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Observation of Longitudinal-type SAWs on a Thin $LiNbO_3$ Plate by Laser Prove System

レーザープローブによる $LiNbO_3$ 薄板上の縦波型弾性表面波変位分布の観測

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1. Introduction

In this paper, we describe measurement of longitudinal-type surface acoustic waves (SAW) by a laser probe system and comparison of its result with the finite element analysis (FEA).

In previous studies, several authors have shown effectiveness of visualization of the SAW vibration by the laser probe as well as that by the computer simulation for finding clues to improve the SAW devices [1-6].

The present authors have reported SAW devices comprising a thin $LiNbO_3$ plate, an acoustic mirror stacked alternately low and high acoustic impedance layers (LAI and HAI) as an acoustic energy confinement portion, and a handle substrate as shown in **Fig. 1** [7-9]. The structure offers much higher frequency and wider bandwidth characteristics simultaneously than those of common ones using 42LT or 128LN owing to exploiting a longitudinal-type SAW propagating in the thin X-cut $LiNbO_3$ (LN) plate.

To the best of the authors' knowledge, there is no report on observation of the longitudinal-type SAW by the laser probe. In this paper, it is shown that the vibration of the longitudinal-type SAW is observable by a laser probe system using the Sagnac interferometer, and the observed field distribution is in good agreement with the FEA results.

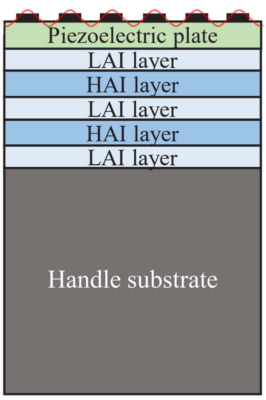

Fig.1 Schematic of the structure used for the discussions in this paper.

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2. Laser prove system

Fig. 2 shows the configuration of the laser probe system developed by the authors' group. It is based on the Sagnac interferometer, and the measurement principle can be found in Section II of Ref. 3. This system enables observation of high-frequency surface vibration on DUTs in minutes order. Optical signals detected by PD are processed by the detection electronics system shown in Fig. 2 of Ref. 3, and both the amplitude and phase of the surface vibration are obtainable.

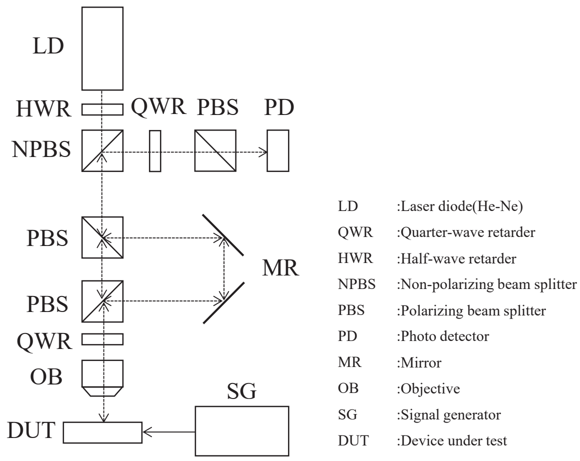
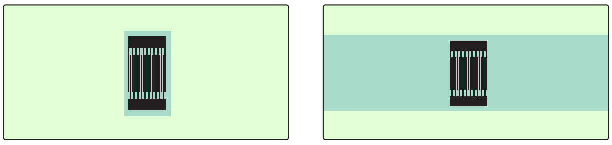


Fig.2 Configuration of laser probe system.

3. Experiment and results

Fig. 3 shows the schematic of two kinds of test samples fabricated for the observation. Both samples are composed of a thin LN plate, an acoustic mirror stacked SiO_2 and Pt films alternately as low and high acoustic impedance layers, and the Silicon substrate under the electrodes. The difference between these two structures is that the sample (a) has no acoustic mirror outside of the interdigital transducer (IDT) region, namely the structure is LN/SiO_2/Si-substrate in the area, while the sample (b) also has the acoustic mirror at both sides of the IDT region. The electrodes material is aluminum and its periodicity (wavelength λ) is 3 μm. The number of finger pairs and aperture length of the IDT are 10 and 30 μm,

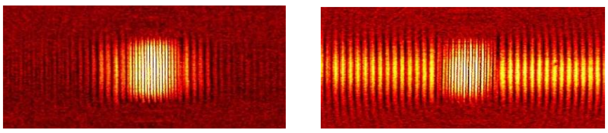


(a) (b)

Fig.3 Schematic of the top view test samples. The acoustic mirror is deployed under (a) only the IDT region and (b) both sides of the IDT region.

respectively. No grating reflectors are placed at both sides of the IDT. The thicknesses of Al, LN, SiO_2, and Pt are 0.15 µm, 0.6 µm, 0.42 µm, and 0.27 µm, respectively.

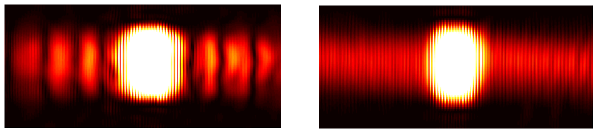
Fig. 4 compares the observation results. The measurement was carried out at the frequency of 2 GHz. Field distribution is expressly visible near the electrodes area in Fig. 4, this means the laser probe system works properly even for the longitudinal-type SAW operating in the 2 GHz range. In the sample (a), vibration is clearly visible only in vicinity of the IDT region and decays rapidly with the distance from the IDT. On the other hand, in the sample (b), the vibration does not decay significantly, and can be observed clearly even for regions far from the IDT. These results indicate that the longitudinal-type SAW excited by the IDT propagates on the LN with small propagation loss owing to good confinement of wave energy near the surface in the sample (b). In contrast, SAWs in the sample (a) exhibits relatively large propagation loss due to lack of the reflector layers; acoustic energy is leaked away to the Si substrate.



(a) (b)

Fig.4 Measured field distribution. Amplitude images of DUTs which acoustic mirror is deployed under (a) only the IDT region and (b) both sides of the IDT region.

Next, these measurement results are compared with the FEA. **Fig. 5** depicts the simulated field distribution of the device structures by the 3D-FEM and the results show a vertical component to the SAW propagation direction when the 2D IFFT was applied after the spectra near bright spots were selectively extracted in an obtained FFT image (not shown). Comparison of these results with those shown in Fig. 4 reveals good coincidence between them. This also proves how the laser prove system is effective measurement for the observation of even the longitudinal-type SAW.



(a) (b)

Fig.5 Simulated field distribution after 2D IFFT was applied. Amplitude images of DUTs which acoustic mirror is deployed under (a) only the IDT region and (b) both sides of the IDT region.

4. Conclusion

This paper described measurement of field distribution of a longitudinal-type SAW on a thin LN plate by laser prove system and the results were compared with the FEA.

The field distribution of the longitudinal-type SAW can be clearly observed at 2 GHz by the laser prove system with the Sagnac interferometer. The results were in good agreement with the simulated results by the FEA.

To the authors' best knowledge, this is the first report of the laser prove observation of the longitudinal-type SAW.

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