Targets for Heavy Ion Inertial Fusion Energy

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General Atomics

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Our emphasis has been on validating our target designs using experiment and theory

- The “hybrid” target has become the target of choice because it allows a large focal spot (~ 5 mm radius)
  - Focusing beams is a critical issue for heavy ion fusion
  - The large beam spot may allow a modular driver with a small number of separate accelerators
  - The hybrid target uses some new target design features that need validation such as shine shields and shims to correct asymmetries
- In a LLNL/SNL/GA collaboration, we did our first experimental test of shims in April ‘04
  - We demonstrated the principle of shims by reversing a P_2 asymmetry
  - Our next experiments are scheduled for this month

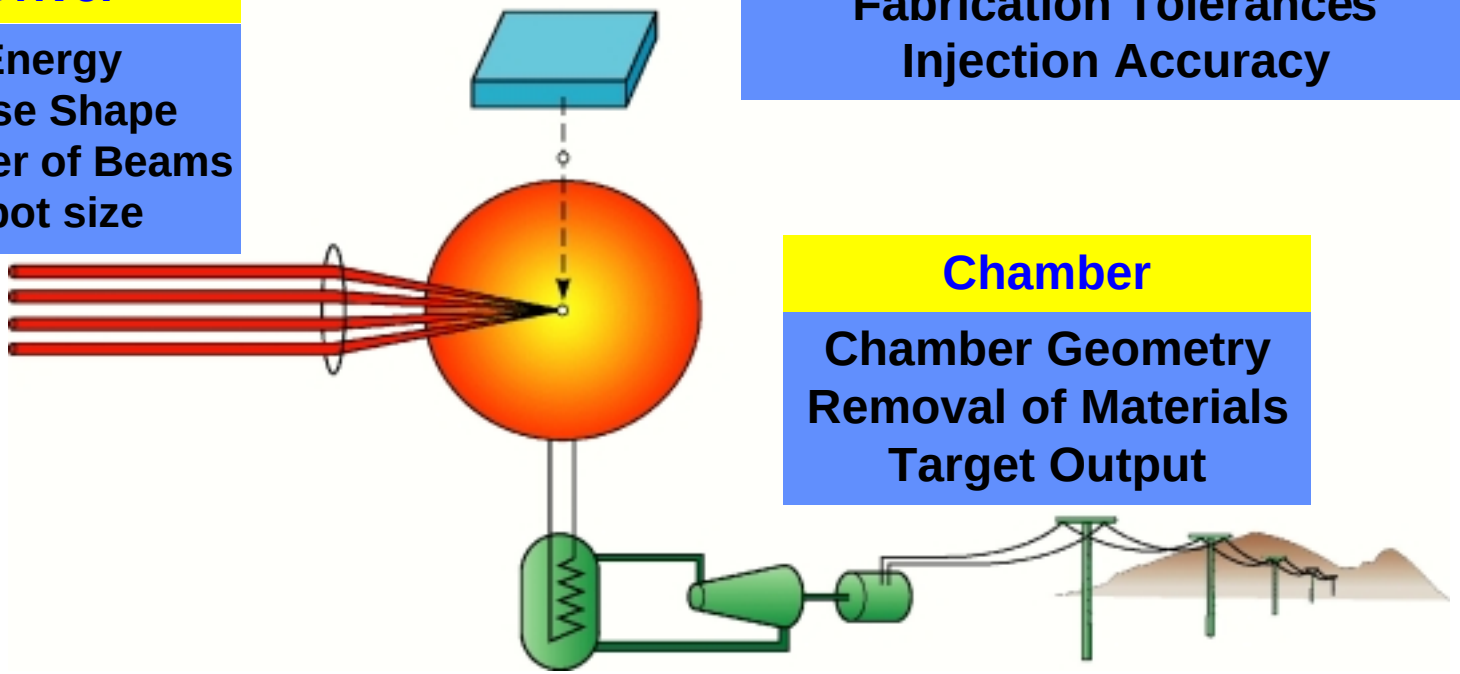
The target interfaces with all the different pieces of the power plant

Target Fabrication and Injection

Target Materials
Fabrication Tolerances
Injection Accuracy

Driver

Energy
Pulse Shape
Number of Beams
Spot size

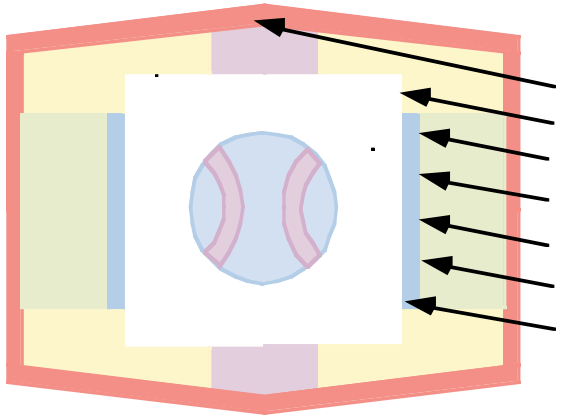


Chamber

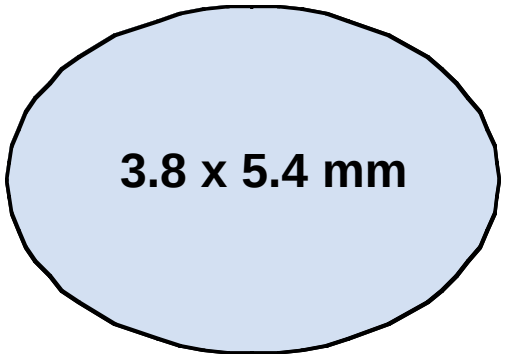
Chamber Geometry
Removal of Materials
Target Output

The “hybrid” target has become the target of choice because it allows a large beam spot

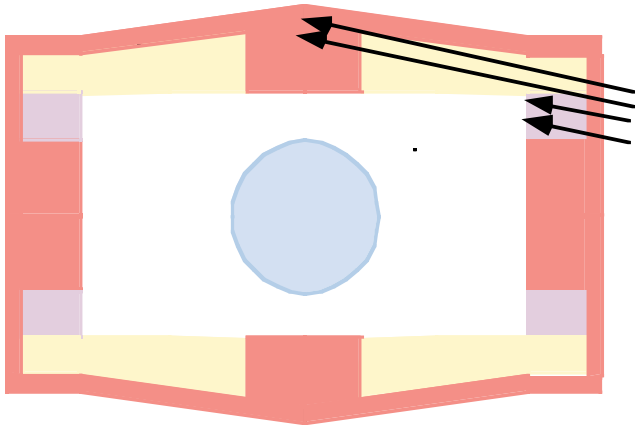
Hybrid Target



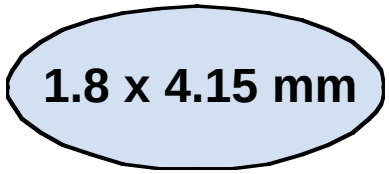
6.7 MJ -- Gain ~ 60



Distributed Radiator Target



5.9 MJ -- Gain ~ 70

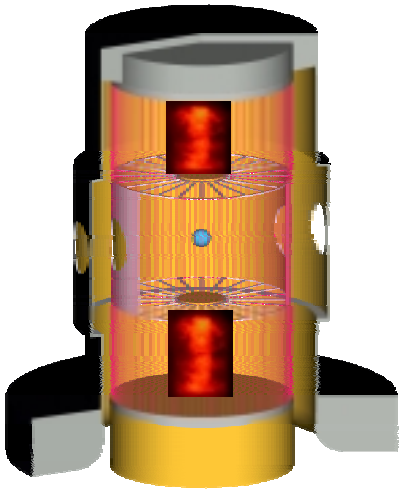


The hybrid target uses shine shields and shims to control symmetry

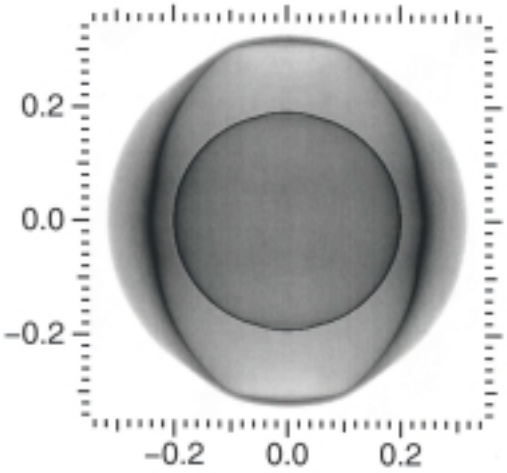
- The distributed radiator target and the NIF point design use beam placement to control symmetry
- The hybrid target uses internal shields to control symmetry
  - A shine shield controls P_2
  - A shim corrects the P_4
- The hybrid target and the Z double-pinch target use similar methods for controlling symmetry
  - This results in a natural area for collaboration

HI hybrid target

Z double-pinch target

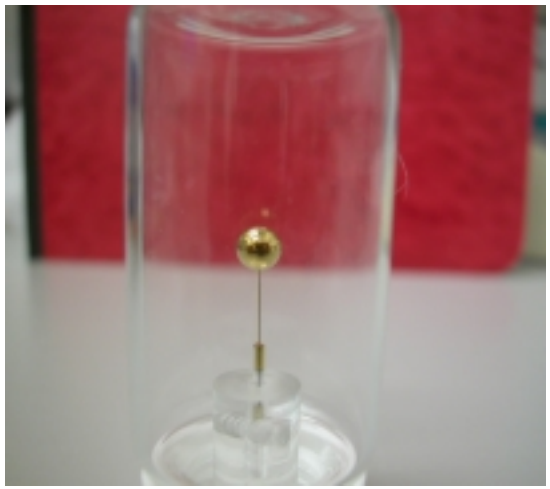


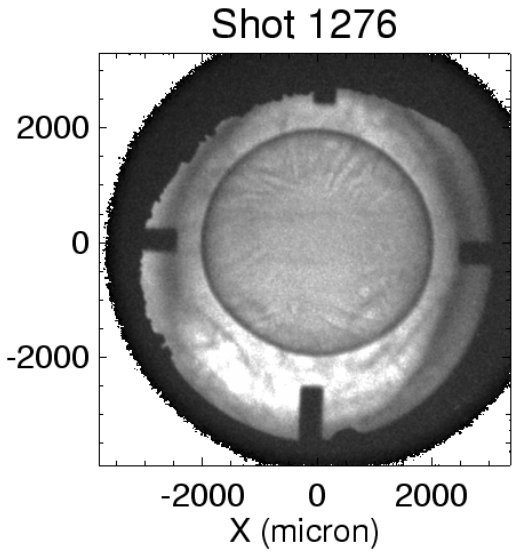
In a LLNL/SNL/GA collaboration, we did the first three experiments to test shims in April 2004



LLNL
Theory and Design

General Atomics
Capsule Fabrication



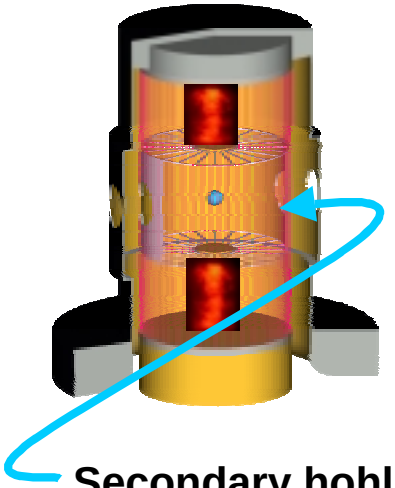


SNL
Experiment and
Hohlraum Fabrication

This collaboration worked very well!

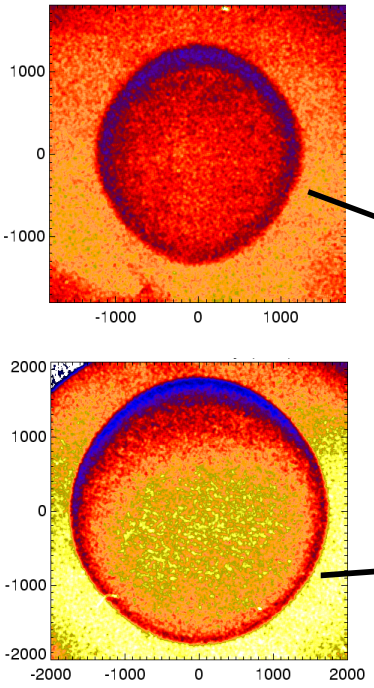
Large thin-shell capsules in double z-pinch hohlraums provide null cases for P4 shimming tests

Z double-pinch hohlraum

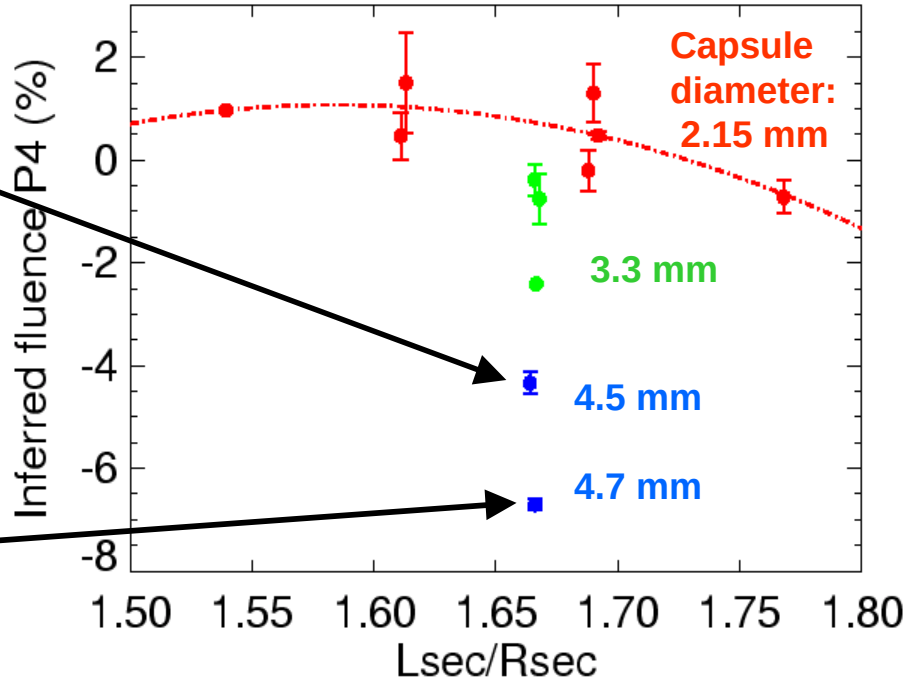


Secondary hohlraum
Radius ≡ R_{sec}
Length ≡ L_{sec}

6.7 keV backlit images



P4 vs. length and capsule size



These experiments had a P_2 asymmetry in addition to the P_4 so the shim was designed to take out this combination

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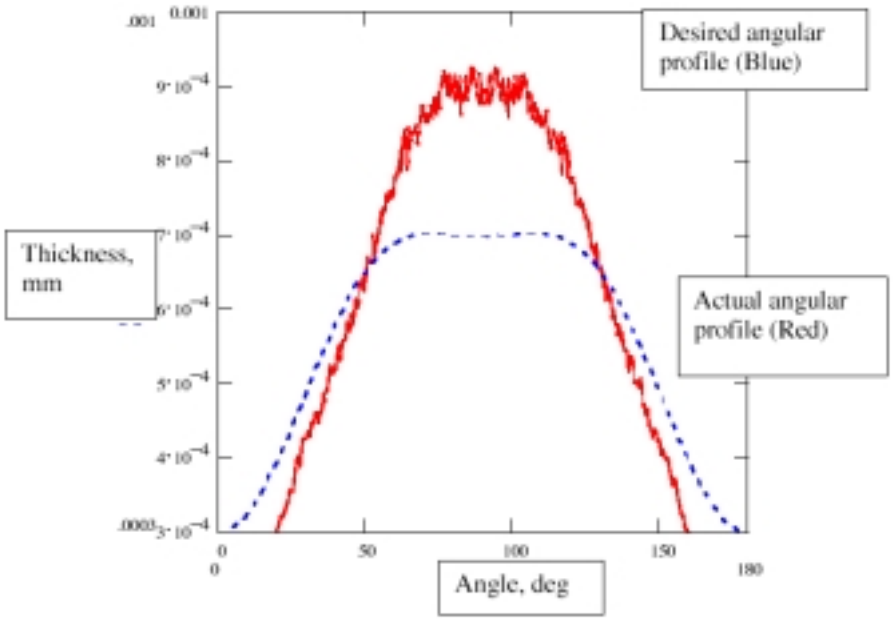
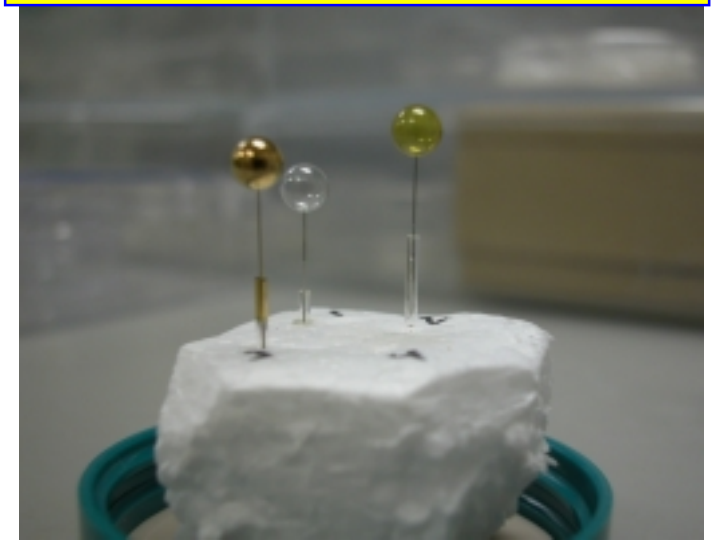
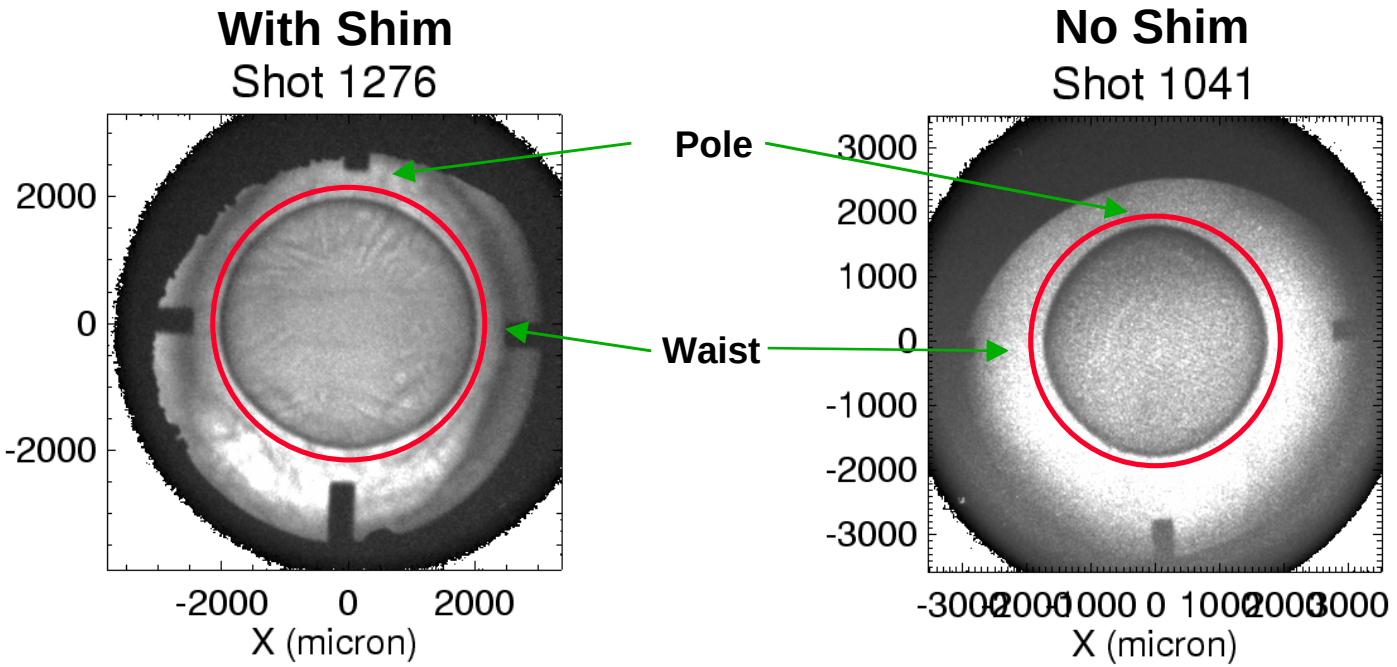
GA fabricated the capsules by rotating them under a coater with a mask to produce the layer profile



Photograph of capsule mandrel, Ge-doped CH shell, and coated target



The first shot gave the best data and shows that we reversed the P_2 asymmetry!

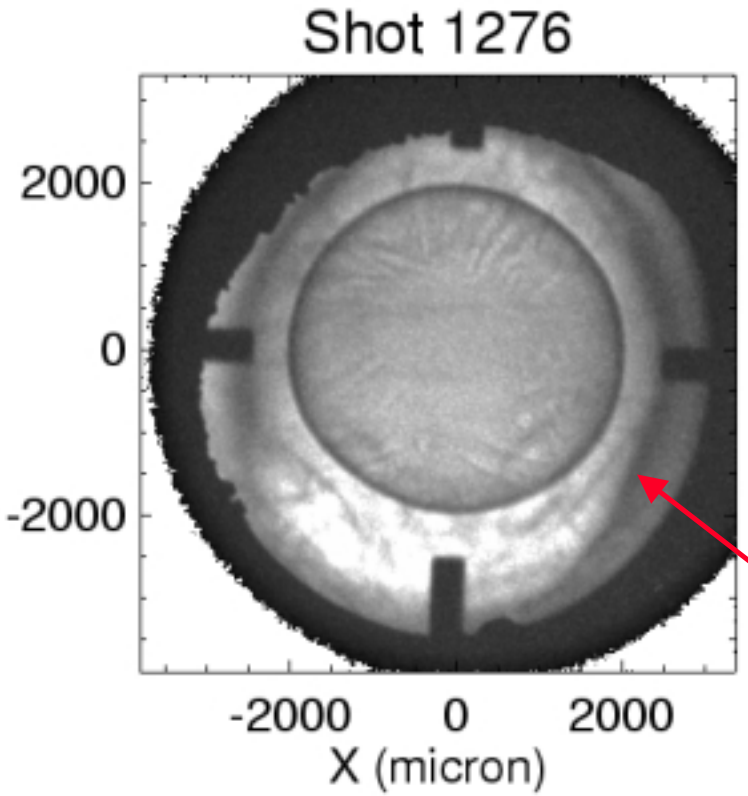


Roger Vesey's preliminary analysis of the images gives:

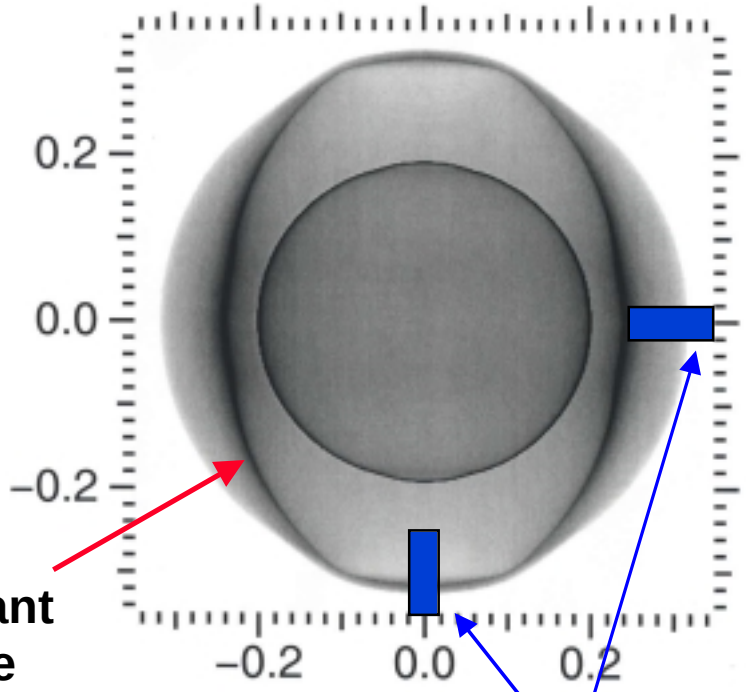
With shim
P_2 = + 15% (pole high)
P_4 = - 3%

No shim
P_2 = - 6% (waist high)
P_4 = - 6.9%

Since the image was caught early in time, we see evidence of the shim layer in the radiograph

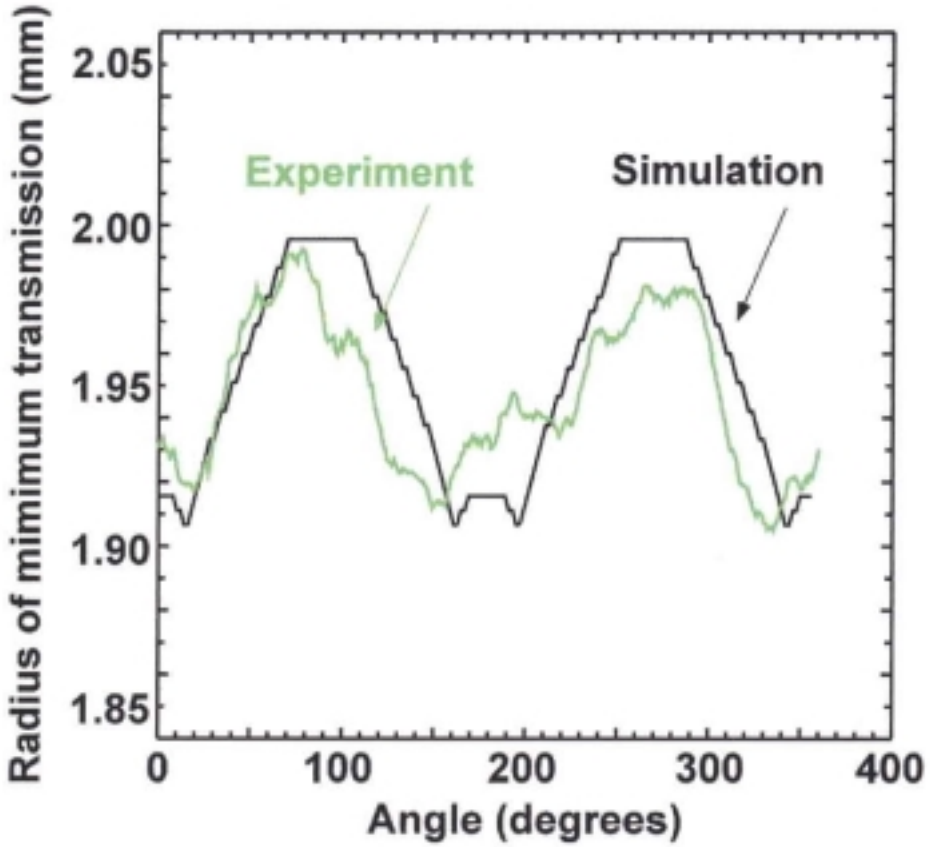


Remnant of the shim layer



Approximate location of the fiducials

A more detailed comparison of the calculation and experiment shows good agreement

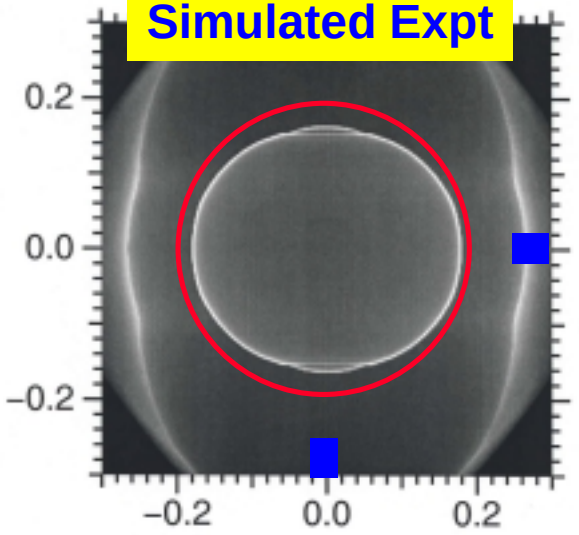


Assumes layer was 0.3 microns thick in the 20 degrees around the poles (no data from target fab in this region)

The second shot was a repeat of the first, but at higher convergence ratio

Experiment

Simulated Expt



- The image is clearly pole high so we have certainly reversed P_2
- Simulated image agrees qualitatively

Shots in September will try to correct and reverse a P_4 asymmetry

- Based on SNL experiments in Feb/March, we should be able to tune out the P_2 asymmetry using hohlraum and shine shield geometry
  - First four shots in September will tune out P_2 and serve as a baseline for the shim shots
  - Four shim shots will try to correct (using nominal shim) and reverse (using a thick shim) a P_4 asymmetry

These experiments give credibility to the heavy ion hybrid target as well as exploring a new symmetry technique for all indirect drive targets

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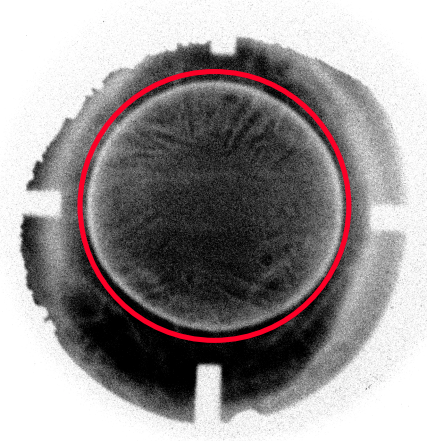
Backup

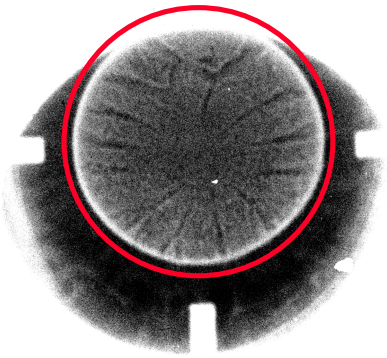
These targets were first-of-a-kind so there were a few problems

- As this was the first attempt at putting the layer on a capsule, the layer ended up being thicker than we had asked for
  - Translation from flat to sphere for the P_4 mask was not as expected--this is certainly fix-able
  - Recent calculations show that the layer we asked for was too thick anyway
- Our plan was to stalk mount the capsules in the hohlraum, using the stalk (200 micron diameter) that was used to hold the capsule under the coater
  - Due to a miscommunication, the stalks were removed and left small (30-200 micron) holes in some of the capsules
  - We did not see any ill effects from these holes!
- The capsules were then mounted with formvar
  - Wrinkles in the formvar caused ripples in the images of the capsule -- this was also seen in previous SNL shots (Sept 03)

The third shot used a shim with half the thickness



Full thickness



Half thickness

- This shot had two purposes:
  - A backup in case the backlighter contrast was poor in shots 1 and 2 due to the remnant of the shim layer
  - A further demonstration of the change in symmetry
- The capsule was put into the coater for half the time
- The image was clipped, making it difficult to determine P_2