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Head-on Collision Experiment of Pulse-like Nonlinear Surface Acoustic Waves
パルス状非線形弾性表面波の正面衝突実験

Koji Aizawa, Masatoshi Yoshimura, and Yoshiaki Tokunaga (Grad. School of Eng., Kanazawa Institute of Technology)
會澤 康治，吉村 政俊，得永 嘉昭 (金沢工大 大学院)

1. Introduction

Nonlinear surface acoustic wave (NLSAW) generated on the piezoelectric crystal has attracted much attention in application to signal processing devices such as convolver, parametric amplifier, and memory correlator. [1-3]

Recently, the dynamic characteristics of NLSAW have been studied using a complex aproach by authors. [4-9] In this approach, dynamic behavior of the fundamental (FUN) and higher-order harmonics (H-HMCs) in NLSAW and their interaction during propagation were investigated by optical diffraction technique. In the collision experiment of two 2nd HMCs, the diffracted light intensities were preserved before and after collision. [7] To understand the dynamic characteristics of the 2nd HMC with dispersive medium, the collision experiment of two 2nd HMCs on Au film with various thicknesses was carried out. [8] As an application using dymanic characteristics of the 2nd HMC, authors have already proposed a novel photonic signal control device. [9] However, further experimental investigation of nonlinear behavior has been needed in order to comprehend the dynamics of NLSAW. In this study, we investigated the variation of the phase velocity and the full-width at half maximum (FWHM) value of a pulse-like NLSAW propagating on $LiNbO_3$ with Au film through a head-on collision experiment.

2. Experimental procedure

Figure 1 shows an illustration of an experimental sample. 128^{o}-rotated Y-cut X-propagating $LiNbO_3$ single crystal was used as substrate. The 20 pair interdigital transducer (IDT) was formed on the substrate, in which their center frequency and insertion loss were 48.7 MHz and 6.85 dB, respectively. A space between IDT(I) and (II) was fixed at 20 mm. The RF burst signal was simultaneously introduced to two IDTs through RF power amplifier from synthesized RF signal generator, in which its duration time and duty cycle were 250 ns and 0.05 %, respectively. 50-nm-thick Au film as dispersive material was deposited on the center of the sample surface by vacuum evaporation, in which its area was 10x10 mm^2. Each pulse-like NLSAW propagating toward the center of the device from IDT(I) and (II) is head-on collision at the center of Au film. The dynamic characteristics of the FUN and the 2nd HMC were measured using optical diffraction method. A He-Ne laser beam with 300 μm in diameter was used for probing the NLSAW. The probing beam was irradiated on the sample surface, and the diffracted light was detected by photomultiplier tube. The waveform shown in **Fig.2** is observed as the envelope profile of NLSAW using digital oscilloscope.

toklab@mlist.kanazawa-it.ac.jp

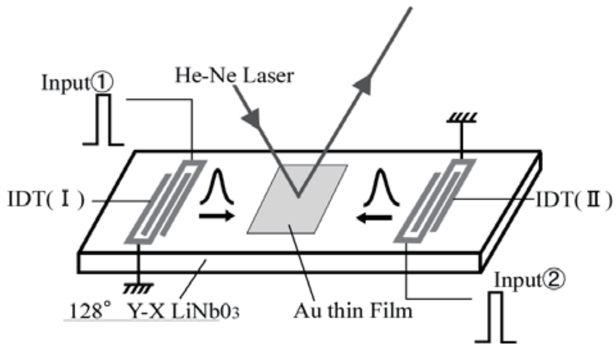

Fig.1 I Illustration of a fabricated SAW device and an optical diffraction method for detecting generated pulse-like NLSAW.

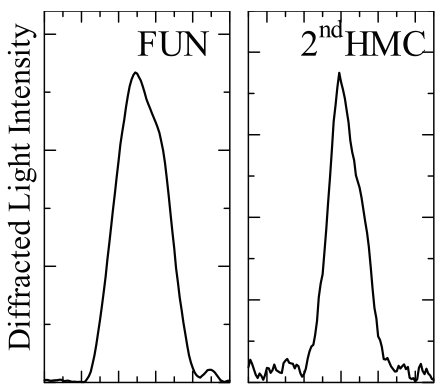

Fig.2 Typical envelope profiles of FUN and 2nd HMC

3. Results and discussion

Figure 3 shows the propagation of the pulse-like

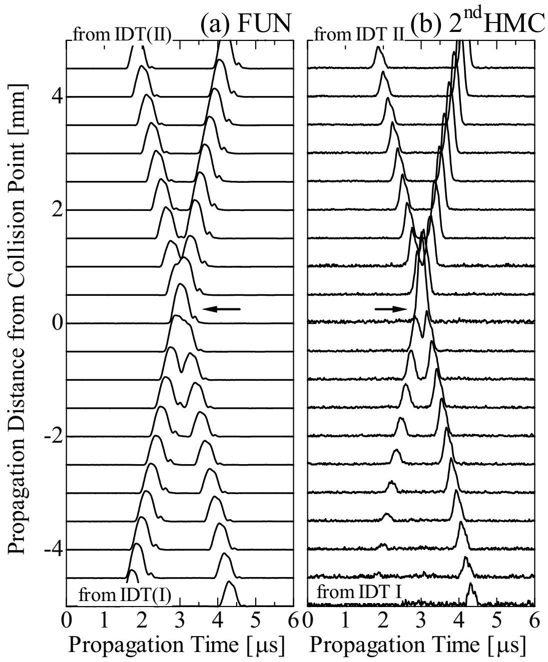

Fig.3 Intensity plot of (a) FUN and (b) 2nd HMC showing propagation of pulse-like waves from IDT(I) and (II). Collision point is indicated by arrow.

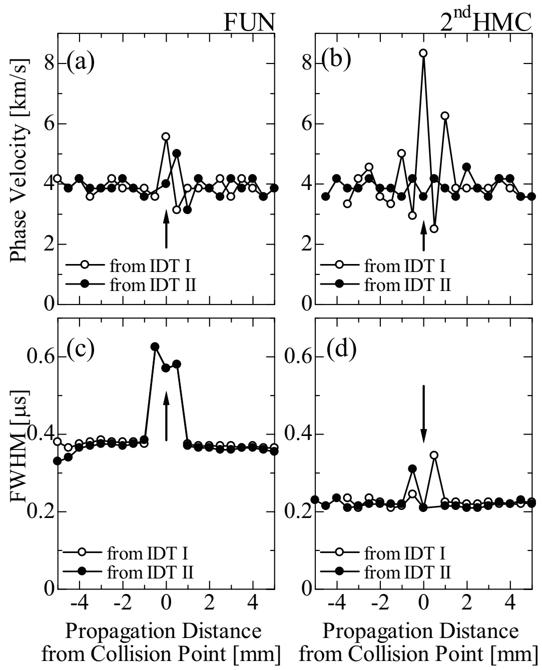

Fig.4 Phase velocity variation of (a) the FUN and (b) the 2nd HMC from IDT(I) and (II) as a function of propagation distance from collision point. (c) and (d) show FWHM variations of the FUN and 2nd HMC, respectively. Collision point is indicated by arrow.

FUN and the 2nd HMC, in which the input power densities of IDT(I) and (II) are 123 and 99 W/mm^2, respectively. The diffracted light intensity was plotted as function of the propagation time and distance from the collision point. As can be seen from these figures, the diffracted light intensity of 2nd HMC at the collision point was larger than the algebraic sum of two pulses before and after collision, whereas its value of FUN was smaller. The diffracted light intensity variation at the collision point must be able to explain the enhancement of coupling efficiency between FUN and 2nd HMC and energy conversion from FUN to 2nd HMC.

From the experimental results shown in **Fig.3**, the phase velocity and the FWHM value can be estimated. **Figure 4** shows the phase velocity and the FWHM value of the FUN and the 2nd HMC from the IDT(I) and (II) as a function of propagation distance from the collision point. It seems from **Fig. 4(a) and (b)** that the velocity perturbation is increased by a head-on collision. These results may suggest the interaction between SAW pulses by nonlinearlity. The FWHM values before and after collision were almost the same as shown in **Fig. 4(c) and (d)**. However, the FWHM value at the collision point was quit different between the FUN and the 2nd HMC. The pulse width of the FUN at collision was wider than that before and after collision, whereas its value of the 2nd HMC was not varied by collision. It seems from these results that a pulse-like 2nd HMC is stable with respect to collision.

4. Conclusion

The dynamic behavior of the phase velocity and the FWHM value of the pulse-like NLSAW was investigated by a head-on collision experiment. The phase velocity at the collision point was perturbed and then the FWHM value of the FUN slightly increased at the collision point, whereas its value of the 2nd HMC was unchanged by collision.

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