

LA-UR- 11-03628

Approved for public release;  
distribution is unlimited.

*Title:*

Single shot ultrafast dynamic ellipsometry of laser-driven shocks in thin aluminum films

*Author(s):*

V.H. Whitley, S.D. McGrane, D.S. Moore, C.A. Bolme

*Intended for:*

The 17th APS Shock Compression of Condensed Matter Conference. Chicago, Illinois. June 26-July 1, 2011



Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

# Single shot ultrafast dynamic ellipsometry of laser-driven shocks in thin aluminum films

---

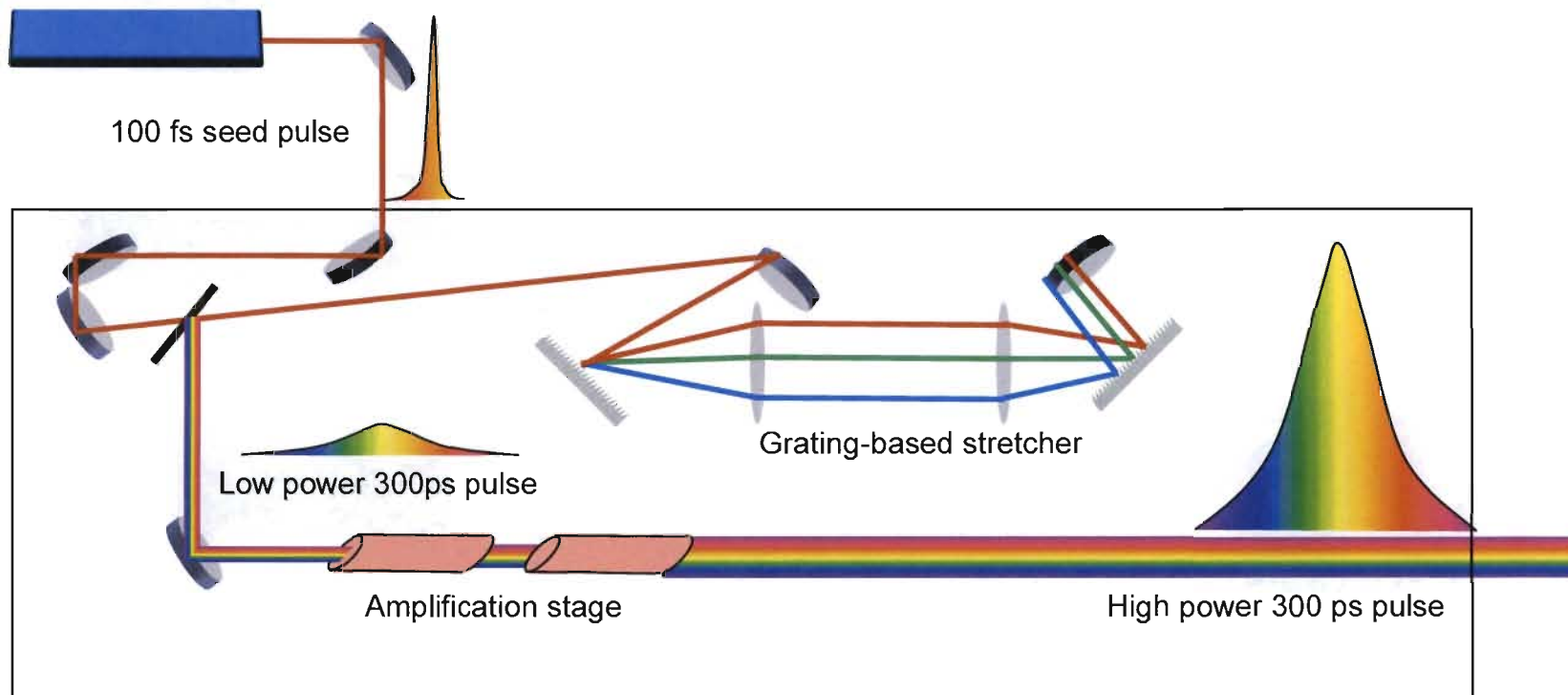
**V.H. Whitley, S.D. McGrane, D.S. Moore, C. A. Bolme**

**Dynamic & Energetic Materials, WX-9**

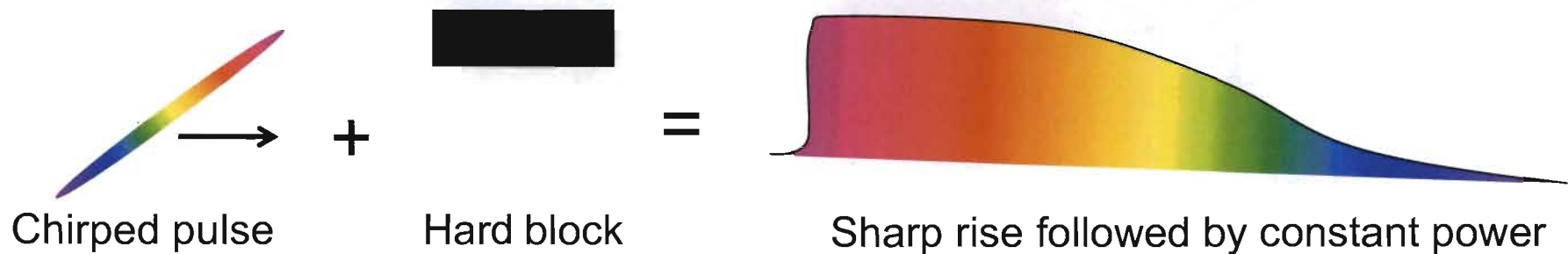
**Los Alamos National Lab**

**Los Alamos, NM 87544**

# Time resolved light collection-Chirped laser amplification

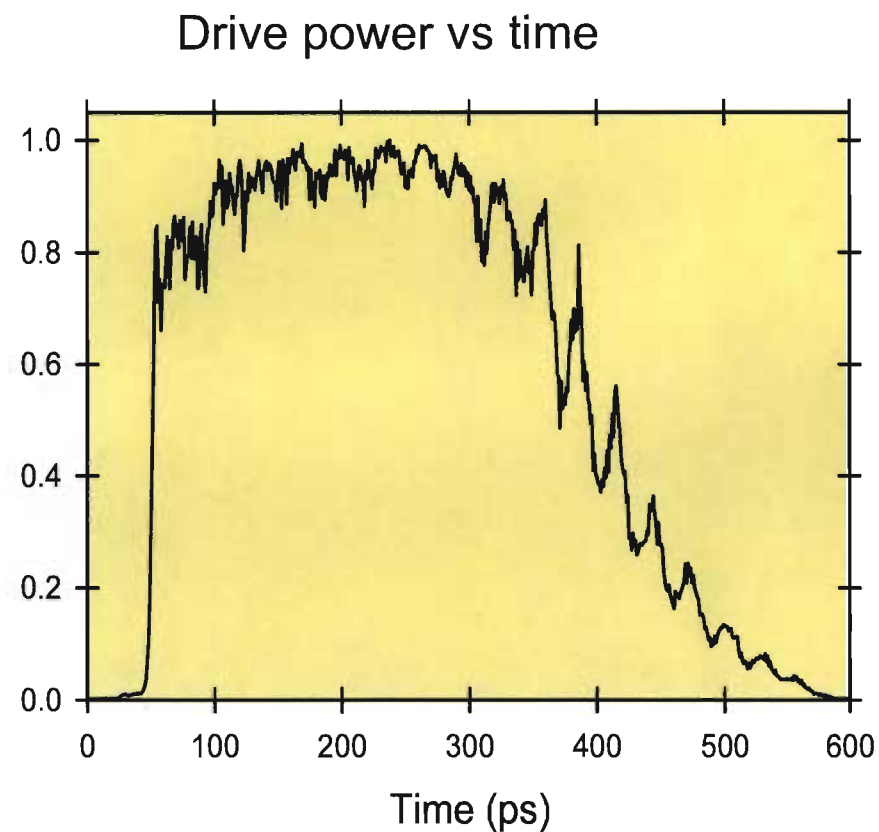
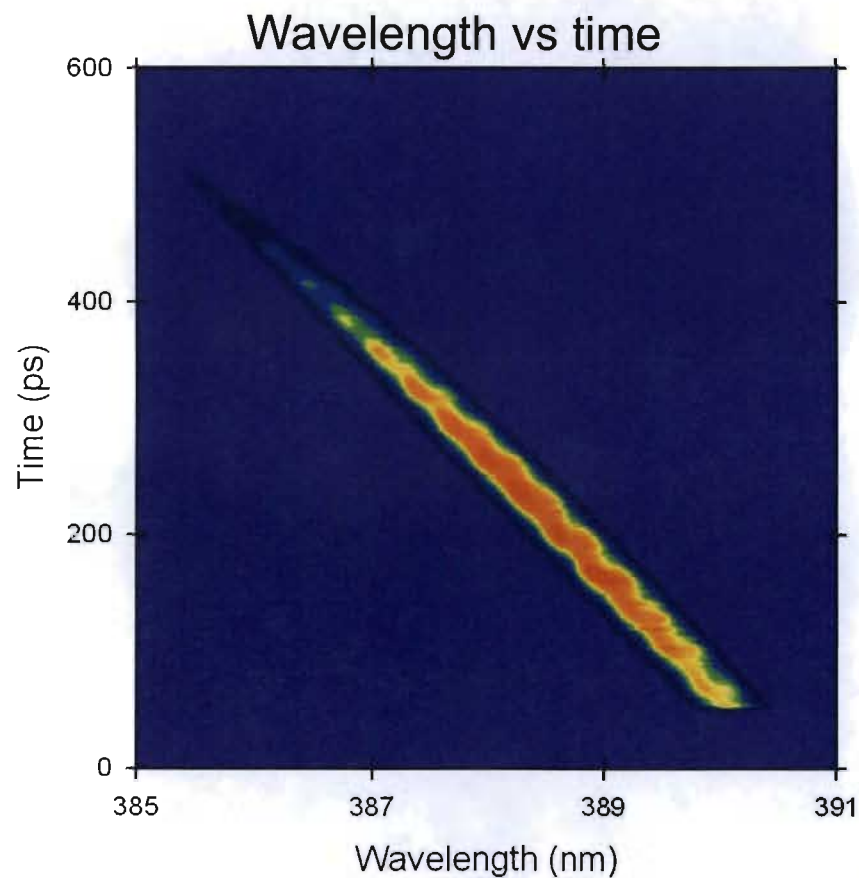


# Shock drive shaping possibilities of Chirped pulses



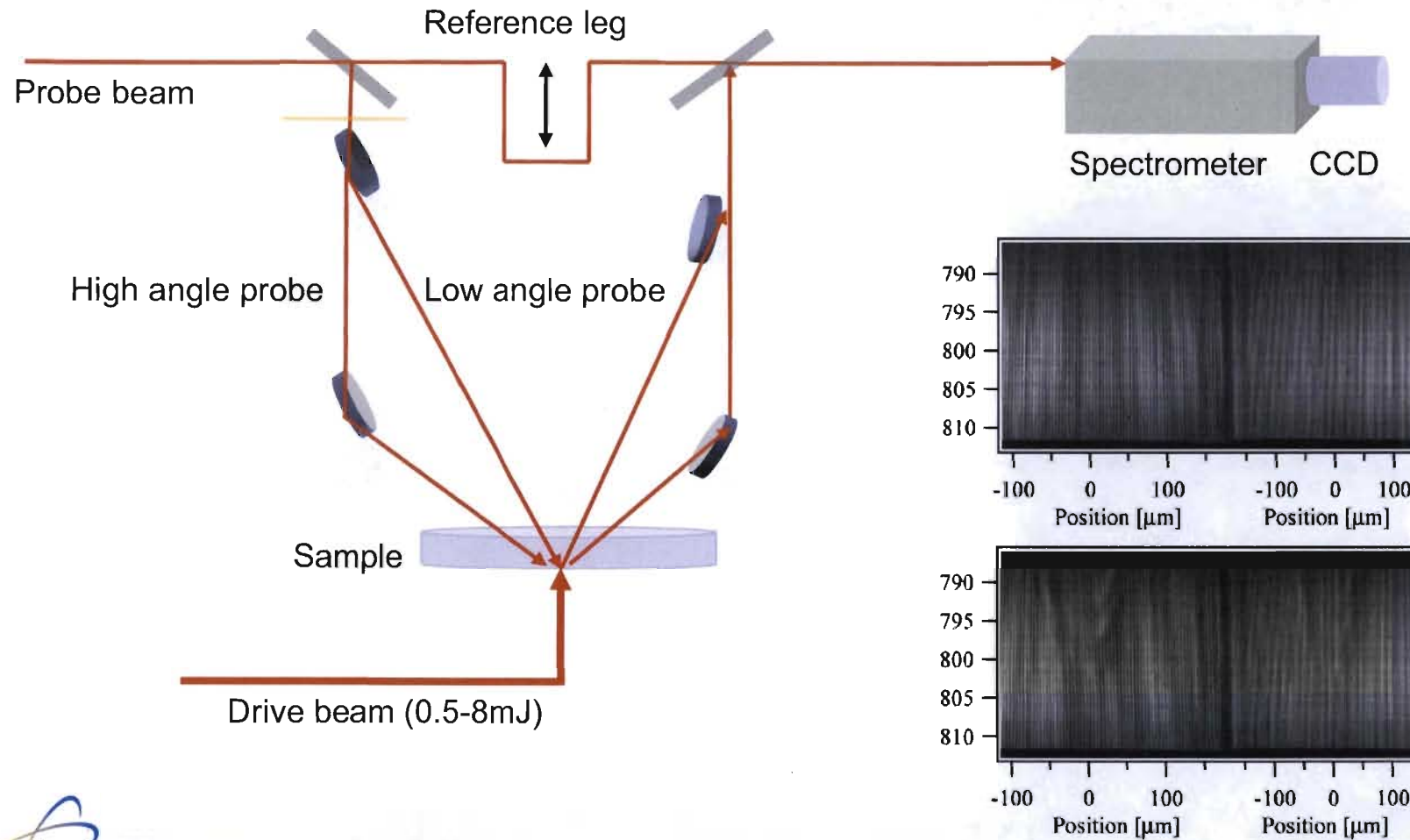
- Block portion of chirped pulse with solid object
- Shock rise ~ 5 ps
- Several hundred picoseconds of support

## Drive pulse profile measured using XFROG

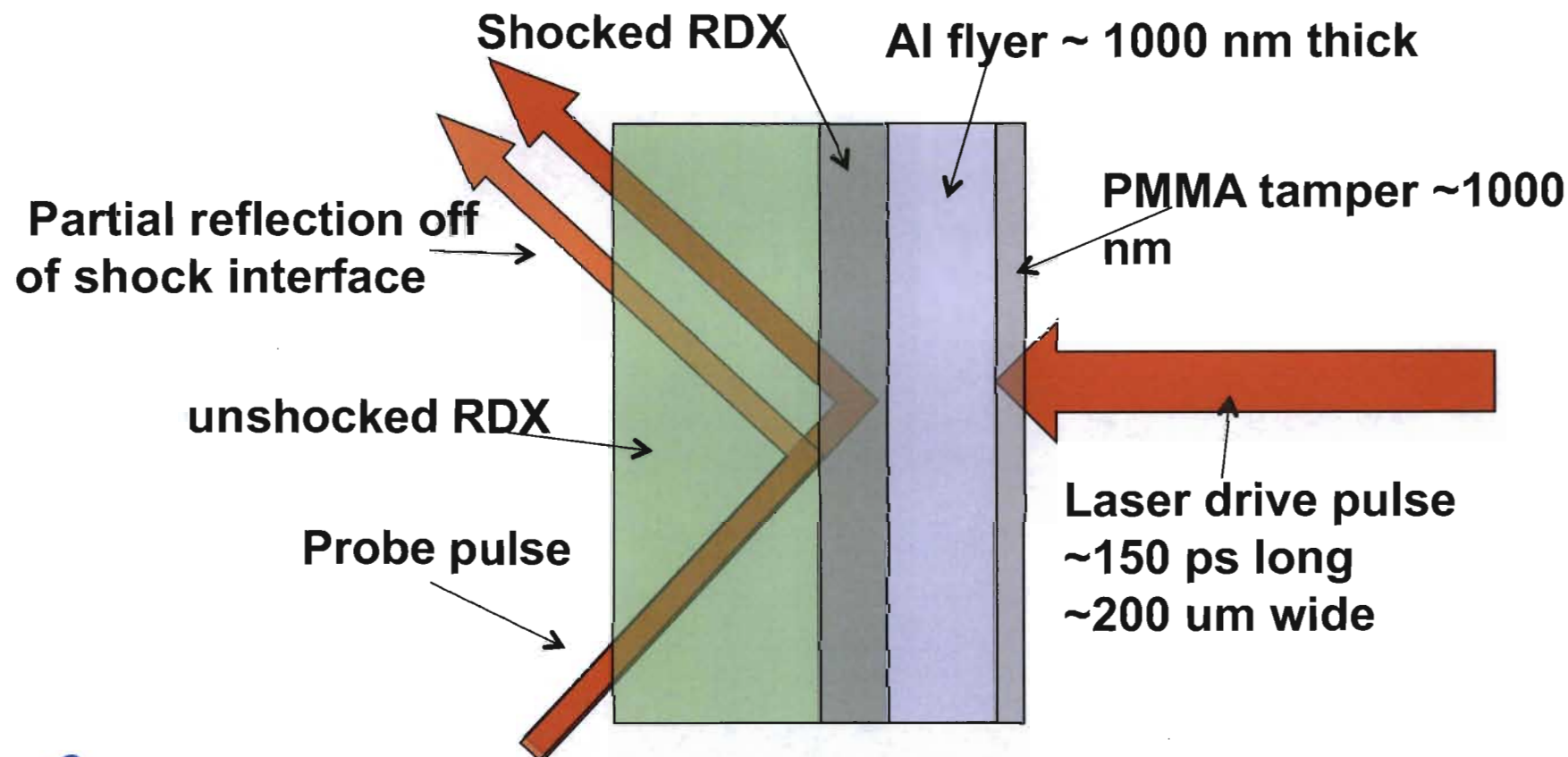




# Creating and measuring shocks with ultrafast lasers



## Shock/laser interactions inside energetic crystal



## Measuring elastic precursor decay in aluminum

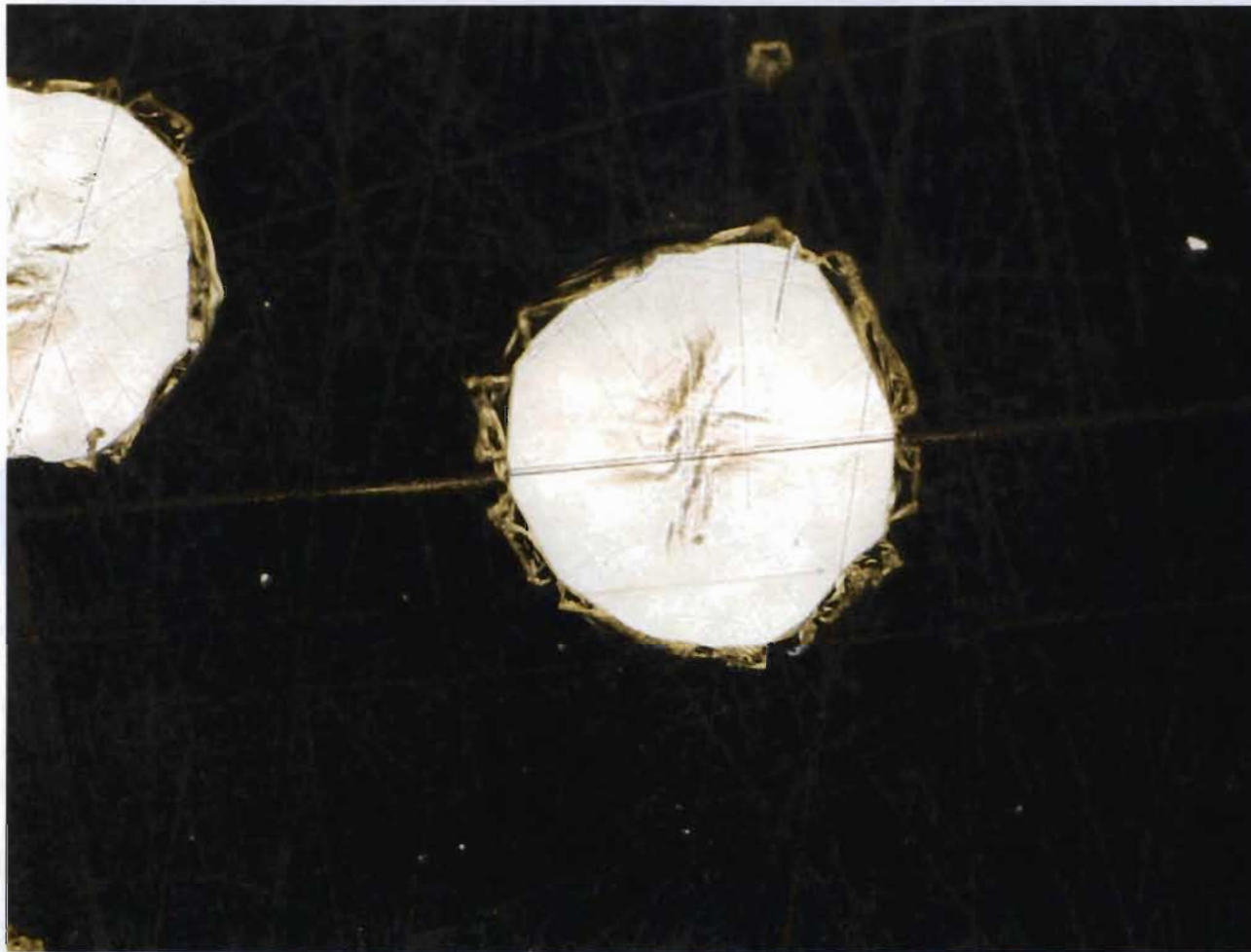
---

- **Bulk aluminum considered to have a constant elastic precursor**
  - Thickness independent
  - Pressure independent
- **Slight elastic precursor decay found in thicknesses ranging from 0.5mm – 10 mm (Asay et al).**
- **Extrapolations suggest that bulk of elastic precursor decay occurs within a few microns of the impact surface and a few hundred picoseconds.**



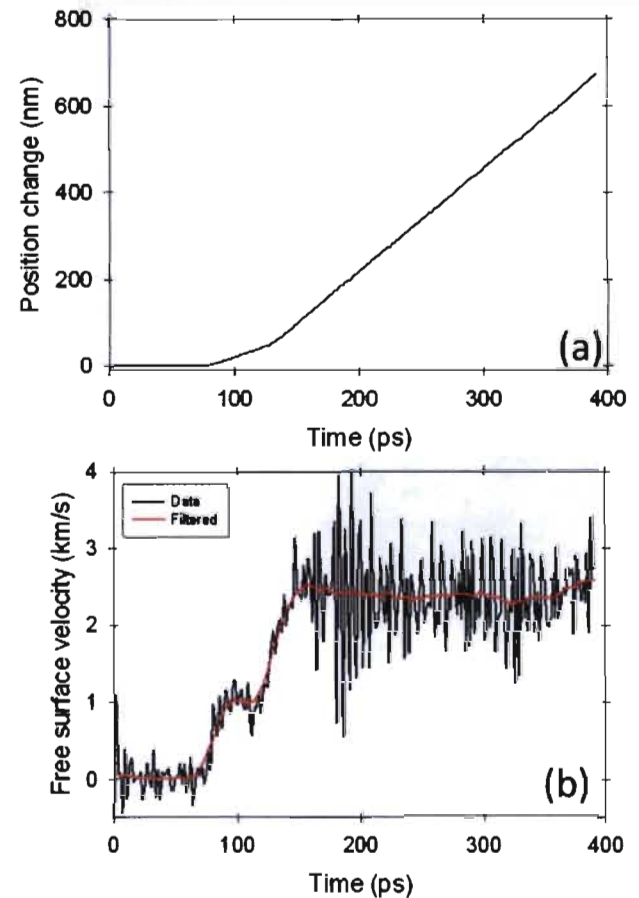
## Post experiment photos of aluminum film

---



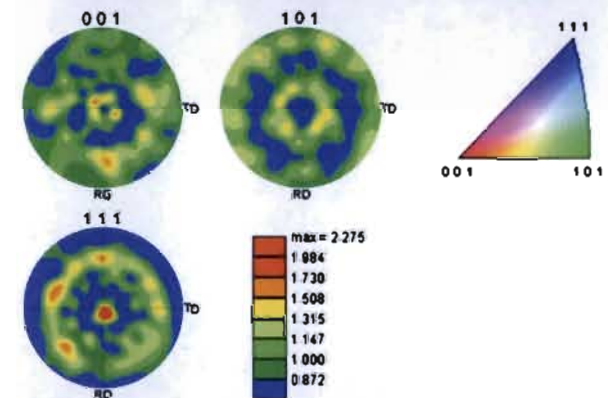
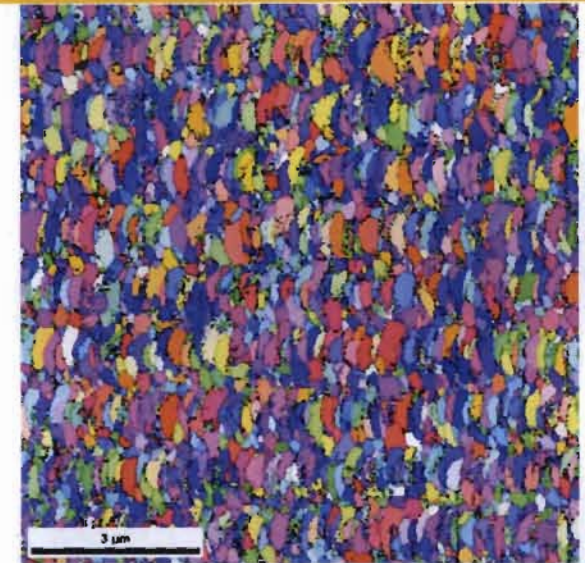
## Free surface measurement of laser-shocked aluminum

- Free surface starts to move at ~80 ps.
- At ~120 ps, the rate of free surface movement increases.
- Differentiating free surface position gives surface velocity (black line)
- Fourier filtering removes much of the noise, but also broadens the shock rise times.



## Surface morphology of aluminum

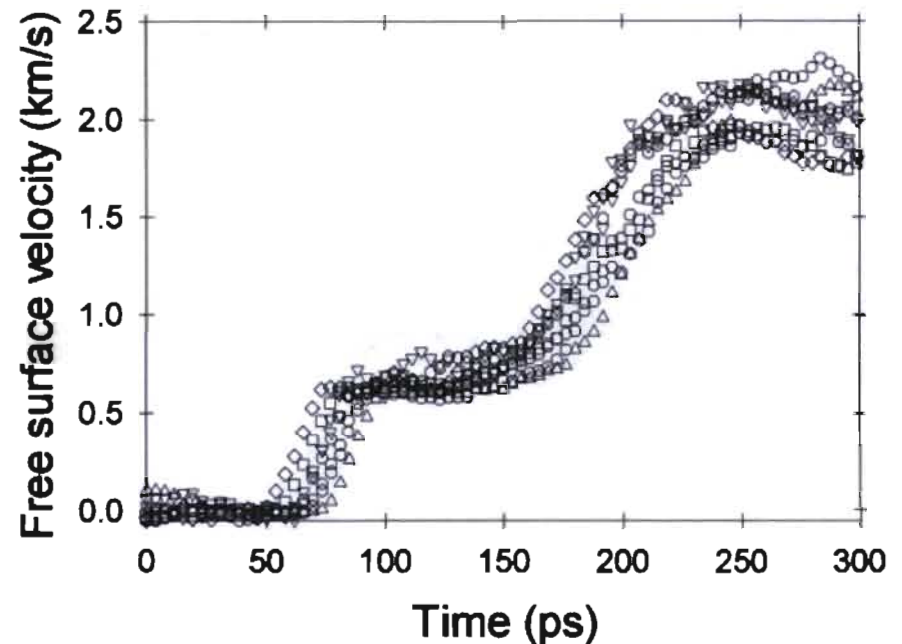
- Grains: Columnar form extending from substrate to free surface.
- Cross section :  $1\mu\text{m} \times 200\text{ nm}$
- Orientation: Random
- If shock region of interest  $\sim 1\mu\text{m}$ , we are only probing a few grains!



# Shot-to-shot reproducibility of shock velocities in 2um aluminum films

## Does grain sampling cause issues?

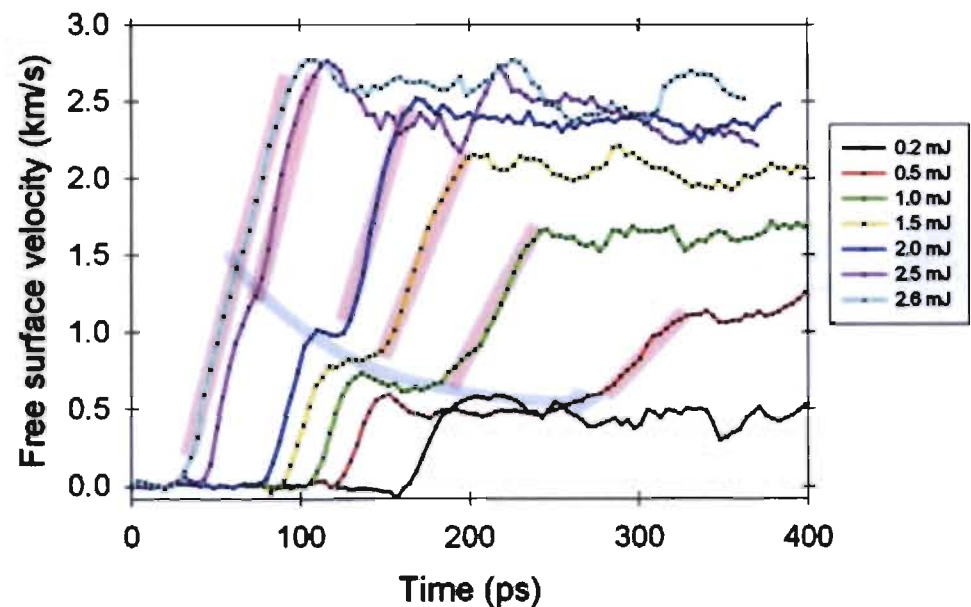
- Overall shape is reproducible
- ~25 ps variation in arrival times
- Shot-to-shot power variations largely responsible for arrival time differences
- Grain-related variation in data is minor.





## Elastic precursor decay dependence on laser power (pressure)

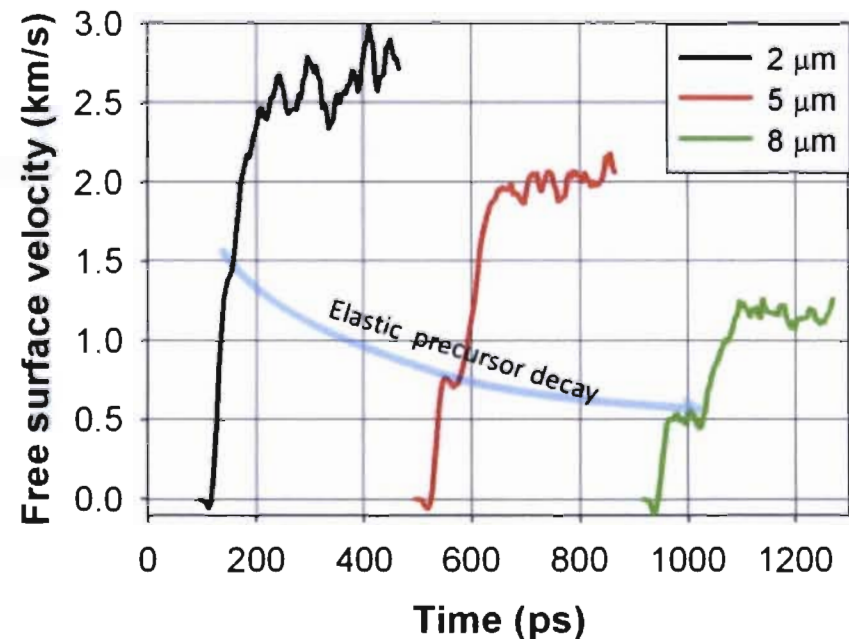
- Sample thickness unchanged
- Laser power varied from 0.2 mJ – 2.6 mJ
- At 0.2 mJ, only elastic response
- At 2.6 mJ, no measurable separation between elastic and plastic





## Elastic precursor decay with metal thickness

- Sample thickness varied from 2-8  $\mu\text{m}$
- Laser power held constant
- Elastic precursor decays from  $\sim 1500$  m/s to 500 m/s in 6  $\mu\text{m}$  of material
- Time separation between elastic stress and plastic stress from  $\sim 20$  ps to  $\sim 100$  ps over 6  $\mu\text{m}$  of material.
- Material response in  $\mu\text{m}$  thick aluminum is phenomenologically similar to bulk samples



# Conclusions

---

## ■ Measured

- Input stress wave dependence to the elastic precursor decay in micron-thick aluminum films.
- Thickness dependent decay to the elastic precursor in micron-thick aluminum films.

## ■ **Magnitude of elastic precursor in micron-thick films is found in a region of space that matches extrapolations from thick films**

## ■ **Material response of aluminum on ps-time scale is similar to response on ns- and longer time scales.**

## ■ **Hugoniot constructed from single laser shock show reasonable agreement to Hugoniot constructed from planar impact events.**

## ■ Future work

- Similar measurements on copper, tin and other metals
- Characterize role of spall.