New design of AOTF using ZnO/$LiNbO_3$ thin-plating surface acoustical waveguide

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In this paper, a new non-collinear configuration of acousto-optic tunable filter (AOTF) which uses ZnO film-loaded surface acoustical waveguide (SAWG) on X-cut Y-propagating $LiNbO_3$ (X-Y $LiNbO_3$) is designed in which the interdigital transducer should be inclined 3.16°. The thickness of the ZnO makes the velocity of surface acoustical wave (SAW) decrease to 3.23%. Cubic spline interpolation method is used to obtain the walk-off angular (the angular from the propagation direction to the power-flux vector) curve with the velocity curve directly and calculation of SAW propagation in ZnO/X-Y $LiNbO_3$ gives that the walk-off angular is 3.16° when the velocity decreases to 3.23%.

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1. Introduction

A ZnO thin-plating surface acoustical waveguide (SAWG) has a strong confinement, excellent filter characteristics and provides design flexibility and simple fabrication technique. It can suppress sidelobes effectively. This is very important in the design of acousto-optic tunable filter (AOTF). In this paper we calculate the velocity change and walk-off angular for the design of ZnO film-loaded SAWG on X-cut Y-propagating $LiNbO_3$ (X-Y $LiNbO_3$).

AOTF are usually designed collinear or quasi-collinear using materials which are anisotropic and piezoelectric as SAW waveguides before [1-2] and they are fabricated ignoring the walk-off angular which usually exists when acoustic wave propagates in anisotropic crystals. But actually a walk-off angular exists in the propagation of SAW in ZnO /X-Y $LiNbO_3$ that causes the confusion of acoustic field.

In this paper, a new non-collinear AOTF which does not cause confusion of acoustic field is designed having an angular compensation set and the angular is about 3.16° and the configuration scheme is given. The design is based on the analysis of the propagation characters of SAW in ZnO / X-Y $LiNbO_3$. We have done similar design to the AOTF using X-Y $LiNbO_3$ waveguide before [3] and gotten good result. Development is given to the calculation proceeding of walk-off angular curve that cubic spline interpolation method [4] is employed to get walk-off angular curve from the velocity-angular curve directly. It is simpler than methods used before, but it can get the same result [5] using values of the elastic and piezoelectric constants of $LiNbO_3$ taken from the work of G.Kovacs, M.Anhorn [6]. Calculation is done for SAW in ZnO / X-Y $LiNbO_3$ and new method is described to get the walk-off angular curve in part two. The third part gives the analysis of the acoustic filed of collinear or quasi-collinear AOTF and shows the designed scheme of AOTF with the design reason given.

2. Calculations and new method to get walk-off angular curve

For study the propagation characters of SAW in ZnO / X-Y $LiNbO_3$ with the surface of ZnO is metallized, a computer program is written to get the velocities using global optimal method [7] based on the theory of J. J. Campbell and W. R. Jones's method [8] with the result shown in Fig. 1 and the values of the elastic and piezoelectric constants of $LiNbO_3$ are taken from the work of G.Kovacs, M.Anhorn [6]. It can be known from the figer that when the velocity decreases to 3.22%, so the SAW can be confined in the waveguide effectively, the thickness of ZnO is 2.11 μm. We determine the thickness of ZnO is this value.

But that is not enough, because when acoustic wave propagates in anisotropic crystals, the direction of power flowing usually deviates from the propagation direction and the angular between them is walk-off angular ϕ. Fig. 2 shows it. The same condition also occurs when SAW propagates in ZnO /X-Y $LiNbO_3$.

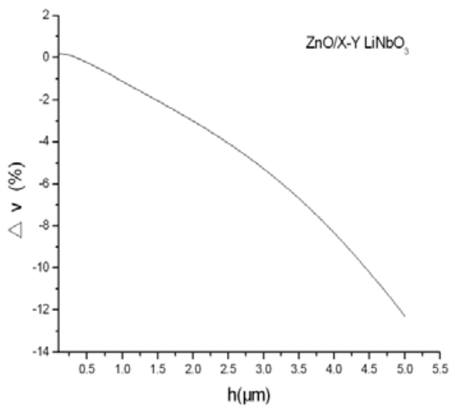

Fig.1. Change of phase velocity curve of SAW as a function of the thickness of ZnO

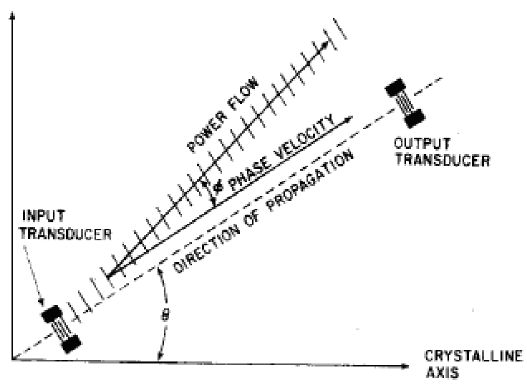

Fig.2. Phenomenon of power flowing away of acoustic wave in anistropic crystals

So further investigation is done to get the walk-off angular after the curve of velocities gained, it can be obtained from the formula (1) [7]

$$\phi = arctg(\frac{1}{V}\frac{\partial V}{\partial \theta}) \tag{1}$$

ϕ is the Walk-off angular wanted which is gotten by the third kind boundary condition cubic spline interpolation method[4] in this paper.

The property of SAW propagating in ZnO /X-Y $LiNbO_3$ has been studied and the velocity curve is obtained first shown in Fig. 1, then the cubic spline interpolation method is used to gain the walk-off angular curve with the result shown in Fig. 3. From it we can get the walk-off angular of SAW in ZnO /X-Y $LiNbO_3$ when the thickness of ZnO is 2.11μm is 3.16°.

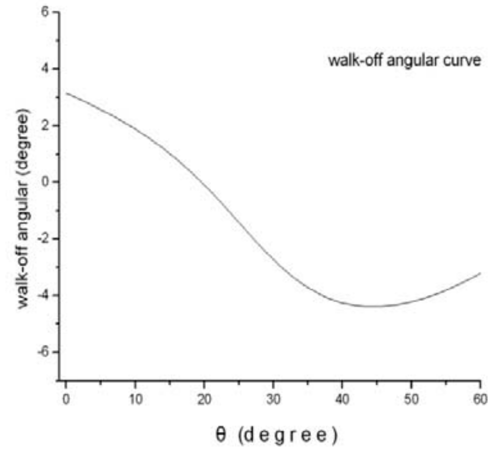

Fig. 3. Walk-off angular curve of SAW in ZnO /X-Y $LiNbO_3$ when the thickness of ZnO is 2.11μm and the θ is the angular from the Y axis of $LiNbO_3$.

3. Analysis and design

3.1 Analysis of the SAW Field of Collinear or Quasi-collinear AOTF

From the calculation result above, there is an angular of 3.16°exists when SAW propagates in ZnO /X-Y $LiNbO_3$, which declares that when the propagation direction of SAW is horizontal, the power flowing direction deviates from it of the angular 3.16°. The phenomenon is shown in Fig. 4. That will cause confusion of acoustic field in collinear or quasi-collinear AOTF.

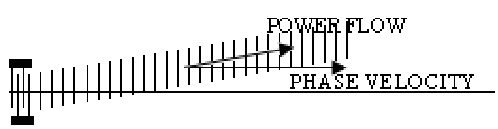

Fig. 4. Phenomenon of power flowing away of SAW

Analysis of that is given below. In collinear AOTF using ZnO /X-Y $LiNbO_3$, the acoustic waveguide and the optic waveguide are collinear with the common scheme is shown in Fig. 5 [1]. From Fig. 5, it can be known that the direction of power flowing is not as same as the optic waveguide, it deviates so that the energy of SAW will reflect when it arrives at the upper bonder of the acoustic waveguide then it will overlap with the incident SAW beam and it will reflect again when it arrives at the next border. Reflected and incident SAW have different directions. It is shown in Fig. 6. Reflection of power of SAW at borders causes many overlapped regions and so the confusion of acoustic field.

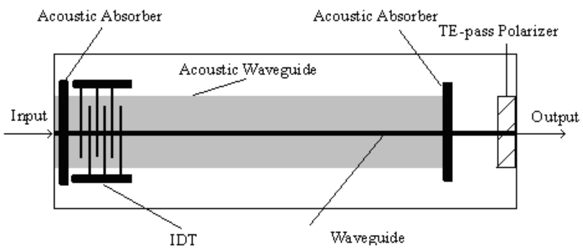

Fig. 5. The scheme of collinear AOTF.

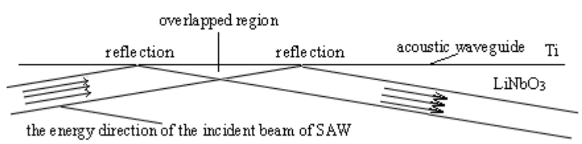

Fig. 6. The propagation of SAW in collinear AOTF.

The quasi-collinear AOTF have the similar features because in them the angles between acoustic waveguide and optic waveguide are very small [2]. So the designs which ignore the walk-off angular are not perfect.

3.2 Design of New AOTF

For design, the image of Fig. 4 is traversed the angular of -3.16°and Fig. 7 can be gained, in which the direction of power flowing is horizontal so that it can have the same direction with optic waveguide in AOTF. The transducer is also traversed the angular -3.16°and the new AOTF is designed according to Fig. 7.

The scheme of the designed non-collinear AOTF is shown in Fig. 8, the acoustic waveguide is ZnO /X-Y LiNbO$_3$ when the thickness of ZnO is 2.11μm and the interdigital transducer get the direction which revolutes -3.16° from the vertical direction. The direction of the power flowing is horizontal that is as same as the one of optic waveguide. In this scheme, there is no confusion of acoustic filed and make better use the energy of SAW.

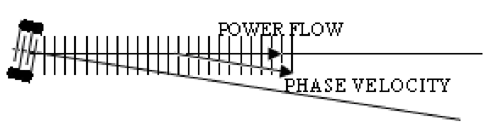

Fig. 7. SAW excited by inclined interdigital transducer

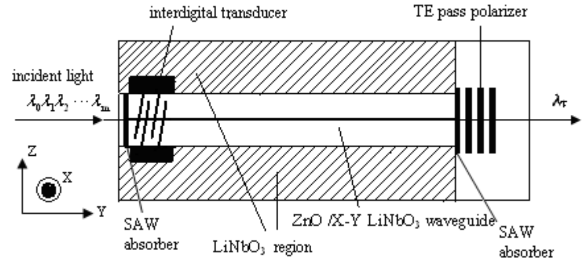

Fig. 8. Configuration scheme of designed acousto- optic tunable filters (AOTF).

4. Conclusion

A new proceeding has been proposed to study SAW propagating in a ZnO /X-Y LiNbO$_3$ filmed scheme which use cubic spline interpolation method to gain walk-off angular curve. SAW in this configulation is investigated. A new configuration of acousto-optic tunable filters has been designed in which the interdigital transducer should be inclined 3.16°.

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