Shock Wave Experiments Using PDV: Window Characterization at 1550 nm

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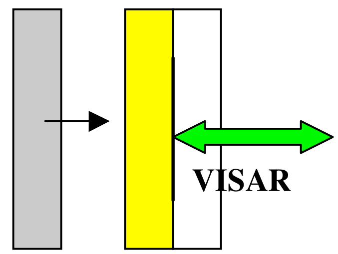
Outline

- Introduction: Traditional shock wave measurements with windows
- Experimental Approach
- Measuring projectile velocity with pins and PDV
- VISAR & PDV results for sapphire
- Window correction results for c-cut sapphire, z-cut quartz, and LiF(100)
- Time-dependent wave profiles
- Summary

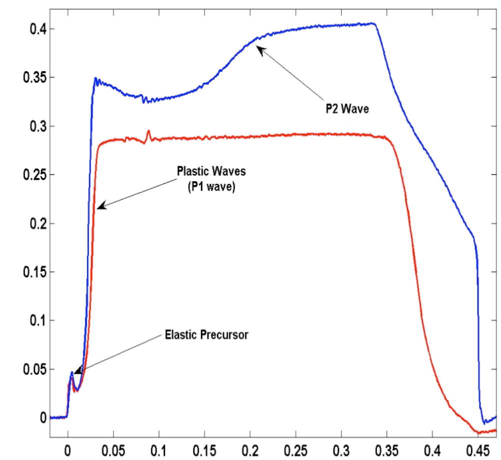
Traditional Shock Wave Experiments

- Many shock experiments use windows to maintain stress at an interface
  - Observe shock wave profile
  - Allows time for phenomenon such as phase transitions to occur
- VISAR commonly used diagnostic
- New Diagnostic – PDV system which operates at 1550 nm
- Objectives of current work:
  - Estimate experimentally the precision of PDV measurement
  - Obtain accurate wave profiles in shock experiments using PDV
  - Obtain window correction factors for 3 common window materials

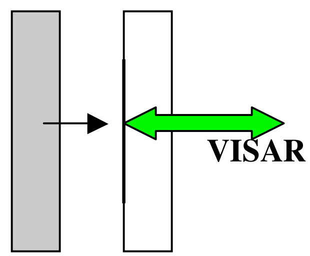
Transmission Experiment



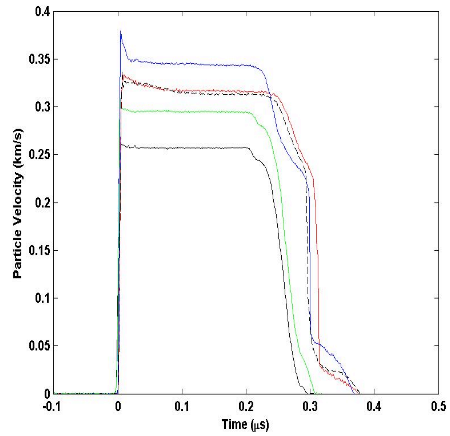
Single Crystal Iron Transmission Data



Front-Surface Impact



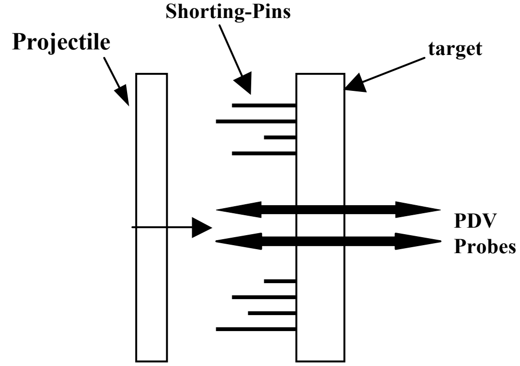
Single Crystal Iron Front-surface Data



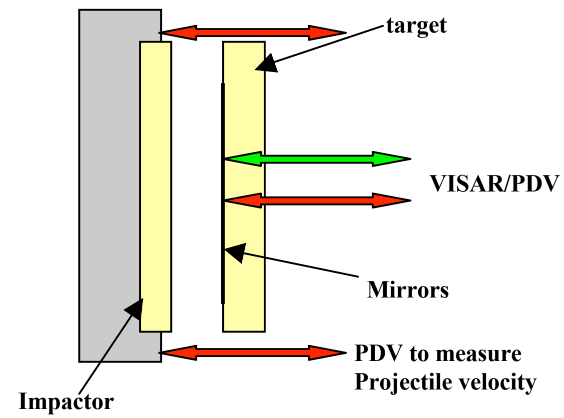
Experimental Approach

- Perform experiments to measure projectile velocity using PDV and typical shorting pin method
- Perform symmetric impact experiments
  - Measure Um at impact surface
  - Use V/2 assumption provides Up
  - Compare Um and Up to determine correction
- Examine 3 standard window materials (z-cut quartz, c-cut sapphire, and LiF(100)
- Free surface measurements in the LiF experiments provide time-dependent wave profile

PDV versus PINS

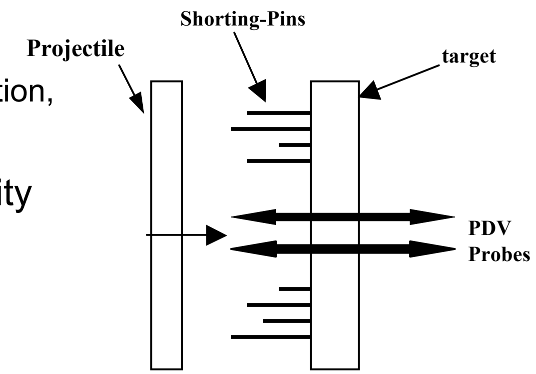


Symmetric Impact Experiments



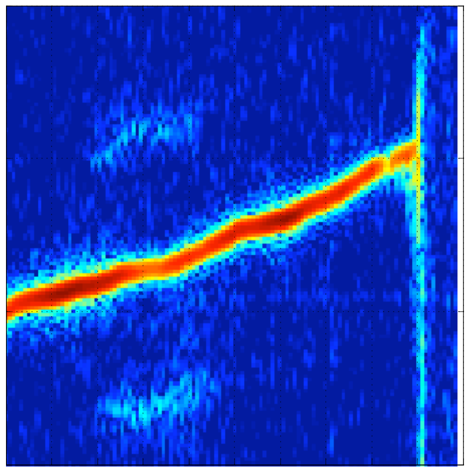
Projectile velocity measurements (0.3 and 0.7 km/s)

- PDV data tracks projectile velocity prior to impact
  - Slight projectile acceleration and some variations
  - Largest error contribution due to localizing frequency
  - Other contributions: probe orthogonality, digitizer time calibration, uncertainty relation
- Pin data measures projectile velocity near impact surface
- Measured projectile velocities:
  - Shot #1
    - 268.62 ± 0.16 (PDV)
    - 268.76 ± 0.41 (Pins)
  - Shot #2
    - 743.14 ± 0.24 (PDV)
    - 742.95 ± 0.57 (Pins)
- Overall very close agreement

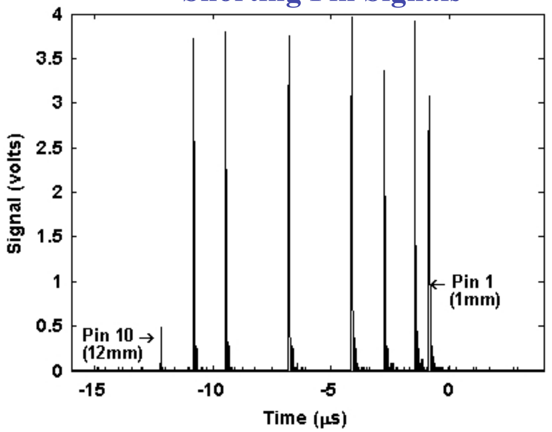


Conclusion - 0.1% accuracy is reasonable for this "ideal" experiment

Projectile Velocity History using PDV

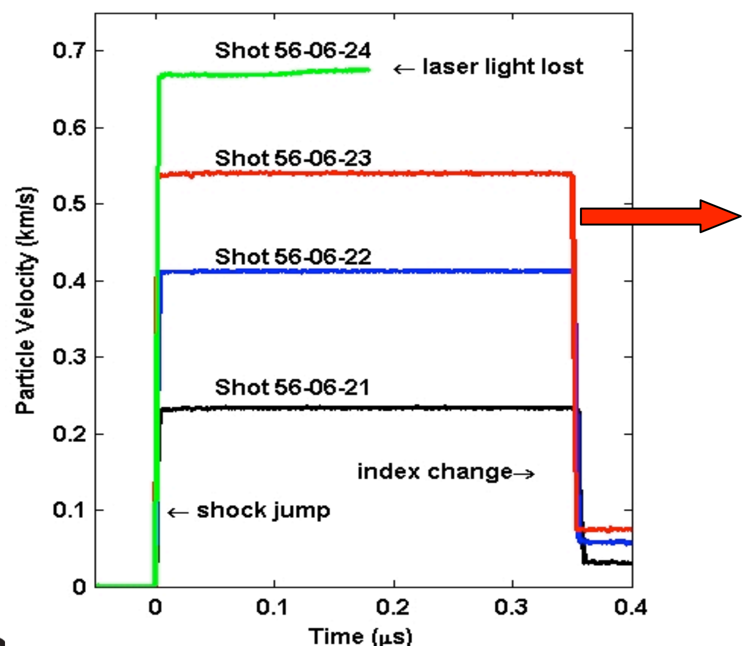


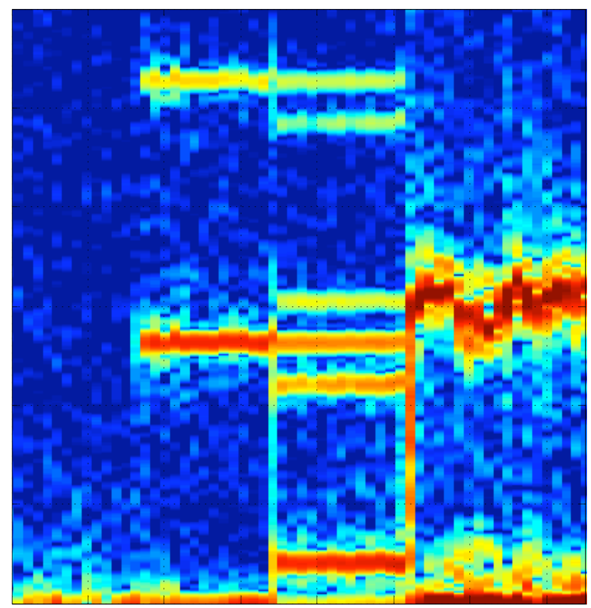
Shorting Pin Signals



VISAR & PDV results for c-cut sapphire

- Impact jump to steady state
- Velocity change as shock wave reflects from the free surface
- VISAR data similar to past work
- PDV data more complex – Dan Dolan's analysis explains features
- Data useful for calculating window corrections, shock velocity, density, etc.



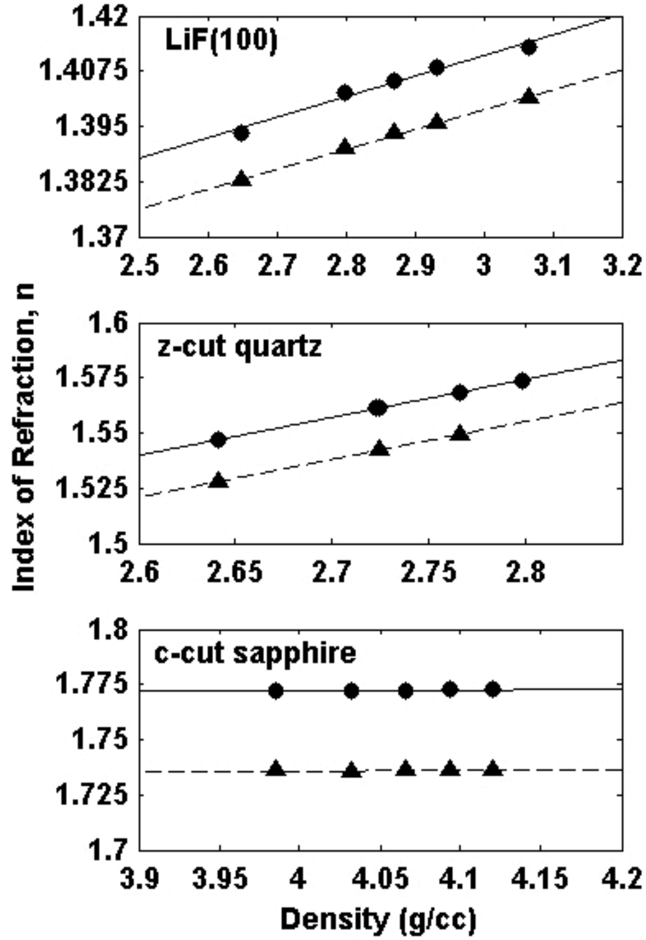


Window Correction Factors

- Used method of Jones (JAP) to determine window correction from front surface, symmetric impact experiments

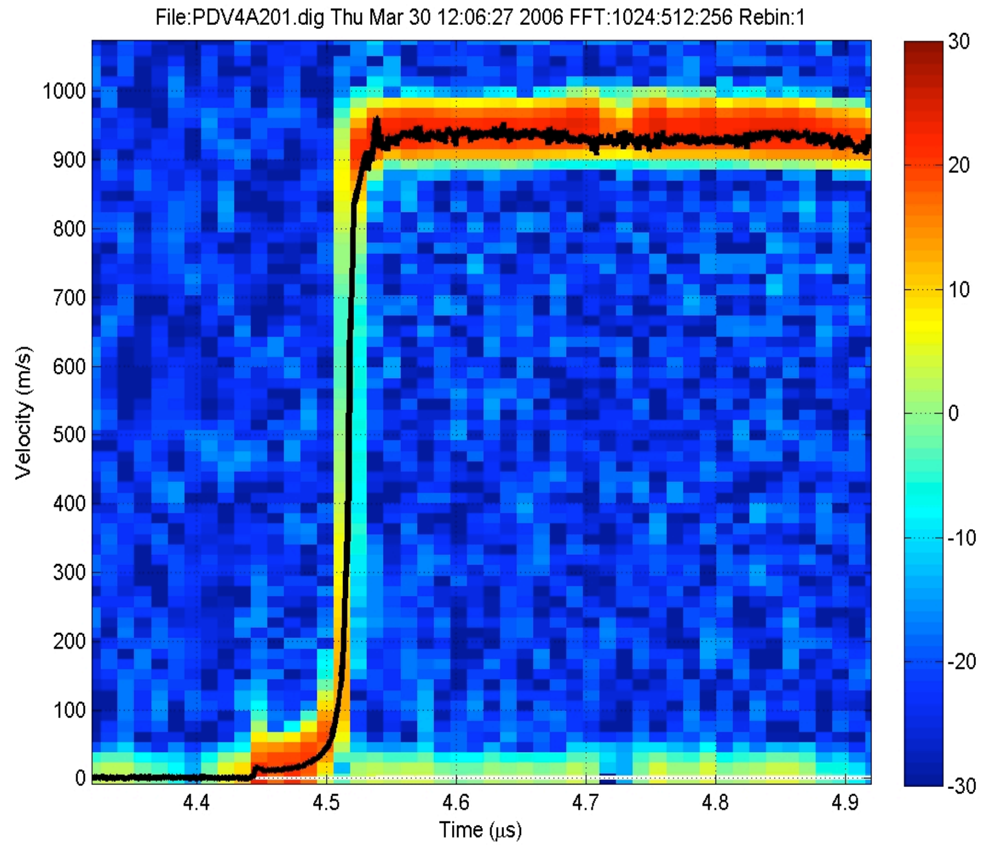
- Fit to linear function n = a + bρ where a is the window correction factor

- PDV (1550 nm) results have similar slope with lower value for the intercept (window correction factor):
  - LiF: 1.271 ± 0.006 (532 nm), 1.264 ± 0.006 (1550 nm)
  - Sapphire: 1.769 ± 0.011 (532 nm), 1.729 ± 0.011 (1550 nm)
  - Quartz: 1.093 ± 0.010 (532 nm) , 1.076 ± 0.016 (1550 nm)



Time-dependent profiles

- Free-surface LiF experiment with PDV and VISAR
- Wave profiles have similar shape
- VISAR data exhibits better time resolution with some noise in the peak state due to low light levels
- Details of elastic-plastic transition in PDV data poorly resolved
- Light loss not a problem with PDV
- Possible to determine peak state more accurately



Summary

- Measured projectile velocities using PDV
  - Good agreement with pins (approx. 0.1% uncertainty)
  - Main error likely due to finding center of frequency/velocity
  - Reasonable error estimate for velocity – 0.1% (free surface)
- Obtained VISAR/PDV profiles for z-cut quartz, c-cut sapphire, and LiF(100)
  - Determined window correction for 1550 nm light
  - Understand effects of using PDV in windowed shock experiments
  - Best to use AR coated windows for shock experiments
  - C-cut sapphire appears to be a good window well above elastic limit at 1550nm
  - Z-cut quartz appears to be good up to 70 kbar (VISAR 532nm)
- Compared VISAR and PDV results for time-varying profile
  - Possible to achieve good resolution in peak state
  - Time-varying velocities difficult with PDV (ns timescale)