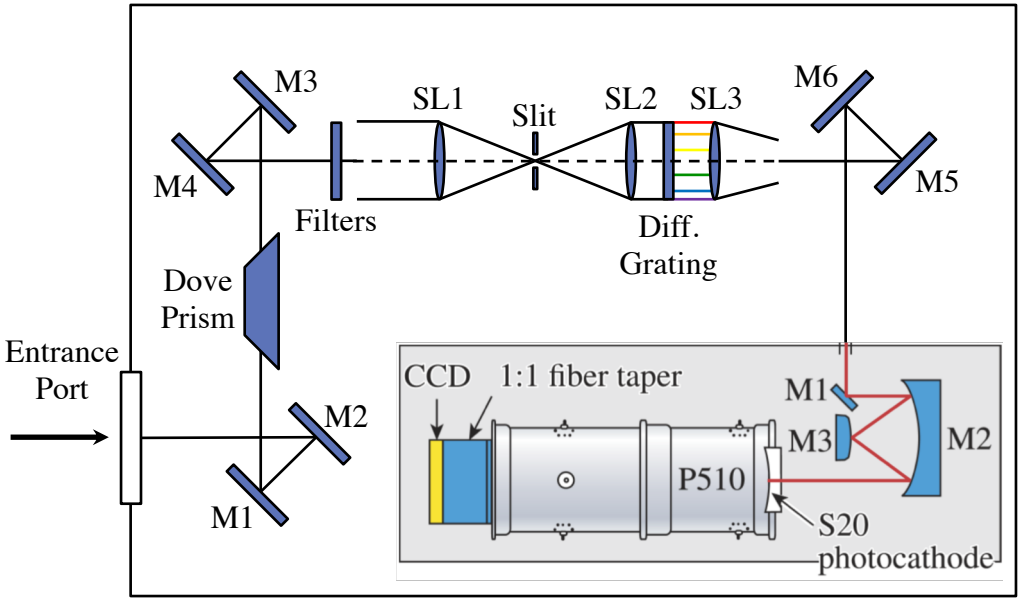
Optical Spectroscopy Measurements of Decaying Shocks in Transparent Crystals



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Division of Plasma Physics
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Summary

We have used a time-resolved optical spectrometer (SOP-Spec) to perform temperature measurements in shocked transparent media

- **SOP-Spec measures optical emission (450-700 nm) from the target chamber; a linear transmission spectrometer module exchanges spatial resolution (‘standard SOP’) for spectral resolution.**

- **This diagnostic can perform temperature measurements in transparent media without an emissivity correction**

- **SOP-Spec is the first of a suite of planned optical diagnostics for OMEGA-EP**

SOP: Streaked Optical Pyrometer

Collaborators

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SOP-Spec provides a crucial framework for optical spectroscopy diagnostics at LLE

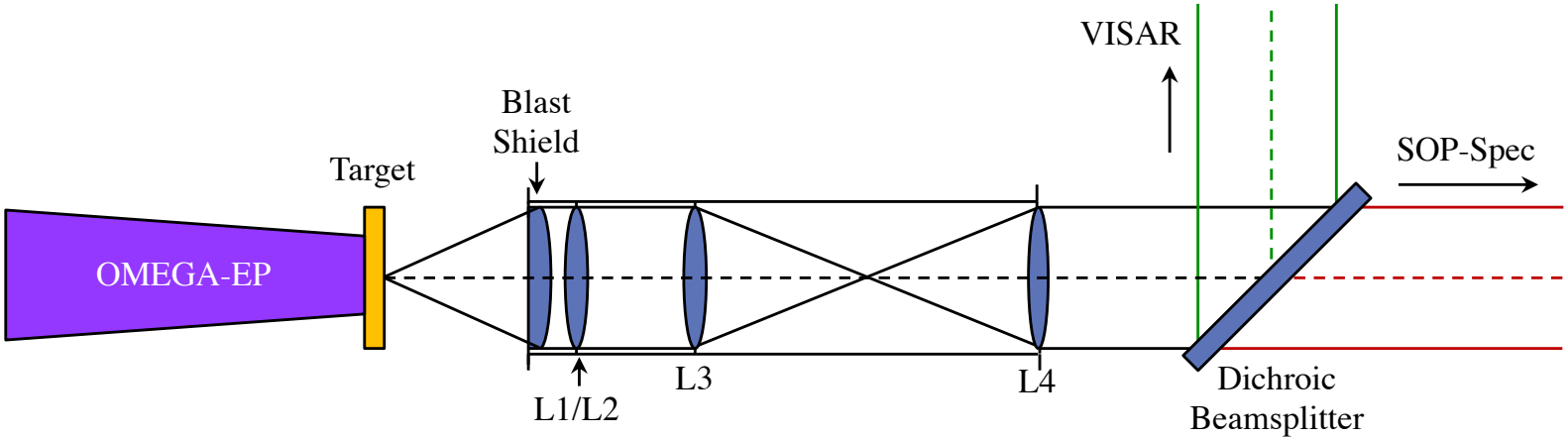
- Measurements of temperature typically use an ‘integrated brightness’ method, requiring assumptions of the material’s optical properties at high temperature
  - Measuring the Planck spectrum directly allows us to determine temperature without an emissivity correction

- Developing an optical spectrometer that couples to the Rochester Optical Streak System (ROSS) was needed for a host of new diagnostics at LLE

- Several permanent optical diagnostics are now planned for OMEGA-EP including: streaked optical pyrometry w/ spectrometer (SOP-Spec), white light reflectance system, streaked Raman spectroscopy

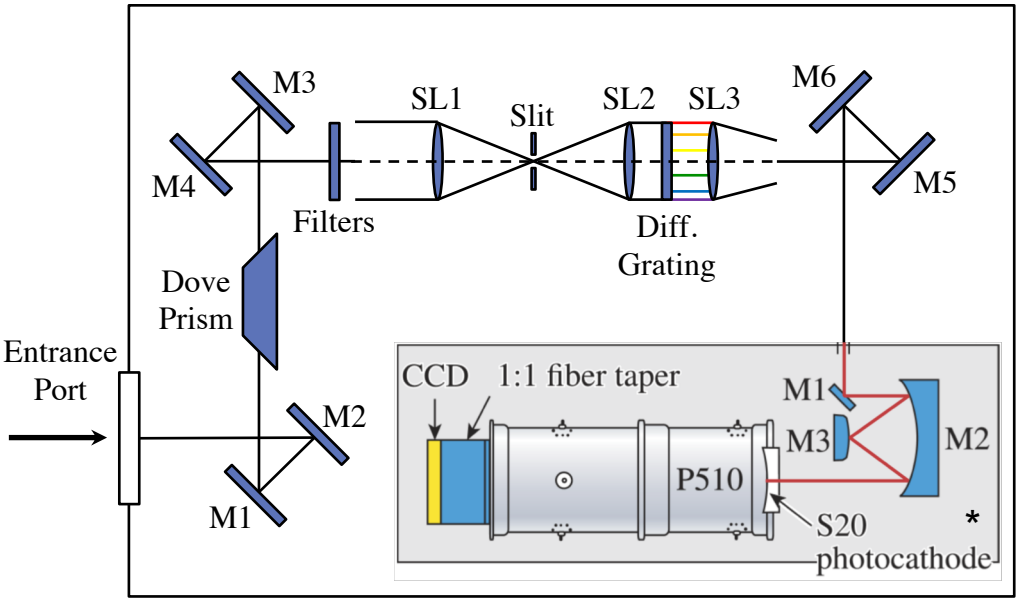
LLE: Laboratory for Laser Energetics

Thermal emission is collected from the target chamber using an optical relay



- **A series of achromatic doublets collimate the light at f/3.3 from the target chamber**
- **A dichroic beamsplitter separates the 532 nm VISAR laser, enabling a simultaneous probe of the shock's velocity**

Linear transmission spectroscopy is used to disperse optical emission from the sample



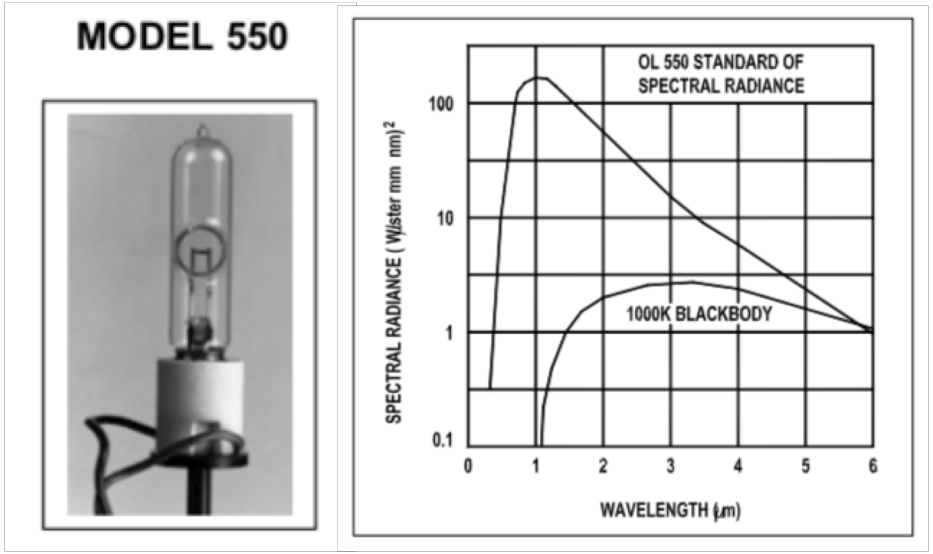
General Specs:

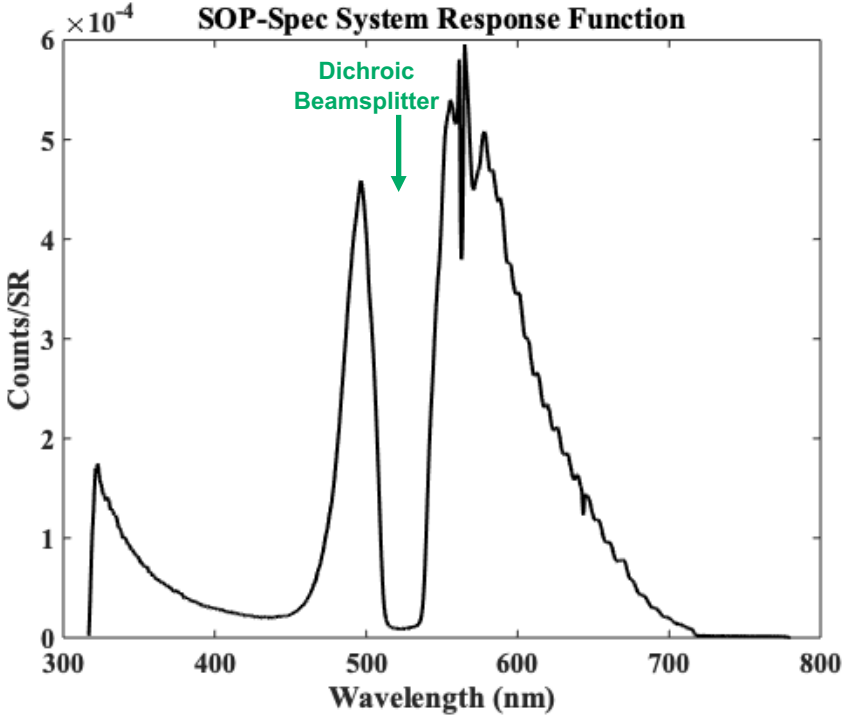
- **SOP-Spec collects optical emission in the 450-700 nm band, with a peak efficiency near 550 nm**
- **150 grooves/mm transmission diffraction grating**
- **200 um input slit sets a spectral resolution of 3.2 nm at best focus**
- **Coupled to a streak camera with 10 ps of temporal resolution**

*M. C. Gregor et al., Rev. Sci. Instrum. 87, 114903 (2016).

SOP-Spec's system response function (SRF) is calibrated by a tungsten lamp

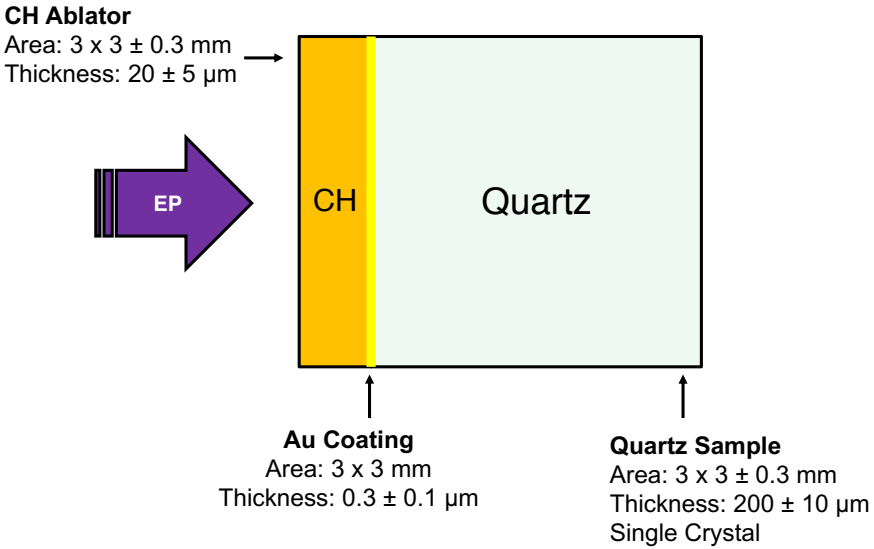
NIST-calibrated Standard of Spectral Radiance



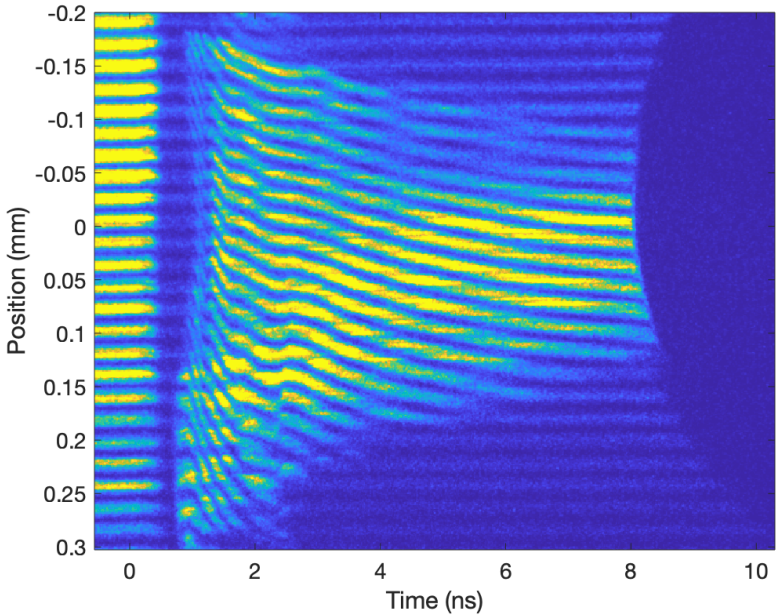


Results

Decaying shocks were driven on OMEGA-EP in 200 um α-quartz samples



VISAR records the time-dependent shock velocity



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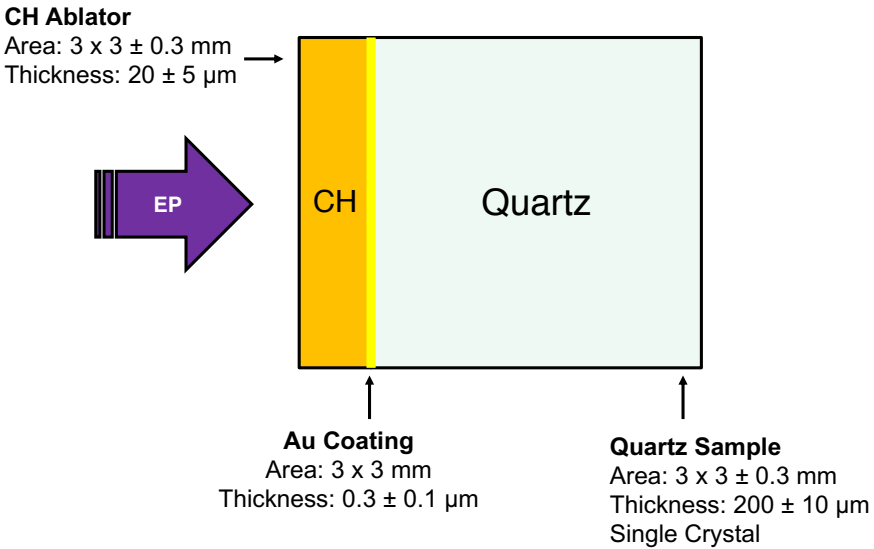
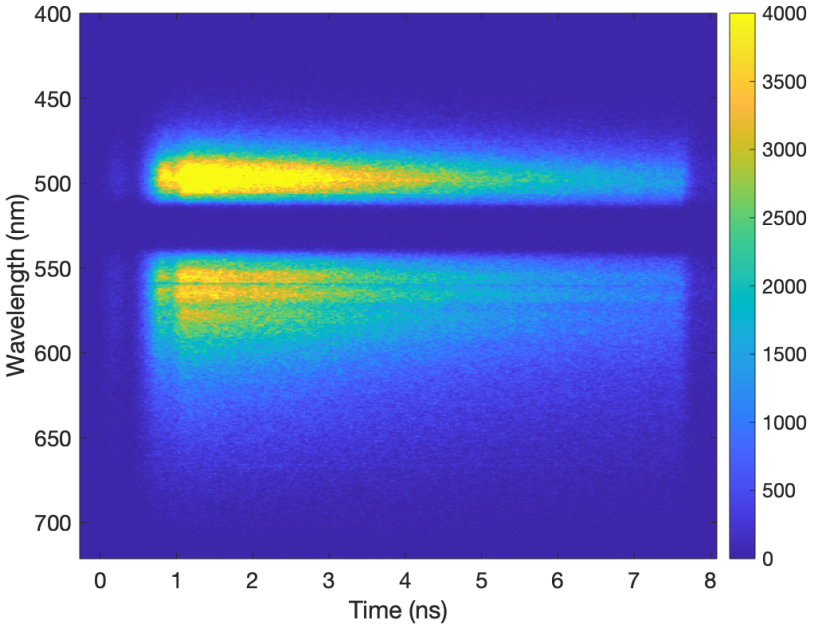
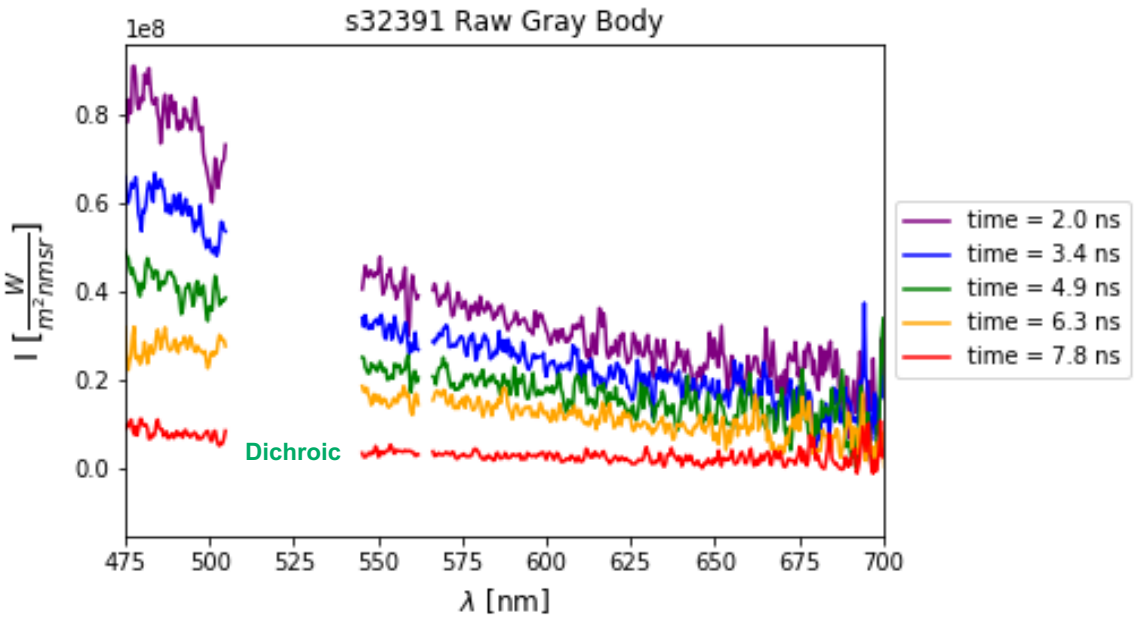


SOP-Spec collects thermal emission from the decaying shock



A spectrum is extracted from SOP-Spec images using the SRF



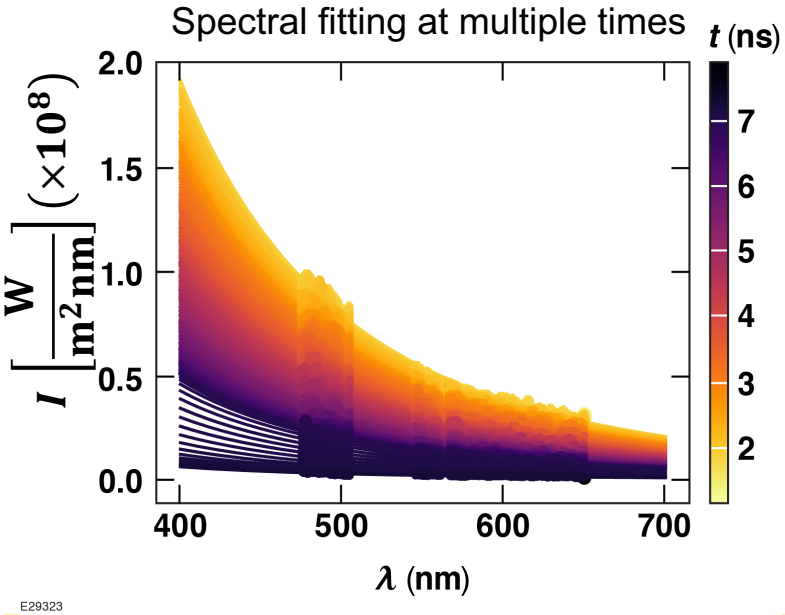
- **The recorded spectrum is expected to take the form of Planck's Law:**

$$I = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{k_b T \lambda}} - 1}$$

- **In HED experiments, the peak in the Planck spectrum is located at extremely short wavelengths, so we measure the slope of the spectrum to the right of the peak**
- **An emissivity correction is not required to measure temperature from these spectrums!**

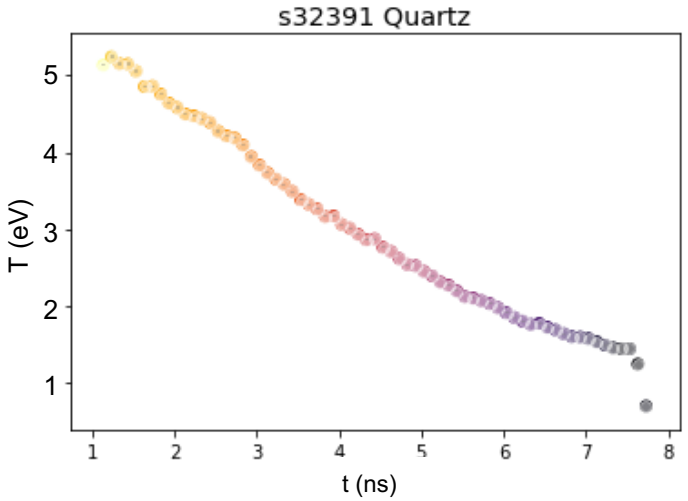
Results

The emission spectrum is fit with Planck's Law to determine temperature



Extracting time-dependence

Bright: Early and Hot
Dark: Late and Cold



Bayesian inference confirms the temperature measured with the least-squares method. It will be used to infer a functional form for the emissivity and confirm uncertainty calculations. *

* J. Ruby, "Bayesian Inference of Energy Transfer in Gigabar Convergent Experiments", VI01

The LLE HEDP group has a suite of planned optical diagnostics for OMEGA-EP

UR LLE

Streaked Optical Spectrometer (SOP-Spec)

- Collects optical radiation in the 450-700 nm band
- Ideal for temperature measurements and searching for optical signals associated with high-pressure chemistry
- Spectral resolution of 1-3 nm, depending on slit size
- Temporal resolution of 10-100 ps, depending on sweep
- *B. Henderson, RSI, 2021 in prep.*

White Light Reflectometer

- Uses white light generated in a liquid cell pumped by a 50-fs Nd:YAG laser
- Will probe broadband efficiency of reflecting surfaces at high pressure
- Uses a CMOS detector for high efficiency and 0.5 ns temporal resolution
- *B. Henderson, PRB, 2021 in prep.*

Streaked Raman Spectrometer

- Uses a 532 nm probe to stimulate Raman scattering in samples
- Will sample vibrational modes in dynamically-compressed crystals, and unambiguously identify phase transitions
- Spectral resolution of 1-3 nm
- Temporal resolution of 10-100 ps

Conclusions

We have used a time-resolved optical spectrometer (SOP-Spec) to perform temperature measurements in shocked transparent media

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- SOP-Spec will become a qualified diagnostic, available to anyone performing experiments on the OMEGA-EP laser system, in early 2021