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

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

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Dynamic & Energetic Materials, WX-9

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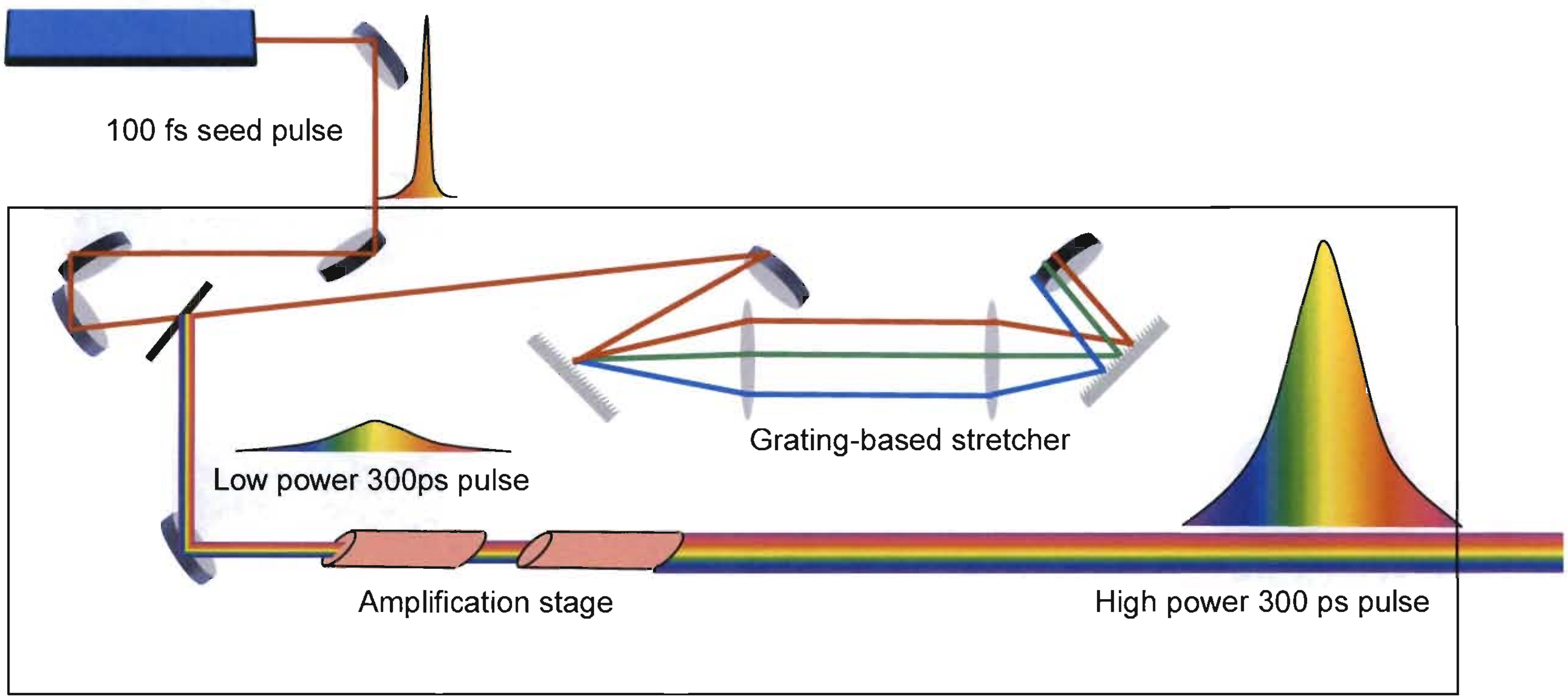
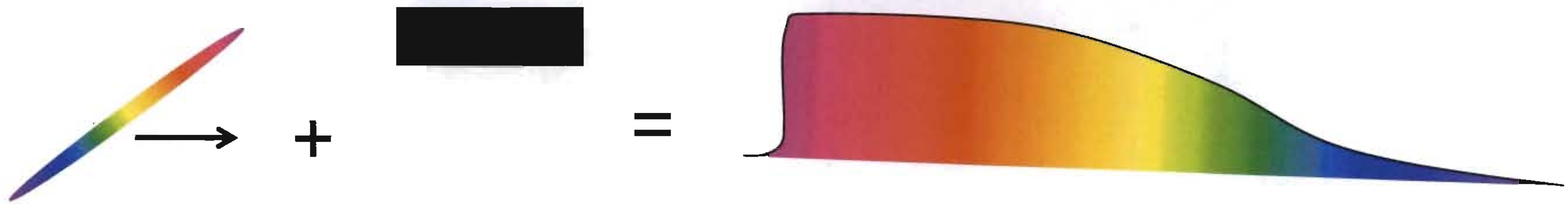
Time resolved light collection-Chirped laser amplification

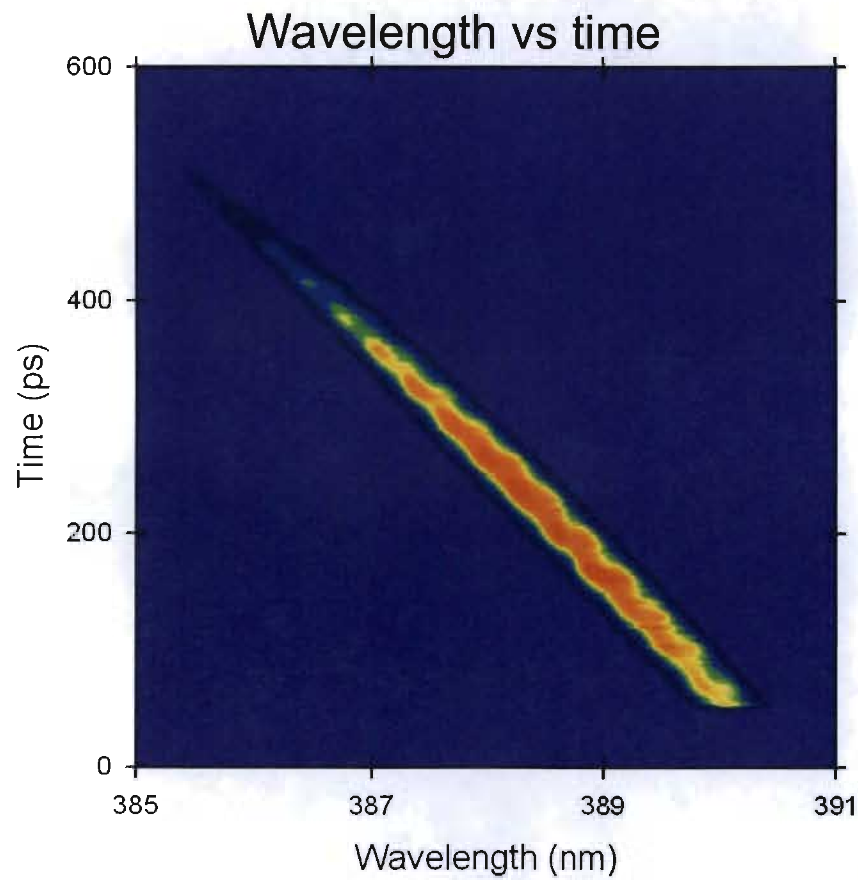


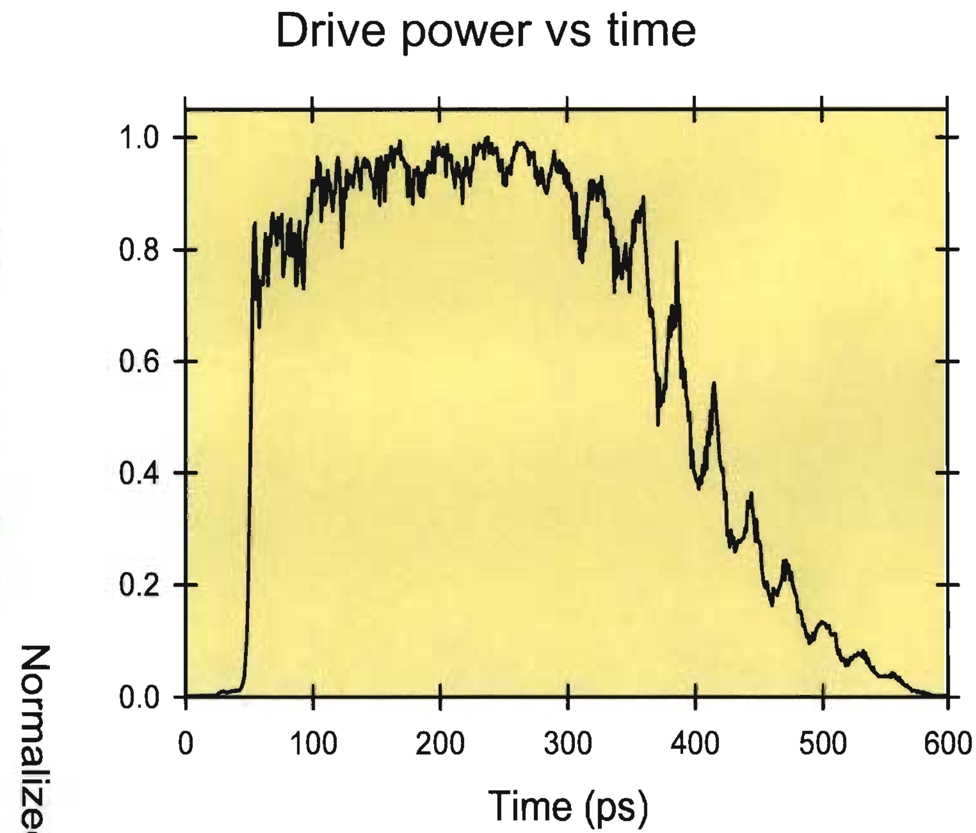
Shock drive shaping possibilities of Chirped pulses



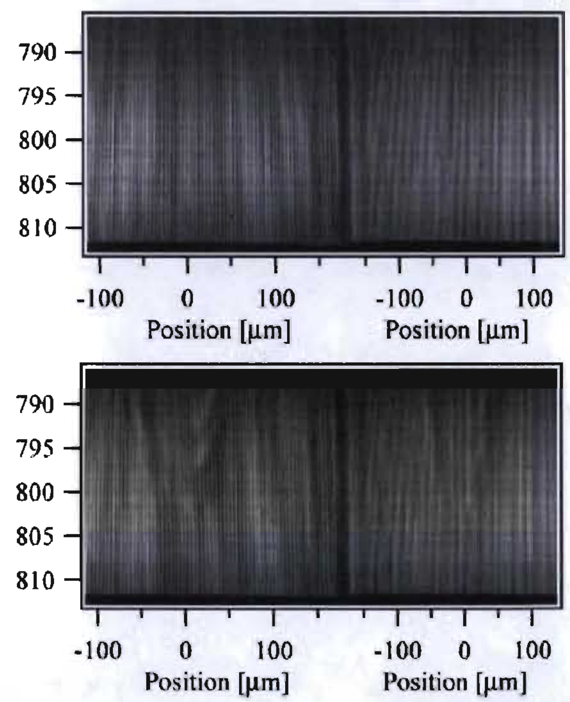
- **Block portion of chirped pulse with solid object**
- **Shock rise ~ 5 ps**
- **Several hundred picoseconds of support**

Drive pulse profile measured using XFROG

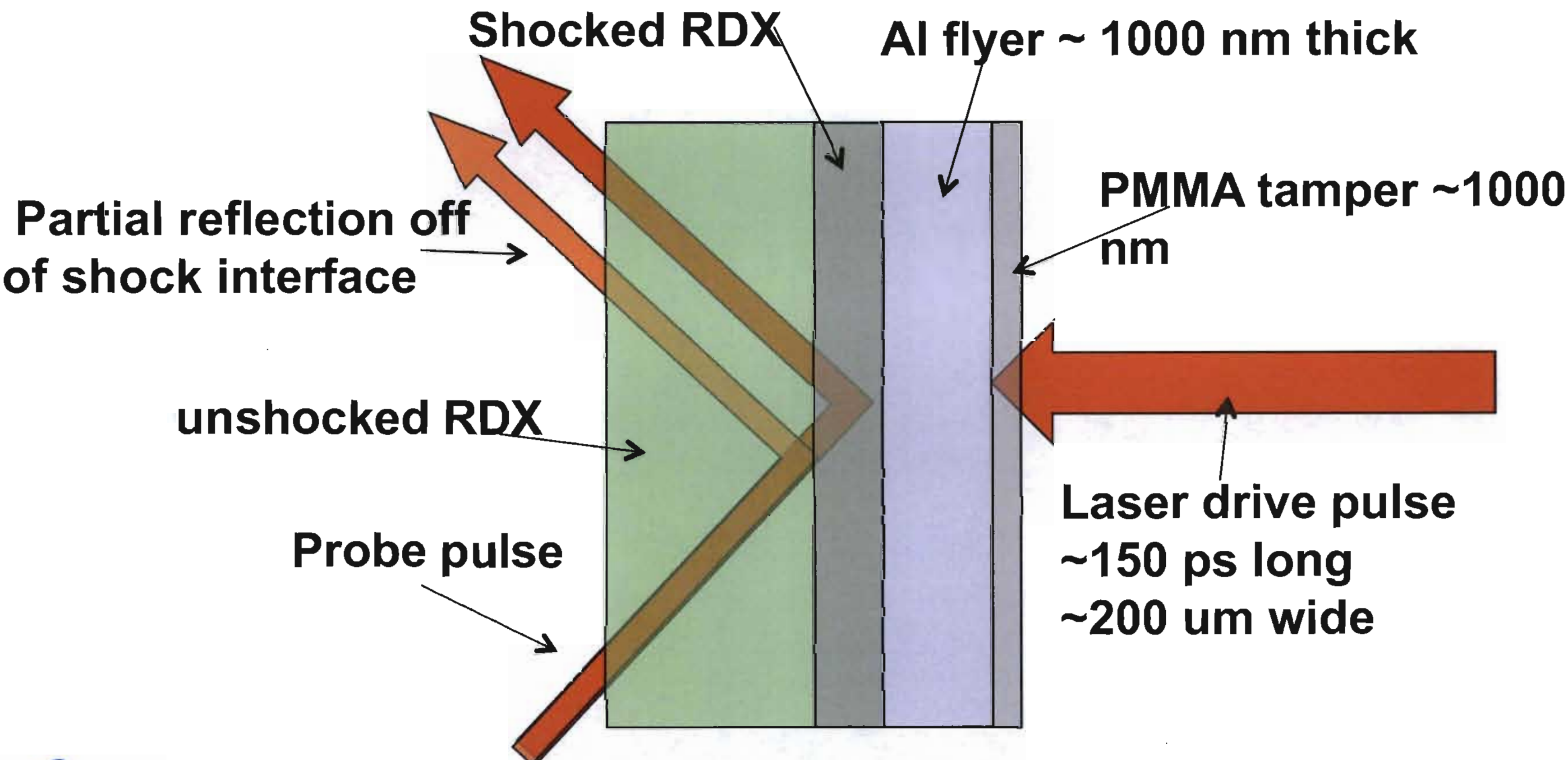




Creating and measuring shocks with ultrafast lasers



Shock/laser interactions inside energetic crystal



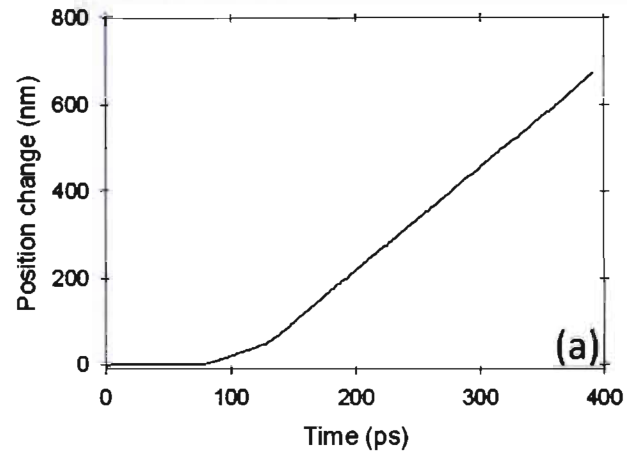
Measuring elastic precursor decay in aluminum

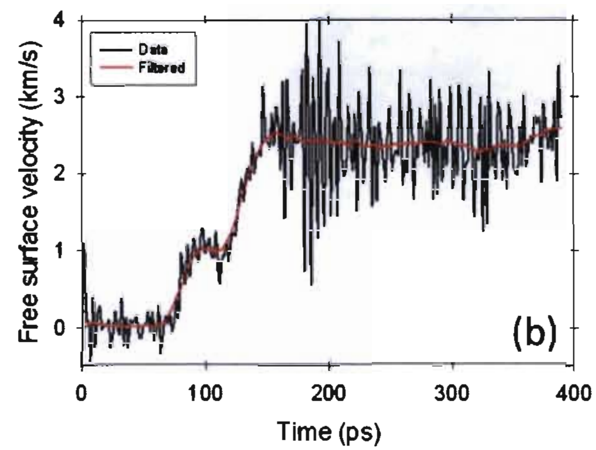
- **Bulk aluminum considered to have a constant elastic precursor**
  - Thickness independent
  - Pressure independent
- **Slight elastic precursor decay found in thicknesses ranging from 0.5mm – 10 mm (Asay et al).**
- **Extrapolations suggest that bulk of elastic precursor decay occurs within a few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

Post experiment photos of aluminum film

Free surface measurement of laser-shocked aluminum

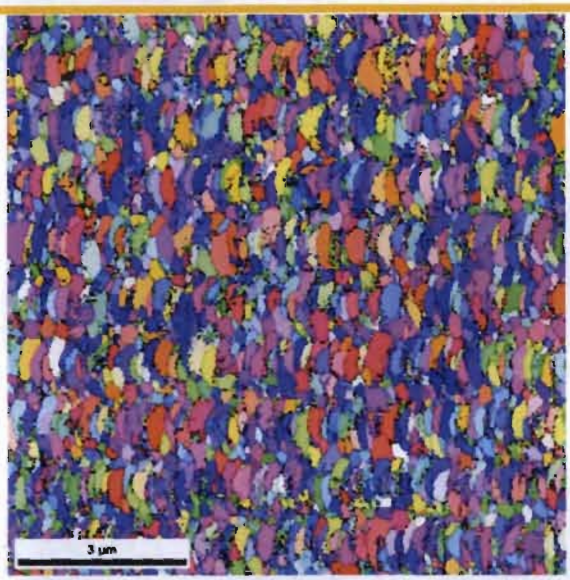
- Free surface starts to move at ~80 ps.
- At ~120 ps, the rate of free surface movement increases.
- Differentiating free surface position gives surface velocity (black line)
- Fourier filtering removes much of the noise, but also broadens the shock rise times.

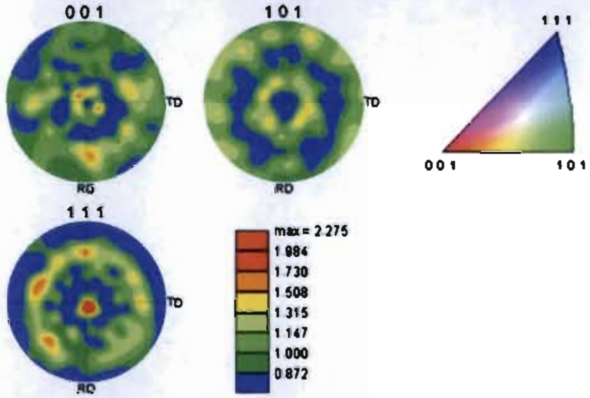




Surface morphology of aluminum

- Grains: Columnar form extending from substrate to free surface.
- Cross section : 1μm x 200 nm
- Orientation: Random
- If shock region of interest ~ 1 μm, we are only probing a few grains!

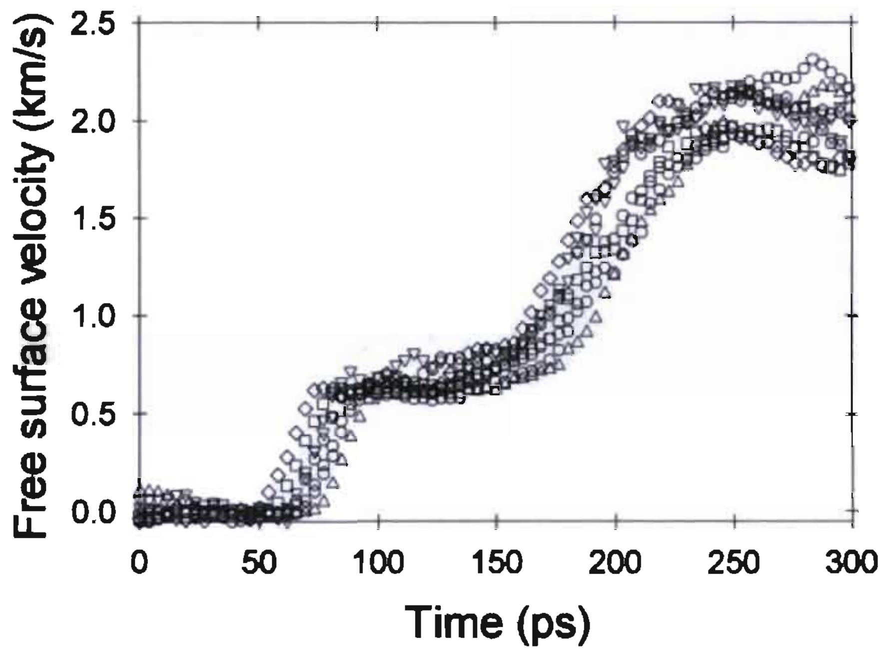




Shot-to-shot reproducibility of shock velocities in 2um aluminum films

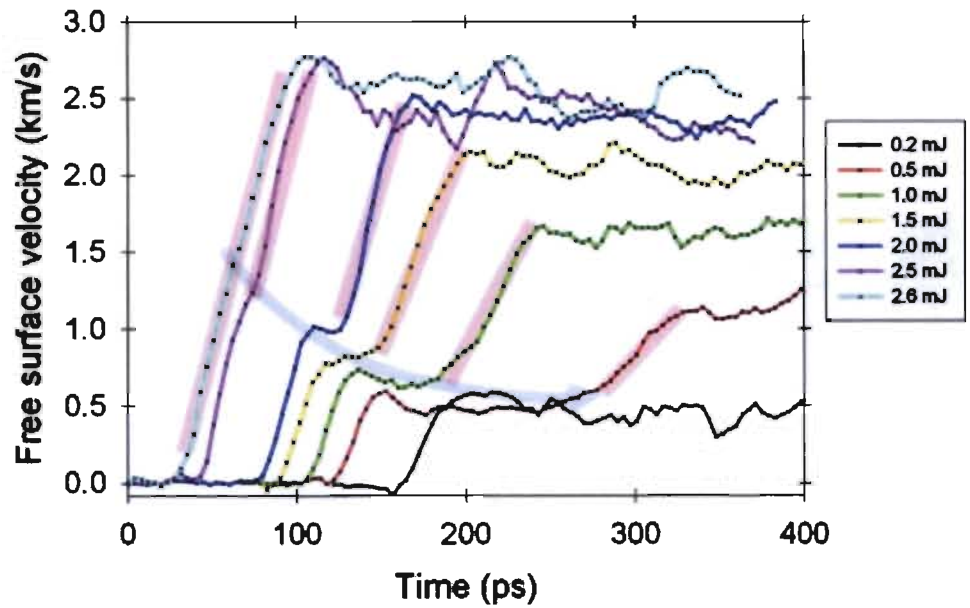
Does grain sampling cause issues?

- 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.



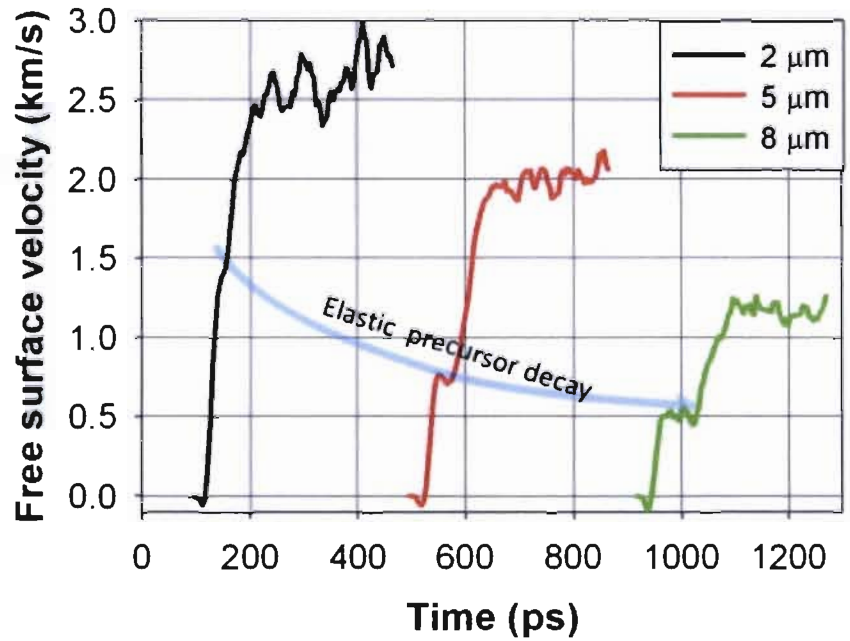
Elastic precursor decay dependence on laser power (pressure)

- 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 μm
- Laser power held constant
- Elastic precursor decays from ~ 1500 m/s to 500 m/s in 6 μm of material
- Time separation between elastic stress and plastic stress from ~ 20 ps to ~100 ps over 6 μm of material.
- Material response in μm 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.**
- **Hugoniots constructed from single laser shock show reasonable agreement to Hugoniots constructed from planer impact events.**
- **Future work**
  - Similar measurements on copper, tin and other metals
  - Characterize role of spall.