Ultrafast Laser Diagnostics to Investigate Initiation Fundamentals in Energetic Materials

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LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Early Career R&D Program

Sandia National Laboratories

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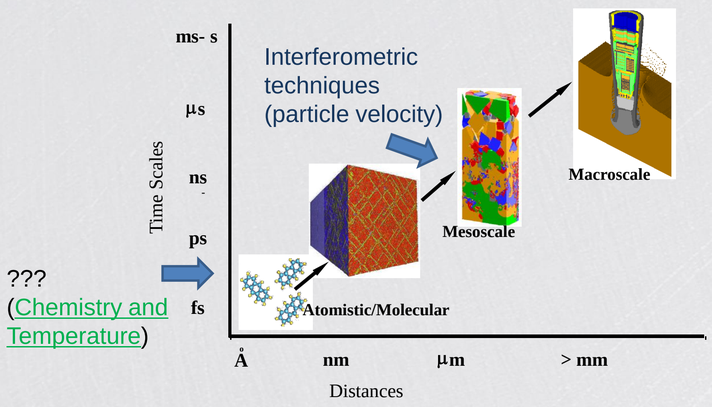
Problem: measuring temperature and kinetics on picosecond timescales

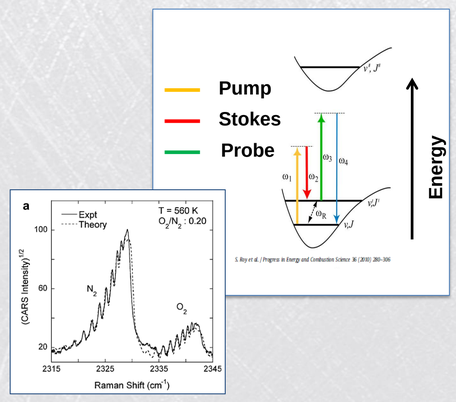


Currently temperature/chemical kinetics cannot be directly observed during initiation in energetic materials.

Develop single shot diagnostic w/ picosecond time resolution to directly measure temperature/chemical kinetics in energetic materials during initiation.

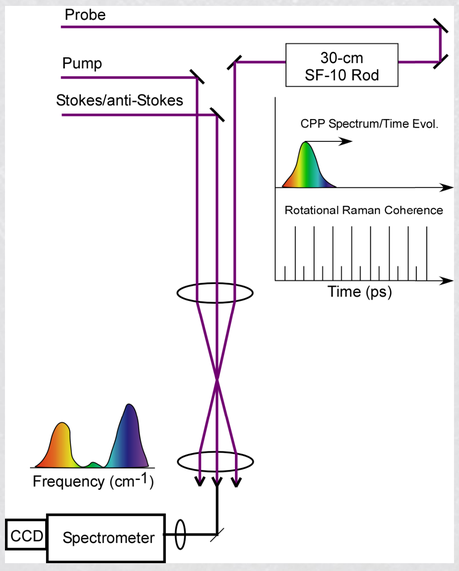
Approach : single-shot, non-linear femtosecond laser spectroscopy.

Femtosecond laser pulses are used to measure distribution of vibrational and rotational energy levels of gas to determine gas temperature with picosecond time resolution with a single set of phased matched pulses (single-shot). We are using Coherent Anti-Stokes Raman Spectroscopy, but other types of non-linear spectroscopy can be adapted for this application.

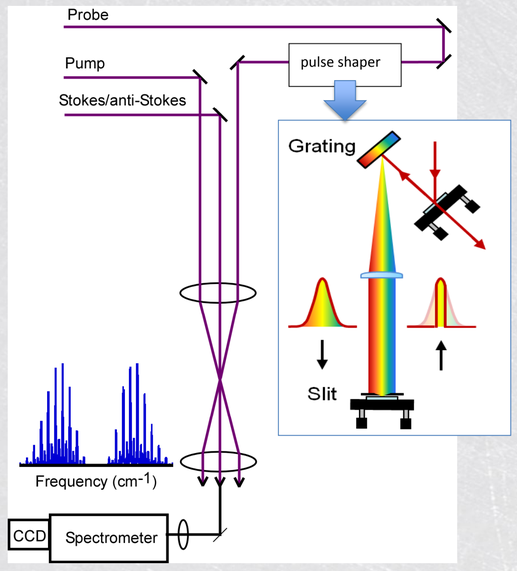


Our goal for FY 11 is to develop a robust method for single shot temperature measurements of nitrogen gas that could be used to measure gas temperature in combusting plumes to characterize igniter performance. We compared two approaches for measuring the rotational temperature of N_2:

Chirped Probe Pulse (CPP)

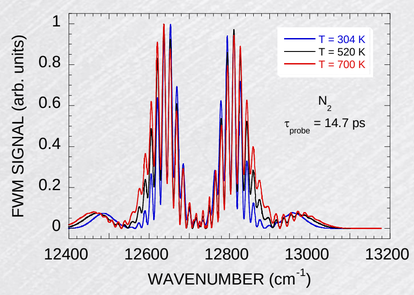


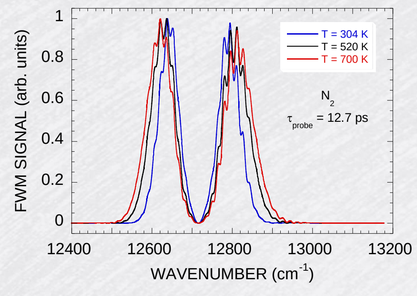
Transform-Limited Probe Pulse (TLPP)



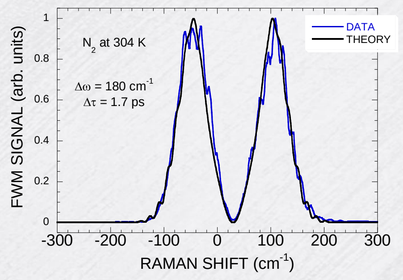
Results

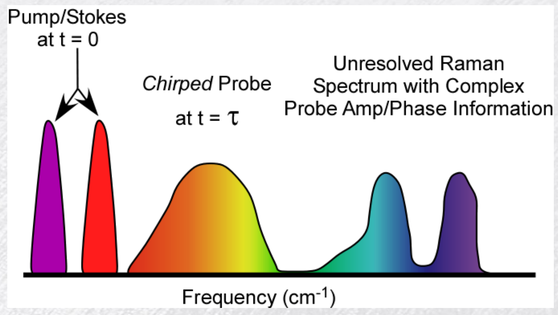
Chirped Probe Pulse (CPP)





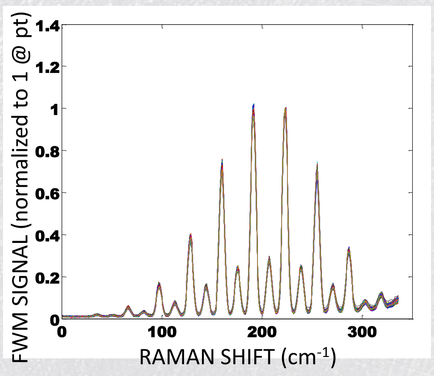
Data qualitatively matches models for N_2 with good S/N, but calculations show small variations in phase in wings of the probe electric field cause significant change in calculated spectra. We are doubtful that FROG based methods of pulse characterization currently available to jus will be sufficient to reproduce fine features in our data during combustion.

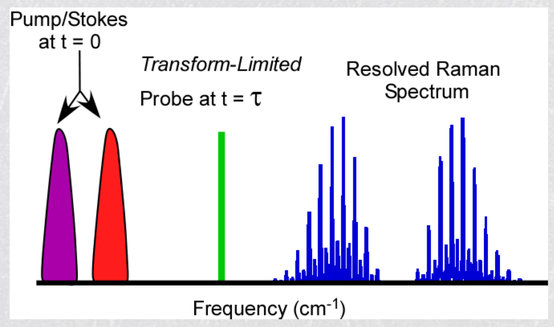




Transform-Limited Probe Pulse (TLPP)

Data taken with probe w/ 4 cm^{-1} FWHM. Rotational transitions sufficiently resolved to fit to temperature model. Initial experiments at RT show excellent S/N (>1000:1) and low shot to shot noise that is a significant improvement in shot to shot noise over ns CARS methods. Data still need to be taken in heated gas where the distribution of signal over a greater number of transitions will reduce S/N.





Significance

- Developing single shot temperature measurements in the gas phase will inform our approach in thin film materials while providing new methods for characterizing igniter output.
- This is a first step in an effort to directly measure species composition and temperature behind the shock wave in situ, on the time scale of detonation. Next FY we plan to develop techniques to test in semiconductors and inert thin films.

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