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Visualization of Focused Ultrasound using Negative Refraction in Phononic Crystal

フォノニック結晶内の負の屈折率を利用する集束超音波の可視化

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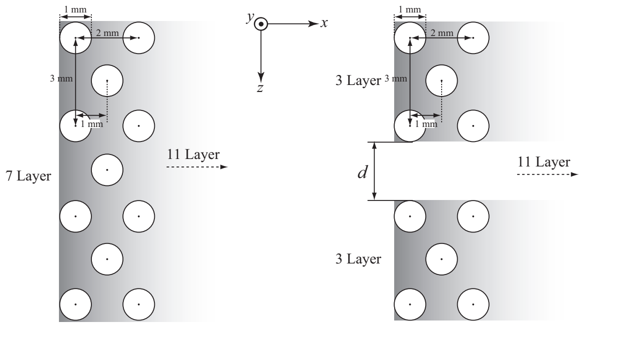
1. Introductions

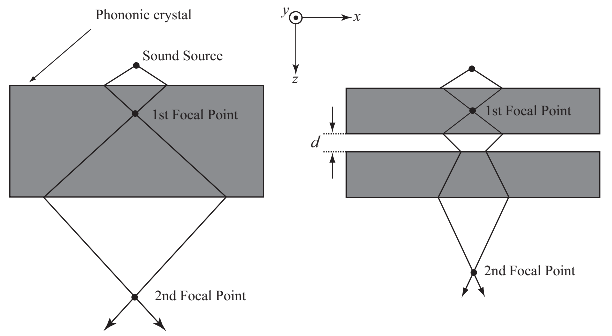
In recent years, the applications of photonic crystals having band gap, group delay and negative refraction are investigated actively. However, it is difficult to deal with the photonic crystal caused by the short wavelength of that. Correspondingly, the phononic crystal gets a lot of attention these days[1]. The wavelength is longer compared to that of photonic crystal, for this reason, we can research easily. Additionally, phonon has more complex characteristics than photon. Light waves propagate as share wave, but sound waves have longitudinal wave and two shear waves in the solid objects. Therefore, the phononic crystal has a number of subjects of research. Among them, we regard the negative refraction of phononic crystal[2]. Acoustic focus lens using in medical field is usually concave in order to focus ultrasound on affected area. However, by using negative refraction of phononic crystal, the acoustic flat lens becomes possible. In this research, we visualize the focused ultrasound using negative refraction in phononic crystal. We aim to visualize the inside of phononic crystal and appearance of focused ultrasound, optically[3]. In this paper, we visualize them using finite element method (FEM) as research at a basic level.

2. Visualization Method

When the acoustic flat lens is investigated, we should verify the appearance that ultrasound wave focuses, because they are not invisible. With that, we used FEM to visualize the focused ultrasound. In this simulation, we observed the sound pressure distributions of focused ultrasound. At next research, we will visualize the focused ultrasound using Fresnel's diffraction, optically. In this diffraction, the sound pressure distribution corresponds to the diffraction grating, directly. In fact, visualizing the sound pressure distribution in



Simple structure of phononic crystal (a) Dual structure of phononic crystal (b)
Fig. 1 Forms of phononic crystals in this experiment.



Simple structure of phononic crystal (a) Dual structure of phononic crystal (b)
Fig. 2 Scheme of focused ultrasound wave using negative refraction in phononic crystal.

FEM is approaching to visualize the focused ultrasound optically.

3. Visualization Objects

Ultrasound wave can focus at a point using negative refraction in phononic crystal. However, when the ultrasound waves propagate in phononic crystals, the energy of waves attenuates acutely. Also, when we use a focusing lens, a necessary focal length is different in each field. With that, it needs that the focusing lens having various focal lengths. In this paper, we considered the form of the dual structure by phononic crystal. The forms are shown in **Fig, 1**. The form (a) is a normal phononic

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crystal having a rectangular lattice. The form (b) is a shape that the only center layer of the form (a) is deleted. Hereby, the form (b) comes to the double structure of the crystals composed 3 layers to *z* axis. The interval of two structures is defined as *d*. The schemes that the ultrasound wave propagates in each phononic crystal are shown in **Fig. 2**. Ultrasound wave using negative refraction focuses twice. In the case of form (a), the one focal point is inside crystal and another point is at opposite direction to the sound source. In the case of form (b), the one focal point is inside the one of double structure and another point is at opposite direction to the sound source. In this paper, we calculated at *d*=2 and 4 (mm). Each crystal is regarded as stainless steal. We attempted to change the sound pressure level at focal point and focal length of phononic crystal by moving *d*.

4. Visualization Results

Sound pressure distributions of focused ultrasound propagating in each phononic crystal are shown in **Fig. 3**. These figures show the appearance that the ultrasound waves propagate in each phononic crystal immersed in water. FEM model is 2 dimension and the mesh numbers are about 587000 triangular elements at each occasion. Bright areas correspond to the high pressure of the acoustic field. The sound source position is at 0 mm on *z* axis and the center on *x* axis. The sound source is spherical wave and about 7.03 MHz. In these figures, all distribution focused at a point. However, the focusing areas were little indistinct. We guess the reason is that the width of crystal is narrow to spherical wave. Next, we considered the sound pressure level at each focal point. The sound pressure level of each crystal at the observation surface in Fig. 3 is shown in **Fig. 4**. It was verified that the focal positions were different at (b) d=2 and 4 (mm). Also, by comparison (a), the sound pressure levels at focal points were high in the case of (b) *d*=2 and 4 (mm).

5. Conclusions

We visualized sound pressure distribution of ultrasound wave propagating in some of phononic crystals by FEM. Among them, it was verified that the dual structure of phononic crystal can obtain high pressure at a focal point and change the focal length by moving *d*.

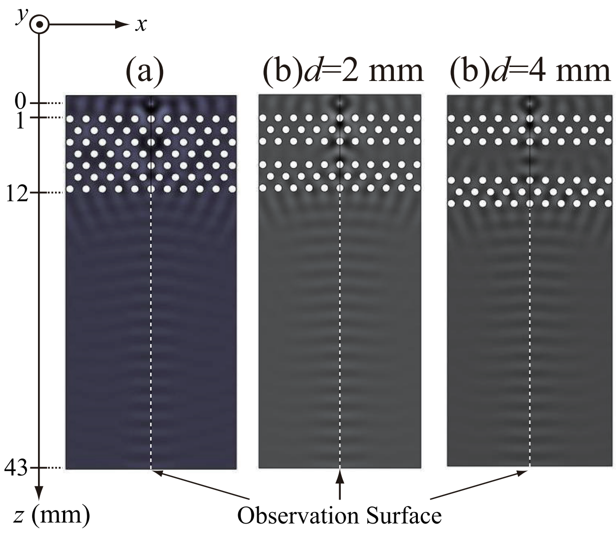

Fig. 3 Sound pressure distributions of focused ultrasound propagating in each phononic crystal.

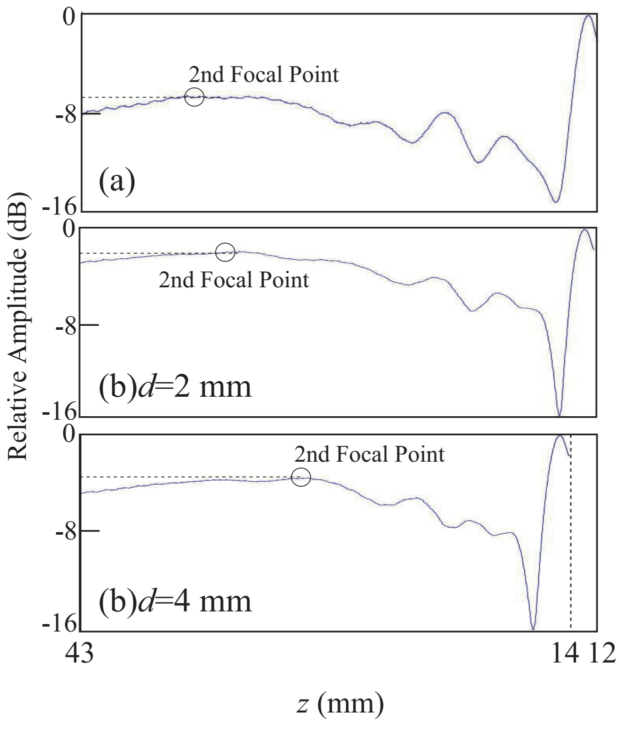

Fig. 4 Sound pressure level of each crystal at a sound axis.

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References

1. T. Miyashita W. Sato, Y. Nakaso and R. Mukuda: Jpn. J. Appl. Phys. **46** (2007) 4684.
2. J. Li, Z. Liu and C Qiu: Phys. Rev. B **73** (2006) 054302-1.
3. K. Nishimiya, K. Mizutani, N. Wakatsuki, T. Ebihara and K. Yamamoto: Jpn. J. Appl. Phys. **48** (2009)07GC06