SAND2011-4440C

Shock Ejecta Entrainment in Gas – PDV Measurements

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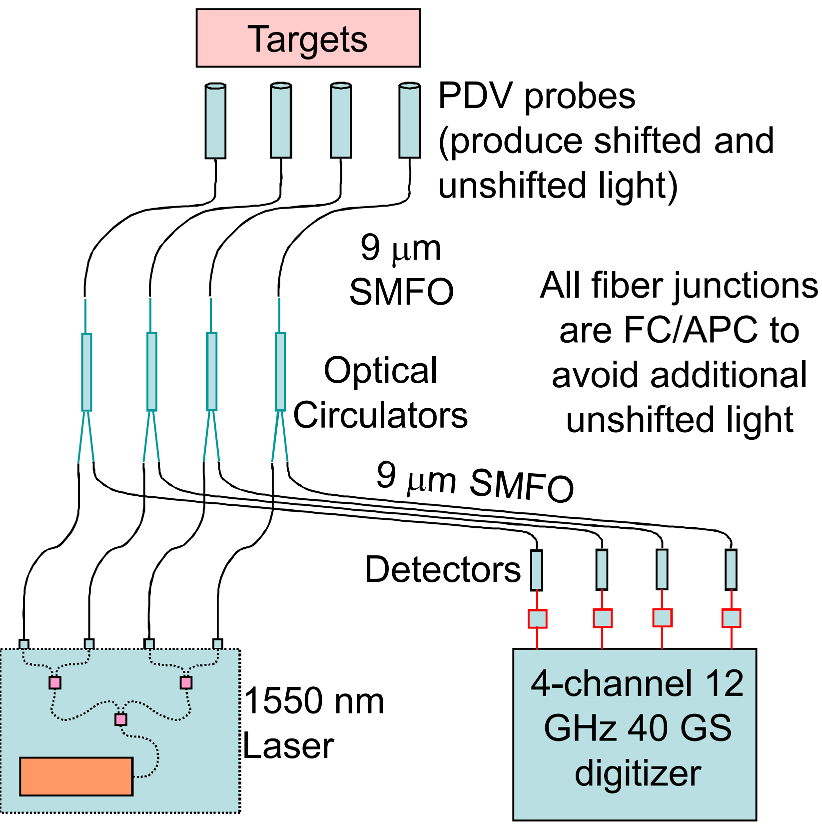
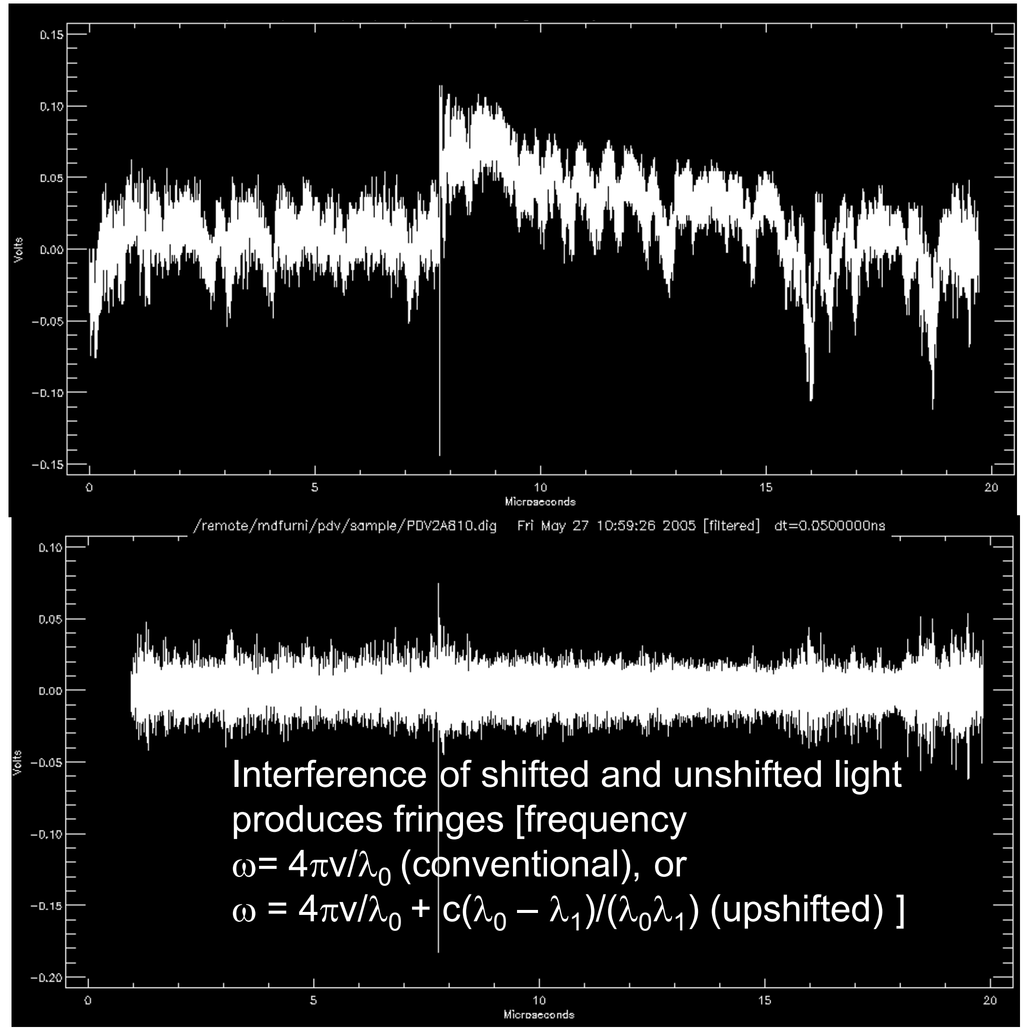
PDV measures the velocities of all objects within its field of view via windowed FFT of the light returned from the target

Conventional PDV: Interferes unshifted ~1550 nm light against Doppler-shifted light to produce fringes, providing velocimetry information.

Upshifted PDV: Same, but uses ~1550+ε nm light as reference; 1550 nm light sent to target (⇒ upshifting frequency of returned signals).





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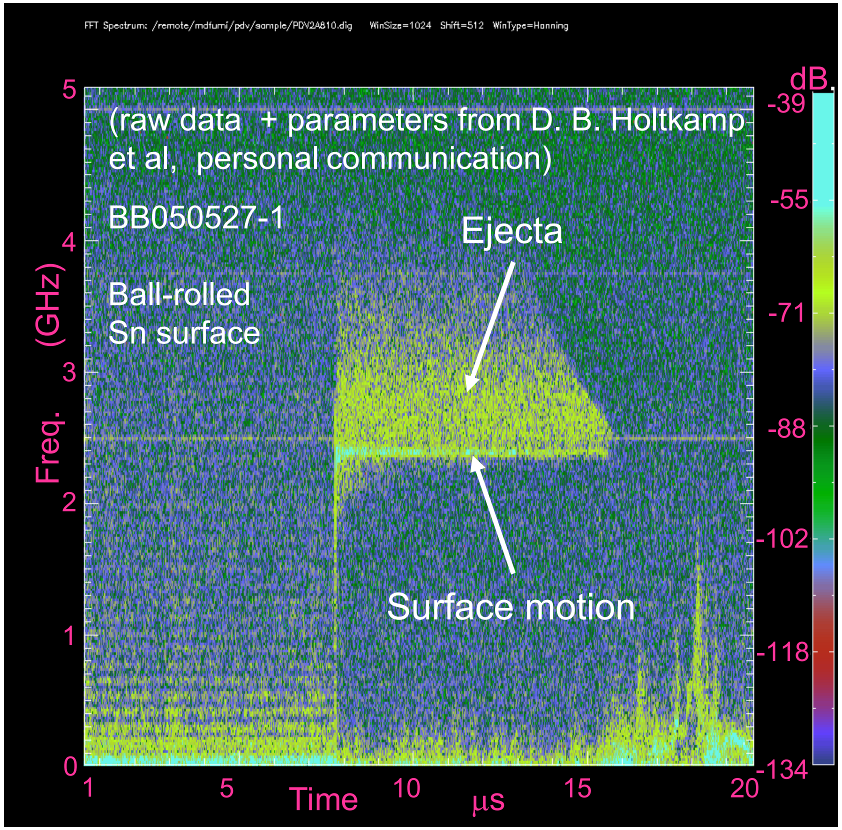
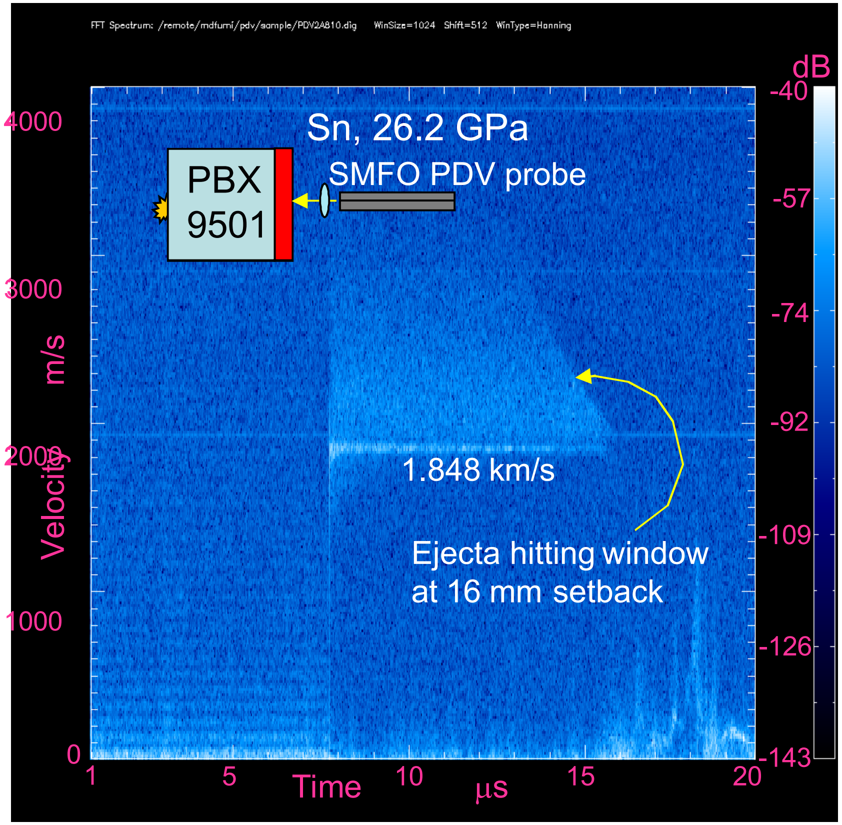
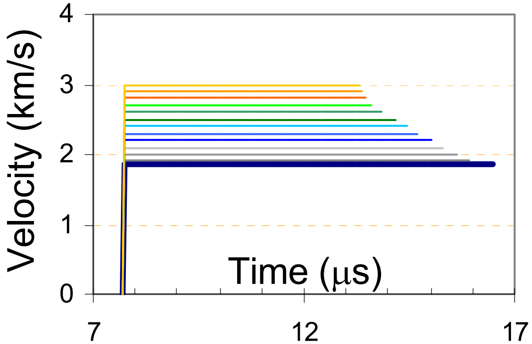
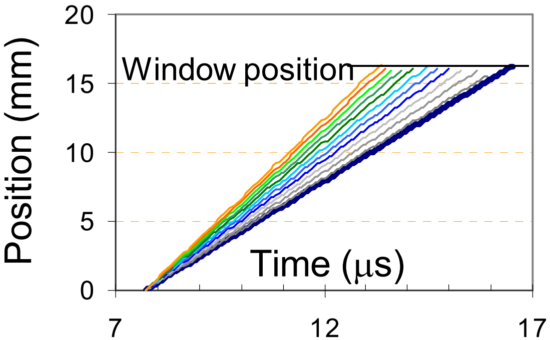
The power spectrum from the FFT may be scaled to a velocity power spectrum ($v = \lambda_0\omega/4\pi$), with λ_0 = 1550 nm)



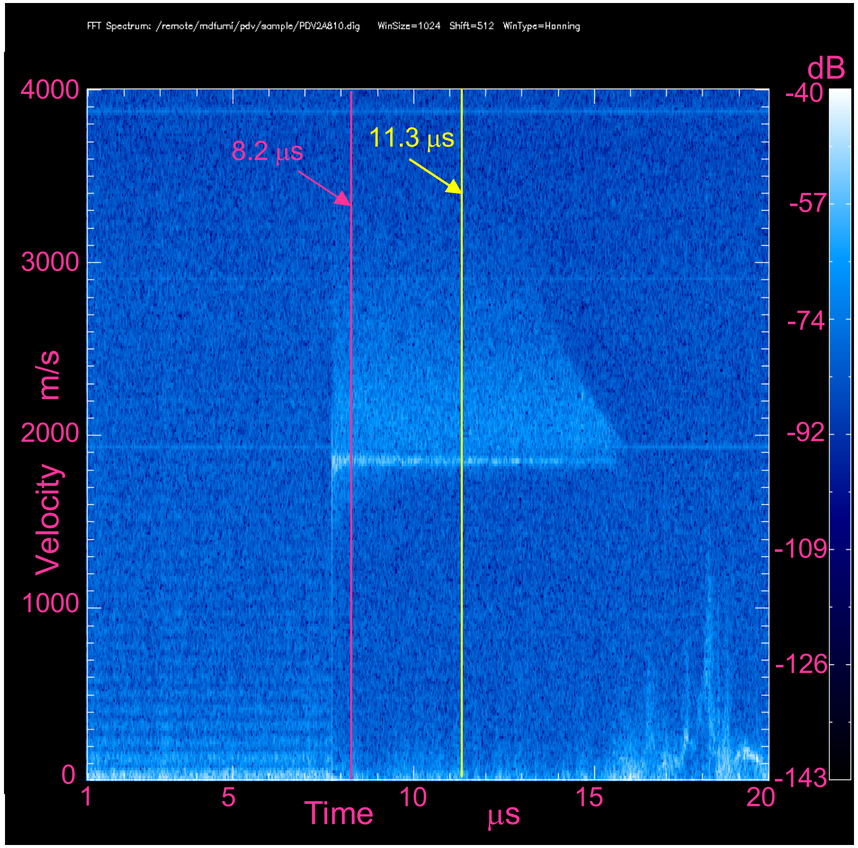


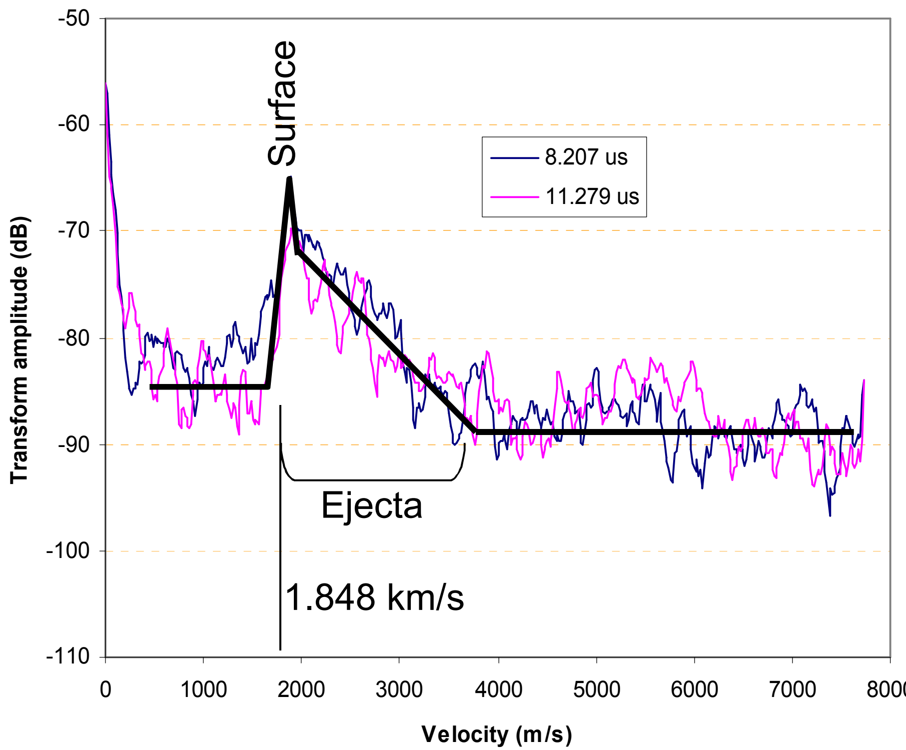


Integrate to give:



This velocity spectrum may be interpreted to mean a principal velocity v(t) and ejecta (or similar) running ahead of the free surface.





The objective of this project is to quantify the measurement of the ejecta density and applied to a gas/ejecta mixture.

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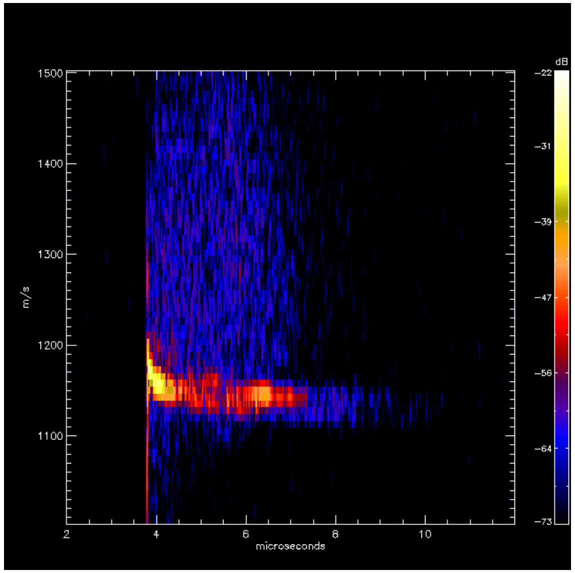
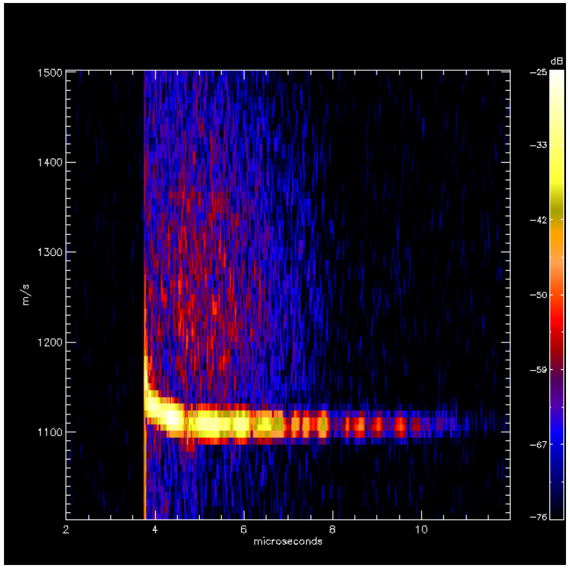
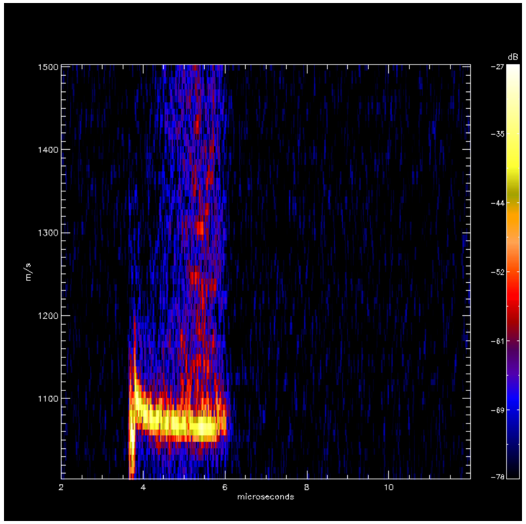
This PDV ejecta signature was also reported for Ortega (presentation earlier today by M. Furlanetto)





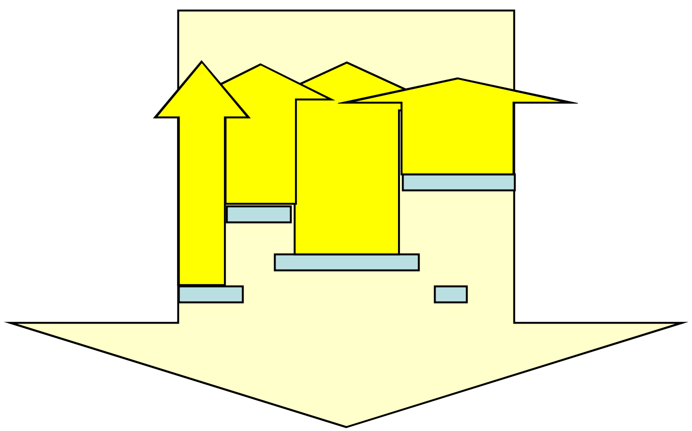
Edge Spots – Ortega
(Furlanetto U4.3)

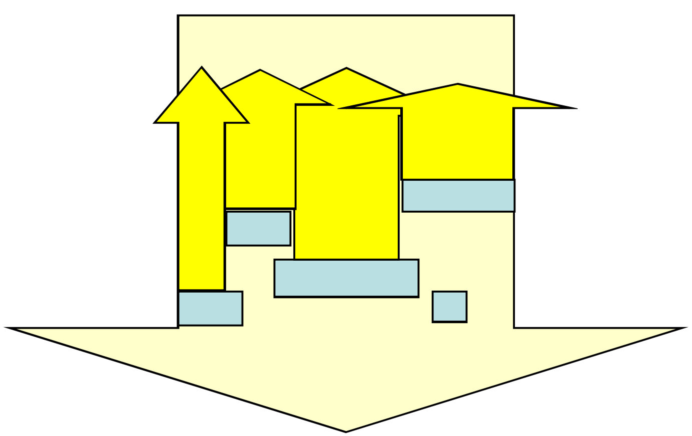


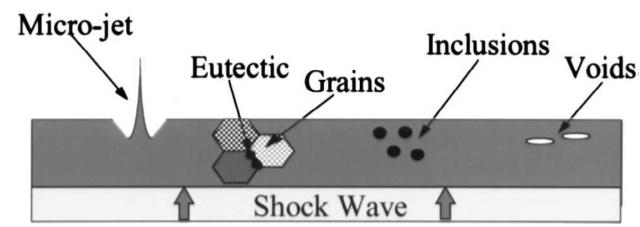
Center Spot – Ortega
(Furlanetto U4.3)

Accurately deducing the ejecta areal density from PDV data requires knowing the thickness distribution of particles

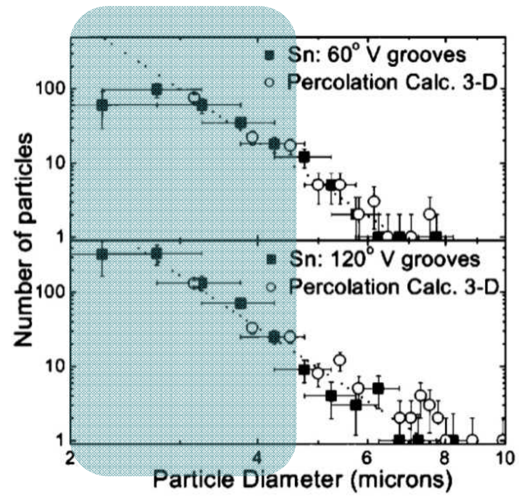
Ejecta size distributions depend on ejection mechanisms, and are predicted by percolation theory.



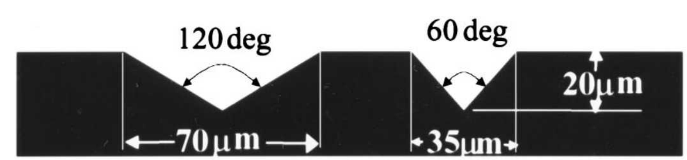




Not visible to PDV (λ = 1.55 μm)?



D. S. Sorenson, R. W. Minich, J. L. Romero, T. W. Tunnell and R. M. Malone, *Ejecta size distributions for shock loaded Sn and Al metals*, J. Appl. Phys., 92, 5830-5836



40 GPa in Sn; <u>λ = 532 nm holography "sees" particles down to 1.5 μm</u>

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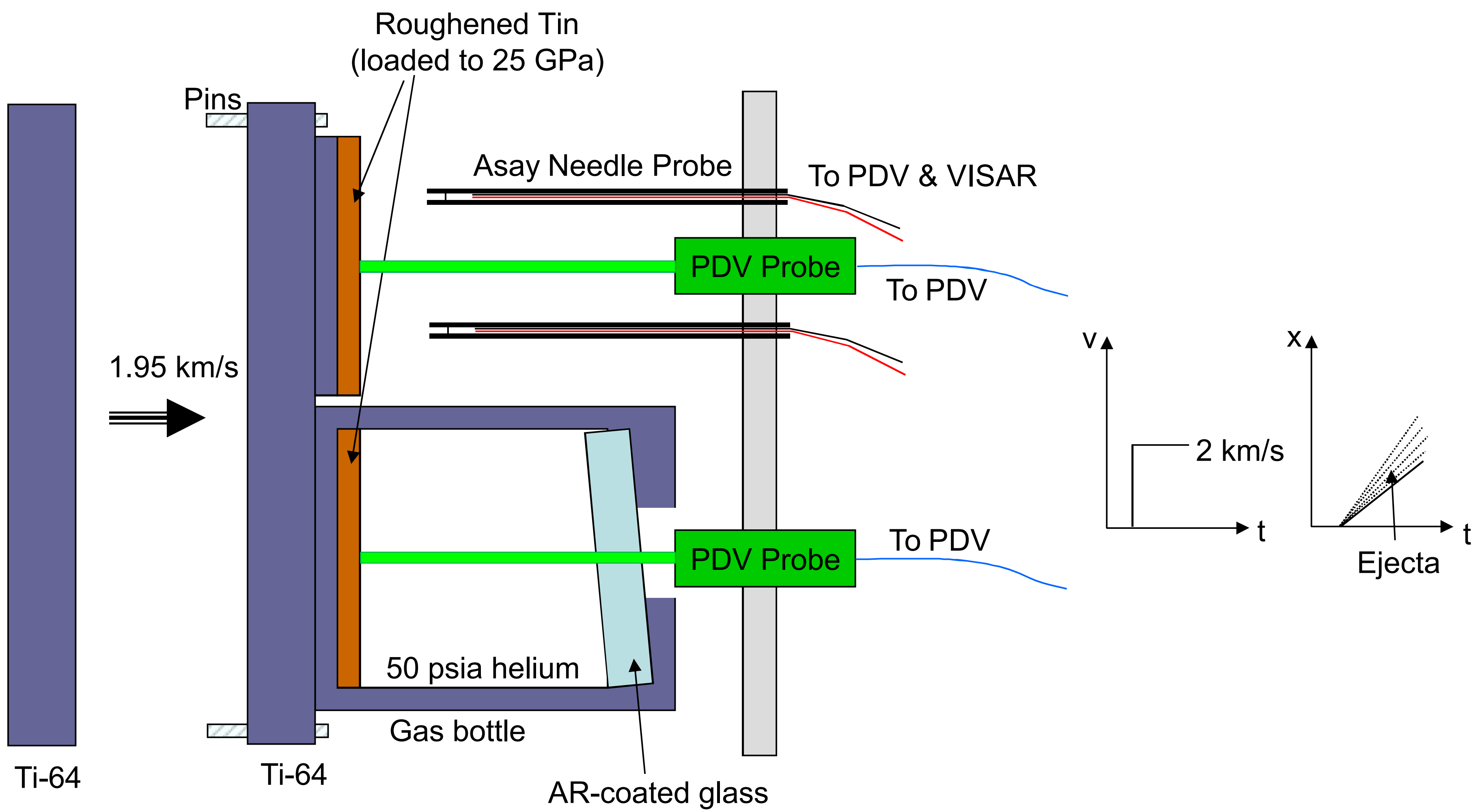
The present study uses Asay foils to “calibrate” the PDV signal amplitudes (does not rely on knowledge of particles)



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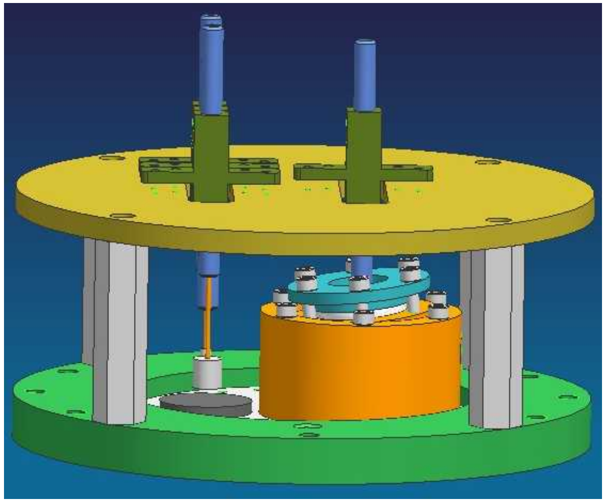
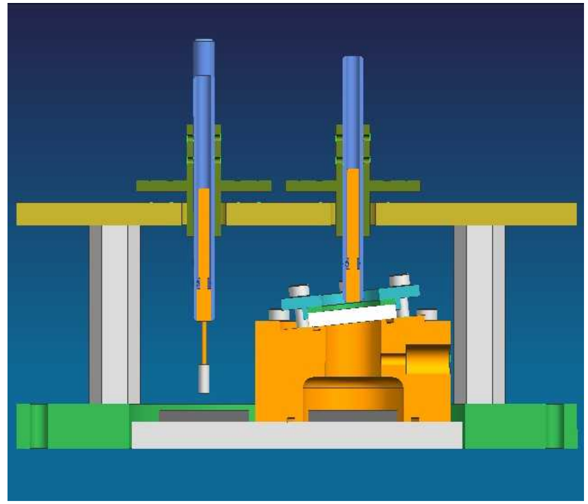
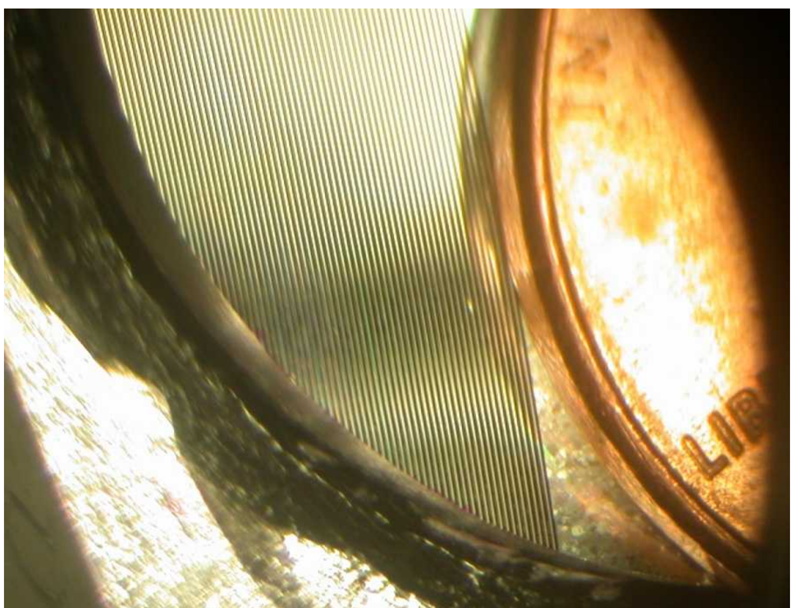
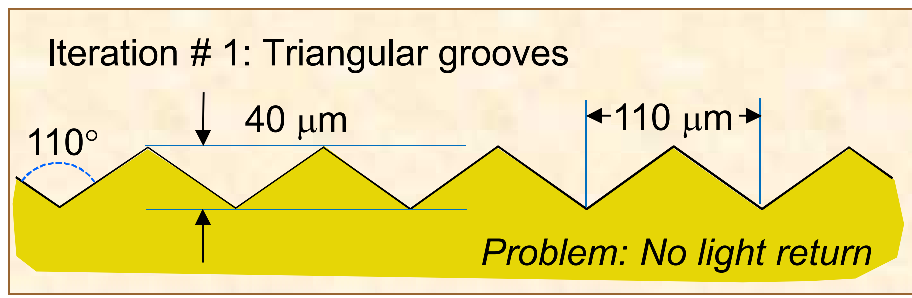
Actual setup: Tilted window, collimated probes, grooved tin

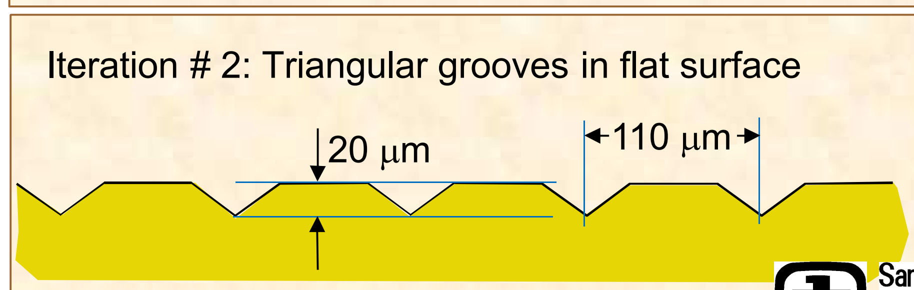




- Impact from below at 1.95 km/s
- Sn: Pressure ~ 25 Gpa
  - Particle velocity U_P ~ 1.0 km/s
  - Temperature ~850K
  - Middle of 19.5 – 33 GPa melt transition (~50% melt)
- Gas 50 psia He







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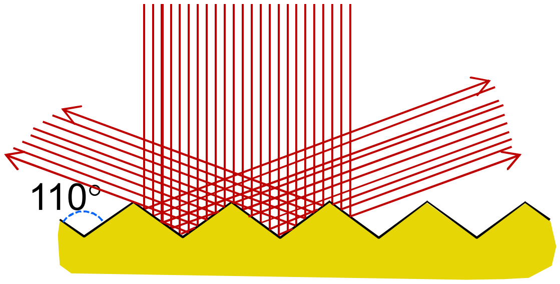
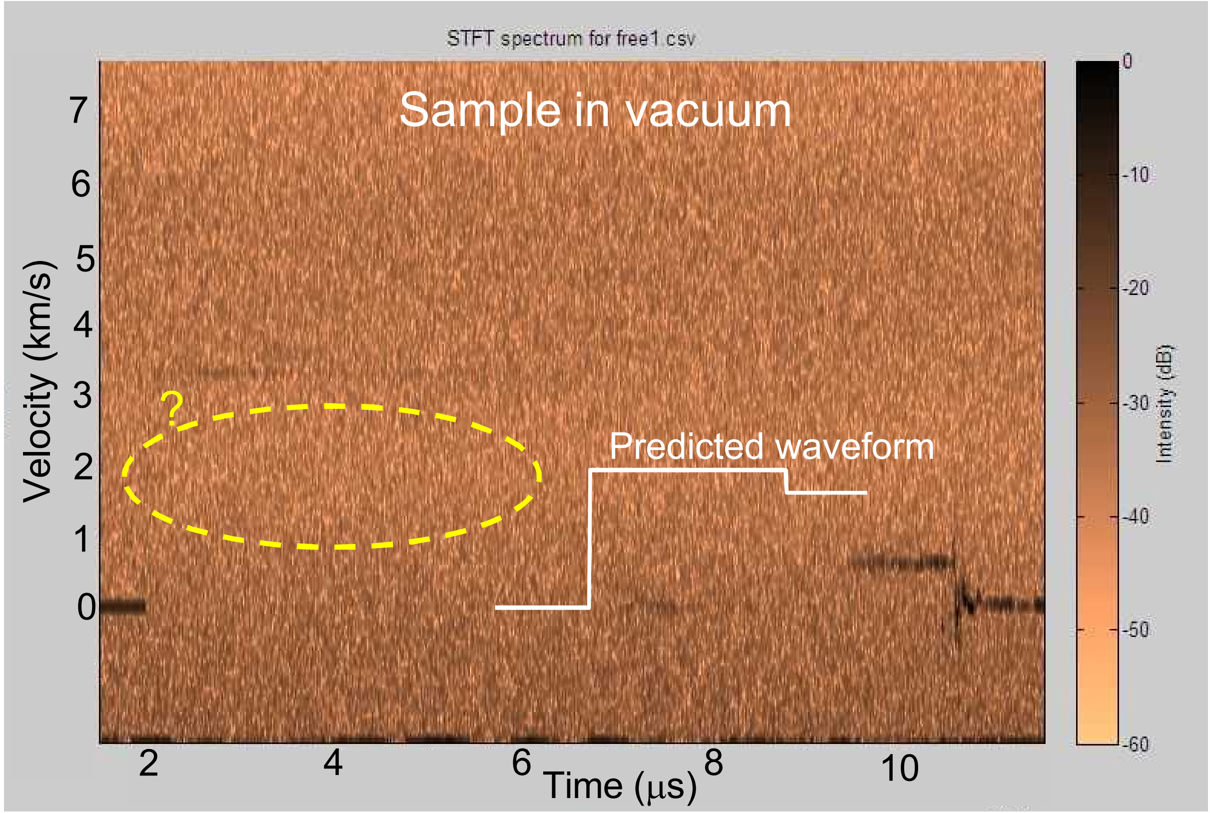
Shot 1: No return from surface – but no return from ejecta either

Thought process: Ejecta kicked out will be visible even if surface motion is not visible

Reality: (1) Ejecta didn't reflect light; (2) Surface sent light off to sides.

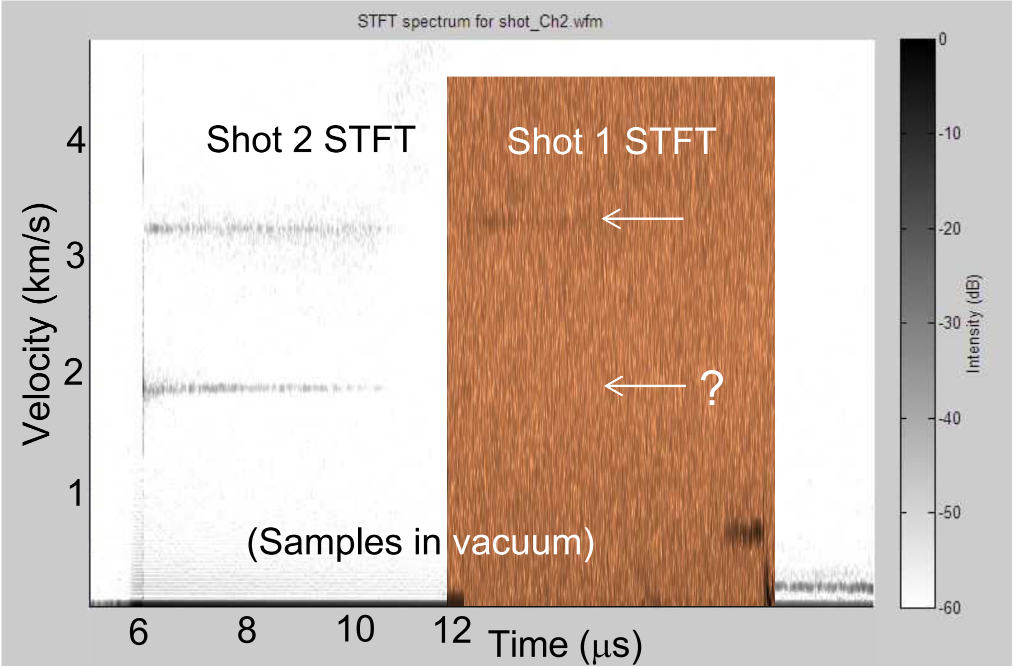




Ejecta areal mass estimated as 2.5 mg/cm^2 (foils accelerated to ~220 m/s – will discuss with Shot 2).

Vacuum sample: Very little PDV return
Sample under gas: No PDV return
Asay Foils: Good VISAR return

Shot 1 showed some indication of spectral amplitude ~~ 3200 m/s



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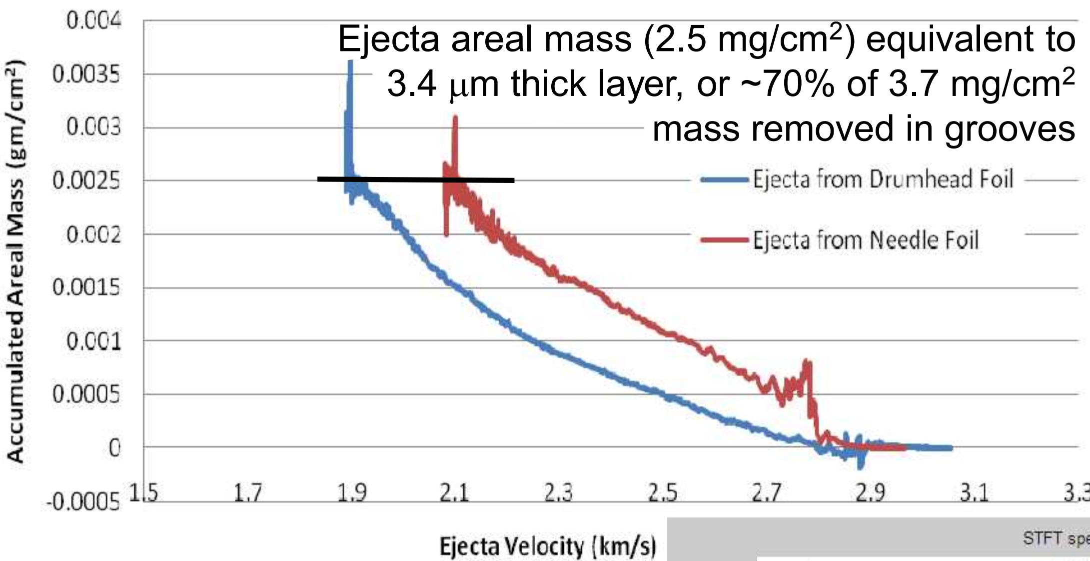
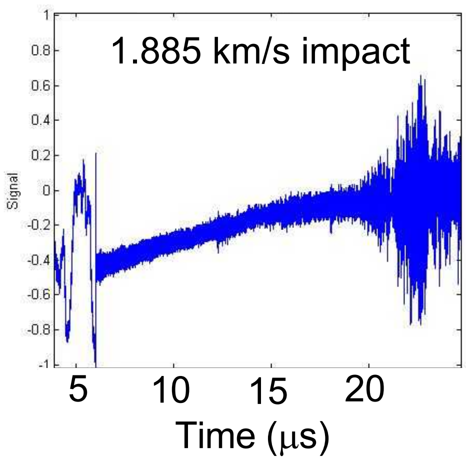
Shot 2: Light return from surface, but not from ejecta

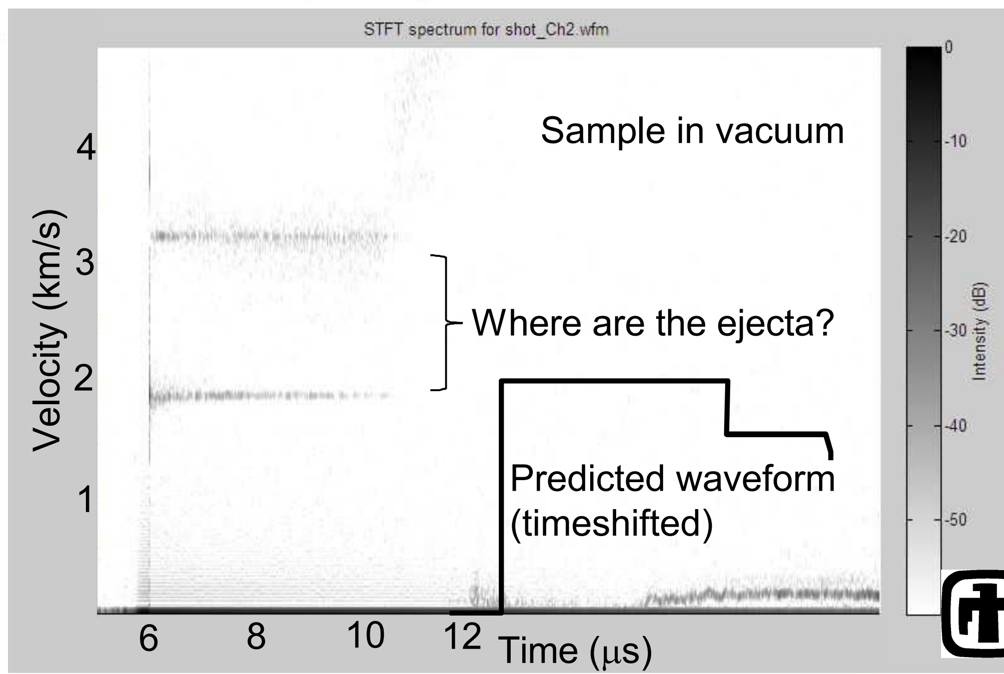


Vacuum sample: Conventional PDV; reasonable return

Sample under gas: Conventional PDV; offscale with low-freq. oscil. (nb. will use upshift in future)

Asay Foils: Good VISAR & upshifted PDV return





Ejecta size considerations (PDV λ = 1.55 μm)

We need bigger chunks of material!

General: Method of ejecta production may affect ejecta size distributions
(e.g. spallation and fragmentation vs. jetting and melting)

So we are sensitive to:
- Material (tin, lead, copper, ceramic, etc.)
- Pressure level (e.g. compared to melting)
  - Sn @25 GPa in the midst of melting (19 – 35 GPa)
- Surface finish (machine marks, grooves, very smooth)

Other facts:
- Above 22 GPa ejecta areal density ↑ 10x *(Seifter, JAP, 105, 123526, 2009)*
- Hot spots, spatial scale ~ 1 mm *(Seifter, 2009; Lutz 2002 SCCM)*
- ~50 μm fragment mean size 150 GPa; laser loaded 50 μm foils
  (Signor, Int J. Impact Engrg, 37, 887, 2010)
- Comprehensive review by *Zellner (JAP, 103, 123502, 2008)* of pressures in mid-melt ranges (~25 GPa) showed dependence on groove angle and pressures. Steeper grooves: more jetting.

Application to our experiments:
- We have plenty of ejecta mass, but small particles.
- Smooth surface (no grooves)?
- Lower pressure?
- Other material completely?
  - (AD995 Alumina 6 μm grain? Powdered dunite?)

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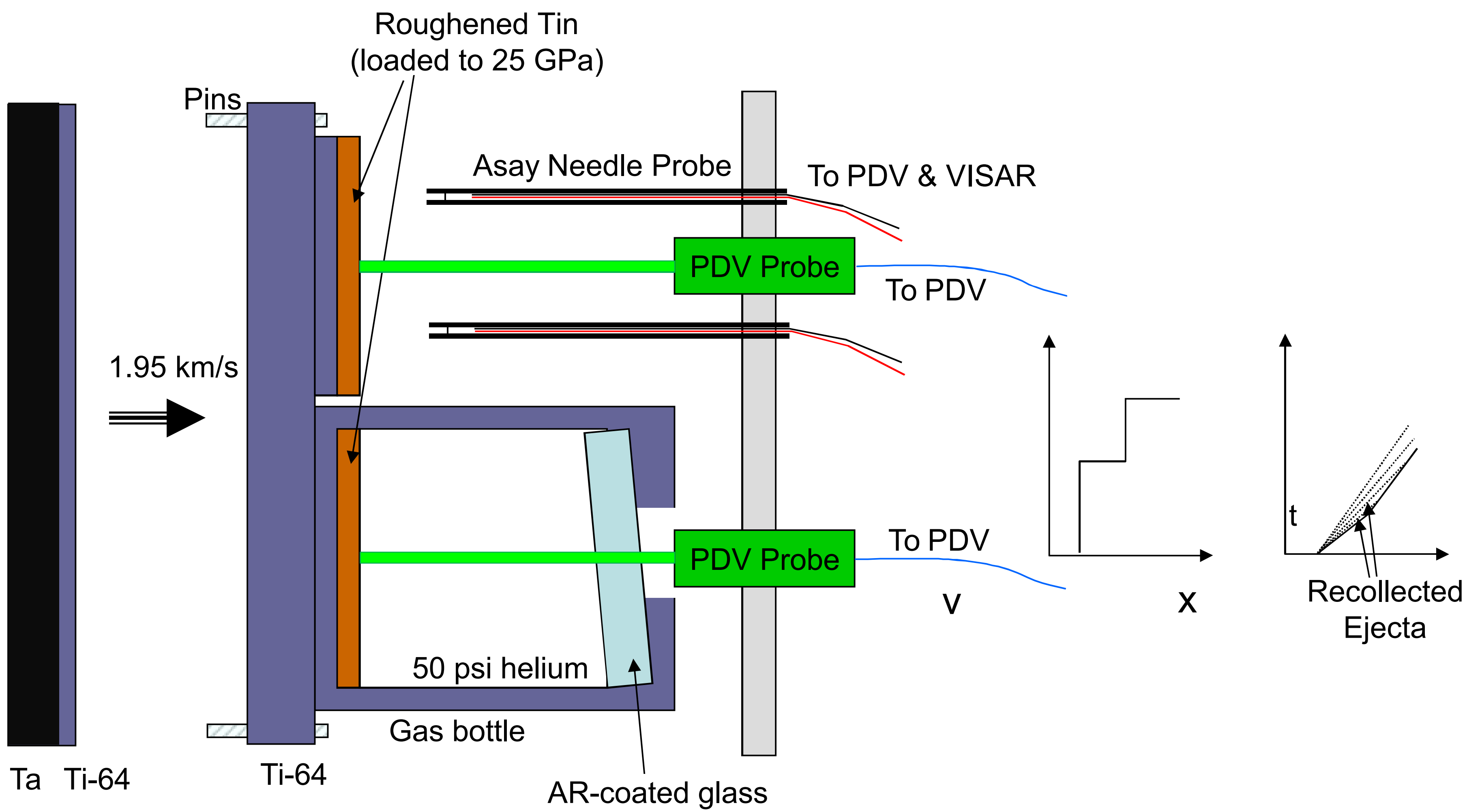
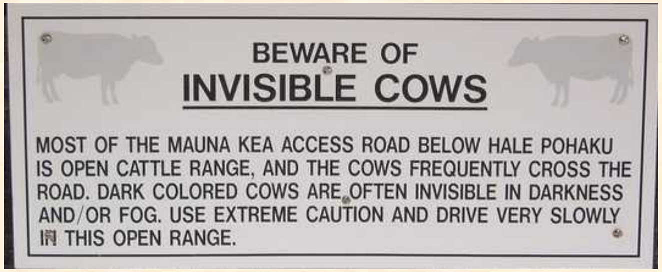
A second set of experiments is designed to study ejecta recollection in gas.



Conclusions

- This is a continuing set of experiments.
  - PDV issues on both experiments
  - Ejecta were invisible – presumably particles were too small to see



- Path forward:
  - 2 tests with multiple materials to assess ejecta visibility
  - Resume tests with successful material
  - Proceed to reshock / recollection experiments

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