Overview of LANL Double Shell Design, Fabrication and Characterization

22nd Target Fabrication Meeting
Las Vegas, Nevada
Tana Cardenas, Derek Schmidt, Blaine Randolph, Chris Hamilton, John Oertel, Brian M. Patterson, Kevin Henderson, Mike Schoff, Marty Hoppe, Neal Rice

March 15, 2017
Outline

• Design
  • Point design
  • Imaging design
  • Keyhole design
• FY17/18 Shot Schedule
• Fabrication
  • Outer Ablator
  • Foam Cushion
  • Inner Capsule
• Assembly
• Characterization
• Assembly Station 3.0
• Design Improvements
LANL Point Design

Design Features
• 128 um thick aluminum hemispheres
• 35 mg/cc CH DVB Foam
• Inner Capsule 460 ID
  • 30 um tungsten pusher
  • 30 um aluminum tamper
• DT with fill tube (not shown)

Fabrication Considerations
• Decrease perturbation from joint
• Delicate foams
• Need to test assembly of fill tube

Point Design Pie Chart, courtesy Daughton
LANL Imaging Design

Design Features
• 106 um thick aluminum hemispheres
• 35 mg/cc CH DVB Foam
• Inner Capsule 750 um OD
  • 30 um SiO2 or Be(Cu) pusher
  • 20 um GDP tamper
• No Fill (yet)

Fabrication Considerations
• First Aluminum machined hemi
• Delicate foams
• Improve assembly accuracy

Imaging Design Pie Chart, courtesy Loomis
LANL Keyhole Design

Still working on design with GA and LLNL input

Design Features
- 128 um thick aluminum hemispheres
- 35 mg/cc CH DVB Foam
- Inner Capsule
  - 30 um W pusher
  - 30 um Be tamper
- Liquid D2 or plastic hemisphere

Fabrication Considerations
- Cryo mismatch of materials
- Can we coat a solid bead and then machine in half?
- How will assembly be handled?
LANL Planar Design 3/8/17

- **Hohlraum driven**
- **35 mg/cc CH DVB Foam**
- **Physics package**
  - 50 um thick Al Ablator
  - 2 um Au coating
  - 150 um thick 35 mg/cc CH
  - 20-60 um thick quartz
  - 200 mg/cc SiO2 Aerogel
- **Diagnostic**
  - Area Backlighters
  - VISAR
# Shot Schedule FY 17 & 18

<table>
<thead>
<tr>
<th>Shot Date</th>
<th>Target Name</th>
<th>Target Description</th>
<th>Physics Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/22/2017</td>
<td>DS_0217-01</td>
<td>2DconA: Al, foam, glass inner shell + tamper</td>
<td>Establish impact shape and inner shell shape</td>
</tr>
<tr>
<td>3/15/2017</td>
<td>DS_0317-01</td>
<td>2DconA: Al, foam cushion only</td>
<td>Establish no-impact, outer shell swing, coupling and velocity</td>
</tr>
<tr>
<td>8/28/2017</td>
<td></td>
<td>1DconA: Al, foam, glass inner shell + tamper</td>
<td>Measuring preheat expansion of inner shell</td>
</tr>
<tr>
<td>FY18 Q1</td>
<td></td>
<td>Keyhole: Al, foam, W inner shell on thick GDP/rexolite</td>
<td>Measuring preheat and impact conditions of high-Z inner shell</td>
</tr>
<tr>
<td>FY18 Q2</td>
<td></td>
<td>Keyhole: Al, foam, W inner shell on thick GDP/rexolite + Be tamper</td>
<td>Measuring preheat and impact conditions of high-Z inner shell</td>
</tr>
</tbody>
</table>
Fabrication: Outer Ablator

Developed new approach for machining this material

- Machined on Hardinge Conquest Gang-Tool Lathe*
- Machining parameters
  - Spindle RPM: 1200
  - Depth of finish pass: 0.0001”
- Fabrication took 3 weeks for 6 pairs
- 0.0025 mm gap added to aide assembly
- Sulfur free cutting oil caused cleaning issues, will use other cutting fluids in future

*See features in “Dry-Machining of Aerogel Foams, CH Foams, and Specially Engineered Pure CD Foams using Turn-Milling Techniques at Los Alamos National Laboratory” - Randolph
Characterization: Outer Ablator

• Surface scans were done using Zygo white light interferometer
• The pole region of the inner and outer diameters of each hemisphere was scanned
• The male and female OD average roughness (Ra) were measured between 0.013 and 0.019 um.
• The Ra of the male and female ID were measured between 0.012 and 0.018 um.
30 mg/cc DVB Foam Hemispheres

- Hemis were machined in one operation using same Hardinge Gang-Tool Lathe*
- Switched from HIPE to DVB because of large amount of voids in the HIPE batch. HIPE density was ~26 mg/cc, DVB was 38 mg/cc
- DVB is harder and more time consuming to machine than HIPE and is also more delicate to handle
- Multiple foam hemi IDs were machined to fit the different ODs of the inner capsules. Many were lost to handling.
- Finished hemis were characterized in the Density Characterization Station
- Large ID foam were still being characterized at DCS during the first build, this may have compounded assembly issues

“Dry-Maching of Aerogel Foams, CH Foams, and Specially Engineered Pure CD Foams using Turn-Milling Techniques at Los Alamos National Laboratory” - Randolph
Inner Capsule

- 5 experimental Capsules were provided by GA*
- First time GA attempted to reach 40 um thick at this diameter
- Partial density glass (1.84 g/cc) with ~630 um ID and 35 um wall
- We decided to stop conversion early because of rushed schedule and to reduce risk of losing the capsules with additional processing.
- A 30 um GDP overcoat brought the final OD to ~750 um
- The Si capsule wall thicknesses were consistent to 1 um while the ODs varied leading to an overall OD spread of 22 um.

*See “Advances in Silicon and Germanium Doped Plastic Capsule and Glass Capsule Fabrication”- Hoppe
Assembly

• Handling was difficult, the parts were very easily scratched
  • Eliminate use of glass slides
  • Use Gel-Pak® to eliminate rolling during transfer
• The DS robot designed in 2009 was reassembled and was found to be lacking in 3 axes of manipulation.
• The tight schedule mandated we assemble using Triple Theta Robot.
• Assembly features that were lacking for this build
  • Optics suitable for small target
  • Micro tweezers for assembling the foam perpendicular from the ablator
  • Automated glue injection
  • Force feedback sensor
  • 3D printed vacuum tips
Assembly Process

• Male ablator is leveled in the vacuum tip and centered in the top camera view.

• The bottom foam hemisphere is brought in with the 5 axis vacuum arm and leveled using tilt and twist motors. The foam is centered in x and y and inserted into the male ablator.

• The inner capsule is brought in with a smaller vacuum tip and inserted into the ID of the foam.

• The process is repeated with the top hemisphere.
Assembly process continued

- The female ablator is leveled and the profile is aligned in perpendicular views.

- It is then lowered until the seam is closed or the hemisphere stops moving.

- A small dot of low viscosity UV glue (Norland 61) is placed on a fine fiber under a microscope and placed onto a manual manipulator.

- The manual manipulator brings in the glue and tacks it in place.

- The glue is cured and the capsule is removed from the vacuum tip and placed on a Gel-Pak® mat.
Characterization: Radiography

- **Imaging** conditions
  - 50kVp and 10W
  - sample was rotated 184 degrees
  - 20s exposure
  - 9.8X objective
  - 2.5 micrometer voxel size

- **Target assembly is interested in the build quality:**
  - Magnitude of gaps in the seam
  - voids in the foam
  - gaps between the foam layers
  - offset between the capsule centers

- **0217-01 was not reconstructable**
  - sample moved on Gel-Pak®
  - The other capsules were imaged by placing in a plastic cone and held secure

*See “Characterization of Target Materials Using a Variety of X-Ray Instrumentation”- Patterson*
Characterization: Capsule 0217-01

- Radiographs show a gap of ~11 µm across the gap. The gap seems to be pretty uniform around the circumference.

- This capsule moved during tomographic imaging and there was not time in the schedule to re-image the capsule.

- This capsule was selected as the primary capsule and was shot February 23, 2017.

- Centering: 7 µm

  Measured Gap: 9.8 and 10.6 µm
Capsule 0217-02

- Capsule 0217-02 was the only double shell with 3D reconstruction
- Was obviously of poorer quality and gives worst case measurements
- Radiographs show a larger separation across the gap. The gap spacing is not uniform around the circumference.
- Possible causes are interference with foam and the presence of a small particle in the joint.
- Capsule centering: 14 um

Measured Gap: 19.4 and 7.8 µm
Video: Slice through perpendicular to the joint.
DS 0317-01 & 02 Radiographs

- Radiographs show a gap of 8.7 and 7.8 µm across the gap. The gap seems to be pretty uniform around the circumference for each.

- Improved assembly may have been due to increased skill or lack of inner capsule made it easier.

- The capsule was sent to GA for AFM analysis (see slide 21).

- This data was helpful in selecting 0317-01 as the primary capsule for the March shot.
Possible interference/galling could have caused failure to bottom out on inner surface as designed

Three dimensional reconstruction of seam for capsule 0317-02, courtesy Patterson
Characterization: AFM at General Atomics

- Ablator capsules to be shot in March were shipped to GA for AFM on spheremapper
- Step joint measured - 3.5 um

Figures courtesy N. Rice, A. Tambazidis
Next Steps: Engineering Design is an iterative process

- **Split production from R&D**
  - Design different joint to aid in assembly and reduce perturbation
  - Experiment with new handling techniques on fragile materials
  - Practice assembly on practice parts

- **Continue to improve assembly station**
  - Force feedback is scheduled to be implemented by FY17 Q3
  - Appropriate optics in stock
  - Controlled glue injection scheduled to be implemented by FY18 Q1
  - Features needed for fill tube/keyhole assembly
Conclusion

• **Design**
  • The design was influenced by existing technology and stretching it

• **Fabrication**
  • Tight schedule, processes were developed concurrently
  • 6 pairs of ablators were machined in 3 weeks

• **Assembly**
  • Tight schedule lead to improvisation
  • 4 Capsules were assembled in 2 days, 2 DS and 2 Ablator

• **Characterization**
  • 17 hour CT scans were done for each target

• **Design Improvements**
  • DS Assembly Station
  • Improve joint for better assembly and less perturbation
THANK YOU

That’s no death star, it’s a double shell!