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Evaluation of ultrasound beam profile of Fresnel zone plate array transducer
フレネルゾーンプレートアレイトランスデューサの超音波ビームプロファイルの評価

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1. Introduction

There is High-Intensity Focused Ultrasound (HIFU) as one of the ultrasound technologies. This is a technology that focuses the ultrasound to one point, and collects high energy in the focus area. is technology has been put to practical use as a method of treatment of the prostatic cancer. It is a method of treatment that heats cancer cell in the focus area up to about 100℃, and kills out the cancer cell.

In the HIFU technology, it is important to control the focus area of the ultrasound spatially. The ultrasound focusing method that operates the focus area by electronic control is hoped for because the focus area is controlled by mechanically operating the HIFU device.

It proposes the method of patterning the Fresnel zone plate to 2D array transducer as a focusing method of the ultrasound. In this study, the ultrasound beam profile formed by this method is evaluated.

2. Fresnel zone plate

The Fresnel zone plate(FZP) is a board that changes penetration and no penetration like the concentric circle. When a concentric circle pattern is changed, the focal length can be changed.

In the case of FZP(Fig.1), given that the distance of sound source and plate is r_1, distance of plate and focus is r_2, the Fresnel zone are given by[3]

$$\sqrt{R_n^2 + r_1^2} + \sqrt{R_n^2 + r_2^2} = n\frac{\lambda}{2} + r_1 + r_2 \qquad (1)$$

where λ is the wavelength, n=1,2,... is a consecutive number and R_n are the zone boundaries of the Fresnel rings.

$r_1 \to \infty$ are given by

$$R_n = \sqrt{n\lambda_0(r_0 + \frac{n\lambda}{4})} \qquad (2)$$

The element in the range of n=2m+1(m=0,1,2…) from n=2m is driven.

3. Simulation

The ultrasound focusing simulation in water was made. A set value of the simulation environment is indicated in Table1.

2D array has 24×50 elements, and size of 2D array is 16.8mm×37.5mm.Three kinds of coordinates of focus were set and simulated. The FZP pattern was constructed respectively.

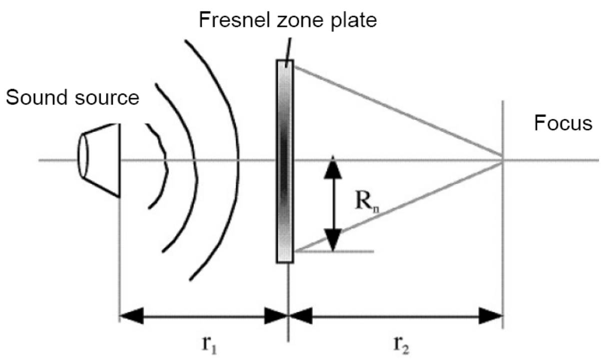

Fig.1 Fresnel zone plate

Width of x coordinates	0.7[mm]
Width of y coordinates	0.7[mm]
Width of z coordinates	1[mm]
Range of x	-8.4≦x≦8.4[mm]
Range of y	-17.5≦y≦17.5[mm]
Range of z	0≦z≦100[mm]
Number of elements	1200
Sound velocity	$1.5*10^6$[mm/s]
Frequency	1.0[MHz]
Wavelength	1.5[mm]
Coordinates of focus	(0,0,30)(0,0,40)(0,0,50)

Table1 Simulation setting value

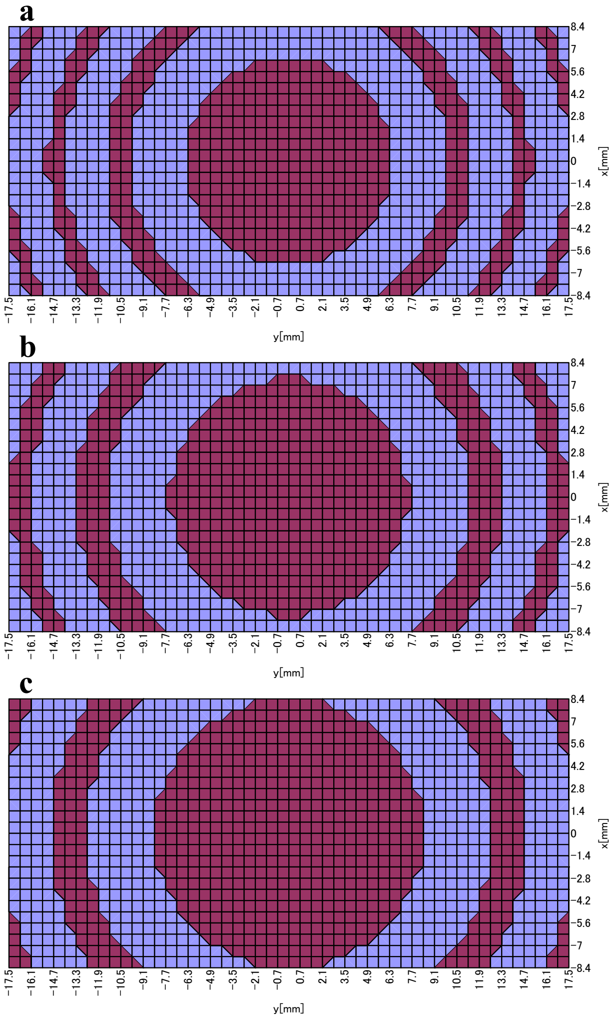

Fig.2 Arrangement of drive element

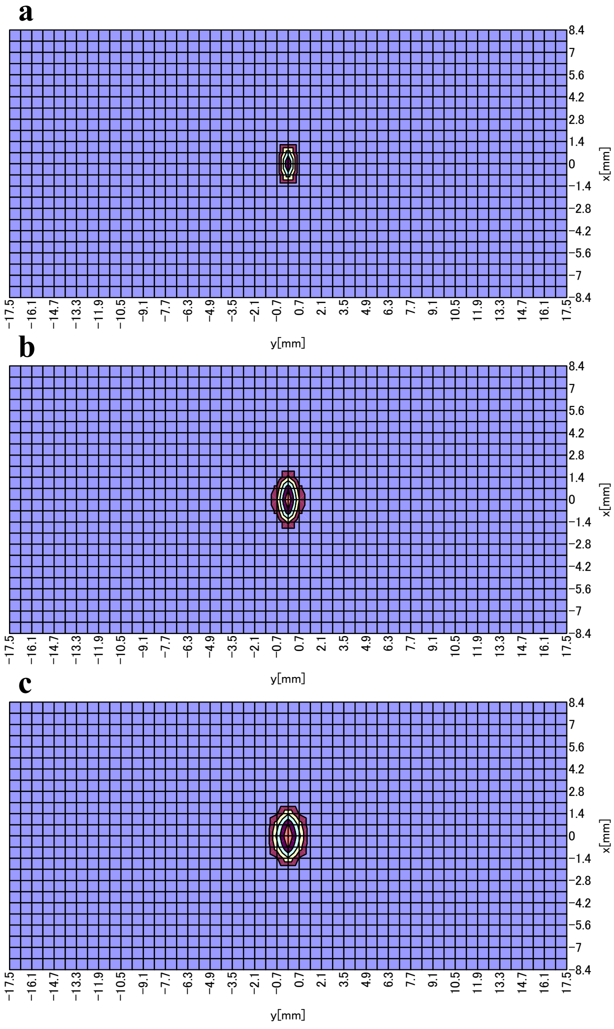

Fig.3 Shape of focus of xy plane

4. Result and Discussion

Fig.2 shows the arrangement of the drive element. Fig.2(a),(b),(c) sets the focus to (0,0,30), (0,0,40), (0,0,50) respectively. It is understood that the arrangement of the drive element follows the FZP pattern from this figure.

Fig.3 shows Shape of focus of xy plane. Fig.3(a) shows shape of focus at (0,0,30) with focal dimensions 2.8mm × 1.4mm × 10mm. Fig.3(b) shows shape of focus at (0,0,40) with focal dimensions 3.5mm × 2.1mm × 14mm. Fig.3(c) shows shape of focus at (0,0,50) with focal dimensions 3.5mm×2.1mm×25mm.

Theory value L of the beam length is calculated by (3)

$$L = \frac{2\alpha}{\alpha^2 - 1}F \quad (\alpha = \frac{D^2}{4\lambda F}) \qquad (3)$$

where F is the focal length, f is the frequency, λ is the wavelength, D is aperture of 2D array.

	(a)(0,0,30)	(b)(0,0,40)	(c)(0,0,50)
Simulation [mm]	10	14	25
Theory value[mm]	7.8	14.1	22.4

Table2 Comparison with theory value of beam length

Table2 shows comparison between simulated beam length and theory value.

The ultrasound focus was formed by patterning the Fresnel zone plate pattern to 2D array transducer. The beam profile became near the theory value.

References

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