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Effect of target material and structures on laser-generated aerial ultrasound

レーザ生成空中超音波に対するターゲット材料と構造の影響

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1. Background and Motivation

High-intensity aerial ultrasound has gained considerable attention to use in non-contact and non-destructive testing. Laser-generated ultrasound has much potential to achieve extremely powerful and small size of sound source because of smaller wavelength of laser light than that of ultrasound. In recent year, an intense aerial ultrasound pulse was generated by irradiating a pulsed laser light to a solid laser absorber covered with a transparent medium. [1, 2) The continuous aerial ultrasound pulses were also revealed in the irradiation of the pulsed laser light to a transparent tube with the flow of black liquid ink. [3)]

It is known that the laser ultrasound at free surface is generated by either thermoelastic expansion or ablative stress. [4)] Moreover, the effects of the surface modification or constraint surface on laser-generated ultrasound are based on very complex phenomena such as optical absorption, energy conversion of ultrasonic, and ultrasonic propagation. In this study, the effect of target material and structures on laser-generated aerial ultrasound were examined.

2. Experimental procedure

A 532-nm-wavelength Q-switched Nd:YAG (Spectra Physics, LAB-130) was used as laser source. The measured maximum output pulse energy in single-shot operation were lower than 0.15 J. A laser pulse with the duration of 10 ns was irradiated to a target as optical absorber through a convex lens with focal length of 200 mm.

Figure 1 shows the illustrations of the target material and structures in this study. Each target is held together with two 5-mm-thick acrylic plates with a through-hole of 7 mm in diameter. A laser pulse is irradiated to a target through the center of a lower hole. The diameter of the irradiated area was approximately 3 mm on the target surface. In Figs. 1(a) and 1(b), a black rubber film is chosen as optical absorber. A black rubber used in Fig. 1(b) is covered with a transparent sheet and a pulsed laser is irradiated through it. On the other hand, the optical absorber of Fig. 1(c) is used the black liquid ink which is circulated in a flow guide constructed by the transparent sheets. Aerial ultrasound generated by laser irradiation is propagated through a 7-mm-diameter hole opened in the upper holder. The sound pressure of the

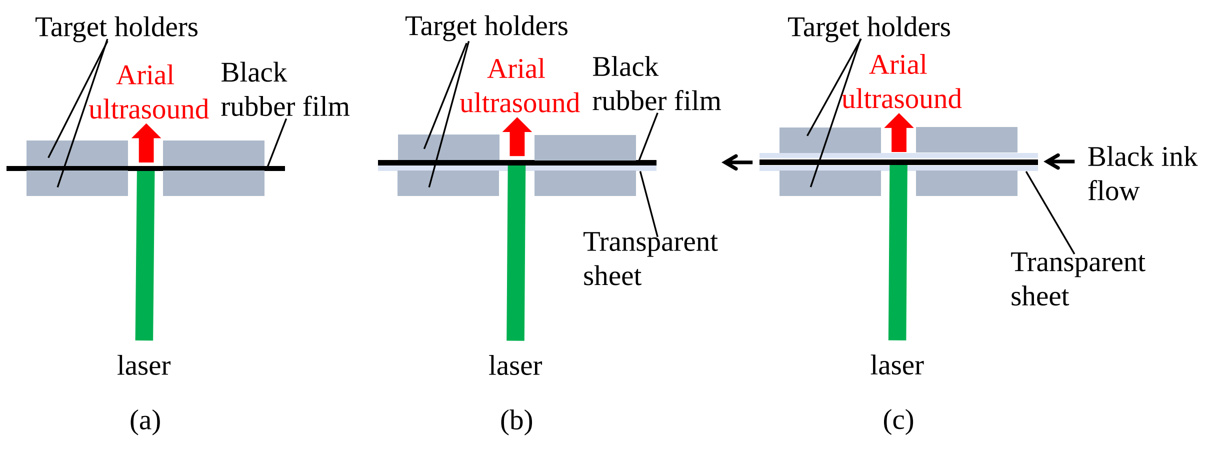

Fig. 1 Illustrations of the target material and structures. A laser target is held together with two solid plates with a through-hole and a laser pulse is irradiated to a target through the center of a lower hole. (a) A black rubber film as optical absorber, (b) a black rubber film covered with transparent sheet, and (c) the black liquid ink circulated in a flow guide constructed by transparent sheets. Aerial ultrasound generated by laser irradiation is propagated through a hole opened in the upper holder.

radiated aerial ultrasound is measured by a 1/8-inch broadband microphone (G.R.A.S, 46DE) installed on the center axis of the 7-mm-hole, and its waveform is observed by a digital oscilloscope (Iwatsu, DS-5654A) synchronized with the trigger signal from the laser equipment.

3. Results and discussion

Figure 2 shows the first arrival waveform of the aerial ultrasound generated by the irradiation of a single shot laser pulse. The distance from the laser irradiation point to the microphone tip is set to 28 mm. The laser target of Figs. 2(a), 2(b), and 2(c) are composed of a 0.1-mm-thick black fluoro-rubber (FKM), 0.1-mm-thick FKM with a 1-mm-thick polycarbonate (PC) sheet, and the black liquid ink circulated in a flow guide constructed by 1-mm-thick PC sheets, respectively. It can be seen from these figures that a peak pressure lager than 15 kPa was only obtained by using a 0.1-mm-thick FKM with a 1-mm-thick polycarbonate PC sheet. However, this structure cannot repeatedly generate the intense aerial pressure pulses because it is irreversibly destroyed by ablation. The continuous generation of aerial pressure pulses with the peak pressure of about 1 kPa was revealed in using either 0.1-mm-thick FKM without transparent sheet or black liquid ink confined in a flow guide.

From several results in Fig. 1(a), the peak pressure increased inversively proportional to the black rubber thickness ranging from 0.5 mm to 0.03 mm. In this case, the maximum sound pressure was approximately 2.7 kPa (163 dB) in average, when the thickness of FKM film was 0.03 mm and the pulse energy of an irradiated laser was approximately 0.12 J. It was experimentally confirmed from the results of Fig. 1(c) that the peak sound pressure can be generated stably and continuously up to 0.5 J of integrated pulse energy regardless of the magnitude of laser energy. In the experiment, the aerial ultrasound pulses with peak pressure of about 1.2 kPa and 280 Pa were obtained about 8 times and 70 times in a row, respectively.

4. Conclusion

The effect of target material and structures on laser-generated aerial ultrasound were investigated. An intense peak pressure was only obtained by using a black rubber film with a transparent sheet. On the other hand, the continuous generation of aerial ultrasound pulses was obtained in using either a black rubber film without transparent sheet or black liquid ink confined in a flow guide.

Acknowledgment

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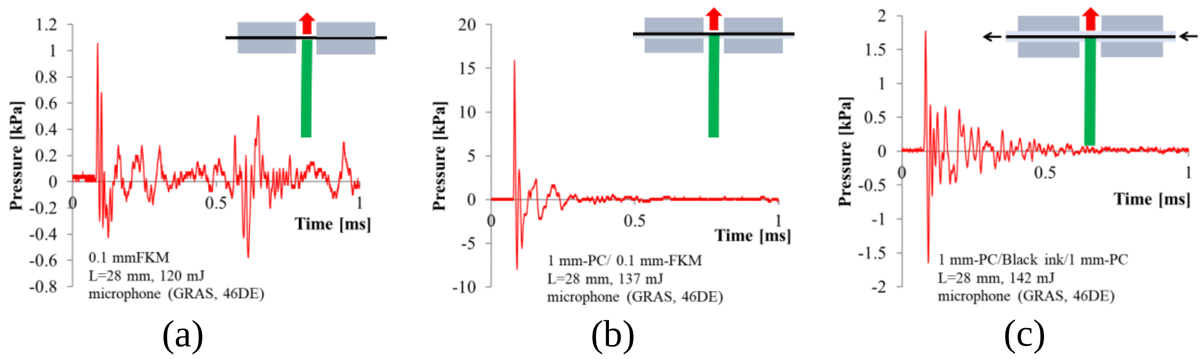

Fig. 2 Typical waveforms of the aerial ultrasound generated after irradiating a single shot laser pulse. The distance from the laser irradiation point to the microphone tip is set to 28 mm. (a) A black rubber film as optical absorber, (b) a black rubber film covered with transparent sheet, and (c) the black liquid ink circulated in a flow guide constructed by transparent sheets.