

§44. Mitigation of Laser Imprinting with Diamond Ablator

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In inertial confinement fusion (ICF) targets, Rayleigh-Taylor instability (RTI) and related hydrodynamic mixing are significant issues with respect to thermonuclear ignition. Because small perturbations on the target surface grow exponentially with time due to the presence of RTI, initial perturbations on the target surface should be as small as possible. The perturbation seeds are due to the following two factors: (I) surface roughness due to target fabrication and (II) imprinting due to laser irradiation nonuniformity. In direct-drive ICF targets, laser imprinting is the primary factor influencing perturbation seeds.

Here we report the results of our investigation of the effect of material stiffness on the laser imprinting of diamond targets. The targets comprised single-crystal diamond foils (Type-Ib, density: 3.51 g/cm³) with a thickness of 12–20 μm. A polystyrene (PS) foil (density: 1.06 g/cm³) with a thickness of 25 μm was employed as a reference material. The experiments were conducted using the GEKKO-XII Nd:glass laser facility at the Institute of Laser Engineering, Osaka University. The diamond and PS foils were irradiated with the second harmonic light (λ: 0.527 μm) from the Nd:glass laser. The pulse shape was Gaussian with a 1.3 ns duration (full width at half maximum), using one beam for the foot pulse stacked with two beams for the drive pulse, with time delays between the beams. We define the time origin (t = 0) at the onset of the main drive pulse. Perturbations were observed on the target via amplification due to RTI growth using the drive beams because the imprinted perturbations were typically too small for visible detection. A schematic of the experimental setup and the typical stacked pulse shape are shown in Fig. 1. Intensity modulation of the foot pulse was achieved using a grid mask placed immediately in front of the focusing lens. The modulation amplitude on the target foil was 100 μm with a 40% intensity perturbation (ΔI/I₀). The intensity of the foot pulse and the main pulse under standard conditions was 4 × 10¹² W/cm² and 1 × 10¹⁴ W/cm², respectively.

The areal-density perturbation growth was measured using a face-on x-ray backlighting technique. A zinc (Zn) target was irradiated to generate ~1.5 keV quasi-monochromatic x-rays coupled with a 10-μm-thick aluminum filter. Temporal evolution of the transmitted x-rays from the Zn backlighter through a diamond or PS foil was imaged through a slit onto the photocathode of an x-ray streak camera.

Examples of raw streaked backlit images of the diamond and PS targets are shown in Fig. 2. The time origin (t = 0) was set as the half maximum of the onset of the drive pulse. Time-integrated lineouts were obtained for each temporal resolution duration. Figure 2 also shows the lineouts for both two targets at t = 1.6 ns. The areal-density

perturbations were obtained by fitting the convolutions of the resolution functions and the sinusoidal perturbation functions to the raw lineouts. The fundamental and second harmonics of the perturbation functions were also taken into account to verify the nonlinear evolution of the perturbation growth. From the lineout for the PS data, a typical “bubble-spike” structure due to saturation of the RTI growth can be seen. On the other hand, the shadow of the backlit diamond data indicates a spiked dip structure.

We have shown the effects of hydrodynamic response on laser imprinting due to material stiffness. The stiff material diamond shows strong reduction of imprint efficiency, which is in good agreement with the simple incompressible model. The results on perturbation shape also indicate the effects of material stiffness between elastic-plastic, and/or liquid-solid phase boundaries. This data platform is crucial for understanding the principal laser-matter interactions and for the ICF target design.

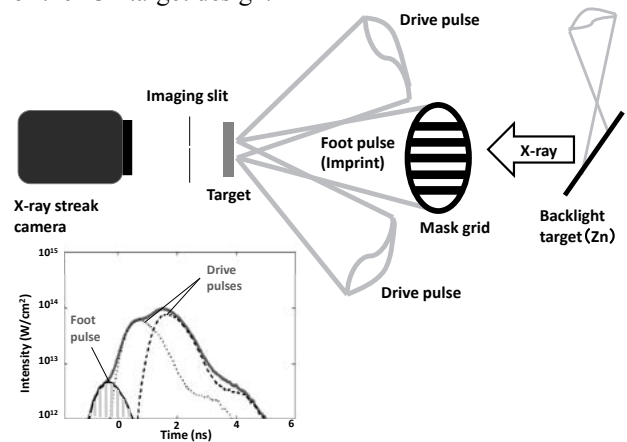


Fig. 1. Experimental setup for measurement of areal-density perturbations seeded by nonuniform irradiation. The pulse shapes for the irradiation laser are also shown.

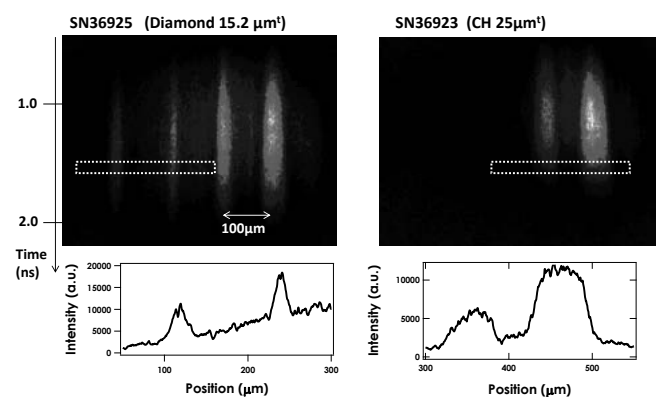


Fig. 2. Raw streaked images of the backlit diamond and PS targets. The lineouts were taken at 1.6 ns after onset of the main drive pulse.