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Time–Resolved Optical Measurements of Shock-Induced Chemistry in Energetic Materials

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Project Overview:

Our ability to simulate initiation and growth to detonation in explosives is limited by the lack of high fidelity data for building and validating the models used to describe chemical reactions.

- Data is difficult to acquire due to the extremely small length and time scales (nm-um and ps-ns)
- Objective is to directly observe evidence of chemical reactions occurring during the shock loading of explosives
- Experiments are enabled by unique samples fabricated by vapor deposition

Two approaches have been pursued that exploit optical access to the explosive:

- Time resolved spectroscopy during initiation, failure, or propagation of detonation.
- Photonic Doppler velocimetry on shock-loaded samples.

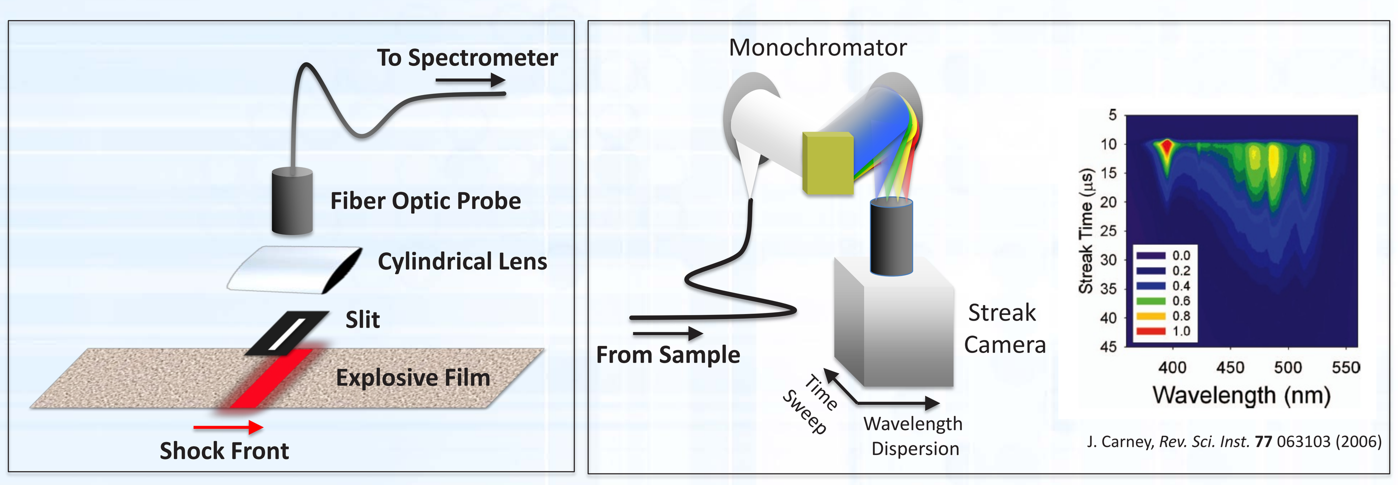
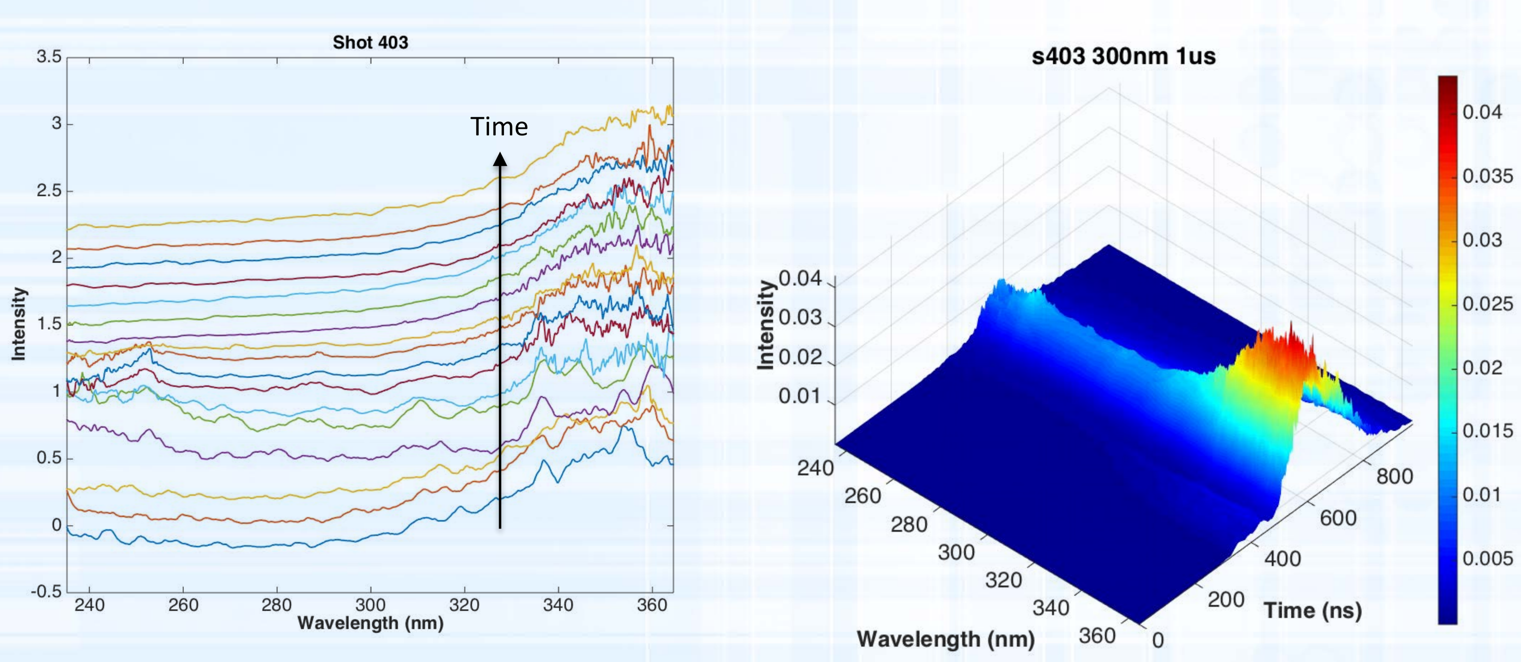
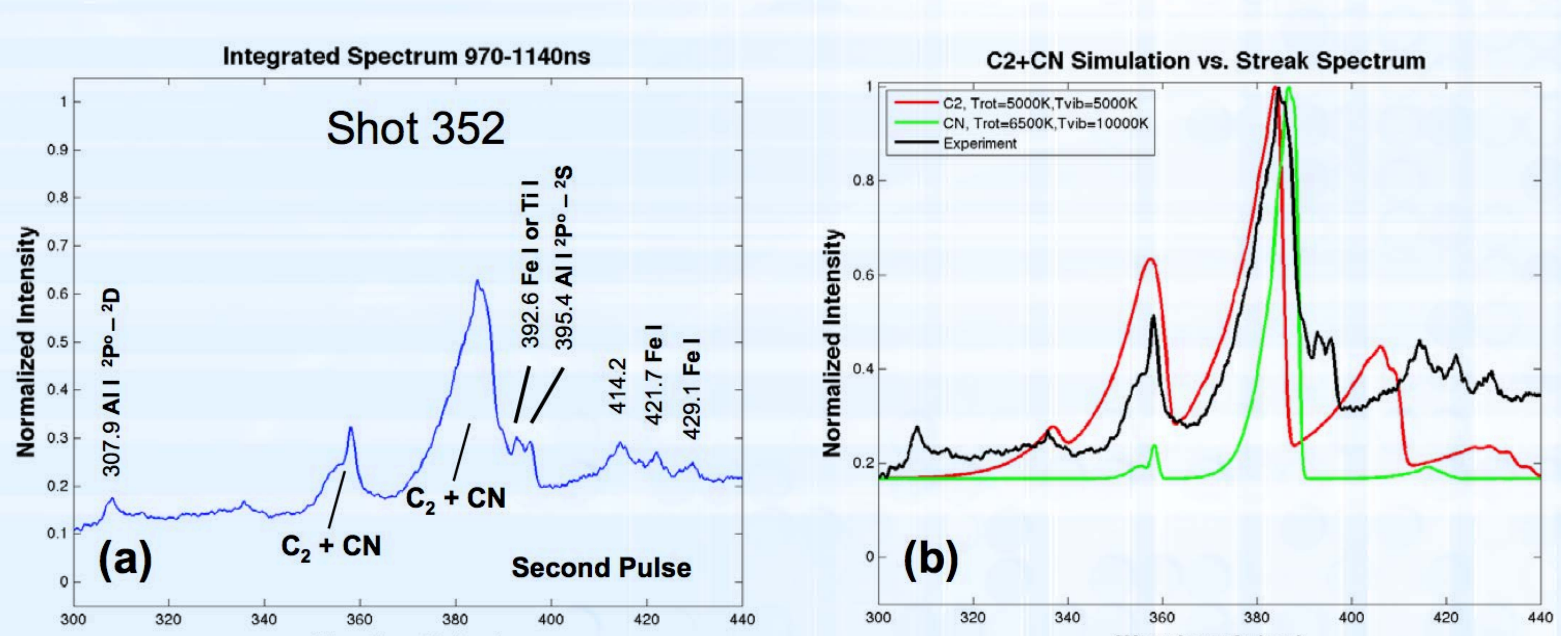


Diagram of the spectroscopy experiment. A detonation proceeds laterally through a vapor deposited film of explosive (PETN, HNS, HNAB). Light emission is captured, spectrally separated, and recorded by a streak-camera.

- We have collected spectra from PETN, HNS, and HNAB films over wavelengths from 220 – 540 nm
- Upcoming experiments will capture this data from failing detonations



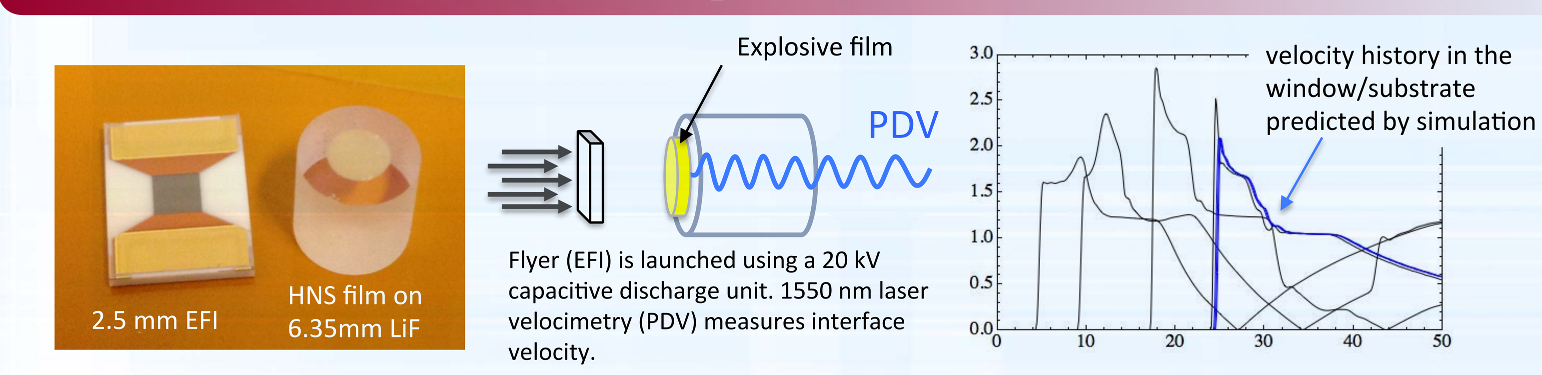
UV emission from detonating PETN, 300 nm center: (left) time resolved spectra, 25 ns increments. (right) spectral surface-map.

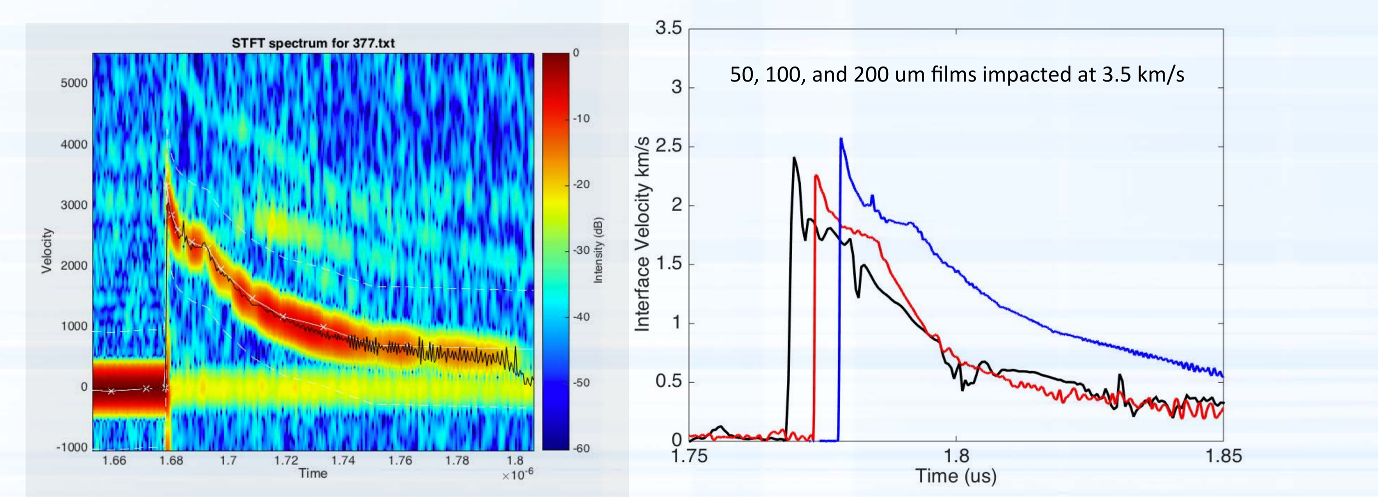


UV emission from detonating HNS, 380 nm center: (a) integrated spectrum and (b) comparison with simulated emission spectra from C2 and CN.

- Data may suggest non-equilibrium thermal distribution.

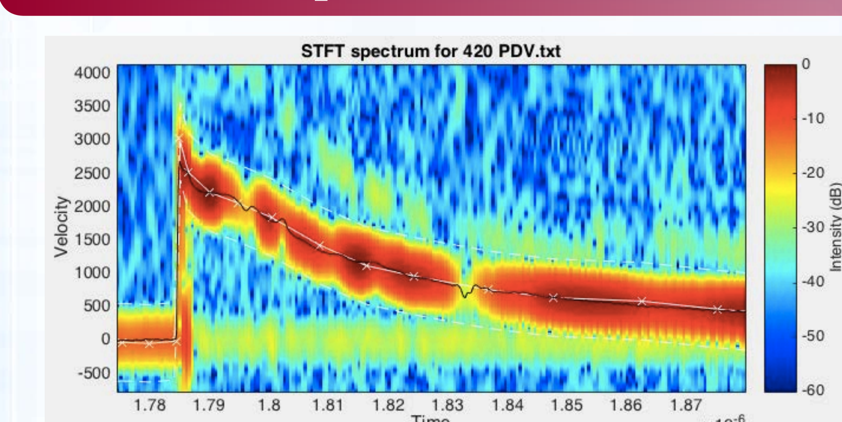
PDV "cut-back" experiments:



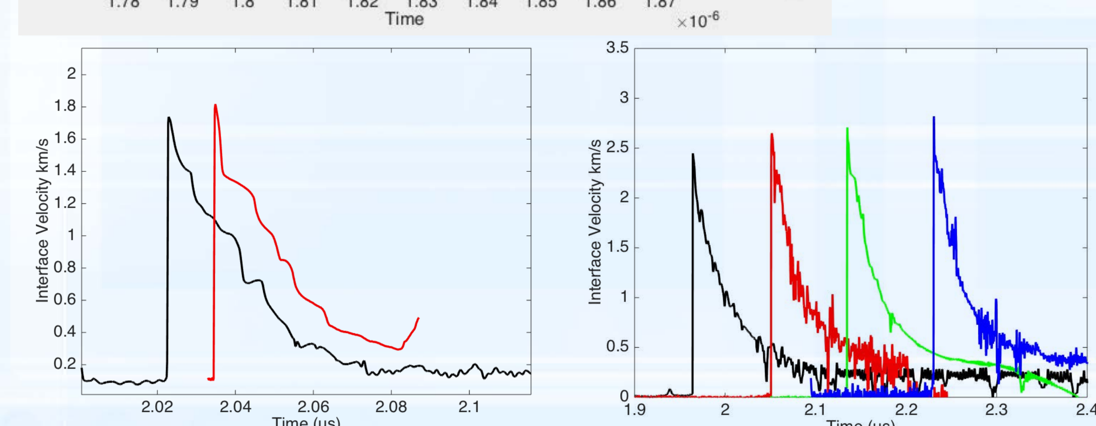


(left) PDV spectrogram, and (Right) velocity histories from PETN films after 3.5 km/s impact

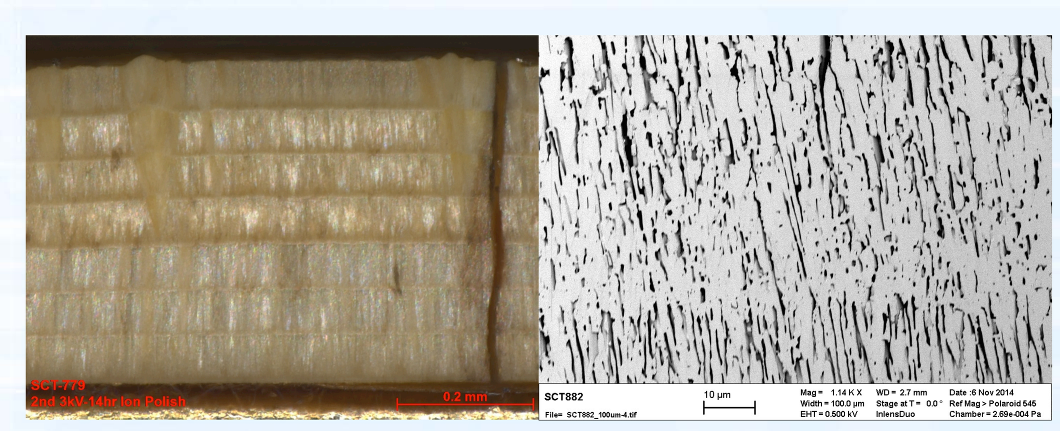
Build-up to detonation in HNS



Next: thicker/slower flyers to capture more of the build-up.

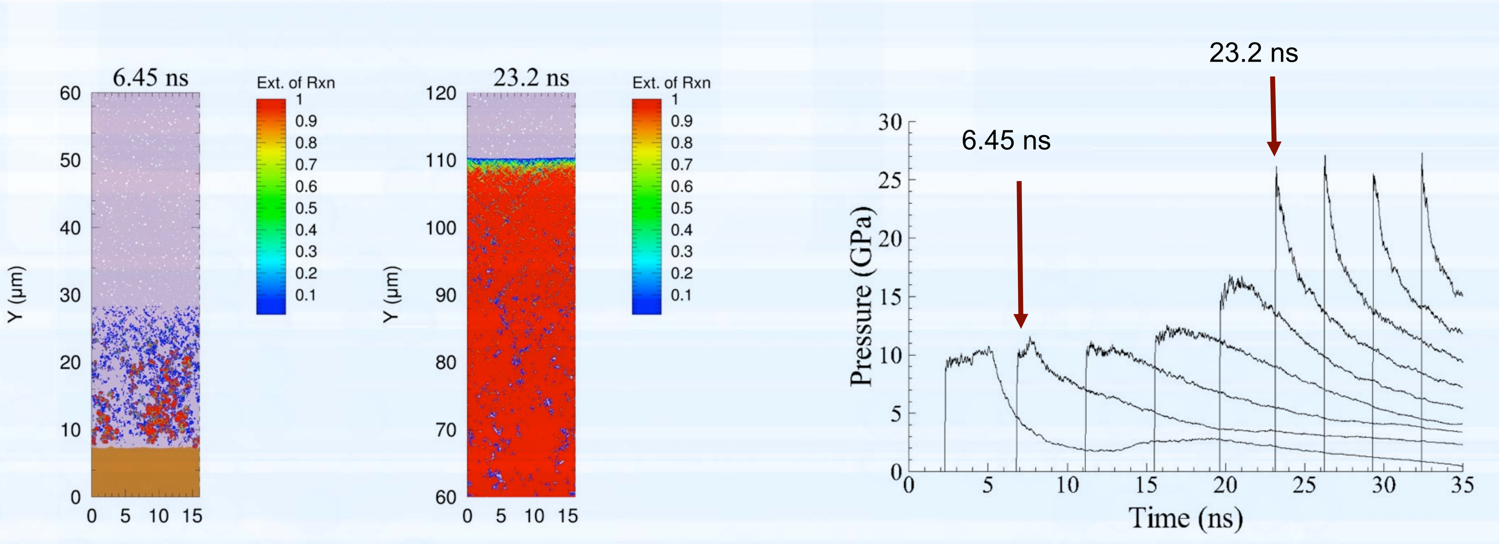


(left) 110 and 155 um thick films (impacted at 3.3 and 3.5 km/s respectively) and (right) 120 um thick HNS films impacted at 3.0, 3.2, 3.3, 3.4 km/s.



(left) Optical micrograph, (right) electron micrograph of ion-milled cross-section of HNS

- Microstructure is being quantified, and used as the input geometry for grain-scale simulations



Grain-scale simulation of HNS initiation. (left) extent of reaction at 6 and 23 ns after flyer impact. (right) pressure histories showing build-up to detonation

Summary

- Fabricated vapor deposited samples in detonable geometries that enable optical access to the reacting explosive.
- Collected time-resolved emission spectra from detonating HNS, PETN, and HNAB.
- Measured the extremely fast build-up to detonation in HNS and PETN
- Will be capturing spectra from failing detonations
- Velocity histories are being used to validate reactive-flow simulations of initiation.

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