Demonstration of Shock-Timing Techniques for Ignition Targets

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Summary

OMEGA experiments have demonstrated the technique for timing shock waves on the NIF

- Ignition targets use a precisely timed sequence of shocks to condition the capsule.
- These will be timed to ±50 ps using optical diagnostics in surrogate targets.
- Various issues associated with this technique were studied and resolved with OMEGA experiments.

Cryogenic hohlraum and direct-drive target experiments show this technique meets NIF requirements.
The success of these experiments is the result of collaboration of four laboratories

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OMEGA Target Fab
LLNL Shock Physics
SNL Target Fab
GA Target Fab
Motivation

Ignition targets use precisely timed multiple shocks to approximate an isentropic compression.
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Tuning experiments will adjust the drive to produce optimal timing: a tight sequence of shock arrivals.

- First three shocks ±50 ps
- Fourth shock ±100 ps
Meet these requirements with separate target types and campaigns.
Surrogate Targets

Shock-timing measurements in direct- and indirect-drive targets use re-entrant cones

**Direct-drive configuration**
- Drive beams
- CH shell
- Au cone
- Liquid D₂

**Indirect-drive configuration**
- Keyhole target
- Be shell
- Au cone
- Liquid D₂

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### Capsules IET

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*Velocity Interferometer System for Any Reflector
Various issues were resolved to demonstrate the shock-timing technique for NIF

**Issues**
- Surrogacy to ignition targets
- Ionization blanking of the window
- Secondary hohlraum
- Effect of D\textsubscript{2} column
- Convergence effects

Hard x rays from laser spots can blank diagnostic window
The velocity interferometer system for any reflector (VISAR) detects Doppler shifts to measure velocity.

\[ \Delta \Phi(t) = \frac{4\pi}{\lambda_0} n \int_{t}^{t+\tau} U_s(t') dt' \]

VISAR has time resolution <30 ps and a velocity precision of ~1%.
Shock velocities are readily measured in transparent targets but “blanking” can be a problem.

![Diagram showing shock waves and measurements](image)

*Velocity Interferometer System for Any Reflector*
Halbraum experiments were used to select window material and optimize target design.

- Liquid $D_2$
- M-band
- Quartz “anvil”
- VISAR

**Developments**

- Quartz windows
  - high band gap
  - optical quality
  - strong/resilient

- Pellicle as spatial fiducial

- Small aperture; large distance to window
OMEGA Experiments

Open line-of-sight targets mimic the effect of NIF laser spots in keyhole targets

X-ray source area of concern

Low-angle beams

9 OMEGA beams at 60°

Quartz window

Aperture

3.5 mm

VISAR

10-μm Au

Be-Cu-Be ablator

E15114c
Stacked-pulse experiments show that neither instantaneous nor integrated flux is expected to be problematic.
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Window test; No D₂

![Graph showing intensity and distance over time for window test with no D₂.](image)

- **Intensity (TW/cm²):**
  - Y-axis from 0 to 250
  - Intensity values include 0, 50, 100, 150, 200, 250

- **Time (ns):**
  - X-axis from 0 to 15
  - Time values include 0, 5, 10, 15

- **Distance (μm):**
  - Y-axis from -500 to 500
  - Distance values include 0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500

- **Markers:**
  - Window
  - Ablator/aperture
  - OMEGA
  - NIF

![Graph showing time vs. distance for an ablator/aperture test.](image)
Warm hohlraum experiments with NIF-sized re-entrant cones demonstrate success at $T_{\text{rad}} = 180$ eV.
Liquid D₂ tuning experiments are good surrogates for ignition designs. D₂ to DT corrections are known and minor.
VISAR measurements were made in targets filled with liquid deuterium and driven at 135 eV.

VISAR and self-emission data show identical features. This meets NIF shock timing requirements.
OMEGA hohlraums produce “hard” x-ray fluxes that exceed those expected on the NIF.

OMEGA-scale hohlraums have higher laser-spot intensities than the NIF.
Windowless targets will make it possible to time the fourth rise (compression wave) at $>220$ eV
Various issues were investigated to demonstrate the shock-timing technique.

Issues
- Surrogacy to ignition targets ✔
- Ionization blanking of window ✔
- Secondary hohlraum ✔
- Effect of D₂ column ✔
- Convergence effects
The timing of multiple convergent shocks is studied using directly driven spheres with re-entrant cones.

- Cannot produce multiple shocks and the requisite radiation temperature in hohlraums on OMEGA.
Three spherically convergent shocks were observed in directly-driven cryogenic spherical targets.
The temporal features in self-emission data confirm shock-timing observed in VISAR data.
Summary/Conclusions

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