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Development of an efficient method for producing standing cavitation bubbles
定在化したキャビテーションバブルの効率的生成法の開発

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1. Introduction

The authors are working in the field of plasma applications. A current topic in the authors' field is "plasmas produced in liquids". Almost all the production methods for producing plasmas in liquids employ high voltages or intense electric fields. In contrast, plasmas induced at violent collapses of cavitation bubbles do not use high voltages. We believe that this is an interesting way for producing plasmas in liquids. We call plasmas produced at the collapse of cavitation bubbles "sono-plasmas" in this work.

In this work, we report a method for the efficient production of "standing sono-plasmas". Although weak sono-plasmas are probably produced in ultrasonic cleaners, the efficiency of the production of sono-plasmas in an ultrasonic cleaner is not high. In addition, the location of the productions of sono-plasmas or the collapses of cavitation bubbles is scattering and is moving with time. We found a method for fixing the location of the collapses of cavitation bubbles.

2. Experimental method

We prepared a rectangular vessel which had an ultrasonic transducer on the back side of the bottom plate. The vessel was filled with water. The depth of water is an important factor to realize efficient production of standing sono-plasmas. The ultrasonic transducer was driven by an electric power supply at a frequency of 32 kHz. We inserted a metal plate into water from the top. The metal plate was planar, and the surface of the metal plate was parallel to the water surface. The metal plate had holes of 3 mm in diameter. The position of the metal plate was another important parameter for the efficient production of sono-plasmas. We employed laser light scattering as a simple method for examining the position and the strength of the bubble formation. We injected cw laser beam at a wavelength of 532 nm from a side window. The laser beam was arranged to be a planar shape using cylindrical lenses. The laser light was scattered by bubbles, and we captured the image of the scattered laser light through another side window using a charge-coupled device (CCD) camera.

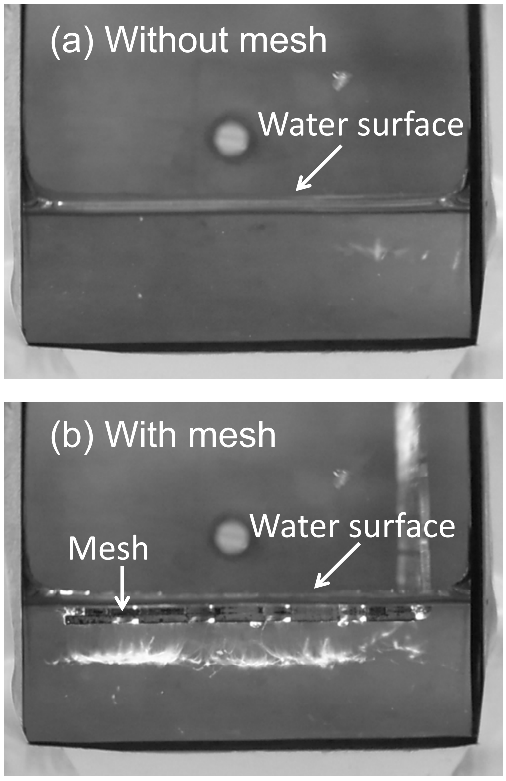

Fig. 1 Image of white light scattered by bubbles. (a) The metal plate was not inserted, and (b) the metal plate was inserted.

3. Experimental results and discussion

The formation of cavitation bubbles was easily observed by necked eyes as the scattering of the room light. Figure 1 shows the pictures of a part of the rectangular vessel, where the water zone was irradiated by intense white lamp light. The region with the bubble formation was seen as the white cloud in the pictures. The metal plate was not inserted in Fig. 1(a). In this case, we sometimes observed scattered light, but it was weak and was moving. This situation is similar to those observed in ultrasonic cleaners. On the other hand, when we inserted the metal plate, as shown in Fig. 1(b), we observed that significant amount of bubbles are produced below the metal mesh. The bubbles had a

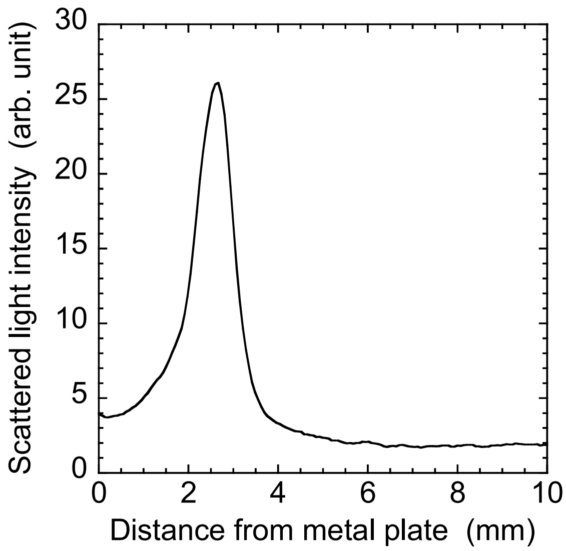

Fig. 2 The intensity of the scattered laser light as a function of the distance from the metal plate. The water depth was 40 mm, and the metal plate was inserted at 1 mm from the water surface.

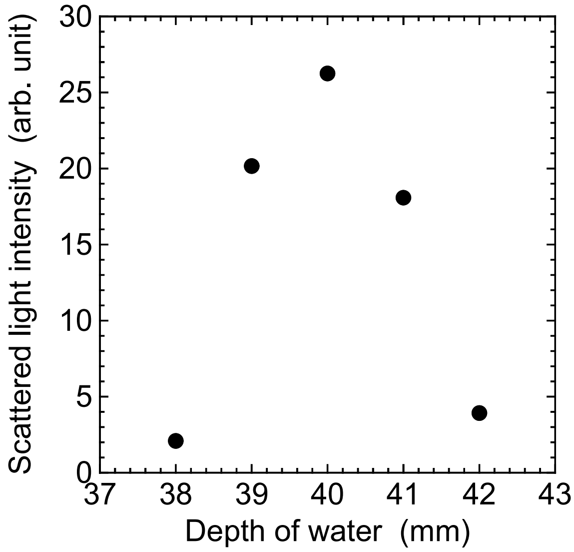

Fig. 3 The relationship between the maximum intensity of the scattered laser light and the water depth. The position of the metal plate was fixed at 1 mm from the water surface.

concentrated spatial distribution at a specific distance from the metal plate. The region of the bubble formation was not moving. The insertion of the metal plate resulted in the significant enhancement of the bubble formation.

The laser light scattering gave us more quantitative information on the characteristics of the bubble formation. Figure 2 shows the intensity of the scattered laser light as a function of the distance from the water surface. The depth of the water was 40 mm, and the bottom-side surface of the metal plate was placed at 1 mm from the water surface. As shown in Fig. 2, the bubbles were formed at a distance of approximately 2.7 mm from the bottom-side surface of the metal mesh. The region of the bubble formation was localized, and the full width at half maximum of the scattered laser light was roughly 1 mm.

The efficiency of the bubble formation was sensitive to the water depth and the position of the metal plate. The optimum values of the water depth and the positions of the metal plate were those employed in Fig. 2. When the bottom-side surface of the metal plate was placed at 2 mm from the water surface, with the water depth being kept at 40 mm, the maximum intensity of the scattered laser light became approximately 40% of that shown in Fig. 2, and the peak position was located at a distance of 2 mm from the bottom-side surface of the metal plate. When the metal plate was placed at distances of >3 mm from the water surface, the bubble formation similar to that shown in Fig. 2 was never observed, and weak scattered laser light was observed in the vicinity to the bottom-side surface of the metal plate.

Figure 3 shows the relationship between the water depth and the maximum intensity of the scattered laser light. The position of the metal plate was fixed at the optimum distance of 1 mm from the water surface. As shown in Fig. 3, the efficiency of the bubble formation was also sensitive to the water depth. The “window” of the water depth for obtaining the efficient bubble formation was as narrow as approximately 2 mm.

The mechanism for the efficient formation of cavitation bubbles has not been understood yet. It may be caused by the modification of the spatial distribution and the strength of the sound pressure by the insertion of the metal plate. We will measure the spatial distribution of the sound pressure by using an optical microphone, and will compare the experimentally-realized optimum conditions with the measurement result of the sound pressure.

4. Conclusions

We found a simple method for the efficient formation of cavitation bubbles or sono-plasmas. The method was the insertion of a metal plate with holes into water with the propagation of ultrasonic wave. When the water depth (40 mm) and the position of the metal plate (1 mm from the water surface) were optimized, we observed the formation of standing cavitation bubbles at a distance of 2.7 mm from the metal plate.