

Infrared absorption spectroscopy of dynamically compressed water

Presenter: Darrell Ramsey

(NNSS, New Mexico Operations, Sandia Office, Albuquerque, NM)

Co-Authors: Jason Mance & Brandon La Lone

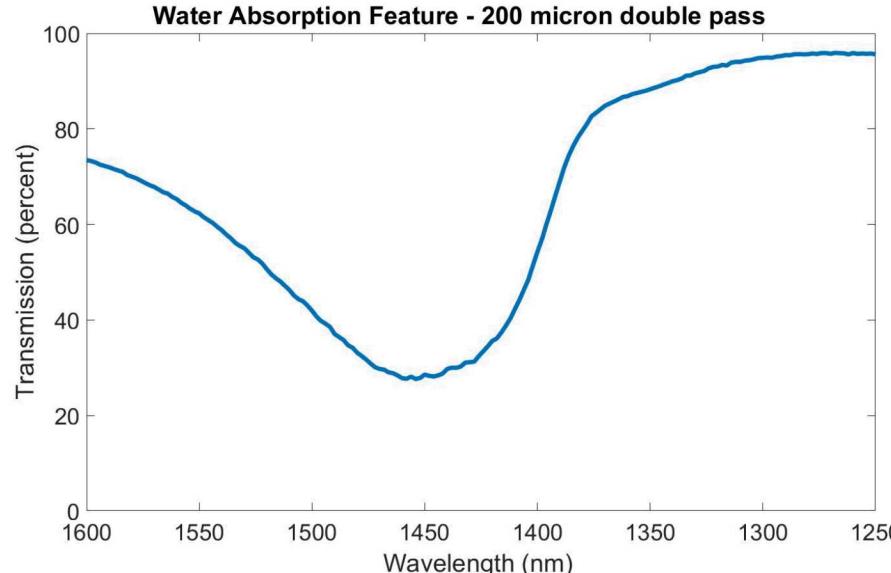
(NNSS, Special Technologies Laboratory, Santa Barbara, CA)

Dan Dolan

(Sandia National Laboratories, Albuquerque, NM)

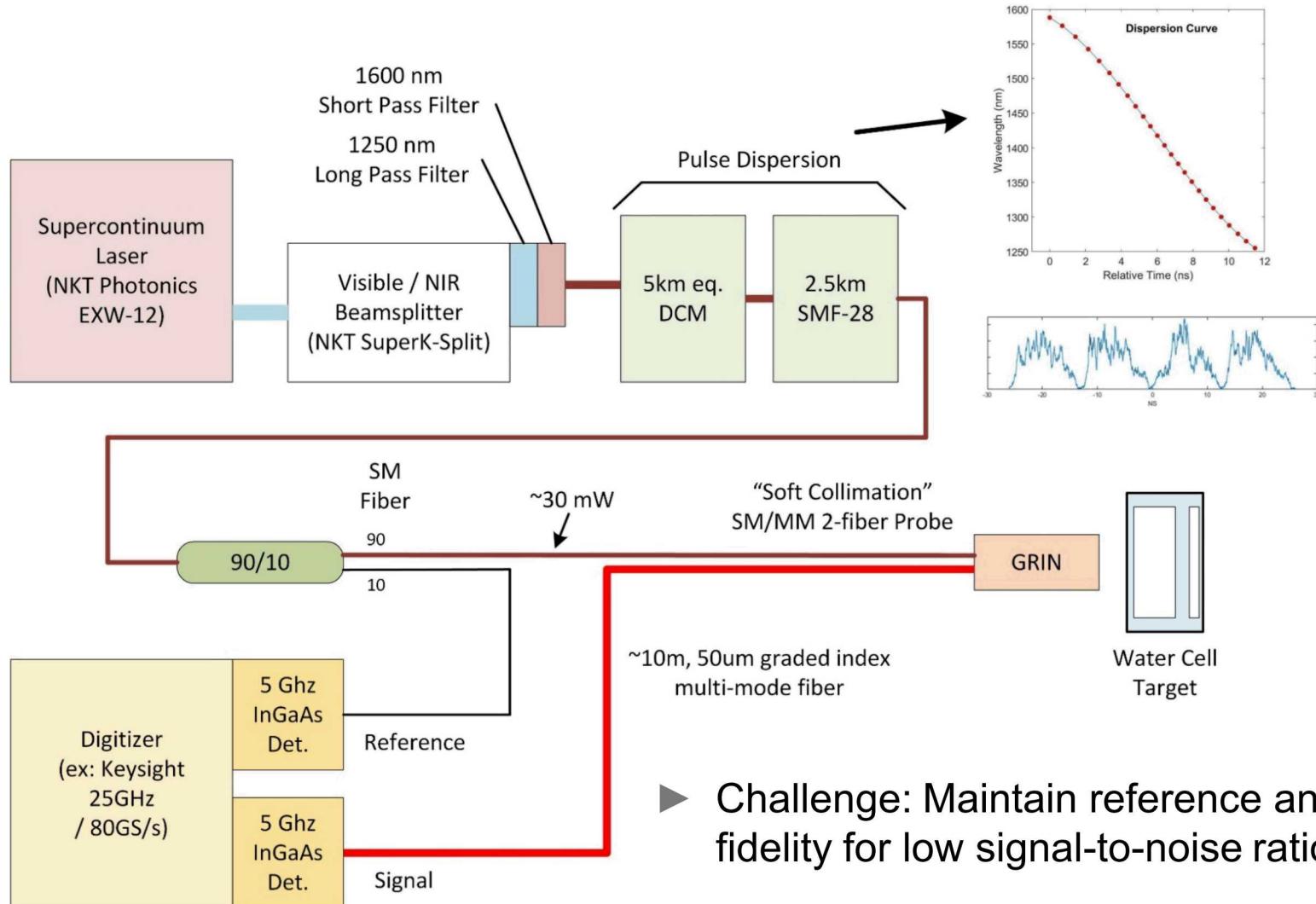
Motivation and Concept

- ▶ 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

3

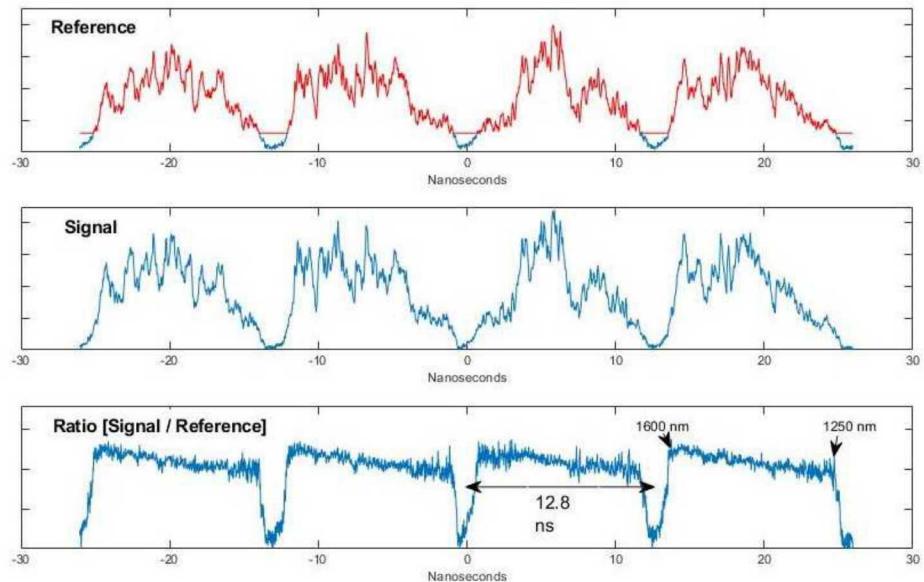


► Challenge: Maintain reference and signal fidelity for low signal-to-noise ratio

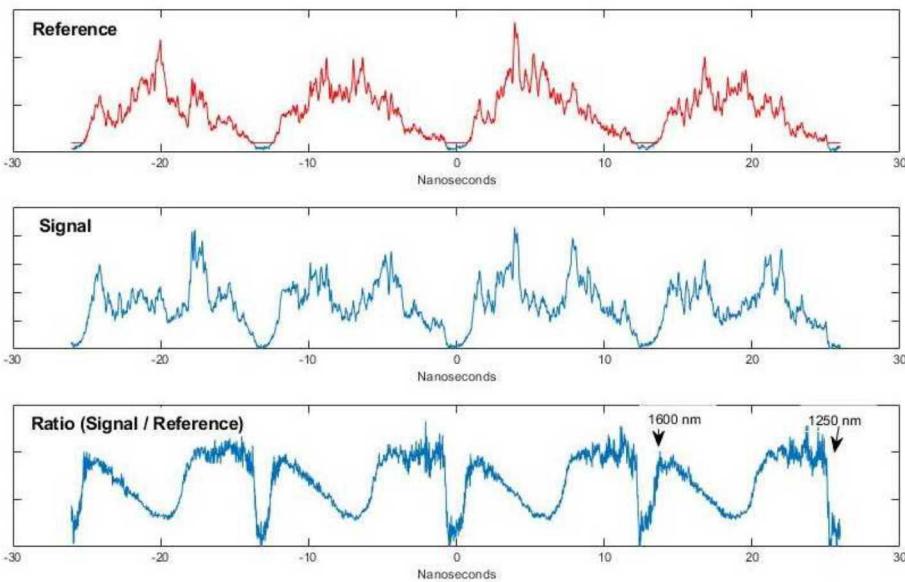
Static Lab Sample Waveforms

- ▶ 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

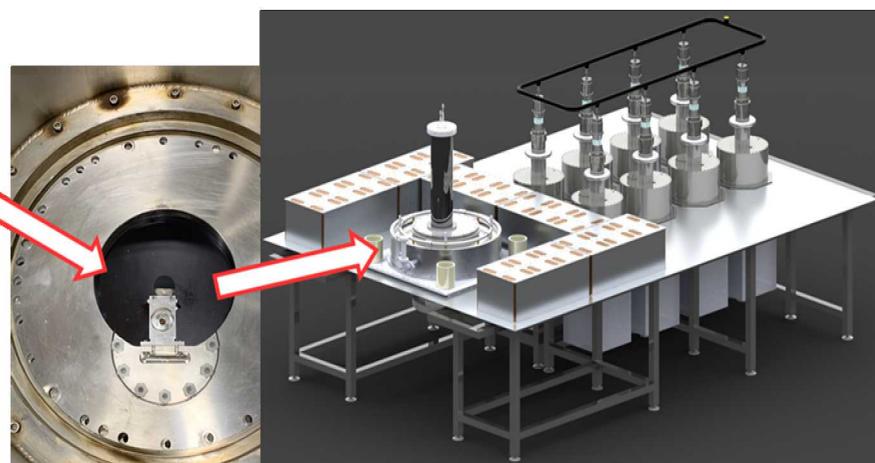
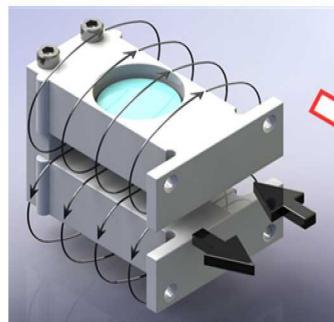


210-micron double-pass water cell

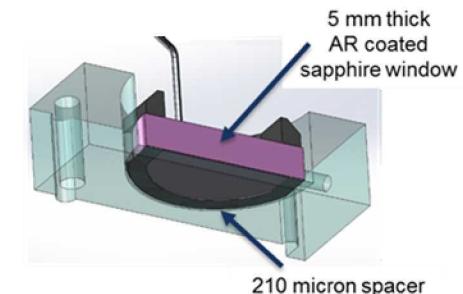
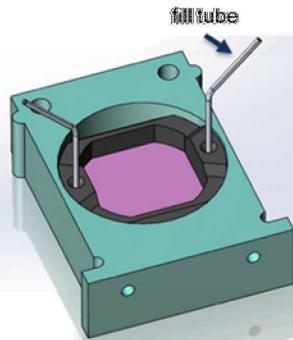


Sandia Experiments

- ▶ 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

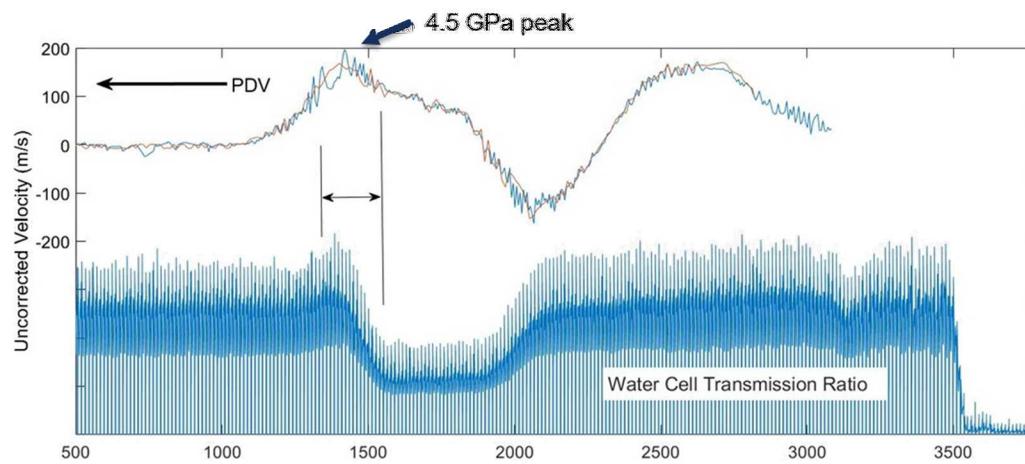


- 20+ GPa ramp-wave compression over a few hundred nanoseconds
- Fabricated custom water cells and probes for Veloce testing

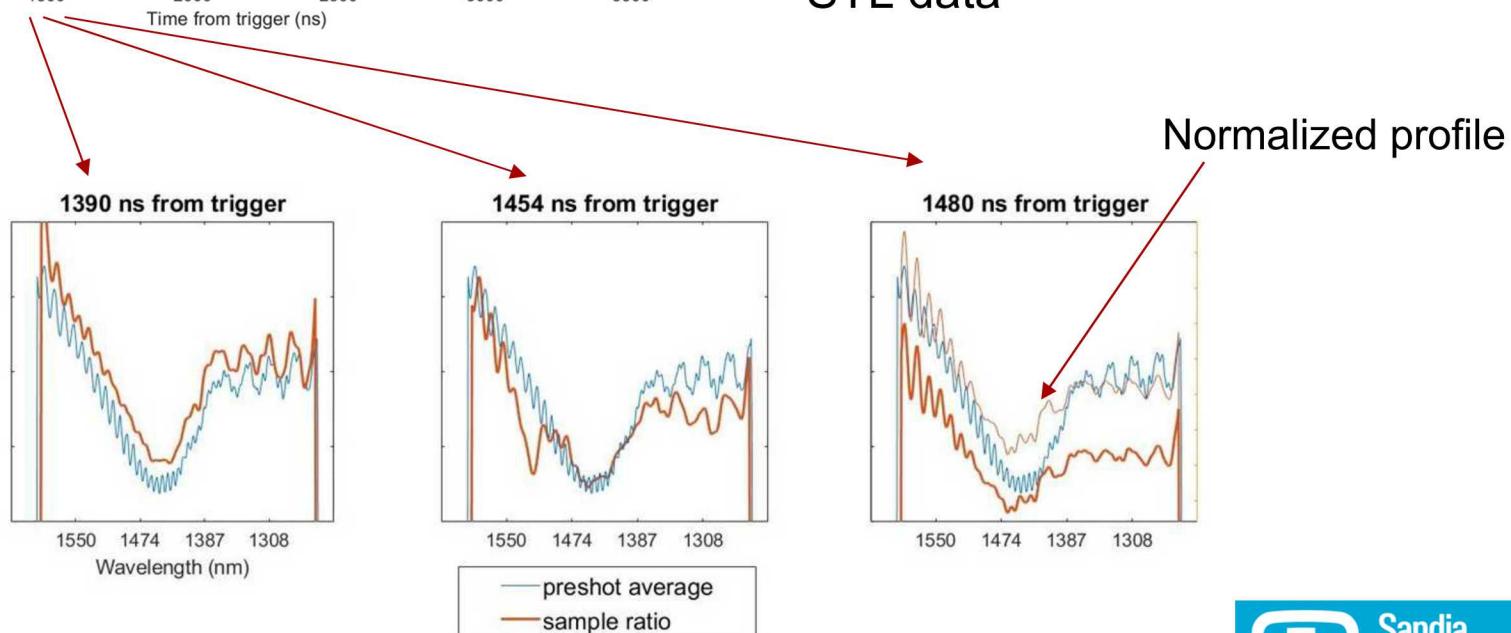


Veloce Test Data – 3rd Shot

6

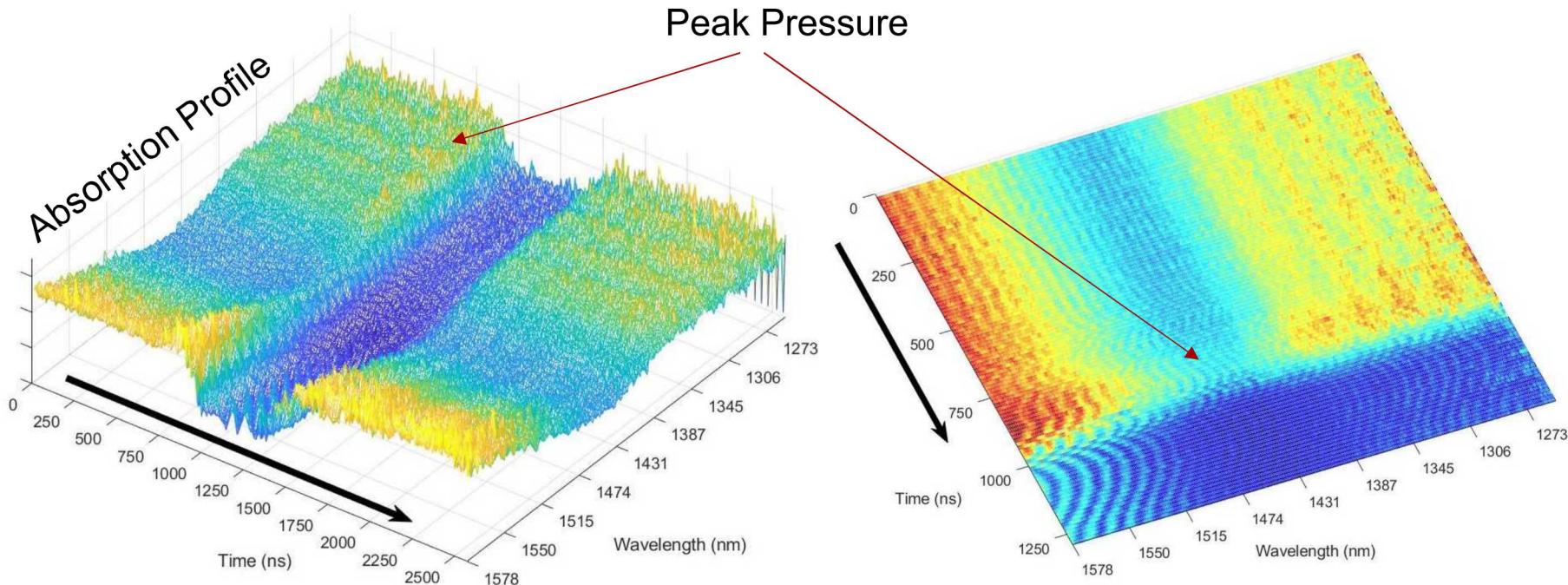


- ▶ 4.5 GPa peak pressure to prevent cell opacity
- ▶ 90-micron water cell thickness
- ▶ Significant water cell interference effects
- ▶ Data noisy, but consistent with STL data



Data Visualization

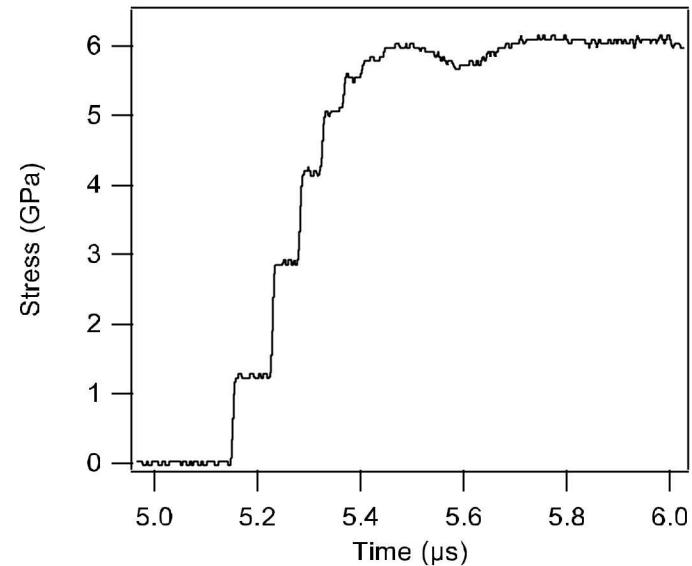
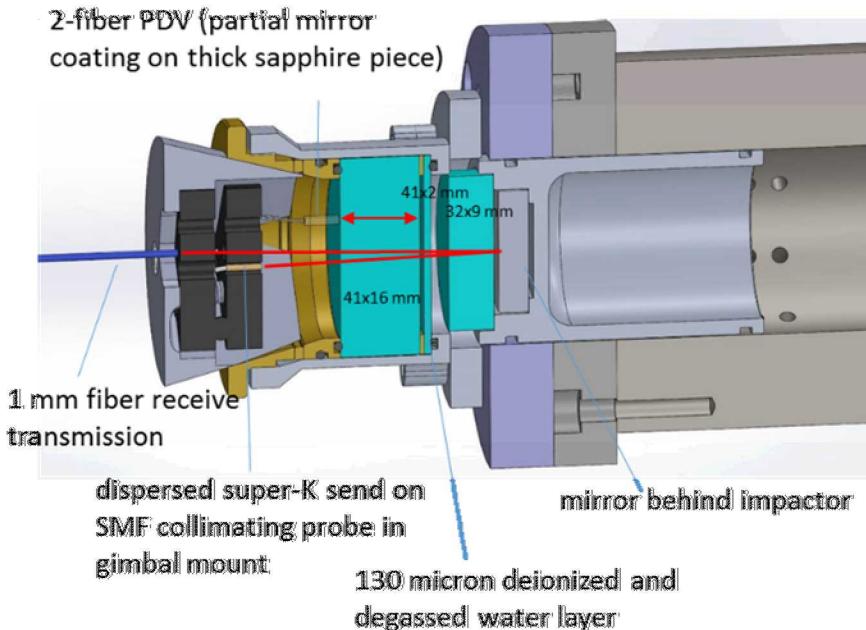
7



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

STL Gun Experiment

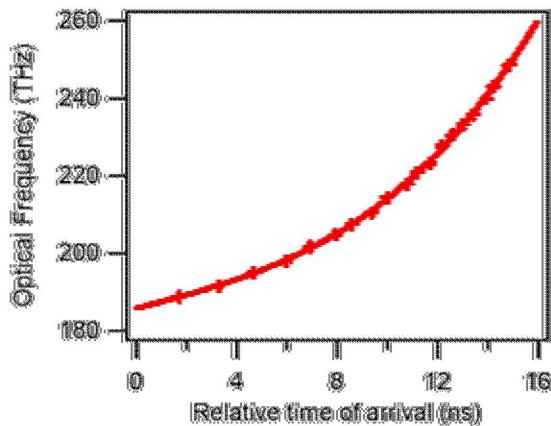
8



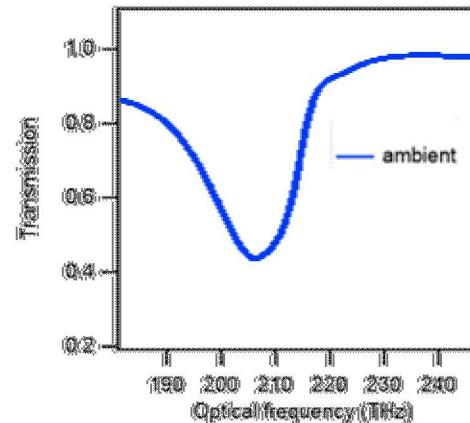
- Thick sapphire window maintains one-dimensional compression for extended time, allowing pulse averaging with nearly static pressure.
- Mirror for supercontinuum beam on back side of impactor protects return from initial impact shock.
- PDV is optically isolated from the water cell.
- Large angle between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

STL Experiment Conditions

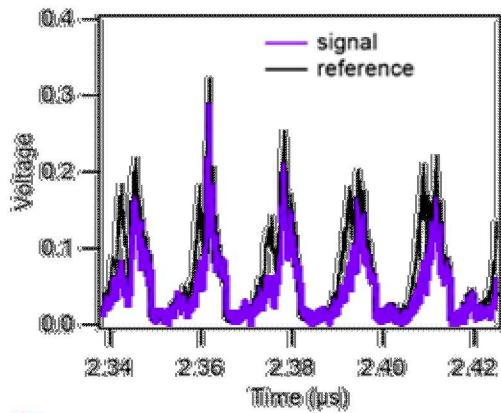
measured dispersion of fiber module



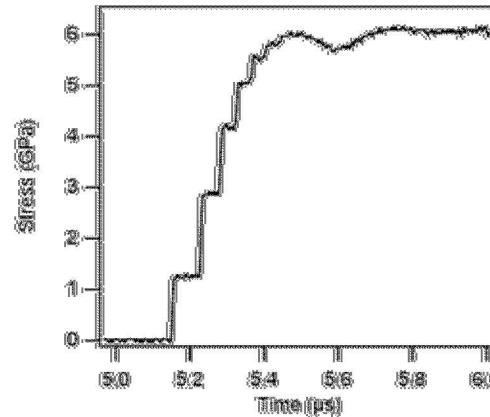
measured ambient spectrum (Cary-5000 on 1 mm sample scaled to 130 microns)



time domain transmission signals

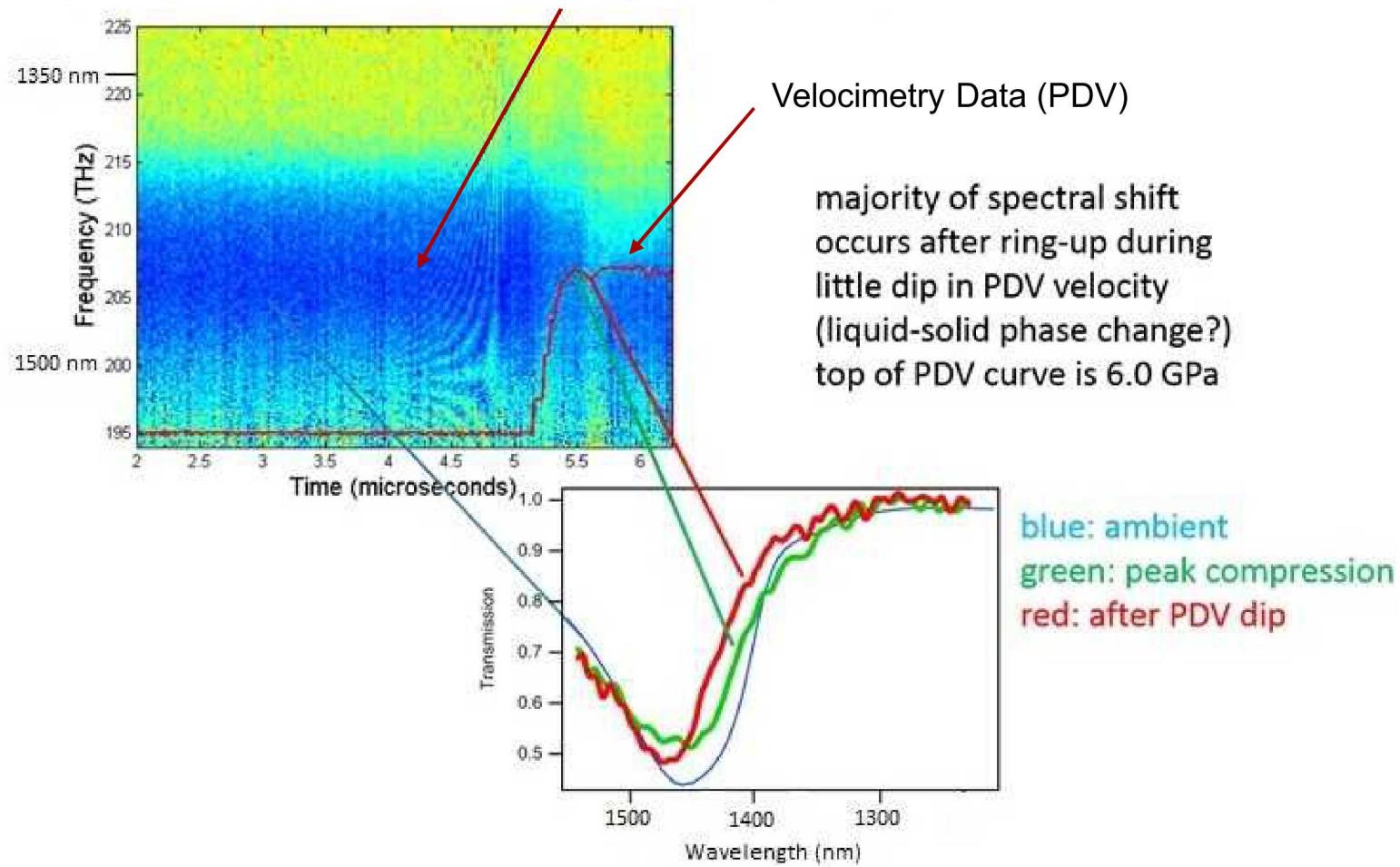


PDV data converted to stress



STL Experiment Results

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



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.