khakhomov S.A., *The method and device for transformation of ultrasound waves*, Patent of Russian Federation, No 2288785, *Inventions*, No 34, 2006, Appl. 22.02.2005, Publ. 10.12.2006.

[10] Ohno M., "Wave front reversal in acoustic phase conjugation by nonlinear electroacoustic interaction in $LiNbO_3$", *Appl. Phys. Lett.,* vol. 55, no. 9, 1989, pp. 832-833.

[11] Khakhomov S. A., Semchenko, I.V., "Spatial acoustic waves of ultrasound range in crystals in the rotating electric field". In: *Proceedings of the Gomel State University*, no. 3, vol. 30, 2005, pp. 38-49.

[12] Semchenko I.V., Khakhomov S.A., Barsukou S.D., Interaction of acoustic waves with rotating electric field in ceramics on the base of barium titanate. In: Proc. 6th Inter-Academia. - 2007. - Hamamatsu, Japan, pp. 126-135.

[13] Barsukov S.D., Khakhomov S.A., Semchenko I.V., "The universal generator for acousto-optic researches". In: Proceedings *of the 7th International Conference on Global Research and Education Inter-Academia 2008*, 15th-18th September, 2008, Pecs, Hungary, pp. 438-443.

[14] Semchenko I.V., Khakhomov S.A., Barsukou S.D., *Device for measurement of the peak-frequency characteristic piezoelement*, Patent of Belarus, no. 4624, BY 4624 Appl. 30.08.2008.