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Design and visualization of ultrasonic wave in phononic structure for efficient energy transmission
高効率超音波電力伝送に向けたフォノニック構造の設計と超音波可視化

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1. Introduction

In recent years, the wireless power transfer (WPT) technology attracts attention. Various applications, such as the space solar power system, the non-contact charging system for electric vehicles, and so on, are proposed by using this technology. Almost all studies and developments about the WPT are using electromagnetic wave. However, the energy of electromagnetic wave greatly attenuates in the human body, water pipes, etc.. To overcome this difficulty, we have been investigating the ultrasonic WPT system and reported a prototype of highly efficient transducer and its ability[1]. In the paper, over 60% energy transmission efficiency in water by using transducers we designed was reported.

As is well known, the ultrasonic wave spreads in a fraunhofer region, therefore it is necessary to control the propagation in order to harvest an energy or transfer an energy to more distant location. Phononic structures are thus introduced for propagation control.

In this paper, the design and visualization of scattering characteristics of ultrasonic wave by the phononic structures produced by a 3D printer are discussed.

2. Ultrasonic WPT experiments in water

A fundamental experiment system is shown in Fig.1. The microwave signal generated by the SG is input to a transmitting transducer. The ultrasonic converted by the transducer from the microwave signal propagates in water. Another transducer receives the ultrasonic wave and converts to the microwave signal. Then, the microwave power consumed by the load is measured. The transmission efficiency is defined as a ratio of this consumed microwave power to the power input to the transmitting transducer. The peak frequency of the transducer is designed to be at 1.2MHz, and diameters of the transmitting and the receiving transducers are 44mm, respectively. The distance between the transmitter and the receiver is 50mm.

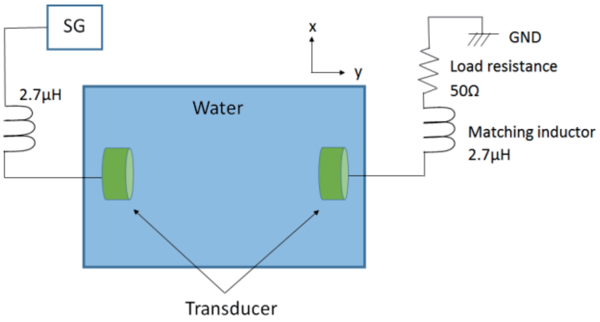

Fig.1 A fundamental measurement system

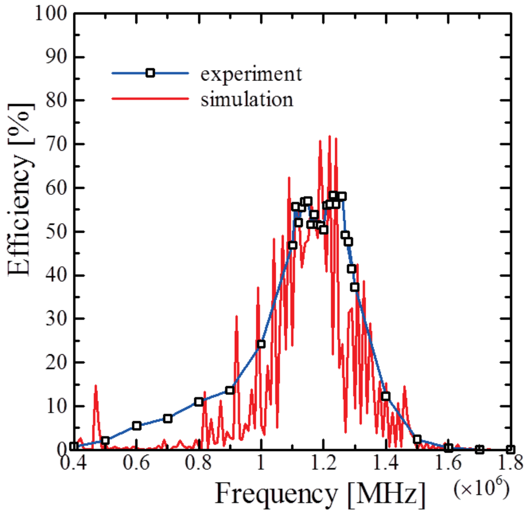

Fig.2 Measured and simulated transmission efficiencies

Measurement and simulation result are shown in Fig.2. The figure clearly confirms that 60% transmission efficiency is achieved at the resonant frequency, 1.2MHz. The measured and the simulated result agree with each other, although convergence of the numerical solution is not so good because of the limitation of the computational resources. The conversion loss at the transducers is estimated to be 30%, due to the electromechanical coupling (80%) in the transducers. Also, ultrasonic wave is attenuated slightly in water.

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3. The design of the phononic structures by using the 3D printer and the visualization of the ultrasonic wave propagation

In the present work, we investigate the phononic structures for an efficient harvesting of the ultrasonic energy. A prototype of the phononic structure is shown in Fig.3.

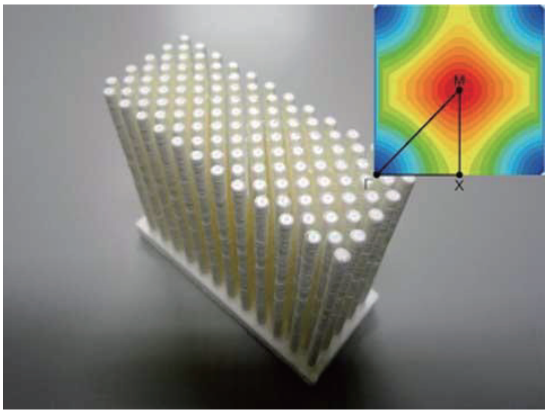

Fig.3 A prototype of the phononic structure made by the 3D printer and a phononic band structure (inset).

This phononic structure is designed so as to exhibit unique properties such as negative refraction of incident waves, based on the phonon band analysis[2] (inset of Fig.3). The structure is a periodic array of cylinders made of polycarbonate which can be easily handled and fabricated by using a 3D printer. The propagation characteristics of the ultrasonic wave scattered by the phononic structure are measured in the system shown in Fig.1.

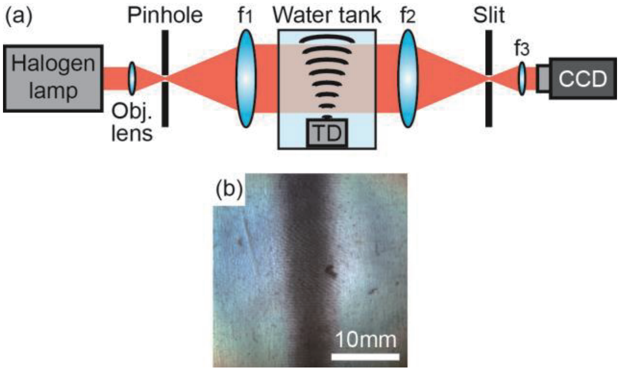

Fig. 4 (a) Schlieren optical system, and (b) measured image of an ultrasonic wave in water (dark area).

Also, the Schlieren optical system[3] shown in Fig. 4(a) is designed to visualize the ultrasonic wave propagation in the phononic structures with a non-destructive manner: The illumination light from a halogen lamp is collimated by using an objective lens, pinhole, and f1 lens, and introduced into the water tank. The light, which interacts with the ultrasonic wave propagation, forms an image onto a CCD camera through the f2 and f3 lenses. The contrast image by ultrasonic wave is obtained by introducing a slit at the focal point between f2 and f3 lenses, and thereby cutting the light diffracted by the ultrasonic wave. Figure 4(b) shows the measured image of the ultrasonic wave at 1.7MHz. The ultrasonic wave propagation is clearly visualized as a contrast image at the center of Fig. 4(b). In this presentation, we will also discuss the visualization of the ultrasonic wave in the phononic structures by using the Schlieren technique.

4. Summary

In this paper, we discussed the design of the ultrasonic WPT system, consisting of impedance-matched transducers, phononic-crystal structure, and the Schlieren optical measurement system. The transducers we designed show 60% energy-transmission efficiency at 1.2MHz. The phononic structure is designed via phonon-band analysis and fabricated by using 3D printer for controlling ultrasonic wave. The Schlieren optical measurement system is also designed for analyzing actual wave propagation in water at MHz regime without disturbing the wave propagation.

Acknowledgment

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References

1. Y. Hori, K. Fujimori, K. Tsuruta, and S. Nogi, "Design and Development of Highly Efficient Transducer for Ultrasonic Wireless Power Transmission System," IEEJ Trans. on Electron. Info. Sys. **132** (2012) 337 (in Japanese).
2. Y. Kanno, K. Tsuruta, K. Fujimori, H. Fukano, and S. Nogi, "Photoni-Crystal Acoustic Lens by Design for Energy-Transmission Devices" Electron. Commun. Jpn. **97** (2014) 22.
3. K. Yamamoto, K. Nishimiya, N. Wakatsuki, and K. Mizutani, "Optical visualization of coupling modes of leaky Lamb waves with negative group velocity in the solid/fluid/solid tri-layer" Acoust. Sci. & Technol. **31** (2010) 185.