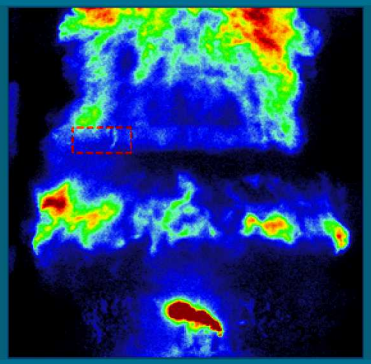
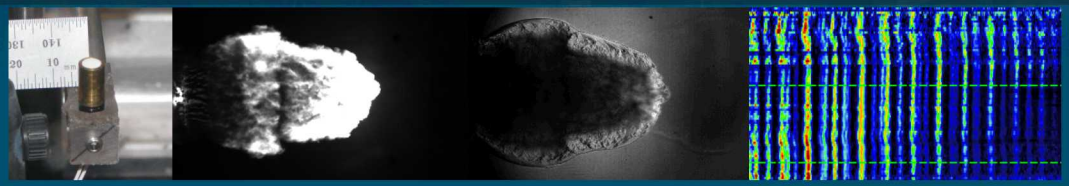
SAND2019-15485C

Post-Detonation Fireball Thermometry via 1D Rotational CARS





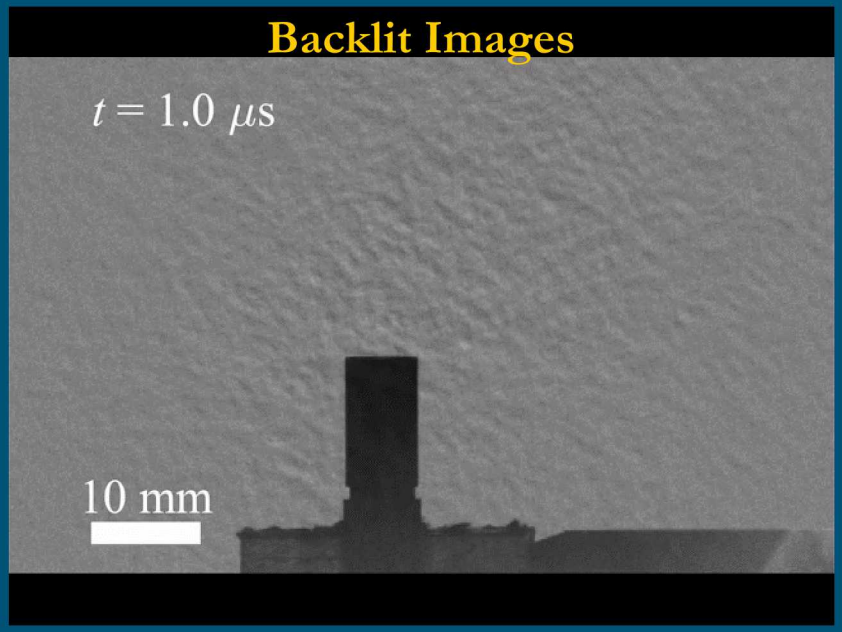
Daniel R. Richardson, Sean P. Kearney, Daniel R. Guildenbecher

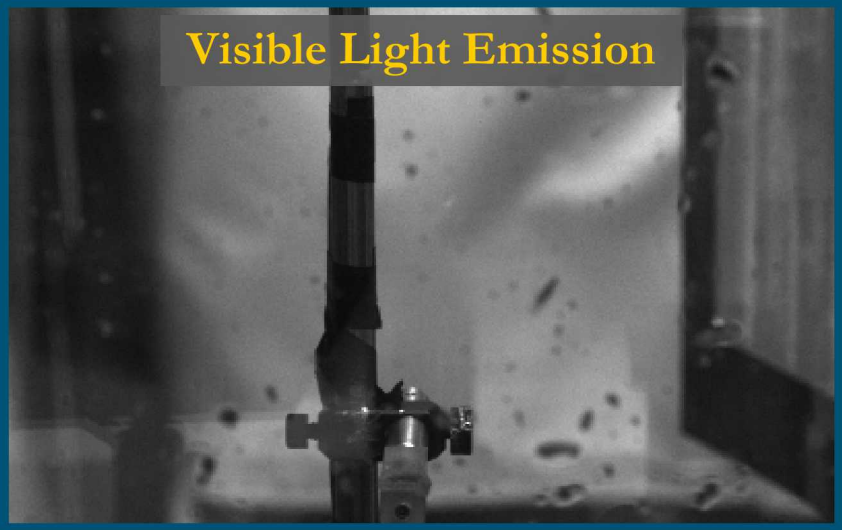
Engineering Sciences Center,
Sandia National Laboratories

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Introduction

- Energetic materials are used in many industrial and military applications
- Understanding the energy released in a detonation is important and challenging due to:
  - Extreme pressures and temperatures
  - Fast time scale
  - Fragments and debris
- Energy released in fireball can be comparable to energy in detonation and blast wave
- This work focuses on the temperature inside the fireball

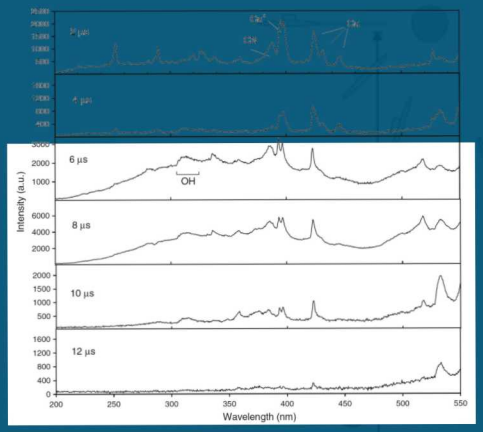




Previous Fireball Temperature Measurements

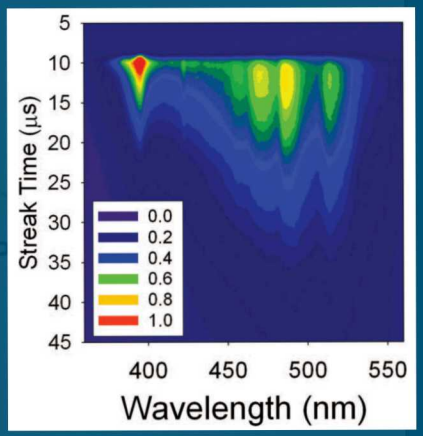
Emission Spectroscopy

Early Times (2–10 μs)



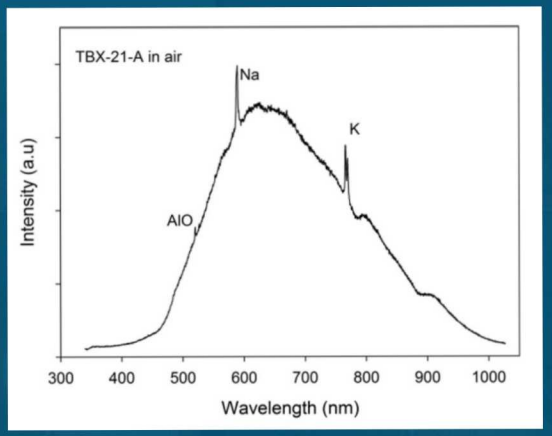
Glumac, Shock Waves 2013

Streak Camera



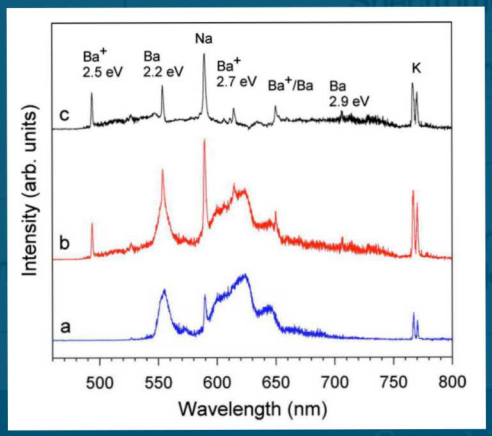
Carney, Rev. Sci. Instrum. 2006

Late Times (4ms)



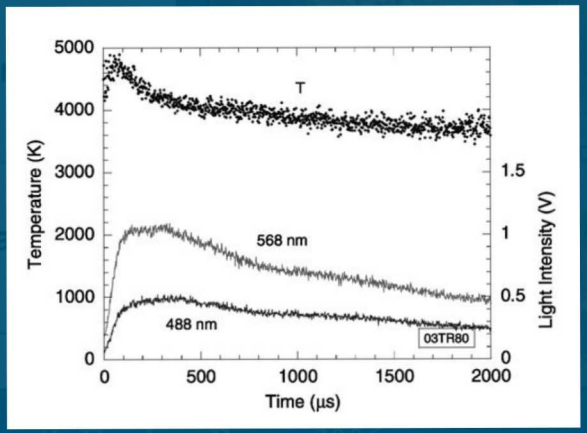
Maiz, Propell. Explos. Pyrot. 2017

Atomic Emission from Tracer



Lewis, J Appl. Phys. 2009

Pyrometric Temperature

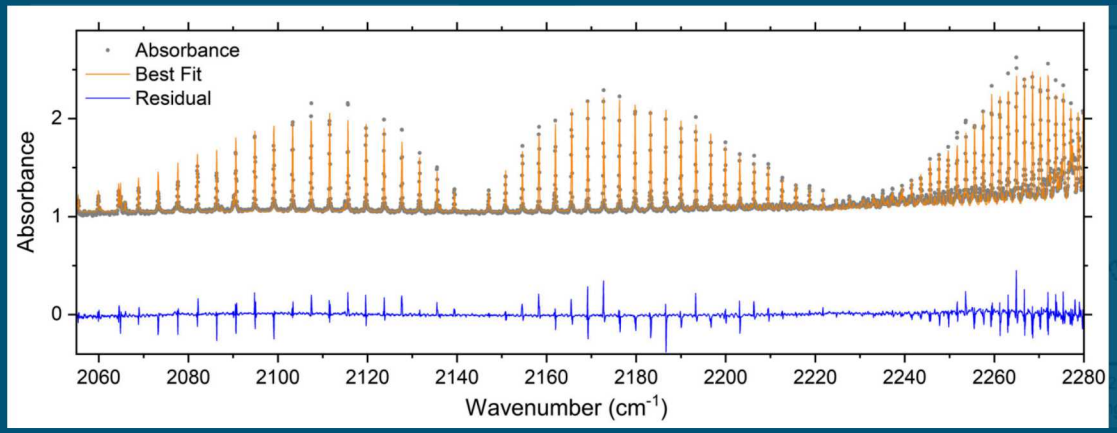


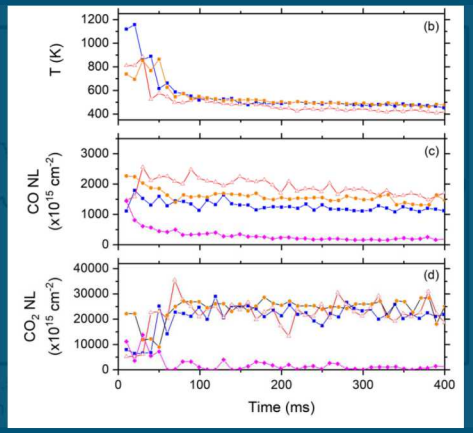
Goroshin, Propell. Explos. Pyrot. 2006

Previous Fireball Temperature Measurements

Absorption Spectroscopy

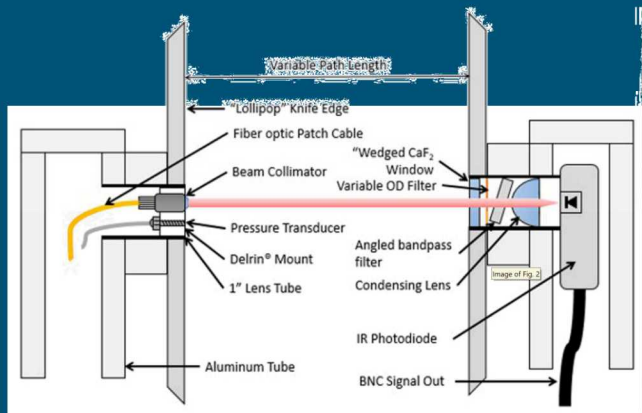
TDLAS, CO, CO_2





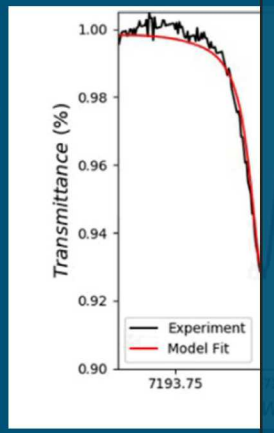
Phillips, J. Appl. Phys. 2019

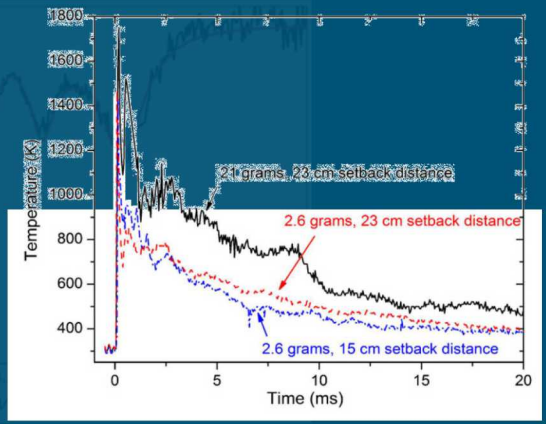
Tunable Diode Laser Absorption (TDLAS), H_2O



Murzyn, Opt. Laser Eng. 2018

TDLAS, H_2O



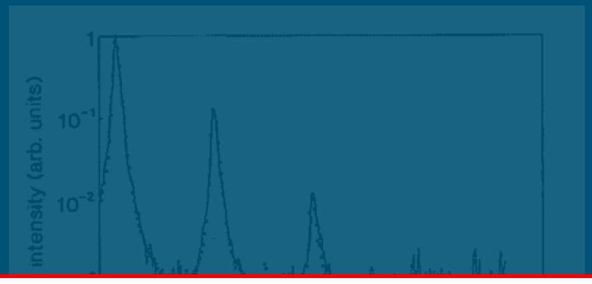


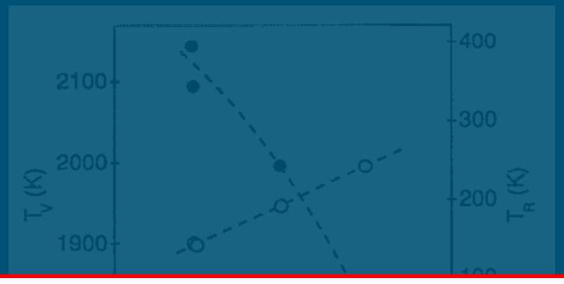
Carney, Meas. Sci. Technol. 2011

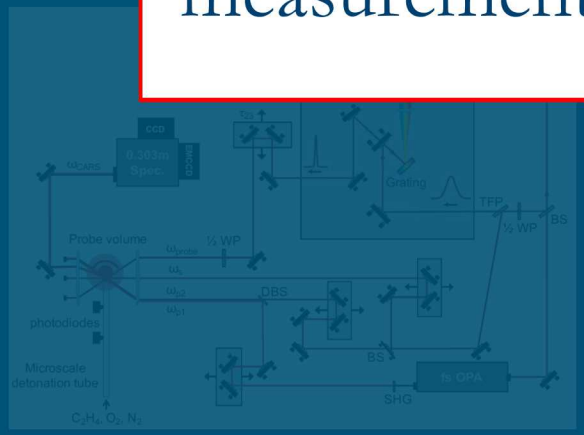
Previous Fireball Temperature Measurements

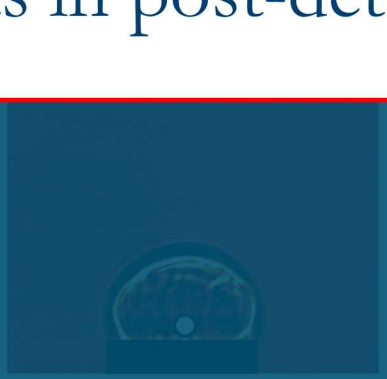
Coherent Anti-Stokes Raman Scattering

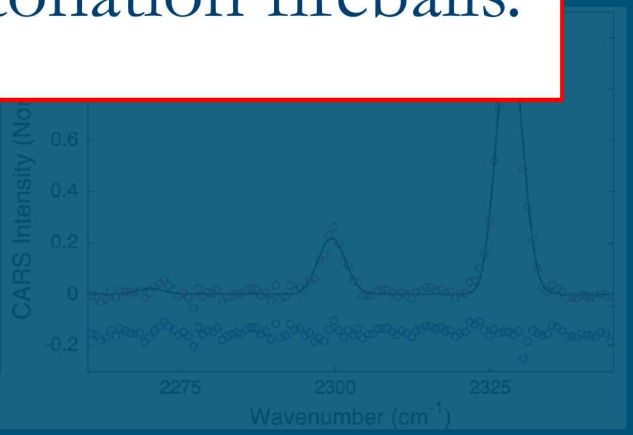
The goal of this work is to perform spatially resolved temperature measurements in post-detonation fireballs.









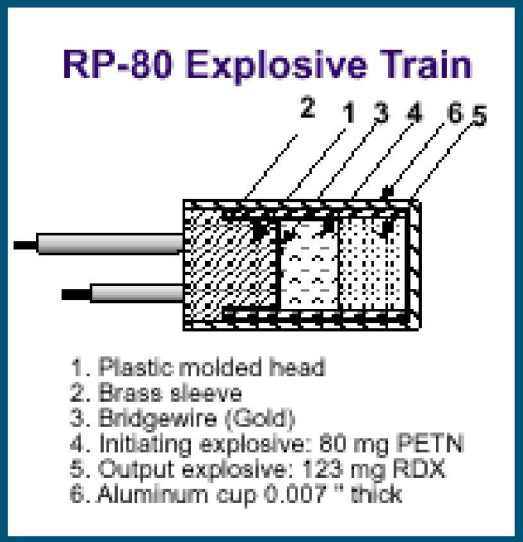


Dedic, AIAA SciTech 2017-0030

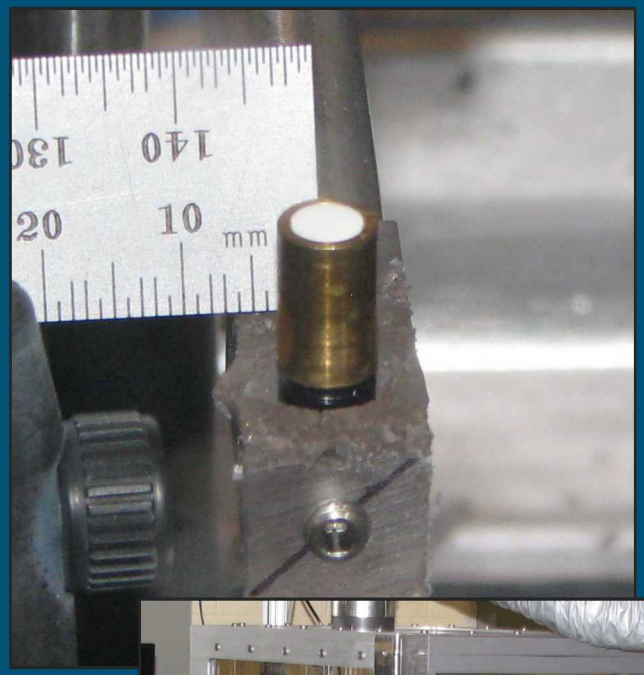
Experimental Setup: Detonator

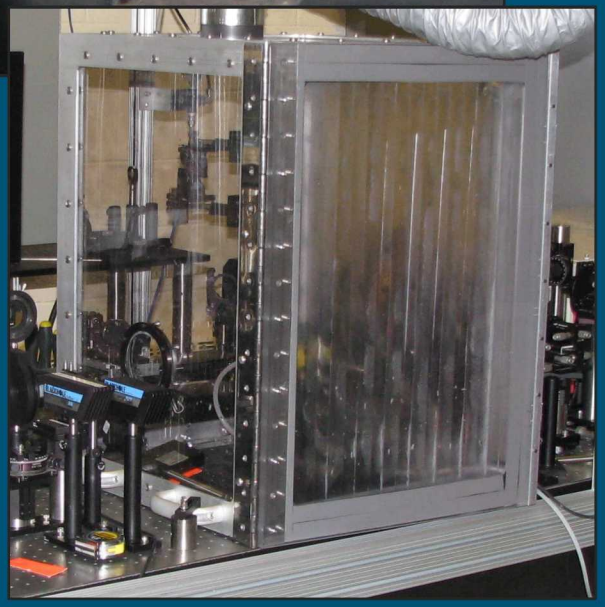
Detonator:

- RP-80 EBW from Teledyne RISI
  - P/N 167-9964
- 80 mg PETN
- 123 mg RDX



http://www.teledynerisi.com/products-services/ebw-detonators/rp-80-ebw-detonator





Expert Help!

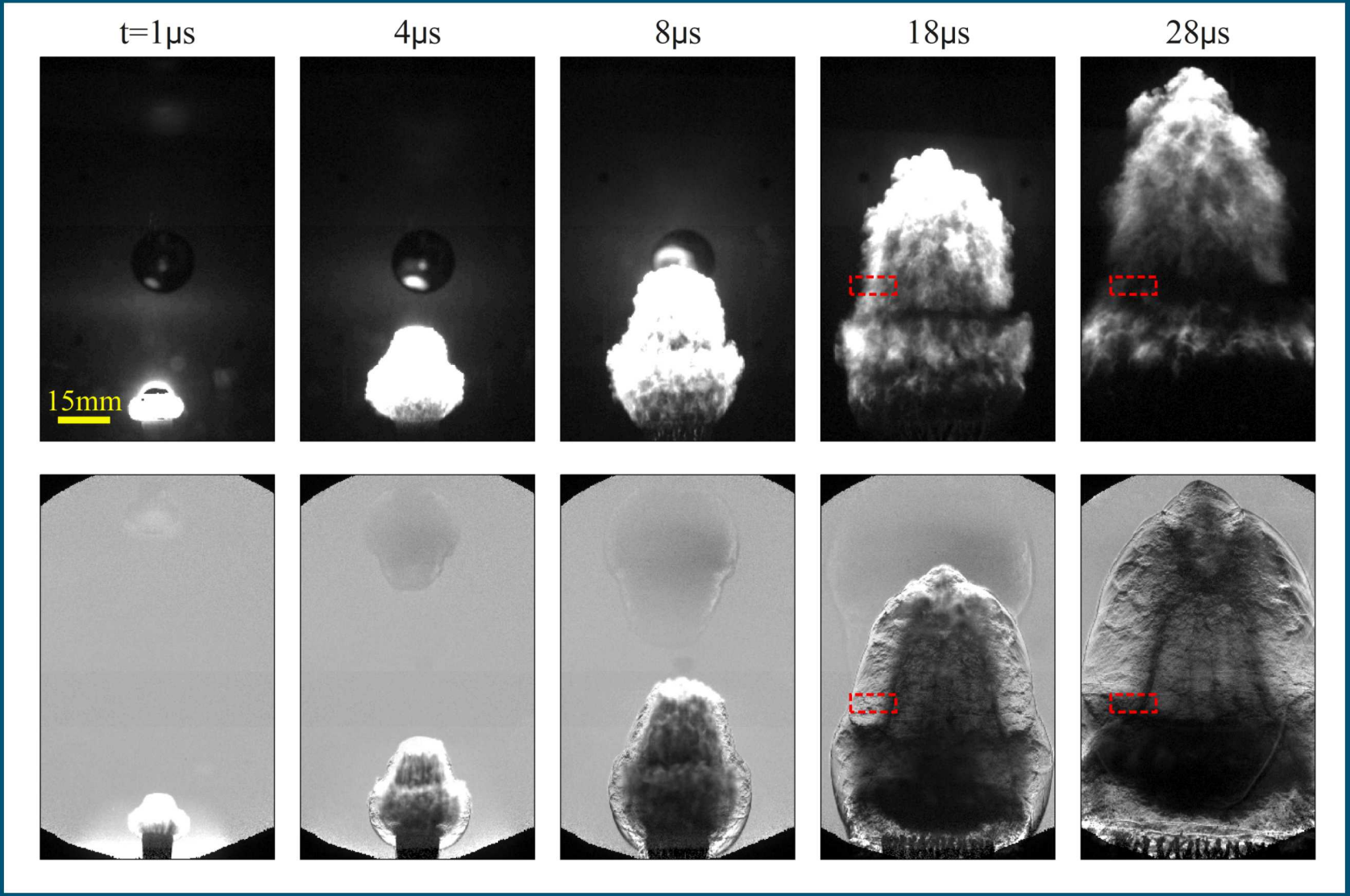
Design of boom box and explosive handling:

- Thomas W. Grasser
- Paul A. Farias
- Lucas K. Lebow
- Howard L. Stauffacher III
- Glen White
- Sam Reardon

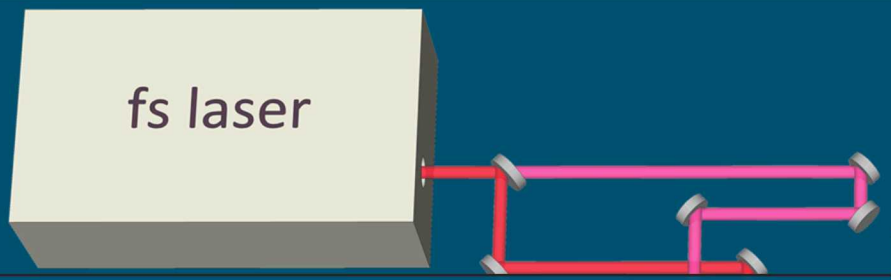
Boom Box:

- Polycarbonate housing contains blast and fragments
- Windows for optical access
  - 100 mm diameter
  - 13 mm thickness

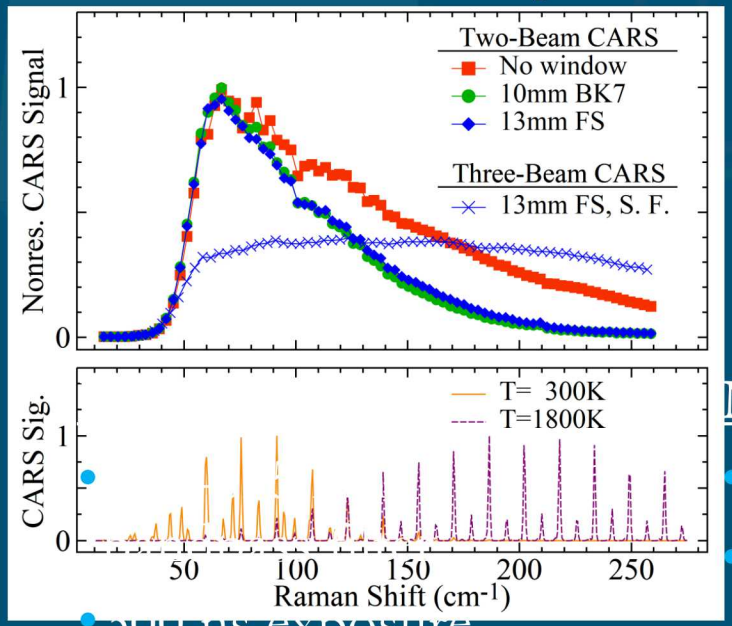
Experimental Setup: Schlieren and HS Imaging

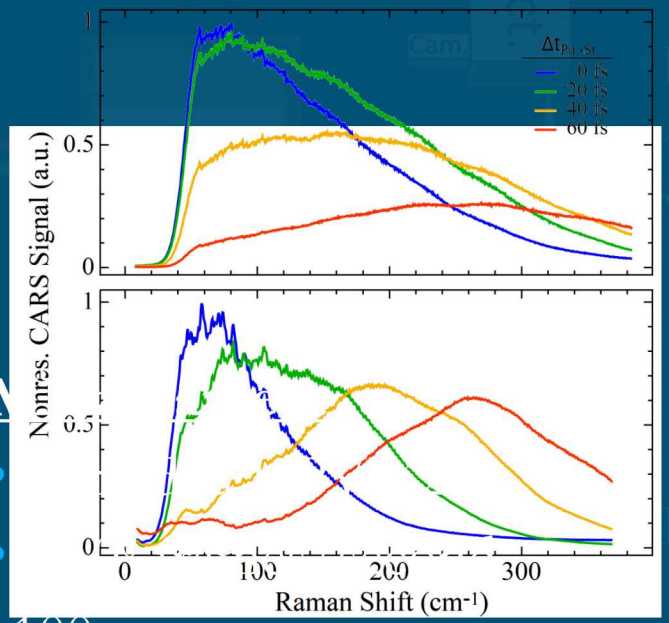


Experimental Setup: CARS and Imaging Systems



Spectral Focusing





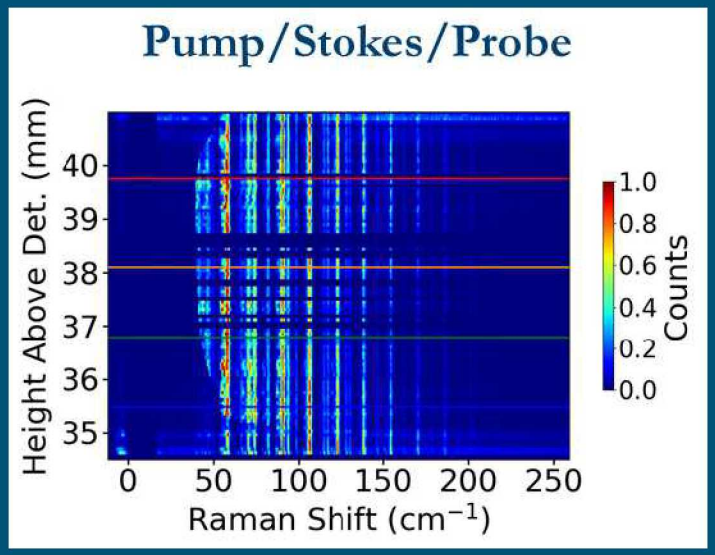
- 500 ns exposure
- Laser-induced incandescence from CARS lasers

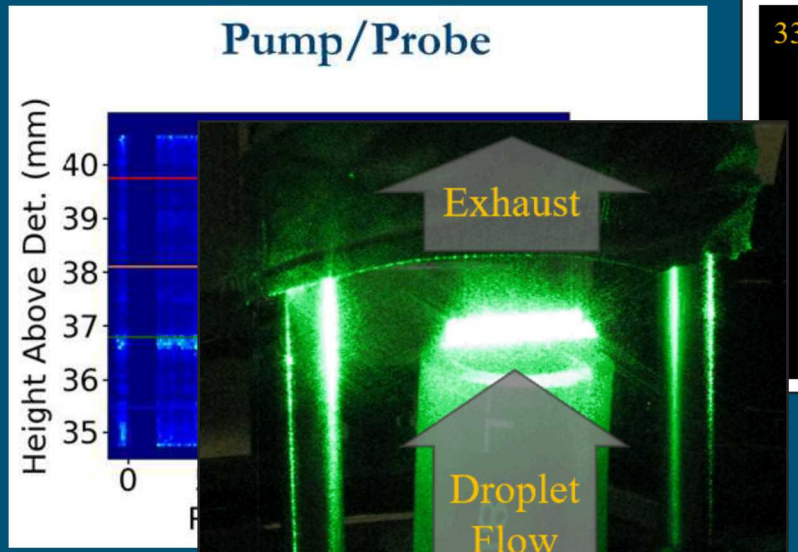
- 100 ns exposure
- Visible light emission

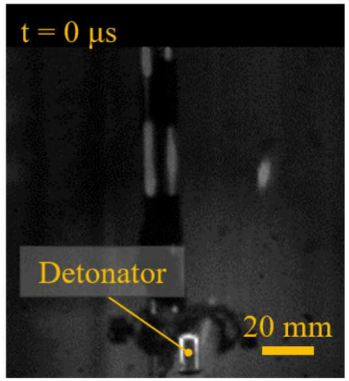
Fs/ps 1D RCARS

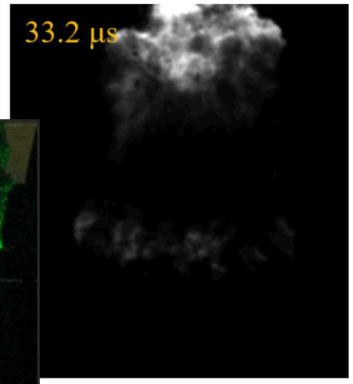
- Fs laser: 1 kHz, 800 nm, 7 mJ
- Ps laser: 20 Hz, 532 nm, 50 mJ
- Locked oscillators
- 1D Measurement Volume
  - 5.5 mm tall
  - 200 μm resolution
  - 2.8 mm long
- Energy at crossing
  - Pump: 2 mJ
  - Stokes: 2 mJ
  - Probe: 25 mJ
- Probe delay 50 ps

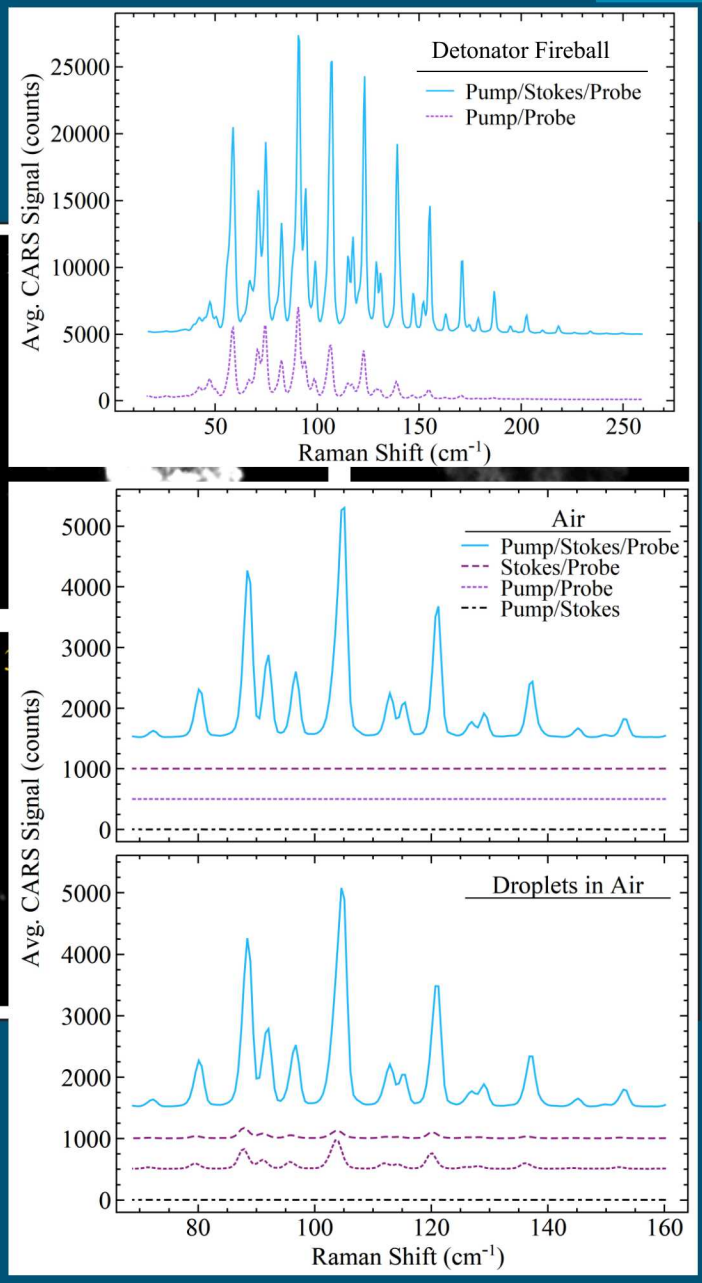
Three-Beam CARS in Scattering Environment



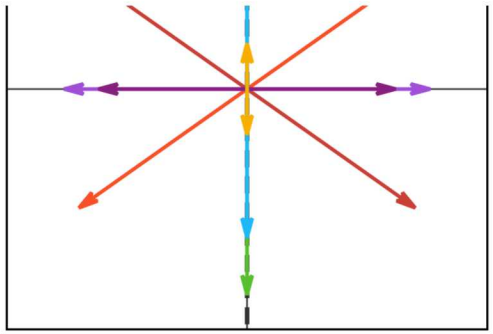




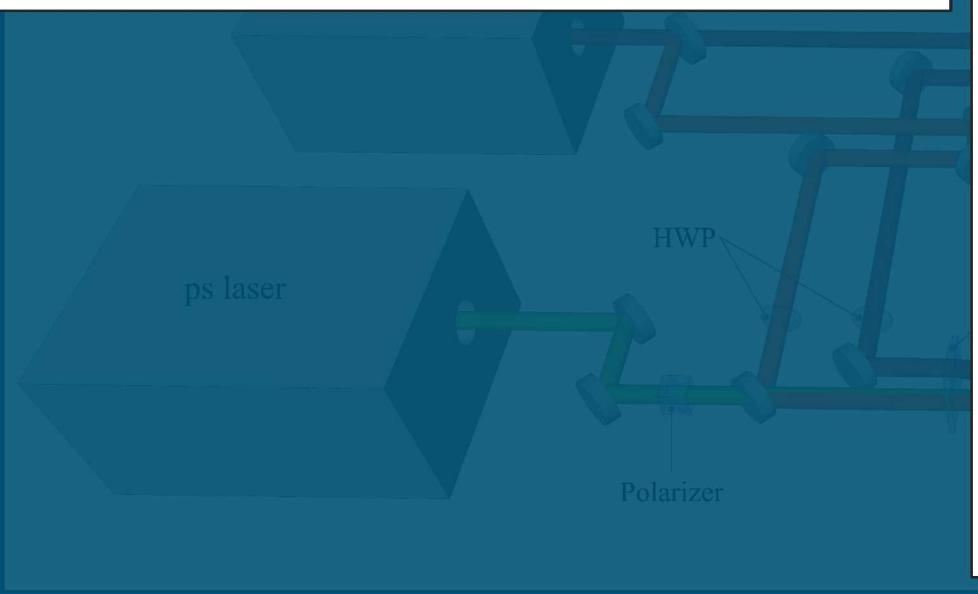


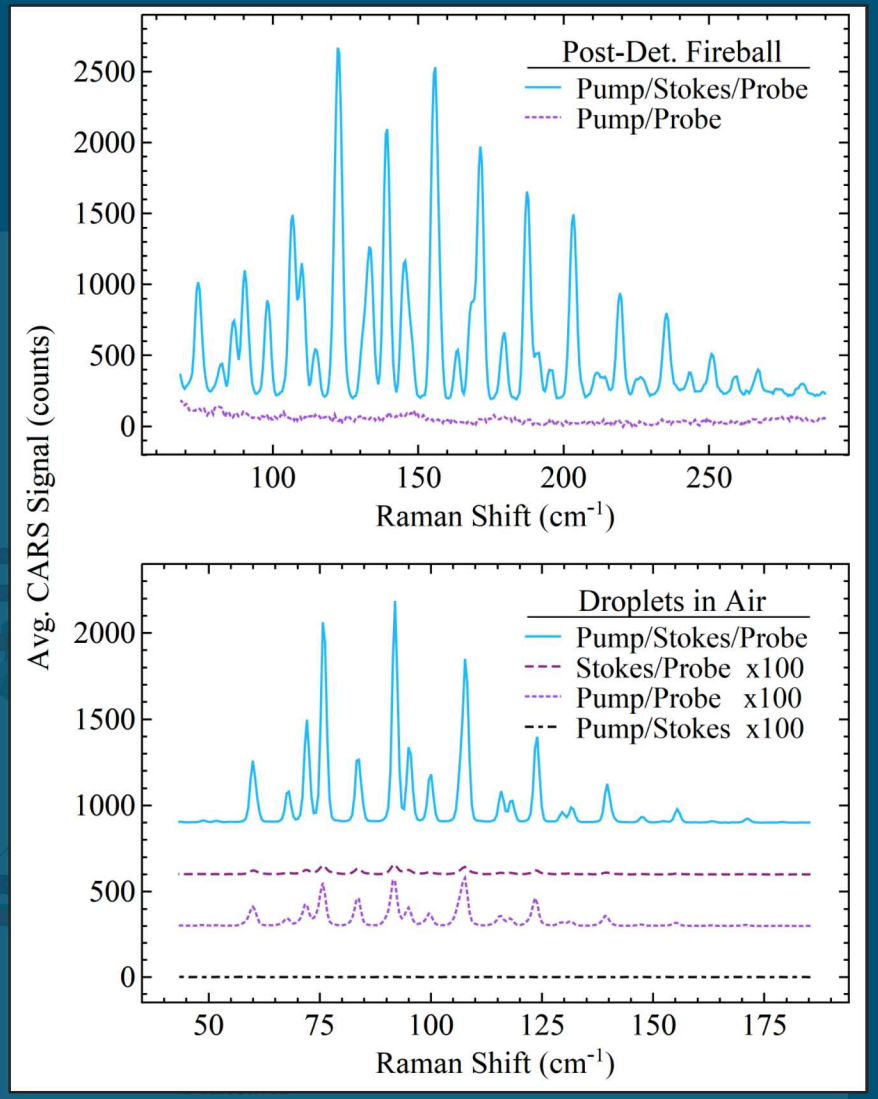


Three-Beam CARS in Scattering Environment



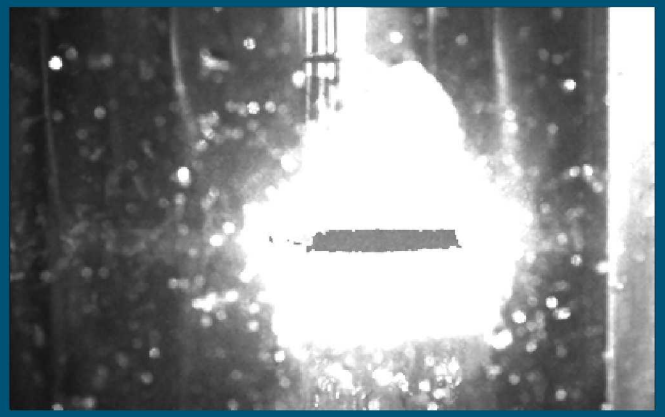
Probe
Pump/Probe CARS
Stokes/Probe CARS
Pump/Stokes/Probe CARS
Pump/Stokes/Probe Nonres.
Analyzer

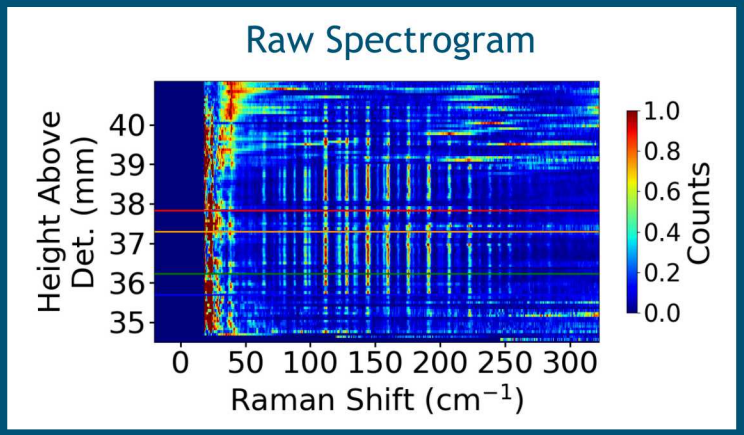


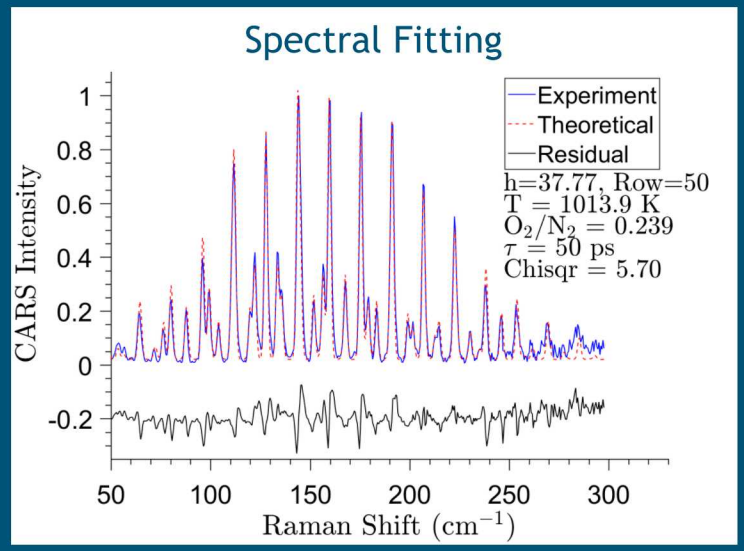


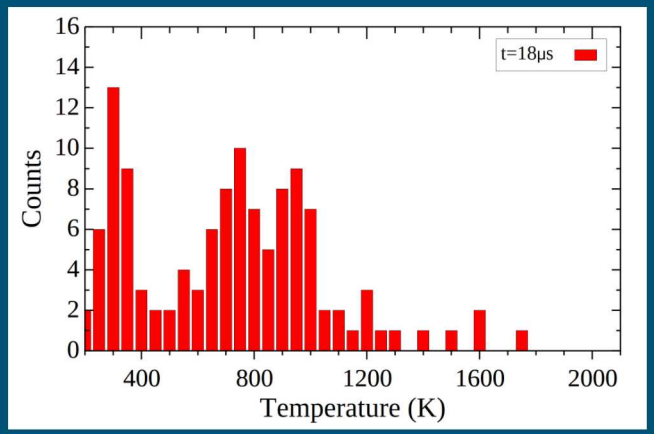
1D CARS Thermometry in Post-Det. Fireball

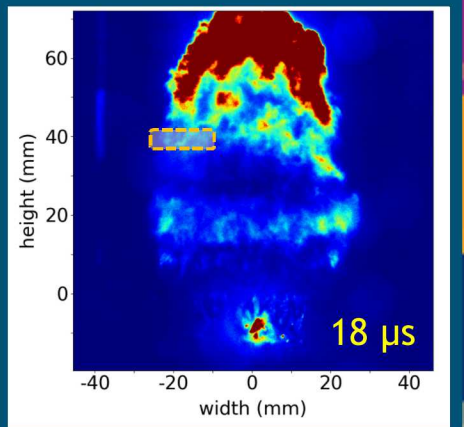
Spatially resolved temperature measurements in detonation fireball!

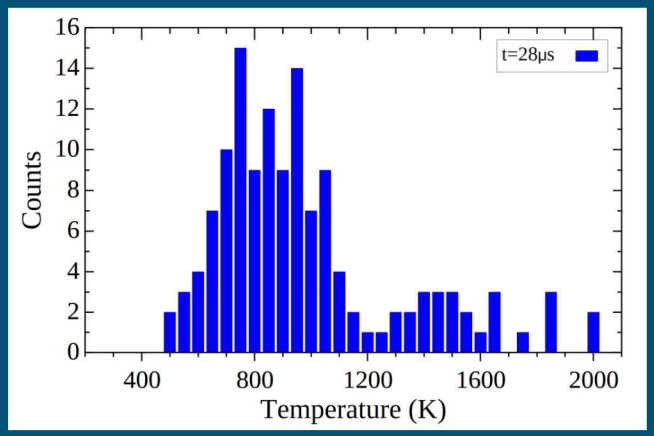


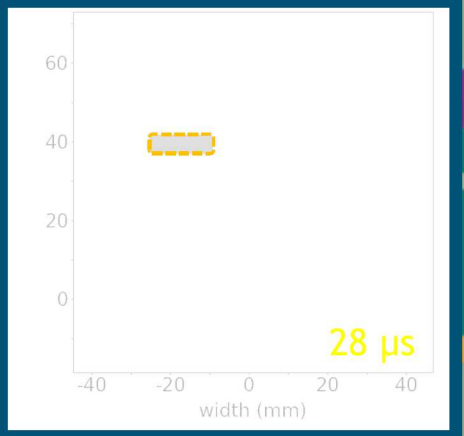






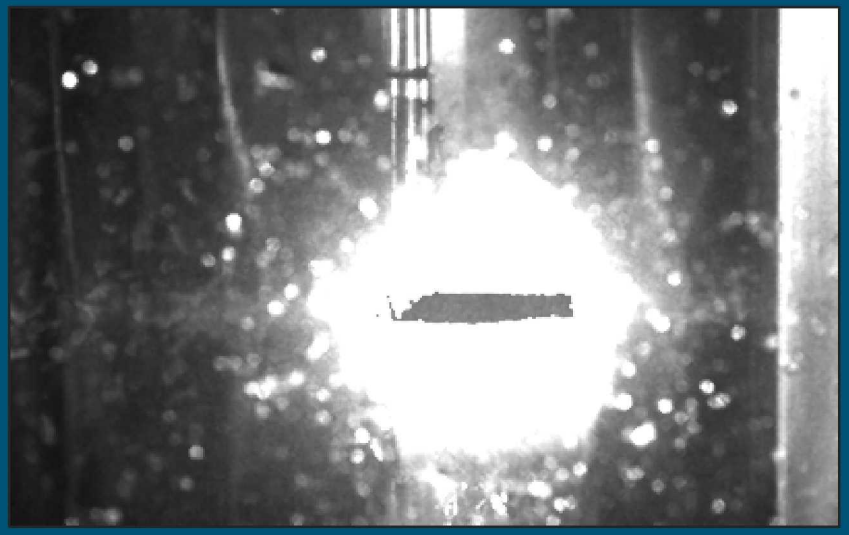






Conclusions

- Fs/ps one-dimensional rotational CARS thermometry has been performed in detonation fireballs
- Independent pump and Stokes pulses were used with spectral focusing to achieve the necessary Raman excitation bandwidth
- Scattered two-beam CARS signals were suppressed using a polarization scheme
- Measurements demonstrated at times and locations with significant mixing of detonation products with surrounding air



Questions?

Backup Slides

1D CARS Thermometry in Post-Det. Fireball