Fabrication of Targets with Foam Lined Hohlraums

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Foam lined hohlraums are seen as a critical means of improving drive symmetry by restricting wall-motion.

- Simulations suggest that low density foam lined hohlraums could mitigate several issues:
  - Wall motion, symmetry swings
  - CBET, SRS, ion-acoustic instabilities
  - Ablation front growth through reduction of M band X-rays
  - Glint, since specular reflection is lowered
- Improving hohlraum drive symmetry is an important goal for NIF experiments

New wall materials open up new operating space for target physics designers.
Mitigating wall motion in low gas fill hohlraums would minimize interference with inner beams with the blow-off bubble and allow better symmetry.

Bubble of the hohlraum material generated by the outer beams interferes with inner beams that are intended to tune the X-ray flux at capsule equator.

Key foam liner attributes for mitigating this:
- Comprised of Hi-Z or Mid-Z materials
- Goal: Rho-r of 5 um-g/cc or ~250um thick liner at ~20mg/cc
- Line of sight channel size <1% of thickness
  - So pore size needs to be small (ideally, homogeneous foam)

Tight requirements for the foam liners present new fabrication challenges.
We are developing several techniques for fabrication of foam lined hohlraums

**Two broad categories**

<table>
<thead>
<tr>
<th>Networked structures cast directly</th>
<th>Deposited on removable template</th>
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<tbody>
<tr>
<td><strong>Molded directly or Machined into a liner</strong></td>
<td><strong>Nano-porous Au template + ALD</strong></td>
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<tr>
<td>- Sol-gel casting + supercritical drying</td>
<td><strong>3-D printed template + ALD</strong></td>
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<tr>
<td>- Ta$_2$O$_5$, Fe$_2$O$_3$, rare earth oxides</td>
<td><strong>EPD of PS spheres + ALD</strong></td>
</tr>
<tr>
<td>- Networking of nanowires + freeze drying</td>
<td>- Ta$_2$O$_5$, ZnO, Al$_2$O$_3$, Pt</td>
</tr>
<tr>
<td>- Ag, Au</td>
<td><strong>CH foam + Nano-particle deposition</strong></td>
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<tr>
<td></td>
<td>- Au, Sm$_2$O$_3$, etc.</td>
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First shot using hohlraums with hybrid ZnO-CH polymer foam showed reduced SBS

- First-look target shot (N151020)
  - Lined with 180 mg/cc ZnO-CH, 200um thick made at General Atomics

- Liner composed of
  - High Internal Phase Emulsions (HIPE) foam with ALD coated ZnO (equivalent density of 35 mg/cc)

- Shot showed strong evidence of low SBS (ion-acoustic damping)
Our initial approach was to use established Ta$_2$O$_5$ aerogel recipe and machine a billet into a liner inside the hohlraum.

Machining steps to make a foam liner

90 mg/cc Ta$_2$O$_5$

Foam lined hohlraum

Finished component: Tanatela foam liner

Cryogenic target was assembled using these machined liners (90 mg/cc Ta$_2$O$_5$)
Ta$_2$O$_5$-lined hohlraums showed that conversion efficiency was essentially the same as with Au

- Peak X-ray flux within 7% of Au hohlraum
- Good laser coupling (99%)
- X-rays > 3keV reduced by 1.8X
- Burn-through timescales were good match to expectation
- Reduction in wall motion suggested by preliminary analysis of self-emission

- Hot spot was pancake-shaped with lot of structure: break-up of ablator seen suggesting possible particles
  - Ta$_2$O$_5$ debris deposited on the capsule during assembly?

Results indicated that liners could improve hohlraum performance
Whereas the machined-liner approach was able to provide early targets, it is greatly limited in meeting our desired goals.

Main issues with machined liners:
- Low densities are not machinable
  - For tantala, the lower limit is about 50 mg/cc
- Machining process generates a lot of debris
- Foam has a tendency to slide

Need a new fabrication approach
A different approach is to form the foam liner inside a Au ring which then gets inserted into the hohlraum. This allows for greater flexibility in material choices & seeks to minimize debris inside the hohlraum.

Foam-lined rings laser machined at densities of 20mg/cc $\text{Ta}_2\text{O}_5$
Foam lined rings were shot in a simpler configuration to study basic parameters before switching to full-fledged cryogenic targets.

Results offer convincing evidence of ability of the liner to arrest wall motion.
Laser cut liners look promising for enabling the next set of low-density FLH targets

Insertion of the foam-lined ring into the hohlraum

See poster by R. Heredia et al, Tues
Range of approaches are being developed that offer greater options for materials, microstructures and specialized shaping.

**Using nanoporous-Au + ALD**
M. Biener et al
- Feature size: <1um
- Density range: 10-100 mg/cc

**Using sol-gel casting**
T. Baumann et al
- Feature size: sub-um
- Density range: 10-100 mg/cc

**Nanowire network thru freeze drying**
T. Fear, S Kuchyev et al
- Feature size: ~1um
- Density range: 10-30 mg/cc

**Using 3-D printed template + ALD**
J. Biener et al, also M. Reese et al
- Feature size: ~1um
- Density range: 10-30 mg/cc

**Using CH aerogel + nanoparticles**
J. Williams et al, GA
- Feature size: <1um
- Density range: 10-100 mg/cc

**Using EPD of PS sphere + ALD**
M. Biener et al
- Feature size: <1um
- Density range: 10-100 mg/cc

See talk by T. Bunn et al on Thurs
See talk by M. Biener et al on Tues
See talk by J. Williams et al on Tues
See talk by J. Oakdale et al on Tues
See talk by Tyler Fears et al on Wed
Summary

- Foam liners expand the performance scope of hohlraums
  - Wall motion mitigation is key
  - Allows low gas fills and greater freedom on pulse width design
  - Also can mitigate m-band X-rays, glint, CBET and back-scatter

- Initial data from foam-lined hohlraums is very promising
  - Wall motion is significantly reduced
  - Drive are comparable to Au and LPI is not greater
  - 2-4 keV x-rays reduced by 1.8x

- NIF target fabrication is developing new capabilities
  - Range of foam materials, densities and microstructures

- Series of targets with FLHs are scheduled for shots on NIF to capitalize on these advantages in the coming months