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Discussion on generation of stress waves in an endothermic material induced by Q-switched Nd:YAG pulsed laser

Q スイッチ Nd：YAG レーザによる誘起応力波に関する検討

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1. Introduction

Method of laser induced stress wave mediated drug delivery or DNA transfection into cell membrane is paid remarkable attention since it is a nonchemical, nonviral, and noninvasive method for transport of drugs and genes into cells. Molecules can be delivered into cells when laser induced stress wave disrupts the cell membrane by a mechanism believed to involve positive stress wave.[1,2] Although it is very difficult to analyze phenomena in a series of processes from ablation to shock wave, quantitative explanation of these processes may be necessary. In the case of understanding the potential to use stress wave for drug delivery or DNA transfection, the quantitative dependence of bio effects on acoustic parameters are insufficiently cleared. In this report, we intend to describe on two kinds of methods, direct and confined ablations, on generation of stress wave with impulsive momentum as entrance for getting our further and fruitful results.

2. Laser induced stress wave (LISW)

Figures 1 (a) and (b) show LISW by direct and confined ablations, respectively. These configurations can eliminate directly the effects of plasma, heat and irradiated light to material. The physical effects associated with optical breakdown are laser ablation, plasma formation, and acoustic shock wave generation as a final stage.

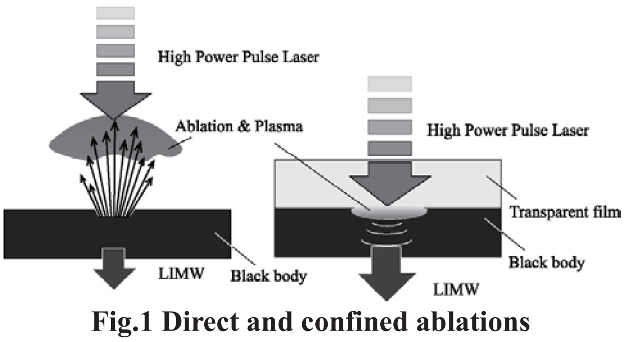

Fig.1 Direct and confined ablations

When Q-switched frequency doubled Nd-YaG pulse laser is irradiated on endothermic surface absorbing material, it will be evaporated in state of higher energy than ablation threshold. In this case thermoelastic wave caused by recoil momentum due to ablation propagate to material. If intensity of irradiated laser will be higher than plasma threshold, the magnitude of thermoelastic wave can be grown rapidly by inverse bremsstrahlung effect. Unfortunately, it is difficult that direct ablation can be generated positive going stress wave because laser plasma by our laser formation cannot be caused the ablation surface from the region near the critical density surface where laser energy is absorbed via inverse bremsstrahlung. So we need a special method for stronger stress wave (shock wave) by increment of recoil momentum. In this paper, we want to emphasize the main differences of the confined regime compared to the direct ablation.

3. Experimental setup and Sample

Figure 2 shows our experimental setup. As an energy source, Nd:YAG (Spectra Physics:LAB-130, USA) was used with 10ns duration with energies up to 200mJ/pulse at 532nm (second harmonics) at one shot. The output voltage of the PVDF transducer was detected and statistical treatment by 1.5GHz digital oscilloscope (LeCloy : LC684DXL、USA). We used a natural rubber (NR) (Sound Lab. Co. Ltd) as an endothermic surface absorbing material as shown in **Fig.3**. A PVDF piezoelectric transducer to measure transient stress waves was used.

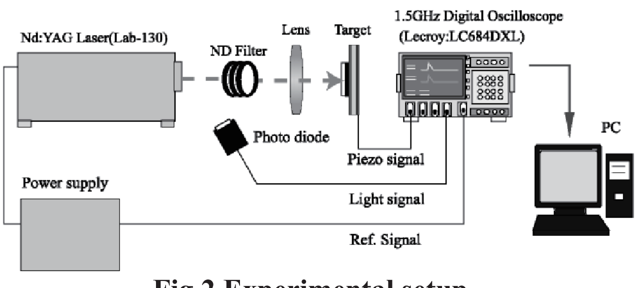

Fig.2.Experimental setup

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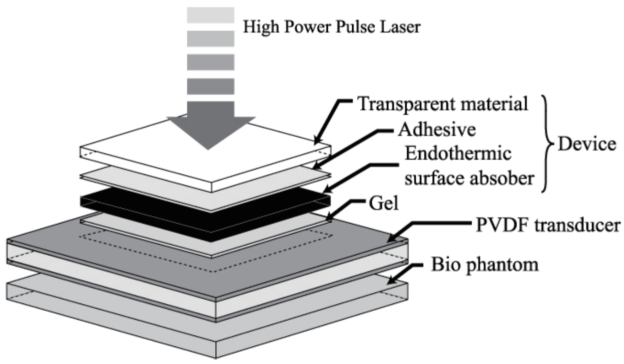

Fig.3 Experimental configuration

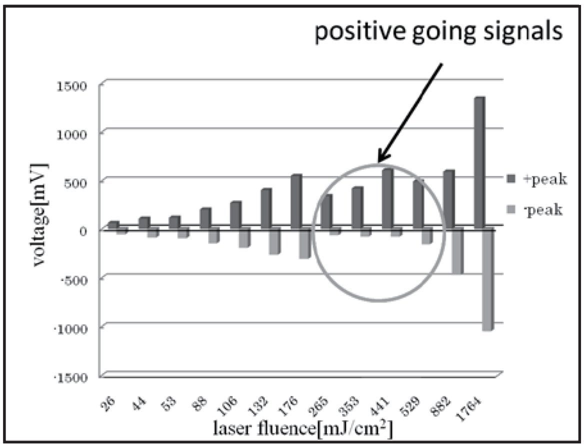

Fig.4. Relation of LISW and laser fluence

4. Experimental Results

Figure 4 shows relation between laser fluence and PVDF output. It was found that positive going signals at thermoelastic waves generated in ranging from about 265 to about 850 [mJ/cm^2]. **Figures 5(a) and (b)** show observed waveforms of LISW generated by direct and confined ablations, respectively. Observed waveform of LISW in the direct was sinusoidal and dynamic of thermoelastic wave not positive–going signal. However, observed waveform in the confined one was just positive-going configuration in ranging from 0.5 to 1.5μs and formation of compression stress wave alone. As the fact must be emphasized, the peak pressure and pulse width of the generated stress wave could be increased by use of this geometry.

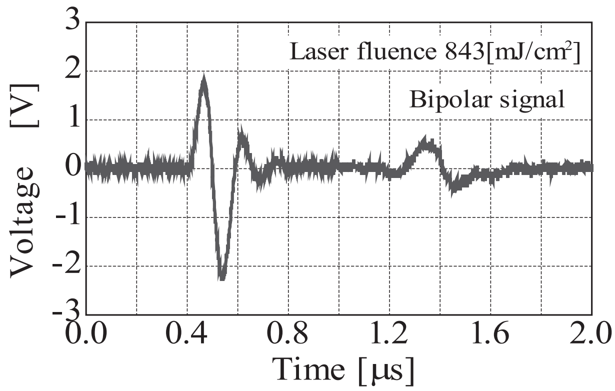

Fig.5(a) Thermoelastic wave in direct ablation

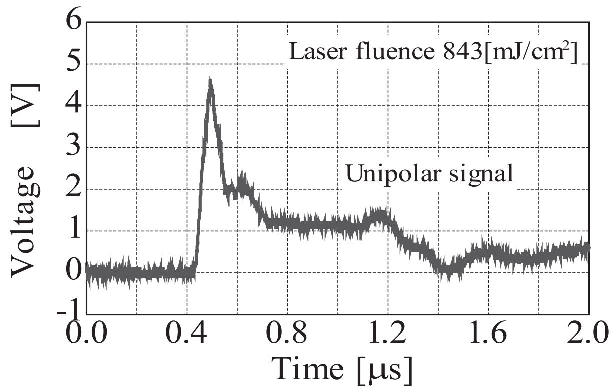

Fig. 5(b) LISW in confined ablation

5. Conclusion

We showed experimental results of stress wave in direct and confined geometry induced by Q-switched Nd:YAG laser.

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