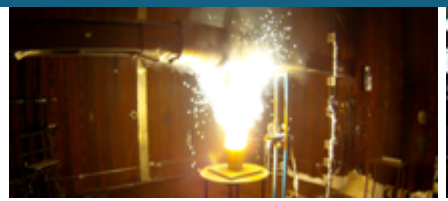
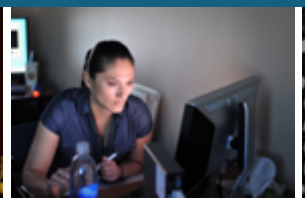
This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

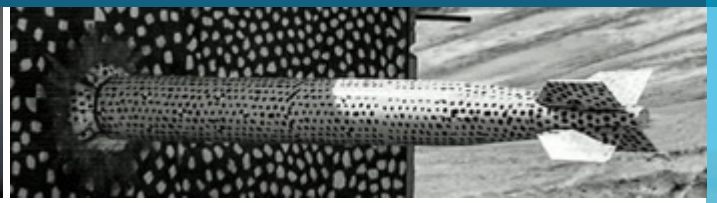
SAND2021-14980C

Sandia National Laboratories

Multi-Color Pyrometry of High-speed Ejecta from Pyrotechnic Igniters







Benjamin R. Halls, William E. Swain, Shawn C. Stacy, Ryan T. Marinis, and Sean P. Kearney

Sandia National Laboratories, Albuquerque, New Mexico, USA

AIAA SciTech 2022, San Diego, CA, USA

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.

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.

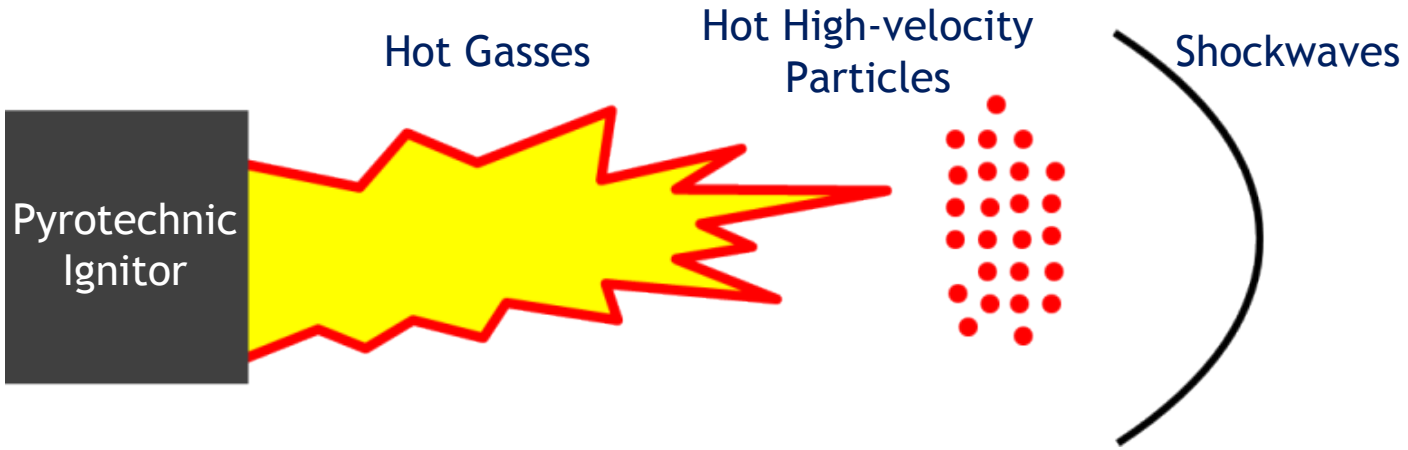
How to isolate and quantify ignitor energy release?

Heat Transfer
- Thermocouples

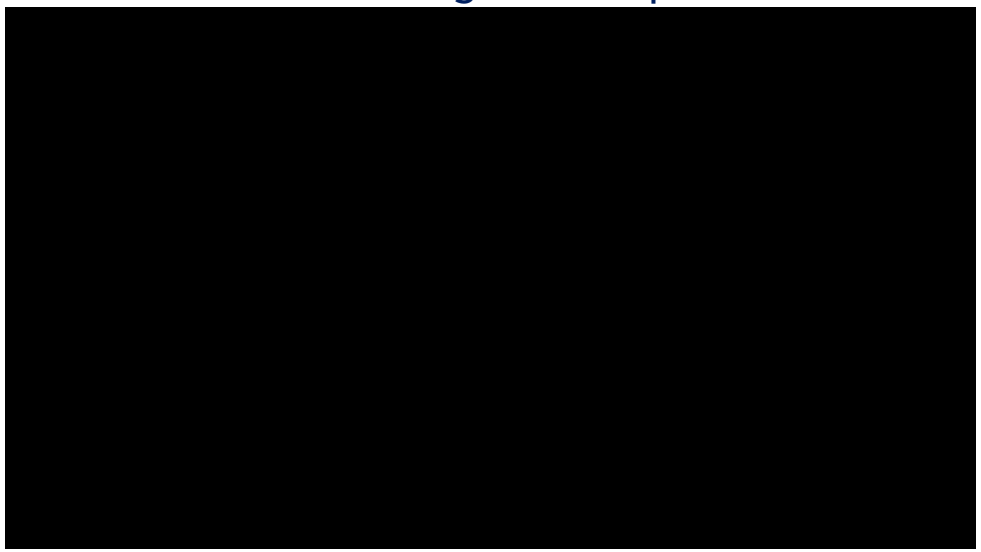
Hot Gases
- Absorption Spectroscopy
- CARS Spectroscopy
- 2-Color PLIF

Particles
- Shadowgraphy
- Holography
- **Pyrometry**

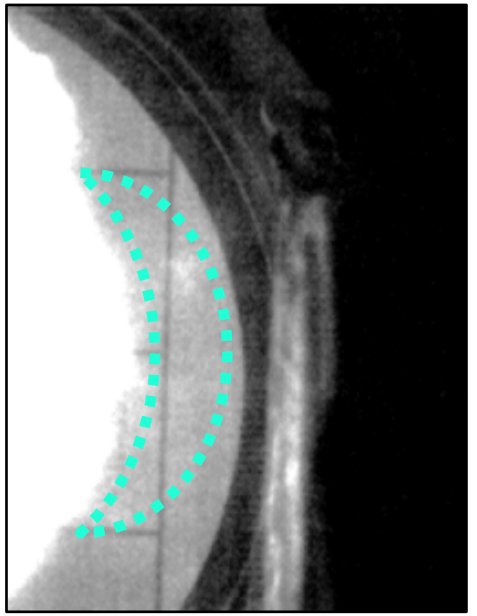
Shockwaves
- Schlieren Imaging



Movie of Igniter Output



Snap Shot of Particle Output



Experimental Setup

Pyrotechnic Igniter
- Enclosed in optically accessible “boombox”
- Particle size 10–100 μm

Nikon Objective
- 105 mm, f/2
- Backwards facing

Long Pass Imaging Beamsplitters
- 765 and 850 nm

Bandpass Filters
- 700, 800, and 900 nm
- ± 25 nm

Photron SA-Z Cameras
- 100 kHz, 160 ns exposure
- 3.7 × 5.5 mm^2 or 312 × 512 pixels
- Nominal resolution of 10.8 μm

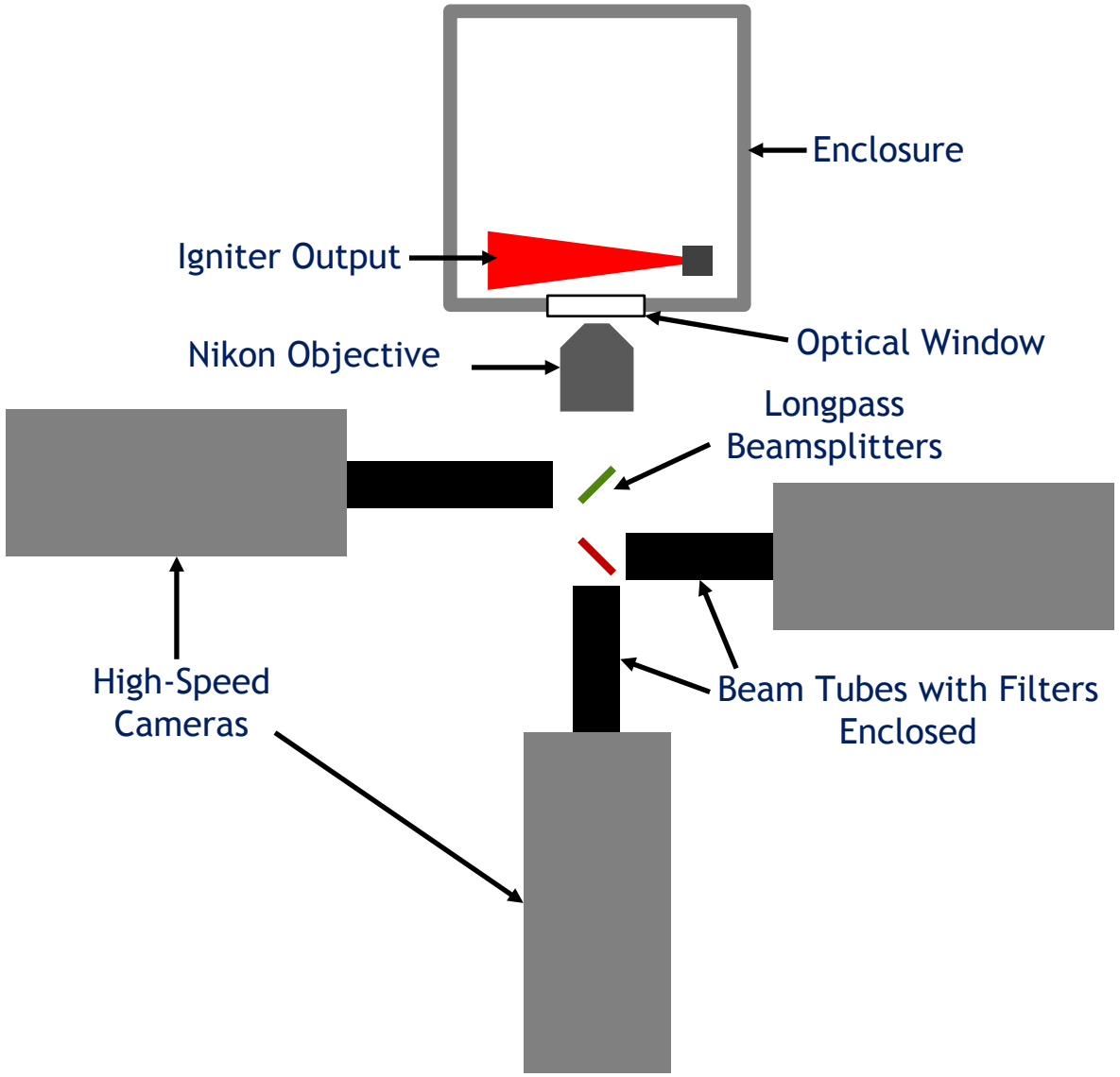


Image Processing (Two-Color)

Camera Registration

- Single objective keeps image distortions similar
- Automated dot target correlation

Product Image

1. Product image increases the contrast
2. Locate the brightest pixel (brightest particle) in the product image

Particle Sub Images

1. Generate sub images from 700 nm and 900 nm centered around that located pixel
   - Sub image size was large to fully encompass the largest particles.
2. If the particle located was determined to be at minimum 16 pixels in area the routine continued
   - Reduces effect of high noise
   - If the non-particle is les than 16 pixels that area is masked in the product image and loop restarts

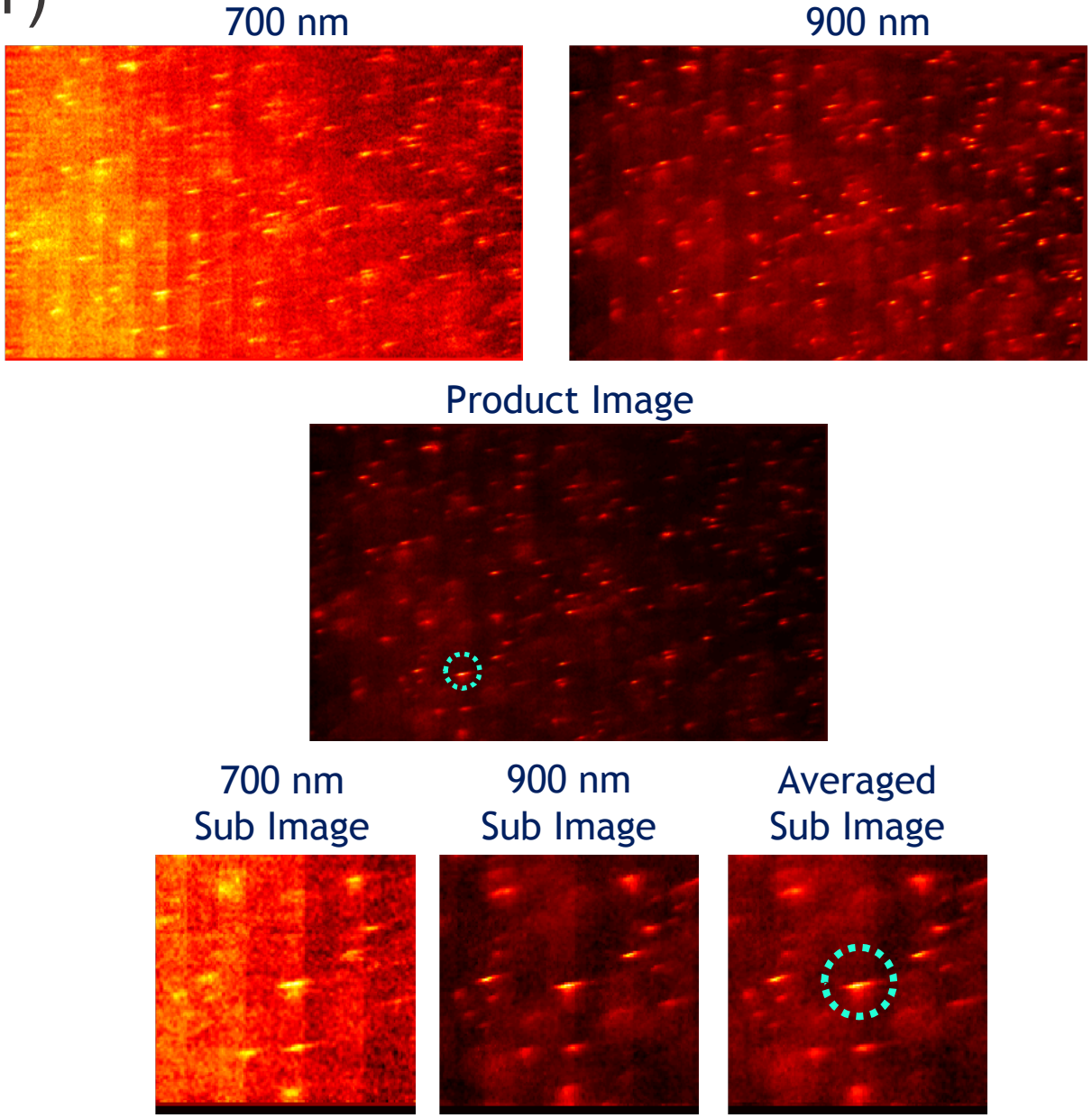
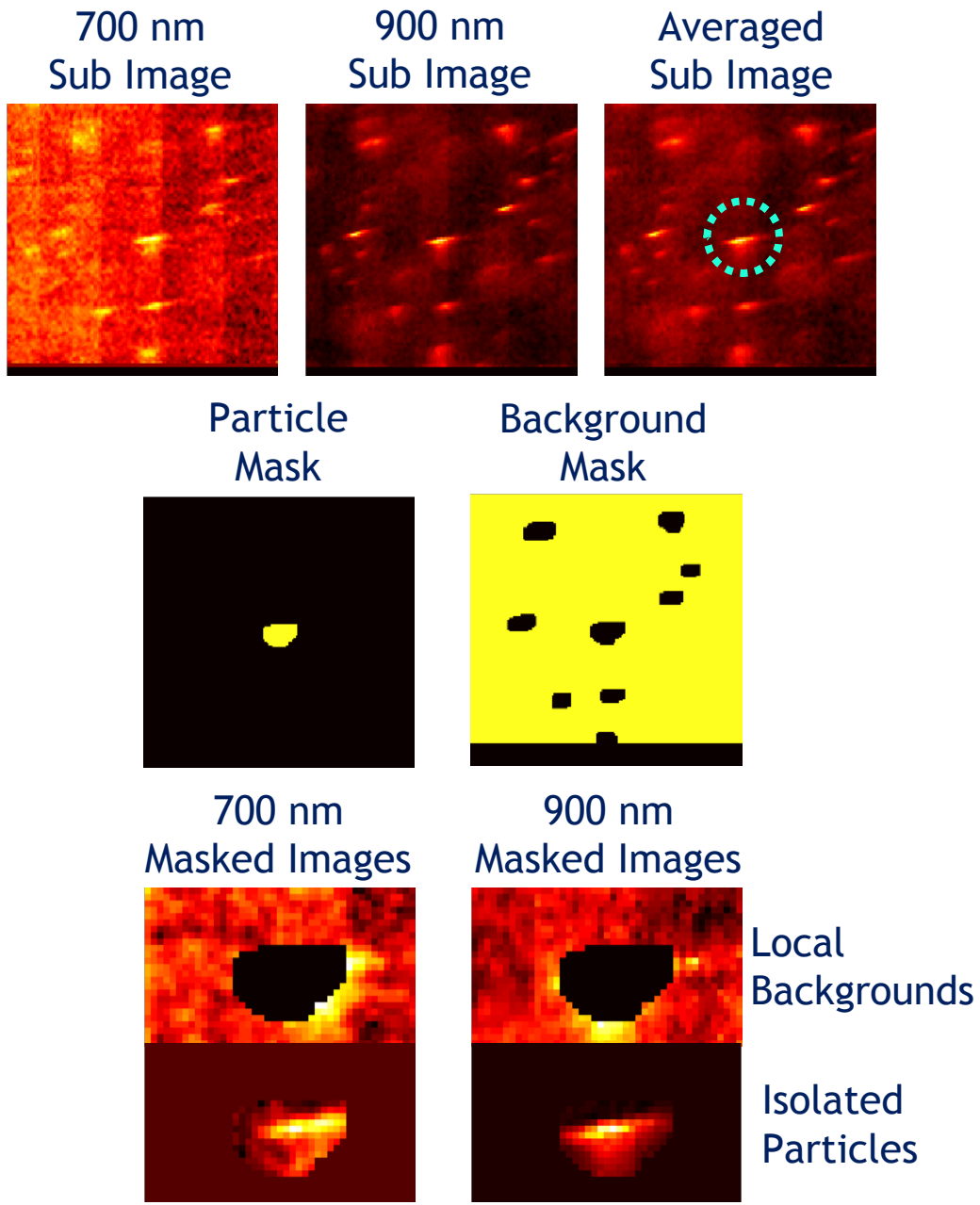


Image Processing (Two-Color)

Mask Generation and Application

1. Masks were generated from the averaged sub image
   - Identical masks for 700 and 900 nm
2. Averaged sub image normalized and binarized
3. Masked areas enlarged by 2 pixels
4. Background mask blocked other particles
5. Background mask applied and sub images cropped
   - Focuses on local background
6. Averaged background counts subtracted from particle
7. Particle masks applied
8. Image intensities integrated and the color ratio determined
9. Particle masked in product image and loop restarts



Particle Temperature Analysis (Two-Color)

Blackbody Calibration

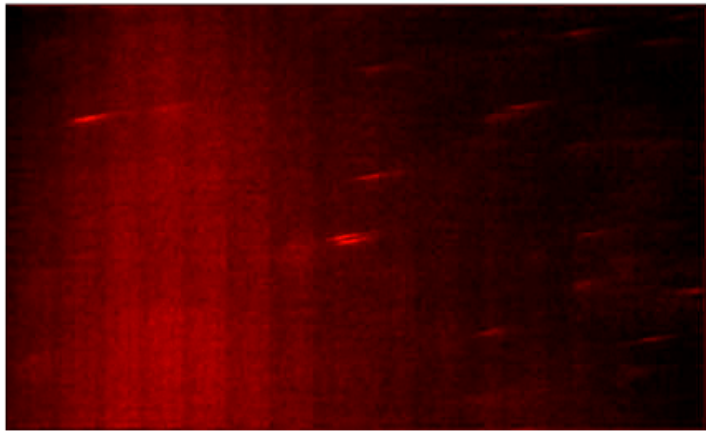
- Mikron 390 blackbody source, 1270 to 3270 K

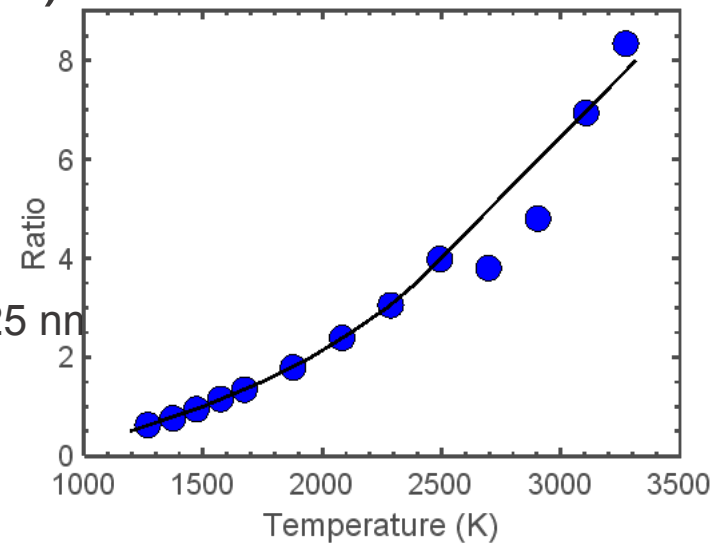
Particle Integrated Temperature

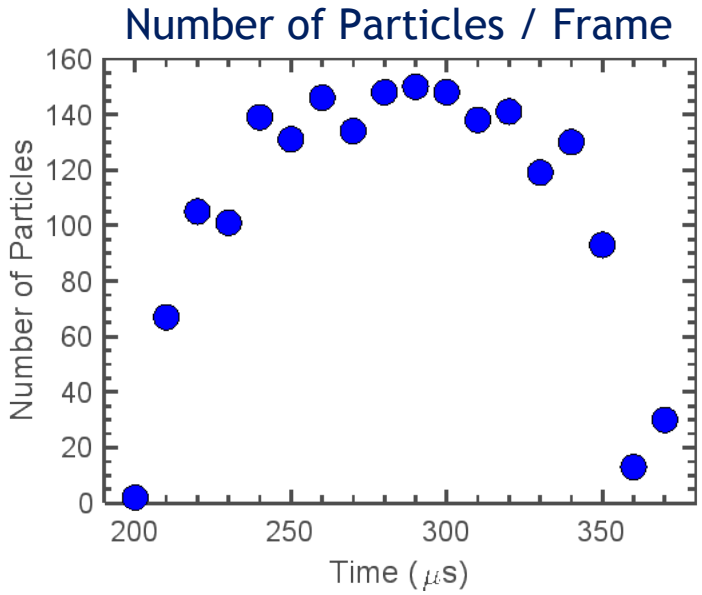
- Emissivity was assumed to be constant over the spectral range (675 to 925 nm

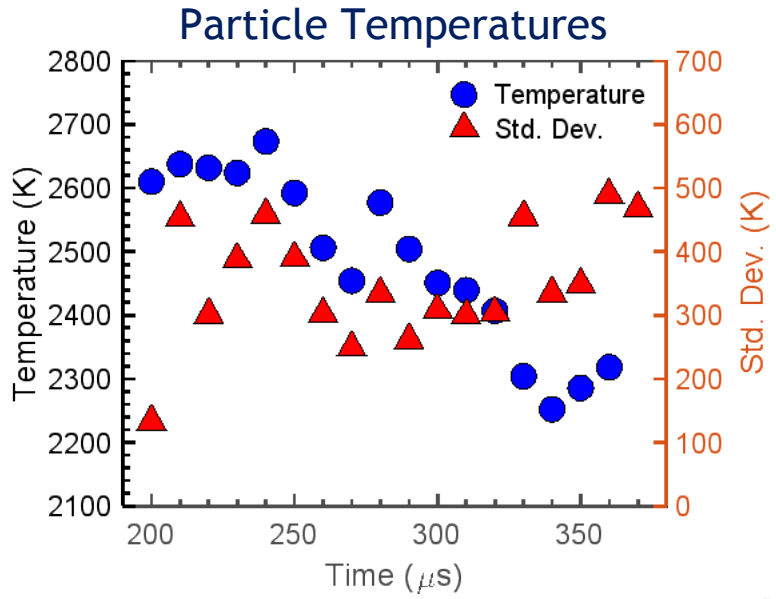
Ignitor Output

- Temperatures appear to reduce from 2700 to 2200 K over time
- More experiments and full understanding of the uncertainties required





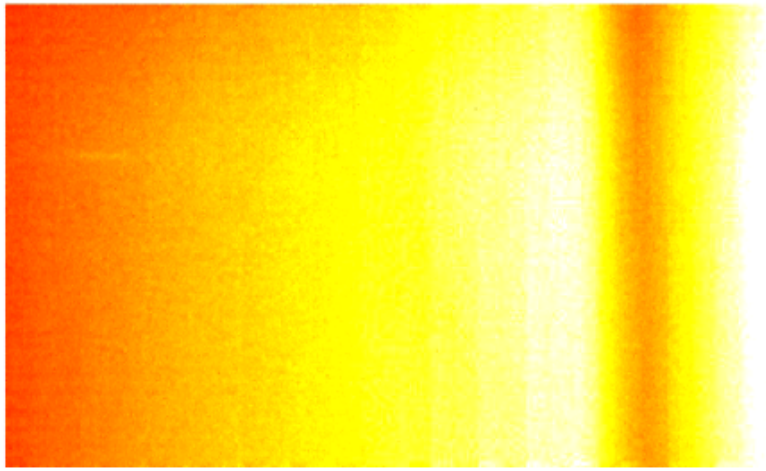




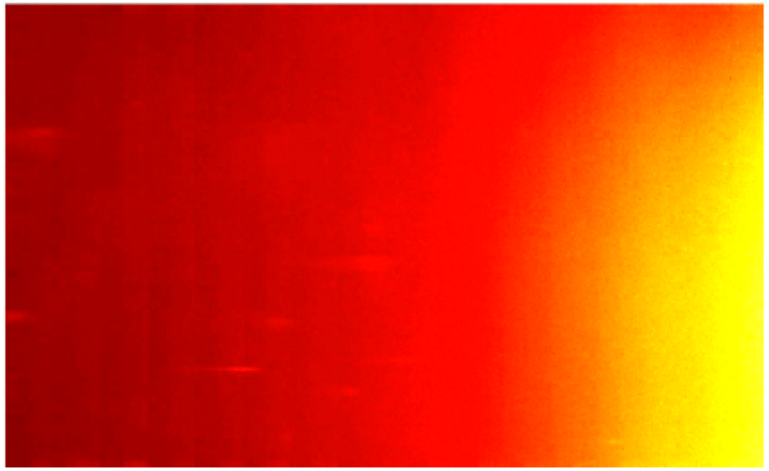
Looking Forward

time = 1200 us

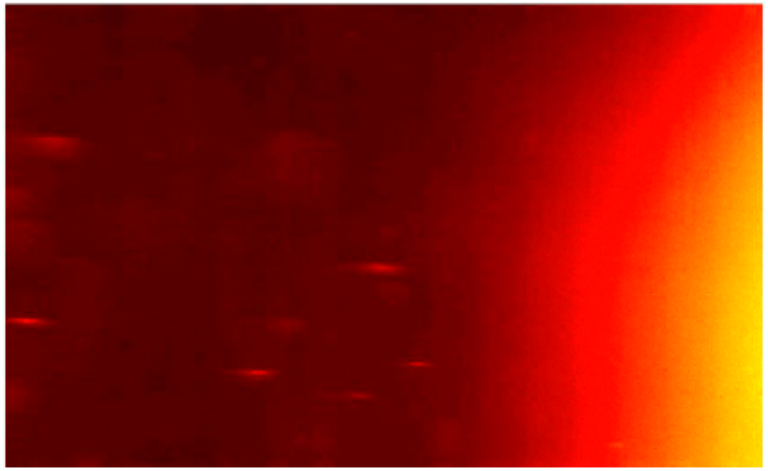
700 ± 25 nm



800 ± 25 nm



900 ± 25 nm



Concluding Remarks

- Successfully measured the temperature of under-resolved particles
- The particle intensity was background subtracted (locally) and integrated to overcome issues with spatial and temporal resolutions
- The three-color pyrometer is operational and we are awaiting the new blackbody source to analyze the data

Thank you for your Attention!