

# Imaging VISAR velocimetry at the National Ignition Facility

NIF User Group Workshop 2026

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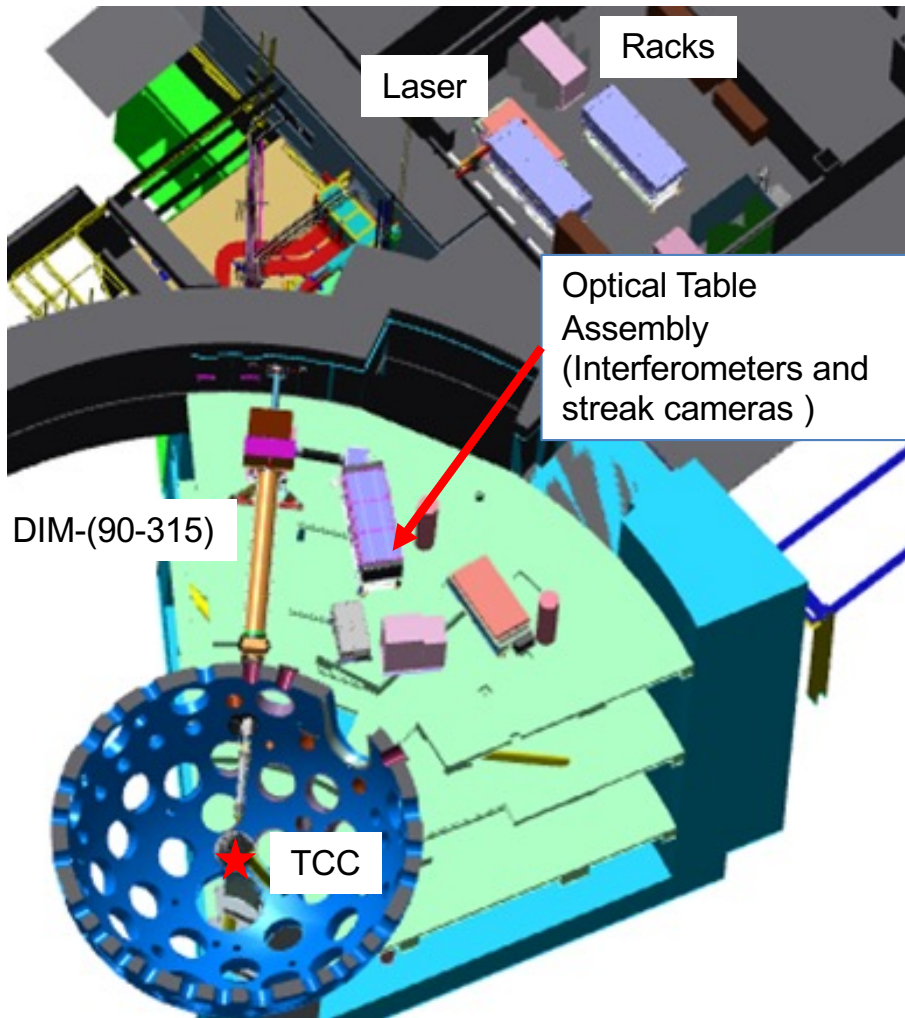
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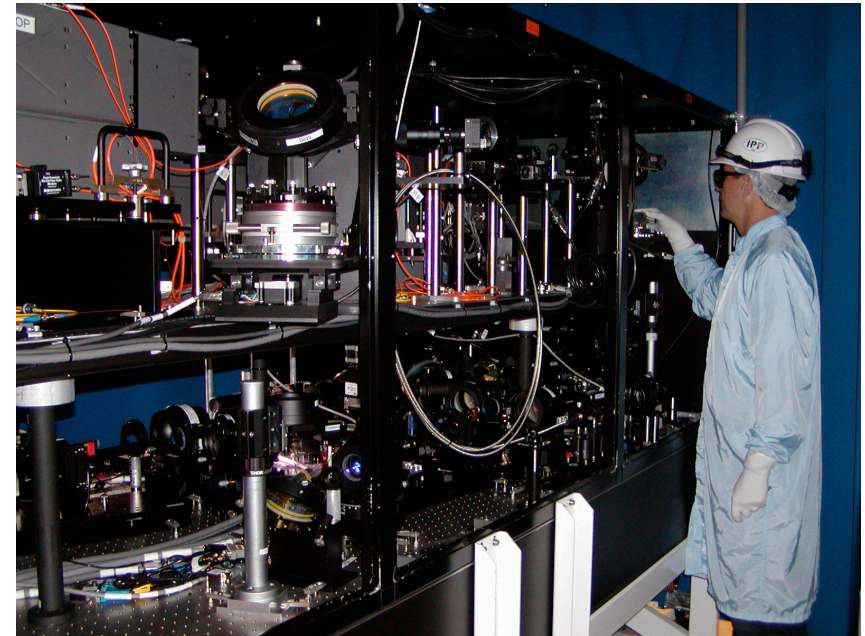
LLNL-PRES-2015445

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# The NIF VISAR is a DIM based Diagnostic



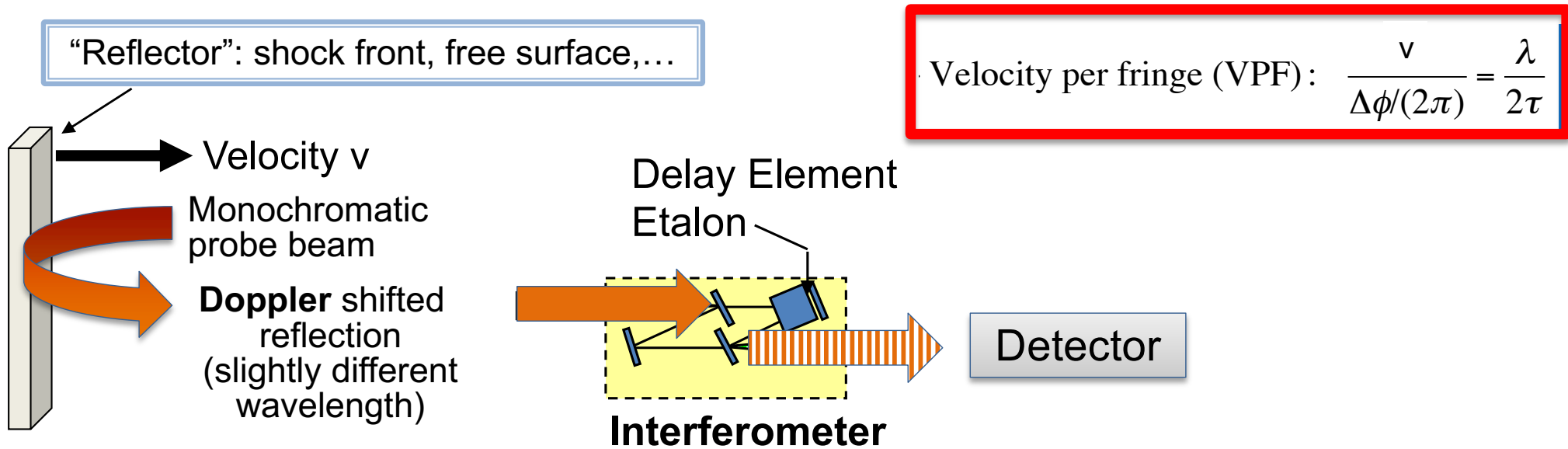
Interferometer table in the target bay



- Two VISAR Channels
- One SOP Channel
- 60kW (nominal), 1.2  $\mu$ s pulsed YAG laser (660 nm)

# VISAR

## “Velocity (Doppler) Interferometer System for Any Reflector”

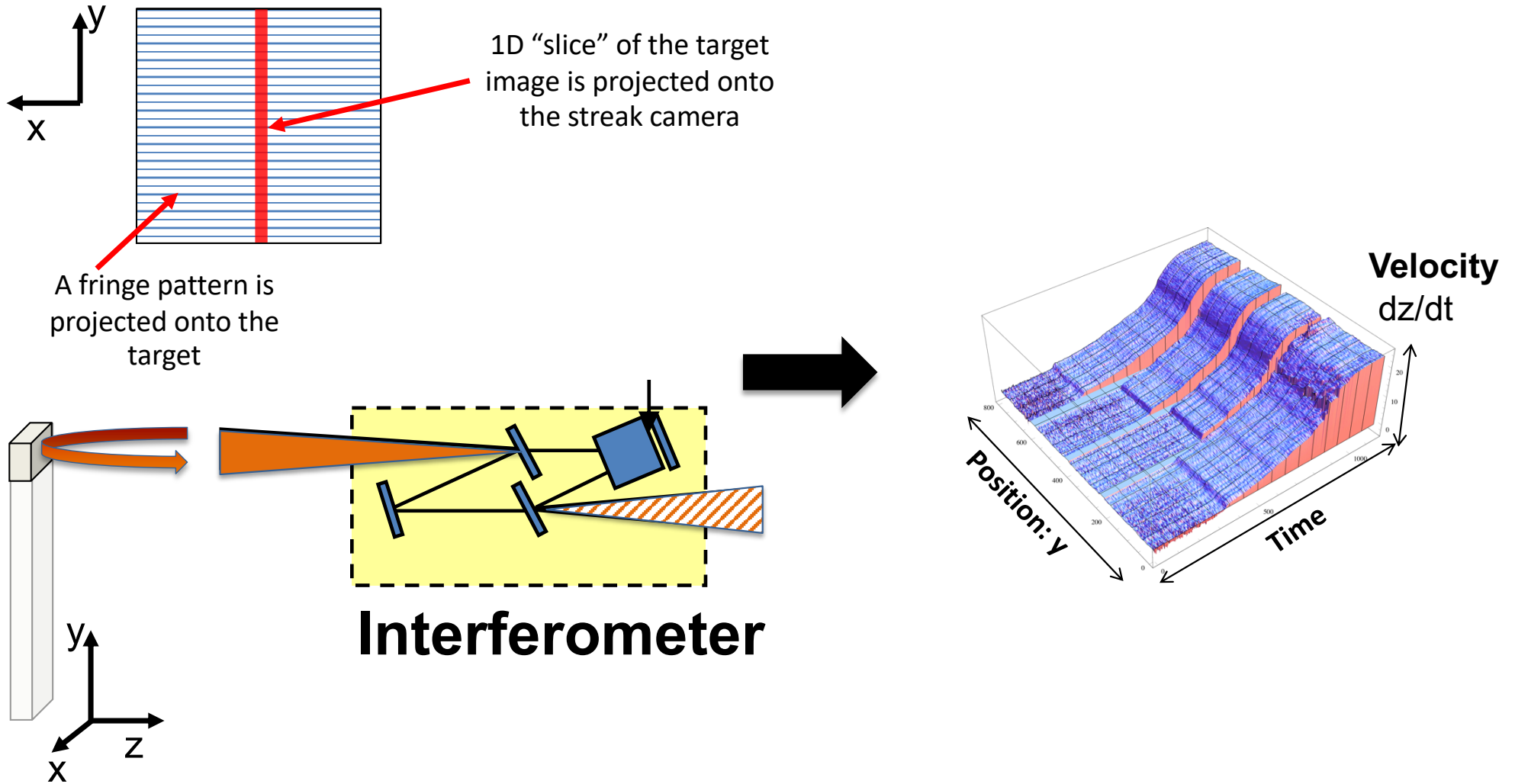


- The interferometer transforms the Doppler wavelength shift into a **fringe phase shift proportional to the velocity**
- The time-delay element determines the velocity sensitivity
- VISAR tracks the velocity of a moving reflecting surface with sub % precision

VISAR is a very powerful, versatile, high precision diagnostic for dynamic compression

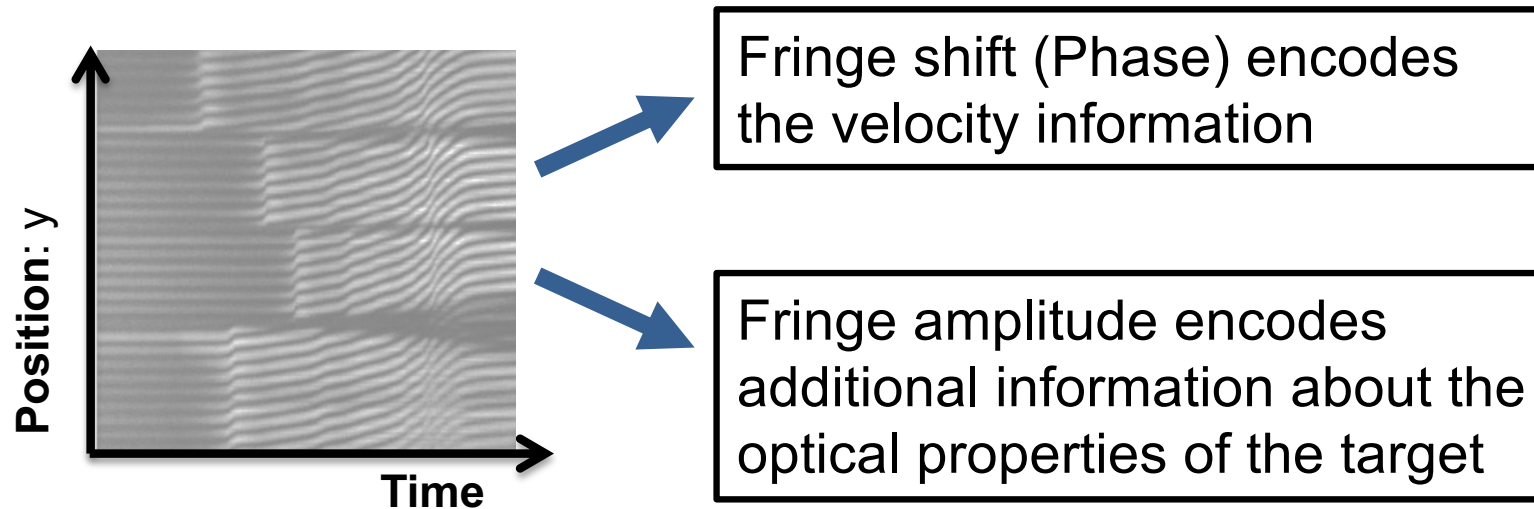


# The NIF VISAR is a “Line” imaging 1D VISAR recording the velocity-time evolution along a slice across the target



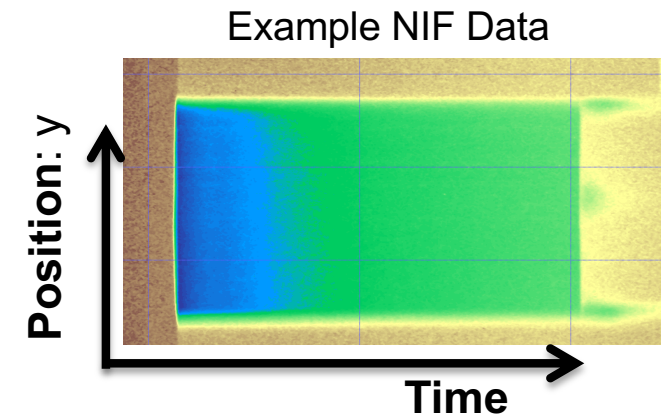
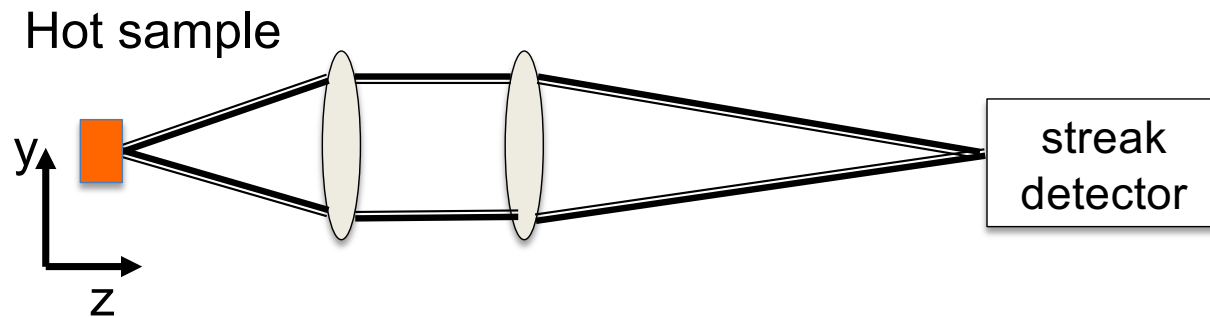
For each position along one axis  $y$ , we record the time evolution of the velocity  $dz/dt$

# VISAR also documents the target's optical properties at the wavelength of the laser probe



- Absorptivity, reflectivity are important physics information
- Critical for temperature measurements with pyrometry

# A Streaked Optical Pyrometer (SOP) shares the line-of-sight with the NIF VISAR

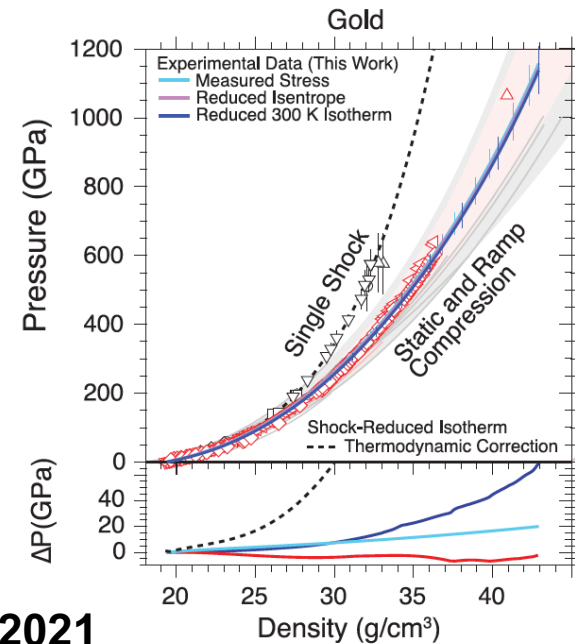
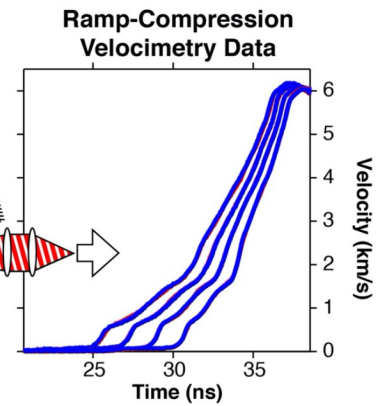
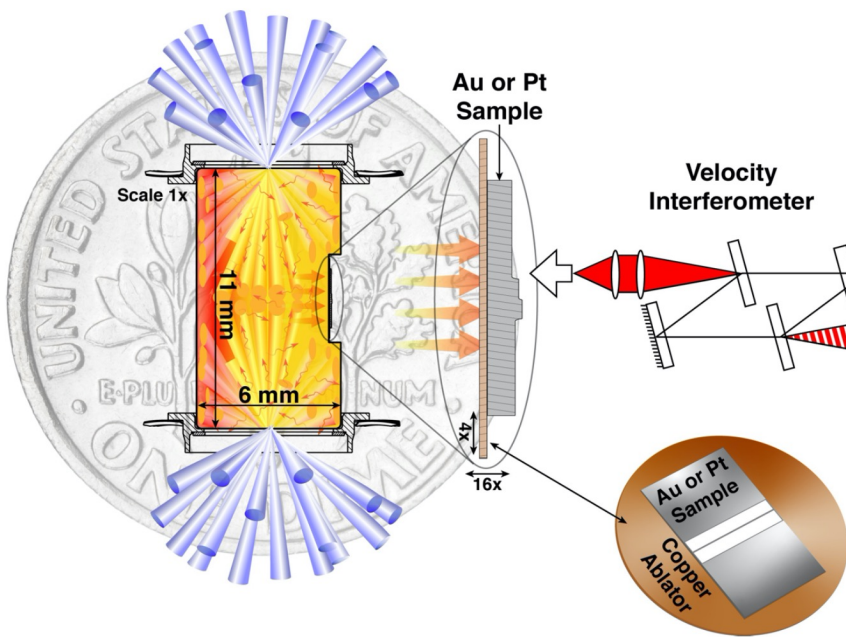


- For each position along one axis  $y$ , we record the time evolution of the spectral radiance (thermal emission)
- Enables quantitative (brightness) **temperature measurements** with **appropriate calibration** of the instrument transfer function

# High Precision Free surface velocity: Ramp compression EOS measurements

After breakout when compressed sample maintains as solid free surface

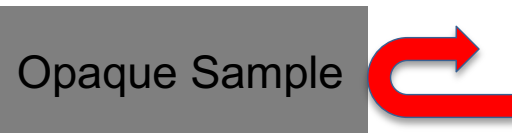
Before breakout



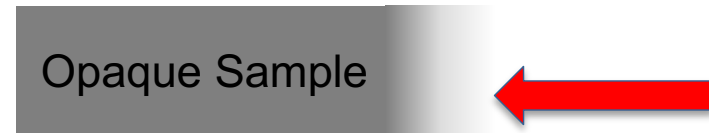
Fratanduono, Science, 2021

# Shock Break Out (SBO) and Active SBO (ASBO): Drive characterization, high Pressure EOS

Before breakout

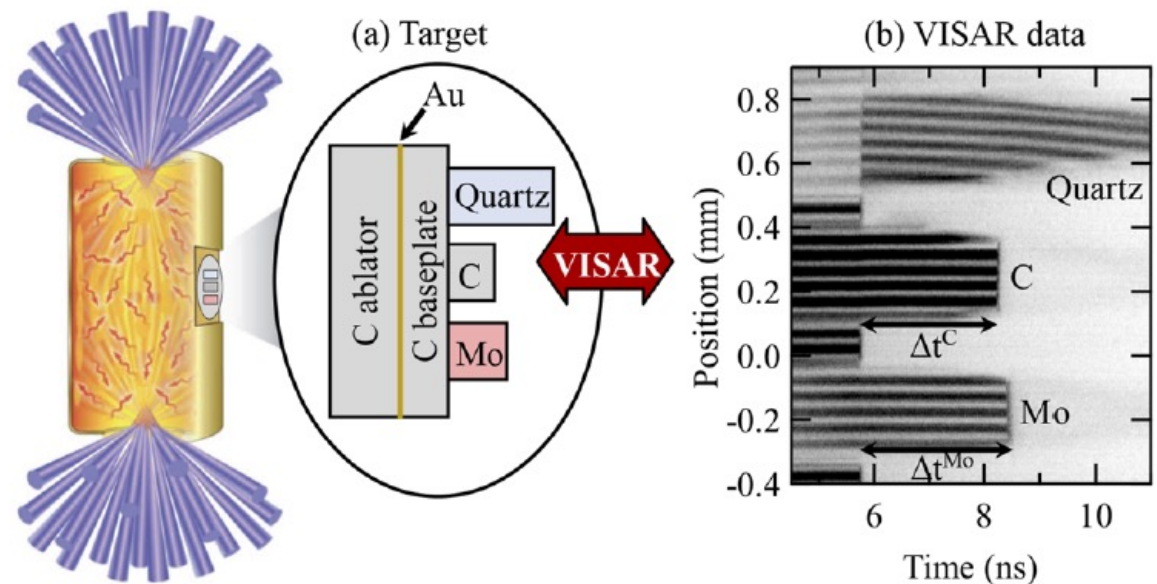


After breakout when shock compressed sample is molten



Density gradient absorbs the laser probe

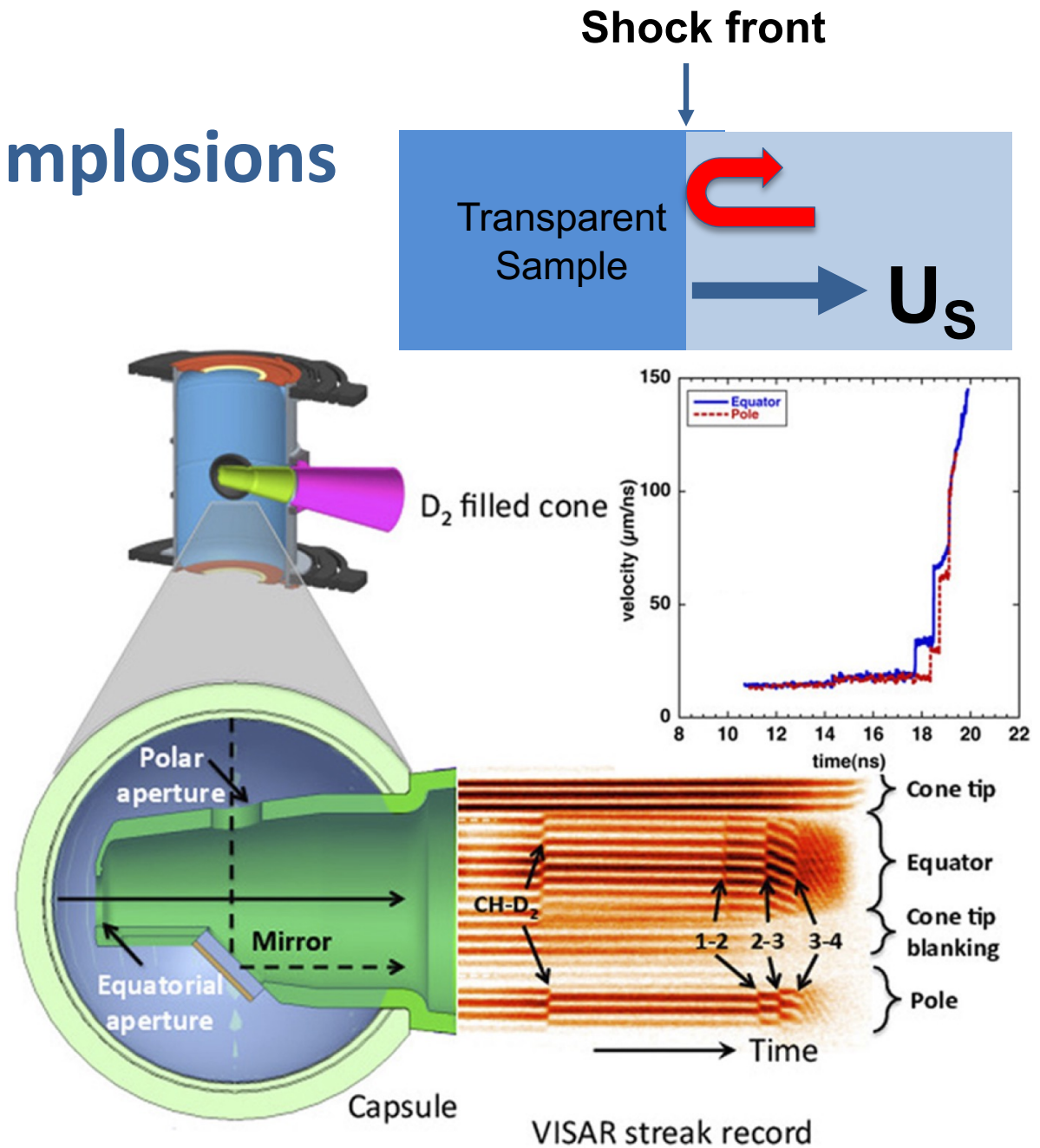
- ASBO documents arrival time of shock at free surface by detecting loss of active probe beam
- Robust method to characterize drive, measure EOS at 100s of Mbar.



**Marshall et al., Phys. Rev. B 99, 174101 (2019).**

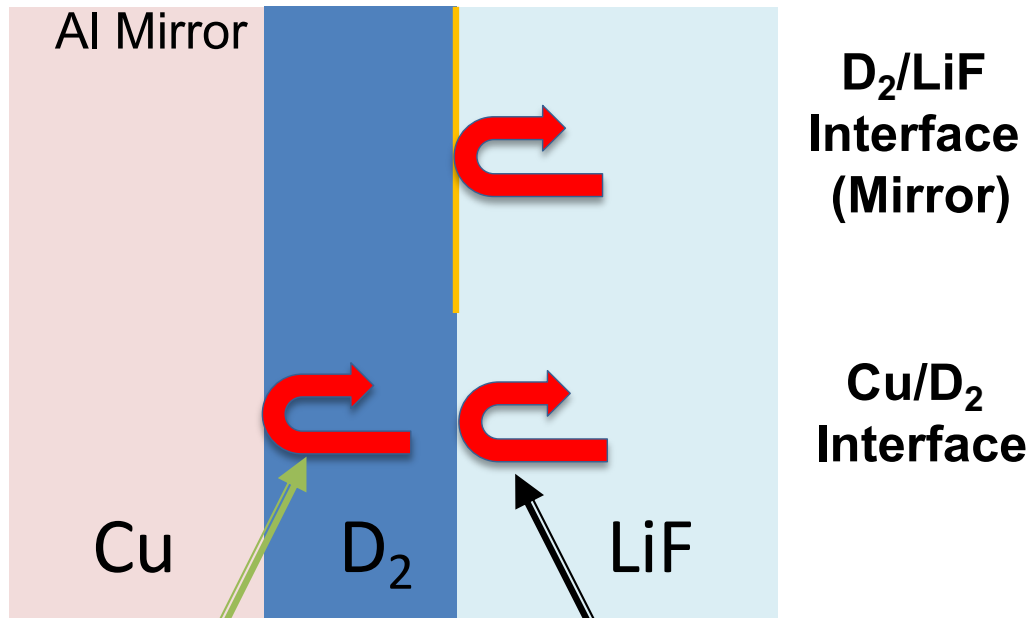
# Reflecting shocks: shock timing for ICF implosions

- Measure the leading shock velocity from ~20 to 150 km/s
- Identify break-out time, shock merging events to within 30 ps
- Reconstruct the shock trajectory along a few directions in the capsule



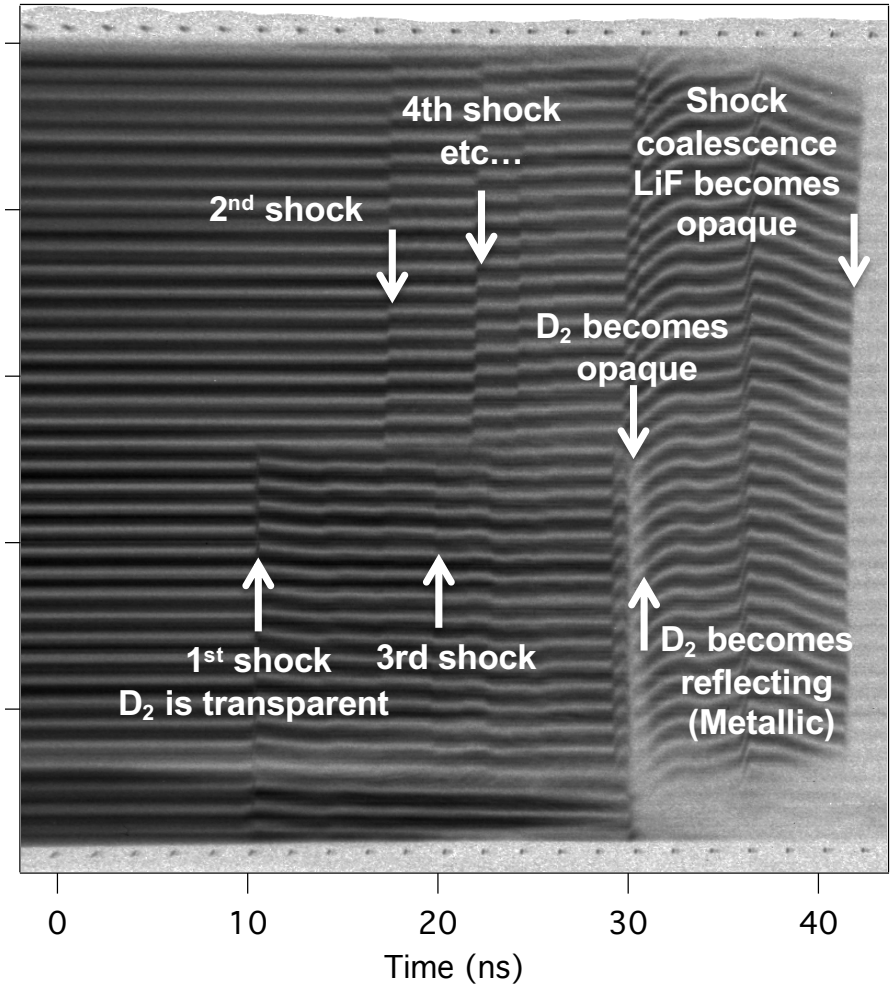
Adapted from *Moody et al., Physics of Plasmas 21, 092702 (2014)*

# Optical Properties: Fluid Deuterium insulator to metal transition



Initially D<sub>2</sub> is transparent and the VISAR tracks the Cu/D<sub>2</sub> interface

Once D<sub>2</sub> becomes opaque the VISAR tracks the D<sub>2</sub>/LiF interface



Optical properties reveal the insulator to metal transition in dense fluid deuterium

# NIF VISAR capabilities enabled successful Discovery Science experiments

- **Diamond and Iron** high-precision quasi-absolute EOS measurements
- **Insulator-to-Metal Transition** in fluid Deuterium
- **High-precision compression path** characterization for various projects
  - Atomic structure and phase transitions
  - Proton stopping power
  - Hydrodynamic instabilities

## LETTER

doi:10.1038/nature13526

### Ramp compression of diamond to five terapascals

R. F. Smith<sup>1</sup>, J. H. Eggert<sup>1</sup>, R. Jeanloz<sup>2</sup>, T. S. Duffy<sup>3</sup>, D. G. Braun<sup>1</sup>, J. R. Patterson<sup>1</sup>, R. E. Rudd<sup>1</sup>, J. Biener<sup>1</sup>, A. E. Lazicki<sup>1</sup>, A. V. Hamza<sup>1</sup>, J. Wang<sup>2</sup>, T. Braun<sup>1</sup>, L. X. Benedict<sup>1</sup>, P. M. Celliers<sup>1</sup> & G. W. Collins<sup>1</sup>

## nature astronomy

LETTERS

https://doi.org/10.1038/s41550-018-0437-9

### Equation of state of iron under core conditions of large rocky exoplanets

Raymond F. Smith<sup>1\*</sup>, Dayne E. Fratanduono<sup>1</sup>, David G. Braun<sup>1</sup>, Thomas S. Duffy<sup>2</sup>, June K. Wicks<sup>2,3</sup>, Peter M. Celliers<sup>1</sup>, Suzanne J. Ali<sup>1</sup>, Amalia Fernandez-Pañella<sup>1</sup>, Richard G. Kraus<sup>1</sup>, Damian C. Swift<sup>1</sup>, Gilbert W. Collins<sup>1,4</sup> and Jon H. Eggert<sup>1</sup>

## Science

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REPORT

### Insulator-metal transition in dense fluid deuterium

Peter M. Celliers<sup>1\*</sup>, Marius Millot<sup>1</sup>, Stephanie Brygoo<sup>2</sup>, R. Stewart McWilliams<sup>3</sup>, Dayne E. Fratanduono<sup>1</sup>, J. Ryan R

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## The New York Times

### Settling Arguments About Hydrogen With 168 Giant Lasers

Scientists at Lawrence Livermore National Laboratory said they were “converging on the truth” in an experiment to understand hydrogen in its liquid metallic state.



# The NIF VISAR is a central diagnostic for NIF

- NIF VISAR: powerful & versatile diagnostic
- Highly reliable system, primary diagnostic on 100 science shots per year (25% of total shots)
- Most accurate tool to characterize how well how the NIF lasers compress and accelerate materials to create extreme pressure-temperature conditions

Review of  
Scientific Instruments

REVIEW

## Imaging velocity interferometer system for any reflector (VISAR) diagnostics for high energy density sciences

Cite as: Rev. Sci. Instrum. 94, 011101 (2023); doi: [10.1063/5.0123439](https://doi.org/10.1063/5.0123439)

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