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Infrared absorption spectroscopy of dynamically compressed water

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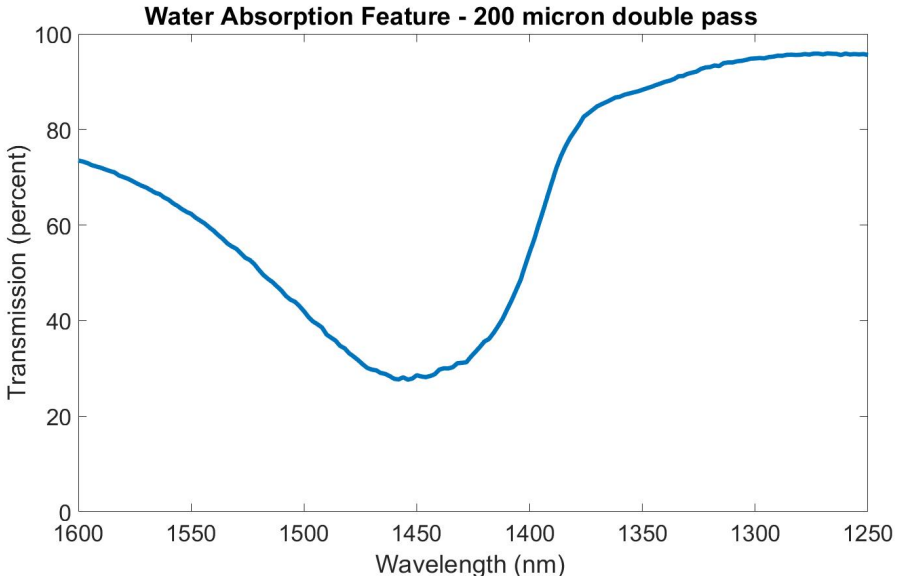
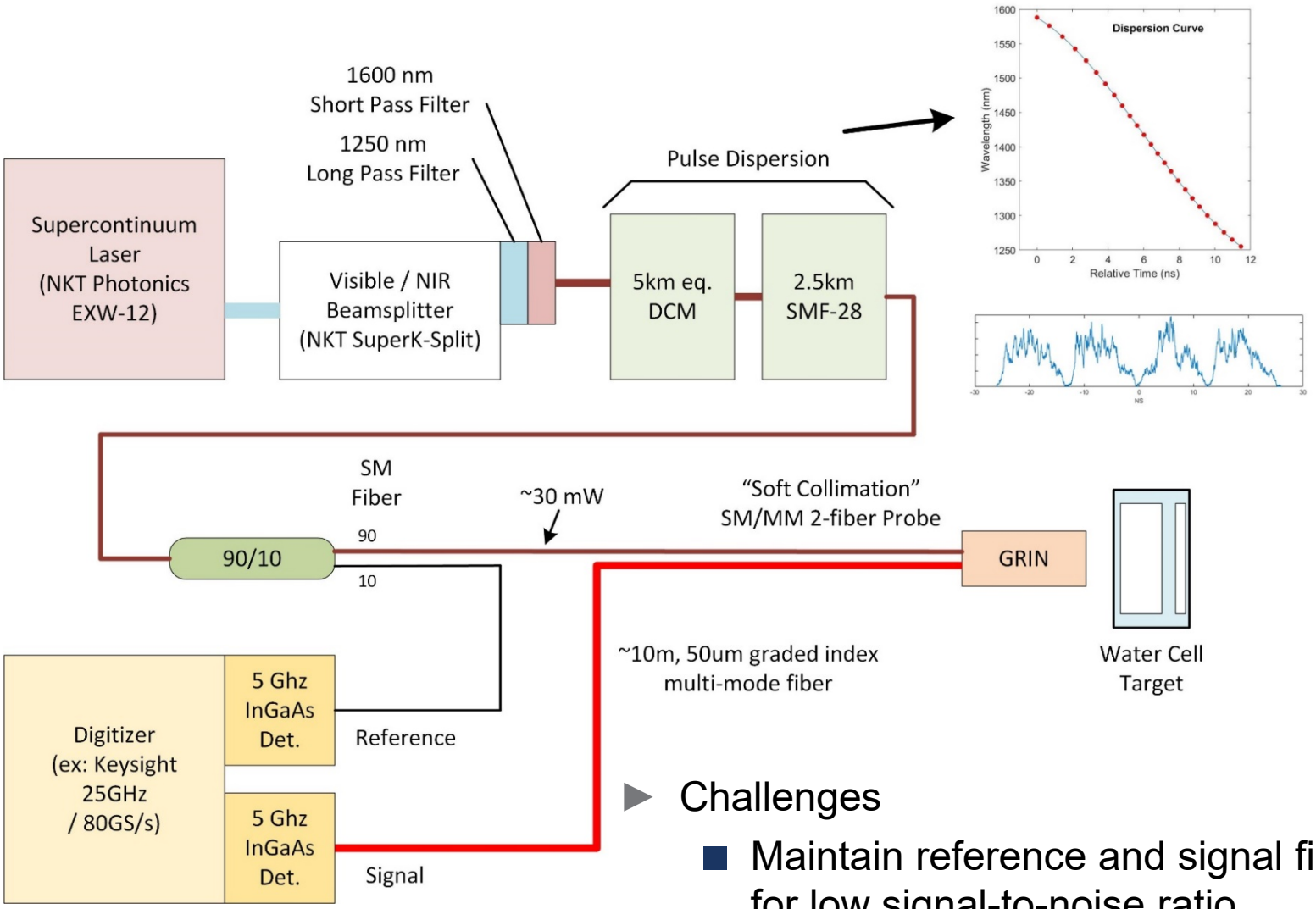
Motivation and Concept

- Time-Stretch Spectroscopy using a supercontinuum laser
  - No IR streak cameras for high-speed IR spectroscopy
  - Map wavelength to time using time dispersed NIR pulses from a supercontinuum laser.
  - Tests conducted at NNSS Special Technologies Laboratory and Sandia National Laboratories using similar technique on different platforms.
- Dynamic compression experiments observing water absorption spectrum between 1250 and 1600 nm.
  - Possible proxy for temperature & pressure in dynamic materials experiments?
  - Basic science



Time-Stretch Spectroscopy System

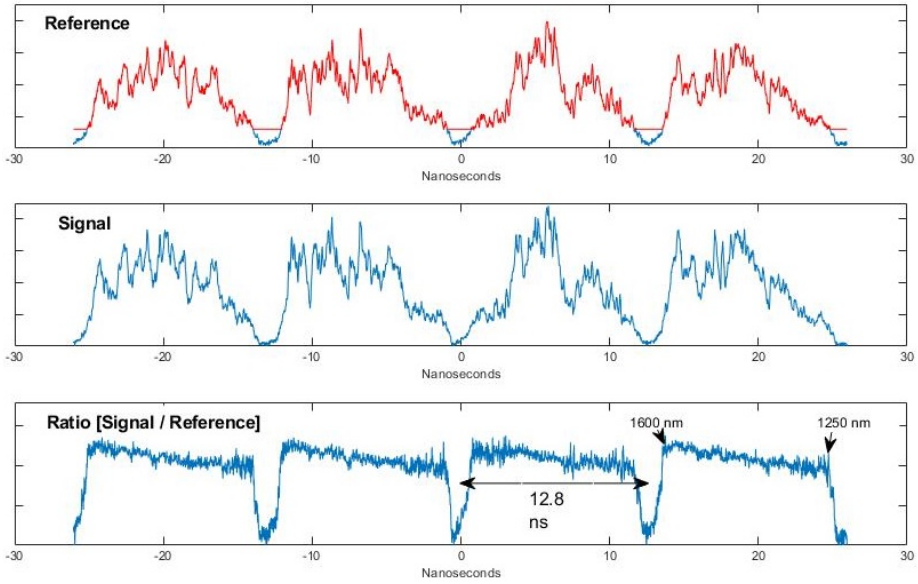


- Challenges
  - Maintain reference and signal fidelity for low signal-to-noise ratio
  - Use available laser and components

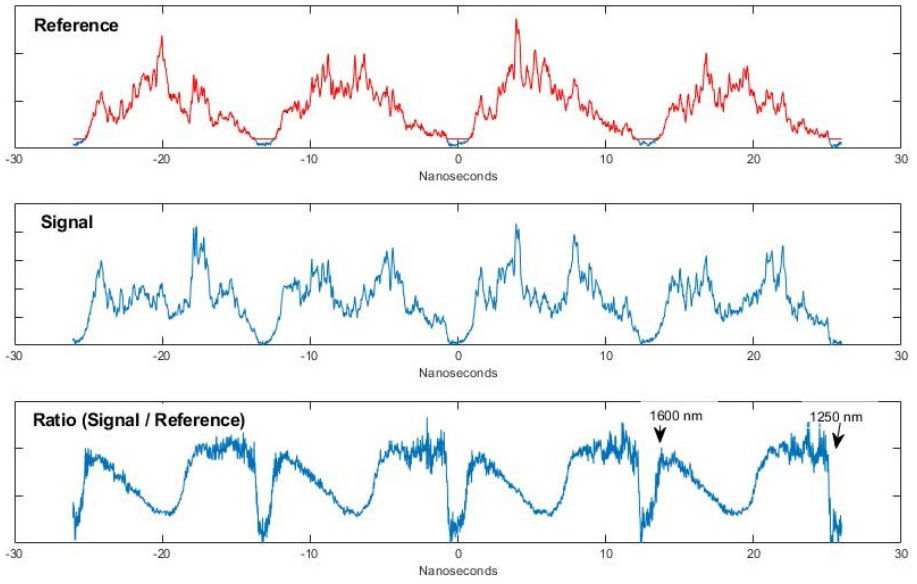
Static Lab Sample Waveforms

- Pulse dispersion matched to 12.8 ns laser pulse period
- Reference is shifted in time to align with signal from target
- Ratio of signal/reference shows transmitted (or reflected) spectrum

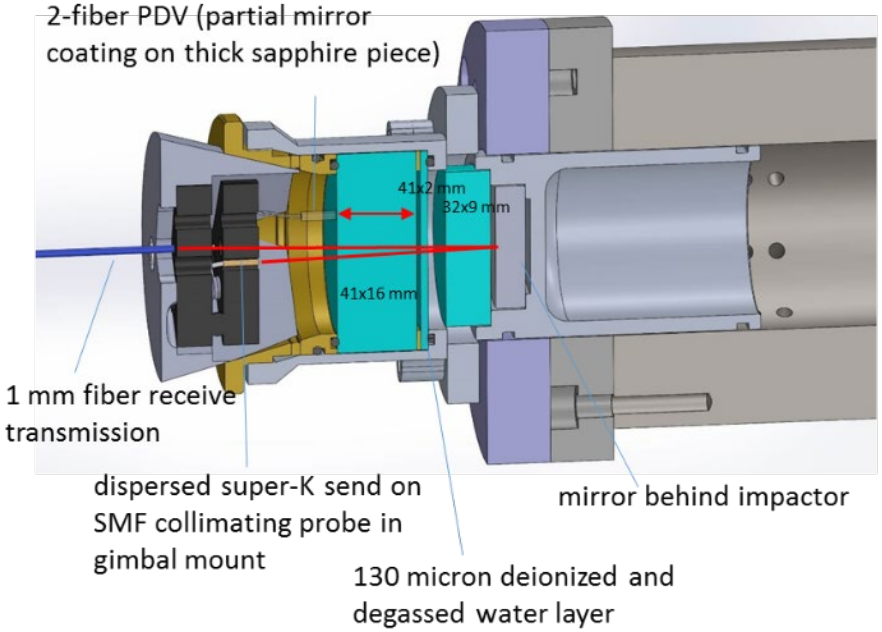
Reflection from gold mirror

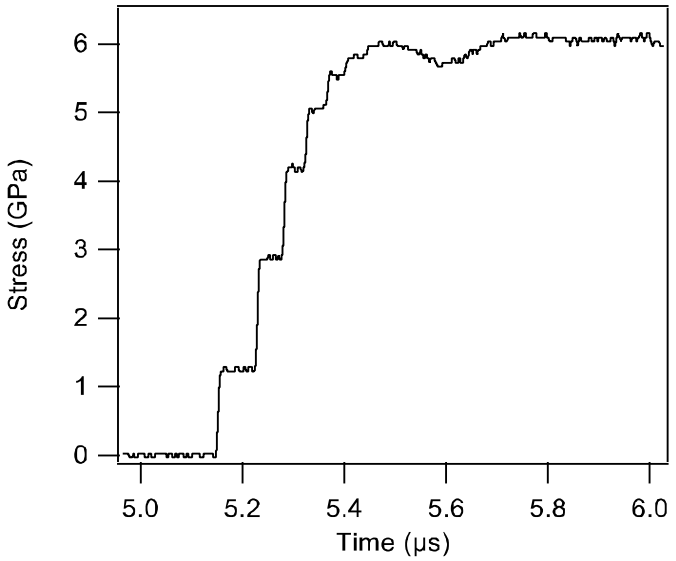


210-micron double-pass water cell



STL Gun Experiment

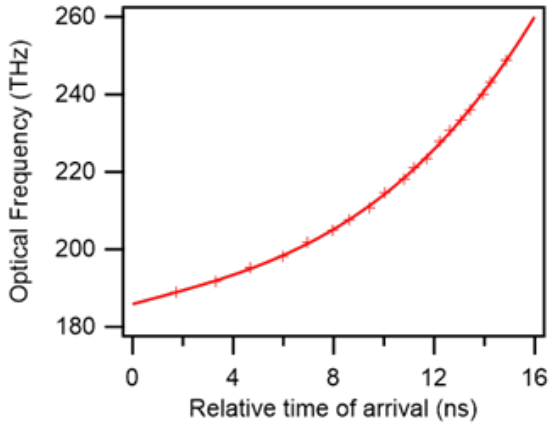




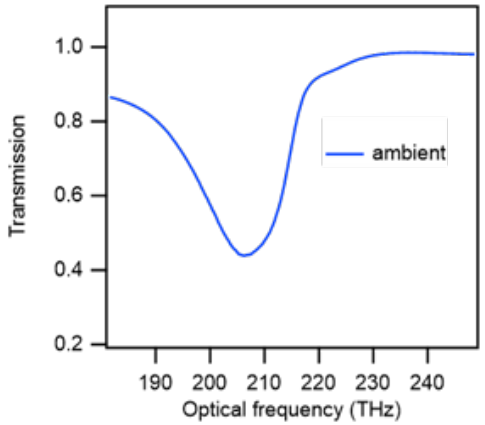
- Thick sapphire window maintains one-dimensional compression for extended time, allowing pulse averaging with nearly static pressure.
- Mirror for supercontinuum beam on back side of impactor protects return from initial impact shock.
- PDV is optically isolated from the water cell.
- Large angle between supercontinuum send and receive reduces interference effects.

STL Experiment Conditions

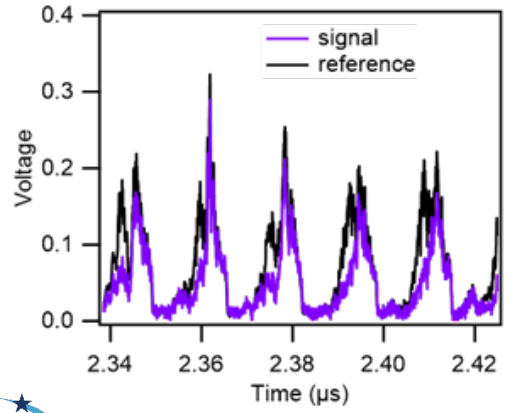
measured dispersion of fiber module



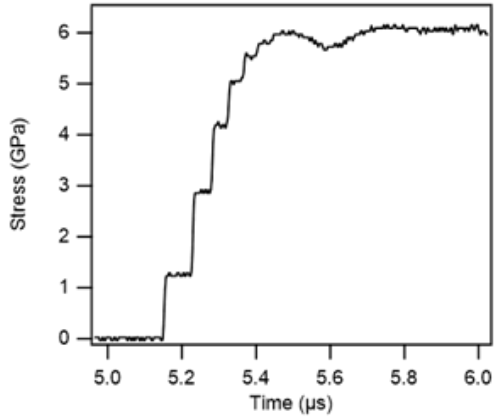
measured ambient spectrum (Cary-5000 on 1 mm sample scaled to 130 microns)



time domain transmission signals

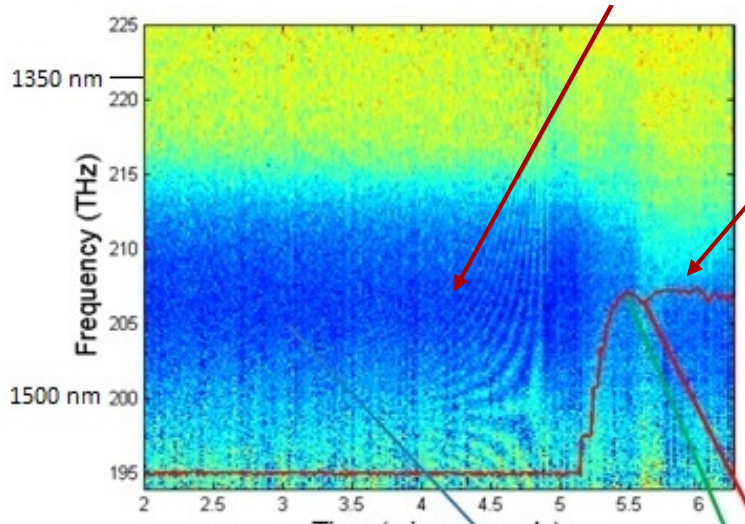


PDV data converted to stress



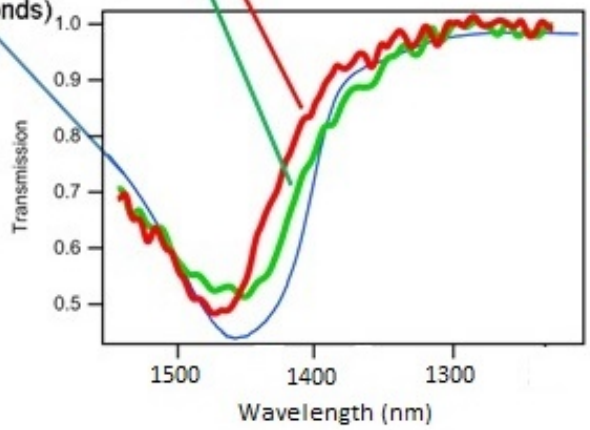
STL Experiment Results

Spectrogram: Dark blue near 205 THz (1460 nm) is water absorption band



Velocimetry Data (PDV)

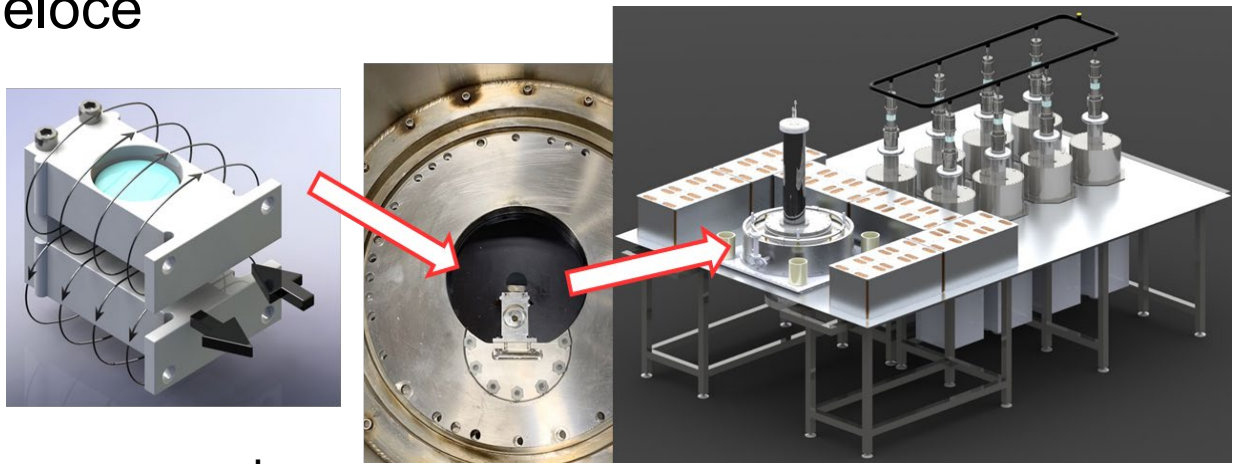
majority of spectral shift occurs after ring-up during little dip in PDV velocity (liquid-solid phase change?) top of PDV curve is 6.0 GPa



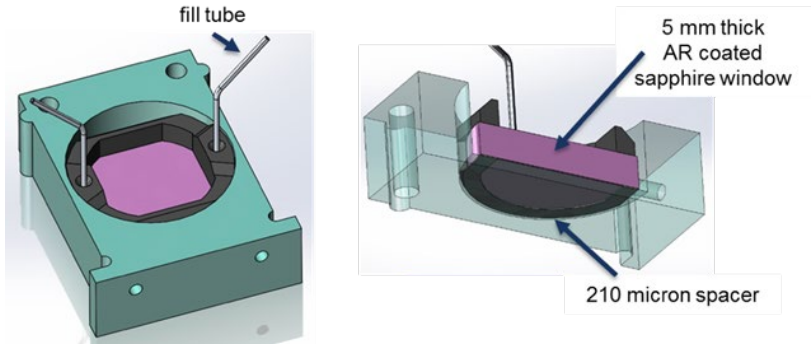
blue: ambient
green: peak compression
red: after PDV dip

Sandia Experiments

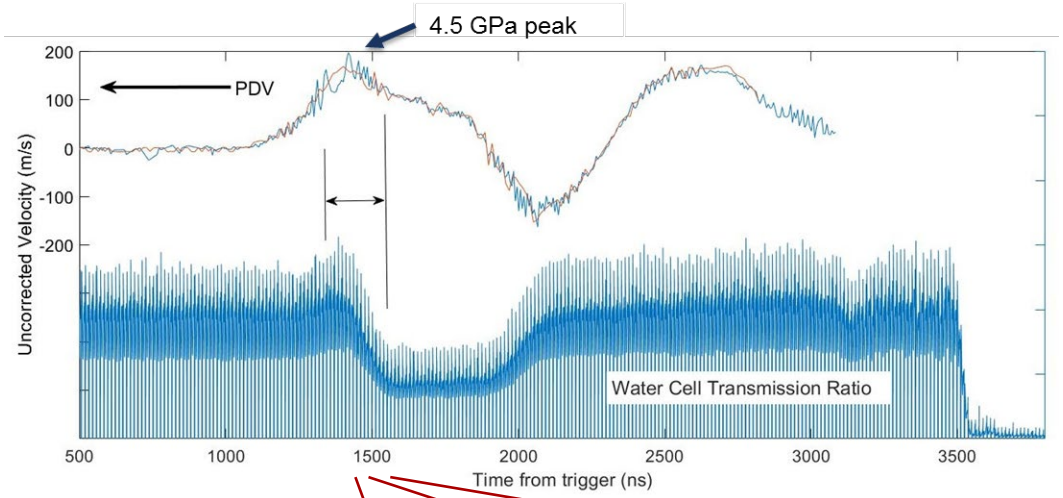
- Early diagnostic development occurred on small Sandia gas gun
  - Available cell windows and velocities not ideal for best data
- Moved to Sandia Veloce pulsed power machine



  - 20+ GPa ramp-wave compression over a few hundred nanoseconds
  - Fabricated custom water cells and probes for Veloce testing

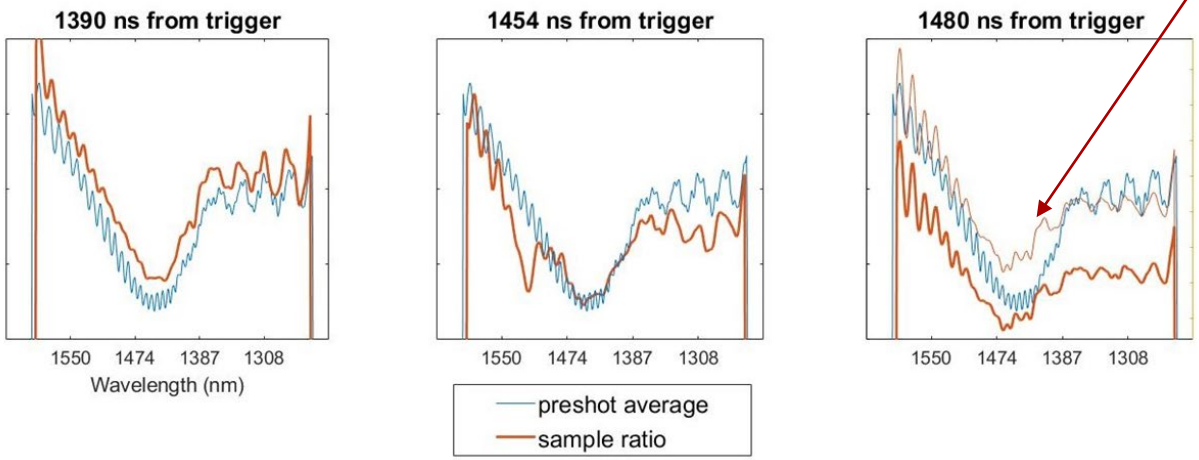


Veloce Test Data – 3rd Shot

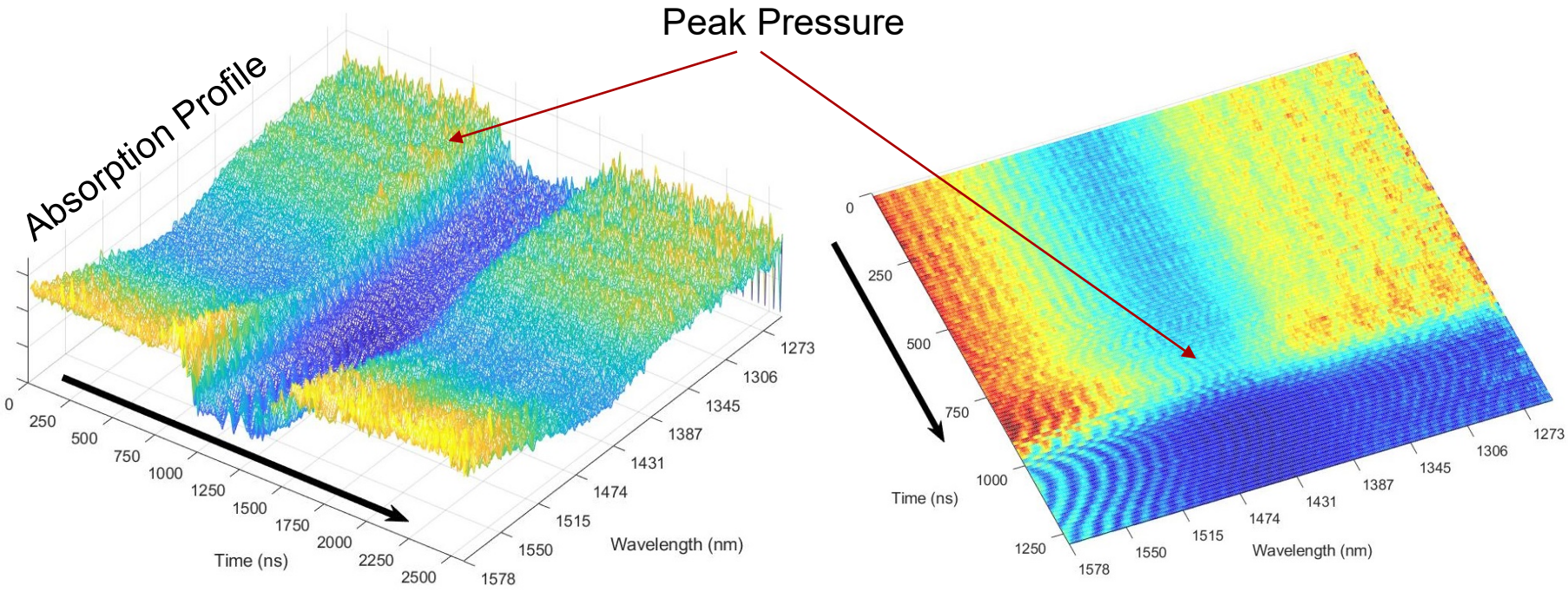


- 4.5 GPa peak pressure to prevent cell opacity
- 90-micron water cell thickness
- Significant water cell interference effects
- Data noisy, but consistent with STL data

Normalized profile



Data Visualization



- Veloce data shown as 12.8 ns profile slices
- Fringes from water cell etalon interference are evident
- Helps to visualize spectrum change over time

Conclusion

- A high-speed time-stretch spectroscopy diagnostic using a supercontinuum laser was developed and is showing promise for NIR spectroscopy in dynamic materials experiments.
- Early investigation of the 1450 nm water absorption band under dynamic compression indicates slight shift to longer wavelengths at ~6 GPa peak pressure.
- Future experiments using this technique may include metal surface reflection, water, and other compounds under dynamic compression.