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

Panel 2 Co-Leads:

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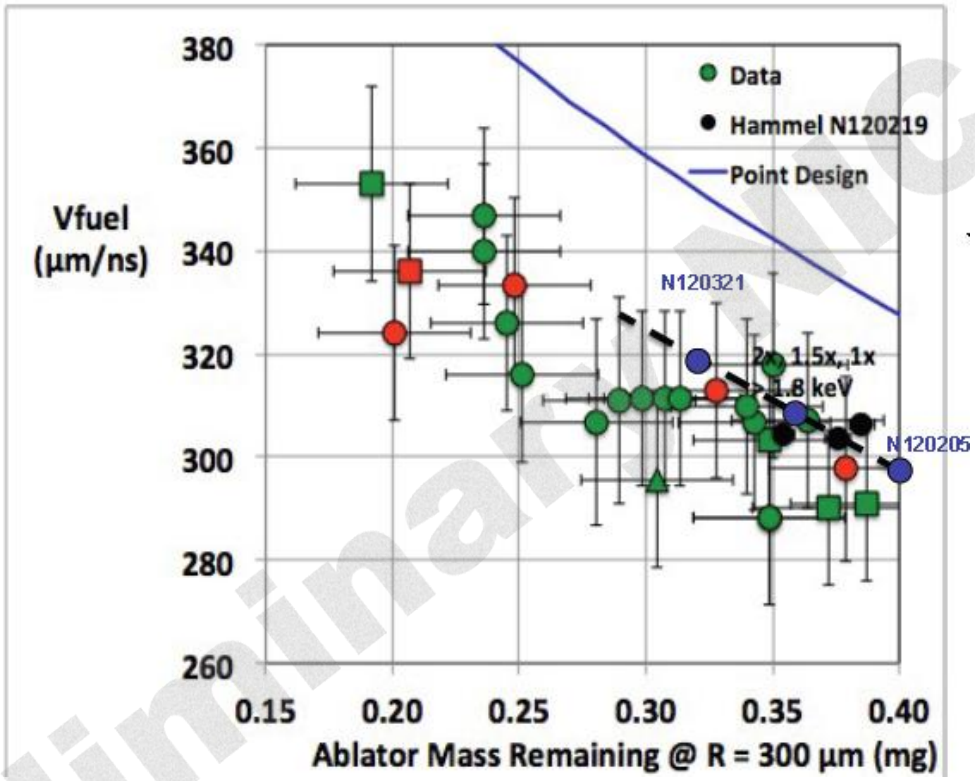
LLNL-PRES-560534

X-ray transport and ablation physics outbrief



Hammer, Jim; Meyerhofer, David; Casner, Alexis; Fernandez, Juan; Giuliani, John; Hockaday, Mary; Hohenberger, Matthias; MacLaren, Stephan; Mancini, Roberto; Murphy, Tom; Myatt, Jason; Olson, Rick; Hill, Edward; Ampleford, David

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 ~200 kJ of drive energy**
  - **Even with this reduced velocity, yields are over-predicted by 2-5X (ρR 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

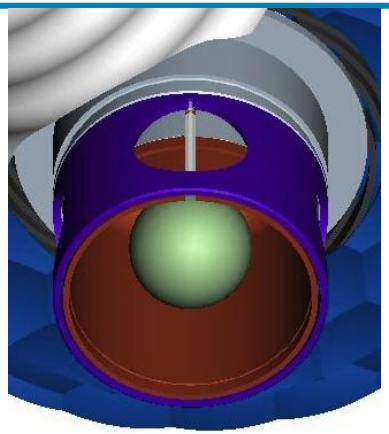
Measuring the x-ray drive seen at the capsule surface suggests priorities

Measured x-ray drive consistent with observed implosion velocity	Yes	No
	Can ablator physics contribute to low yields?	What ablator physics is contributing to reduced coupling?
	Why is the measured x-ray drive lower than predicted?	Is the x-ray drive the whole story?

Improved understanding of ablator physics will be ongoing

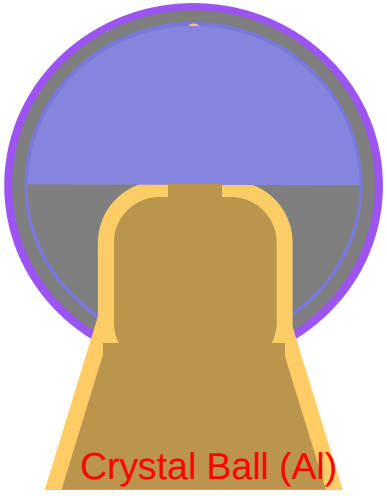
Experiments should be developed at LLNL and LLE to measure and understand discrepancies in the 1-D ignition platform performance – some examples:

- Measure hohlraum emission directed at capsule
- Measure LEH closure
- Update hohlraum/LPI model



View Factor

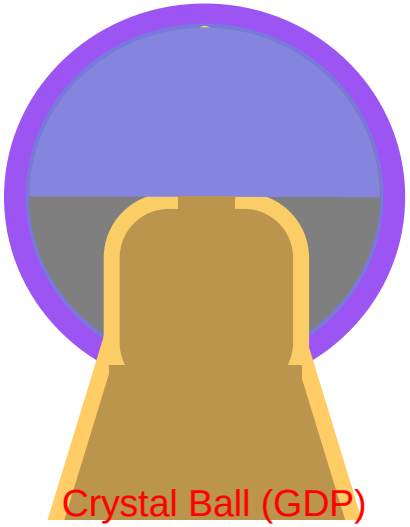
- Measure x-ray drive at capsule surface
- Confirm updated model reproduces Al drive pressure



Crystal Ball (Al)

Potential Experiments

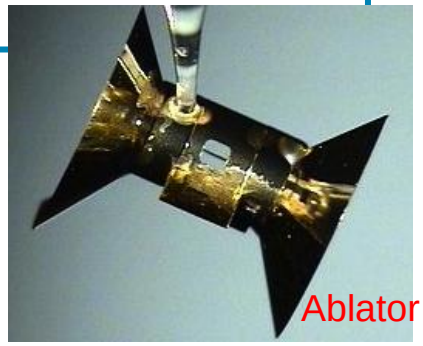
- Measure ablation pressure of known drive into GDP
- Evaluate other ablator candidates (Be, B_4C,…)



Crystal Ball (GDP)
Crystal Ball (Alt Abl)

On to mix…

- Confirm/revise NLTE ablator model



Ablator Opacity (Omega)

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 $I_{rad}(t, \lambda, \Omega)$
- Relying on simulations to relate Dante to capsule drive.

Learned from Recent Experiments

- For baseline calc $V_{sim} > V_{exp}$, but $P_{rad,sim} \sim P_{rad,Dante}$
- 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

UR LLE

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
- Halfraum driven-planar experiments
- Plasma profiles near ablation surface determine ablative RT growth – 4ω 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

Underlying physics to be addressed

- X-ray radiation generation and transport in the hohlraum, including capsule blow-off
- Why does the LEH close more slowly than predicted?

Research Directions

- Measure time-dependent LEH closure
- x-ray transport in the blowoff plasma-reemission, keyhole target
- x-ray conversion/opacity/albedo with 20 ns drive
- How effective is the gas-fill tamping? Is the Au where it is predicted to be? Is thermal transport correct? – 4ω and x-ray Thomson scattering
- See also Panel 1

Learned from Recent Experiments

- LEH does not close as much as predicted
- Indications that Au distribution is different than simulated
- Reduced flux simulations require discarding 200 kJ

Outcome and Potential Impact

- Basis for improved implosion hydrodynamics models
- Basic understanding and possible mitigation

X-ray Transport and Ablation Physics

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

Underlying physics to be addressed

- What ablator issues could reduce x-ray-capsule coupling?
- Is Carbon the problem?
- Importance of NLTE effects

Learned from Recent Experiments

- Contingent on capsule drive measurement

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 4ω 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

How do we address it (the path to success)? III

- **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