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X-ray flux and x-ray burnthrough experiments on reduced-scale targets at the NIF and OMEGA lasers

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Abstract. An experimental campaign to maximize radiation drive in small-scale hohlraums has been carried out at the National Ignition Facility (NIF) at the Lawerence Livermore National Laboratory (Livermore, CA USA) and at the OMEGA laser at the Laboratory for Laser Energetics (Rochester, NY USA). The small-scale hohlraums, laser energy, laser pulse, and diagnostics were similar at both facilities but the geometries were very different. The NIF experiments used on-axis laser beams whereas the OMEGA experiments used 19 beams in three beam cones. In the cases when the lasers coupled well and produced similar radiation drive, images of x-ray burnthrough and laser deposition indicate the pattern of plasma filling is very different.

1. Introduction

Our program[1-3] seeks to use high power lasers to extend hohlraum performance to higher radiation temperatures. This is accomplished by putting all the available laser energy into as small a hohlraum as possible in as short a time as possible. The result is a hot cavity filled with high Z plasma and x-radiation, a "hot hohlraum". Hot hohlraum performance is limited by the hot wall material ablating and filling the can with plasma. The laser interacts with this plasma[1-4] outside and inside the can limiting laser-hohlraum coupling. In this paper, we study hohlraum performance vs laser geometry.

2. The Experiment

Experiments were performed at the NIF laser in Livermore, CA, USA [5] and the OMEGA laser in Rochester, NY, USA [6]. About 9.5kJ of 351nm laser energy in 1ns (OMEGA) or 1.1ns (NIF) flattop pulses were incident into reduced-scale hohlraums. Figure 1 shows the geometry and the hohlraum.

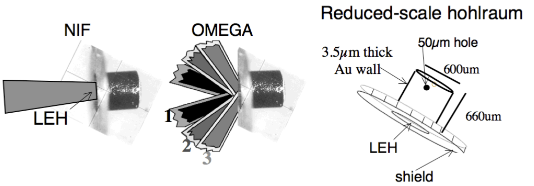


Figure 1. Experimental geometry and target. At NIF, four laser beams are incident along hohlraum axis. At OMEGA, 19 laser beams are incident in 3 cone angles (23^o, 48^o, 59-62^o). The targets were 3.5µm thick Au cans with large Pb-doped plastic shields around the laser entrance hole (LEH). The shields were coated with 4µm parylene. The 50µm diameter holes in hohlraum wall allowed x-rays to be detected by diagnostic at onset of laser pulse.

At NIF, the laser beams were conditioned with small phase plates and polarization smoothing crystals[1,2]. At OMEGA, the beams expand with f/6.7 so the six 23^o beams were defocused by –1.8mm, the six 48^o beams were defocused by -2.2mm, and the ~60^o beams had distributed polarization rotator plates (DPRs)[7] (five), or 100µm small phase plates (two).
The x-radiation coming out of the LEH is measured with a low spectral resolution, but absolutely calibrated spectrometer called DANTE. At NIF, DANTE[8] has eighteen channels : 3 mirror+filter combinations in front of an x-ray diode for channels in the 100-500eV x-ray range plus 15 filter plus x-ray diode for channels in the 600-10000 eV x-ray range. At OMEGA[9], DANTE had ten channels : 3 mirror+filter channels and 7 filter channels covered the 600-3000eV x-ray range. The DANTE views the LEH at 21.8^O to the hohlraum axis at NIF and at 41.8^O at OMEGA.

Timed-pinhole images at x-ray energies of ~10keV and 1keV were taken with a soft x-ray snout mounted to a four-strip microchannel plate (MCP) framing camera. The snout is similar to previous designs[10] but had four (not two) mirror+filter channels and one straight-through channel. It produced four soft x-ray images(~1keV) separated by ~50ps and one hard x-ray image per MCP strip. Images recorded in hard x-rays(~10keV) transmitted through the 3.5µm thick gold wall show the laser deposition region. Images recorded in soft x-rays show the glowing outside wall. The x-radiation inside the can heats the inner wall, and the heat diffuses through the wall in a Marshak heat wave[11]. The time it takes to heat a wall of known thickness is the x-ray burnthrough time[11]. The targets had a large shield around the laser entrance hole (LEH) (Figure 1) to prevent the DANTE spectrometer from seeing the glowing of the outside walls.

3. Results

X-radiation fluence as measured by DANTE is shown in Figure 2. Within the error, both targets produce similar fluences (but different time dependences). Backscatter is about 15% [1].

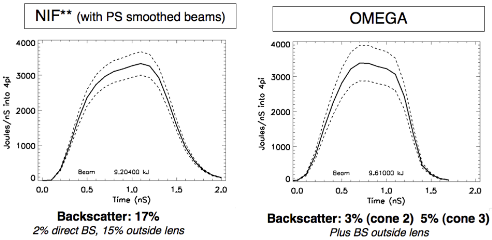


Figure 2. DANTE results on radiation drive: Both targets reached the same fluence (~3300 Joules/ns into 4π), corresponding to T_{rad} ~327eV. The DANTE views the bright laser spot(s), whose position in time is a function of the plasma filling. Fluence peaked at end of pulse for NIF target and at ~0.5ns for OMEGA target.

Pinhole images from NIF experiments are compared to LASNEX simulations [1,2] in Figure 3.

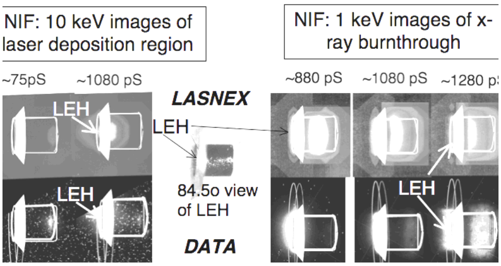
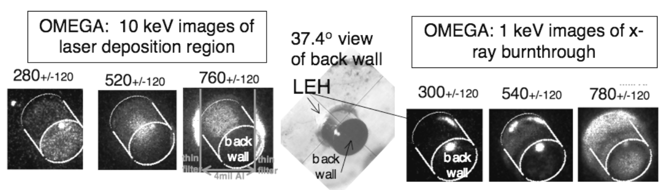


Figure 3. NIF Images of LASNEX simulations and data: View is 84.5° into LEH. 10keV LASNEX simulations predict laser spot moves to LEH by 1080ps but data still sees some spot reaching back wall. 1keV LASNEX simulations show bright burnthrough occurs near front of can at ~880ps but data shows burnthrough beginning at ~880ps near back of can and is very bright at ~1280ps.

Pinhole images from OMEGA experiments are shown in Figure 4. The 10keV images show the lasers deposit their energy near the LEH (the interior of the hohlraum is near or above critical density) and the burnthrough occurs near the LEH. At NIF, burnthrough occurs first near the back wall, and the 10keV images indicate laser beams can still reach the back wall. Thus, the OMEGA targets fill faster than the NIF targets, which helps explain the time behavior of the x-ray fluences.

Figure 4. OMEGA images of data (view is 37.4° to back wall): Time is given in ps. 10keV images show laser deposition åregion moves from back wall towards LEH; 1keV images show x-ray burnthrough occurs first near LEH.



Acknowledgments

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