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Acousto-optic Bragg Diffraction Using Longitudinal-type Leaky SAW
縦型漏洩弾性表面波を用いた音響光学ブラッグ回折

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1. Introduction

A light wave that is guided to the propagation region of a surface acoustic wave (SAW) is Bragg-diffracted by an acousto-optic (AO) effect and shows an optical frequency shift caused by the frequency of the SAW. A device that induces the optical frequency shift is called an AO frequency shifter (AOFS), which is applied to a frequency shift feedback (FSF) fiber laser.[1] Since the laser output consists of a chirp frequency comb, it is expected to be widely applied in optical measurements such as optical distance measurement. Presently, to improve the accuracy of such a measuring device, it is necessary to increase the amount of frequency shift of the AOFS. Therefore, the SAW wavelength should be shorter or the SAW velocity should be higher. The former has a problem in that the particle displacement obtained at an equivalent SAW power decreases and the SAW power required for light diffraction increases. On the other hand, the SAW mode used in the conventional AOFS is a Rayleigh-type SAW (R-SAW),[2] which is expected to increase the amount of frequency shift by adapting a longitudinal-type leaky SAW (LLSAW) with a higher phase velocity than the R-SAW.

In this study, to increase the amount of frequency shift, a Ti-diffused optical waveguide was fabricated on an *X*-cut 36°*Y*-propagating $LiNbO_3$ substrate with a large electromechanical coupling coefficient K^2 for the LLSAW (*X*36°*Y*-LN, K^2=12.9%), and its diffraction properties were evaluated.

2. Fabrication of AO Bragg Deflector

Figure 1 shows the configuration of the Ti-diffused planar waveguide-type AO Bragg deflector fabricated in this study. The process of fabricating the Bragg deflector is as follows. First, a Ti film with a thickness of approximately 500 Å and a width of 5 mm was deposited on an *X*-cut $LiNbO_3$ substrate by RF magnetron sputtering with a metal Ti target. Second, the Ti film was diffused on the substrate surface by heating at 950 °C for 10 h in Ar atmosphere. Finally, interdigital transducers (IDTs) with a period Λ of 20 μm, an overlap length of 3 mm, and 20 finger pairs were fabricated on the substrate surface in the 36°*Y* propagation direction using an Al film.

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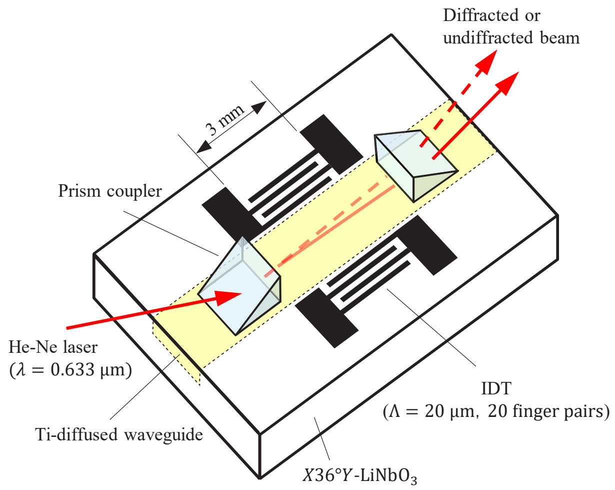


Fig. 1 Configuration of Ti-diffused planar waveguide-type AO Bragg deflector.

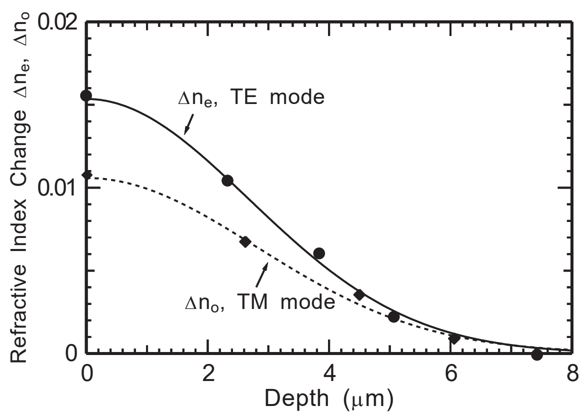
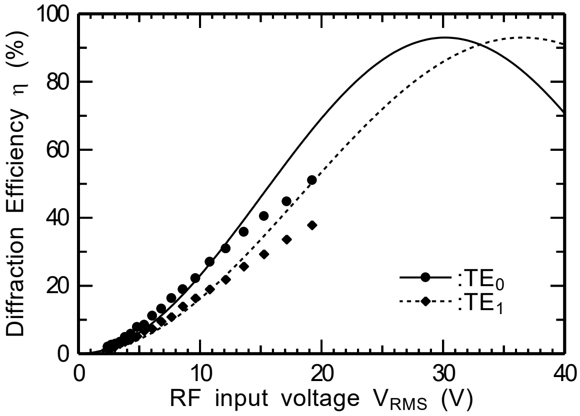
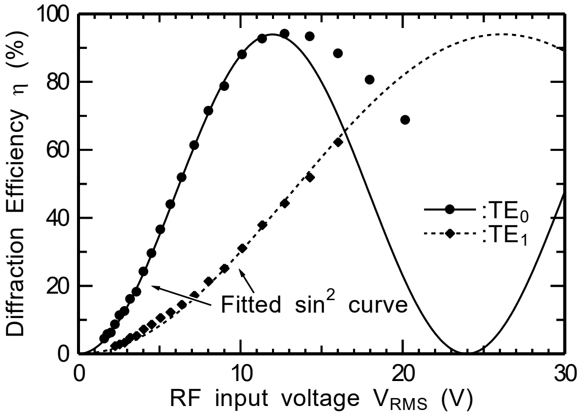


Fig. 2 Measured profile of refractive index for Ti/*X*36°*Y*-LN sample (λ=0.633 μm).

Figure 2 shows the profiles of the ordinary and extraordinary refractive index changes, Δn_o and Δn_e, respectively, measured using a prism coupler at an optical wavelength of 0.633 μm and an inverse WKB method[3] for Ti/*X*36°*Y*-LN. The solid and broken lines shown in Fig. 2 are curves fitted to the Gaussian profile. Δn_o and Δn_e on the surface were measured to be 0.011 and 0.016, respectively. The waveguide depth d at $\Delta n/e$ was measured to be in the range of 3.8–4.0 μm.



(a) Property of diffraction by LLSAW



(b) Property of diffraction by R-SAW

Fig. 3 Measured diffraction efficiency for Ti/*X*36°*Y*-LN sample.

3. Evaluation of Diffraction Properties

As also shown in Fig. 1, to excite a TE-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. A RF burst signal was applied to the input IDT, and the R-SAW (187 MHz) or LLSAW (359 MHz) was excited by adjusting the frequency of the RF input signal. The output light was picked up using the output-side prism coupler, and its intensity was measured using a photomultiplier. Diffraction efficiency was determined from the decrease in the intensity of the undiffracted light.

The measured diffraction efficiency as a function of the RF input voltage is shown in **Figs. 3(a) and 3(b)**. The measured results were fitted using the $\sin^2$-curve solution of coupled-mode equations,[4] as shown in Fig. 3. For the R-SAW, the diffraction peak was observed, as shown in Fig. 3(b), when the guided light was in the TE_0 mode. The diffraction of the guided light by the LLSAW was observed for the first time as shown in Fig. 3(a), and the diffraction efficiency in the TE_0 mode was about 50%. The experimental value was taken as the peak value of the fitting curve. The required input voltage for the peak of diffraction by the LLSAW in the TE_0 mode was estimated to be 30 V, which was 2.5 times

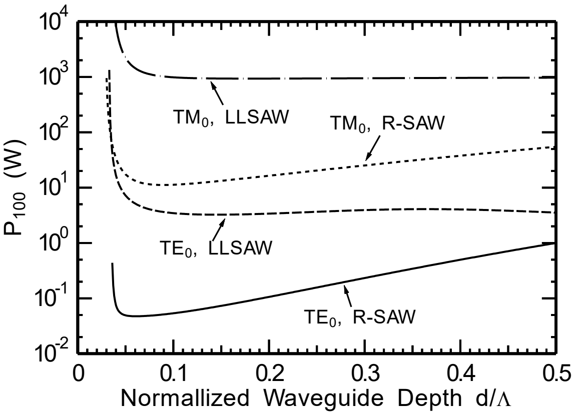


Fig. 4 SAW power required for 100% diffraction. Ti/*X*36°*Y*-LN, Λ=20 μm, and λ=0.633 μm.

that in the case of the R-SAW. Since the LLSAW has a larger propagation loss than the R-SAW, it is considered that the particle displacement in the interaction region is small and the refractive index change due to the AO effect are smaller than those in the R-SAW. A reduction in the propagation loss of the LLSAW was observed when a high-velocity thin film was loaded on LN, which is expected to lower the driving power upon its loading. In both the R-SAW and LLSAW, no diffraction of TM-mode light was observed. This is opposite to a report indicating that AO interaction with low driving power can be obtained using the R-SAW and TM-mode on 128°*YX*-LN.[1]

For *X*36°*Y*-LN, the SAW power required for 100% diffraction P_{100} was calculated using a coupled mode theory.[4] **Figure 4** shows the theoretical P_{100} as a function of the normalized waveguide depth d/Λ. In both the R-SAW and LLSAW, P_{100} was found to be smaller in the TE-mode than in the TM-mode. Therefore, since the guided light either in the TE or TM mode that can be diffracted at a lower driving power depends on the cut angle of LN, the existence of the LN cut angle with a strong AO interaction is expected for the LLSAW.

4. Conclusions

In this study, we investigated AO interaction using an LLSAW. The diffraction of the guided light by the LLSAW was observed for the first time. In our next study, we will reduce of the input voltage required for diffraction by reducing the loss of the LLSAW by loading s high-velocity thin film and optimizing the cut angle of LN.

References

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