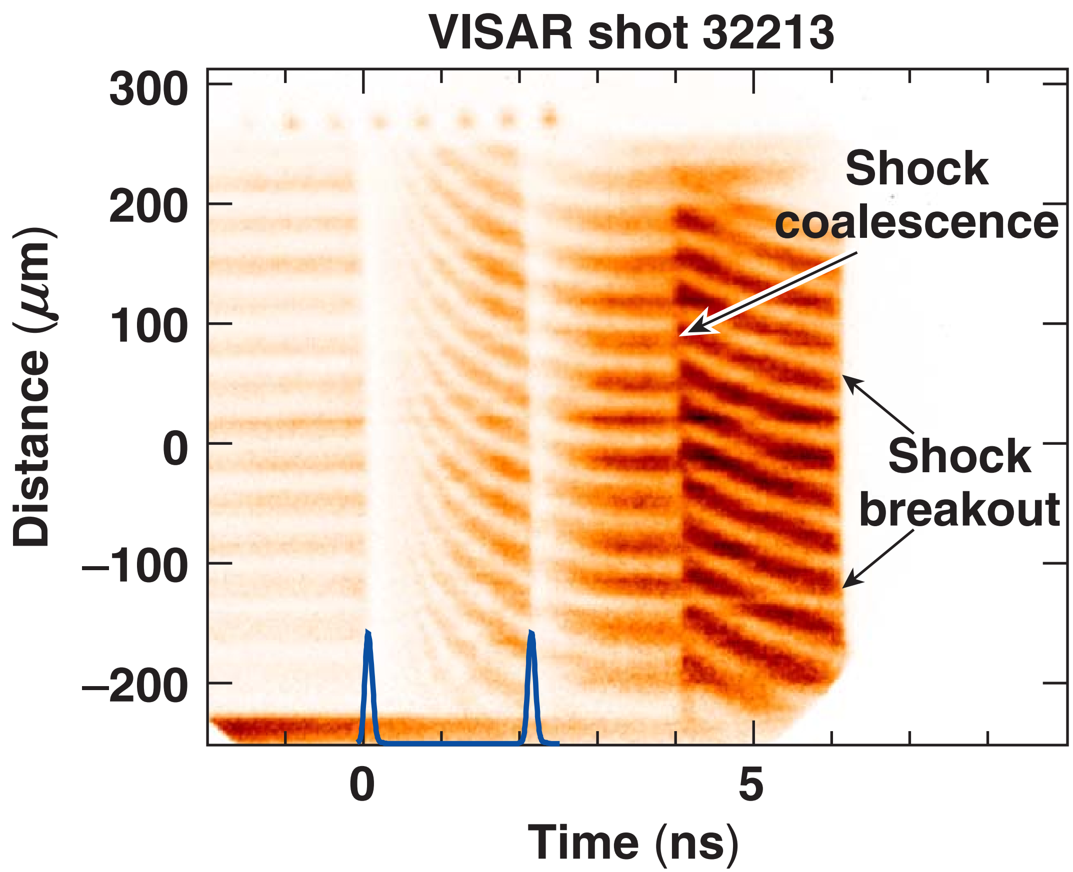
Shock-Timing Experiments in Planar Targets



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Division of Plasma Physics
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Summary

We are measuring shock timing to the accuracies required for ICF ignition

- Multiple shock waves condition ICF capsules before implosion; accurate timing of these shocks is critical to target performance.
- The OMEGA laser is used to develop shock-timing techniques for OMEGA experiments and the National Ignition Campaign.
- In experiments with multiple shocks in CH and cryogenic deuterium targets we measure
  - shock velocities to 3% and
  - shock coalescence and breakout times with better than < 50 ps accuracy.
- These events produce unambiguous features in the data that can be resolved with accuracies that exceed the requirements for ignition targets.

Collaborators

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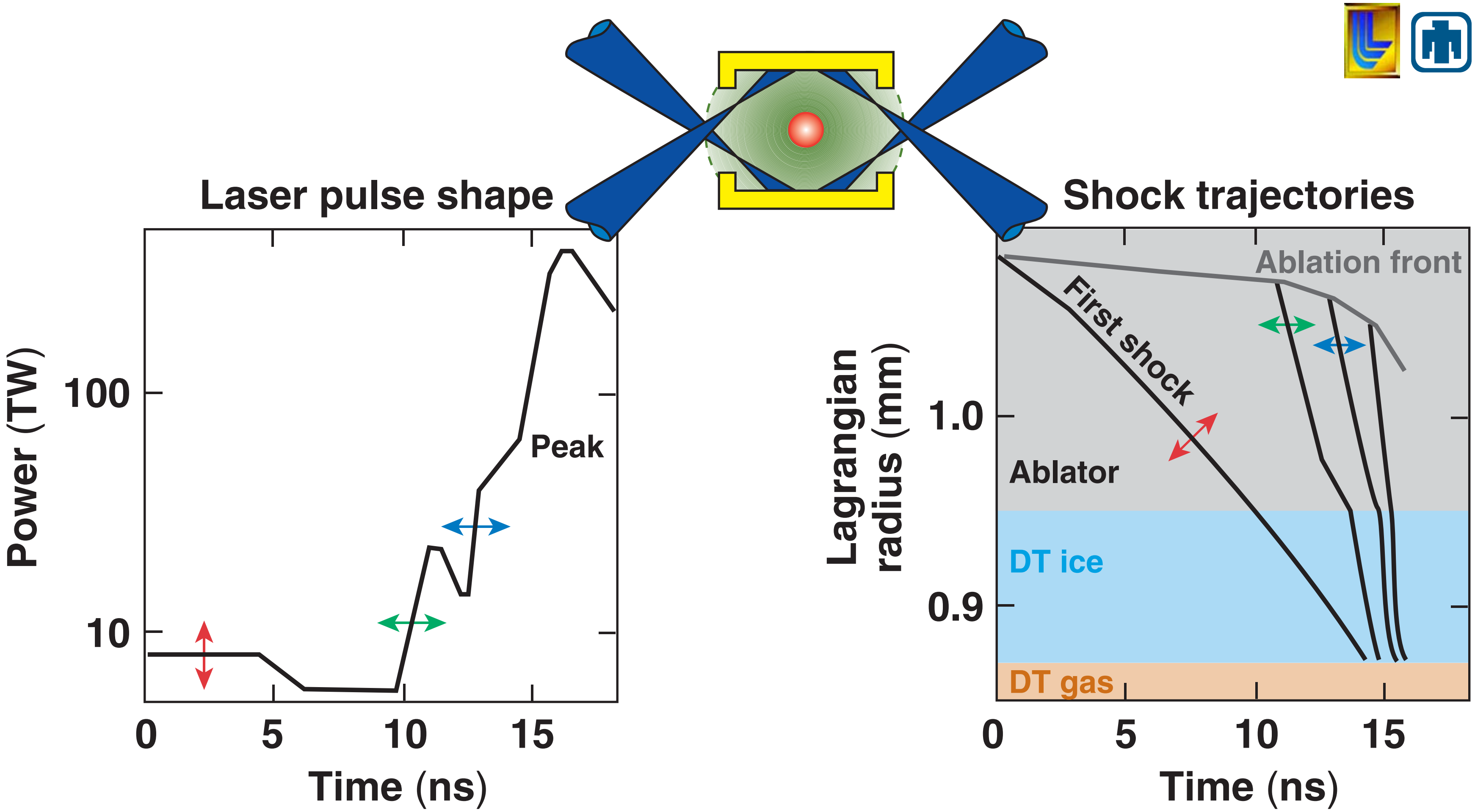
Indirect-drive ignition capsules use four shocks to achieve ignition



– First three shocks ±50 ps
– Fourth shock ±100 ps

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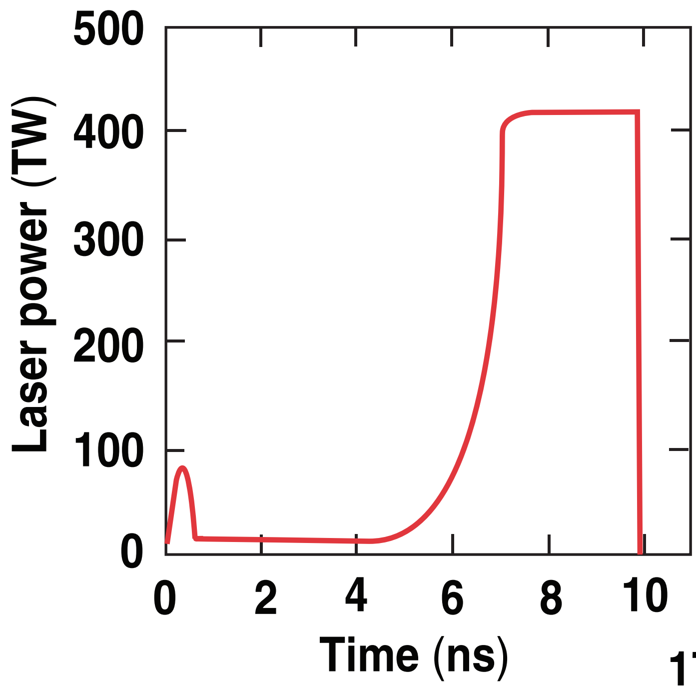
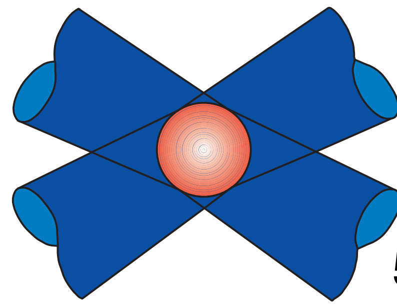
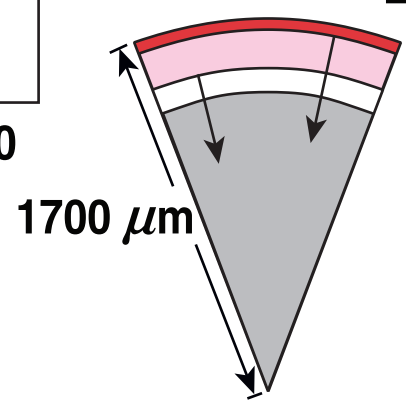
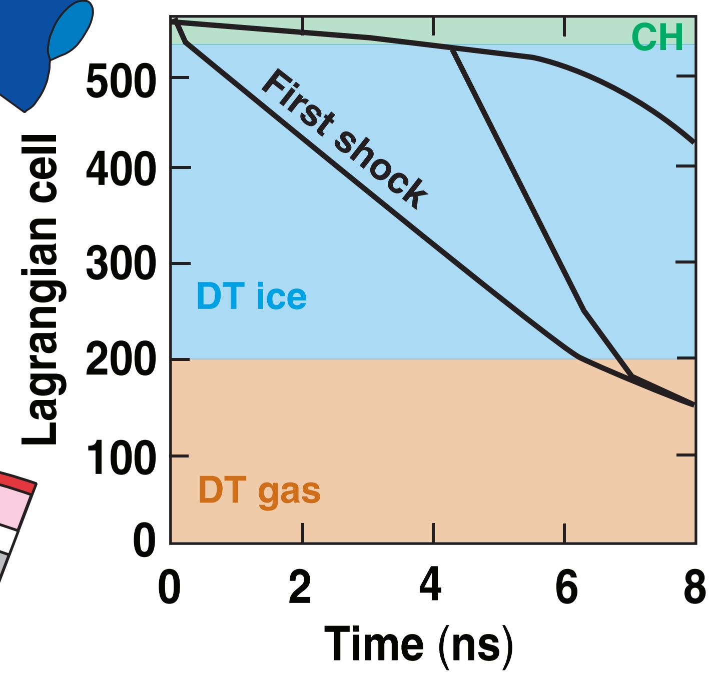
Direct-drive capsules use two shocks to achieve ignition









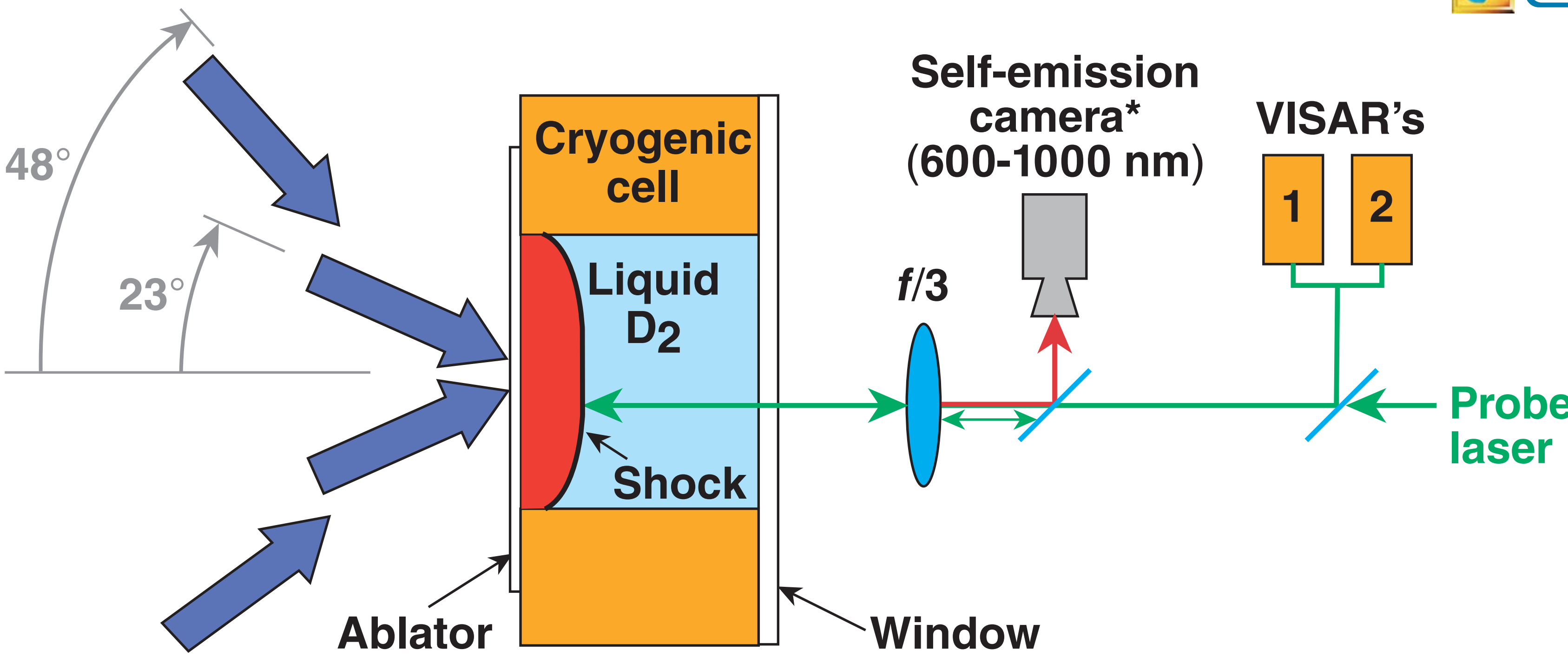
Time two shocks to ±150 ps

E14088

We use proven diganostics to observe and time laser-driven shockwaves

- Planar targets allow a study of shock timing in cryogenic D_2.
  - 1-D approximation is good for the initial shocks
- Optical diagnostics such as VISAR and self-emission detect shocks with the high accuarcy needed for EOS studies.
- These will be used to provide shock velocity (to $<3\%$) and coalescence data (<50 ps) for the first three shocks.
- X-ray radiography will be required to measure the timing and trajectory of the final shock.
- OMEGA experiments have demonstrated these techniques to observe multiple shocks.

Shock velocity and self-emission in laser-driven shock experiments are measured optically

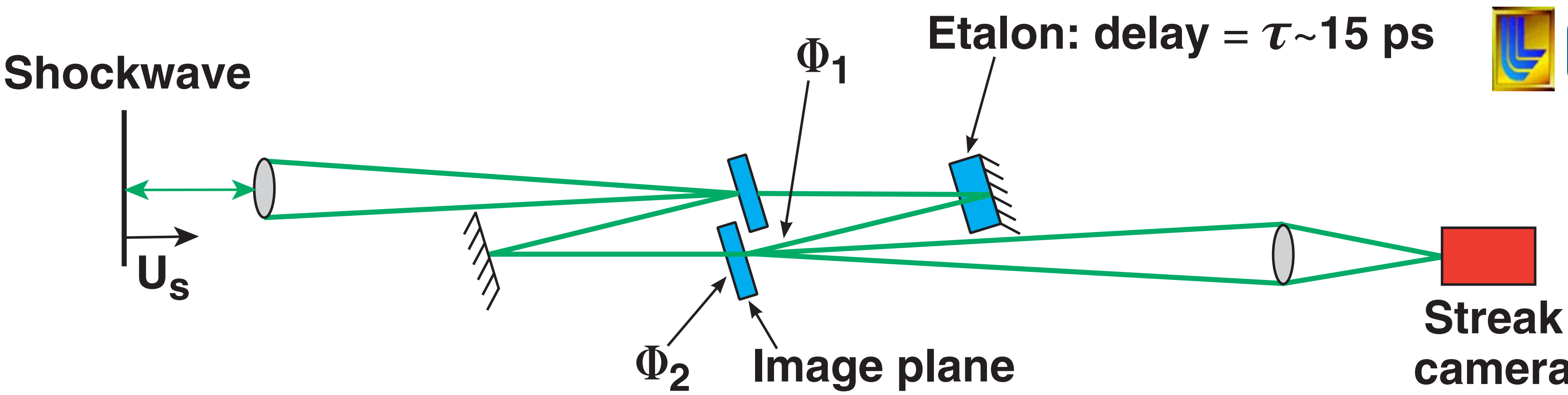


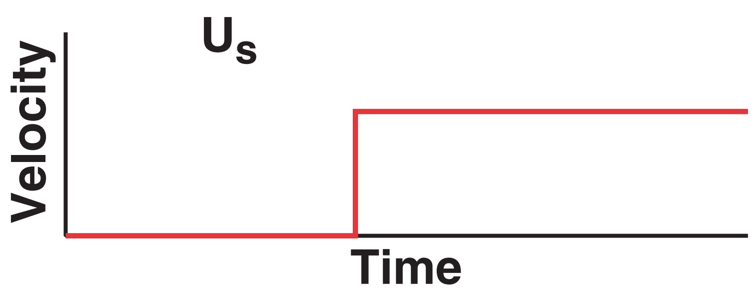
At ICF pressures, shocks are hot (> 5,000°K), steep, and overdense. They emit and reflect optical wavelengths.

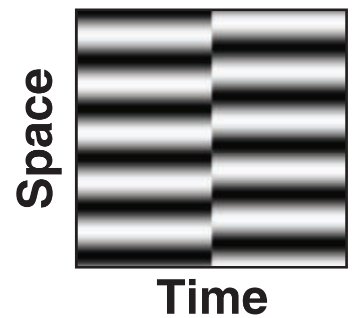
E12812e

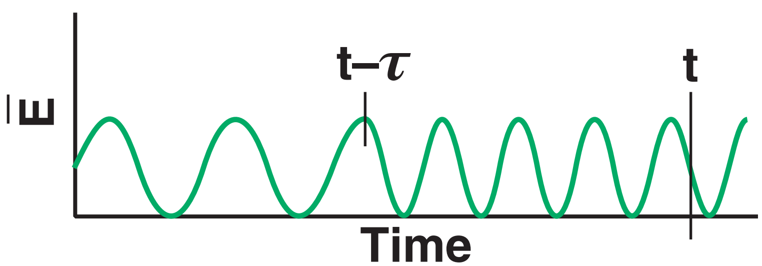
*J. Ortel (LANL)

The velocity interferometer system for any reflector (VISAR) detects Doppler shifts to measure velocity







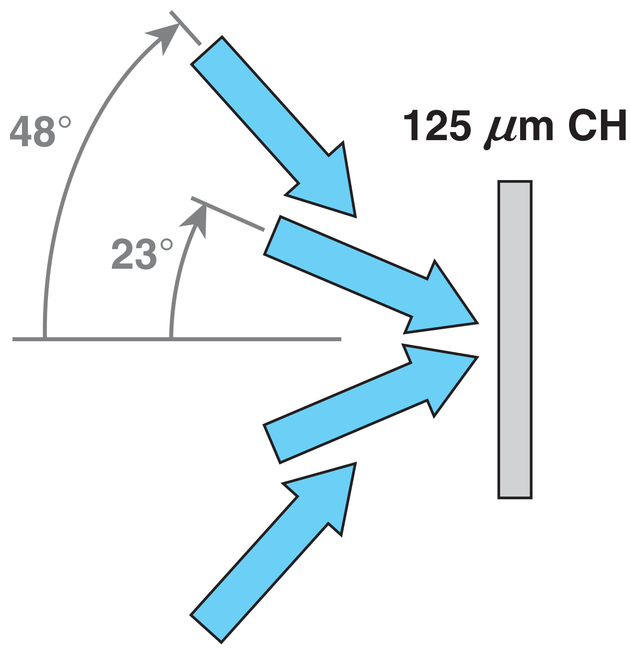


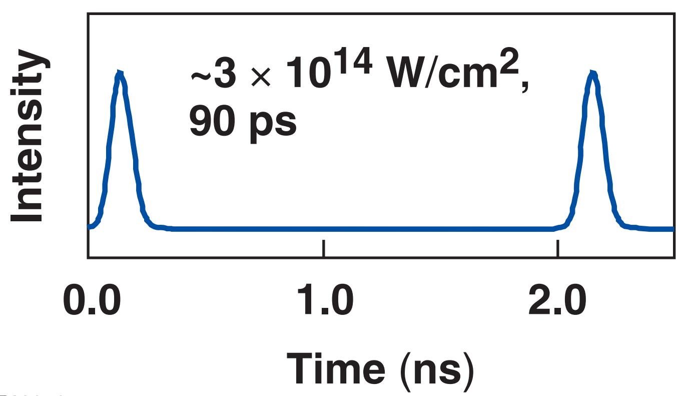
$$\Delta\Phi(t) = 2\pi c\left[\int_0^t \frac{1}{\lambda(t')}dt' - \int_0^{t-\tau} \frac{1}{\lambda(t')}dt'\right]$$

$$= \frac{4\pi}{\lambda_0} n \int_{t-\tau}^{t} U_s(t')\,dt'$$

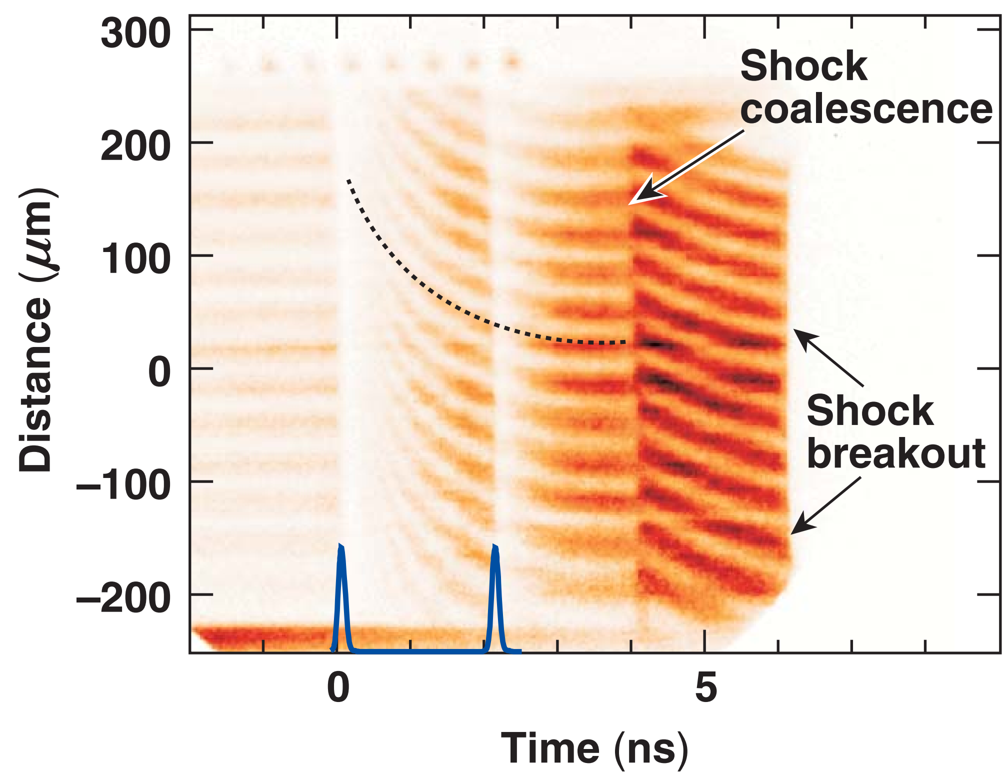
E11467a

Shock timing is studied using two pulses and CH targets



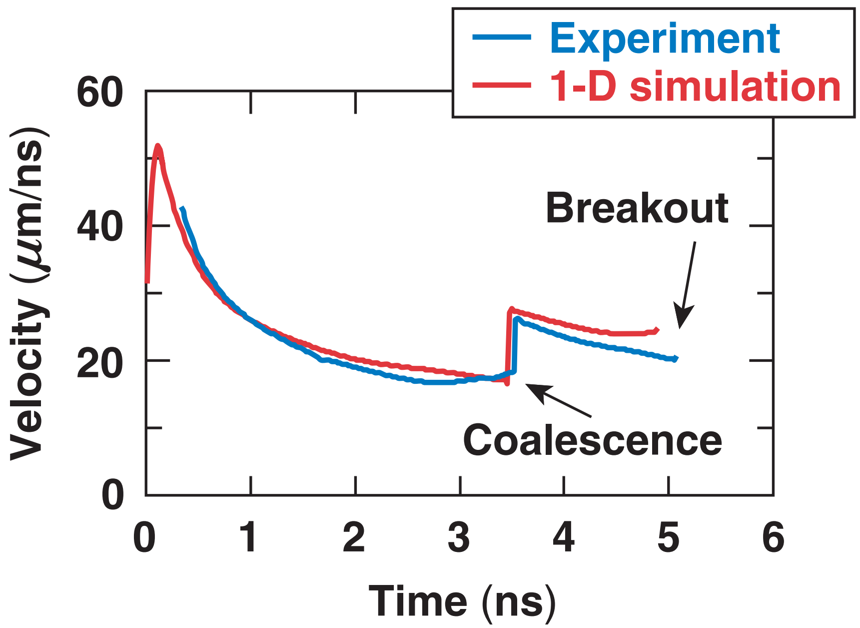


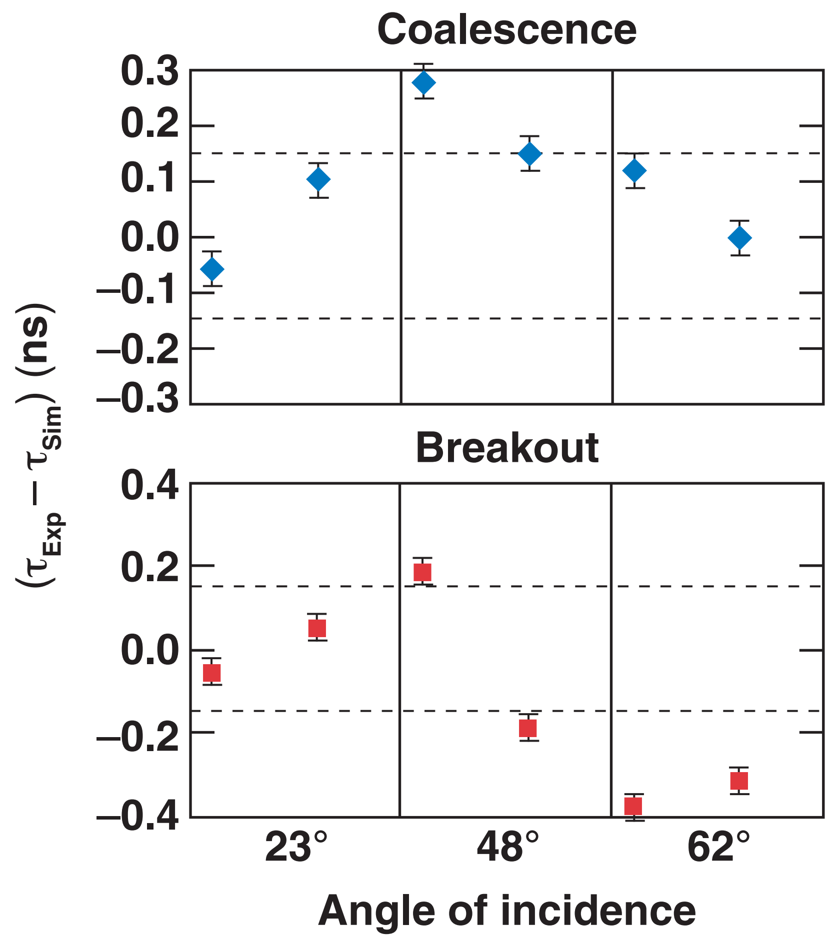
VISAR shot 32213



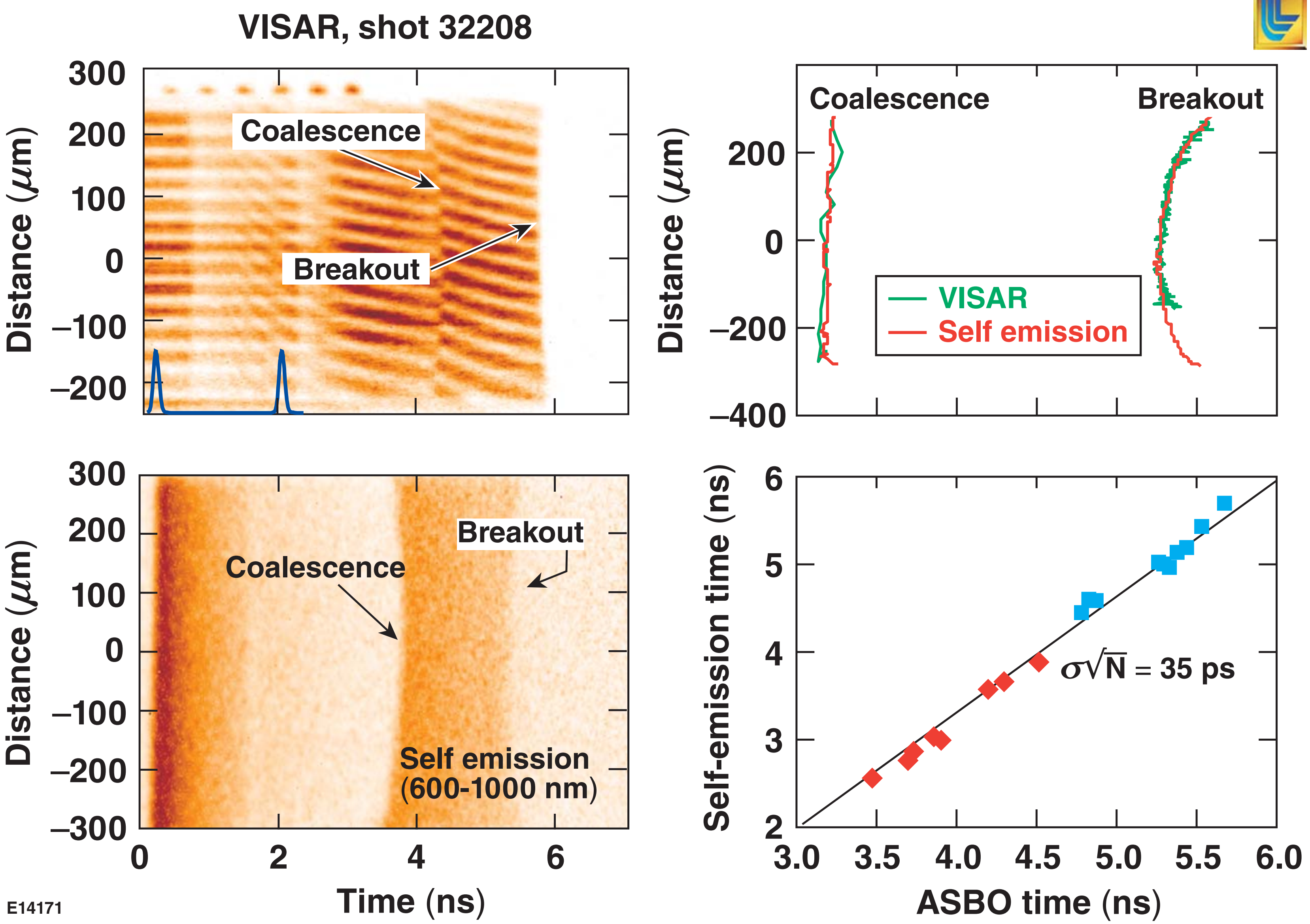
Measure coalescense and breakout to $\lesssim$ 30 ps

1-D simulations, including a ray tracing routine, are in good agreement with double-shock experiments in CH





Simultaneous VISAR and self-emission profiles provide corroborative data



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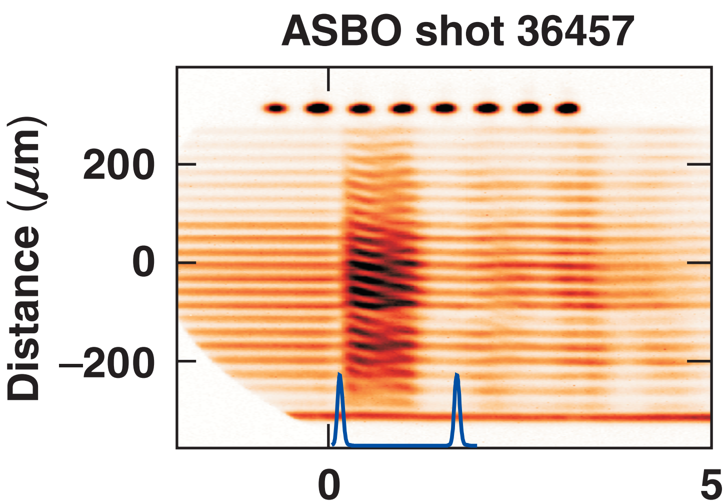
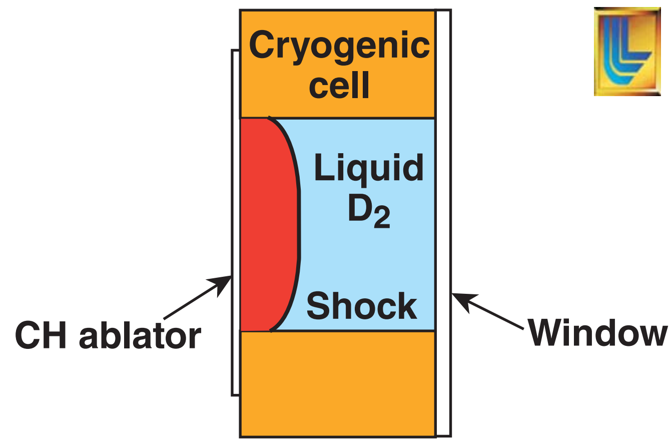
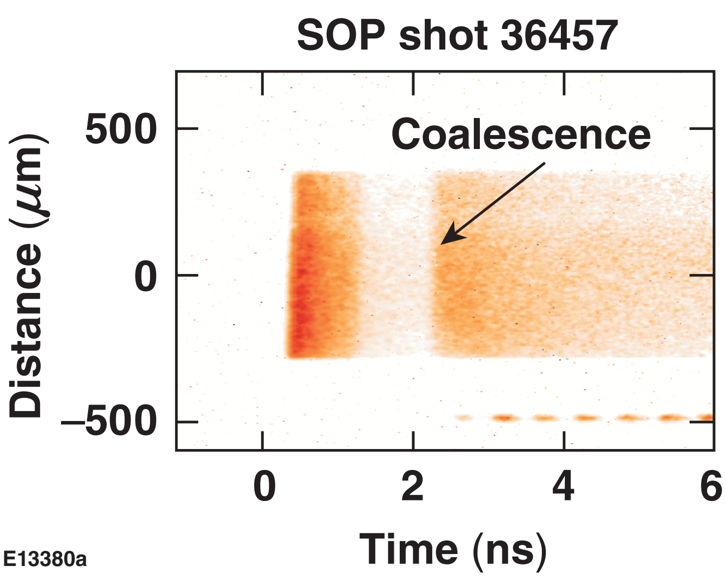
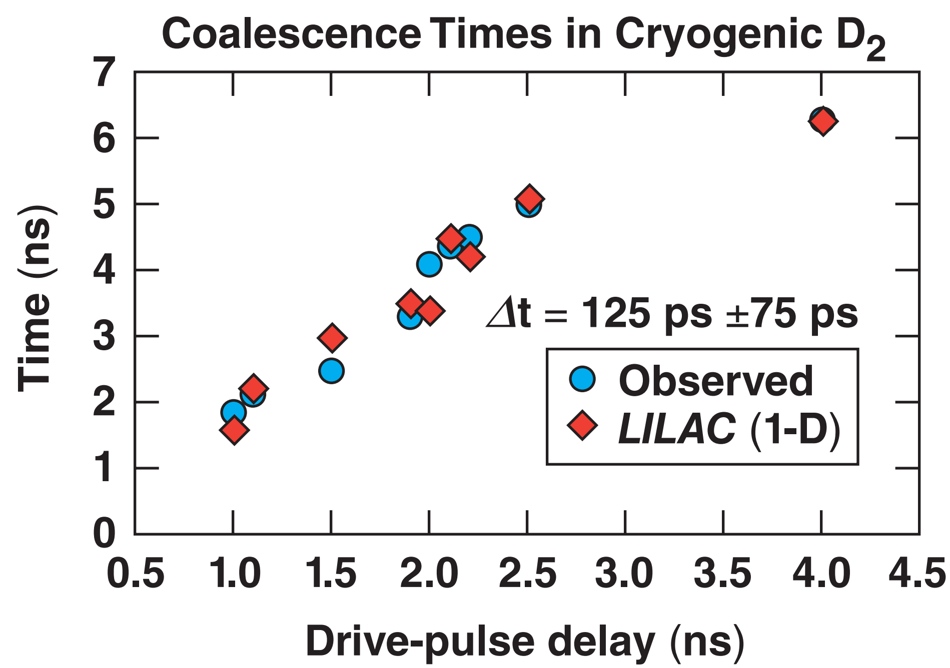
Cryogenic D_2

Simulations of shock coalescence in cryogenic D_2 agree well with self-emission measurements



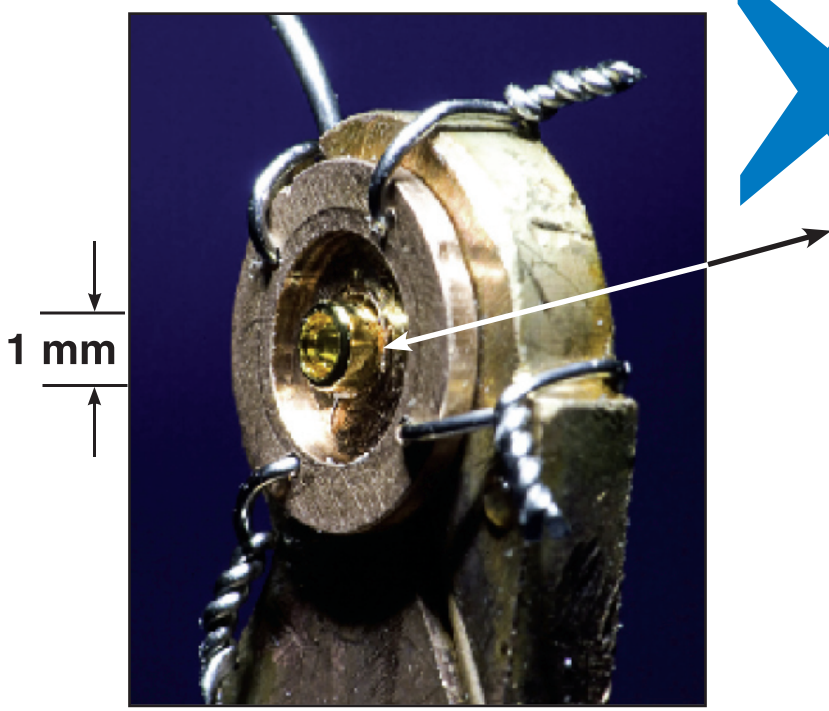


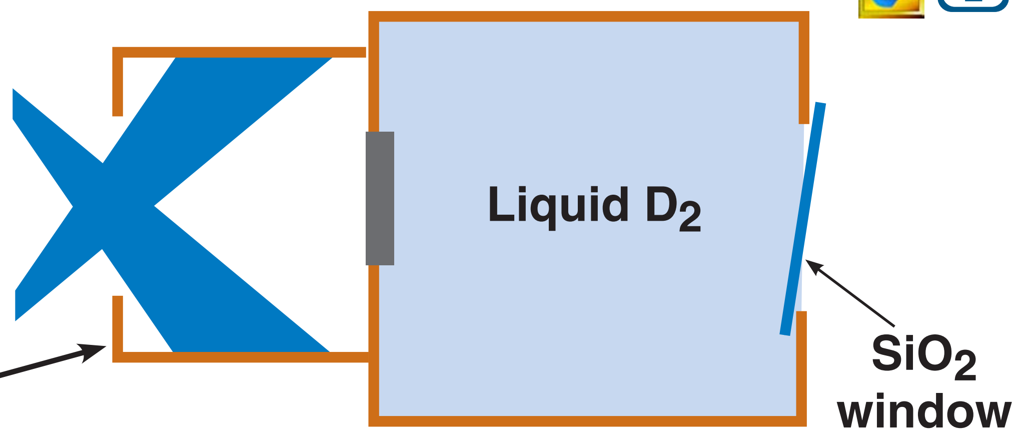


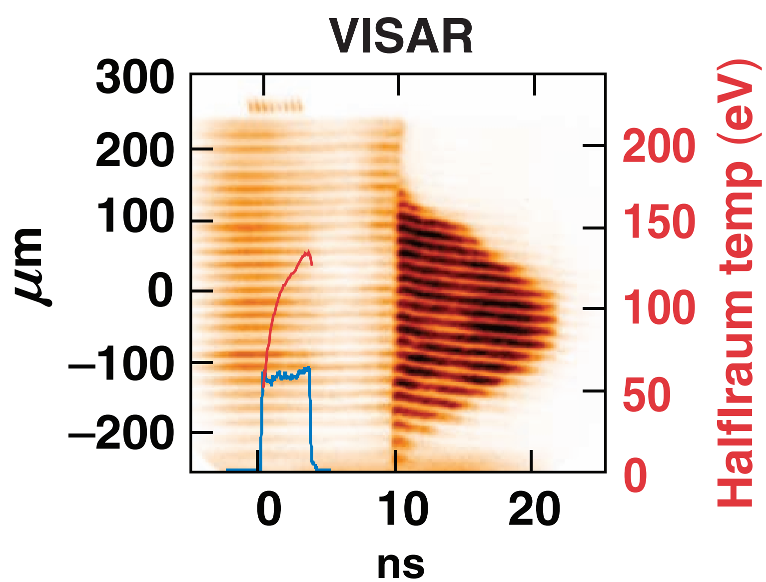


E13380a

Initial indirect-drive shock-timing experiments were performed on OMEGA

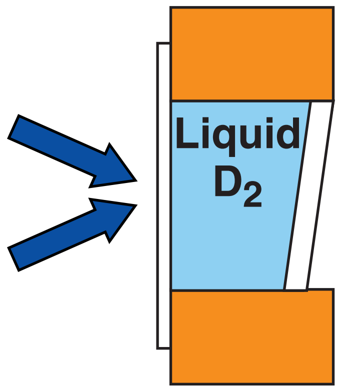


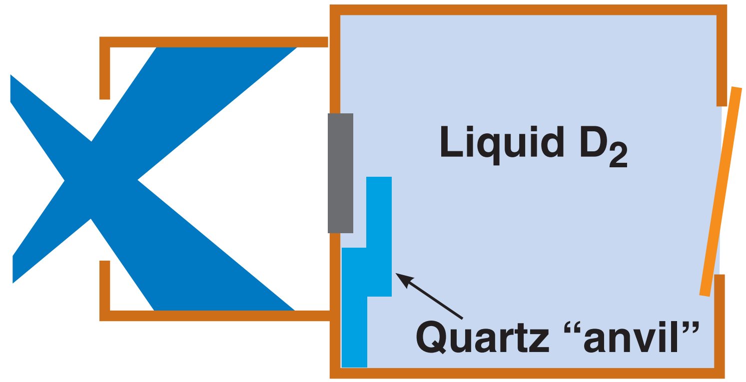


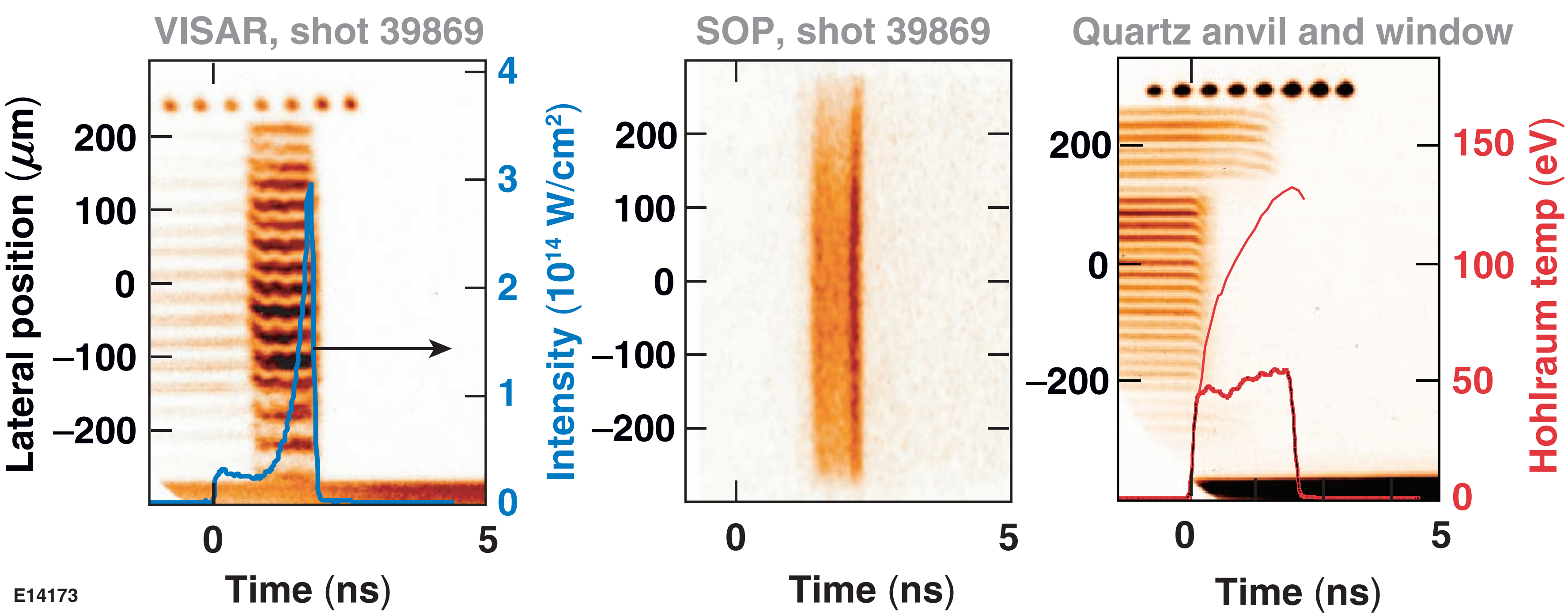


E14172

We have observed ionization "blanking" of windows in high-intensity experiments

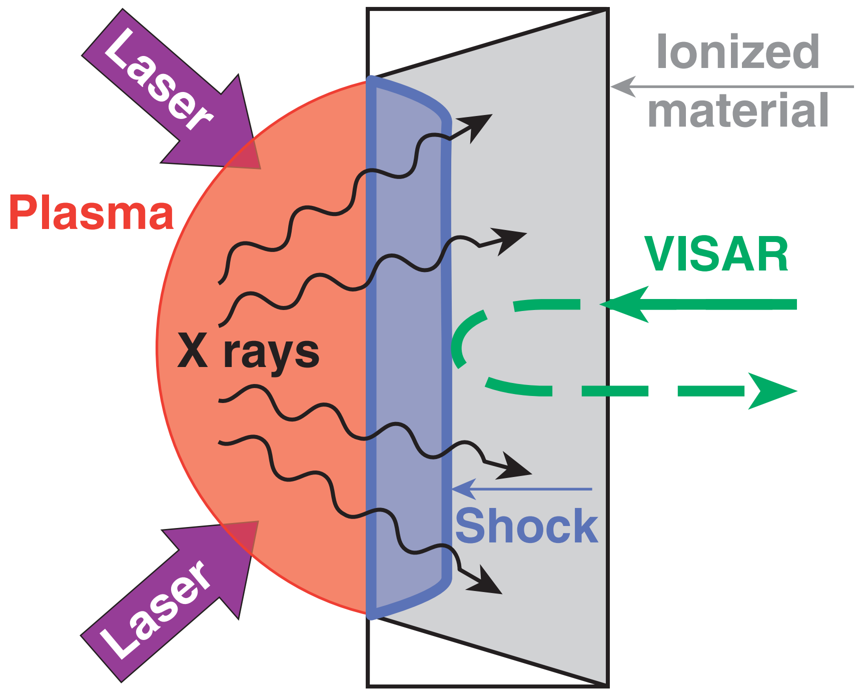


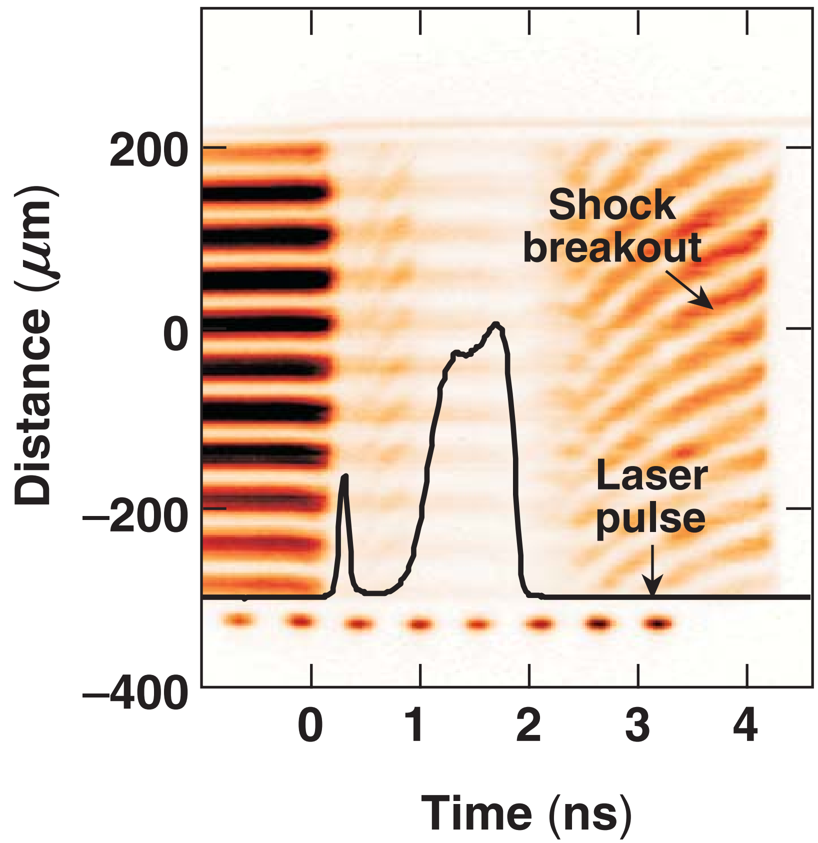




E14173

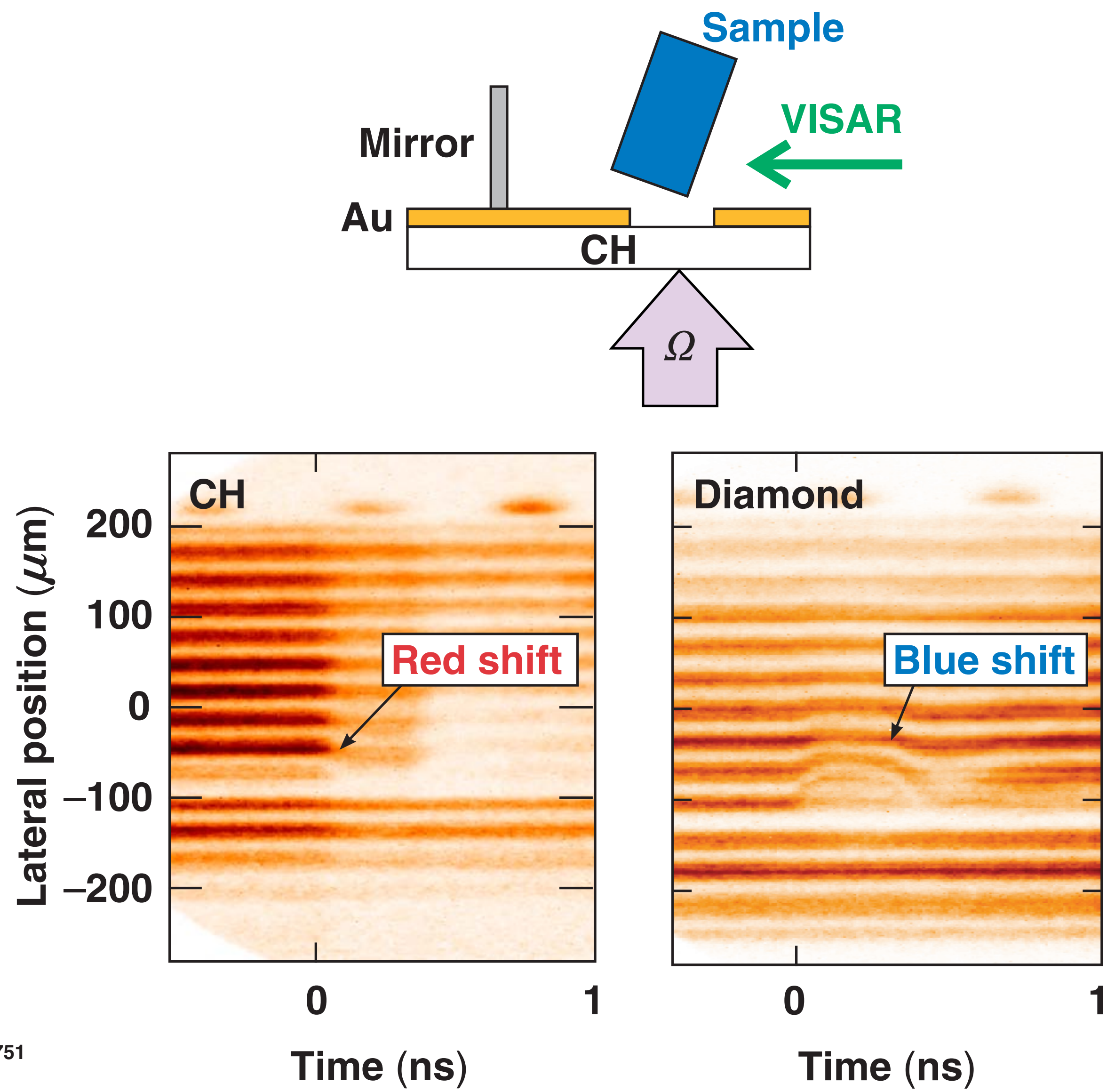
Ionization by x-rays can limit diagnosis of shock velocity during the laser pulse





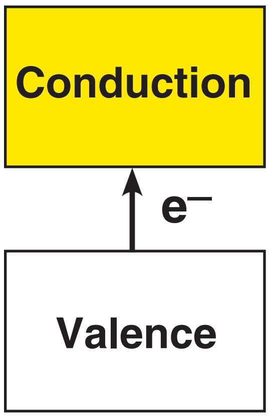
E12366d

A strong absorption and phase shifts are measured in x-ray ionized polystyrene and diamond



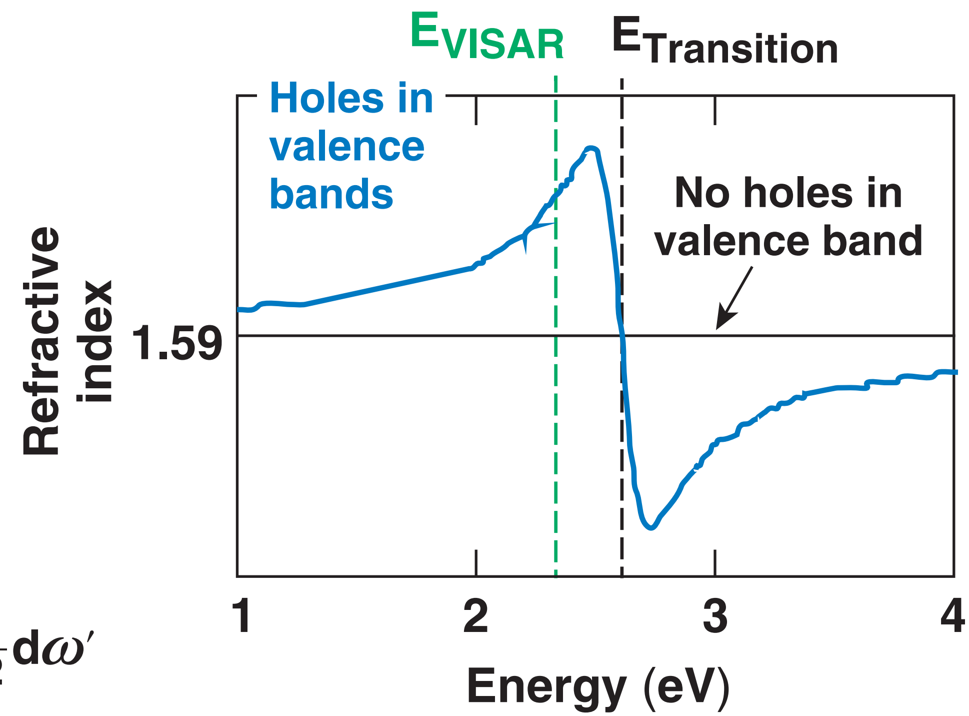
Shot 36456, 38786, 40751
E14154

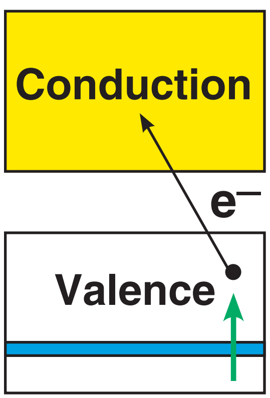
Ionization by x-rays creates "free" electrons and in some materials optical transitions in the valence band



$$n \approx \sqrt{n_r^2 - \frac{\omega_p^2}{\omega_0^2 + \nu^2}}$$

Ionization: $\omega_p \uparrow$
dn/dt < 0 → blue shift





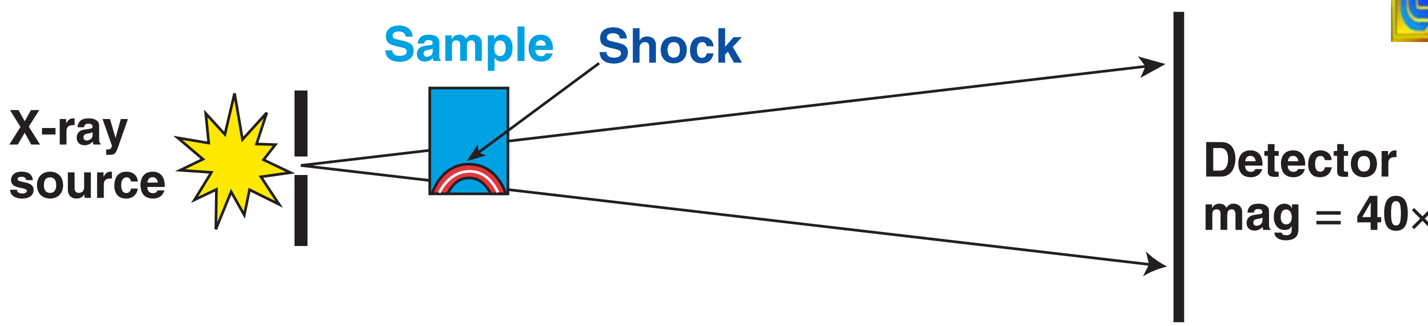
$$n \simeq 1 + \frac{2P}{\pi} \int_0^\infty \frac{\omega' \alpha(\omega')}{\omega'^2 - \omega^2} d\omega'$$

> 2.33 eV

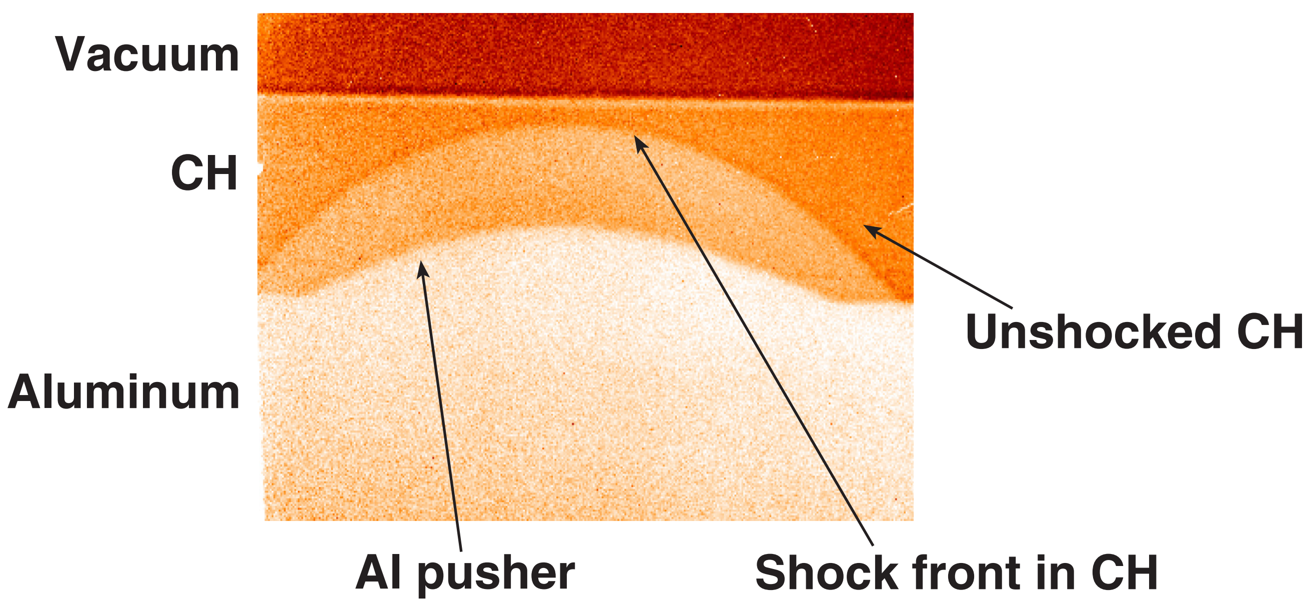
dn/dt > 0

*W. Theobald UO1.00006

An x-ray radiograph of an ~4 Mb shock in polystyrene shows a spherical shock driven by an Al pusher



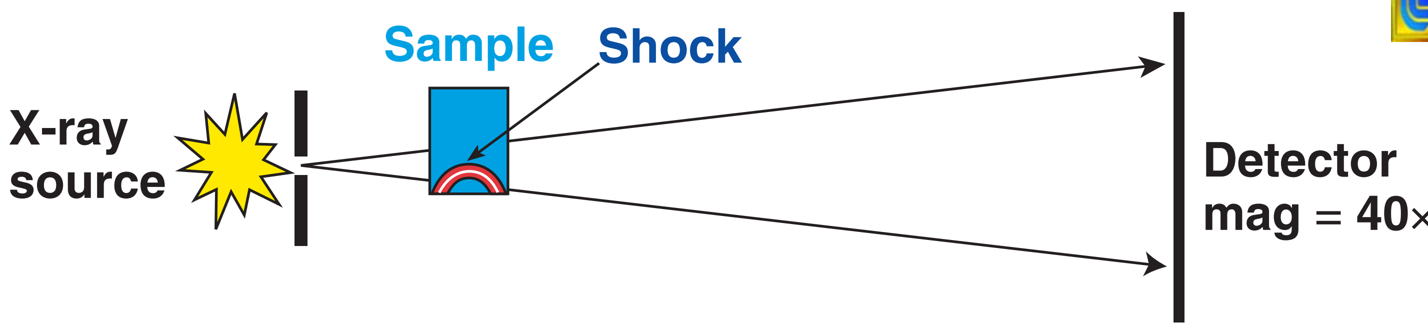
- Drive pulse: 1 ns at ~2×10^{14} W/cm^2



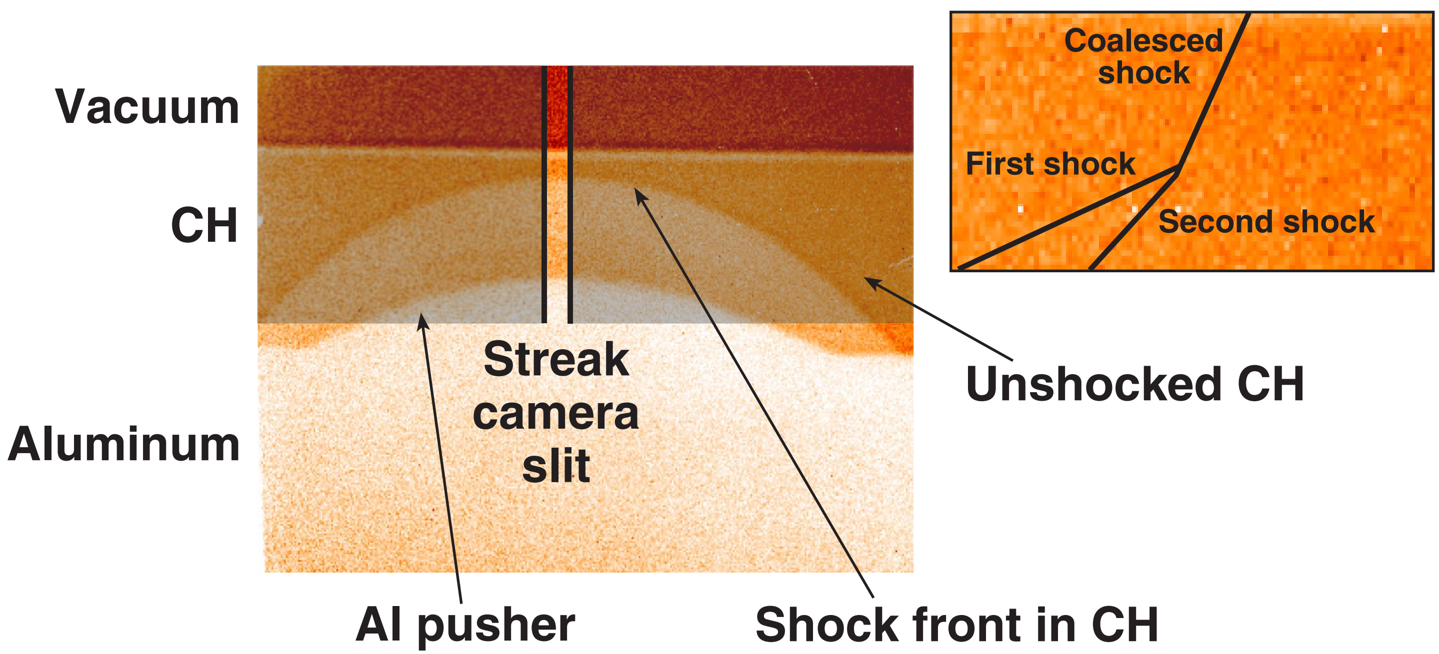
E13904b

Final Shock Timing

An x-ray radiograph of an ~4 Mb shock in polystyrene shows a spherical shock driven by an Al pusher



• Drive pulse: 1 ns at ~2×10^{14} W/cm^2



E13904c

Summary/Conclusions

We are measuring shock timing to the accuracies required for ICF ignition

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- In experiments with multiple shocks in CH and cryogenic deuterium targets we measure
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