3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

High-efficiency rugby-shaped hohlraum designs for driving large gas-filled capsules on the NIF*

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In indirect-drive inertial confinement fusion a high-Z enclosure (or "hohlraum") surrounds a low-Z capsule containing DT fuel. Laser beams irradiate the interior of the hohlraum through a pair of laser entrance holes, creating an x-ray radiation bath that compresses the fuel to ignition conditions. The coupling of laser light to the capsule is typically ~10%, resulting in ~200 kJ absorbed energy for the ~2 MJ-scale laser at the National Ignition Facility (NIF). A 7 mm-wide rugby-shaped Au hohlraum design is found that can accommodate ~50% larger (DT) gas-filled capsules for up to 500 kJ capsule absorbed energy and ~30% coupling efficiency. This new integrated design is made possible by using a high-density gas fill (6-8 mg/cc) that limits the fuel convergence ratio (C) to <14 while providing ~100 kJ of 14 MeV neutron output. The low convergence greatly limits the degrading effects of hohlraum drive asymmetry and hydrodynamic instability from surface roughness and target-fielding fixtures, e.g., capsule tent supports and the DT fuel-delivery fill tube. Integrated hohlraum simulations in 2-D show good implosion symmetry with peak radiation temperatures reaching 295 eV at <1.8 MJ of laser energy and 440 TW peak power while delivering nearly 100 kJ (compared with ⩽60 KJ in DT-layered DT implosions to date). The hohlraum design is made possible by employing a shaped two-shock laser power history for compressed energy delivery and desired margin to late-time hohlraum filling (and loss of symmetry control). Confidence in this design is supported by a recently reported campaign on the NIF using a reverse-ramp pulse shape to drive a similar rugby-shaped hohlraum and a ~ 3.5 mm-scale Al shell filled with 7 mg/cc DT gas [1]. The high fuel-adiabat (α~6-7) character of the 2-shock design is tolerated due to the ~3× higher performance margin from the large-capsule design. This platform can be extended to include varying thicknesses of DT solid-fuel layering for increased yield (> 1 MJ), while benefitting from the favourably low fuel convergence (<20). Further inroads into understanding ignition thresholds and the transition from volume-dominated ($-PdV$) ignition to higher-convergence hot-spot ignition could result from initially leveraging an optimized low-C gas-fill design.

[1] Y. Ping, V. Smalyuk, P. Amendt et al., Nature Phys. (https://doi.org/10.1038/s41567-018-0331-5).

* Work performed under the auspices of U.S. Department of Energy by LLNL under Contract DE-AC5207NA27344 and supported by LDRD-17-ERD-119