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TITLE: RESOLVING A CENTRAL ICF ISSUE FOR IGNITION: IMPLUSION SYMMETRY

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Abstract

The Los Alamos National Laboratory Inertial Confinement Fusion (ICF) Program focuses on resolving key target-physics issues and developing technology needed for the National Ignition Facility (NIF). This work is being performed in collaboration with Lawrence Livermore National Laboratory (LLNL). A major requirement for the indirect-drive NIF ignition target is to achieve the irradiation uniformity on the capsule surface needed for a symmetrical high-convergence implosion. Los Alamos employed an integrated modeling technique using the Lasnex radiation-hydrodynamics code to design two different targets that achieve ignition and moderate gain. Los Alamos is performing experiments on the Nova Laser at LLNL in order to validate our NIF ignition calculations.

1. INTRODUCTION

A goal of the U.S. Inertial Confinement Fusion (ICF) Program is to demonstrate ignition and moderate gain in the proposed National Ignition Facility (NIF). The NIF is designed to illuminate both direct- and indirect-drive targets with 1.8 MJ of 0.35- μ m laser light from a frequency tripled Nd:glass laser (in indirect drive, the laser light is converted to x-rays at the wall of a cavity called a hohlraum, and the x-rays are used to implode the fuel capsule in the center of the hohlraum). The U.S. ICF Program has recently completed conceptual design of the NIF [1].

The ICF Program at Los Alamos National Laboratory is focusing its effort on resolving target-physics issues related to achieving ignition using indirect drive. The Los Alamos activities for the NIF include:

NIF Target Design: Calculating performance and studying sensitivity of ignition target designs [2];

Target Experiments: Designing, fielding, and analyzing data from target-physics experiments, generally on the Nova Laser at Lawrence Livermore National Laboratory (LLNL) but also on the Trident Laser at Los Alamos [3];

Target Fabrication: In addition to fabricating targets for our experiments, Los Alamos is developing both the β -layering technique for producing uniform layers of frozen deuterium/tritium mixtures and the manufacturing techniques for producing beryllium capsules [4];

Diagnostic Development: Designing and fielding x-ray, optical, and neutron target diagnostics; and

Laser Science: Developing techniques for producing low cost optics and researching third-harmonic conversion for Nd:glass lasers [5].

The remainder of this paper emphasizes the work Los Alamos is performing in collaboration with LLNL in understanding implosion symmetry in indirect-drive targets.

2. CALCULATIONS OF THE NIF TARGET DESIGN

Los Alamos calculations of the performance of the NIF target use integrated modeling, a technique that has been demonstrated to model the greatest variety of Nova experiments. Using the Lasnex radiation-hydrodynamics code [6], these self-consistent 2-D calculations include physics for laser deposition, hohlraum conversion of laser light to x-rays, radiation transport of x-rays including deposition on the capsule, the best available atomic physics, hydrodynamics, and thermonuclear reactions. These calculations do not include the physics of interpenetrating plasmas, losses from laser-plasma instabilities, and are typically not adequately zoned for examining hydrodynamic instabilities.

To date, Los Alamos has successfully calculated two NIF targets to ignite. The first, similar to the baseline design first demonstrated by LLNL to ignite computationally, uses a plastic (CH) capsule. The other design, developed at Los Alamos, uses a beryllium capsule [2]. Both targets are illustrated in Fig. 1, and both are calculated to have a yield of approximately 5 MJ.

Many techniques have been proposed to help control symmetry in indirect-drive targets. In 1988, laser-spot motion from the inward movement of the heated high-Z wall was identified as too large in high-Z hohlraums to meet the ignition uniformity requirements [7]. Low-Z liners and mid-z liners (on the inside of the hohlraum wall) have been proposed to reduce movement of the high-Z wall and thus reduce time-dependent symmetry variations from laser-spot motion, but they currently appear to be inadequate to achieve the required symmetry. Mid-Z liners are calculated to absorb too much laser energy within the hohlraum volume, and low-Z liners are calculated to collide and stagnate on the hohlraum axis, creating an asymmetric pressure pulse on the capsule.

The proposed solution to these problems is to fill the hohlraum with gas (see the current design of the NIF target shown in Fig. 1). The gas calculates to limit the wall motion to acceptable levels while effectively eliminating the pressure spike on the axis of the hohlraum. The two rings of beams used inside the hohlraum allow for compensation of the spot motion that does occur. Because the capsule needs to be a frozen layer of deuterium/tritium, helium appears to be the gas of choice. Recent experiments and calculations show that an equal atomic mixture of helium and hydrogen gas in the hohlraum is more desirable for limiting laser-plasma instabilities [8] and maintaining the deuterium/tritium fuel in a cryogenic state, and is now the gas in the baseline design.

3. LOS ALAMOS SYMMETRY EXPERIMENTS ON NOVA

Over the past three years, Los Alamos has performed numerous target physics experiments on the LLNL Nova Laser. Many of these experiments have been directed at determining our understanding and accuracy of integrated modeling calculations of symmetry.

Symmetry experiments have been aimed at comparing experiments and calculations for two goals: understanding *time-integrated* symmetry, and understanding *time-dependent* symmetry. Symmetry is often diagnosed by examining the shape of the x-ray emission from the imploded capsule. The geometry of the experiments is shown in Fig. 2.

Time-integrated symmetry studies, where the cumulative effect of the entire laser pulse is measured, have been performed to test the accuracy of our modeling. Experiments have been fielded for unlined gold, Ni-lined, and CH-lined hohlraums with laser pulse shapes that include 1 ns flattop and longer

shaped pulses. Experiments with gas-filled hohlraums have just started. Los Alamos and Livermore have significant experience in fielding gas-filled hohlraums as part of laser-plasma instability experiments, but only a few symmetry experiments have been done.

One way to test our modeling accuracy is to vary the laser pointing over a series of target experiments. Fig. 3 shows a graph of the imploded capsule image distortion as a function of the axial laser pointing. We see good agreement between the experimentally measured eccentricity and the integrated modeling calculations.

Time-dependent symmetry experiments have been performed to further test our understanding of hohlraum physics and our calculational accuracy. The symmetry of the x-ray flux on the capsule changes in time primarily because of motion of the laser spots caused by inward hohlraum wall motion and the time-varying hohlraum wall albedo. Primarily, we used two techniques to examine time-dependent symmetry: Symmetry Capsules [9] and Reemission Balls [10]. Symmetry Capsules are capsules that by design vary the implosion time. Capsules that implode faster measure the irradiation uniformity at earlier times. Reemission Balls are high-Z spheres (used in place of an imploding capsule) that absorb x-rays and reradiate. By measuring the spatial profile of x-rays emitted from the Reemission Ball, we can diagnose symmetry. Generally, experiments performed for a variety of lined and/or unlined vacuum hohlraums have shown good agreement with Lasnex integrated-modeling calculations for time-dependent symmetry.

4. CONCLUSIONS

The Los Alamos ICF Program focuses on development of the National Ignition Facility in collaboration with the U.S. ICF Program. Past work and plans for future work include addressing target physics issues, NIF target performance and robustness, target fabrication development for the NIF, diagnostic development, and laser science.

Los Alamos has used the integrated modeling technique with Lasnex to successfully calculate ignition with two different NIF targets. Both targets are calculated to have a yield of approximately five megajoules. Sensitivity studies to determine the robustness of these targets are underway.

The NIF target design studies have helped to identify major issues for the ignition target, and experiments performed by Los Alamos on Nova in collaboration with LLNL have begun to address these issues. The main issues for the NIF indirect-drive target and their status currently appear to be:

Symmetry: Time-integrated and time-dependent symmetry experiments in lined and unlined hohlraums have shown very good agreement with calculations. However, more work is needed to verify our predictive capability for gas-filled hohlraums.

Laser plasma Instabilities: Laser plasma instability experiments have shown very encouraging results relevant to NIF targets, with experiments showing < 1% backscatter from SBS [11]. Unfortunately, results do not show good agreement with theoretical models for processes such as Stimulated Brillouin Scattering. More work will be done to try to understand laser plasma instabilities in hohlraum plasmas and thus allow more confident extrapolations for NIF plasmas.

High Convergence: An improved understanding of hydrodynamic instabilities and mix in high-convergence experiments is needed to assure adequate NIF capsule performance.

Additional future work is planned by Los Alamos, including experiments on the Omega Upgrade and Nike Lasers, to begin to examine issues for direct-drive ignition targets for the NIF.

5. ACKNOWLEDGMENTS

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FIGURE CAPTIONS

Fig. 1. Geometry of the CH- and Be-ablator NIF ignition targets. Both targets use the same cylindrical hohlraum, but the laser pulse shapes, capsules and required laser energies are different.

Fig. 2. Geometry for drive symmetry experiments, showing measurement of the shape of the imploded capsule from two orthogonal directions.

Fig. 3. Experimental results and comparison to integrated modeling calculations of the imploded capsule eccentricity as a function of laser pointing.

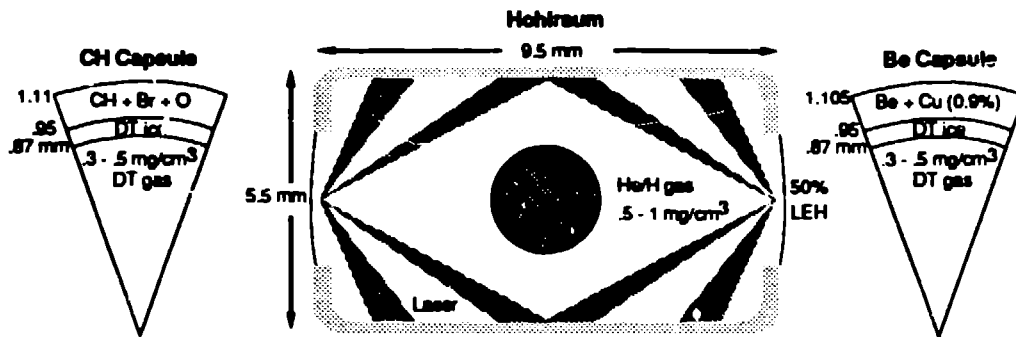


Fig. 1.

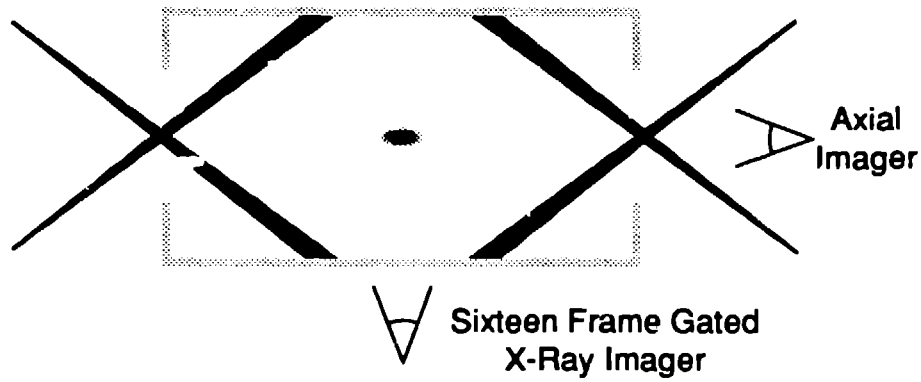


Fig. 2

Au hohlraum, PS22

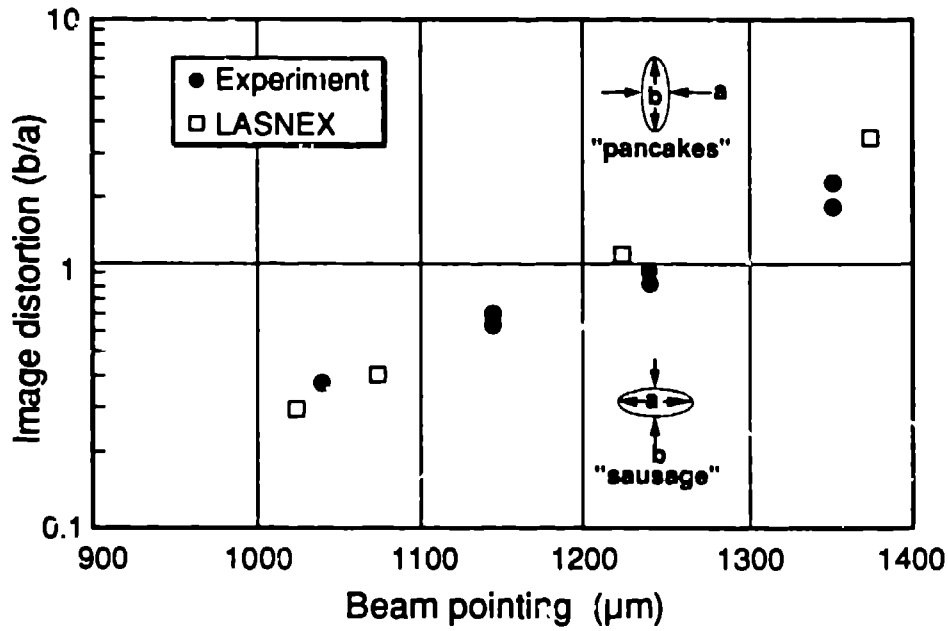


Fig. 3