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Comprehensive research on emergence of impulsive stress wave using a nano-second pulse laser
ナノ秒パルスレーザを使う創発的インパルス応力波の形成に関する包括的検討

Yoshiaki Tokunaga, Motoaki Nishiwaki, and Koji Aizawa (KIT)
得永　嘉昭,西脇　基晃,會澤 康治 (金沢工大)

1. Introduction

Since various high-performance lasers have become available for purchase at affordable prices, scientists and engineers engaged in research of ultrasound have used them, for instance, as a probe for ultrasonic measurements, as an energy source for generation of ultrasound. We also used various lasers to photoacoustic microscopy investigation [1] and investigation of surface acoustic soliton on LINbO3 dielectric substrate. [2] Recently, available usages of various lasers for gene therapy research have been done as important request to the suppression of medical costs in an aging society. We have investigated a method for high efficiency transfection of plasmid DNA into mammalian cells using nanosecond impulse stress waves generated by laser irradiation on target material. [3] However, we have not been able to achieve a good goal of this research since intensity of laser induced stress wave (**LISW**) generated by interaction of target and laser was not strong. The reason is that our laser is a laboratory–type small Nd:YAG laser. In order to resolve this problem, we have attempted a method for power enhancement of **LISW** by using a confined geometry. We defined a new wave generated by confined geometry as laser induced emergent stress wave (**LIESW**). We are very interesting to physical and hydrodynamic processes of **LIESW** creation. In this paper, we discuss physical and fluid-dynamic description on morphogenesis of **LIESW** using comprehensive approach.

2. Construction of a confined geometry

Figure 1 shows a schema of a confined geometry. The geometry composed of three different materials which are an endothermic surface absorbing target, an organic polymer sheet and an adhesive for close contact.

toklab@mlist.kanazawa-it.ac.jp

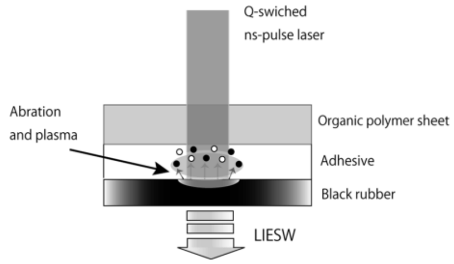

Fig.1 A schema of ablation and plasma in adhesive (adhesive :20μ m,target:0.5mm,polymer:1mm)

3. LIESW acoustic signature

Figure 2 shows an observed acoustic signature of **LIESW**. It was found that it was drastically changed on characters such as peak intensity, full width at half maximum in comparison with those of the direct geometry.

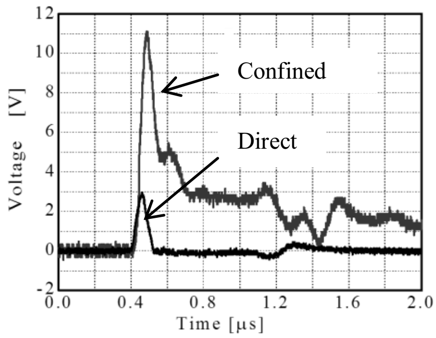

Fig.2 Acoustic signatures of direct and confined geometries (laser fluence: 2.4J/cm^2)

4. Discussion

Up to now, ablation and plasma generated in vacuum of direct geometry have been investigated in detail. However, information on ablation and plasma in confined geometry has never been investigated. We attempted to study physical and fluid-dynamic characters in **LIESW** in order to understand deeply acoustic signature of it. When the laser irradiates on surface of the sheet, it reaches to the target surface through the adhesive film without loss.

By applying laser fluence above plasma threshold, both ablation and plasma will be caused in a boundary of the target. Most of published experiments were ignore an influence of the adhesive since it was very thin. [5] However, we consider that the adhesive plays important role on the plasma creation and a detonation wave formation. We should consider that **LIESW** is generated in the adhesive since the plasma is formed in adhesive close to the target. In order to analyze physical phenomena of **LIESW**, we should understand that it may be emerged by complex integration of nonlinear phenomena such as laser ablation, heated plasma, shock wave, and detonation wave in there. During laser pulse duration, the plasma with high temperature depends strongly on vaporization of the adhesive and interaction with free electrons and positive ion particles ablated from the target. In this process, the plasma will be further growth since irradiated laser light is absorbed by free electrons in the plasma (**Inverse Bremsstrahlung** effect).[6] The blow-off of the high temperature plasma generates on the target, and then the surface can induce a mechanical impulse stress wave. In consequence of the pressure with above Mach speed generated at the surface, the shock wave is launched inside the target. By continuous supply of laser energy, a voritical wave due to nonlinear effect such as **Richtmyer Meshkov Instability** [7] will be grown up and sooner it will go to turbulent chaos. It was found that an available pressure formed by remaining plasma in the adhesive played important role for positive going components of **LIESW** even if laser was switched off**.** Temporal position of the acoustic signature of **LIESW** containing the **detonation wave** and **new emergent wave**, like a blast wave, caused by remaining plasma was shown in Fig.3.

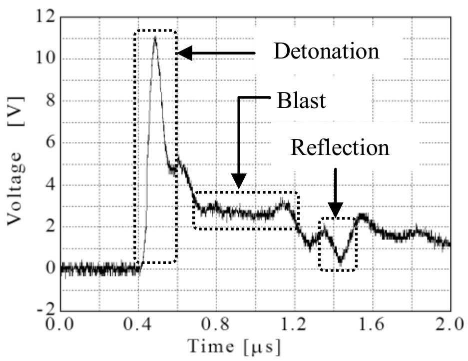

Fig.3 Temporal profile of the acoustic signature (The profile may be composed of, at least, three different categories)

We consider that voltage of the acoustic signature corresponds to recoil momentum to the target given by **LIESW** because it is measured by PVDF film transducer as sensing device. The acoustic signature reflects on three different characters. Therefore, first sharp peak from 0.4μ s to about 0.5μ s in it was mainly formed to depend on detonation wave due to during laser irradiation(I**nverse Bremsstrahlung** effect), intermediate region (from 0.5μ s to about0.6μ s) by effect such as **Richtmyer Meshkov** instability in adiabatic cooling after laser switching off and component detected in long range from 0.6μ s to about 1.3μ s depends on remaining component of plasma formed in turbulence by interaction of factors such as laser ablation, heated plasma, shockwave, detonation wave .

5. Conclusion

In this paper, we discussed qualitatively physical and fluid-dynamic phenomena composing of an acoustic signature of **LIESW** from standpoint of comprehensive research.

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