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Symmetry Experiments on Omega* with LMJ like Multiple Beam Cones Irradiation

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ABSTRACT

We carried out a set of experiments on the Omega laser facility at Rochester with Laser MégaJoule (LMJ) like indirect drive irradiation. We studied the irradiation non-uniformity with the foam ball radiography technique and the implosion symmetry with (D_2 + Argon) filled capsules core emission. Cylindrical "Nova scale 1" thin wall hohlraums were used. Forty of the Omega beams, arranged in three cones on each side of the hohlraum (5, 5, and 10), were used to create the X-ray drive. Eight additional beams were used on a Ti source to radiograph the foam balls. The shaped laser pulse was about 3 ns duration. The radiation drive was measured on each shot. The images were recorded with a 5 μm resolution Gated X-ray Imager coupled to a CCD camera.

Keywords: Foam ball, implosion, implosion symmetry, irradiation symmetry, indirect drive, Laser MégaJoules, Multiple rings irradiation, Omega,

1. INTRODUCTION

To reach ignition large laser facilities are planned in France with the Laser MégaJoules (LMJ) [1] and in the United States with the National Ignition Facility [2].

LMJ facility will have 240 beams arranged by clusters of 4 and will deliver 1.8 MJ in a 3 ns main pulse at 0.35 μm.

A key issue to succeed in reaching ignition is the control of the symmetry of the irradiation through all the implosion process.

Experiments were performed previously on Nova [3] and Omega [4] in indirect drive with cylindrical Nova scale 1 hohlraums. One or multiple rings of irradiation were used.

2D simulations with FCI2 code showed good agreement with the experimental data [5].

The designs of ignition targets for LMJ plan to use three cones of laser beams, creating three rings of irradiation on each side of the hohlraum [6].

To check our ability to model an irradiation scheme relevant to LMJ we designed and performed three rings experiments on Omega.

2. EXPERIMENTAL ARRANGEMENT

The experiments were performed in indirect drive at the Omega laser facility from the Laboratory of Laser Energetics (LLE) [7], University of Rochester.

The $3\omega_0$ laser light was converted into X-rays in a scale 1 Nova type thin wall hohlraum, composed of an inner layer of 2 μm of gold, coated with about 100 μm of epoxy for supporting it.

Forty of the sixty Omega laser beams were used to create the drive in the hohlraum (as the facility is mainly dedicated to direct drive, not all the beams can be used). They were converted into X–rays at the wall of the hohlraum to create the three rings of irradiation, 20 beams on each side of the cylinder.

The half-angles of the beam cones were respectively for the cones 1, 2 and 3: 21.4°, 42° and 58.9°. The beam cones were pointed in such a way to insure the designed three rings of irradiation.

We used a shaped laser pulse about 2.6 ns duration with a 1 ns foot and a contrast ratio between peak and foot about 10. The energy per beam was about 370 J. The total drive energy was about 14.5 kJ.

For each shot the radiation drive was available from broadband X-ray spectrometer (Dante [8]) measurements through the laser entrance hole.

An example of a typical X–ray drive derived from the measured spectra is shown hereunder.

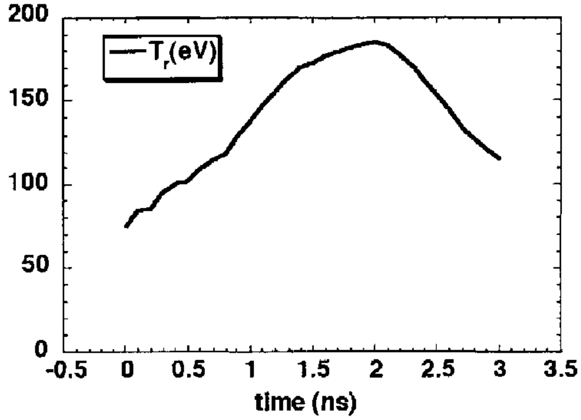

Figure 1: Radiation drive from Dante, for a typical experiment

As we were using thin wall hohlraums we were able to image the beam spots on the wall with a Gated X-ray Imager. It allowed us to check for the pointing of the beams and the spots displacements. In figure 2 we show one image recorded at early time.

As we go from the outer ring to the inner ring, it becomes difficult to see the spots (with the small angle of incidence of the inner cone relative to the hohlraum axis the flux on the wall is lower).

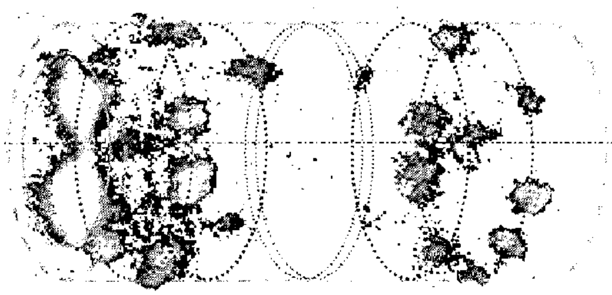

Figure 2: Position of the spots observed through the hohlraum wall

1. Integrated implosion symmetry

The experimental arrangement is shown in figure 3.

The integrated symmetry of the implosion was studied by imaging the X-ray emission of the heated argon at maximum compression of the implosion of a capsule filled with a mixture of deuterium and argon [9]. The argon is used only for diagnostic purpose. Its proportion is low enough not to perturb the hydrodynamics of the implosion.

The capsule was a 30 μm thick plastic shell of about 450 μm inner diameter. Deuterium and argon pressures were respectively 50 atm and 0.1 atm.

With thin-wall hohlraums the imaging of the core of the implosion (at about 4-5 keV) is made through the wall without requiring any opening in the line of sight.

The main diagnostic was a Gated X-ray Imager with a magnification of 22x and pinholes diameter of 5 μm, coupled to a CCD camera. The exposure time was about 80 ps. The inter-frame delay was 200 ps.

As the port on the target chamber is at 79° from the hohlraum axis (P5–P8 ports on the target chamber), the diagnostic was tilted in such a way to observe perpendicularly.

The neutrons yield, bang time, core ion temperature and areal density were also measured.

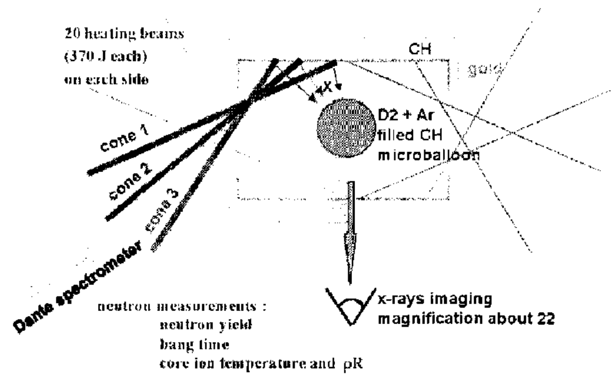

Figure 3: Experimental arrangement for implosion symmetry experiment.

2. Time-resolved irradiation symmetry

The experimental arrangement is shown in figure 4.

The time-resolved symmetry of irradiation was studied with the foam ball technique [11], previously used on Nova and Omega.

A 0.3 g.cm^{-3} SiO_2 foam ball is used instead of a capsule. For our experiment its diameter was about 490 μm.

A shock is propagating into the low density foam.

The ablation front location is distorted by the irradiation asymmetry. This asymmetry is observed by backlighting the ball.

We used the same type of hohlraum as for the implosion experiments but with diagnostic holes in the line of sight to allow for the radiography measurement.

On the hole opposite to the observation side, we placed a 7 μm thick Titanium foil; two times four laser beams were impacting on its rear face to create the radiography source. These beams were delayed compared to the drive beams so as to radiograph the ball at different times along the pulse.

The main diagnostic was the same as for the implosion experiments but with a magnification of 8x. The inter–frame delay was set to 500 ps so as to be able to observe the irradiation symmetry on a longer duration.

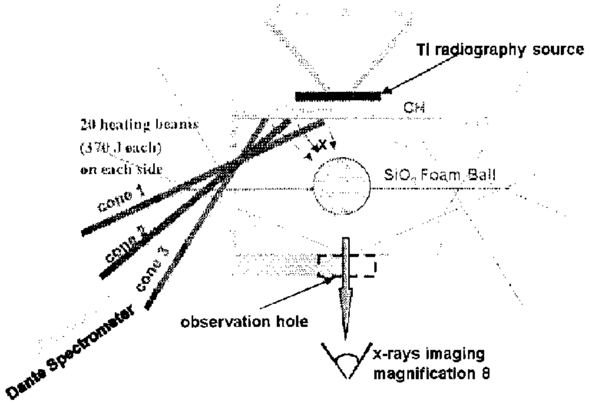

Figure 4: Irradiation symmetry experimental arrangement.

3. DATA REDUCTION

The data were reduced by tracing contours over the recorded pictures either of the core emission for the implosion experiment (figure 5) or of the radiography of the foam ball (figure 6).

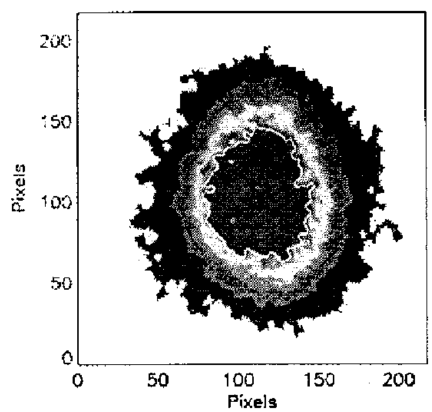

Figure 5: Framing camera image (90 μm x 90 μm) of imploded capsule core (hohlraum axis horizontal)

Then these contours were decomposed in Legendre polynomials.

For the implosion experiment shown here we derived a distortion of about 1.2.
The neutron yield was 4.10^8.

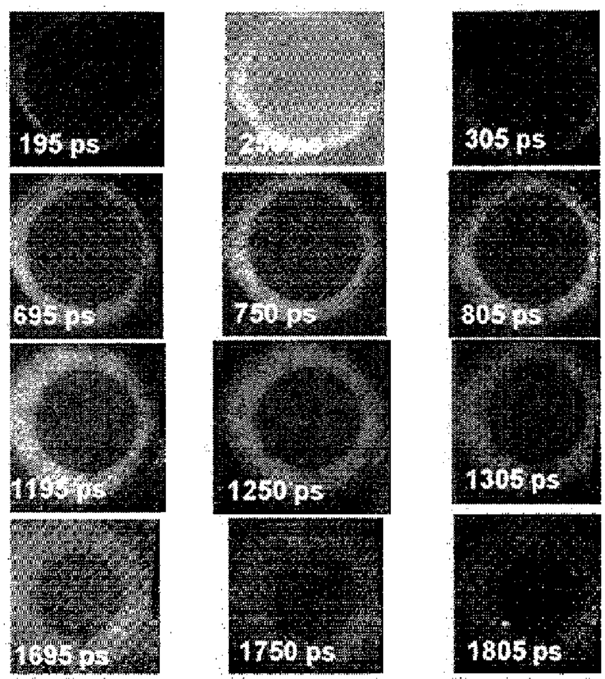

Figure 6: Framing camera images of the foam ball radiography

From the Legendre analysis of the foam ball experiment, we derived the plot of the mean radius of the ablation front (figure 7) and the plot of the modes 2 and 4 of the Legendre decomposition (figure 8).
The ablation front mean radius is related to the drive and the modes 2 and 4 of the Legendre decomposition of the ablation front location are related to the irradiation asymmetry.
To limit the dispersion of the data and as the delay between two pictures on a same frame is less than the exposure time, we plotted the mean values "by frame", which allows us to estimate an error of the measurement.

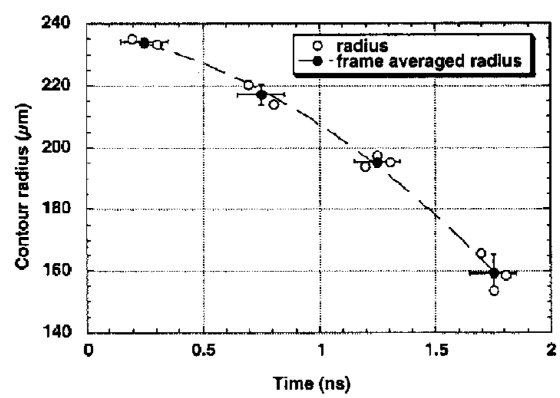

Figure 7: Contour (ablation front) mean radius.

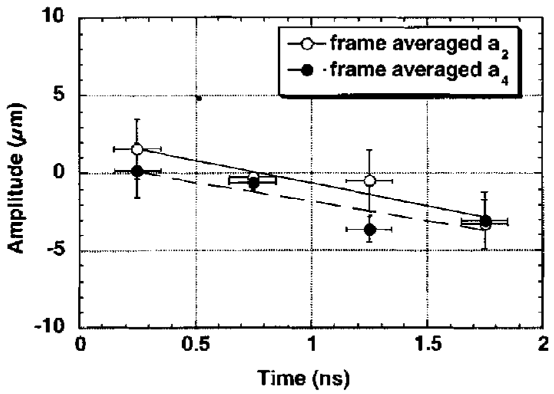

Figure 8: Modes 2 and 4 averaged by frame from the Legendre analysis.

The standard deviation (on a frame) is between one and two microns.

We start with a small initial positive mode 2.

Then negative values are obtained for the modes 2 and 4 which is consistent with a pancake implosion.

The amplitudes of modes 2 and 4 increase after 1 ns and at 1.8 ns are about 2 % of ablation front radius.

4. CONCLUSION

The control of the symmetry of irradiation is a key issue to reach ignition on the future large laser facilities LMJ and NIF.

The indirect drive target design for LMJ plans the use of three cones of laser beams on each side of the hohlraum to create the X–ray drive.

We designed experiments at Omega relevant to this LMJ type of irradiation.

We performed implosion and foam ball experiments to study respectively the time integrated symmetry (through all the process of the implosion) and the time resolved irradiation symmetry.

We got a pancake implosion and an irradiation asymmetry (from foam ball experiment) qualitatively consistent with it.

These experiments will be continued on Omega to further investigate the control of the symmetry with LMJ-like irradiation.

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