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Diamond ablator for direct drive inertial confinement fusion targets

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Introduction

In inertial confinement fusion (ICF) targets, the laser imprinting primarily caused by pressure perturbations resulting from irradiation non-uniformity. The Rayleigh-Taylor instability (RTI) occurs at the deformed interface of accelerating materials with different densities. In ICF targets, the RTI and related hydrodynamic mixing are the crucial factors with respect to thermonuclear ignition during the implosion timeline. The imprinting due to irradiation non-uniformity on the ICF targets should be as small as possible because small perturbations on the target surface grow exponentially with time by the RTI. In addition, the parameters (neutron yield and areal density) of reasonable conditions for ICF ignition depend on the level of laser imprinting [1]. Previous investigations have been performed in order to mitigate the laser imprinting by thermal smoothing [2-4]. However, thermal smoothing is not effective for long wavelength perturbations nor when the effective separation distance between laser absorption region and ablation front (stand-off distance) is small in very early timing. In this study, we perform an experimental investigation on effects of diamond strength on surface perturbation due to irradiation non-uniformity.

Experiments

Schematic view of experimental arrangement is shown in Fig. 1. In experiments, the target foils were irradiated with a foot pulse at intensity of 4.0×10^{12} W/cm^2 (low foot) or 5.0×10^{13} W/cm^2 (high foot), on which stationary spatial non-uniformity (~10% or ~40 %) with sinusoidal perturbation of 100 μm wavelength. The foils were subsequently accelerated by uniform main pulses of ~10^{14} W/cm^2. The amplitude of laser imprinting was observed by amplifying its perturbation via RTI with face-on x-ray backlighting technique. We measured areal-density perturbation for flat crystal diamond foil (thickness 13-14 μm), poly-crystal diamond (thickness ~ 11 μm), and polystyrene (PS) foils (thickness 25 μm) as a reference.

Experimental results

Figure 2 shows raw experimental results on areal-density perturbation by the x-ray shadowgraph technique. In irradiation non-uniformity ~10%, the experimental results show that the imprinting amplitude (fundamental) was reduced for the diamond foil due to material compressibility. The experimental results in good agreement with results of 2D hydrodynamic simulation (PINOCO [5]).

On the other hand, when irradiation non-uniformity is ~40%, harmonic contents of the areal density perturbations generate very early in time of shock wave propagation. As a consequence, 2D hydrodynamic simulations did not reproduce experimental results. We found that there is different physics on generation of crack-like structure due to large pressure perturbation on the diamond surface. The physics of the material compressibility and strength on laser irradiation is very important for direct-drive ICF target designs.

References

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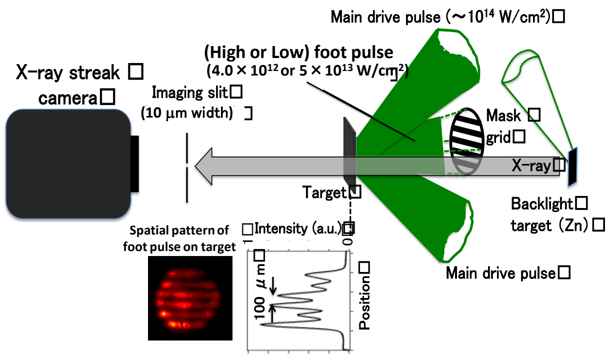

Figure 1. Schematic view of experimental arrangement for measuring laser imprinting with face-on x-ray backlighting technique

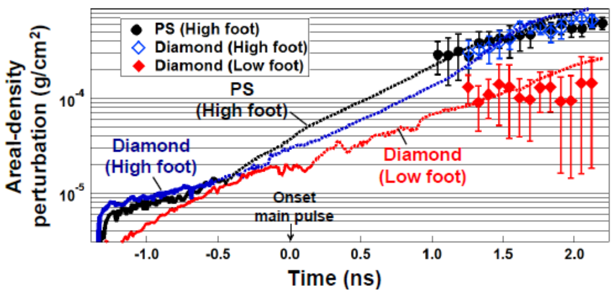

Figure 2 Experimental results on areal-density perturbation for diamond and PS foils