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Title: H_Burn_Key2_Dshell_CCC : Pre-shot Report

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H_Burn_Key2_Dshell_CCC : Pre-shot Report

Shot date – 06/18/24

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Introduction

The double shell implosion platform presents an opportunity to explore the dynamics of a burning plasma within a volumetric burn framework. The double shell campaign and the ICF program at Los Alamos National Laboratory (LANL) is focused on achieving burning plasma using an indirectly driven double shell implosion at the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory (LLNL). Double shell implosion is aimed at achieving robust ignition with lower convergence, albeit introducing more engineering and physics complexity due to the intricacies of assembling the capsule. The double shell target is comprised of an outer aluminum ablator shell and an inner high-Z (made of molybdenum or tungsten) pusher shell, separated by a cushion of low-density foam. The outer shell undergoes ablation driven by hohlraum-generated x-rays, which compress the foam to immense pressures, reaching several gigabars. This creates a pressure reservoir that propels the high-Z metal pusher, compressing and heating the deuterium-tritium (DT) liquid fuel to significant densities and temperatures, thereby igniting the plasma.

Recent designs using a novel 2-shock pulse shape predict significant improvements in outer shell assembly joint and fill tube behavior. Having a lower power first shock also allows one to control early time shock symmetry, which simulations suggest are very important for symmetric fuel compression at the end of the implosion. The 2-shock trajectories for the full design is shown in Fig. 1 using approximately 1.5 MJ laser energy. In this pulse shaping strategy a strong first shock (picket) is driven into the ablator. The second main drive shock is launched well after the first shock, merging with it inside of the foam cushion layer. The first shock itself is intentionally unsupported (hohlraum cools following first laser picket) causing it to decay in strength setting up an inward facing density gradient of the ablator. The decaying first shock and a delayed second shock are the key ingredients for its improved engineering feature performance.

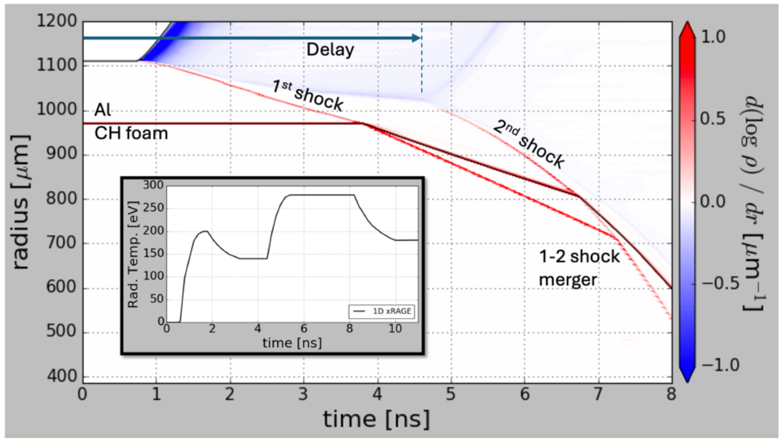


Figure 1: 2-shock trajectories for 1.5 MJ design

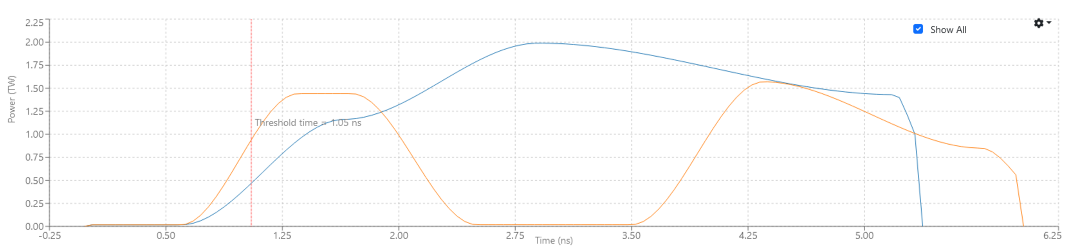
This pre-shot report outlines various efforts, including target production, diagnostic setup, and the objectives for the upcoming shot day. (Note this shot was twice deferred by NIF)

Experimental purpose and goals

A previous shot (2DconA N240306) was the first test of symmetry control for this long delay 2-shock pulse. In that shot we measured a strongly oblate (P2 ~ -50 microns) outer shell and high backscatter (Outer cone Stimulated Brillouin Scattering) of 6%. The goal for the present shot is to reduce backscatter and measure first shock symmetry and strength using the NIF 2-axis keyhole platform. To improve both symmetry and backscatter we are applying 2- and 4-color wavelength separation to induce cross beam energy transfer (CBET). This will be the first use of wavelength separation by LANL double shells.

Laser Drive

For this experiment, we are using all 192 beams to drive the hohlraum. For this first keyhole experiment we are reducing peak power to get total laser energy below 1 MJ. We do this to avoid 'blanking' the VISAR with too much preheat, which could prevent us from obtaining quality data. The keyhole pulse shape for inner and outer cones is compared to our DT platform pulse shape that uses a simple single shock drive (Fig. 2).



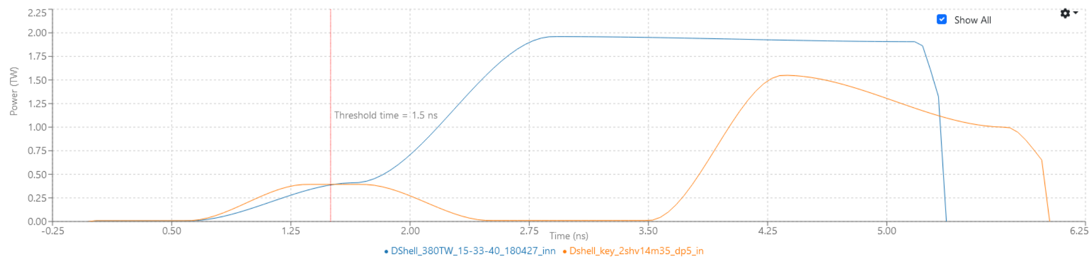


Figure 2: Keyhole 2-shock pulse shape compared to existing reversed ramp for (top) outer and (bottom) inner cones

Two other major differences from our 2018-2023 reversed ramp pulse shape are a repointing of the outer cone beams (Z – 300 microns) and the use of 2-color and 4-color wavelength separation (delta lambda). We are applying 2 angstroms of 2-color and 0.5 angstroms of 4-color to transfer power from outers to inners (2-color) and from 50's to 44's (4-color).

Target design and build

This shot is using the NIF 2-axis keyhole platform, which places a reentrant Au cone through the equator of the hohlraum and into the capsule. This cone allows VISAR laser to measure velocities inside the capsule, specifically shock velocities in the liquid D2 filled aluminum capsule shown below (Fig. 3).

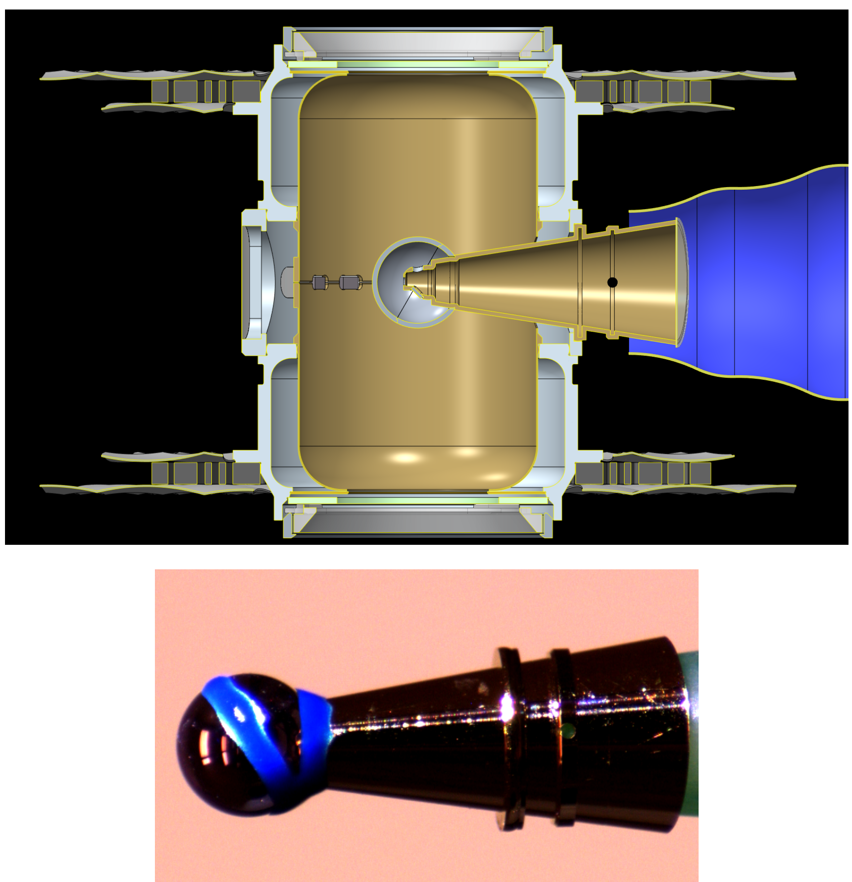


Figure 3: Keyhole target design showing (top) 5.75 mm scale Au hohlraum, Al capsule filled with D2, and Au VISAR cone. (Bottom) as-built cone/capsule assembly ready for insertion.

A portion of the VISAR laser is reflected off a mirror in the cone tip giving it a view of the capsule pole. For our Al ablator shell design we must diamond turn machine the shells into hemishells for assembly. The resulting assembly gap must be sealed (blue colored glue in figure) in order to hold high pressure liquid D2 (170 mg/cc). To keep the VISAR diagnostic from seeing this glue, we rotate the capsule by 30 degrees in order to have clean ablation surfaces at the VISAR pole and equator views. The cone/capsule assembly was made at MST-7 before sending to LLNL for final hohlraum assembly. The Al ablator is 118 microns thick with an outer radius 1110 microns. The hohlraum is our standard 5.75 mm diameter, 10.1 mm long design.

Diagnostics

The table provided above outlines the diagnostics intended for use in the upcoming experiment.

	Diagnostic	**DIM**	**Comment**
x-ray spectrum	DISC-NXS	0-0	Time-dependent Au L-shell spectrum
Optical	FABS (Q31B)		backscatter
	FABS (Q36B)		
	NBI (Q31B)		
	NBI (Q33B)		
	VISAR	90-315	Shock symmetry
x-ray	Dante-1		
	Dante-2		
	EHXI		
	FFLEX		
	SXI Lower		
	SXI Upper		
	VIRGIL		
	SPIDER		

Figure 4: Table showing the list of diagnostics used in the experiment.

Simulation

A series of xRAGE and HYDRA simulations was conducted to assess 2-shock performance (full point design) including assembly joint, fill tube, and symmetry control. Design of the keyhole shot itself mainly used HYDRA due to its benchmarked inline CBET model.

Figure 5 shows (left) predicted 'shock plots' and (right) shock velocities for the experiment. These simulations were performed without the CBET model turned on and provide and baseline (no CBET) prediction. In the absence of 2-color delta lambda (CBET) HYDRA is predicting good 1st shock symmetry (pole to equator within 100 ps) and a first shock velocity in the liquid D2 of 70 km/s. Due to the extreme 2nd shock velocity (D2 dissociates/ionizes absorbing VISAR light) we do not expect VISAR to measure the 2nd shock velocity, but we should measure its arrival time.

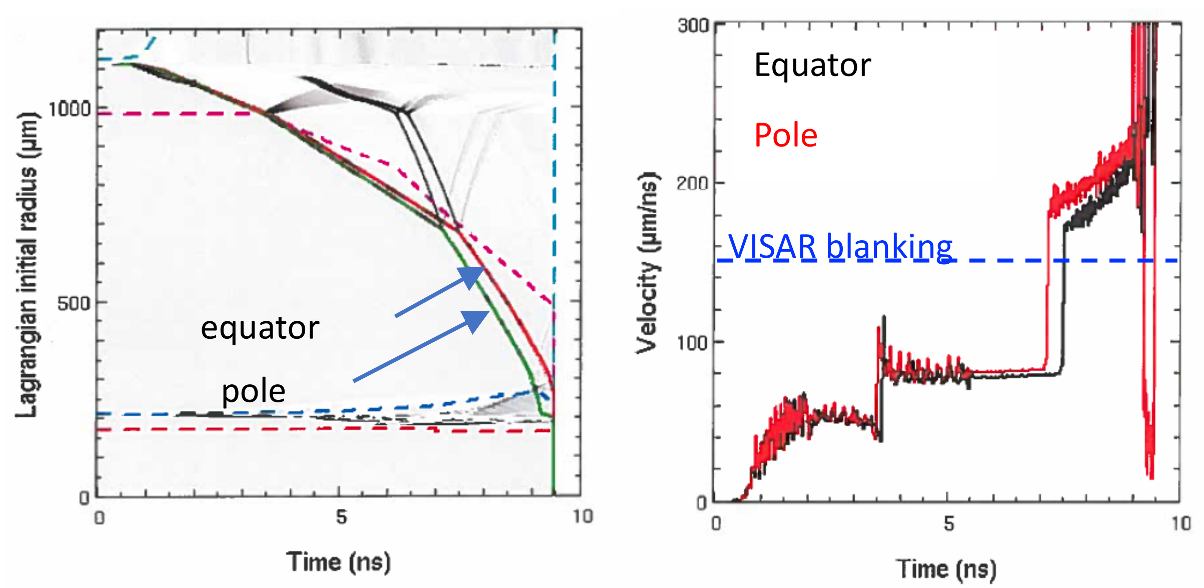


Figure 5: HYDRA (left) shock plot and (right) shock velocity for pole and equator

The HYDRA inline CBET model was used in a series of simulations to check a variety of simulation and design parameters. The main free parameter in the CBET model is the ion acoustic wave saturation level. This is a time-dependent parameter, which controls the density fluctuation at which CBET turns off [A. Kritcher et al., Phys. Rev. E 98 (2018)]. This parameter must be determined via experiments, such as this keyhole and future 2DconA's. The design parameters are the 2-color and 4-color delta lambdas.

Figure 6 below shows CBET power transfer predictions for (left) 2-color only of 2 angstroms and (right) 2-color of 2 angstroms and 4-color of 0.5 angstroms. From these calculations we see significant power transferring from outer cones to inner cones during the picket (< 2 ns) and around peak power. CBET then saturates near 6 ns. The addition of 4-color delta lambda (right) shows transfer from 50 degree cone to 44 degree cone throughout the laser pulse. The combination of total power transfer due to CBET is expected to reduce measured backscatter on the 50 degree cone.

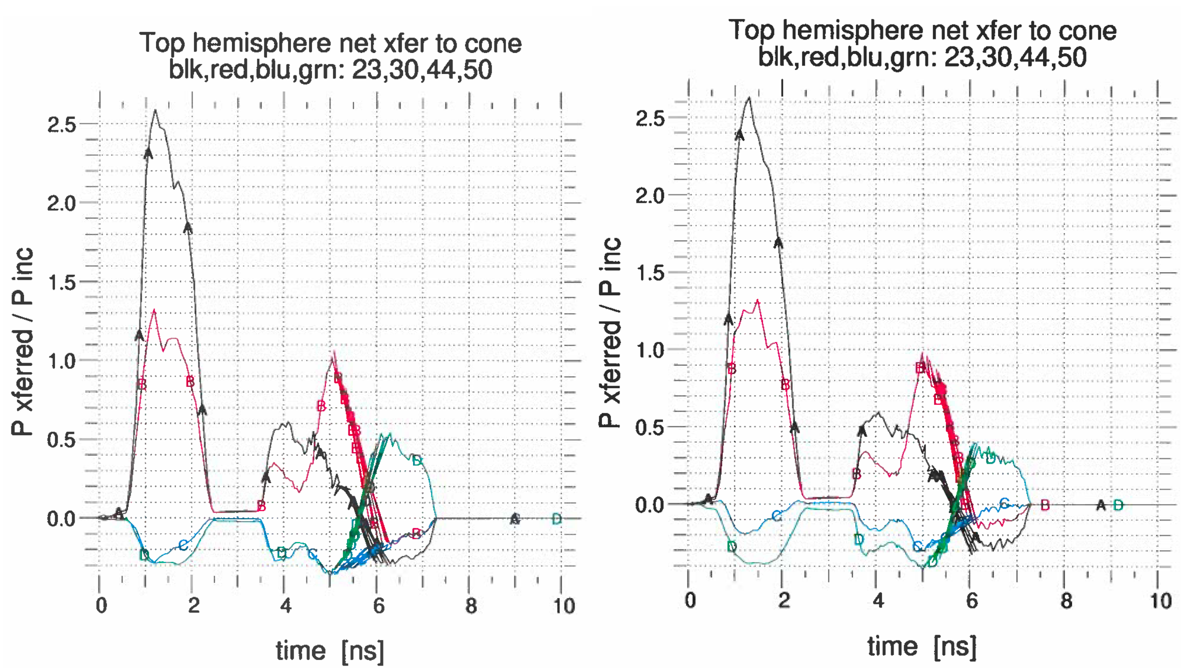


Figure 2: HYDRA CBET power transfer predictions for (left) 2-color only and (right) 2-color + 4-color delta lambda

Essential numerical data from the simulation are provided in the table below.

Parameter	Simulated value
1st shock breakout time (equator)	3.5 ns
1st shock breakout time (pole)	3.4 ns
1-2 shock merger time (equator)	7.6 ns
1-2 shock merger time (pole)	7.3 ns
Picket temperature	200 eV

Conclusion

The scheduled June 18, 2024 2-axis keyhole will be the first attempt at an outer shell only shock symmetry measurement for the double shell campaign. It is thus also the first keyhole in the 2-shock campaign and first to use wavelength separation to control back scatter and symmetry. It will provide very valuable data for tuning CBET models in HYDRA and xRAGE.