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# Sonoluminescence observed in a generator of standing acoustic cavitation with the help of a punching metal plate

パンチングメタル援用定在化音響キャビテーション発生装置におけるソノルミネッセンス

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## 1. Introduction

We are very much interest in plasmas which are produced at the collapses of cavitation bubbles. This type of plasmas is sometimes called “sonoplasma”. Sonoplasmas are unique liquid-phase plasmas since they need neither high voltage nor intense electric field for producing plasmas.

We have reported a simple method for the efficient generation of standing cavitation bubbles.[1)] The method is simply inserting a punching metal plate into water irradiated by ultrasonic wave. The depth of water and the position of the punching plate are optimized. This work reports sonoluminescence observed in the generator of standing cavitation bubbles. The intensity distribution of sonoluminescence gives us hints for estimating the structure of ultrasonic pressure in the sonoplasma generation system.

## 2. Experimental apparatus

A schematic of the generation system of cavitation bubbles is shown in Fig. 1. It was a box-type vessel with a 90x90 mm$^2$ square base, and had three windows on the sides. An ultrasonic transducer was attached at the bottom of the vessel. The frequency of the ultrasonic wave was 32 kHz. The vessel was filled with distilled water with no gas bubbling. A punching plate with a surface area of 40x40 mm$^2$ and a thickness of 1 mm was inserted into water from the top. The punching plate was made of aluminum and had many holes with 3 mm diameter.

The spatial distribution of the intensity of sonoluminescence was observed through an observation window using a charge coupled device camera with a gated image intensifier (ICCD camera). The gate width of the ICCD camera was adjusted at 3 μs, which was approximately 1/10 of the cycle period of the ultrasonic power. The sonoluminescence image was accumulated for $10^6$ times on the ICCD camera. The time of gate opening was varied, so that we obtained phase-resolved images of sonoluminescence over one cycle of the ultrasonic power.

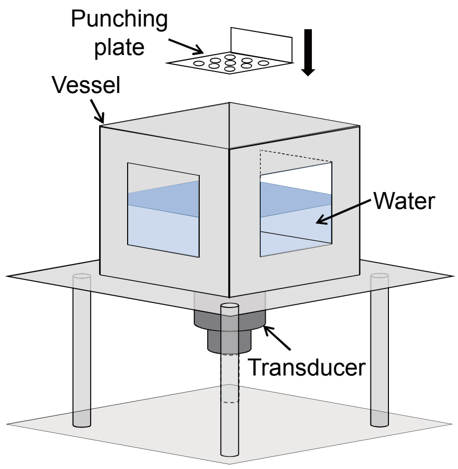


Fig. 1 Schematic of the generation system of cavitation bubbles.

## 3. Results and discussion

We adjusted the depth of water at 40 mm, which was the optimum condition for obtaining the efficient production of cavitation bubbles with the help of the punching plate. Sonoluminescence was never observed at (relative) phases between 0.8π and 1.8π both in the presence and the absence of the punching plate, while we observed sonoluminescence at phases between π and 1.6π. The intensity and the spatial distribution of the sonoluminescence were significantly dependent on the phase. Figure 2 shows images of sonoluminescence observed at a phase of 1.2π in the absence (Fig. 2(a)) and the presence (Fig. 2(b)) of the punching plate. The bottom-side surface of the punching plate was positioned at 1 mm from the water surface in Fig. 2(b), which was the optimum condition for obtaining the efficient production of cavitation bubbles. The frame of the observation window, the position of the water surface, and the

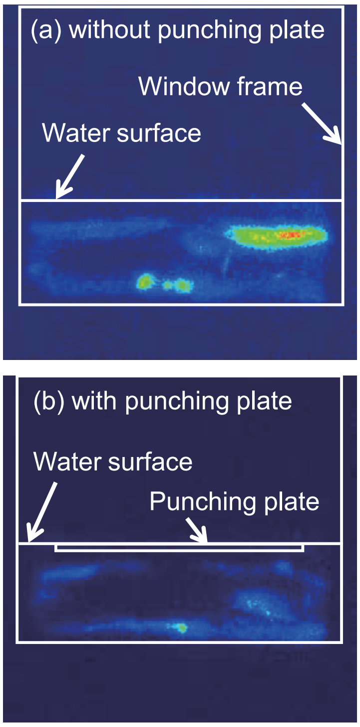


Fig. 2 Spatial distribution of sonoluminescence observed at a phase of 1.2π (a) in the absence and (b) in the presence of the punching plate.

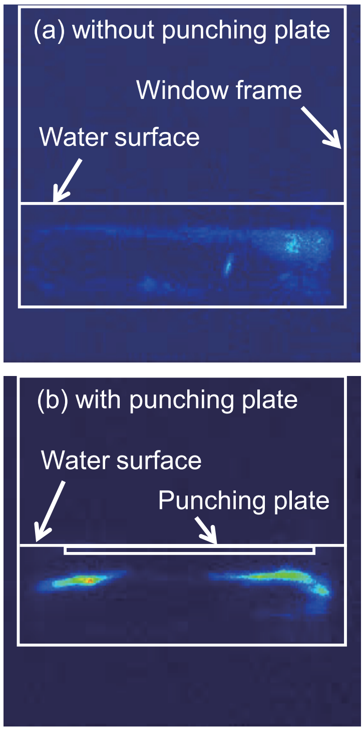


Fig. 3 Spatial distribution of sonoluminescence observed at a phase of 1.4π (a) in the absence and (b) in the presence of the punching plate.

position of the punching plate are illustrated in the figure.

The most intense sonoluminescence in the absence of the punching plate was observed at a phase of 1.2π. As shown in Fig. 2(a), we observed two planar regions with sonoluminescence. The planar regions were roughly parallel to the water surface, and the distances between the water surface and the regions with sonoluminescence were 6 and 15 mm. A weaker sonoluminescence was observed in the presence of the punching plate at the phase of 1.2π, as shown in Fig. 2(b). The distribution of sonoluminescence in the presence of the punching plate was similar to that in the absence of the punching plate.

The most intense sonoluminescence in the presence of the punching plate was observed at phases of 1.4π and 1.6π. As shown in Fig. 3(b), the distribution of sonoluminescence in the presence of the punching plate is concentrated in a thin planar region at a distance of 5.5 mm from the water surface. The sonoluminescence at a distance of 15 mm disappeared at this phase. The region with the concentrated sonoluminescence coincided with the location of cavitation bubbles which can be seen by necked eyes. The intensity and the distribution of sonoluminescence observed at 1.6π were roughly similar to that shown in Fig. 3(b). The sonoluminescence at a phase of 1.4π was much weaker than that at 1.2π in the absence of the punching plate, as shown in Fig. 3(a). The sonoluminescence at 1.6π was almost negligible in the absence of the punching plate.

It is reasonable to assume that the distribution of sonoluminescence represents the distribution of the ultrasonic pressure inside the vessel, since the sonoluminescence is generated at the collapses of cavitation bubbles. Considering the fact that the wavelength of the ultrasonic wave at 32 kHz is 47 mm in water, it is difficult to understand the distribution of sonoluminescence shown in Figs. 2(a) and 3(a) without assuming the oblique propagation of the ultrasonic wave due to the reflection on the side walls. According to Figs. 2(a) and 2(b), it is suggested that the punching plate does not affect the structure of the ultrasonic pressure significantly at a phase of the ultrasonic wave. However, at another phase, the punching plate affects the structure of the ultrasonic pressure as shown in Fig. 3(b). We will carry out the numerical analysis of the ultrasonic pressure inside the vessel on the basis of the present experimental observation.

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**References**

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