Innovation in target fabrication can reduce cost, schedule and risk of ignition and compensate for driver inflexibility.

300 eV graded-doped Be design:

Original CH Desi
Optimiz.

6 μm OD fill tube in 2 mm OD shell

US Japan IFE Workshop
3-22-05

Joe Kilkenny
General Atomics
Success in HEDP, and Ignition requires:

- **Drivers**
  - major investment

  - NIF
  - OMEGA EP
  - Z-R
  - & Nike, Trident,..

  - Simulations, ASCI
  - major investment

  - 3D rad.-hydro Simulation of igniting target

- **Target S&T**
  - Cinderella
  - ~$25M FY 04

There has been inadequate investment in target fabrication S&T commensurate with its role in the SS Program
3D codes allow sophisticated 3D targets, reduce risk, cost and schedule & compensate for driver limitations

- Hohlraums-gas fill reduces symmetry swings
- Cocktail hohlraum wall reduce x-ray wall loss-helps all drivers
- Graded doped ablators reduce instability, allow fill tubes & reduce cryo cost for NIF ignition target

Innovation in target fabrication compensates for driver and facility limitations
Innovation in target fabrication: gas fill in Hohlraums provides symmetry control—Compensates for driver inflexibility

Gas fill
Reduces wall Motion

BUT

Convection

Baffles
or low $\rho$ foams

Target fabrication challenges remain!
Target fabrication and characterization
Drives target choices

• Beryllium is the best ablator -

The development and advantages of beryllium capsules for the National Ignition Facility*


Thomas R. Dittrich, Steven W. Haan, Michael M. Marinak, Stephen M. Pollaine, and Jorge J. Sanchez
Lawrence Livermore National Laboratory, Livermore, California 94551

• But Be has fabrication and characterization issues:
  - surface finish
  - filling
  - no augmented beta layering
  - characterization difficult- opaque

The first choice NIF ignition target was diffusion filled plastic with fewer target fab. issues
The NIF baseline target was plastic diffusion filled

- Baseline target-diffusion fill
  - Physics issues
    - Surface finish
    - Augmented $\beta$ layering
    - Optical characterization

BUT

- $\$ and schedule issues with The NIF cryogenic target handling system because diffusion fill/cold transport

The large number of cryo. sub-systems increases complexity & cost
A 10 year ~ $30M GA & LLE effort was required for the OMEGA diffusion & cold fill cryo system: NIF prototype

Tritium use late 2004?
Innovation in target fabrication: graded dopant Be shells less unstable & may allow a fill tube

Graded Cu dopant in Be shell

Is less Unstable
How much less?

A small fill tube may Not cause too large A perturbation:

Filling in situ reduces the cost of the NIF cryo system
Dopants in the ablators are required to reduce x-ray preheat at the ablator-ice interface

- X-ray preheat at ice-ablator interface heats absorbed by ablator not by ice
- This makes ablator less compressible than DT ice
- Can lead to a hydrodynamically unstable interface

Reducing x-ray preheat can reduce density jump (Atwood number) at interface

But:
- Shorter ablation scalelength
- Lower mass ablation rate
Innovations in target fabrication using Be with graded Cu dopant provide much more stability margin.

300 eV design:

- Initial ablator roughness (rms, nm)
- 0
- 5
- 10
- 15
- 20
- 25

Yield (MJ)

Polyimide capsule
Surface achieved with PI

300 eV graded-doped Be(Cu) design, at same scale

But can the targets be made and then characterized to the required precise specifications?
Be and CH are both potential ablator materials for ignition capsules

<table>
<thead>
<tr>
<th>Physics Issues</th>
<th>Be</th>
<th>CH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorption Efficiency (density/opacity)</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Stability</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Fill tube tolerance</td>
<td>+</td>
<td>0/–</td>
</tr>
<tr>
<td>Drive temperature range</td>
<td>+</td>
<td>0/–</td>
</tr>
<tr>
<td>Morphology effects</td>
<td>0/–</td>
<td>+</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Fabrication Issues</th>
<th>Be</th>
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<tbody>
<tr>
<td>Surface finish</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Morphology (internal structure)</td>
<td>0/–</td>
<td>+</td>
</tr>
<tr>
<td>Fill tube/Fill hole</td>
<td>0/+</td>
<td>0/–</td>
</tr>
<tr>
<td>Dopant gradient flexibility</td>
<td>0/–</td>
<td>+</td>
</tr>
<tr>
<td>Characterization</td>
<td>0</td>
<td>0/+</td>
</tr>
<tr>
<td>Enhanced β-layering (DD and layer temp)</td>
<td>–</td>
<td>0/+</td>
</tr>
<tr>
<td>Hohlraum layering (conductivity)</td>
<td>0/+</td>
<td>0</td>
</tr>
</tbody>
</table>

Be capsules are preferred for physics performance but present greater fabrication challenges
The Indirect Drive Ignition point design continues to evolve to optimize coupling efficiency

10-20% of the laser energy to capsule

<table>
<thead>
<tr>
<th>Cocktail, LEH shields - Be Capsule</th>
<th>Cocktails - Be Capsule</th>
<th>Au with Be Capsule</th>
<th>Au with CH Capsule</th>
<th>Laser light (MJ)</th>
<th>Absorbed Xrays</th>
<th>Wall loss</th>
<th>Hole loss</th>
<th>Capsule</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.85</td>
<td>0.77</td>
<td>0.655</td>
<td>0.295</td>
<td>0.220</td>
<td>0.14</td>
<td>16.5%</td>
<td>9.7%</td>
<td>11.7%</td>
</tr>
</tbody>
</table>
Simulations indicate that a 10-20 µm diameter tube will have an acceptable impact on the implosion:

- Graded doped 200 kJ Be(Cu) capsule
- Calculation ignites and burns with near 1D yields
- Graded doped Be capsules are best but simulations carried out with uniformly doped Be, and graded doped CH capsules all give near 1D yields with 10 micron diameter tubes.

Update with point design scale info
New capsule provides new opportunities but also presents major fabrication challenges

Cu-doped Be capsules are made by sputter deposition onto CH mandrels in a bounce pan

Cross-section of 100 µm thick shell

Uniform copper Distribution by TEM

Vacuum Chamber

Sub-micron grains

Tiny holes have been laser drilled for filling
We can attach ~ 6 µm fill tubes to capsules but with too large a perturbation so far.

6µm OD fill tube, 2mm OD shell

Target fabrication issues: too large a perturbation by the glue.
Key fabrication capabilities for fill-tubes are being developed and demonstrated

<table>
<thead>
<tr>
<th>Laser Drilling in Be</th>
<th>10 µm Glass Tube in Al Flat</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Laser Drilling in Be" /></td>
<td><img src="image2" alt="10 µm Glass Tube in Al Flat" /></td>
</tr>
</tbody>
</table>

The glue layer is ~1µm thick

Laser: Ti:sapphire
405 nm, <1 µJ, 120 fs, 3.5 kHz
drilling time: ~40 sec
The 2010 ignition plan has risk mitigation options for the key features of the point design target

<table>
<thead>
<tr>
<th>Feature</th>
<th>Point Design (Risk)</th>
<th>Risk mitigation options</th>
<th>Impact of Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hohlraum geometry</td>
<td>Includes LEH shields (Low)</td>
<td>No LEH shields</td>
<td>0.85 to 1.0 MJ (17%)</td>
</tr>
<tr>
<td>Hohlraum material</td>
<td>Cocktail (Low)</td>
<td>Au</td>
<td>1.0 to 1.2 MJ (20%)</td>
</tr>
<tr>
<td>Ablator Material</td>
<td>Be (Low/moderate)</td>
<td>CH</td>
<td>1.2 to 1.45 MJ (20%)</td>
</tr>
<tr>
<td>Hohlraum low-z fill</td>
<td>SiO₂ foam (for operational simplicity and flexibility) (Low/moderate)</td>
<td>▪He/H gas fill ▪SiO₂, Be, or Ni solid liner (with prepulse to eliminate hydro coupling)</td>
<td>(Scattering could increase from 10% to 30%) 1.45 to 1.7 MJ (20%)</td>
</tr>
<tr>
<td>Capsule fill method</td>
<td>Fill Tube (Low/moderate)</td>
<td>Diffusion Fill (CH)</td>
<td>More complex cryo system</td>
</tr>
</tbody>
</table>
Nano technology methods can be used for monolithic fill tube manufacture

~ 5 micron mandrel grown with laser CVD on Be sphere in a laser drilled hole

Be or Boron tube is grown off of the sphere and surrounding the mandrel also by laser CVD

Mandrel is dissolved leaving fill tube
LLE and GA are investigating monolithic fabrication of fill-tube targets

- Laser hole drilled in PAMS shell (polyalphamethylstyrene)
- PAMS fiber 10-µm OD, 50-µm long
- Cut GDP tip, pyrolyze for final target

1 µm steps 40 µm holes 25 µm holes

Control of joint defects during coating is key.

Exitech products