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Abstract. In preparation for the start of NIF ignition experiments, we have designed a porfolio of targets that span the temperature range that is consistent with initial NIF operations: 300 eV, 285 eV, and 270 eV. Because these targets are quite complicated, we have developed a plan for choosing the optimum hohlraum for the first ignition attempt that is based on this portfolio of designs coupled with early NIF experiements using 96 beams. These early experiments will measure the laser plasma instabilities of the candidate designs and will demonstrate our ability to tune symmetry in these designs. These experimental results, coupled with the theory and simulations that went into the designs, will allow us to choose the optimal hohlraum for the first NIF ignition attempt.

1. Introduction

Choosing the optimum hohlraum for the first ignition attempt on the National Ignition Facility (NIF) Laser [1] involves trading off several aspects of hohlraum design. Laser-plasma interactions (LPI), hohlraum energetics, capsule performance, laser performance, drive asymmetry, and target fabrication all must be considered. Ultimately, the choice of optimal hohlraum will be based on experiments performed early in NIF's operations. To prepare for these experiments, we have designed NIF ignition hohlraums that span a range of hohlraum temperatures consistent with initial NIF operations – 300 eV, 285 eV, and 270 eV. Early NIF experiments using 96 beams are designed to emulate these ignition designs and the results from these experiments will be used to guide our choice of the optimal hohlraum. These 96 beam experiments will measure the LPI for the candidate designs [2] and show that we can tune the symmetry.

2. Hohlraum Designs with Graded-doped Beryllium Capsules at 300 eV, 285 eV, and 270 eV

2.1. 300 eV, 1.05 MJ design

The starting point design is a 300 eV hohlraum driving a 1 mm radius graded-doped beryllium capsule. The hohlraum and capsule are shown in Figure 1. The hohlraum wall is made of a mixture of

75% (atomic) uranium and 25% gold. It is lined with a thin (0.5 micron) liner of gold that prevents the uranium from oxidizing [3] The hohlraum is filled with 1.3 mg/cc He gas. (In a later design, we changed the gas to a mixture of 80% (atomic) H, 20% (atomic) He at 0.89 mg/cc and hohlraum liner to 80% Au/20% Boron for LPI control.) The hohlraum has a laser entrance hole (LEH) that is 50% of the hohlraum radius. The lip of this LEH is lined with a 35 micron thick layer of plastic (CH) that is used to tamp the motion of the LEH lip and keep the hole open during the pulse. The gas is held in the hohlraum by a 0.5 micron thick plastic window.
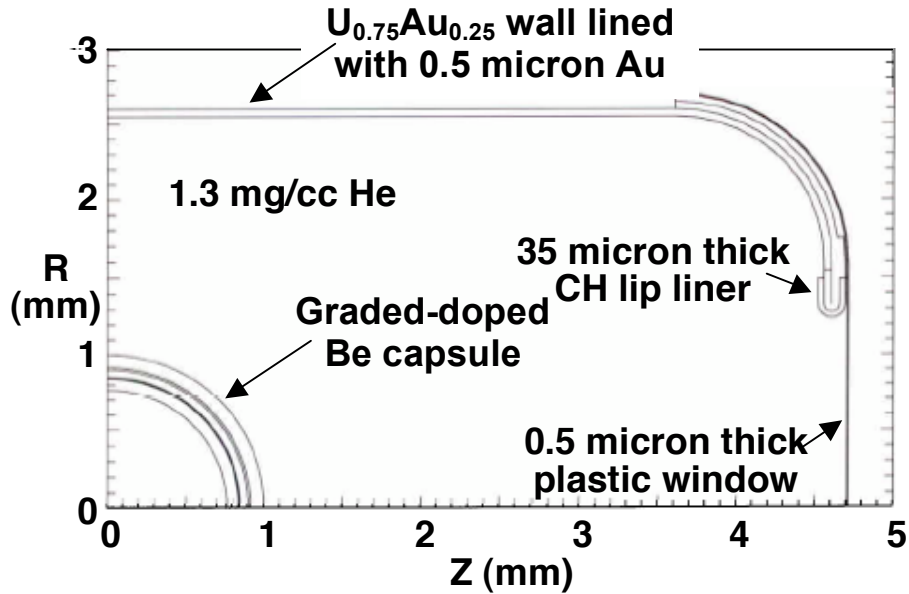

Figure 1: Diagram of ¼ of the 300 eV hohlraum. Full hohlraum is a reflection about Z=0 and rotation about R=0. Capsule radius is 1 mm, hohlraum half length is 4.6 mm and hohlraum radius is 2.55 mm. Inner cone beams enter at angles of 23.5 and 30 degrees from axis with laser spots of 590 x 824 microns (semi minor and major axes of ellipse). Outer cone beams come in at 44.5 and 50 degrees with spots of 343 x 593 microns (semi minor and major axes of ellipse).

Figure 2 shows the power versus time needed to drive the radiation temperature shown in Figure 3. The target absorbs 940 kJ (with no allowance for light backscattered via LPI); adding 10% for backscatter brings the total energy to 1.04 MJ. The nominal yield for this capsule is 13 MJ.

2.2. 270 eV, 1.32 MJ design

As we reduce the radiation temperature, we need to increase the size of the capsule to maintain constant capsule "robustness." If we follow the scaling presented by Lindl [4], we find that as we change the radiation temperature, the capsule absorbed energy should scale as $E_{cap} \sim T_{rad}^{-4.5}$. The capsule radius should scale like $r_{cap} \sim E_{cap}^{1/3} T_{rad}^{-1.03}$. This says that if we want to scale from 300 eV to 270 eV, we expect the capsule absorbed energy increase by a factor of 1.6 and the capsule radius to increase by a factor of 1.3. Since the 300 eV capsule is 1 mm in radius, the 270 eV capsule should be 1.3 mm in radius.

A simple method for estimating the total laser energy required to drive the 270 eV design is to assume that $E_{laser} \sim s^3 T_{rad}^4$ where s is the scale of the target compared to 300 eV. Using 270 eV and s=1.3, we find that E ~ 1.44 x 940 kJ = 1.35 MJ with no allowance for backscatter. Lasnex [5] calculations of the scaled design used 1.3 MJ (without backscatter). In an attempt to reduce the laser energy, we reduced the case-to-capsule ratio slightly by using a 1.3 mm capsule in a 1.275 scale hohlraum. The beam spots were also scaled up by a factor of 1.275 from the 300 eV design. This

brought the absorbed laser energy down to 1.25 MJ without backscatter or 1.32 MJ adding an additional 5% for backscatter.   Figure 2 shows the laser power vs time and figure 3 shows the resulting drive temperature vs time for the 270 eV design. The nominal yield for this capsule is 25 MJ.
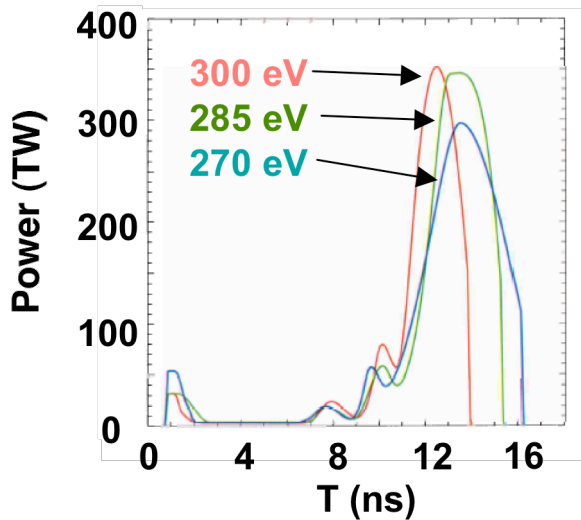

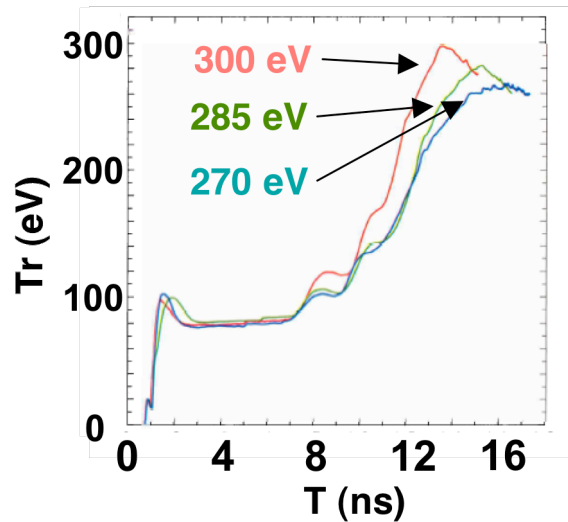Figure 2: Power vs time for the three targets, 300 eV, 285 eV, and 270 eV

Figure 3: Hohlraum temperature versus time that results from pulseshapes in Figure 2 for the three targets.

2.3. 285 eV, 1.3 MJ design
In the 270 eV design, we added an additional 250 kJ of required laser energy but kept the capsule robustness equal to that of the 1.05 MJ, 300 eV target.   If we use Lindl's scaling above to scale to 285 eV, we would find a 1.13 mm radius capsule and estimate a 1.17 MJ of energy.   Instead of using the pure scaling, we tried to keep the same total energy as the 270 eV target (1.3 MJ) and use the additional energy to add robustness to the capsule. As such, we use a 1.2 mm radius capsule and a hohlraum that is 1.175 times larger than the 300 eV design. Again, the beam spots were scaled with the hohlraum size – 1.175 times as large as the 300 eV beam spots. Lasnex calculations of this design use 1.2 MJ of absorbed laser energy or 1.3 MJ assuming 7.5% for backscatter (7.5% being in between the 10% assumed in the 300 eV design and 5% assumed in the 300 eV design). The pulse shape and resulting drive temperature for the 285 eV design are shown in Figure 2 and Figure 3.

3. Comparing the three designs
Comparing the three designs, we will see that
- The 300 eV design is the most conservative energetically, but has higher LPI gains
- The 270 eV design uses an extra 250 kJ reduce the LPI gain via lower intensity (lower power and larger spots both contribute to lower intensity)
- The 285 eV design also uses an additional 250 kJ but shares the extra energy between LPI and increased capsule robustness (as described above)

All three designs meet the specification for asymmetry – the allowance for asymmetry is that the RMS deviation of the hotspot radius be no more than 10% of the hotspot radius.   The current best designs

have 10% RMS hotspot variations for the 300 eV design, 3.5% RMS hotspot variations for the 285 eV design and 5% RMS hotspot variations for the 270 eV design.

One method for comparing the LPI gains is to look at the gain along each laser ray in the radiation/hydrodynamics calculations and calculate an LPI gain. For each ray, we then find the peak LPI gain (regardless of backscattered wavelength) and plot a distribution function of the ray gains. Figure 4a and 4b show this distribution for the 3 target designs at peak power (the time of peak power varies between the designs) for the 23.5 degree beams. (Gains for the 30 degree beam tend to be similar.) We see that in the 300 eV design, there are a significant fraction of the rays ($\sim$ 50%) with high stimulated Raman scattering (SRS) gain (e.g. gain > 20). In contrast, the 285 eV design has ~25% of the rays with SRS gains > 20 and the 270 eV design has ~ 15% of the rays with SRS gain > 20. More detailed pF3D calculations along with experiments are needed in order to quantify how much backscatter is produced by these gains. However, having a set of designs that has a wide spread in LPI gain gives us the flexibility to use better calculations and early NIF experiments [2] to choose the optimal design.
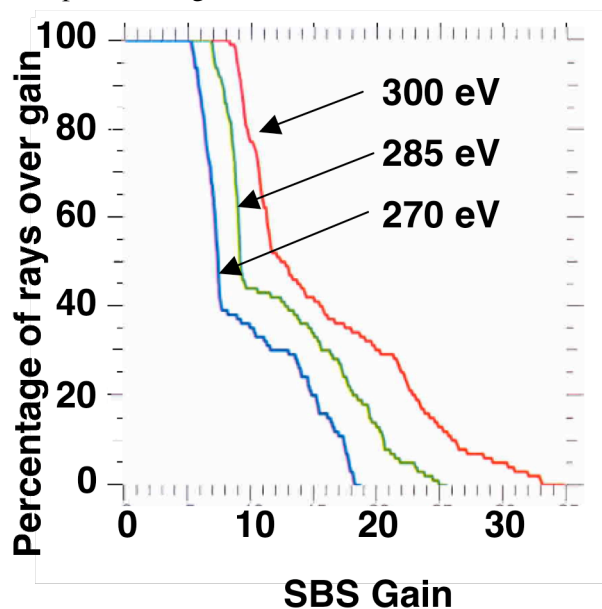

Figure 4: Distribution of rays with SBS gain above gain as a function of gain for 300 eV, 285 eV, and 270 eV designs
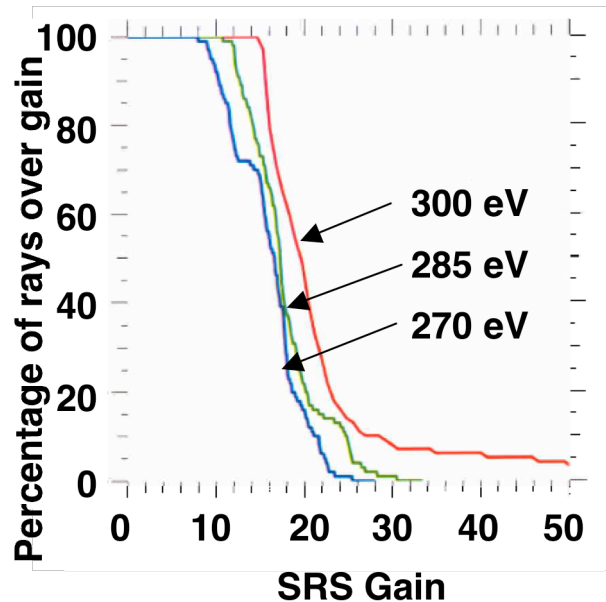
Figure 5: Distribution of rays with SRS gain above gain as a function of gain for 300 eV, 285 eV, 270 eV designs

4. Conclusions

We have designed a portfolio of targets that are consistent with initial NIF operations. Having this set of designs allows us to explore the trade-offs between the different parts of the system – LPI, symmetry, capsule performance, laser performance, target fabrication. This puts us in a position to use early 96 beam NIF experiments to determine the optimal hohlraum for ignition by measuring the LPI and demonstrating our ability to tune symmetry in the candidate designs. We believe that this approach--using both theory and experiment to optimize the hohlraum--will significantly increase our chance of choosing the best hohlraum for the first ignition attempt.

5. Acknowledgements

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