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# Effects of hydrodynamic response due to material stiffness on laser imprinting

## 物質の硬さによる流体力学的応答がレーザーインプリントに及ぼす影響

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Hydrodynamic response by non-uniform intense laser irradiation as a function of material was investigated. Diamond was employed as a possible ablator material for direct-drive inertial confinement fusion target to mitigate the initial imprinting due to laser irradiation non-uniformity. The imprinting amplitude due to irradiation non-uniformity was measured for diamond foils and polystyrene foil as a reference material. Experimental results indicate material stiffness has an effect of hydrodynamic response on laser imprinting.

## 1. Introduction

Hydrodynamic instabilities are the most important issue on inertial confinement fusion (ICF) targets because they disturb uniform target fuel compression. The seed of its hydrodynamic instability growth is initial perturbations on the target. The initial perturbations are classified roughly into surface roughness due to target production and imprinting due to laser irradiation non-uniformity. When laser beam with the irradiation non-uniformity irradiates on the target, non-uniform ablation pressure is applied on the target, which produces spatial perturbations. The mitigation of initial imprinting is very important in direct-drive ICF targets. Here we focused the mitigation mechanism due to an effect of material stiffness with diamond foils.

## 2. Experimental conditions

Fig.1 is a schematic of the experimental setup. In the imprint experiments, diamond foils were irradiated with a foot pulse at an intensity of 2.0-8.0×10$^{12}$ W/cm$^2$ with 1.3 ns pulse duration. Spatial irradiation non-uniformity with sinusoidal shape of 100 μm wavelength was imposed by a grid mask just before the focusing lens. The foils were subsequently accelerated by a uniform main laser pulse of ~1.0×10$^{14}$ W/cm$^2$. Imprinted perturbations were observed by amplifying due to Rayleigh-Taylor instability with face-on x-ray backlight method. We deduced the equivalent initial surface roughness for the imprinted foil from the data. Also polystyrene foils were irradiated as a reference material in order to compare the imprint level.

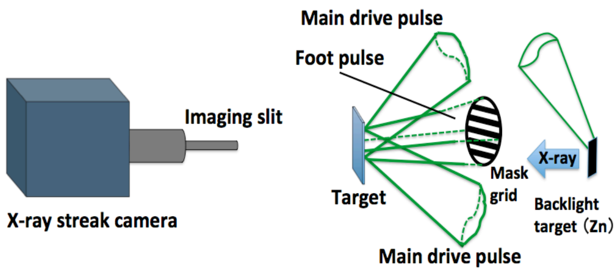



Fig.1. Experimental setup for measurement of areal-density perturbations seeded by non-uniform irradiation.

## 3. Experimental results

Examples of raw streaked backlit images of the diamond and polystyrene foils are shown in Fig.2. The time origin (*t*=0) was set as the half maximum of the onset of the drive pulse. Figure 2 also shows the time-integrated lineouts with its temporal resolution (~75 ps) for both two target at $t$ = 1.6ns. As shown in Fig.2, the perturbations indicate typical bubble spikes structure due to RT instability on polystyrene. On the other hand, the perturbation on the diamond is apparently different from polystyrene occurs.

Figure 3 shows analysis of the temporal evolution of the areal-density perturbations for the diamond and polystyrene target. In these plots, both the fundamental and second harmonic perturbations are included. In the polystyrene, areal-density perturbations of the fundamental are amplified by Rayleigh-Taylor instability, and second harmonic component appears after saturation of the fundamental perturbation.

The model calculation [1] for each foil is also plotted in Fig. 3. The calculations show qualitative agreements with the experimental results. However, the experimental results are systematically factor of ~3 larger than the calculations. The difference is likely due to the assumptions in the simple model about the shock wave propagation.

On the other hand, the diamond data shows much larger order harmonic perturbations from in early timing. The phase of the second harmonics is “negative”, which means the shape of the perturbation on the diamond foil is like a spiky dip.

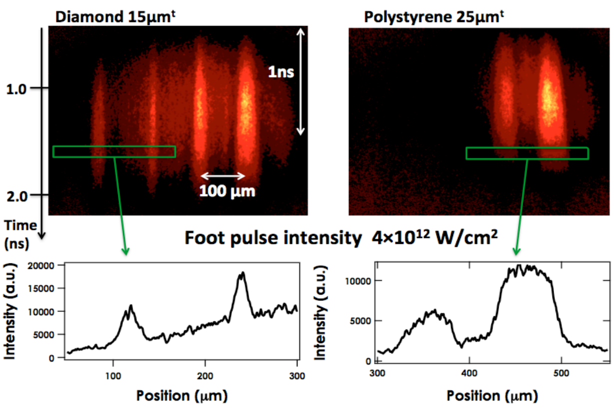
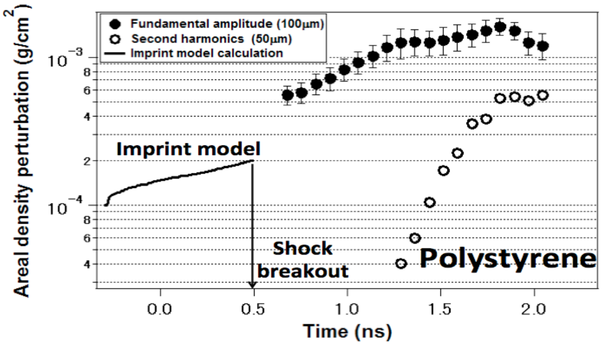



Fig.2. Raw streaked images of the backlit diamond and polystyrene targets. The lineouts were taken at 1.6ns after onset of the main drive pulse.

(a)




(b)

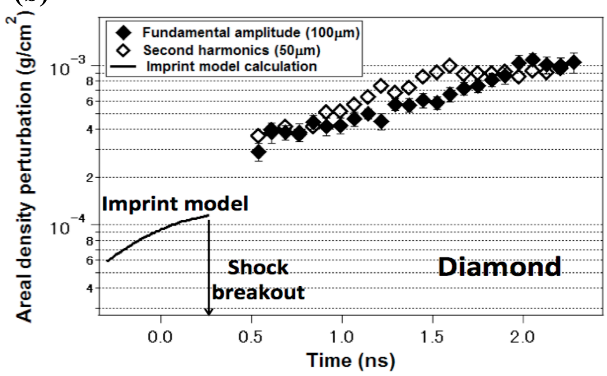



Fig.3. Areal-density perturbation growth for (a) polystyrene and (b) diamond foils. Solid curves are the calculations with the imprint model coupled with the 1-D hydrodynamic simulation.

**4.discussion**

The difference of shape of the perturbations between polystyrene and diamond indicate that material stiffness have an effect of hydrodynamic response on laser imprinting. There are two possible interpretations for the result. One reason is elastic-plastic (E-P) transition of the diamond at pressures near 150-200 GPa [2]. Below the E-P pressure, diamond is less compressible. Since the pressure at the intensity modulation minimum in the experiment is likely below the E-P pressure, whereas at the intensity modulation maximum the pressure is above the E-P pressure, the perturbation is non-sinusoidal. Second candidate is rapid melting [3]. Under intense laser irradiation, the target is heated not only due to shock compression but also by the coronal plasma via thermal conduction and radiation, which might cause the local heating on the diamond foil. Further understanding of the phenomenon and quantitative analysis is required by using a two-dimensional hydrodynamic simulation including the phase transition.

**5. Conclusion and Summary**

We have verified the mitigation effects of laser imprinting with the diamond ablator. The experimental results indicate that hydrodynamic response due to material stiffness has played an important role in laser imprinting.

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