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OBSERVATION OF LEAKY SAW AND OTHER ACOUSTIC MODES ON 49° Y-ROTATED $LiNbO_3$ BY OPTICAL DIFFRACTION METHOD

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The propagation properties of LSAW and SAW as well as acoustic bulk waves on the substrate of 49° Y-rotated $LiNbO_3$ excited by IDT are investigated by Schaefer-Bergmann diffraction technique and electrical method. The inverse phase velocity curves in the propagation plane are obtained both experimentally and theoretically. The existence of LSAW in some directions on the substrate has been verified.

In the late sixties, the leaky surface acoustic wave (LSAW) was discovered[1,2], which propagates along the free surface of an anisotropic crystal and at the same time radiates the bulk wave into the crystal. In the substrate of 49° Y-rotated $LiNbO_3$, LSAW has a higher electromechanical coupling constant and a faster propagation velocity than SAW, and the propagation attenuation is very low in some propagation directions.

So far, there have been a lot of papers on observations of acoustic bulk waves and SAW by optical method, however, only a few on LSAW. In this paper, we present the experimental study on the propagation features of LSAW and other acoustic modes launched from interdigital transducer (IDT) on 49° Y-rotated $LiNbO_3$ by Schaefer-Bergmann diffraction technique and electrical method, and also give the corresponding theoretical calculations.

As is well known, the Schaefer-Bergmann diffraction pattern, which is produced by acousto-optic interaction in a crystal, corresponds to the inverse phase velocity curve of the crystal, from which the propagation phase velocity in different directions can be determined. In our experiments, both reflection and transmission method were used, and the experimental systems are shown in fig.1 and fig.2, respectively. Two kinds of samples with dimensions of $30\times12\times8mm^3$ and $30\times15\times1mm^3$ were used. For the former, the six surfaces were optically polished, and for the latter, only one or two surfaces were polished. The coordinate system of the specimen is shown in fig.3. The x axis coincides with the principal axis x of $LiNbO_3$, and the z axis orients to the normal direction to the specimen surface. The IDT consisting of 15 finger pairs with an aperture of 40 wavelengths was deposited on the surface, and it excited acoustic

waves to propagate in the x direction.

In the reflection case, we have measured the diffraction patterns under three surface conditions: free surface, metallized surface, and surface covered with an optical reflection film consisting of MgF and ZnS. The results are similar to each other and are shown in fig.4 (free surface) and fig.5 (surface with reflection film). The photograph for metallized surface is not shown here.

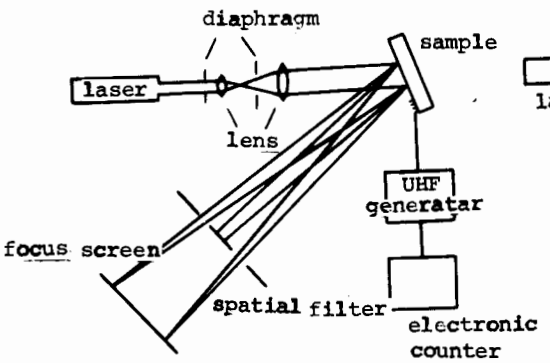

fig.1

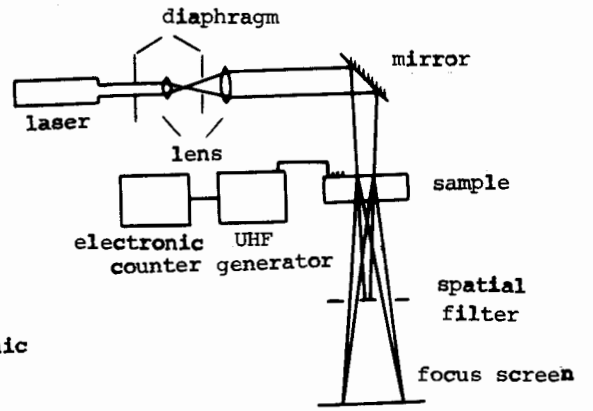

fig.2

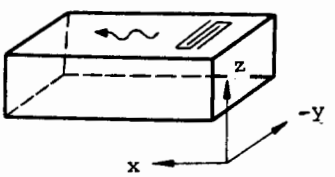

fig.3

fig.4

In the pictures, we can observe the following phenomena:

1) In the x direction, there are two points marked by arrowheads.

2) There is a curve which is approximately a circle.

3)Near y direction, there are two segments discriminated from the half circular curves.

If some acoustic absorber was put, or a groove was cut, between the IDT and the projected position of laser beam on the specimen surface, the intensity of the two points and the curves obviously decreased. It means that the acoustic modes correspond to these points, and the curves have the feature of surface wave.

If the IDT was rotated from x axis through a small angle, the two

diffraction points also appeared but deviated from x axis by the same angle.

The inverse phase velocity curves of LSAW and SAW in the x-y plane were calculated based on the way of Xue et al.[3] and were shown in fig.6. Four segments of the inner broken curve near x axis and y axis represent the inverse phase velocity curve of LSAW, which indicates that LSAW has solutions only in directions near x and y axis within about ±5 degrees. However, in directions near y axis, the inverse phase velocity curve of SAW described by solid line is broken, i.e., in this range SAW has no solution.

The theoretically calculated results of LSAW, as well as SAW, velocities along x and y axis and the corresponding measured values from the diffraction patterns are listed in table 1. Comparing the above results, it is confirmed that, in fig.4 or 5, the two diffraction points in the x direction and the two segments near the y direction are produced from LSAW, and the other curves are caused by SAW.

The LSAW velocity along x axis was precisely measured by electrical impulse overlap method for verification[4] . The results are also given in table 1.

Table 1. The propagation velocity of LSAW and SAW in the xy plane of 49° Y-rotated $LiNbO_3$ substrate

Propagation direction	Surface condition	Propagation velocity(km/s)				
		LSAW			SAW	
		Theory	Experiment		Theory	Experiment
			Optical	Electrical		Optical
x	Free	4.788	4.74	4.775±.009	3.674	3.64
	Metallized	4.424	4.41	4.430±.002	3.672	3.64
	Cover film		4.76			3.64
y	Free	3.762	3.76			
	Metallized	3.759	3.75			
	Cover film		3.75			

The theoretical propagation attenuation values of LSAW are shown in table 2. It shows that the attenuation of LSAW in all directions are almost of the same order for both free and metallized surface conditions, which is different from those of 41° and 64° Y-rotated $LiNbO_3$ substrates.

Table 2. The theoretical propagation attenuation of LSAW in the xy plane of 49° Y-rotated LiNbO substrate

θ(from x axis)	0°	2°	4°	6°	8°	10°	83°	84°	86°	88°	90°
Free (dB/λ	.031	.051	.095	.127	.114	.052	.941	.675	.288	.070	$<10^{-10}$
Metallized $\times 10^{-1}$)	.154	.243	.543	.876	.846	.823	.849	.614	.264	.065	$<10^{-10}$

In the transmission case, the laser beam impinged on the specimen

along the z and y directions. The diffraction patterns of the acoustic waves in xy and xz plane are shown in fig.7 and fig.8, respectively, which are in agreement with the theoretical calculations.

As demonstrated on fig.7, the outmost curve is produced by SAW and LSAW, which have been found in fig.4 or fig.5; the inmost curve is caused by the longitudinal bulk wave; and the others are generated by transverse bulk waves. In fig.8, however, only two transverse modes are observed.

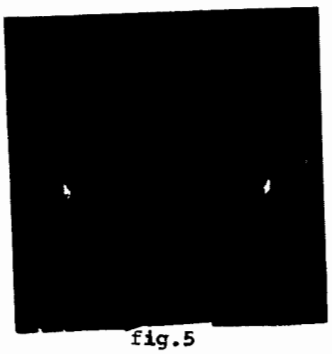

fig.5

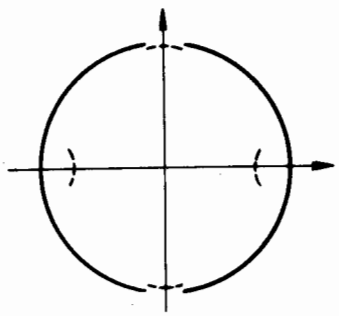

fig.6

fig.7

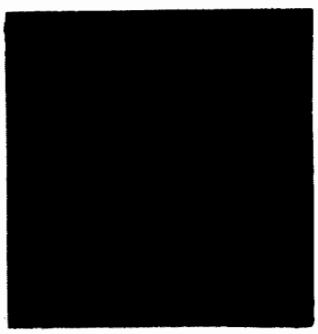

fig.8

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REFERENCES

1. H.Engan et al., Appl.Phys.Lett.10(1967)311.
2. T.C.Lim and G.W.Farnell, J.Acoust.Soc.Amer.45(1969)845.
3. Q.Xue et al., Chin.Phys.Lett.3(1986)273.
4. Z.N.Lu, The 1st National Conference on SAW, (1987)579(in Chinese).