Hybrid Target Design for Imprint Mitigation in Direct-Drive Inertial Confinement Fusion

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We propose a novel target design, called the hybrid direct-drive target design, for mitigating the Rayleigh–Taylor instability (RTI) in high-energy-density and direct-drive inertial confinement fusion experiments.[1] Figure 1 shows a schematic of the design in both (a) spherical and (b) planar geometries. The target is surrounded by a thin (less than 1-μm) CH membrane that is externally coated with a tens-of-nm-thick layer of Au. The membrane is offset by several hundred microns from the target's surface. A high-intensity laser picket pulse is incident on the membrane, producing smooth x-ray radiation that serves as the initial seed on the target surface and drives the first shock through the target. After giving the target time to develop its conduction zone, between a few hundred ps to ~1 ns, the main pulse propagates through the underdense plasma from the exploded membrane and drives the target itself. A proof-of-concept experiment in planar-target geometry on the OMEGA EP laser explored the performance of

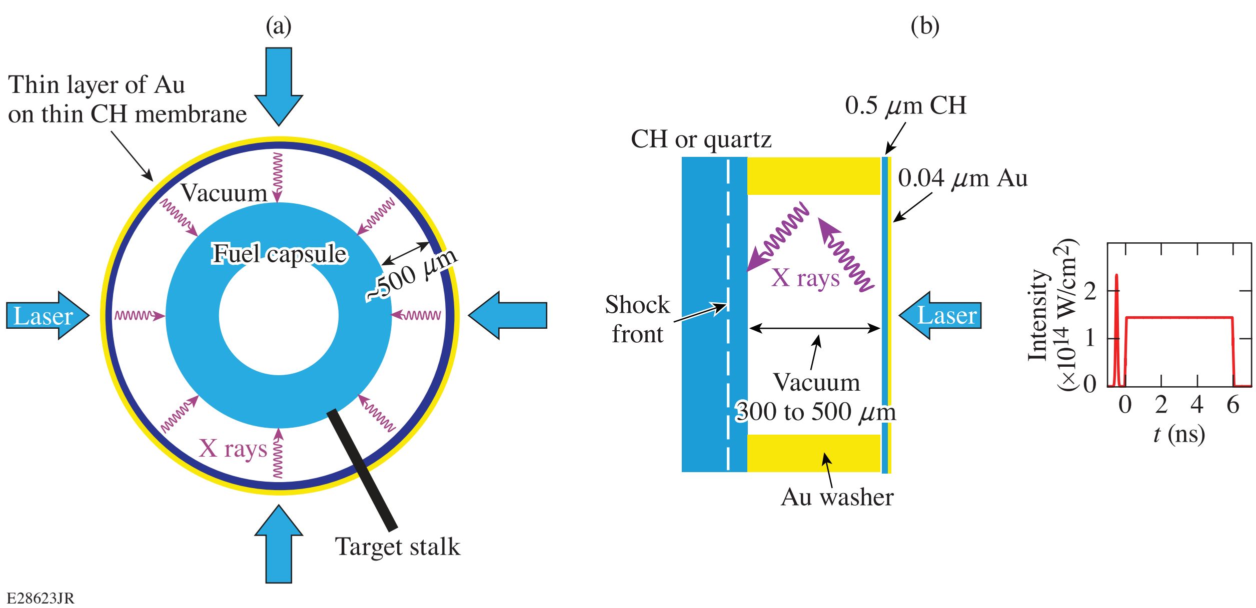

Figure 1
Schematic of (a) the spherical hybrid direct-drive target design and (b) the planar target design that was tested in the experiment.

this newly proposed concept for the first time. The experiment provided the pressure of the x-ray–driven shock wave and tested the target's imprint-mitigation capabilities. Figure 1(b) shows the design of the planar target.

A 1.5-mm-OD Au washer with a 20-μm-thick wall and a height of 300 μm or 500 μm was glued on planar quartz or polystyrene foils. The height of the washer determines the standoff distance of a 0.5-μm-thick CH membrane from the target plane. Depending on this height, the targets will be referred to as the "Hybrid300" or "Hybrid500" targets, respectively. The membrane was coated with an ~40-nm layer of Au. The space between the planar target and the membrane was held at vacuum. The Au side was irradiated with one UV beam equipped with an SG8-750 distributed phase plate. The pressure measurements used 140-μm-thick polystyrene and quartz foils. A short picket pulse (no main pulse) with a 150-ps duration and an intensity of 1 to 2 $\times$ 10^{14} W/cm^2 interacted with the Au coating to generate the x-ray pulse that created the shock wave that was observed from the target back side with a velocity interferometer system for any reflector (VISAR) diagnostic and a streaked optical pyrometer (SOP). The diagnostics measured the propagation velocity and the emission temperature, which made it possible to infer the pressure of the decaying shock wave. The Hybrid300 target obtained a pressure of ~8 Mbar at ~0.5 ns after the start of the laser pulse, while about half of the pressure was obtained at this time with the Hybrid500 target. The imprint shots applied a standard platform of time-gated face-on x-ray radiography but used a thinner 30-μm-thick planar polystyrene foil to be able to accelerate the target with a 6-ns square pulse and to amplify the seeds by RTI. No smoothing by spectral dispersion was used, causing the beam speckle pattern to serve as 3-D, multimode imprint seeds for ablative RTI. The evolution of ablative RTI was observed through face-on x-ray radiography at different times. The performance of the hybrid targets was compared to a bare 30-μm-thick polystyrene foil without an Au washer. The picket intensity was increased by about a factor of 2 in the hybrid case so that the x rays created by the picket would generate an initial shock matching the 1-D performance of the bare targets. The 1-D simulations show that the behavior of both targets is identical across designs, yielding an acceleration of 35 μm/ns^2.

Azimuthally averaged Fourier spectra of the OD modulations at different times are shown in Figs. 2(a) and 2(b) for both the bare and hybrid targets. Modulation growth was significantly reduced in both hybrid targets. The bare target reached a peak amplitude of 4.1 $\times$ 10^{-2} OD after just 3.1 ns as opposed to Hybrid300 reaching a similar level of 2.6 $\times$ 10^{-2} OD after 4.2 ns. The Hybrid500 target did not exceed noise band. The experiments show a reduction of the RTI growth and a delay in the time of target perforation by ~40% in the Hybrid300 target compared to the bare CH target. In summary, the performance of the hybrid target design

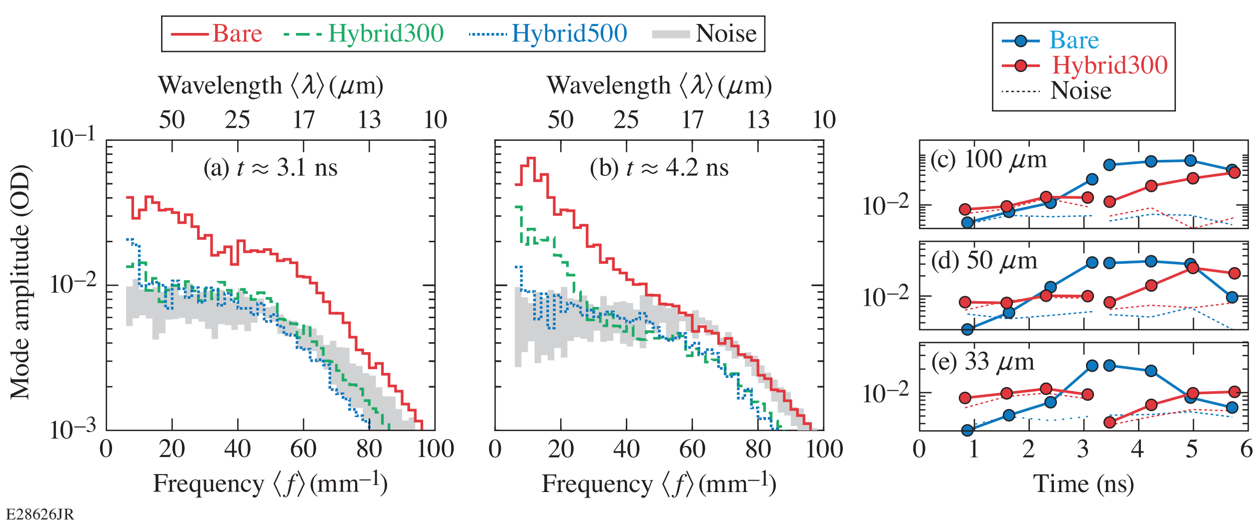

Figure 2
The azimuthally averaged Fourier spectra of the three targets and individual wavelength evolution. (a) Significant growth above noise has occurred by 3.1 ns for the bare target across the measurable spectrum. (b) The Hybrid300 target begins to exceed noise by 4.2 ns only at frequencies below ~30 mm^{-1}. [(c)–(e)] The evolution of specified wavelengths are compared between bare (blue) and Hybrid300 (red) targets. The dotted lines represent the noise levels of the corresponding target type.

has been measured for the first time through planar experiments performed on the OMEGA EP laser. Shocks were shown to be generated by the x-ray flashes with pressures that are in agreement with calculated pressures from 1-D radiation-hydrodynamic simulations using the code *LILAC*, and the growth of the ablative RTI was significantly reduced for the hybrid targets.

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1. L. Ceurvorst *et al*., Phys. Rev. E **97**, 043208 (2018).