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Pressure estimation of laser-induced emergent stress wave in direct and confined geometry targets
レーザ誘起応力波の圧力推定法の研究

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1. Introduction

Recently, various studies have been actively carried out by the analysis of the gene. As one of them, there is a gene therapy. It has been developed as the treatment for malignant tumors such as cancer and congenital disease. In this treatment, it is necessary to transfer a gene from outside the cell. However, the most common method is virus vector, it has been confirmed cases of death [1]. Therefore non-virus vector method has begun to be studied. As an attractive method for gene transfection, laser has been focused [2-3]. We propose a method using laser-induced emergent stress wave (LIESW). LIESW is ultrasound and stress wave caused by laser-target interaction. LIESW never generates cavitations and extra heat therefore it can prevent serious damage to cells. However, physical characteristics of LIESW have not been clear in detail. In this study, we investigate pressure value and distribution of LIESW. It is necessary to clarify propagation pressure of LIESW in target because it closely relates to gene transfection.

2. Experimental setup and Target

Figure 1 shows our experimental set up. Our experimental system is simple and possible to make various experiments. In our experiment, we used Nd:YAG laser (Spectra physics LAB-130, 10 ns pulse duration and Q-switch one shot energy 200 mJ/pulse at 532 nm in the specification) as an energy source and adjust laser energy using neutral density (ND) filter. In addition, we used condenser lens for setting up beam diameter 2.3 mm. We used energy/power meter (Newport 842-PE) to measure laser output. In addition, we used the oscilloscope (Wave runner IWATSU-LeCroy LT342L) to detect piezo signal of LIESW waveform. Detected signal was transmitted to PC and we do the result of data processing on PC.

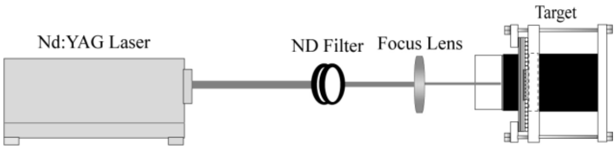
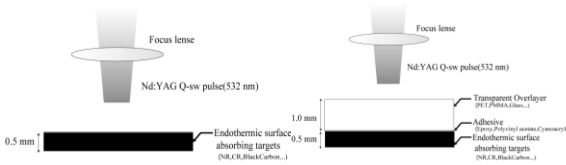


Fig.1 our experimental setup

In our experiment, we prepared two kinds of target that were direct and confined geometry. **Figure 2** shows direct and confined geometry.



(a) direct type (b) confined type
Fig.2 direct and confined geometries

Direct geometry is constructed by endothermic surface absorbing materials (ESAMs) only, in addition black natural rubber (NR: Best Sound lab, 0.5 mm thickness) is used as ESAMs. On the other hand, confined geometry is constructed by transparent over layer, adhesive and ESAMs. In the case of confined geometry, ESAMs is NR, transparent over layer is PET sheet (ACRYSUNDAY Co.,Ltd, 1.0 mm thickness)and adhesive is epoxy resin(CEMEDINE Co.,Ltd, 20~40 μm thickness).

3. Pressure Estimation of LIESW

We used PRESCALE® (Fujifilm Co.,Ltd,) for pressure estimation of LIESW. PRESCALE® is a thin sheet and it is colored red dye when it senses the pressure. We used two kinds of sheets for low pressure (2.5~10MPa) and middle pressure (10~50MPa). The colored image was analyzed by using a software (Fujifilm Co.,Ltd FPD-100S). It enabled to visualize pressure distribution with its value. **Figure 3(a)** shows an illustration of the geometry between laser target and PRESCALE® in this experiment and, **3(b)** illustrates the process of coloring.

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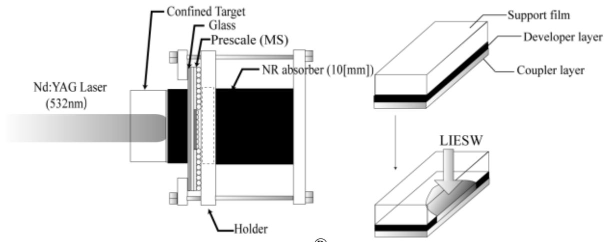


(a) target and PRESCALE® (b) process of coloring
Fig.3 pressure estimation of LIESW

4. Result and discussion

Table 1 summarizes the estimated value of LIESW such as maximum pressure (P_{max}), average pressure (P_{ave}) and pressured area (P_{area}). Direct and confined geometries were used and a laser fluence was 3.2[J/cm^2].

Table 1. Pressure value

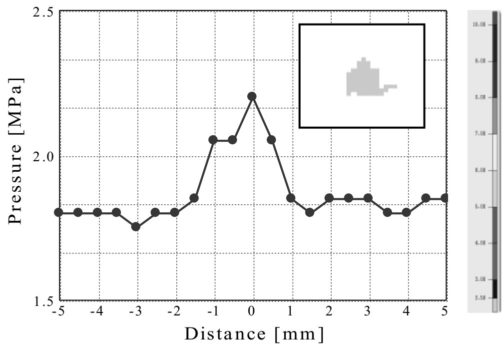
Type	P_{max} [MPa]	P_{ave} [MPa]	P_{area} [mm^2]
Confined	39.8	29.5	5.0
Direct	2.45	2.15	2.0

From **Table 1**, the pressure value of confined geometry was about 16 times larger than that of direct one. When laser energy was increased, the pressure value of LIESW and pressure area also increased. We consider that these experimental results depend on the type of target structure and process of LIESW generation. In the case of direct geometry, the particles generated by laser ablation would spread out in the air therefore it is difficult to form plasma. This causes low peak pressure of stress wave. However in the case of confined geometry, the laser beam is absorbed efficiently and plasma expands than direct geometry because ablated particles and plasma are confined between ESAMs and PET film. Therefore High peak pressure of LIESW is formed due to expansion of plasma [2,4]. **Figure 4(a) and 4(b)** show the pressure distribution of direct and confined geometry, respectively.

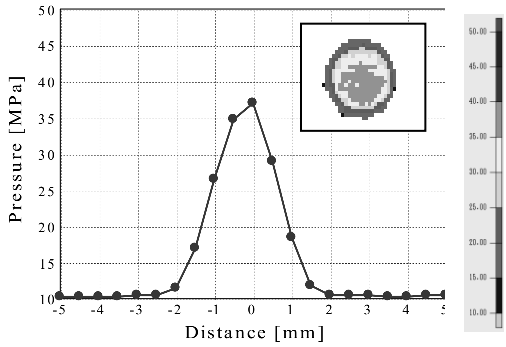
In Fig.4, 0 mm is center of distribution of pressure. Distribution of direct geometry was instability, on the other hand, distribution of confined one was sharp and spread in concentric circle. In confined geometry, it was found that P_{area} spread 1.2 times wider than beam area.

5. Conclusion

In this study, we estimated pressure value and its distribution of LIESW experimentally. By using this method, we were able to clarify pressure character of LIESW in short time. It was found that pressure value and area depended on laser energy.



(a) distribution of direct geometry



(b) distribution of confined geometry
Fig.4 pressure distribution of LIESW

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