Workshop on the Science of Fusion ignition on NIF
May 22 – May 24, 2012
http://lasers.llnl.gov/workshops/science_of_ignition/

Panel 2: X-ray Transport and Ablation Physics

May 24, 2012: Final Panel Outbriefs Plenary Session

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X-ray transport and ablation physics outbrief

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Issues – X-ray transport and ablation physics panel

• Experimental implosion velocity is lower than baseline calculations (remaining mass higher)
• Baseline calculations reproduce the Dante measurement
  – probably due to cancelling errors – LEH closure error balances excess $T^4$
• Modified simulations with flux multipliers can reproduce velocity and shock timing, but discard $\sim 200$ kJ of drive energy
  – Even with this reduced velocity, yields are over-predicted by 2-5X ($\rho R$ and stagnation pressure low)
  – Is this due to 2/3-D effects or additional 1-D physics?

The panel is concentrating on 1-D physics
Measuring the x-ray drive seen at the capsule surface suggests priorities

<table>
<thead>
<tr>
<th>Measured x-ray drive consistent with observed implosion velocity</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can ablator physics contribute to low yields?</td>
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<tr>
<td>What ablator physics is contributing to reduced coupling?</td>
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<tr>
<td>Why is the measured x-ray drive lower than predicted?</td>
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<tr>
<td>Is the x-ray drive the whole story?</td>
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Improved understanding of ablator physics will be ongoing
Experiments should be developed at LLNL and LLE to measure and understand discrepancies in the 1-D ignition platform performance – some examples:

- Measure hohlraum emission directed at capsule
- Measure LEH closure
- Update hohlraum/LPI model
- Measure x-ray drive at capsule surface
- Confirm updated model reproduces Al drive pressure
- Measure ablation pressure of known drive into GDP
- Evaluate other ablator candidates (Be, B₄C,…)

Potential Experiments

- Confirm/revise NLTE ablator model

View Factor

Crystal Ball (Al)

Crystal Ball (GDP)

Crystal Ball (Alt Abl)

Ablator Opacity (Omega)

On to mix…
## X-ray Transport and Ablation Physics

Determine the x-ray drive at the capsule ablation surface

### Underlying physics to be addressed

- Ablator physics and hydrodynamic coupling
- What is the x-ray drive seen by the capsule $I_{\text{rad}}(t, \lambda, \Omega)$
- Relying on simulations to relate Dante to capsule drive.

### Learned from Recent Experiments

- For baseline calc $V_{\text{sim}} > V_{\text{exp}}$, but $P_{\text{rad,sim}} \sim P_{\text{rad,Dante}}$
- Closure of LEH in sim compensates excess $T^4$.
- Using measured LEH closure reduces drive discrepancies.
- Drive flux multipliers($t$) can be specified to match data, discarding 200 kJ.
- Measured ablation rates strongly suggest reduced drive.

### Research Directions

- Separate the physics issues at the capsule surface
  - Viewfactor (scheduled)
  - Crystal Ball (scheduled)
  - X-ray spectrum through keyhole
  - Reemission spectrum from high Z target

### Outcome and Potential Impact

- Prioritize next steps
- Is the drive consistent with measured velocity and mass remaining?
- Foundation for understanding other physics
# X-ray Transport and Ablation Physics

Understand ablator issues that could impact yield

## Underlying physics to be addressed

- Response of ablator to x-ray drive and impact on yield
- Is there a “5th” shock?
- Are estimated RT growth factors correct?
- Is there ablator preheat that is not accounted for?
- Is the Atwood number correct at interfaces?

## Learned from Recent Experiments

- Implosions have 2-5X lower neutron yields than reduced drive simulations
- Low stagnation pressure
- CEA OMEGA experiments match uniform but not graded doping

## Research Directions

- “Fifth” shock – Crystal Ball
- Self-consistent EOS/Opacity NLTE models; multi-code comparisons
- Halffraum driven-planar experiments
- Plasma profiles near ablation surface determine ablative RT growth – \( 4\omega \) and x-ray TS
- Ablator microstructure seeding of instabilities

## Outcome and Potential Impact

- Basis for improved ignition designs
- Basic understanding and possible mitigation
## X-ray Transport and Ablation Physics

### Why is x-ray drive different than predicted

<table>
<thead>
<tr>
<th>Underlying physics to be addressed</th>
<th>Learned from Recent Experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>• X-ray radiation generation and transport in the hohlraum, including</td>
<td>• LEH does not close as much as predicted</td>
</tr>
<tr>
<td>capsule blow-off</td>
<td>• Indications that Au distribution is different than simulated</td>
</tr>
<tr>
<td>• Why does the LEH close more slowly than predicted?</td>
<td>• Reduced flux simulations require discarding 200 kJ</td>
</tr>
</tbody>
</table>

### Research Directions

| • Measure time-dependent LEH closure                                    | Outcome and Potential Impact                                                                    |
| • x-ray transport in the blowoff plasma-reemission, keyhole target    | • Basis for improved implosion hydrodynamics models                                             |
| • x-ray conversion/opacity/albedo with 20 ns drive                     | • Basic understanding and possible mitigation                                                   |
| • How effective is the gas-fill tamping? Is the Au where it is predicted to be? Is thermal transport correct? – $4\omega$ and x-ray Thomson scattering |                                                                                               |
| • See also Panel 1                                                     |                                                                                                 |
# X-ray Transport and Ablation Physics

What ablator issues could significantly reduce x-ray-capsule coupling?

<table>
<thead>
<tr>
<th>Underlying physics to be addressed</th>
<th>Learned from Recent Experiments</th>
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<tbody>
<tr>
<td>• What ablator issues could reduce x-ray-capsule coupling?</td>
<td>• Contingent on capsule drive measurement</td>
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<tr>
<td>• Is Carbon the problem?</td>
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<tr>
<td>• Importance of NLTE effects</td>
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</table>

## Research Directions

- ConA Be implosions, Be shock timing – also need Be EOS/Opacity, Crystal ball with Be,
- Ongoing Carbon EOS/Opacity measurements and models
- Thermal transport in the ablator
- Simple implosion experiment to validate integrated codes

## Outcome and Potential Impact

- Basis for improved ignition designs
- Basic understanding and possible mitigation
How do we address it (the path to success)? – Split the problem at the capsule surface

• The first step is to assess whether the drive at the capsule surface is consistent with the measured velocity.
  – Measure drive at the capsule
    - Viewfactor, including drive spectra measurement
    - Crystal ball (A/B comparisons with different ablators)
    - Direct spectral measurement through keyhole, with and without capsule
    - Ablation rate measurement - halfraums
    - Time-dependent spectroscopy of target reemission
    - Planar packages at different locations on hohlraum walls to map drive
  – Time-dependent measurement of the LEH closure
    - Could be part of the Viewfactor with GXD in the Polar DIM
How do we address it (the path to success)? II

- The next step depends on the results of radiation measurement
- If measured radiation/coupling at the capsule substantially explains the velocity
  - Highest priority becomes understanding why the yield is still low
  - Understand where the missing energy went
    - LPI, x-ray transport in the blowoff plasma, x-ray conversion/opacity/albedo with 20 ns pulses, etc.
    - How effective is the gas-fill tamping? Is the Au where it is predicted to be? – need 4\(\omega\) and x-ray Thomson scattering
  - Continue development of ablator NLTE, etc. models to explain remaining discrepancies
  - Why does the LEH close more slowly than predicted
    - Backscattered light heating LEH region
    - X-ray drive is low
    - Integrated simulations don’t have full hardware
• Ablator issues that could affect the yield
  – A fifth shock – shock velocity not measured at late times
  – Plasma profiles, ablation velocity, near ablation surface – determine ablative RT growth
  – Atwood number at the ablator/ice interface, other interfaces?
  – Preheat – missing energy?
  – 3-D seeding of instabilities
How do we address it (the path to success)? IV

- If measured radiation does not explain the velocity, the problem is likely to be the ablator
  - Is Carbon the problem? Crystal ball with Be, ConA Be implosions, Be shock timing – also need EOS/Opacity
  - Ongoing Carbon EOS/Opacity
  - Thermal transport in the ablator
What is uncertain? (where are we?)

- What is the relationship between the Dante measurement and the radiation seen by the capsule
  - Radiation distribution in the hohlraum
- LEH closure time history is not known, time-integrated measurements show it doesn’t close as much as predicted
- Post-processed simulations with measured LEH closure reduce the drive discrepancies
- Ablator response to the drive:
  - EOS/Opacity, NLTE effects, hot electrons
  - Radiation transport effects in flowing ablated material
- Hohlraum EOS/Opacity, etc.
- Preheat (electron, radiation)
- Accuracy of the remaining mass measurements
- Shock history after VISAR blanking