Characteristics of Shock Waves by CNT Coated Laser Generated Ultrasound Transducers

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1. Introduction

Recently it has been reported that the laser generated ultrasound transducer (LGUT) made of carbon nanotube (CNT) and poly-dimethylsiloxane (PDMS) coated on a transparent substrate radiates high frequency ultrasounds effectively. Baac et al.¹ demonstrated successfully that the laser generated focused ultrasound by a concave lens can be used for high precision target therapy. However, the characteristics as well as the generation mechanism of the strong shock waves near the focal point is not clarified, even though they explained it is caused by nonlinear propagation of the finite amplitude pulses. The waveform shows very high and short positive but not so low and relatively long negative phase. This asymmetric distortion was assumed to be related with generation of cavitations. However, the similar waveforms of the shock waves were also obtained from plane LGUTs.² For the cases, the waveform deformation is hardly explained by nonlinear propagation. In this study, we demonstrate that the waves are kinds of the blast waves through analysis of the waveforms, and show some characteristics of them by using LGUTs fabricated by coating CNT and PDMS on the substrates of PMMA.

2. Experiment

Figure 1 shows a schematic diagram of the experimental setup. A Q-switched Nd:YAG laser (Quanta-Ray, Spectra-Physics Inc.) with 532 nm wavelength and about 8 ns pulse width was used as a light source. The laser can radiate maximum 160 mJ per pulse with 20 Hz PRF. To make parallel beam with maximum 40 mm diameter, the laser beam was expended by a lens(NT55-582, Edmund Ltd.) after passing an iris. It was collimated by a plano-convex lens with 50 mm diameter and 36 mm focal length. The illuminated area could be changed by the iris and the laser power was measured by a power meter(PM100D, Thorlabs Inc.) with a 8 dB preamplifier in water and recorded by a digital oscilloscope and a PC. The measurement position was changed by a stepped x-y-z scanner.

Fig. 1 Experimental setup for shock wave generation and measurement.

Fig. 2 Structure of the fabricated LGUT.

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3. Results and discussions

A blast wave in water is the pressure and flow resulting from the deposition of a large amount of energy in a small volume. The simplest waveform of it could be described by the Friedlander equation\(^3\), that is given as following:

\[
p = p_0 e^{-\frac{t-t_0}{T_0-t_0}} \left( 1 - \frac{t-t_0}{T_0-t_0} \right),
\]

where, \(p_0\) is the peak pressure. \(t_0\) and \(T_0\) are the times when the shock wave begins and the pressure first becomes zero before the negative pressure, respectively. The eq. (1) represents the pressure variation with time after detonation at \(t_0\). The typical waveform of radiated shock wave from a fabricated LGUT in this study is shown in Fig. 3. It is compared with the calculated one by eq. (1). Here, \(p_0 = 3.0\) MPa, \(T_0 = 13.369\) ns and \(t_0 = 13.333\) ns, respectively, and the profile for \(t < t_0\) is linearly fitted as rising time before detonation. The pressure wave was measured at the position 1.0 cm apart from the center of the LGUT. It is known that the -6 dB pulse duration is about 15 ns and two waveforms are quite similar.

4. Summary

In this study, to demonstrate that the shock wave from LGUTs fabricated by coating CNT and PDMS on a PMMA substrate is a kind of the blast wave, the pressure waveforms were compared with the calculated one. And, some characteristics of the shock waves were given. Hereafter, we will investigate the propagation characteristics of the waves including sound speed and attenuation in detail.

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References