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Acoustooptic Bragg Diffraction in Ti-Diffused Rotated Y-Cut $LiNbO_3$ Optical Waveguide

Ti 拡散回転 Y カット $LiNbO_3$ 光導波路を用いた
音響光学ブラッグ回折

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1. Introduction

Various acoustooptic (AO) devices have been investigated over many years. In paticular, optical waveguide devices using the AO effect due to a surface acoustic wave (SAW) have attracted interest recently, because they can realize a lower driving power and a greater freedom of design compared with bulk devices. As an SAW mode, a Reyleigh wave has been utilized in these devices. By utilizing a leaky SAW (LSAW) with a shar-horizontal (SH) particle motion, a lower driving power can be expected because the LSAW generally has a higher electromechanical coupling factor (K^2) than the Rayleigh wave. Nakamura *et al.* have reported a theoretical investigation of the collineat AO interaction between the optical guided wave and SH-SAW in a ZnO film/Y-cut $LiNbO_3$ substrate.[1] However, little is known about the experimental investigation.

In this study, Ti-diffused optical waveguides were fabricated on 64°-rotated Y-cut $LiNbO_3$ (64° Y-LN, K^2=11.3%) for the LSAW and 128° Y-LN (K^2=5.5%) for the Rayleigh wave, and the properties of coplanar AO interaction, that is, Bragg diffraction, were investigated theoretically and experimentally.

2. Fabrication of Bragg Deflectors

Figure 1 shows the structure of the Bragg deflector used for the measurement of AO interaction. The fabrication process for the Bragg deflector is as follows. First, a Ti thin film with a thickness of 50 nm and a width of 5 mm was deposited on 64° Y-LN or 128° Y-LN substrate by RF magnetron sputtering with a metal Ti target. Second, the Ti thin film was completely diffused on the substrate surface by heating at 950°C for 10 h in the atmosphere. For 128° Y-LN, to reduce a roughness on the substrate surface, the diffusion was carried out in Ar. Then, interdigital transducers (IDTs) with a period Λ of 20 μm, 20 finger pairs, and an overlap length L of 3 mm were fabricated in the X propagation direction using an aluminum film. The distance between the two IDTs was 6 mm.

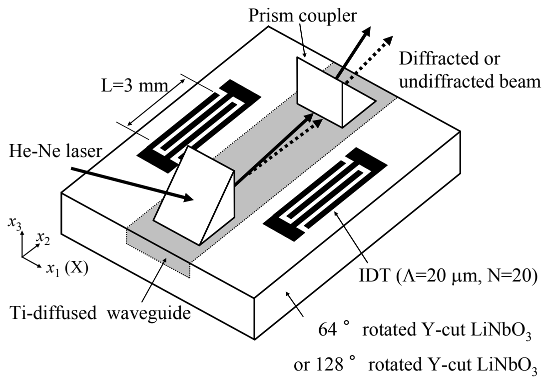

Fig. 1 Structure of Bragg deflector.

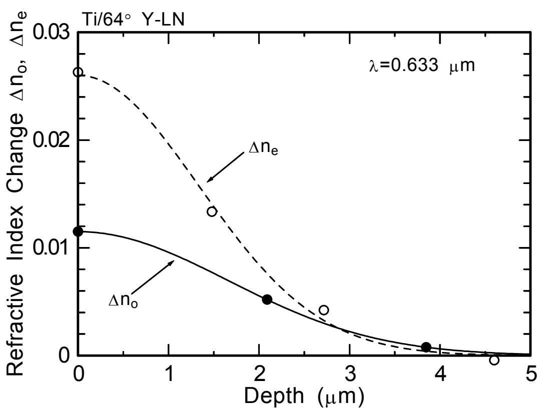

Fig. 2 Measured profile of refractive index for Ti/64° Y-LN.

Figure 2 shows the profiles of the ordinary and extraordinary refractive index changes, Δn_o and Δn_e, measured using a prism coupler at an optical wavelength of 0.633 μm and an inverse WKB method[2] for Ti/64° Y-LN. Solid and dotted curves shown in Fig. 2 are fitting curves of Gaussian profile. Δn_o and Δn_e at the surface were measure to be 0.012 and 0.026, respectively. The waveguide depth d at $\Delta n/e$ was measured to be 1.9-2.3 μm. For Ti/128° Y-LN, refractive index profiles similar to those of Ti/64° Y-LN were obtained. Therefore, it was found that a refractive index profile similar to that of the conventional Ti diffused Z-cut LN or X-cut LN can be obtained on those rotated Y-cut LN substrates.

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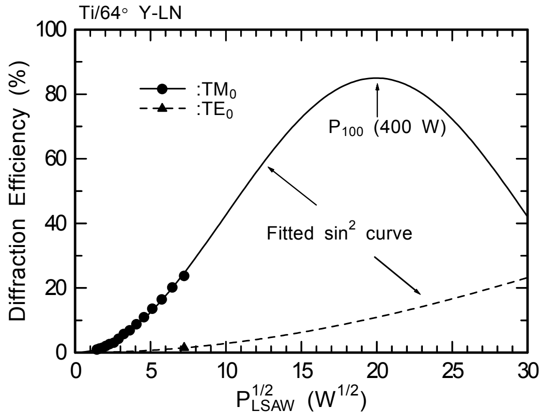
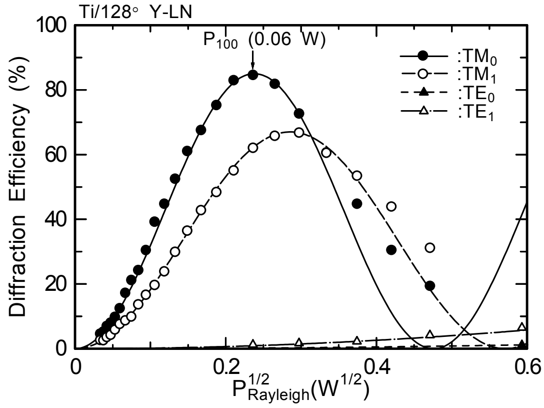


(a) Ti/64° Y-LN



(b) Ti/128° Y-LN

Fig. 3 Measured diffraction efficiency.

3. Measurement of Diffraction Property

As also shown in Fig.1, to excite a TE-mode or TM-mode light beam, a He-Ne laser light with a wavelength of 0.633 μm was guided to the Ti-diffused waveguide using the input-side rutile prism coupler. To excite the SAWs in the interaction region, a RF voltage was applied to the input IDT. The output light was picked up using the output-side prism coupler, and its intensity was measured using a photodetector. Diffraction efficiency was determined from the decrease in the intensity of the undiffracted light. The SAW power in the interaction region determined from the ratio of the vertical particle displacement on the surface measured by an optical probe method to the calculated one.

The measured diffraction efficiency as a function of the square root of the SAW power is shown in **Figure 3**. The measured results were fitted using the $\sin^2$-curve solution of coupled-mode equations,[3] as shown in Fig. 3. The SAW power required for maximum diffraction P_{100} was determined from the peak power of the fitted curve. For Ti/64° Y-LN, in which the maximum diffraction efficiency was not obtained experimentally, the maximum diffraction efficiency of 85%, in which was measured in TM_0 mode of Ti/128° Y-LN, was assumed.

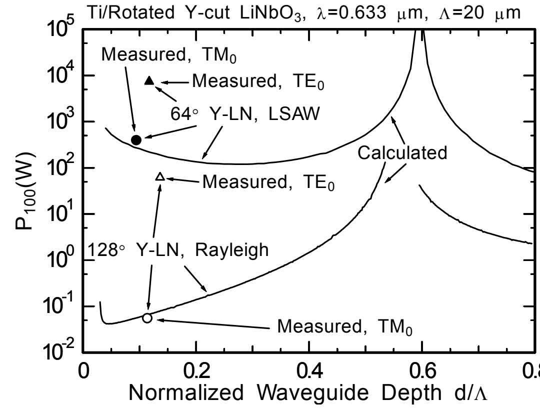


Fig. 4 SAW power required for 100% diffraction.

The experimental values of P_{100} of TM_0 mode were determined to be 400 W for Ti/64° Y-LN and 0.06 W for Ti/128° Y-LN, respectively. The P_{100} for the LSAW is approximately 10^4 times larger than that for the Rayleigh wave. Unfortunately, the utilization of the LSAW was found to be not suitable for AO Bragg diffraction. For a TE-mode light beam, 10-10^3 times larger driving power than that for a TM-mode light beam was required for the Bragg diffraction for both cases of the LSAW and the Rayleigh wave. In the coplanar arrangement shown in Fig. 1, since the strain due to the SH particle motion is perpendicular to the electric field of the optical guide wave, those interactions may be extremely weak.

The theoretical P_{100} for TM_0 mode was calculated by using the coupled mode theory.[3] The overlap integral in the depth direction between the electric field of the optical guide wave and the strain due to the LSAW was calculated from a depth of 10Λ to the surface because the LSAW does not decay to zero in the depth direction. **Figure 4** shows the theoretical P_{100} as functions of the normalized waveguide depth d/Λ. The theoretical values were close to the experimental values. Therefore, the theoretical estimation of the AO interaction due to the LSAW was successfully performed.

4. Conclusions

The Bragg diffraction properties due to the SAWs in planar Ti/rotated Y-LN waveguides were investigated theoretically and experimentally. Unfortunately, the utilization of the LSAW was found to be not suitable for AO Bragg diffraction. However, the theoretical estimation of the AO interaction due to the LSAW was successfully performed. In our next study, the collinear AO coupling using the LSAW will be investigated.

References

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