2P5-10

Proceedings of Symposium on Ultrasonic Electronics, Vol. 33 (2012) pp. 249-250
13-15 November, 2012

Visualization of Therapeutic Ultrasound Fields in Small Chamber using Image Subtraction Schlieren Technique

画像差分シュリーレン法を用いた小型容器内の治療用超音波音場の可視化

Hiroki Obara†, Nobuki Kudo, Koichi Shimizu (Graduate School of Information Science and Technology, Hokkaido Univ.)
小原浩貴†，工藤信樹，清水孝一　(北海道大学　大学院情報科学研究科)

1. Introduction

Sonoporation is a technique to introduce foreign genes or drugs into cells by ultrasound exposure and has attracted recent interest as a drug delivery system. In typical *in vitro* studies on sonoporation, cells were cultured in a Petri dish or a multi-well plate filled with culture medium and sonicated by an ultrasound transducer placed under the dish or well. In this condition, ultrasound wave is reflected at the surface of the culture medium, and a standing wave field is generated inside the dish. Since ultrasound reflection also occurs at various position such as a bottom plate and side wall of the chamber, ultrasound fields produced inside the chamber becomes complex. Precise dosimetry of ultrasound exposure is important especially in studies on ultrasound therapy; however, it is difficult to explore the complex acoustic fiealds using a hydrophone. Schlieren is an established method used for visualizing acoustic fields using optical technique but requires a pricisely-tuned high- quality optics.

We have proposed another optical method visualizing ultrasound fields [1,2] and named image subtraction Schlieren technique. In this paper, this method was applied for visualization of ultrasonic standing wave fields inside a small chamber, and its usefulness was investigated.

2. Materials and methods

Figure 1 shows the experimental system developed for this study. This is an optics used for direct shadowgraphy but a shadow screen was replaced by a camera. Ultrasound fields are produced inside a water chamber placed between a light source and the camera. Two shadowgrams were captured in the conditions with and without ultrasound exposure. In the case without ultrasound exposure, the camera captures an image of a collimated light beam. In the case with ultrasound exposure, the light that transmits through the ultrasound field is deflected, and the camera captures the beam spot image with local brightness disturbance, i.e. shadow of the field. Sensitive detection of the shadow is then carried out by software image subtraction of these two shadowgrams.

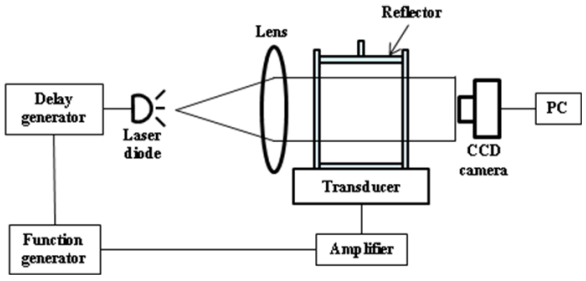


Fig. 1. Observation system used in this study.

An infrared laser diode of 5 ns in pulse width and 1 W in peak power was used for the light source, and a low noise CCD camera with 16 bit A/D (BU-51LN, BITRAN) was used to capture shadowgrams. A focus of the camera was placed on the position of 50 mm away from the ultrasound field to the camera. Stroboscopic technique was used to capture snapshots of traveling ultrasound. Ultrasound pulses were irradiated repeatedly with the camera shutter open, and light pulses generated following each ultrasound pulse with a certain delay time illuminate the ultrasound fields.

A cuboid-shaped water chamber of 30 mm in width, 15 mm in height, and 10 mm in thickness was used for the experiments. This chamber has the same cross-sectional shape as that of a Petri dish. The chamber was placed on a disk-shaped PZT transducer of 30 mm in diameter, and the transducer was driven by 100-cycle burst pulses of 2 MHz in center frequency and 100 Hz in pulse repetition frequency.

2. Results and discussion

Schlieren technique is widely used for visualization of ultrasound fields but has no ability to take snapshot images of traveling fields. Taking advantage of the proposed technique, we carried out two experiments visualizing (1) traveling ultrasound fields and (2) standing wave fields.

Figure 2 shows ultrasound fields captured with the delay times of (a) 6.00 μs, (b) 6.12 μs, and (c) 6.24 μs after irradiation of ultrasound, respectively. The brightness curves of these images are shown in (d). The wave front of the burst pulse

did not arrive at the water surface in these delays, and ultrasound field traveling toward the surface was visualized.

Figure 3 shows the ultrasound fields captured with the delay times of (a) 45.00 μs, (b) 45.12 μs, and (c) 45.24 μs, respectively. The brightness curves of these images are shown in (d). During this experiment, the water surface was covered with a plastic plate that enables ultrasound reflections at a right angle. In these delay conditions, the wave front of the burst pulse reflected five times at the bottom and top of the chamber, generating standing wave fields. Figures 3(a), (c), and (d) show generation of antinodes at the interval of λ/2, and Fig. 3(b) shows disappearance of the field caused by cancel of two antiphase waves propagating opposite directions. The maximum brightness at the antinodes of the standing wave was approximately twice of the maximum brightness in the traveling wave, indicating the possibility to evaluate the ultrasound pressure inside the chamber.

Figure 4 shows a standing wave field visualized in the same delay condition but with no reflector at the water surface. In this condition, the surface was disturbed by a convection flow generated by radiation force of the burst ultrasound, and reflection of the ultrasound became unstable. Unstable changes in positions of nodes and antinodes were visualized, indicating usefulness of the proposed technique for visualization of complex ultrasound fields.

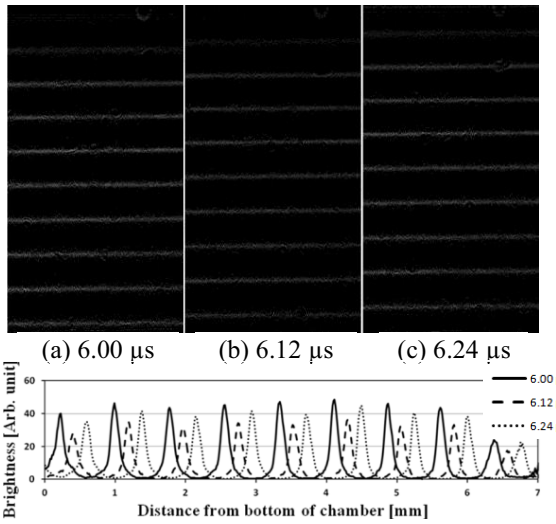
4. Conclusion

Standing wave fields generated inside a small chamber were visualized using image subtraction Schlieren technique. Effects of water surface disturbance on the fields were visualized, indicating the usefulness of the technique for accurate dosimetry of therapeutic ultrasound exposure used for *in vitro* cellular studies.

This study was partially supported by JSPS KAKENHI, 23300182 and 23650247.

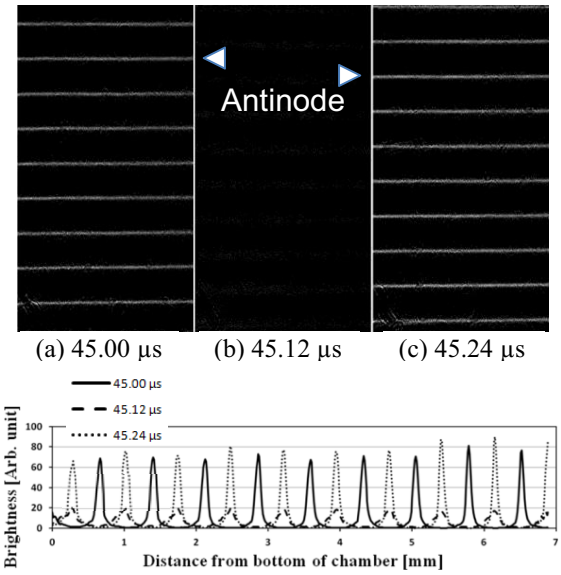
4. Reference

1. N. Kudo, H. Ouchi, K. Yamamoto and H. Sekimizu: J. Phys. Conference Series **1** (2004) 146.
2. N. Kudo, Y. Sanbonmatsu, and K. Shimizu: IEEE Ultrasonics Sympo. Proc. (2010) 829.



(d) Brightness curves

Fig. 2. Acoustic field of traveling ultrasound.



(d) Brightness curves.

Fig. 3. Generation of standing wave field.

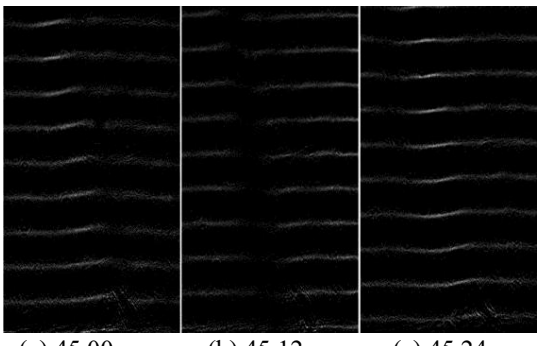


Fig. 4. Unstable changes in positions of node and antinode caused by disturbance in water surface.