Polar Direct Drive—Ignition at 1 MJ

Polar direct drive (PDD) is a new and viable option for achieving ignition on the NIF using direct drive while the beams are in the x-ray drive configuration. This allows both x-ray-drive and direct-drive ignition experiments to be performed using the same beam configuration, saving the time and expense that would be incurred from switching beams to different ports. Although PDD target drive will not be as uniform as standard direct drive, computer simulations indicated that moderate to high target gains in the range of 10 to 30 can be achieved (compared to gains of 40 or higher in the symmetric illumination configuration) at the 1-MJ level.

PDD intentionally increases the irradiation intensity at the target equator relative to the pole to compensate for the reduced laser coupling and reduced hydrodynamic efficiency characteristic of oblique irradiation. This is done by a combination of beam pointing, beam focal-spot shaping, and increased laser power of the "equatorial" beams. The beam pointing strategy currently employed is illustrated in Fig. 104.25(a) and the pulse shapes are in Fig. 104.25(b). The beam focal-spot shapes for the polar and midlatitude beams are all circular, with the intensity varying as $\exp[-3(R/R_{\text{target}})^4]$. The equatorial beams use the same circular beam, but with a 5:1 ellipse superposed on them to concentrate a little additional laser intensity at the equator (as discussed in Ref. 1). Also, a wetted-foam target similar to that described in Ref. 1 was used, but scaled down to 1 MJ.

The optimal irradiation pattern is found by varying the pointing, spot shapes, and pulse shapes of the beams. Multidimensional hydrodynamic simulations of the implosion are required to evaluate time-dependent variations in the irradiation pattern caused by the beam axes not pointing toward the target center. A parameter search for the optimal irradiation configuration was done using LLE's 2-D hydrocode *DRACO*. The *DRACO* simulations included a 3-D ray trace to model the laser irradiation and Monte Carlo alpha-particle transport to model the thermonuclear burn.

The pulse shapes were the same for the polar and midlatitude beams. The equatorial beams used a two-parameter modification of this shape to allow for early-time shock timing and later-time target drive. The division occurred at 4.6 ns, at the start of the peak of the pulse. At that time, the peak power of the equatorial beams was increased by 30% to compensate for the reduced laser coupling for the oblique irradiation during

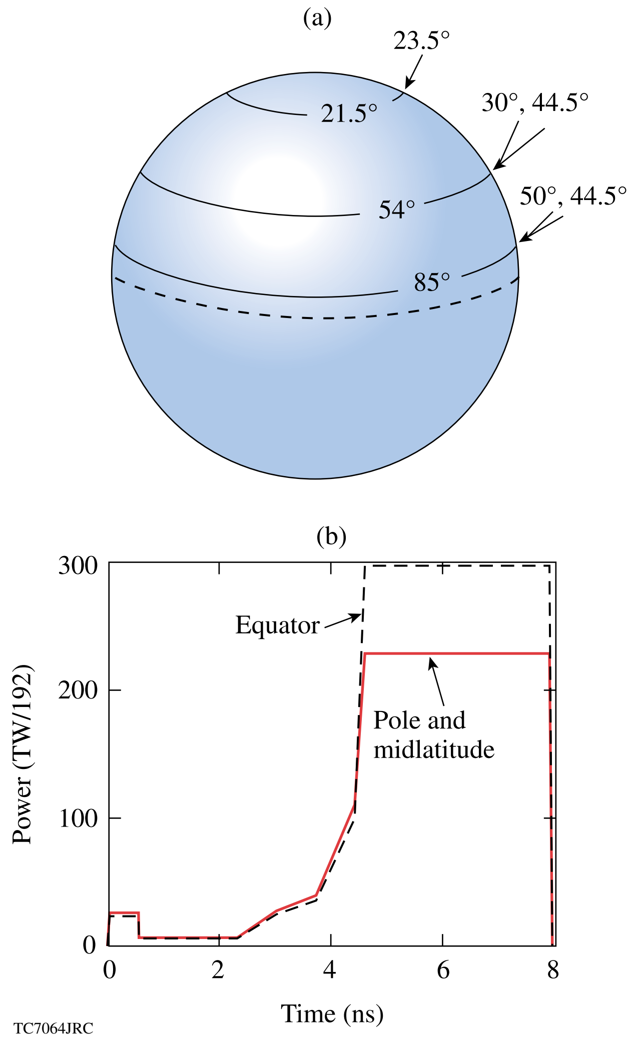

Figure 104.25
(a) Beam pointing strategy for polar direct dive. (b) Pulse shapes.

the target drive. At earlier times, the power was decreased by 10% to achieve good shock timing.

Target conditions near peak compression are shown in Fig. 104.26. Density contours and the ion-temperature contour lines of 10 and 15 keV are plotted. At this point in the simulation ignition has already occurred, and the thermonuclear burn wave is starting to propagate outward. This simulation results in a target gain of 35. This target gain is maintained over a range of laser conditions. Figure 104.27 shows how the gain varies as the pointing of the three rings changes. High performance is maintained over a spread of 40 μm in pointing, which is well within the capability of the NIF.

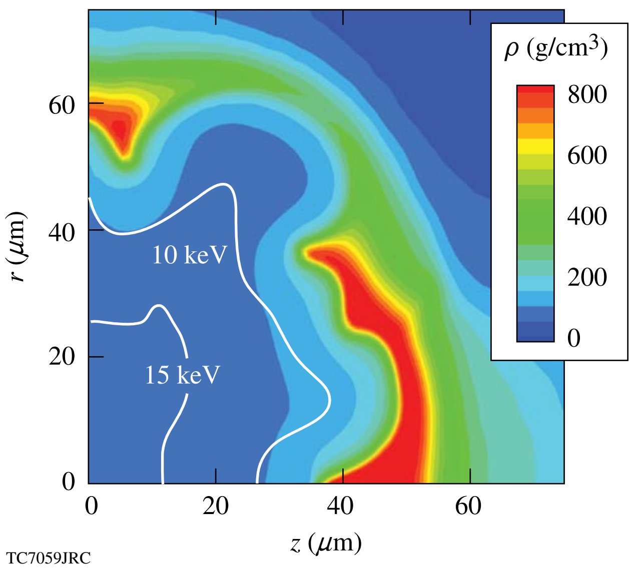

Figure 104.26
Density and temperature contours of the target near peak compression. At this point, the target has ignited and the burn has started to propagate.

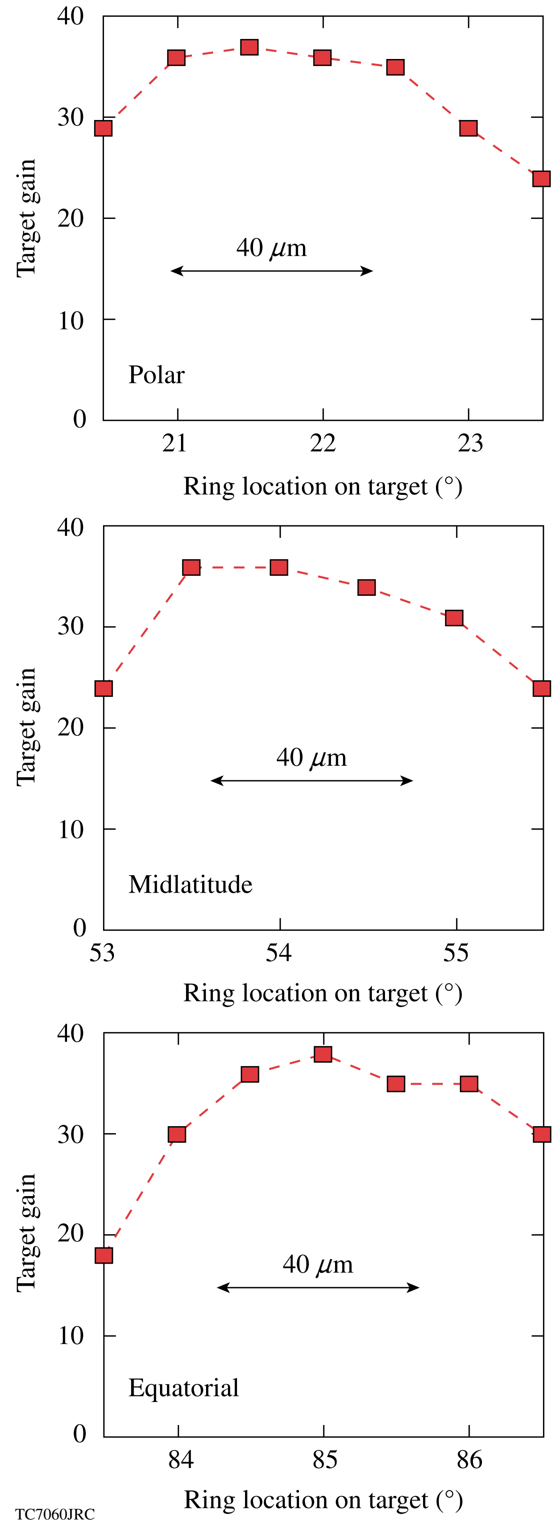

Figure 104.27
Sensitivity of target gain to beam pointing.

Similarly, the sensitivity of target gain to variations in pulse shapes was examined. Three variations were considered: (1) variations in the length of the low-power foot of the pulse, (2) variations in the peak power, and (3) variations in the ratio of peak powers between the equatorial beams and the polar beams (and midlatitude beams). Over a reasonable range, the high gain is maintained.

Finally, the effect of inner surface roughness was considered (Fig. 104.28). Nonuniformity modes 2–10 were used in the simulations, with a spectrum similar to that obtained in current cryogenic experiments on the OMEGA laser. Most of the nonuniformity was concentrated in mode 2. The sensitiv-

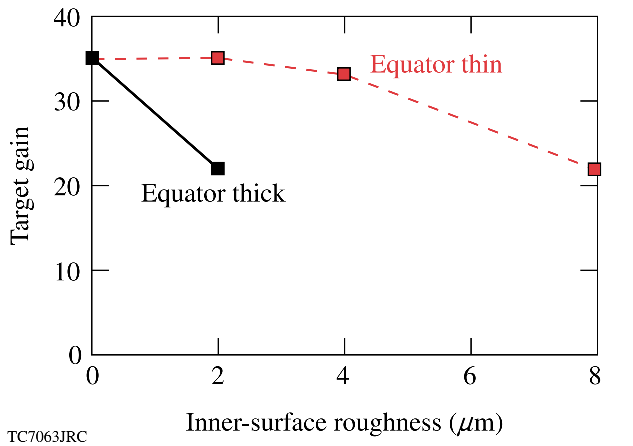

Figure 104.28
Sensitivity of target gain to inner-surface ice roughness.

ity of target gain to this form of nonuniformity depends on how the phases of the modes add up. When the phases result in a thinning of the equator (and a corresponding thickening of the pole) the target can survive a relatively large amount of nonuniformity. The target is much more sensitive to a thickening of the equator. This suggests that PDD might benefit from "shimming" the ice layer to make the equator intentionally thinner. For a shimmed target, a different beam-pointing strategy might be more optimal.

Further work is in progress to validate these results. This includes simulations with higher resolution, and examination of sensitivity to alternate numerical techniques.

ACKNOWLEDGMENTS

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REFERENCES

1. S. Skupsky, J. A. Marozas, R. S. Craxton, R. Betti, T. J. B. Collins, J. A. Delettrez, V. N. Goncharov, P. W. McKenty, P. B. Radha, T. R. Boehly, J. P. Knauer, F. J. Marshall, D. R. Harding, J. D. Kilkenny, D. D. Meyerhofer, T. C. Sangster, and R. L. McCrory, Phys. Plasmas **11**, 2763 (2004).