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Numerical analysis for ultrasonic beam of variable line focus transducer

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1 Introduction

Line-focus-beam ultrasonic transducer has been used for material characterization system[1][2]. Such system has solid acoustic lens that has an arc of a true circle. On the other hand, submicron film of polyurea was synthesized by vapor deposition process[3]. This technique enables evaporatation of polyurea piezoelectric film onto a polyimide film. Bending the film to curved shape, we obtained variable line focus transducer[4]. The bent film transducer has an sinusoidal cross section[5], however, radiated ultrasonic beam was not studied. In this report, radiated ultrasonic beam from the variable line focus transducer is numerically analyzed by FDTD (Finite difference time domain method)[6] and by the wave theory for liquid-solid interfaces[7].

2 Problem description

Fig.1 shows the geometry for the numerical calculation. The problem is treated as two-dimensional, that has infinite length for the depth. The 5-mm-length film transducer is bent between fixtures at the base. The cross section of the film results a sinusoidal curve. Polyurea piezoelectric film is deposited on the center 3 mm area of the polyimide film. In this report, this area is treated as the transmitting and receiving region. An aluminum plate is fixed at the distance of 0.8 mm from the baseline of the sinusoidal curve. The space between the transducer and the aluminum plate is filled with water. When the baseline length of sinusoidal curve is changed, the film transducer is bent and the height of the curve is changed. This shape change of the sinusoidal curve causes the change of the focal length of the film transducer. The sinusoidal shape of the film transducer is calculated by the elliptic integral of second kind[5]. The calculation is carried out at the frequency of 38.1MHz, which is the experimental resonance frequency of the polyurea transducer.

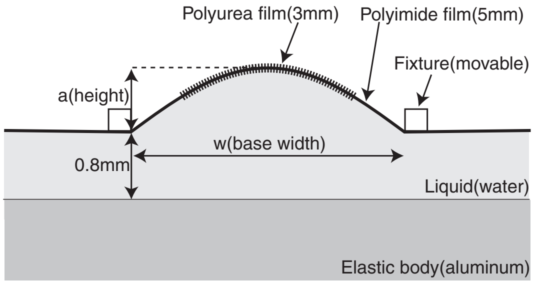

Figure 1: Problem geometry.

3 Calculation method

Fig.2 shows the geometry for the FDTD calculation. In this report, the FDTD method for elastic body is applied. The space discrete step Δd is 1.5μm, and the time discrete step Δt is 116.8 ps. These values are determined in consideration of the acoustic phase velocity in water(1500m/s) and the ultrasonic frequency. Since FDTD analysis is restricted to finite calculation area, the absorbing boundary condition for the propagating wave[8] is applied to the outer boundary of the water. An elastic vibration is given as the normal component of the particle velocity on the transducer surface. The 50 cycles of 38.1 MHz sinusoidal waves are inputted. Total received intensity is obtained by numerically integrating the normal component of particle velocity on the lens surface. FFT is applied to the total received signal on the lens, and the intensity at 38.1 MHz is extracted. In addition to the FDTD calculation, we executed the numerical calculation by liquid-solid interface reflection theory according to ref.[9].

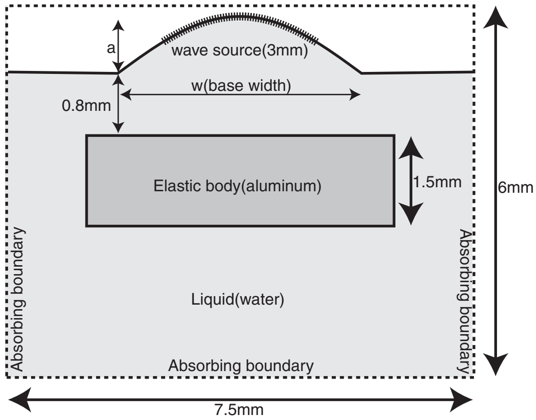

Figure 2: FDTD geometry.

4 Calculation Results

Fig.3 shows the relative intensity vs. lens width calculated by FDTD. The result has a peak value at the lens width of 4.35 mm. The ripples caused by leaky surface

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acoustic wave can be observed. Fig.4 shows the results calculated being based on the liquid-elastic wave reflection theory. The leaky saw velocity is assumed to be 2480 m/s, and the loss coefficient α is varied from 0.001 to 0.01. The positions of the local maximums and the local minimums of the ripple have good agreement with Fig.3. In Fig.4, the solid line shows the calculated result without leaky saw effects. Unlike true circular arc lens case, the ripple caused by leaky saw is observed at both side of the focal point($w = 4.37$ mm). The curvature of the sinusoidal lens is not constant, therefore the leaky saw excites around the focal point. Fig.5 shows the case of $\alpha = 0.01$, and the leaky saw velocity is varied from 2840 m/s to 5000 m/s. Fig.4 and Fig.5 show reasonable results like the true circle arc lens case as in the former paper[9].

5 Conclusion

In this report, the characteristics of ultrasonic beam radiated by the variable line focus transducer was numerically calculated using FDTD and the liquid-elastic wave reflection theory. The position of the local minimums and the local maximums of the ripple showed good agreement in both results. The interference ripple caused by leaky-saw was observed in lens width vs. received intensity curve. As the conventional V(z) curve, the ripple changed according to the loss parameter α and the leaky saw velocity. Comparison of these results with experiments are left for further study.

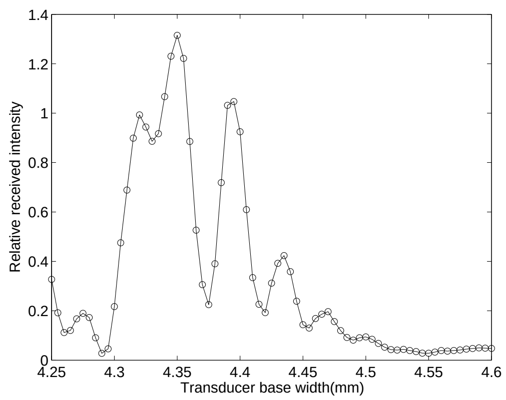

Figure 3: V(z) curve calculated by FDTD.

Acknowledgement

FDTD calculations in this report were performed on TSUBAME supercomputer of Global Scientific Information Center, Tokyo Tech. during test use period.

References

[1] J. Kushibiki and N. Chubachi: IEEE Trans. Sonics Ultrason. **SU-32** (1985) No. 2, 189.

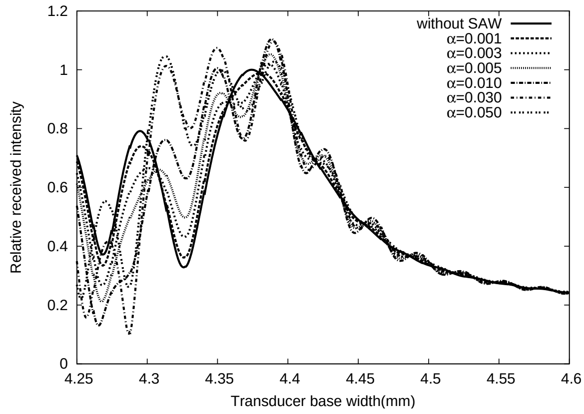

Figure 4: V(z) curve calculated by wave theory($v_{LSAW} = 2840$ m/s).

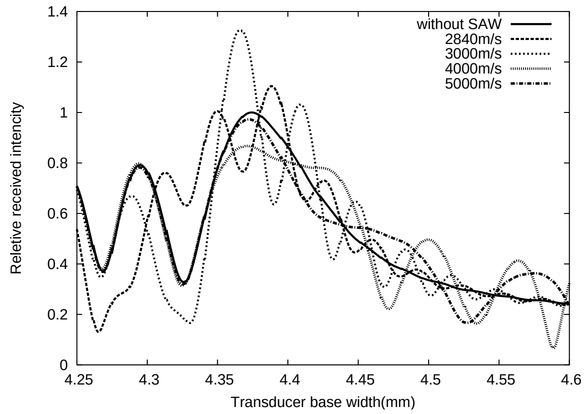

Figure 5: V(z) curve calculated by wave theory($\alpha = 0.01$).

[2] Y. Ohashi, M. Arakawa and J. Kushibiki: Jpn. J. Appl. Phys. **45** (2006) No. 5B, 4505.

[3] T. Hattori, Y. Takahashi, M. Iijima and E. Fukada: Jpn. J. Appl. Phys. **79** (1996) 1713.

[4] T. Kosugi, H. Nagatsuka, T. Ishii, K. Nakamura, S. Ueha and Y. Hirao: Proc. Intl. Conf. on New Piezoelectric Materials and High Performance Acoustic Wave Devices (2002) p.179.

[5] M. Nakazawa, T. Kosugi, A. Maezawa, K. Nakamura and S. Ueha: Proc. Spring Meet. Acoust. Soc. Jpn. (2005) p.973[in Japanese].

[6] M. Sato: *FDTD hou niyoru danseisindou·hadou no kaiseki nyuumon* (Introduction to analysis for elastic vibration/wave by FDTD) (Morikita shuppan, Tokyo, 2003)[in Japanese].

[7] H. L. Bertoni and T. Tamir: Appl. Phys. **2** (1973) 157.

[8] C. J. Randall: Geophysics, **54** (1989) No. 9, 1141.

[9] J. Kushibiki, A. Ohkubo and N. Chubachi : Proc. IEEE Ultranson. Symp. ,1982, p.623.