

# Infrared absorption spectroscopy of dynamically compressed water

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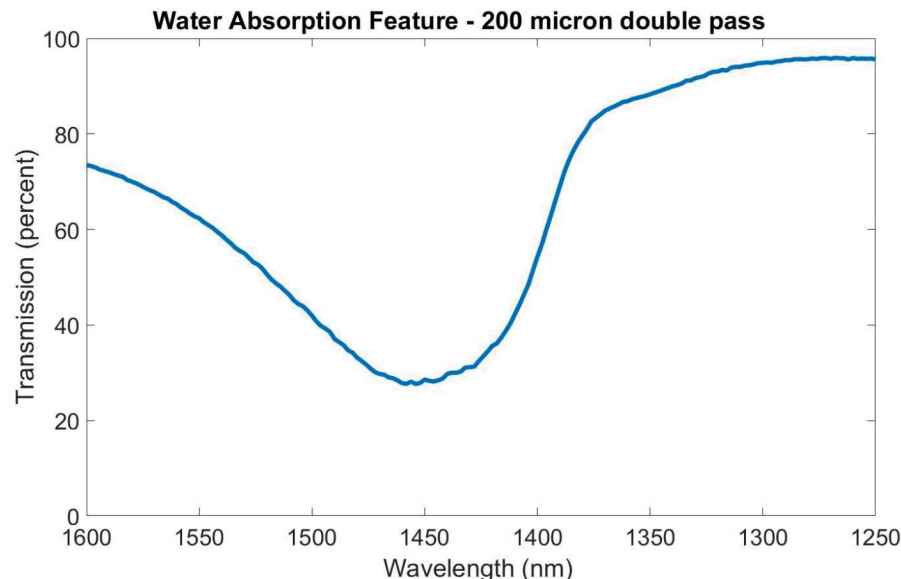
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Dan Dolan

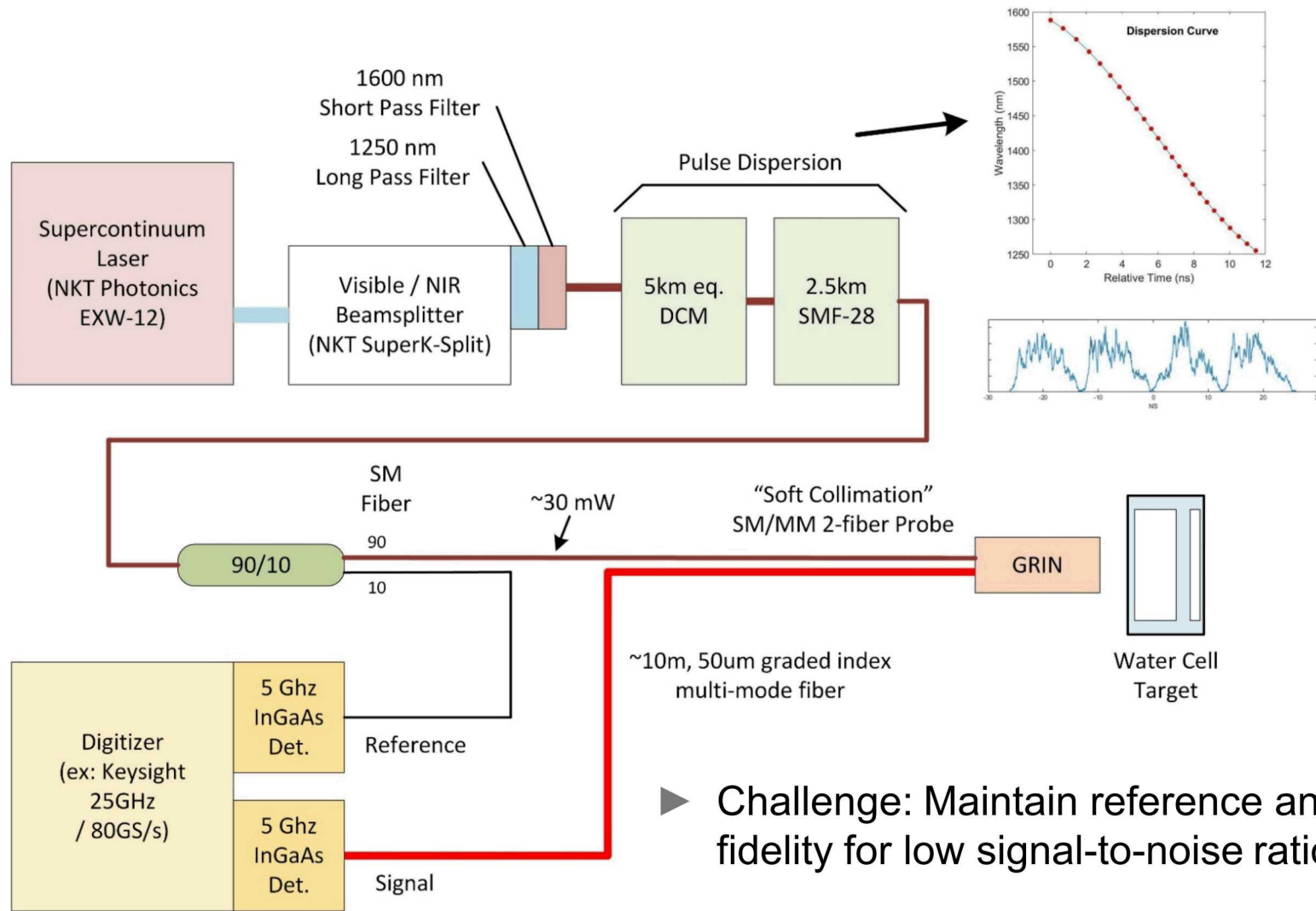
(Sandia National Laboratories, Albuquerque, NM)

- ▶ 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

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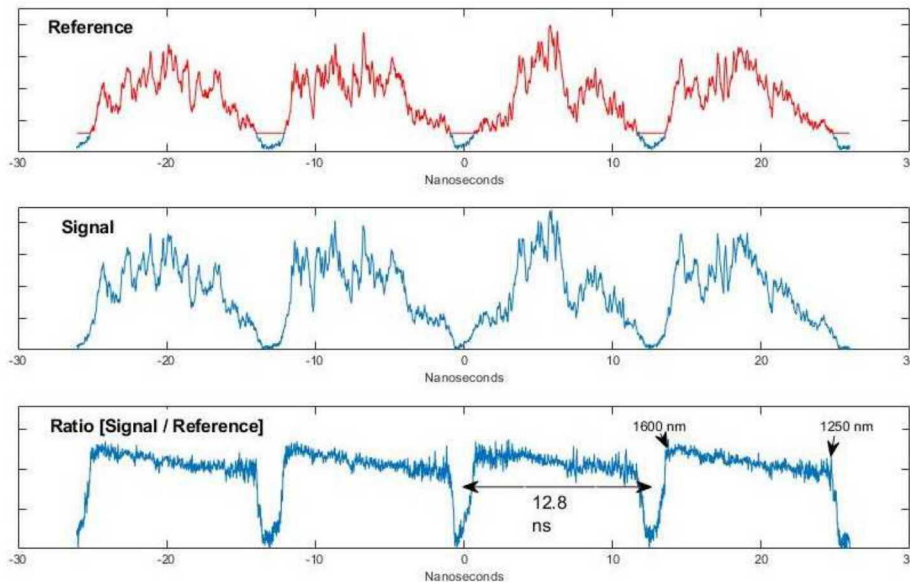
► Challenge: Maintain reference and signal fidelity for low signal-to-noise ratio

# Static Lab Sample Waveforms

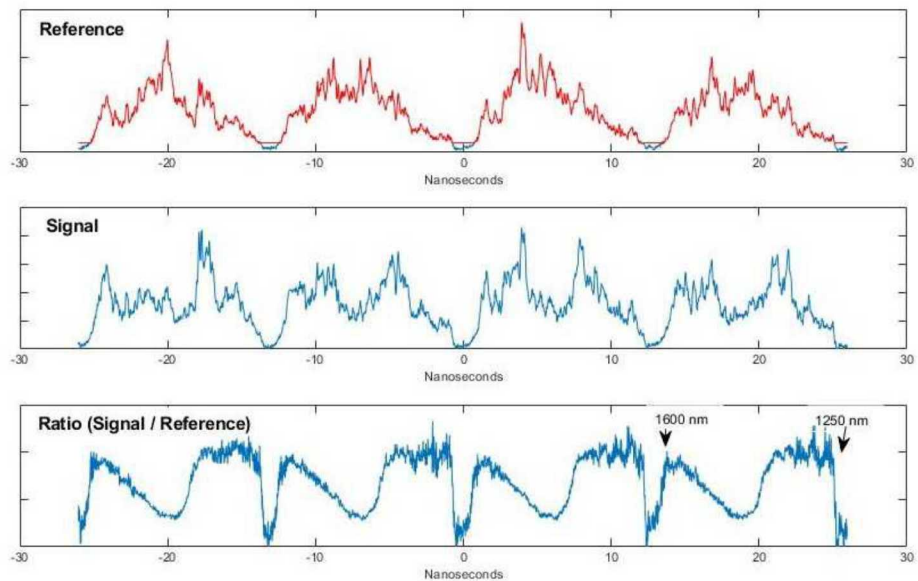
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- ▶ Pulse dispersion matched to 12.8 ns laser pulse period
- ▶ Reference is shifted in time to align with signal from target
- ▶ Ratio of signal/reference shows transmitted (or reflected) spectrum

Reflection from gold mirror



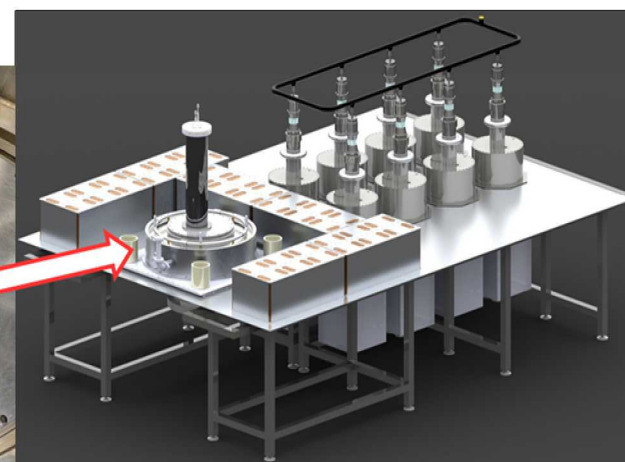
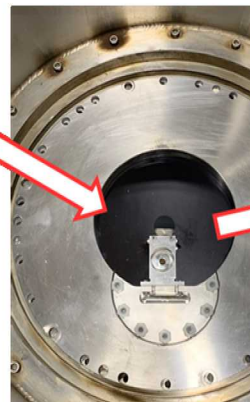
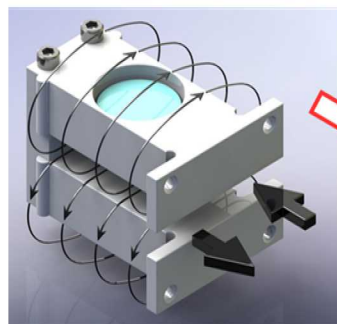
210-micron double-pass water cell



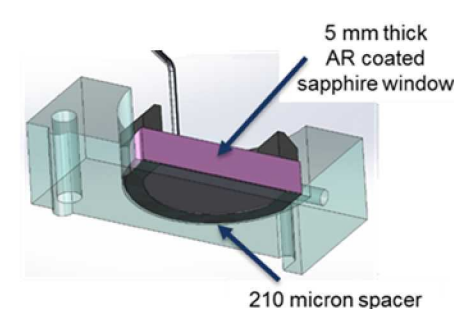
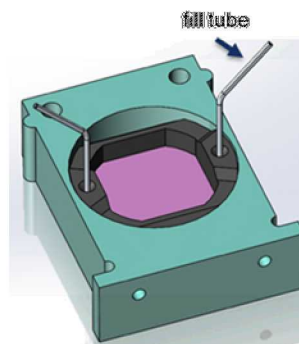


- ▶ Early diagnostic development occurred on small Sandia gas gun
  - Available cell windows and velocities not ideal for best data

- ▶ Moved to Sandia Veloce pulsed power machine



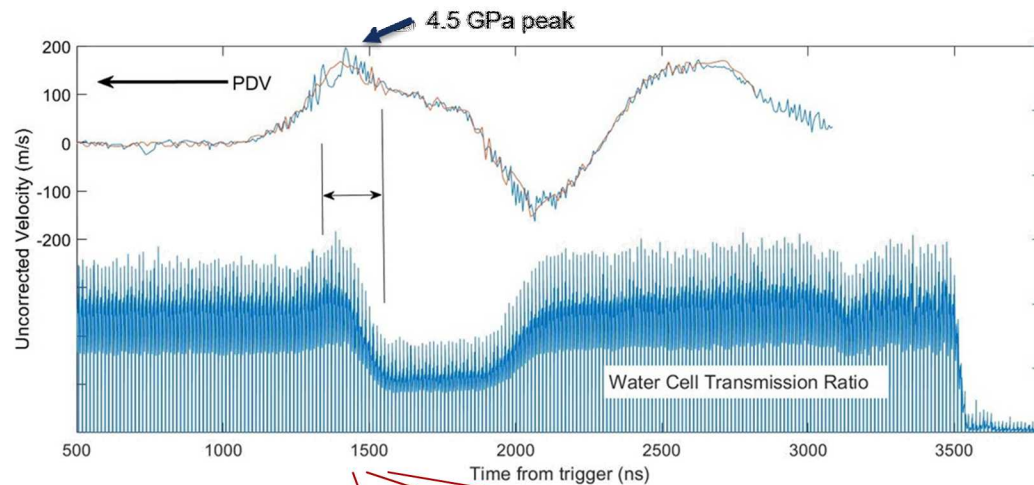
- 20+ GPa ramp-wave compression over a few hundred nanoseconds
- Fabricated custom water cells and probes for Veloce testing



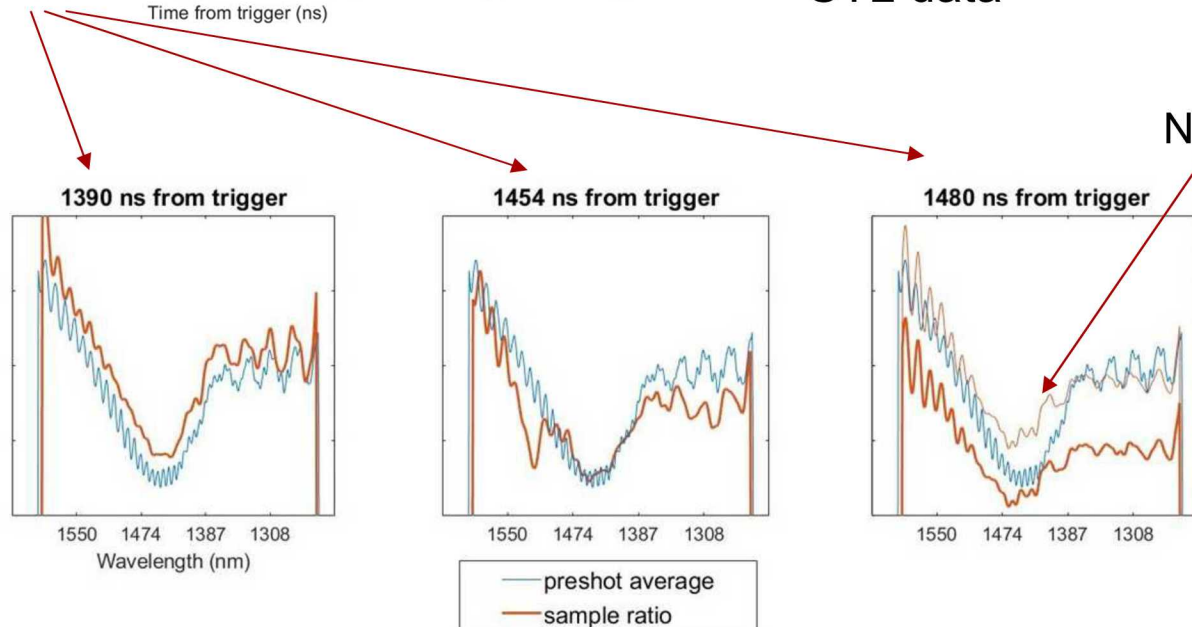
210 micron spacer

# Veloce Test Data – 3<sup>rd</sup> Shot

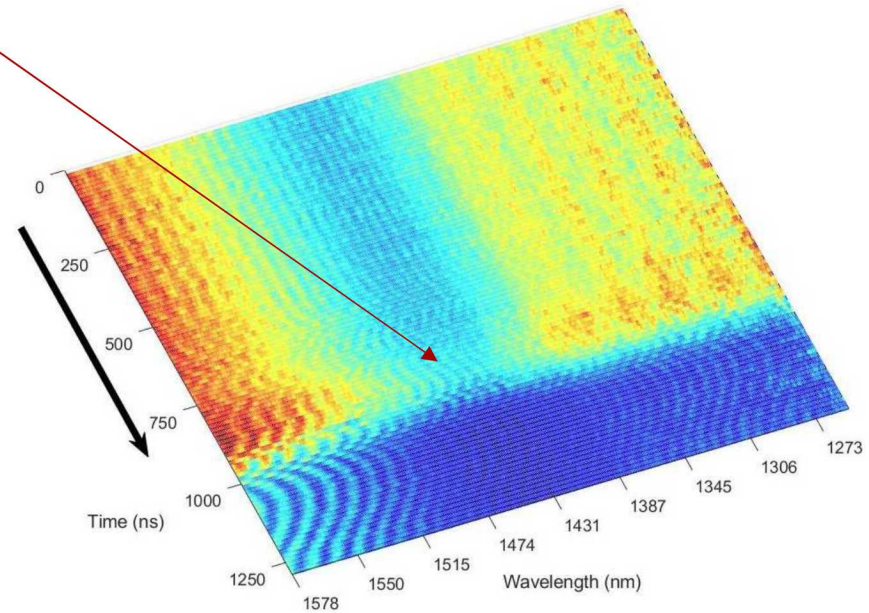
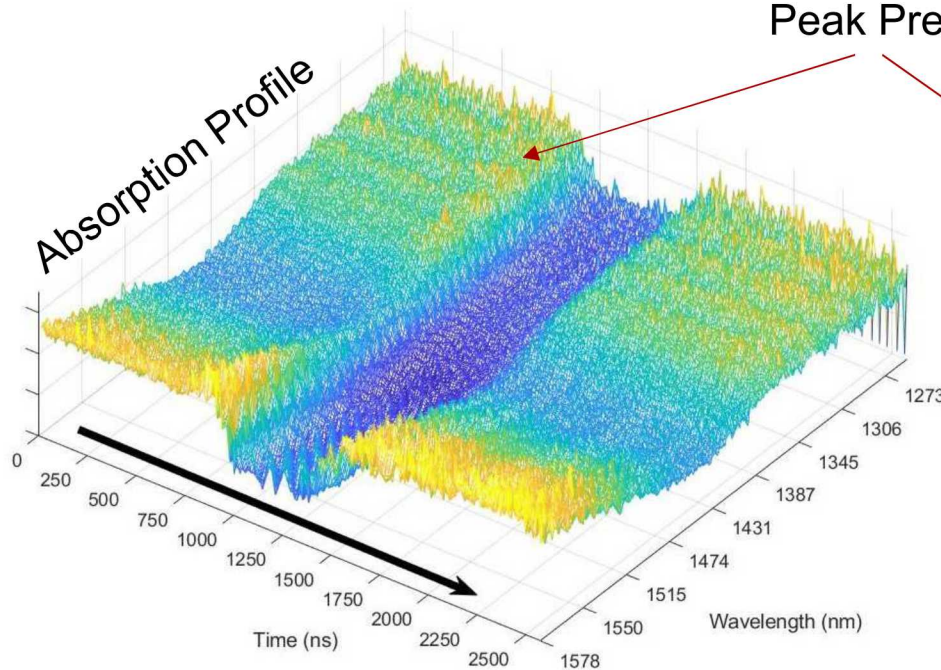
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- ▶ 4.5 GPa peak pressure to prevent cell opacity
- ▶ 90-micron water cell thickness
- ▶ Significant water cell interference effects
- ▶ Data noisy, but consistent with STL data



Peak Pressure

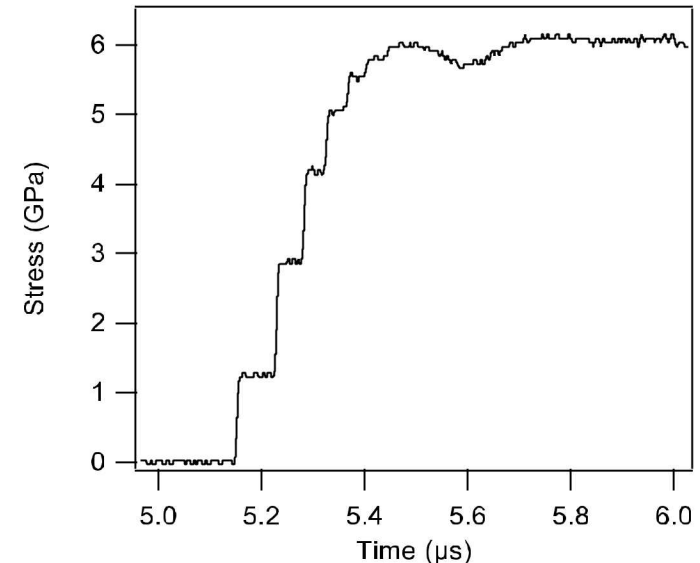
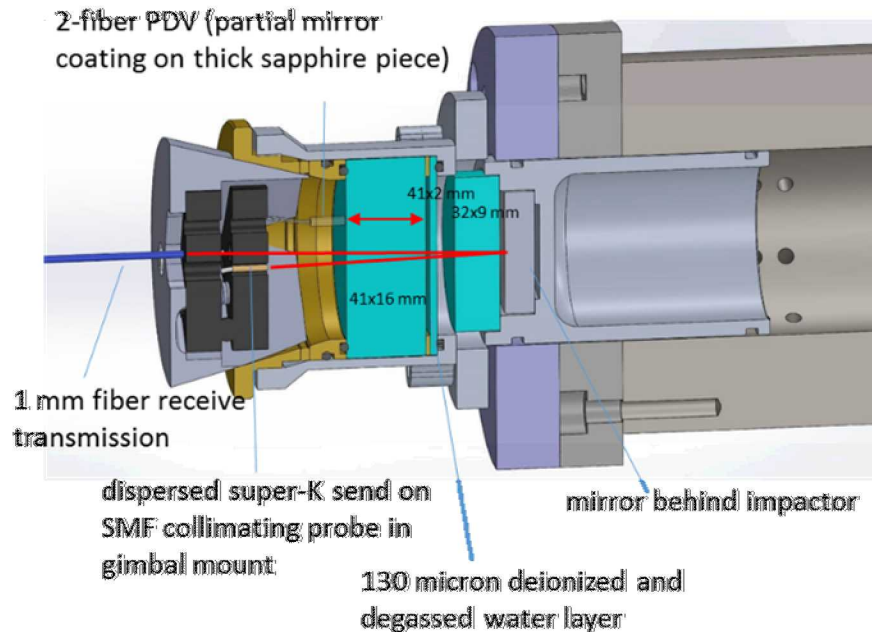


- ▶ Veloce data shown as 12.8 ns profile slices
- ▶ Fringes from water cell etalon interference are evident
- ▶ Helps to visualize spectrum change over time



# STL Gun Experiment

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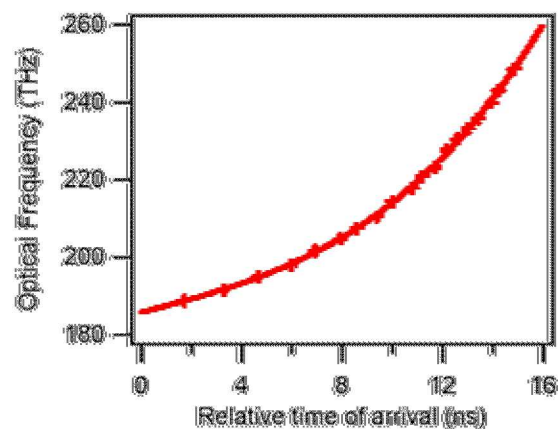
- ▶ Thick sapphire window maintains one-dimensional compression for extended time, allowing pulse averaging with nearly static pressure.
- ▶ Mirror for supercontinuum beam on back side of impactor protects return from initial impact shock.
- ▶ PDV is optically isolated from the water cell.
- ▶ Large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



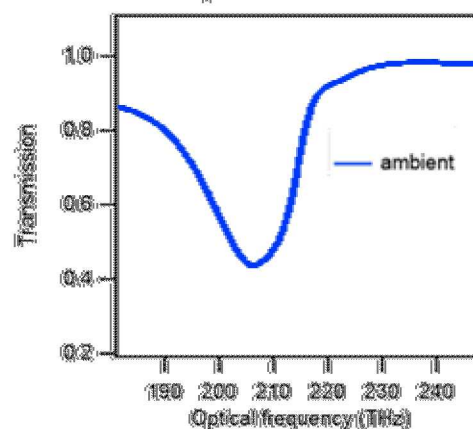
# STL Experiment Conditions

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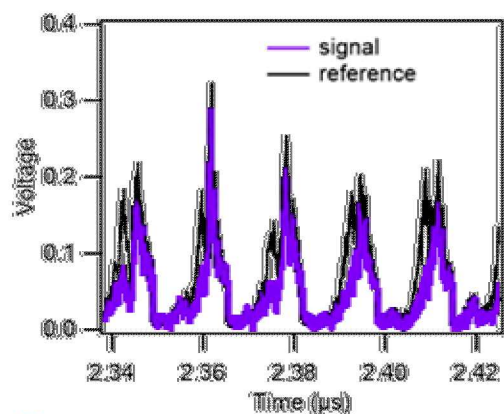
measured dispersion of fiber module



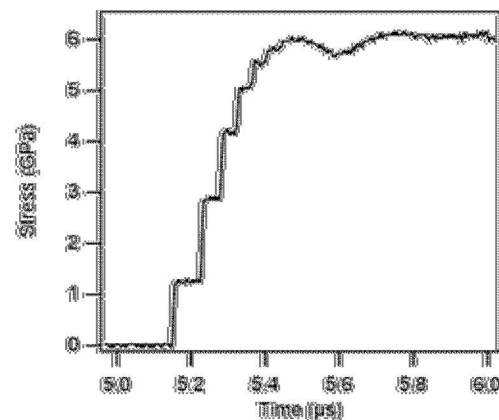
measured ambient spectrum (Cary-5000 on 1 mm sample scaled to 130 microns)



time domain transmission signals



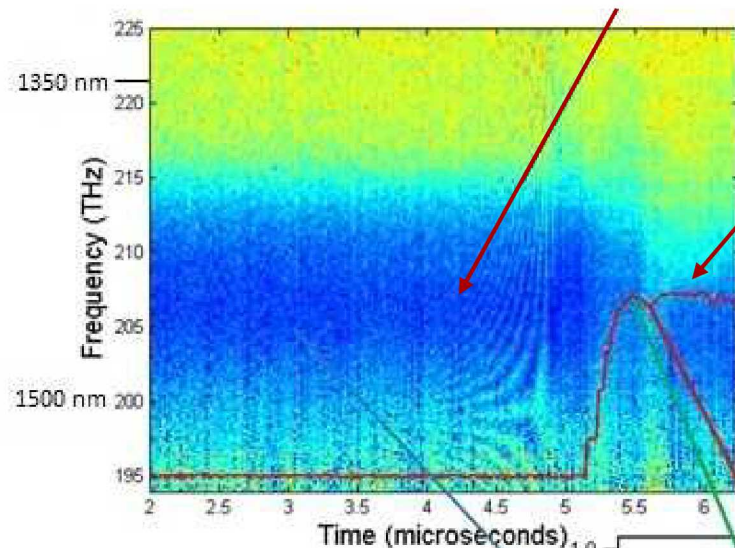
PDV data converted to stress



# STL Experiment Results

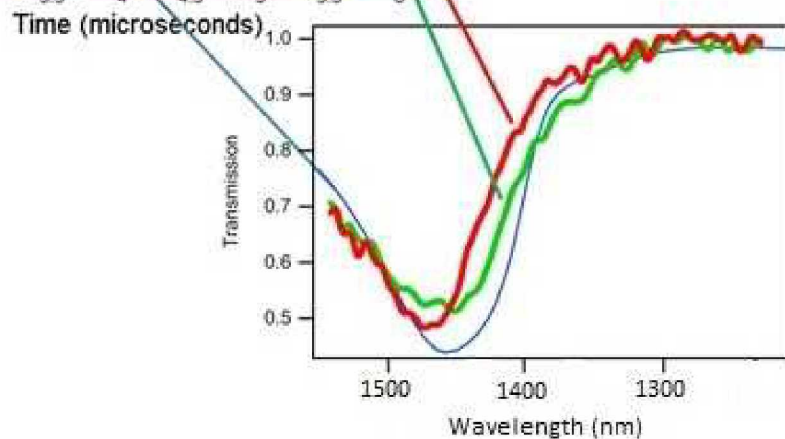
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Spectrogram: Dark blue near 205 THz (1460 nm) is water absorption band



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

- ▶ 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.