

Progress in measuring detonation reaction zone wave profiles using PDV (LAUR-08-05576)

2008 PDV workshop

September 3&4, 2008

Sandia National Laboratories, Albuquerque, NM

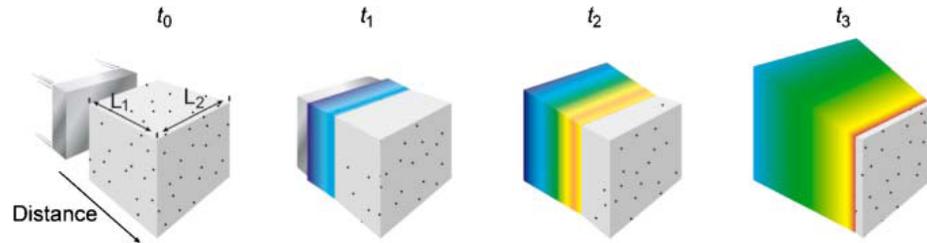
R.L. Gustavsen, Shock & Detonation Physics Group, LANL

B. Bartram, L. Gibson, N. Sanchez, & D. Hooks

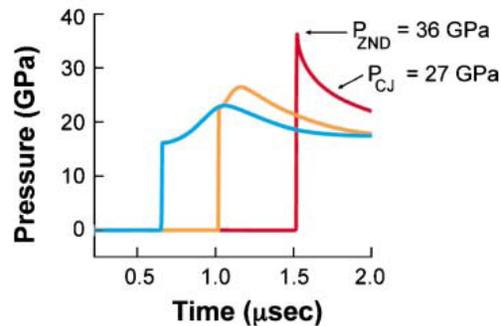
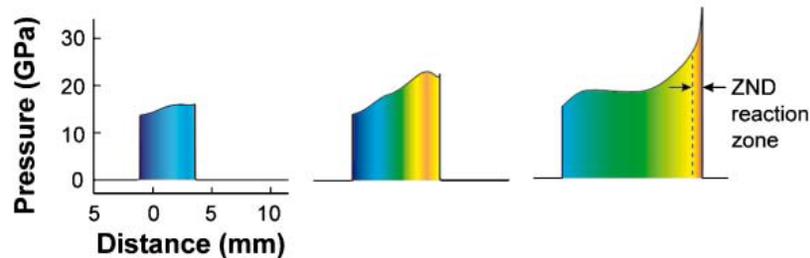
Plan of Talk

- **Background**
- **Shock physics experiment**
- **Analysis**
- **Explosive, window and mirror combinations**
- **Conclusions**

Background: Initiation and propagation of a Zeldovich-Neuman-Doring (ZND) detonation wave

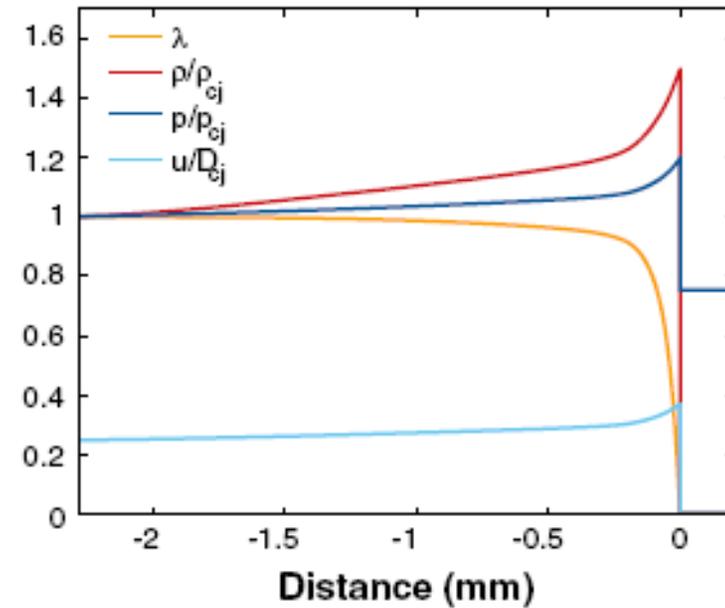
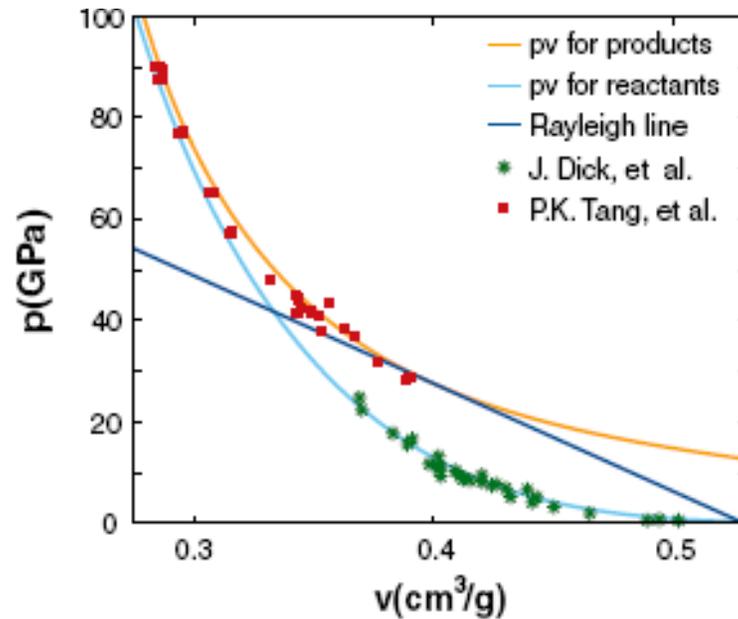


Bdzil & Stewart, Annu. Rev. Fluid Mech. 2007. 39:263-292
fluid.annualreviews.org



Reaction zone estimates are $\approx 1-2$ mm (200 ns) in TATB based explosives, ≈ 200 μm (20 ns) in HMX based explosives.

Background: propagation of the ZND detonation wave



EOS for reactants has large uncertainties at high pressures, has large effect on some calculations.

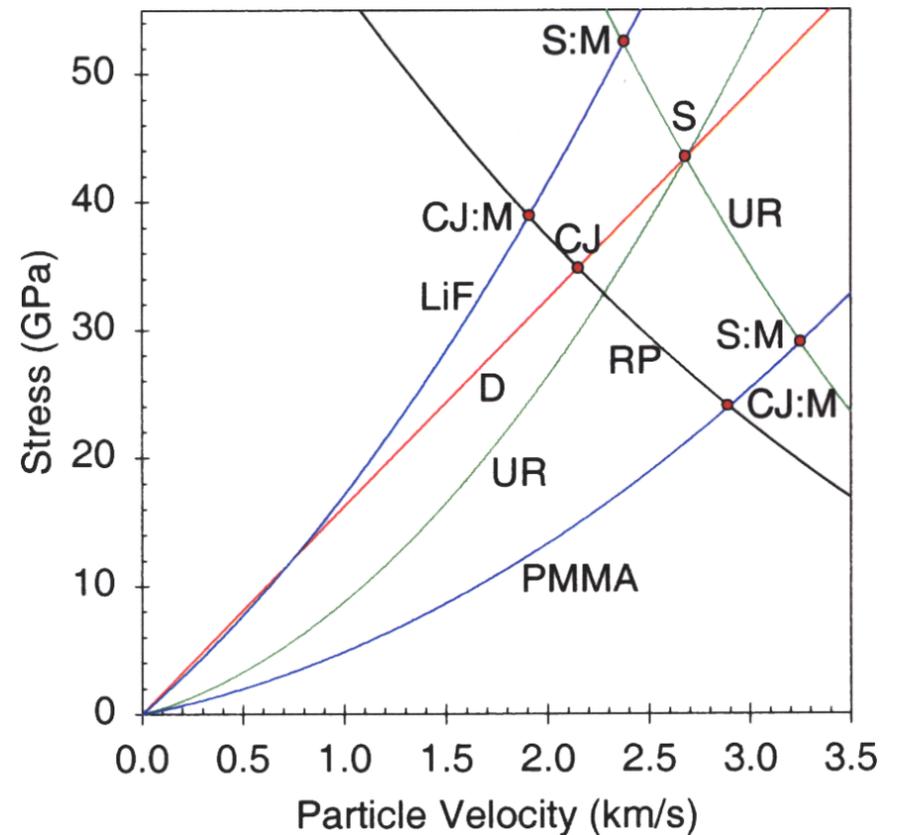
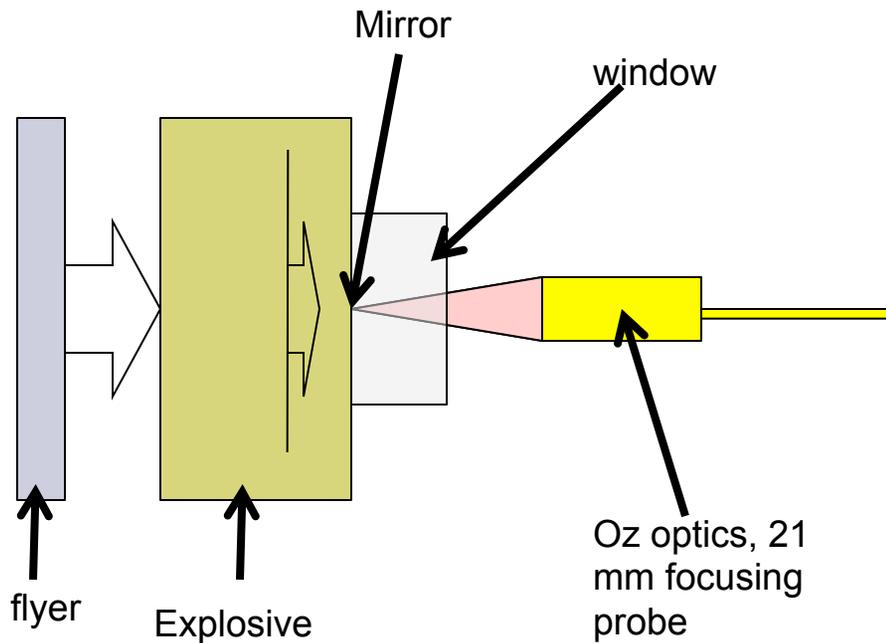
Bdzil & Stewart, Annu. Rev. Fluid Mech. 2007. 39:263-292
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Our group has a long standing interest in measuring detonation wave profiles

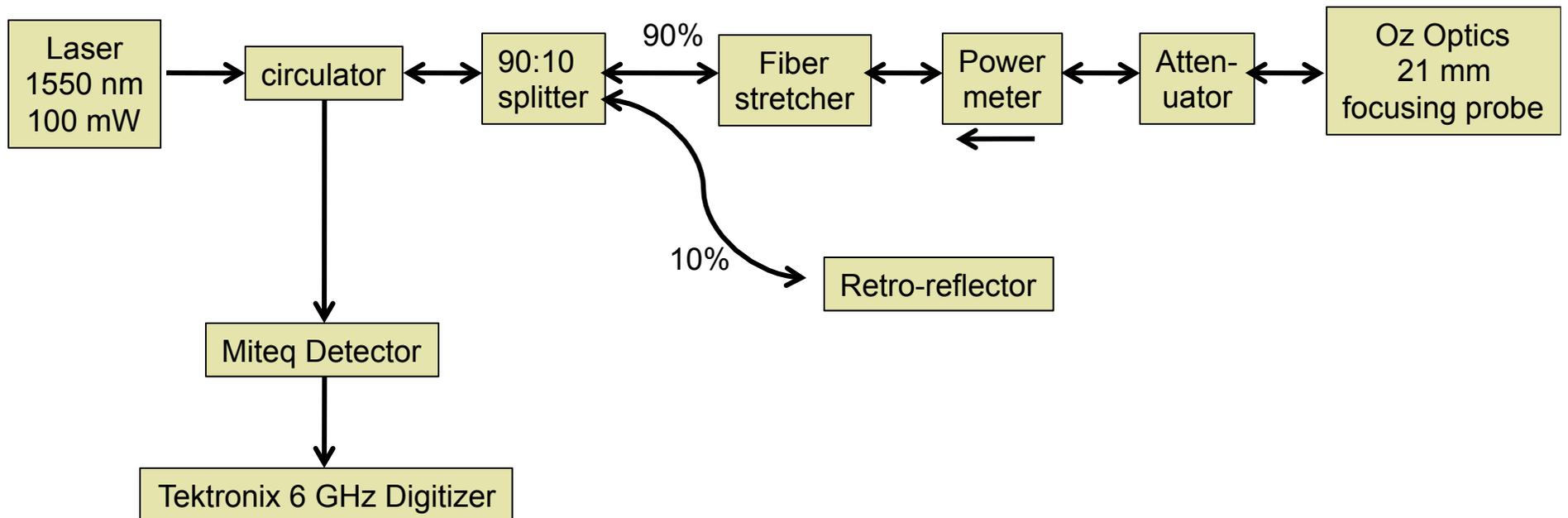
- S. A. Sheffield, D. D. Bloomquist, and C. M. Tarver, *Subnanosecond measurements of detonation fronts in solid high explosives*, **The Journal of Chemical Physics**, 80, 3831 (1984).
- W.L. Seitz, H.L. Stacy, and Jerry Wackerle, *Detonation reaction zone studies on TATB explosives*, in **Eighth Symposium (International) on Detonation**; 1985, p. 123.
- R. L. Gustavsen, S. A. Sheffield, and R. R. Alcon, *Progress in measuring detonation wave profiles in PBX 9501*, in **Eleventh International Detonation Symposium**; 1998, p. 821.
- S. A. Sheffield, R. Engelke, R. R. Alcon, R. L. Gustavsen, D. L. Robbins, D. B. Stahl, H. L. Stacy, and M. C. Whitehead, *Particle velocity measurements of the reaction zone in nitromethane*, in **Twelfth International Detonation Symposium**; 2002, p. 159.

Shock physics experiment: window controls re-shock state & reaction rate

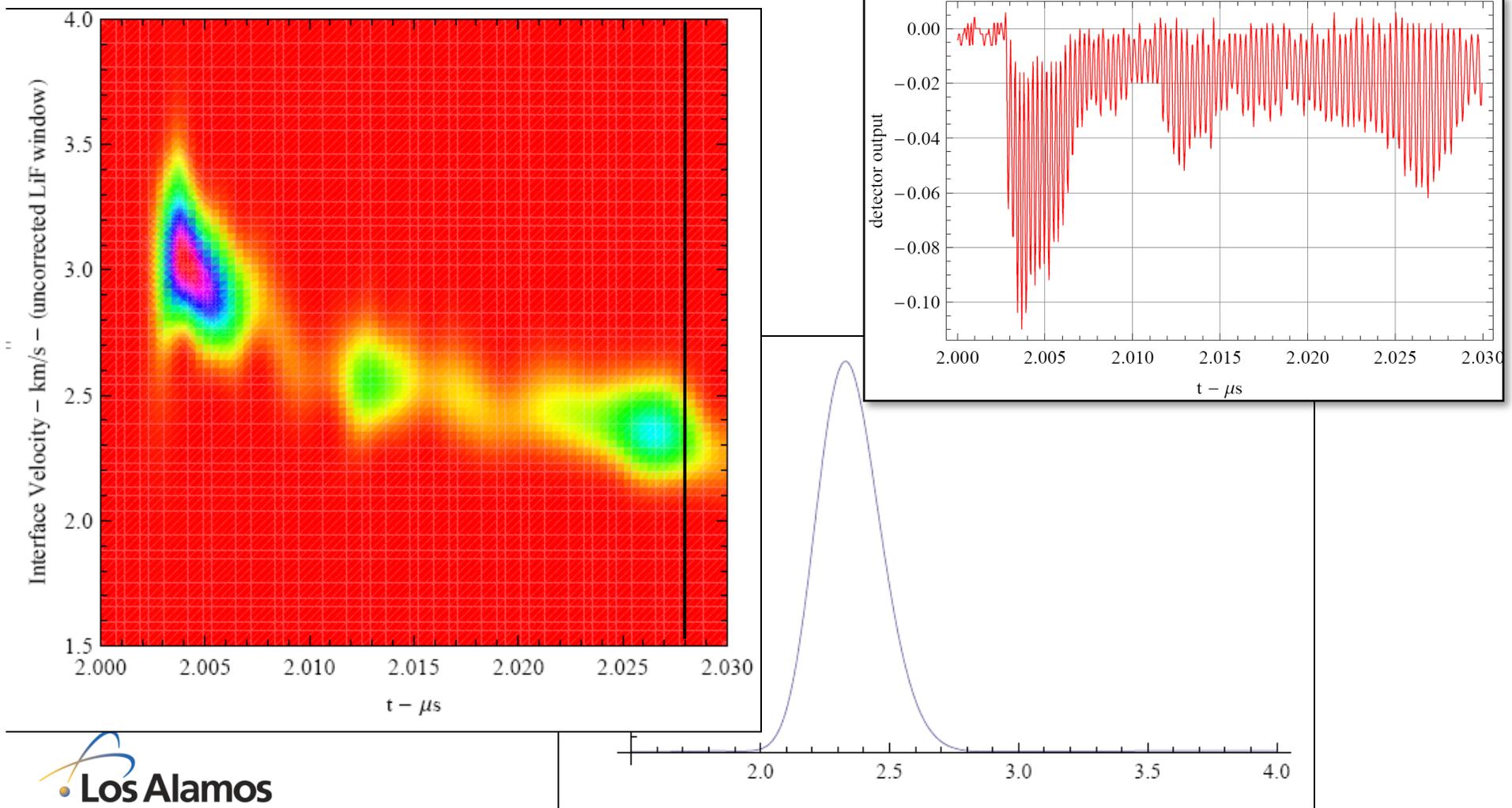
Hugoniot and Isentrope for a 95% HMX explosive



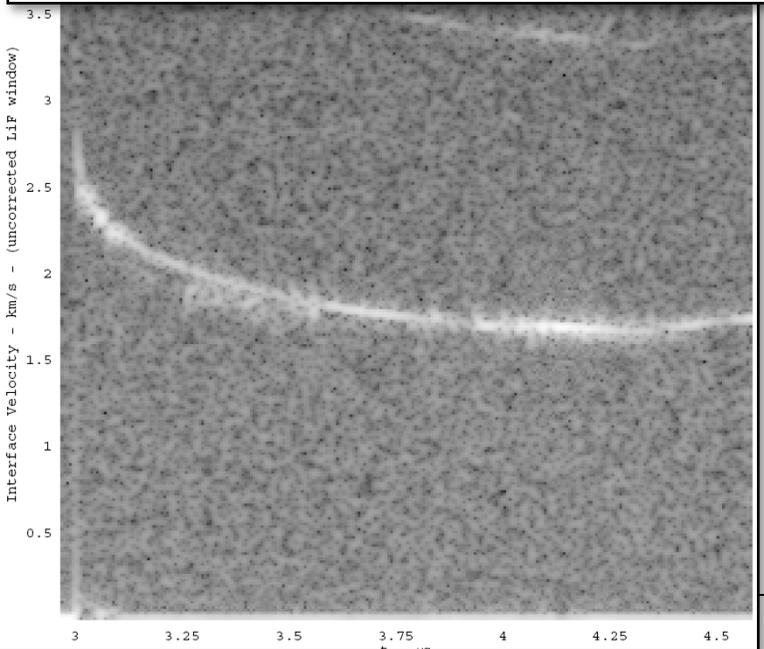
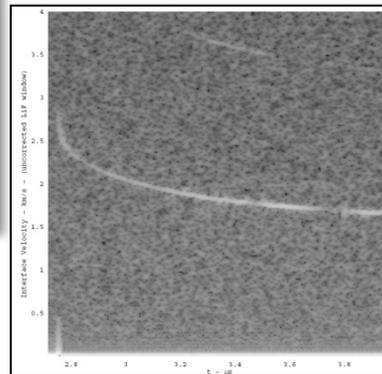
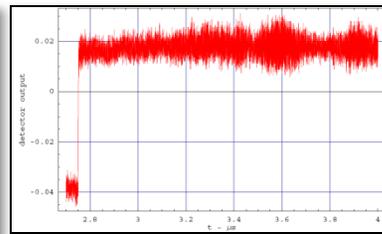
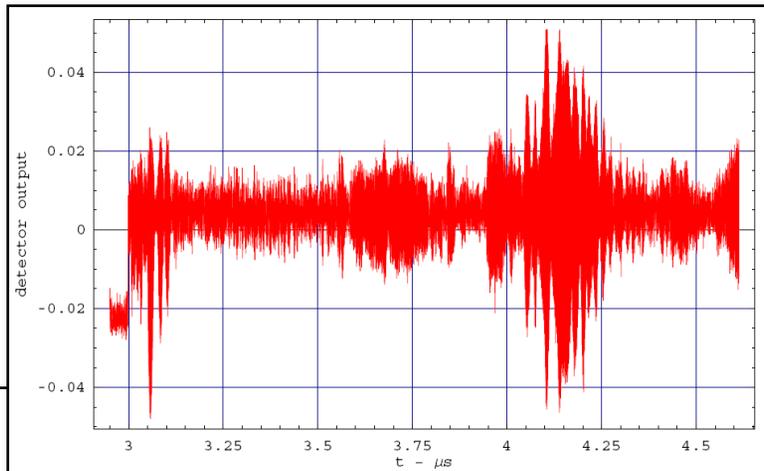
Our PDV interferometer



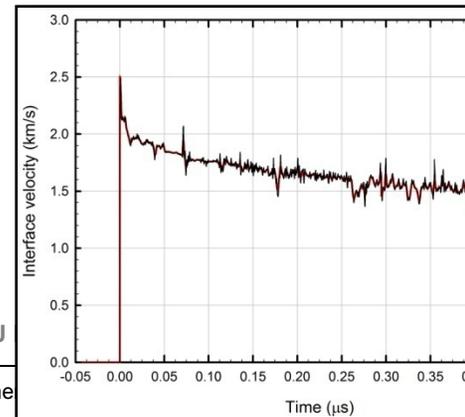
Detailed Spectrogram w. ca. 1 ns resolution: Explosive=PBXN9/ Window=LiF/ Mirror= 6 μm thick, diffuse, Al foil



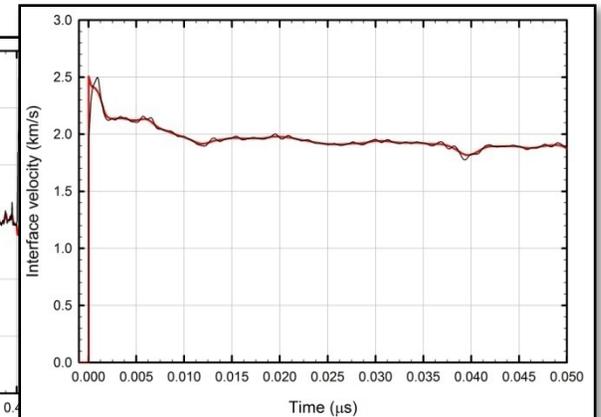
Explosive=TATB:Kel-F/ Window=LiF/ Mirror= vapor deposited Al, diffuse/ no barrier



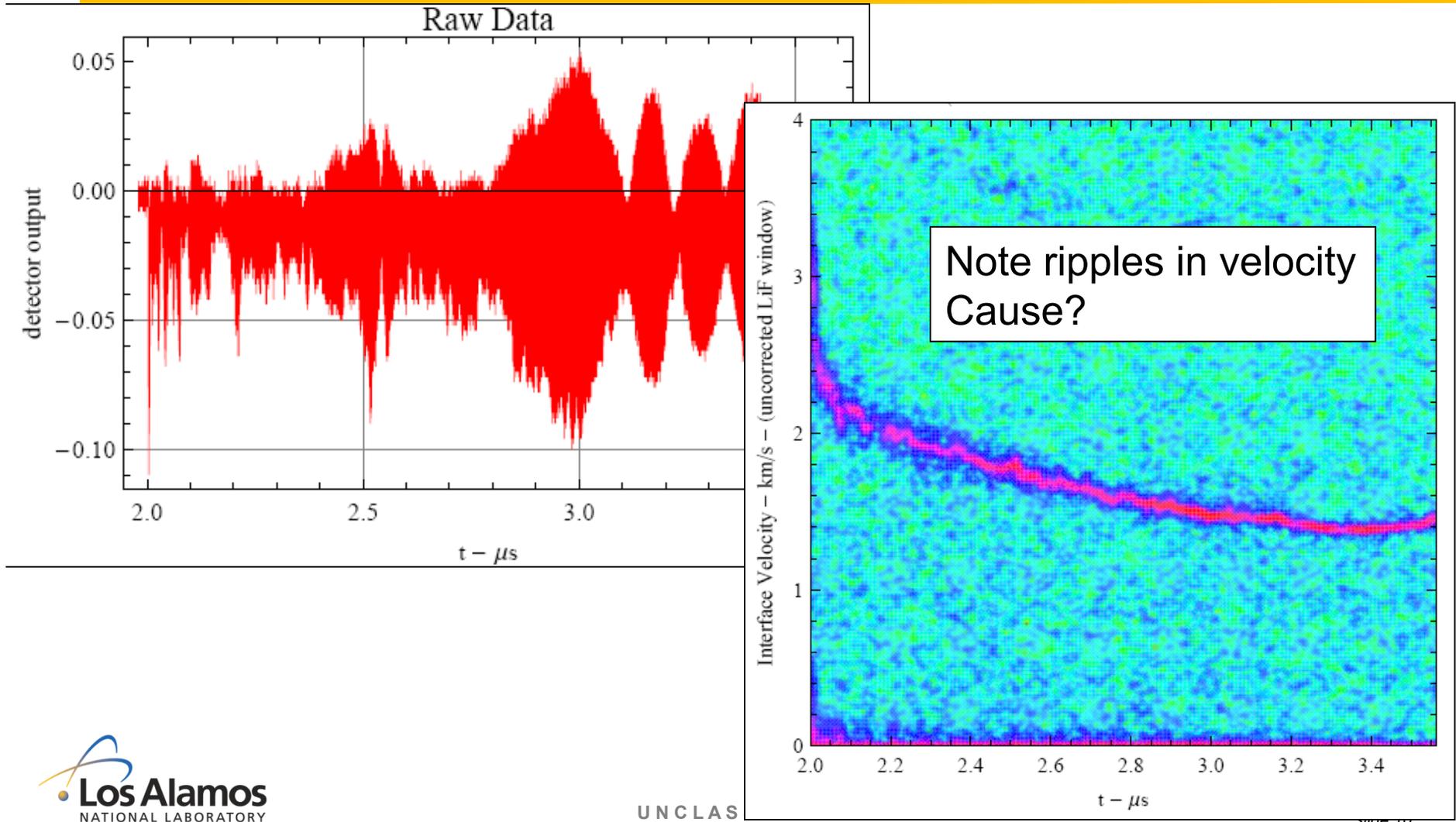
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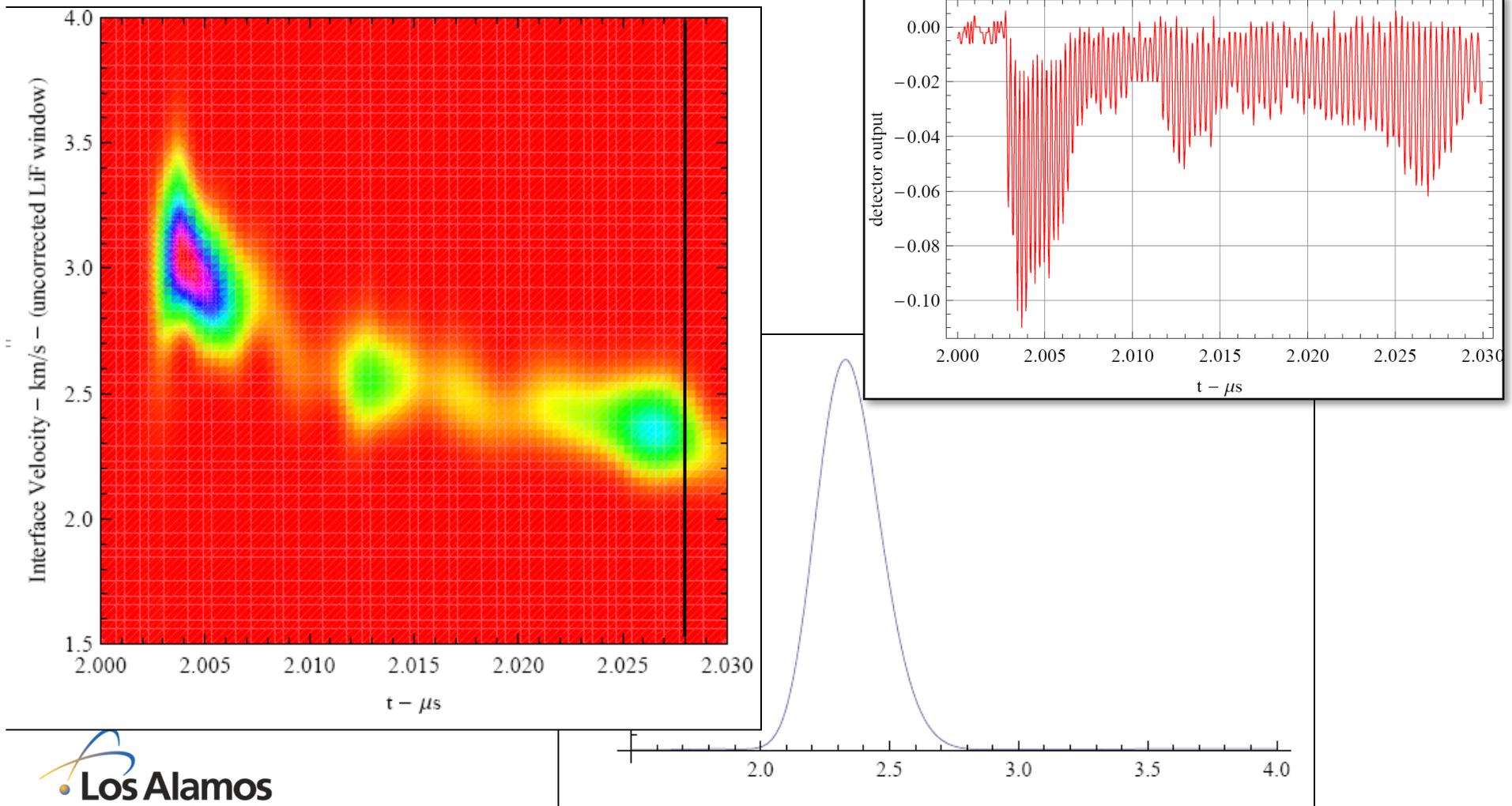
- Mirror surface roughened according to our best VISAR prescription
- Light levels drop dramatically when wave hits mirror
- Assume mirror is burning up
- best records are extracted below (and they're bad)
- N=2



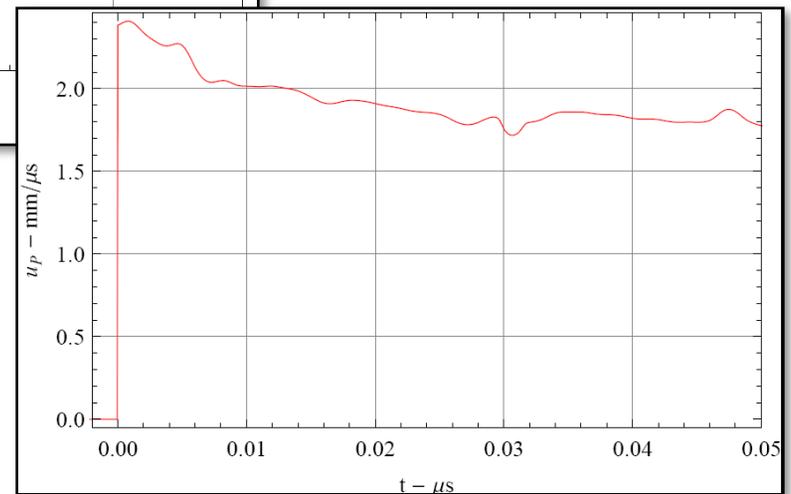
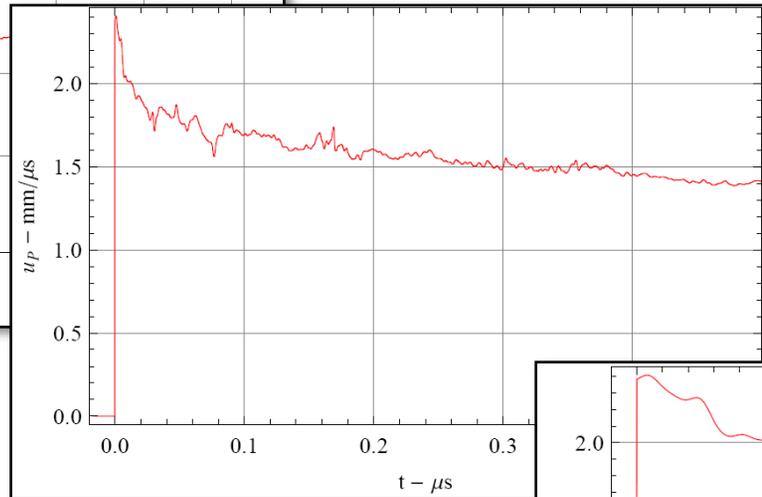
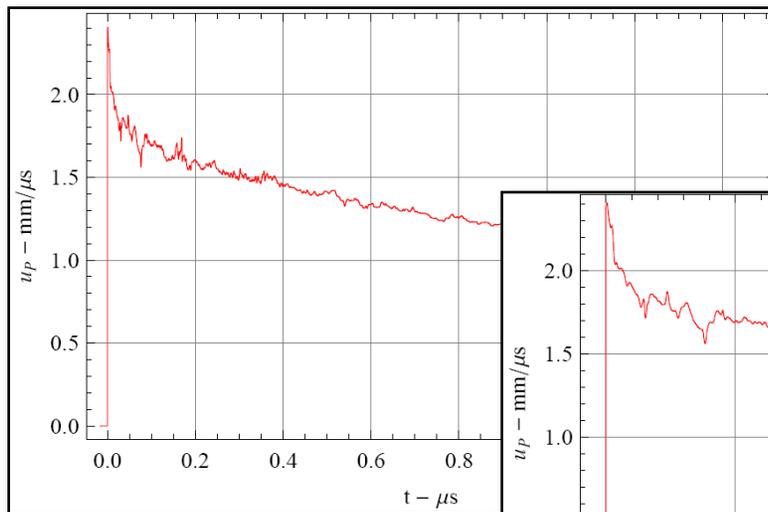
Raw Data & Spectrogram: Explosive=PBXN9/ Window=LiF/ Mirror= 6 μm thick, diffuse, Al foil



Detailed Spectrogram w. ca. 1 ns resolution: Explosive=PBXN9/ Window=LiF/ Mirror= 6 μm thick, diffuse, Al foil



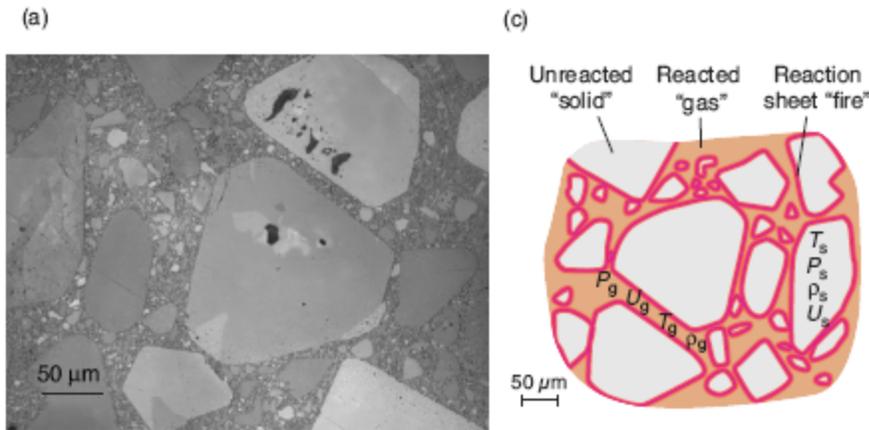
Extracted/corrected wave profiles: Explosive=PBXN9/ Window=LiF/ Mirror= 6 μm thick, diffuse, Al foil



- Ripples until recently thought due to 60 μm laser spot size, 150 μm grain size i.e. grain scale hydrodynamic fluctuations.
- Ripples generally, but not always, coincident with intensity fluctuations.

N=5

Micrograph of PBX 9501 and notional reaction process



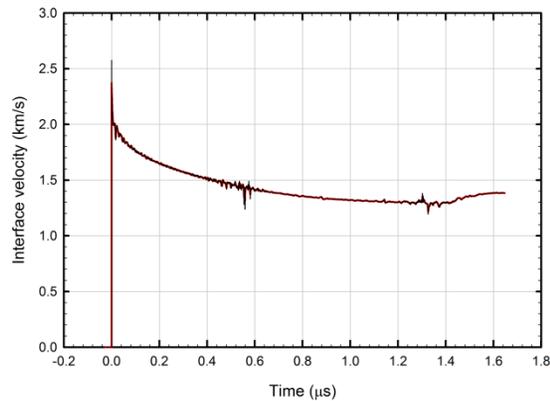
- Ripples until just lately thought due to 60 μm spot size, 150 μm grain size i.e. grain scale hydrodynamics.
- Mel Baer et al. at SNL and Ralph Menikoff et al. at LANL are simulating shocks in composite explosives such as these.

Figure from Bdzil , et al., Los Alamos Science, No 28, 2003, page 96.

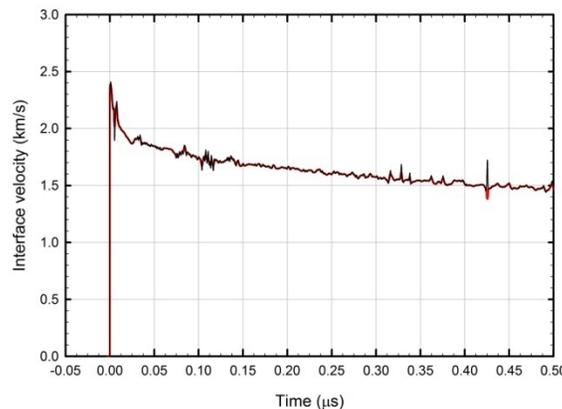
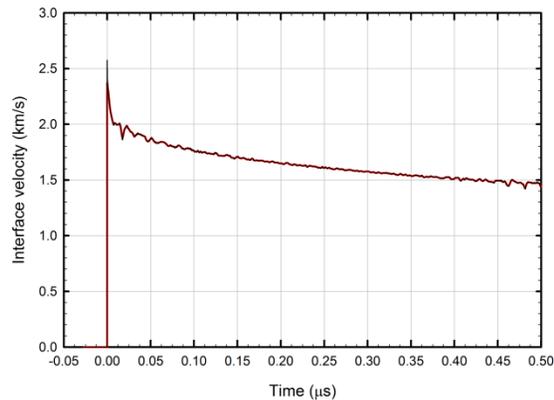
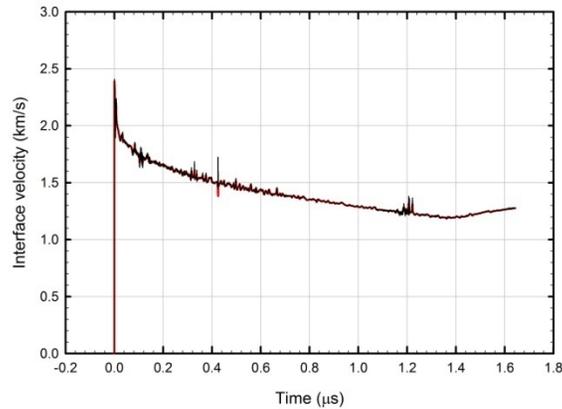
Micrograph originally from Skidmore et al. (LANL)

Explosive=TATB:Kel-F/ Window=LiF/ Mirror= 6 μm thick, diffuse, Al foil

Good



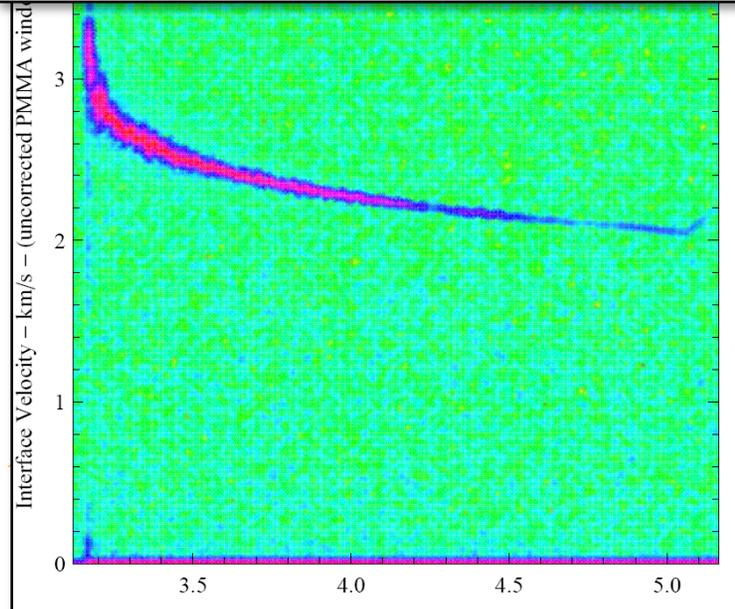
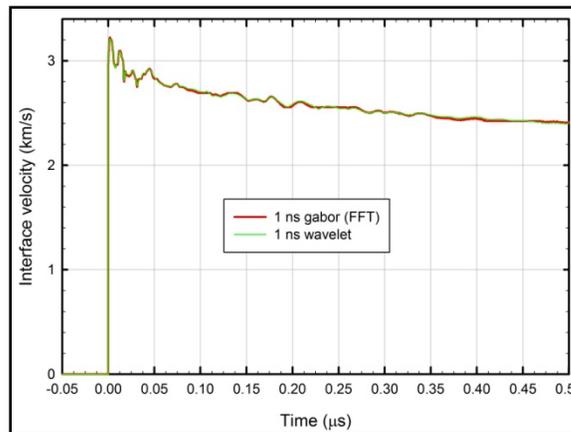
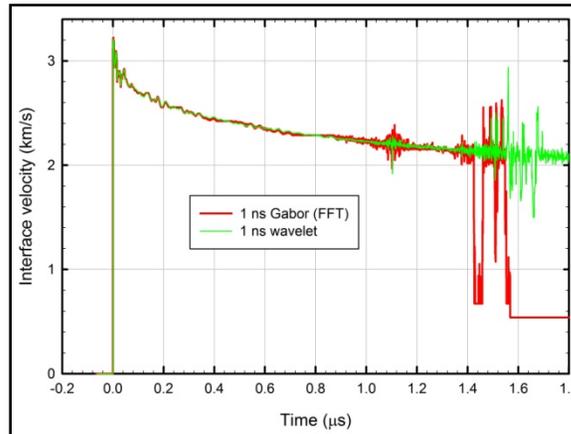
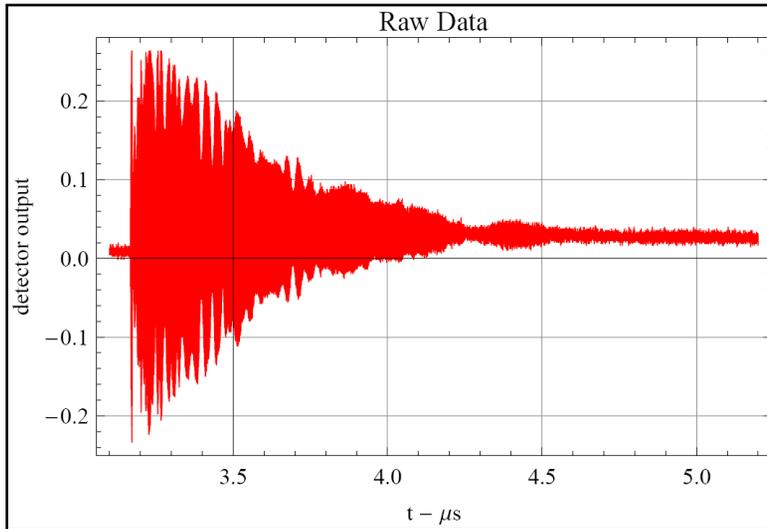
Not so good



- 2 reactions observed: fast ≈ 20 ns, slow ≈ 200 ns
- LiF windows with diffuse Al foil mirrors are robust.
- Ripple (or noise) levels vary quite a bit from one experiment to the next.

- N=8

Explosive=TATB:Kel-F/ Window=PMMA/ Mirror= 6 μm matte Al foil



Comments on PMMA windows

- + different impedance
- + inexpensive
- do it yourself optical finish
- no 1550 nm correction factor
- light goes out at high pressures
- Lots of noise in typical records (my best records are shown)

N=3

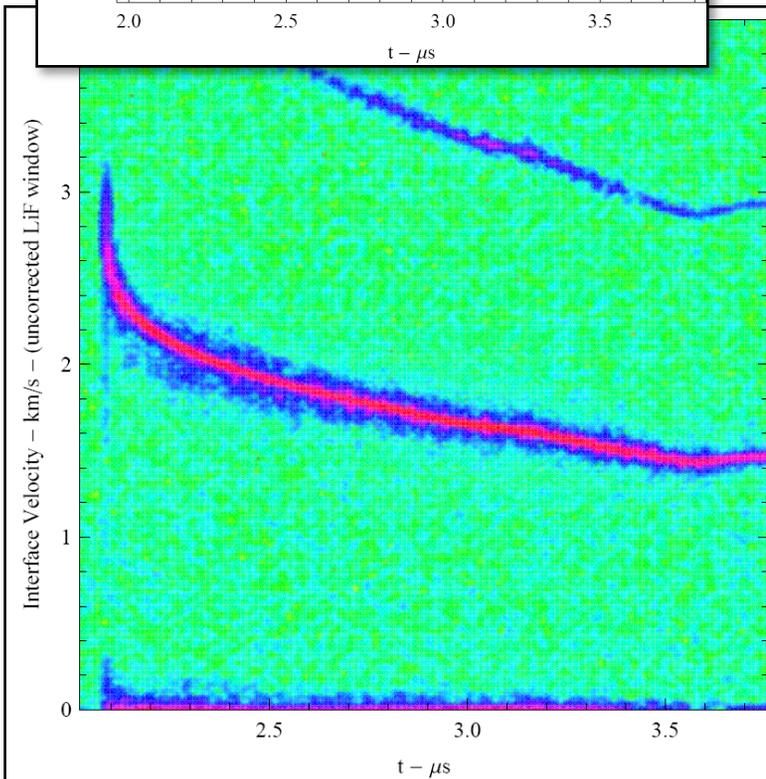
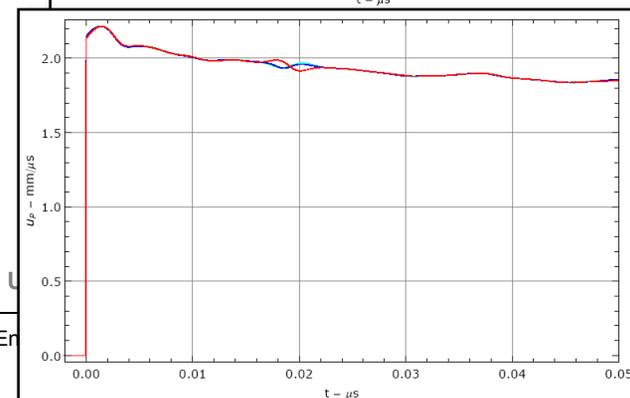
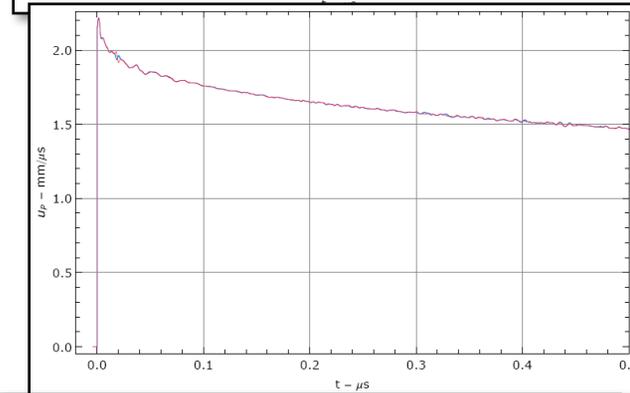
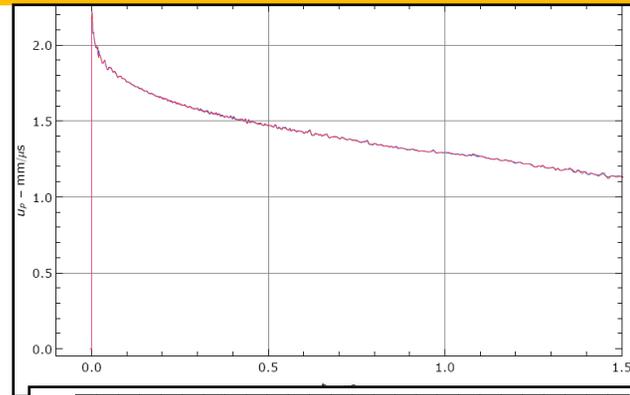
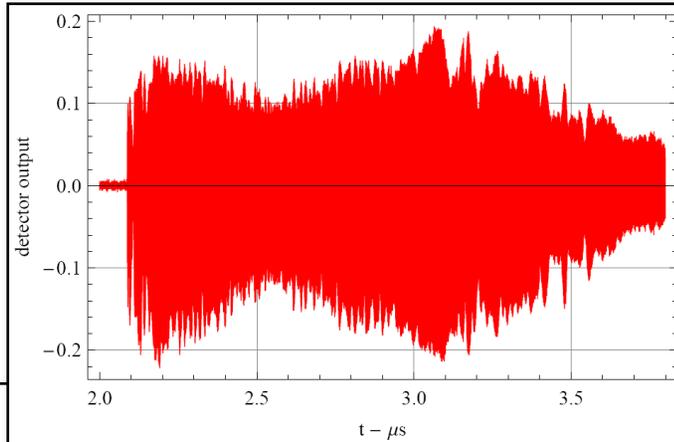
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Slide 15

of Energy's NNSA



Explosive=TATB:Kel-F/ Window=LiF/ Mirror= vapor plated Al, specular, No barrier



Comments

- Best yet!
- Resolution shown 1ns
- As good as VISAR?
- What improvements can be made?
- Are there better analysis methods to apply if you have really good data?

N=1

Summary

▪Windows

- LiF > PMMA
- Still need correction factor for PMMA windows
- Are the PMMA problems due to the do it yourself optical finish?

▪Mirrors

- Specular vapor plated Al > 6 μm Al foil > diffuse vapor plated Al
- Barriers not needed (except maybe for diffuse vapor plated Al)
- Ripples mostly correlated with intensity fluctuations. Intensity fluctuations likely due to laser speckle from diffuse mirrors (much reduced with specular mirrors).
- Would an uncoated window work?
- Should the explosive be polished? Currently just machined finish.

▪General comments

- Some ripples remain in the best data. These are likely due to grain scale hydrodynamic fluctuations. We need to look at profiles in homogeneous materials (nitromethane) where these are not expected.
- ≈ 1 ns resolution can be achieved with good data.
- Slowly varying intensities highly desirable.
- With PDV you can always get something!