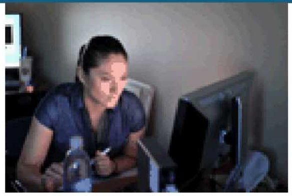
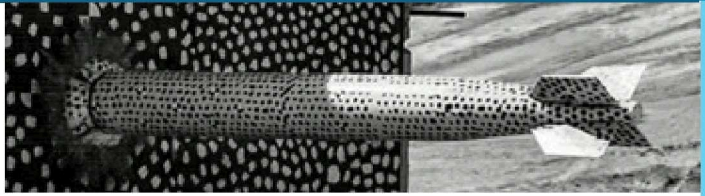
SAND2020-6088C

Emission Diagnostics for Benchtop-Scale Explosive Fireballs





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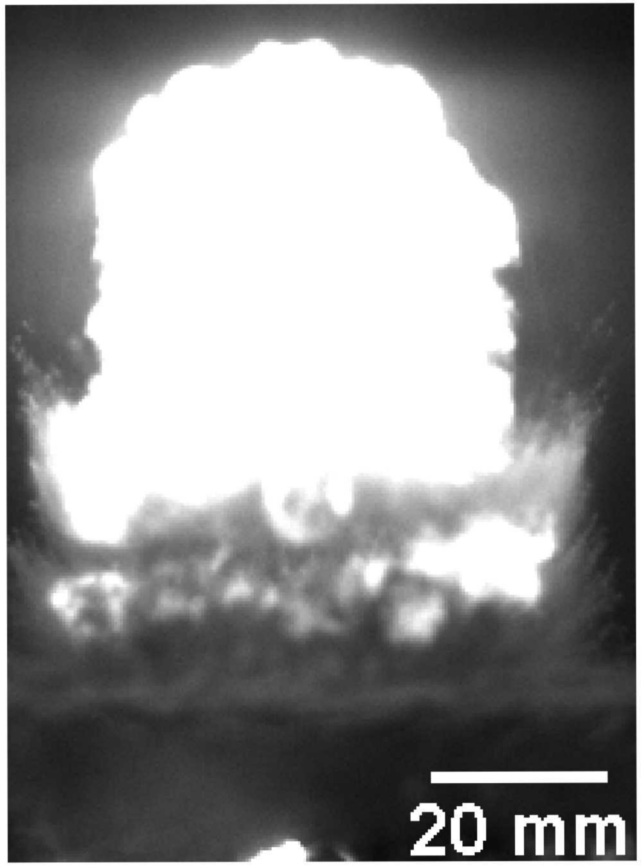
Outline

- Motivations
- Background
- Experimental Diagnostics and Results
- Conclusions and Future Work

Motivation

- Fireball characterization
- Validation of numerical models such as CFD
- Platform for diagnostic development in a transient environment



A PETN detonator fireball at 27 μs

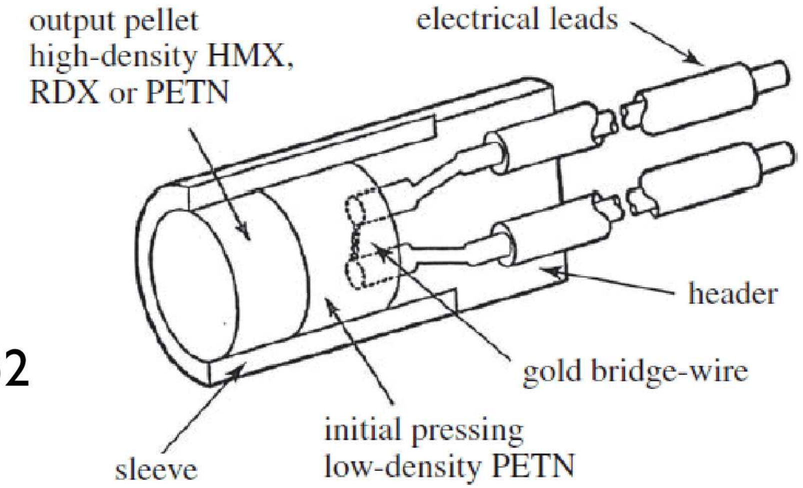
vs.

A standard flat flame burner (Holthius and Associates)

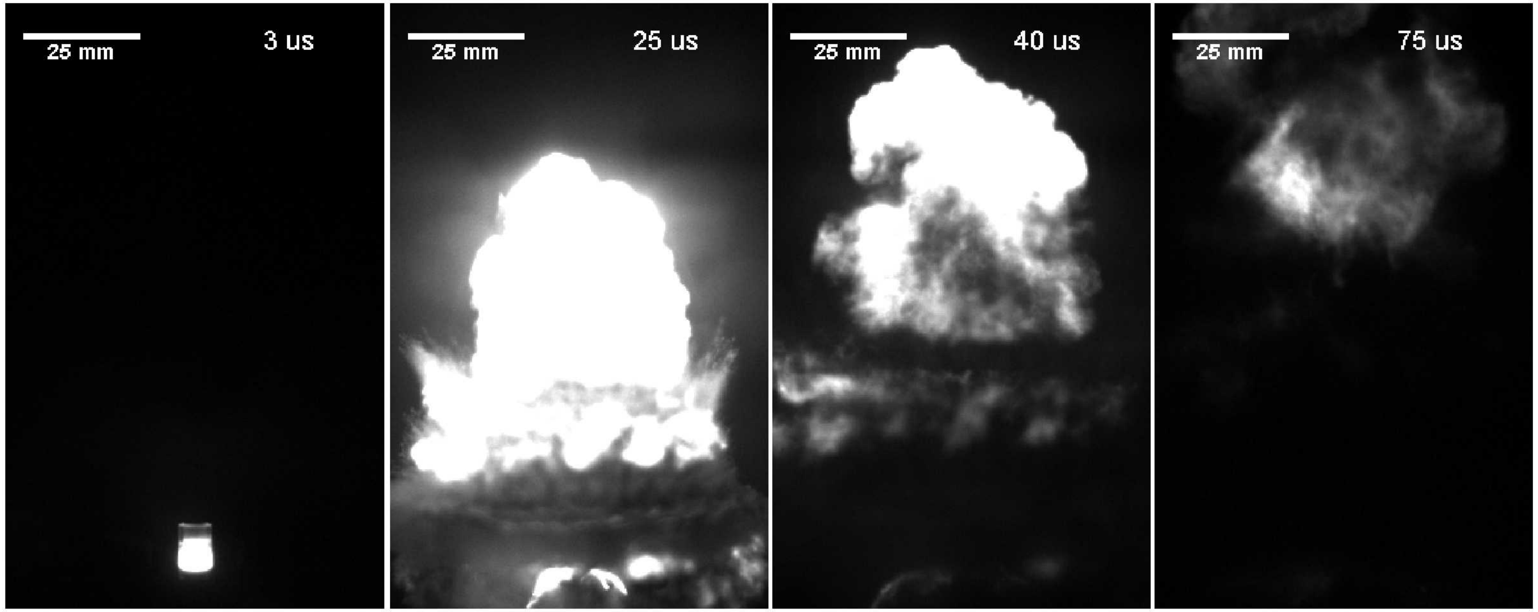
Background

Detonators:

- Commercial RP-80
- Custom made PETN, PETN/Al, PETN/Ba(NO3)2



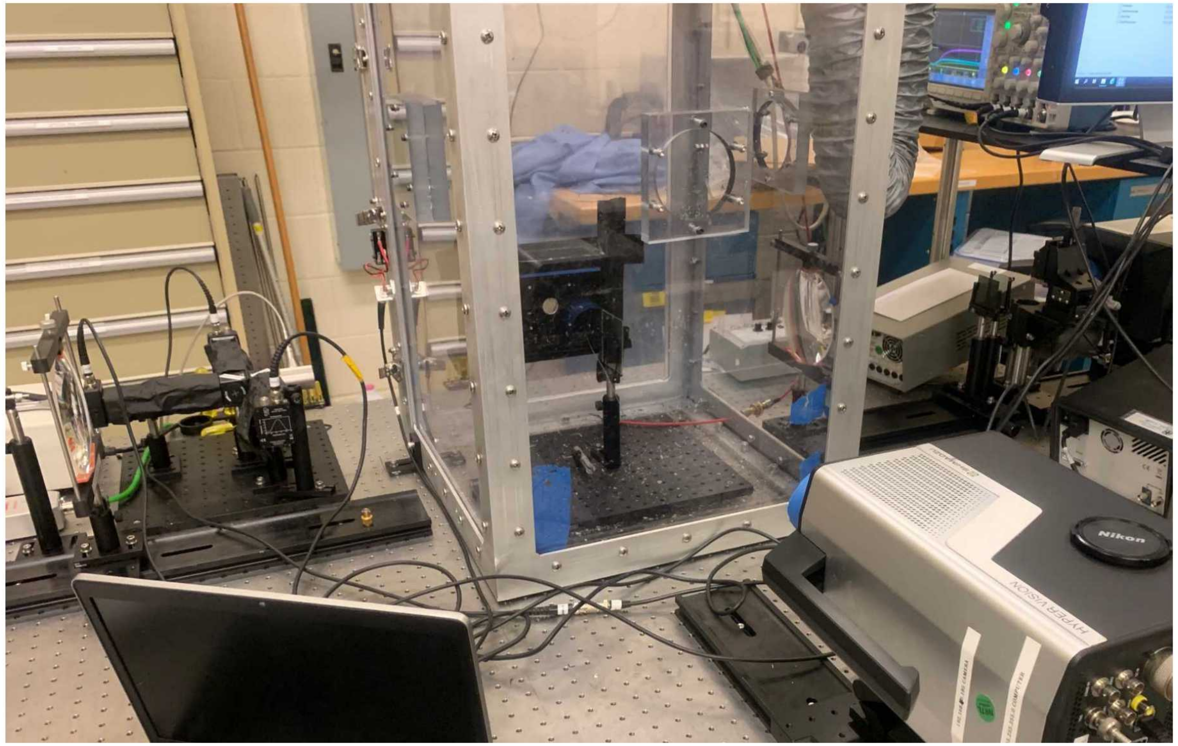
EBW Detonator [1]

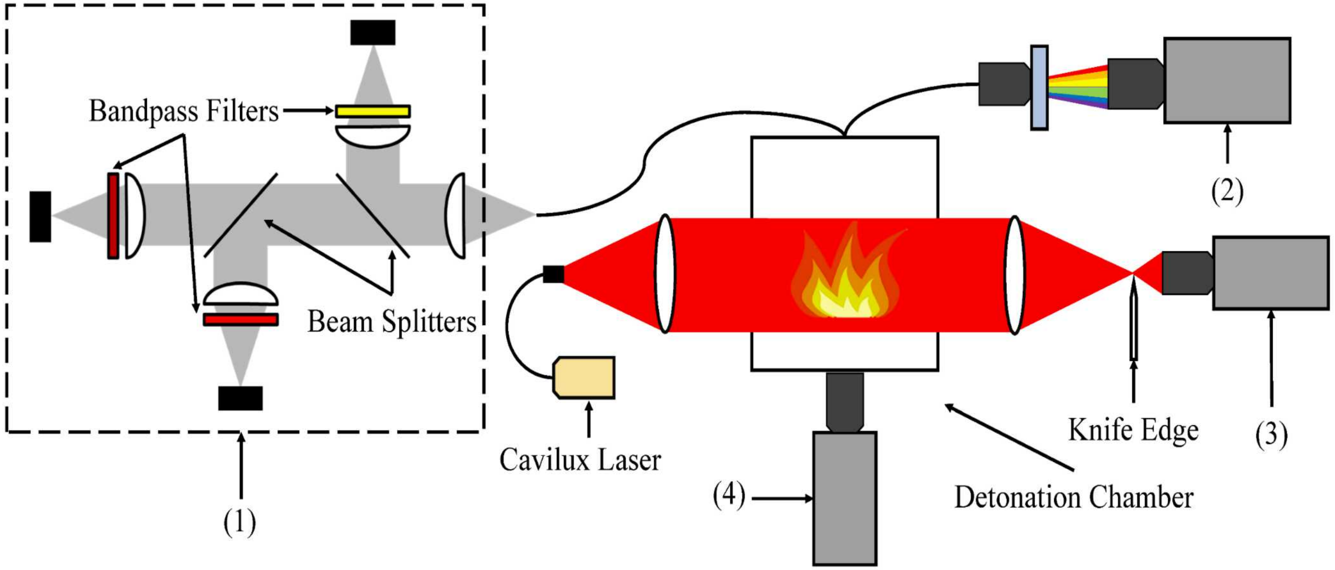


Observed Detonator Timeline

Experimental setup

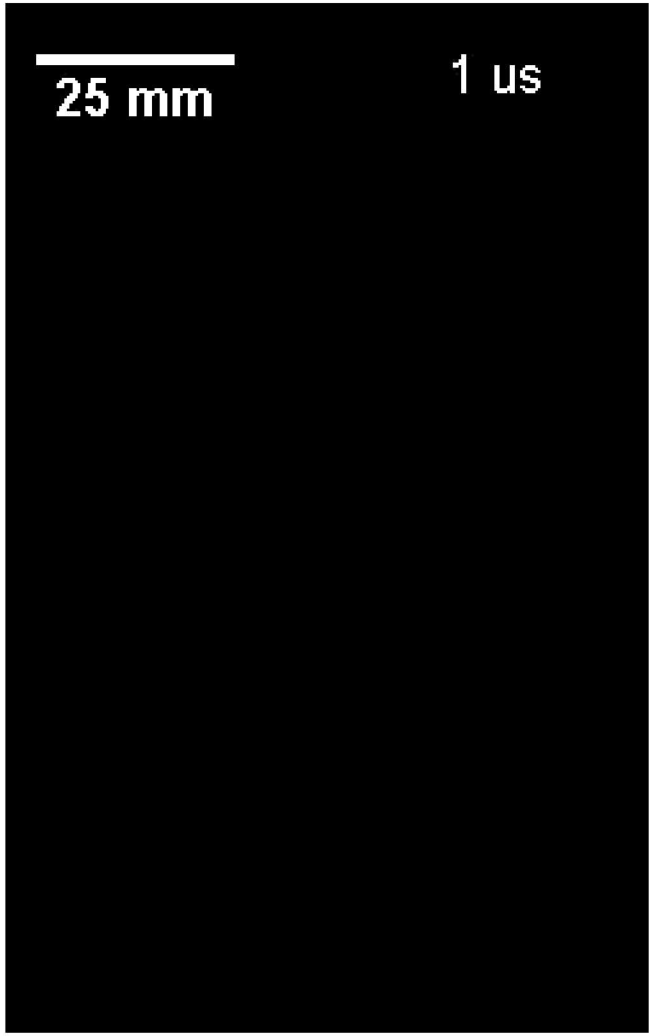
- Narrowband Emission (1)
- Broadband Emission spectroscopy (2)
- MHz schlieren (3)
- High speed imaging (4)





High Speed Imaging

- 1 MHz rate imaging using a Shimadzu high speed camera perpendicular to the schlieren axis
- Exposure was set to 200 ns to reduce overexposure as much as possible while still capturing sufficient fireball emission

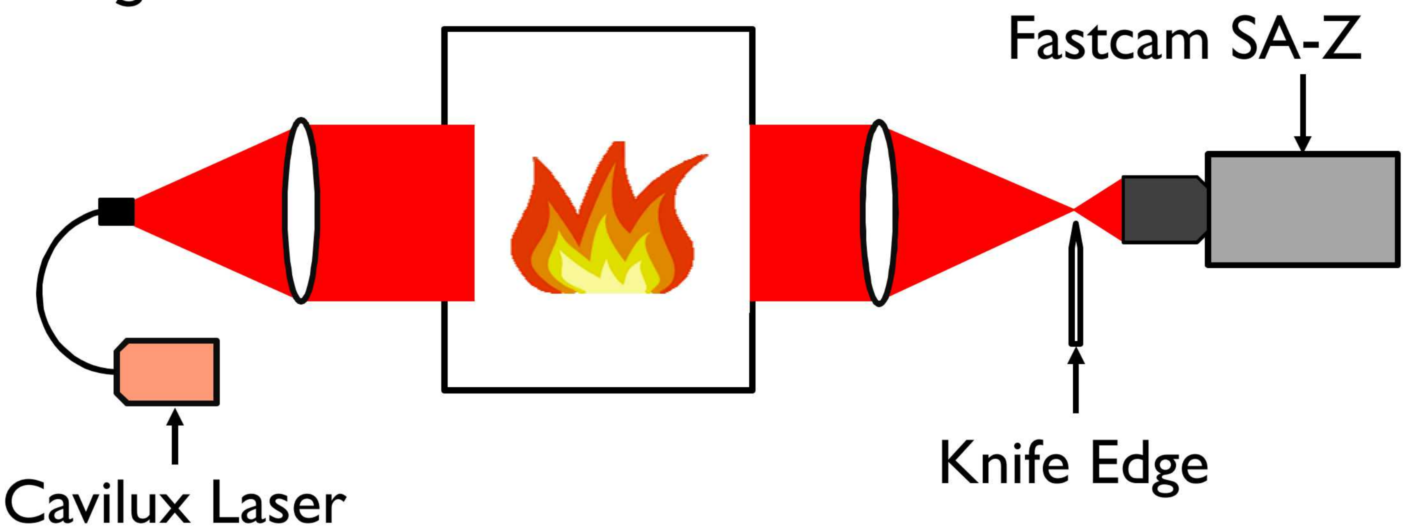


Custom PETN Detonator

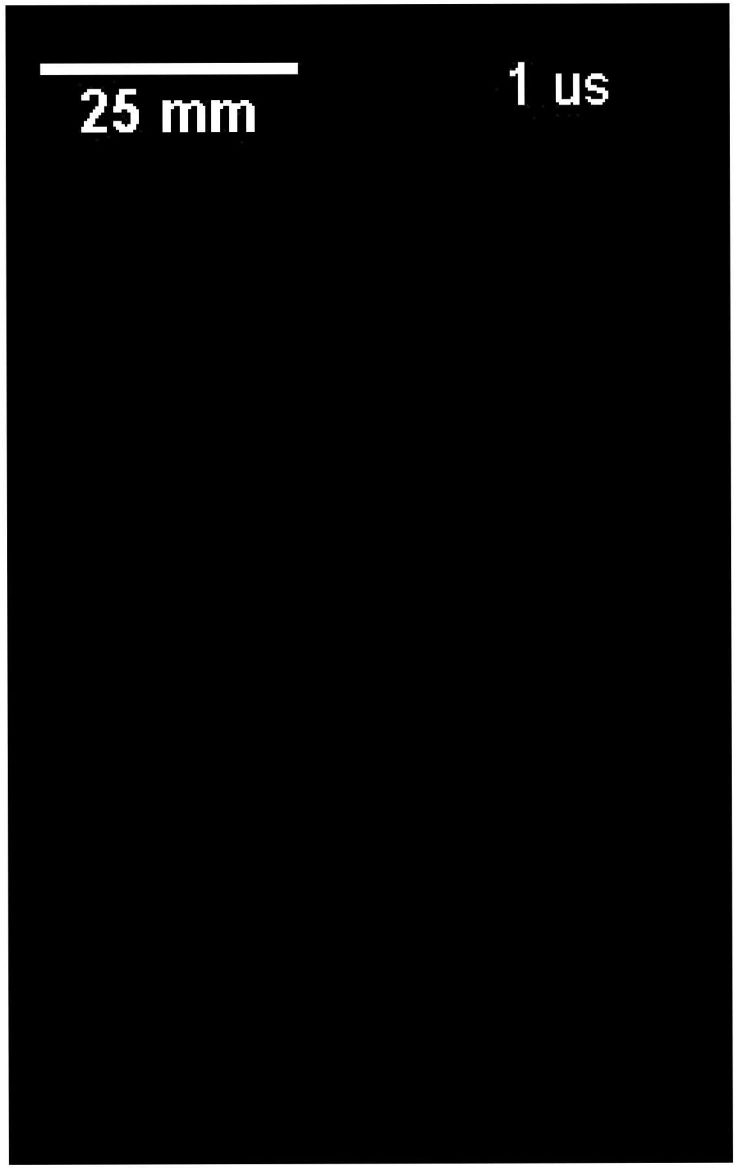
Schlieren

- 1 MHz rate schlieren imaging for gas phase density gradients

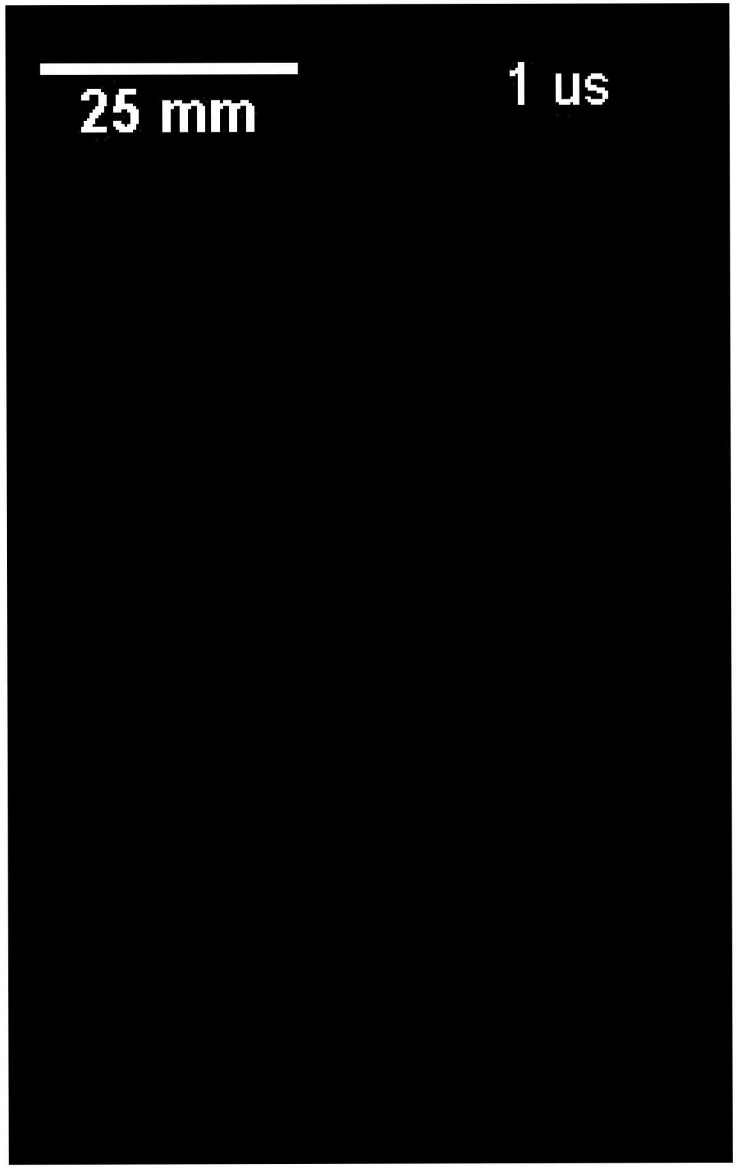
- 640 nm Cavilux Smart laser unit with 10 ns pulses imaged using a Shimadzu high speed camera



Schlieren Results



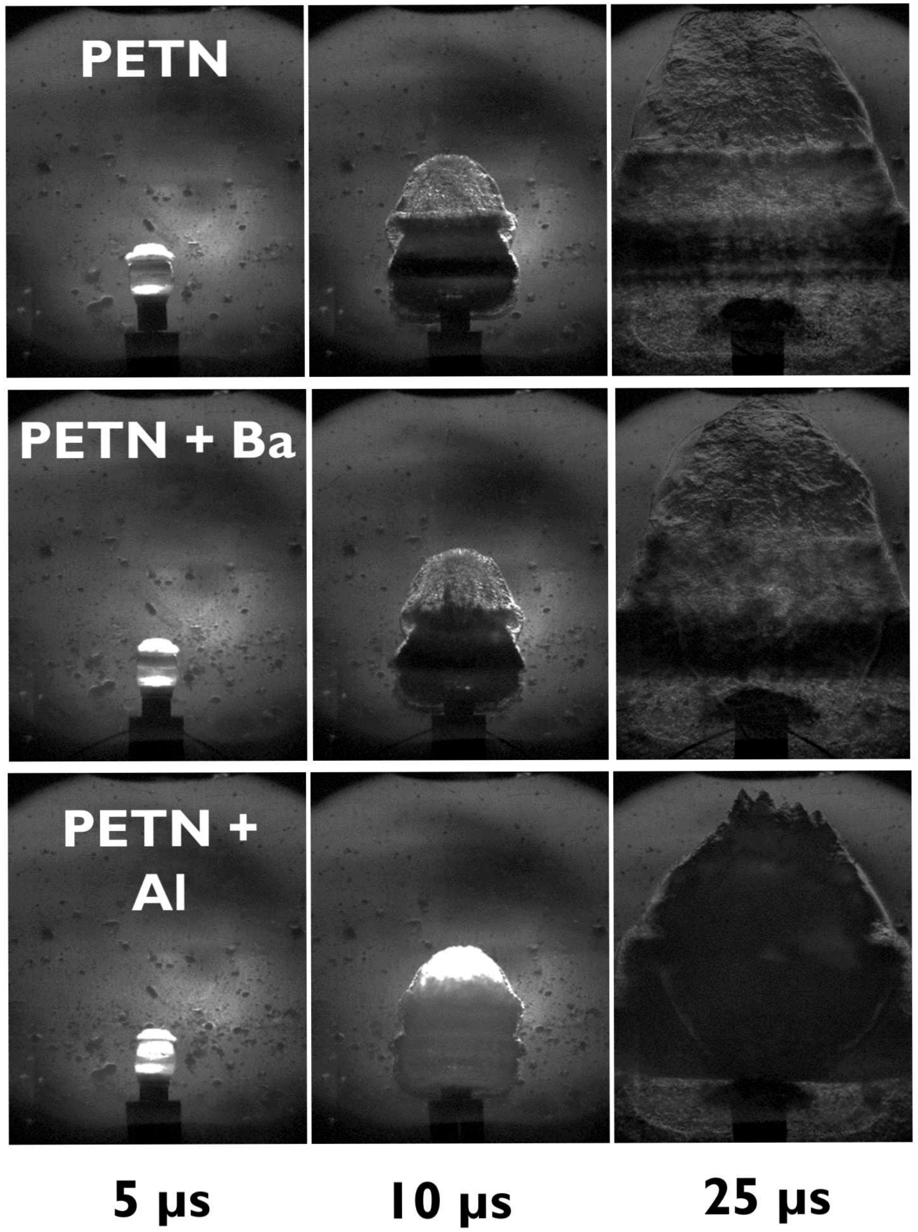
Custom PETN Detonator



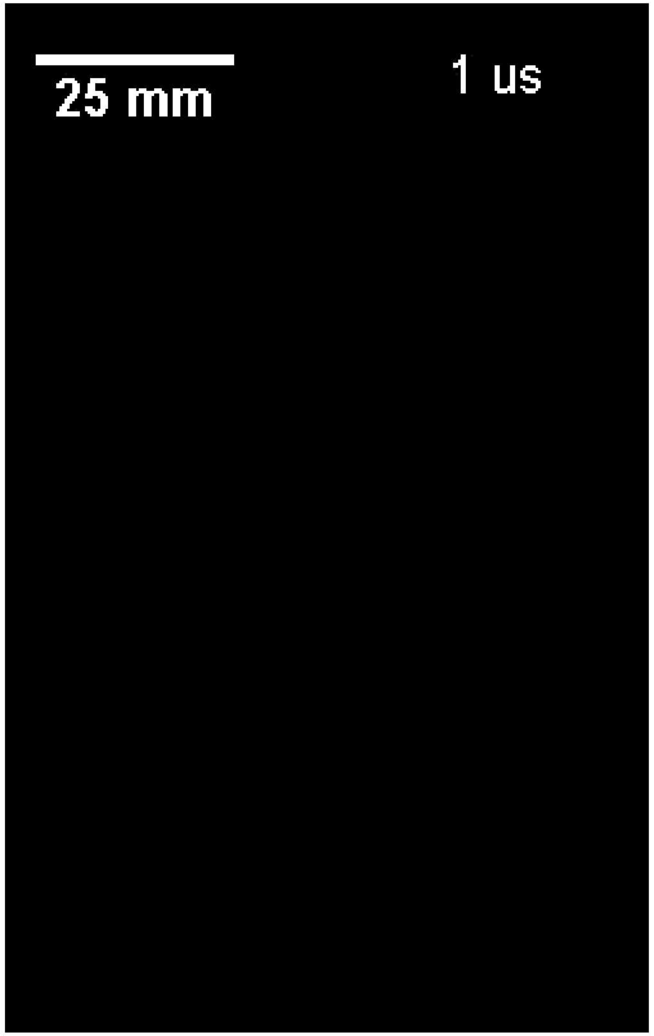
Custom PETN/Al Detonator

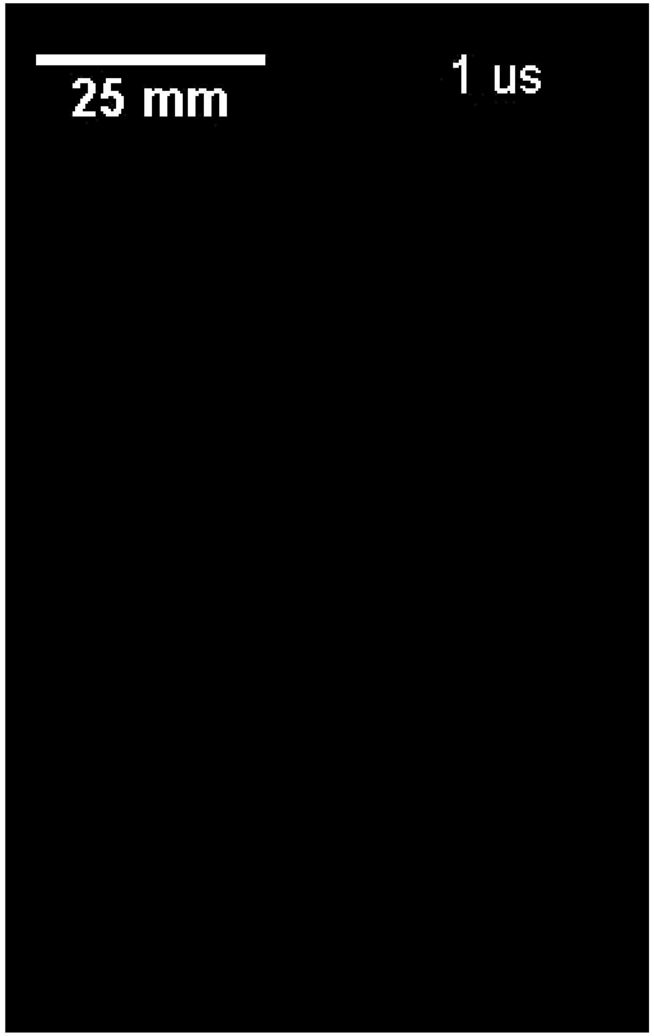
Schlieren Results

- Introduction of aluminum greatly increases density gradients within the detonation fireball
- Introduction of barium as a tracer does not greatly affect the schlieren measurements
- Aluminized detonator features particulates maintaining momentum past shock front



Side by Side Schlieren and Visible Emission

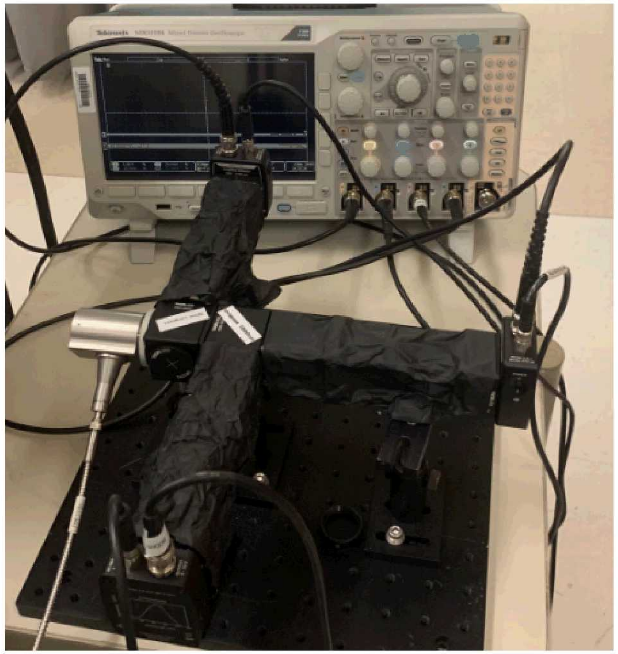


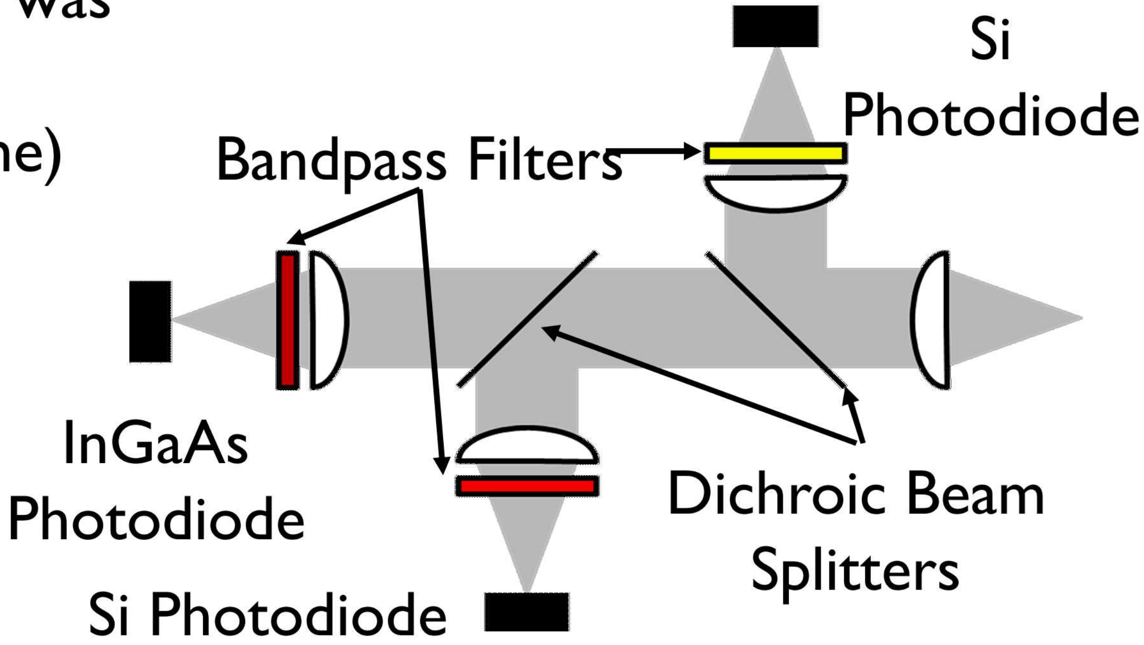


Custom PETN Detonator, Synced Timing

Narrowband Emission

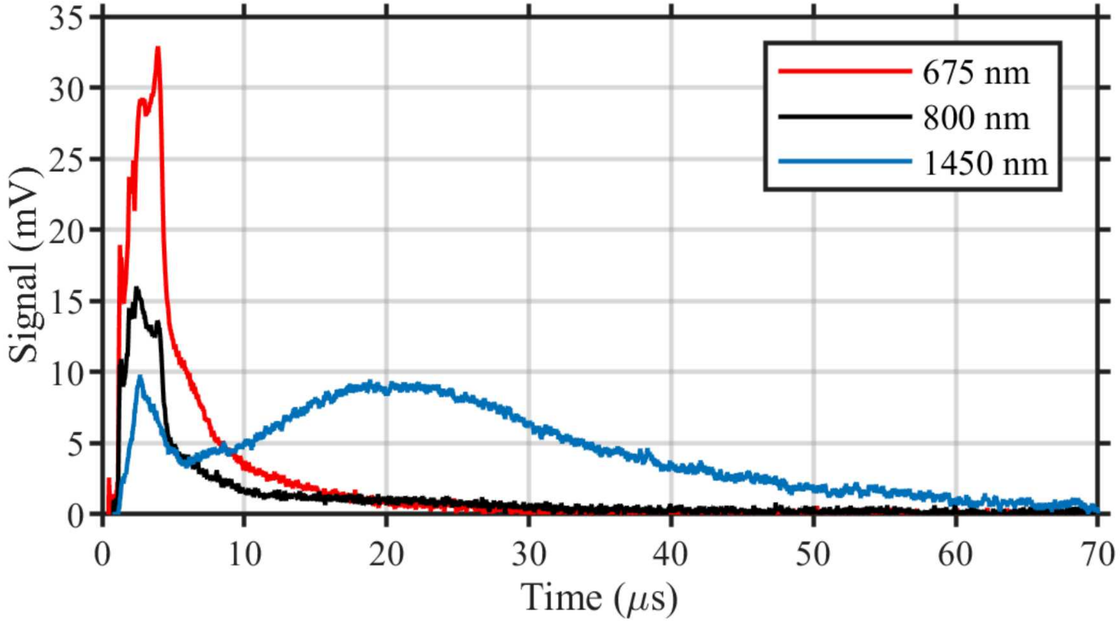
- Pyrometer designed for measuring fireball emission at 675 nm, 800 nm, 1450 nm
- 675 nm and 800 nm emission was collected using Si Photodiodes (2.3 ns rise time) and 1450 nm was collected using an InGaAs Photodiode (15 ns rise time)



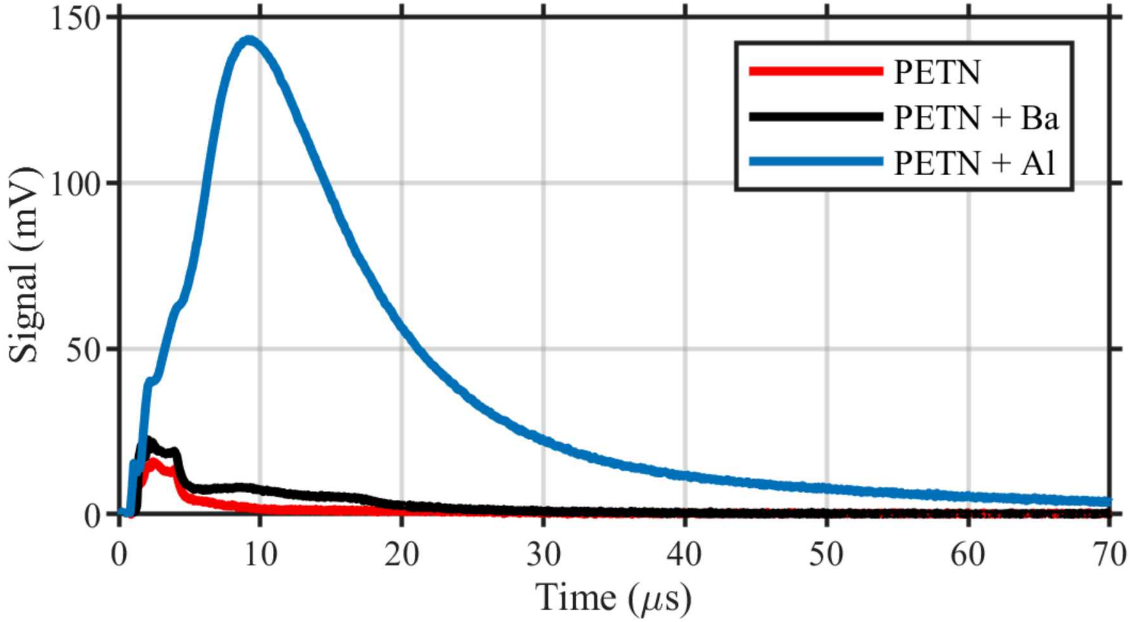


Narrowband Emission Results

- Each emission band was normalized to the 675 nm band using a gray body tungsten source at 2800 K



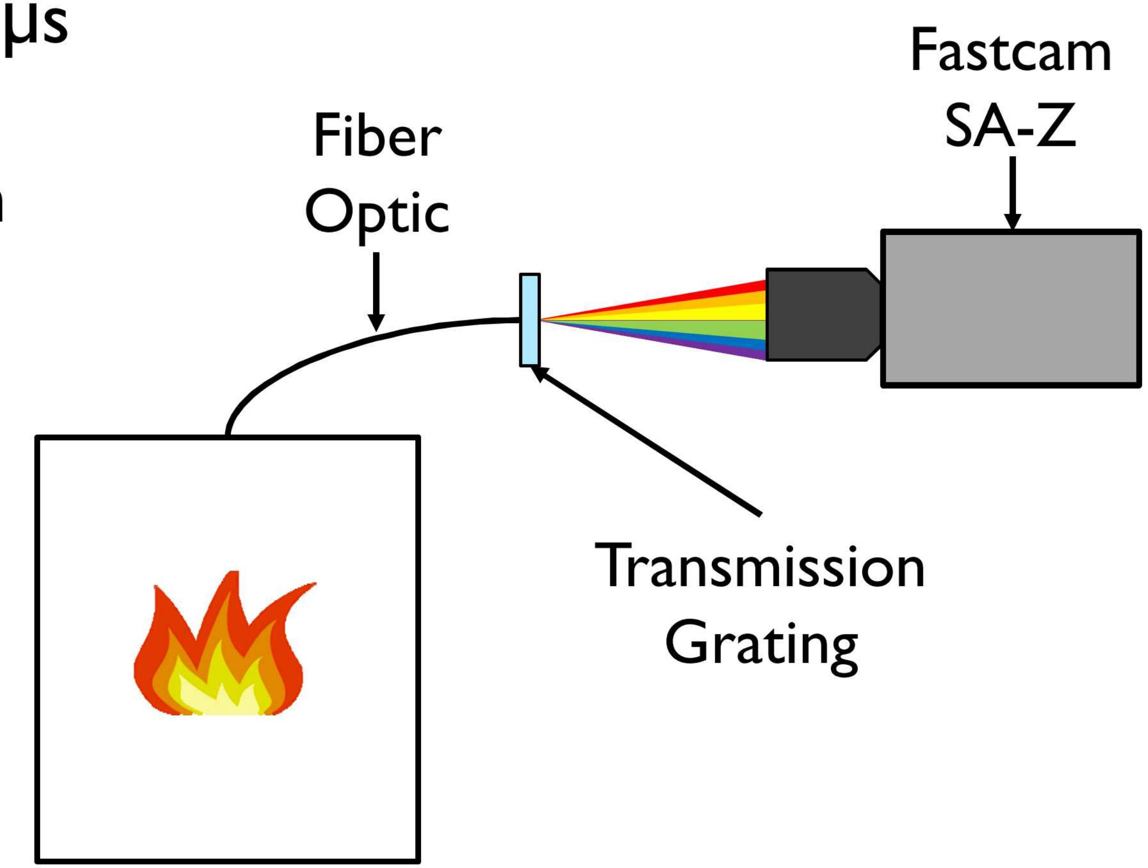
Custom PETN Detonator



800 nm Emission for Varying Detonators

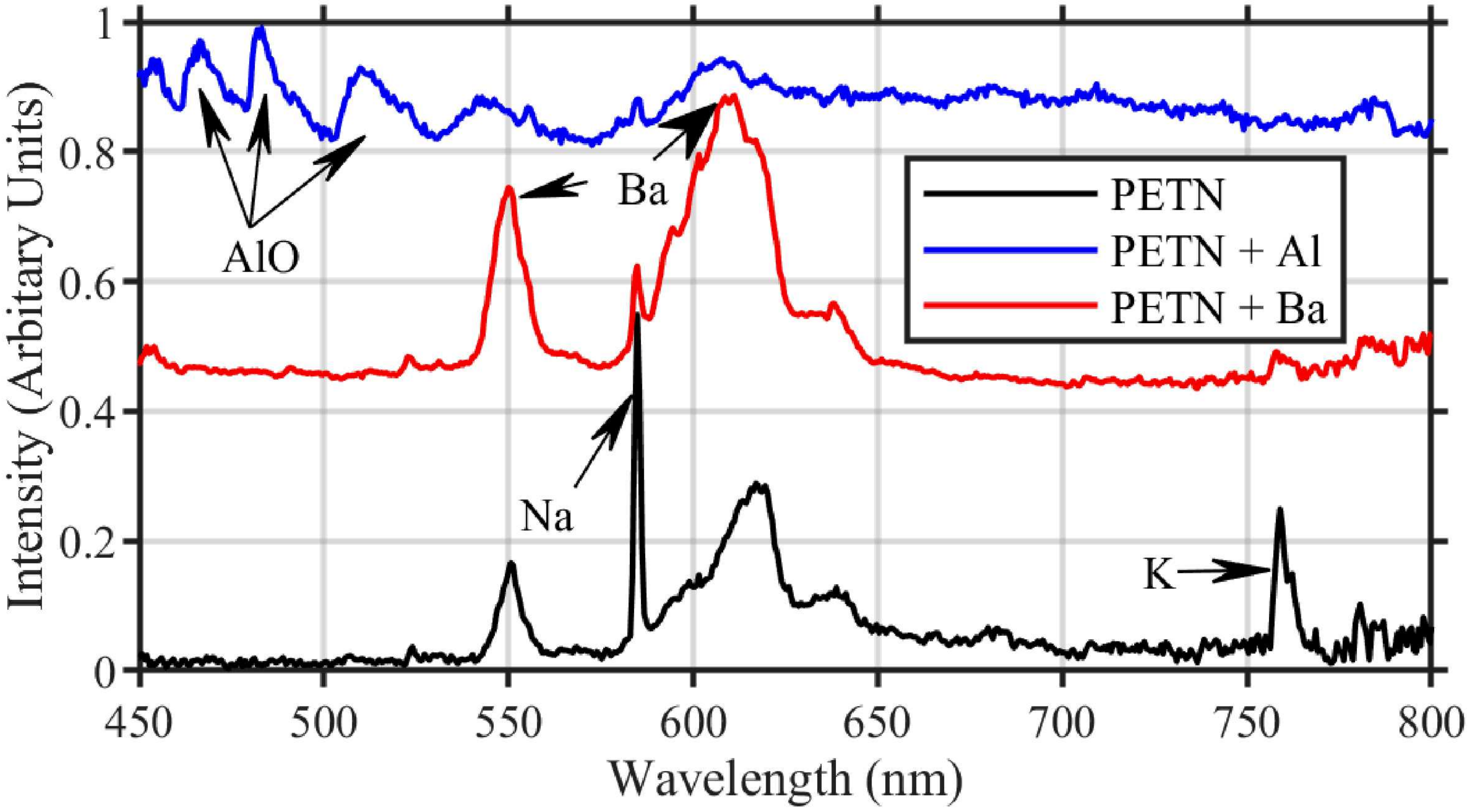
Broadband Emission Spectroscopy

- 200 kHz rate spectra imaged using a Fastcam SA-Z with an exposure of 3.26 µs
- Collected light dispersed to 400-800 nm using a transmission grating



Corrected Broadband Emission Spectroscopy Results

- Molecular emission of AlO and atomic emission of barium observed
- Potential for future temperature sensitive measurements as demonstrated by Lewis [2,3,4]



Emission Spectra from Varying Detonators

Conclusions

- Demonstrated ability to perform simultaneous optical diagnostics of benchtop-scale post detonation fireballs
- Capability for resolving optical differences for various fireball compositions
- Potential for future diagnostic efforts such as using molecular and atomic emission tracers such as barium
- Complementary to laser techniques in development at Sandia and Purdue

References

[1] Rae, P. J., and P. M. Dickson. "A review of the mechanism by which exploding bridge-wire detonators function." *Proceedings of the Royal Society A* 475.2227 (2019): 20190120.

[2] Lewis, W. K., and C. G. Rumchik. "Measurement of apparent temperature in post-detonation fireballs using atomic emission spectroscopy." (2009): 056104.

[3] Lewis, W. K., C. G. Rumchik, and M. J. Smith. "Emission spectroscopy of the interior of optically dense post-detonation fireballs." *Journal of Applied Physics* 113.2 (2013): 024903.

[4] Lewis, William K., Nick G. Glumac, and Eduardo G. Yukihara. *Time-Dependent Temperature Measurements in Post-Detonation Combustion: Current State-of-the-Art Methods and Emerging Technologies.* No. DTRA-TR-16-20. University of Dayton Research Institute Dayton United States, 2016.