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Title: Observing and Modeling Hot Spots in Individual Explosive Crystals with Shock Compression Microscopy

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Observing and Modeling Hot Spots in Individual Explosive Crystals with Shock Compression Microscopy

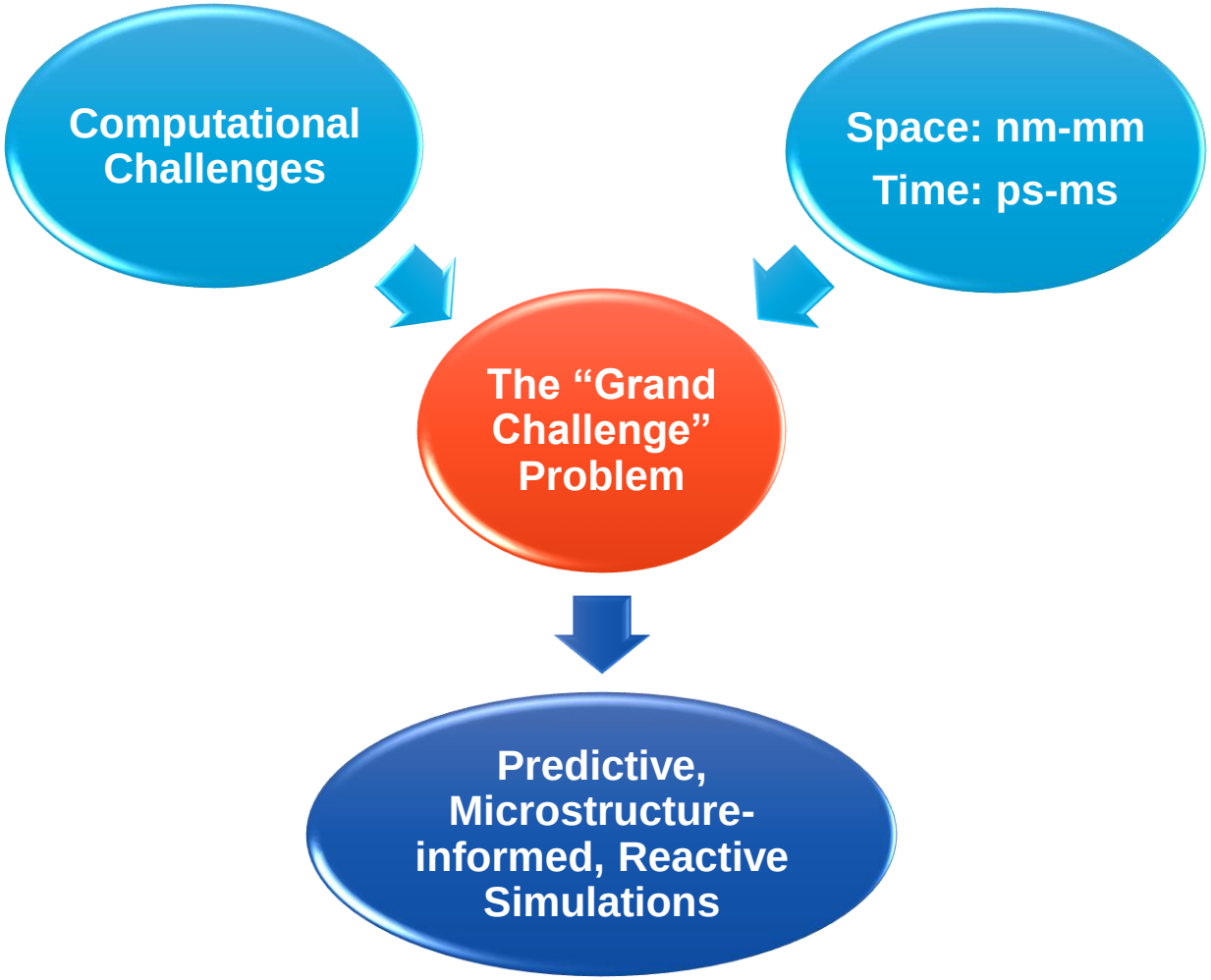
Belinda Pacheco Johnson

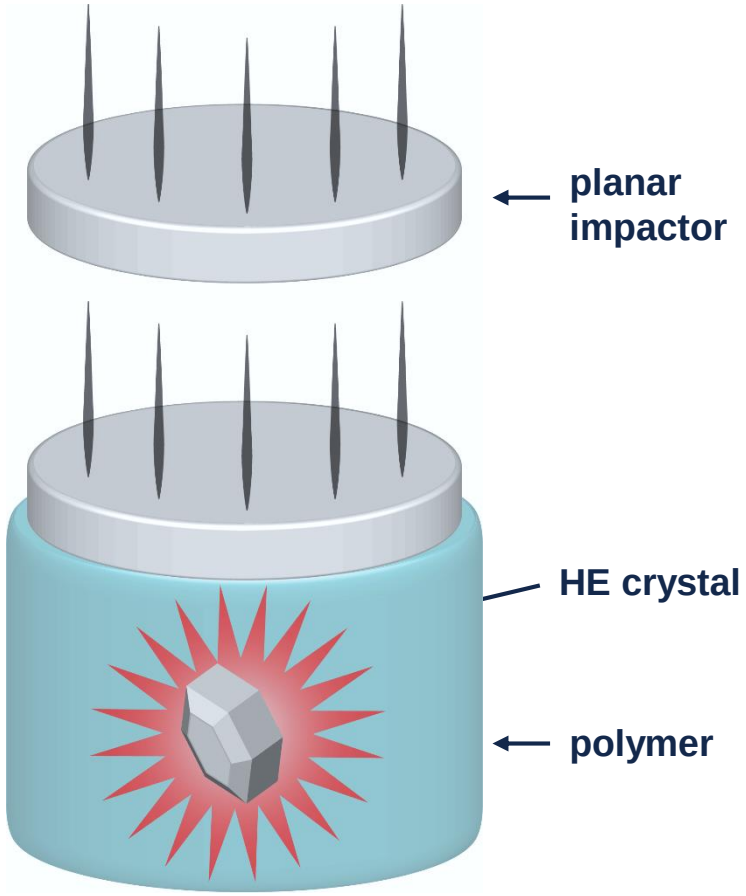
Dr. Xuan Zhou, Hoya Ihara, Prof. Prof. Dana D. Dlott
Shobhan Roy, Yen Nguyen, Prof. H.S. Udaykumar (University of Iowa)

GSCCM Virtual Seminar
December 7, 2021

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

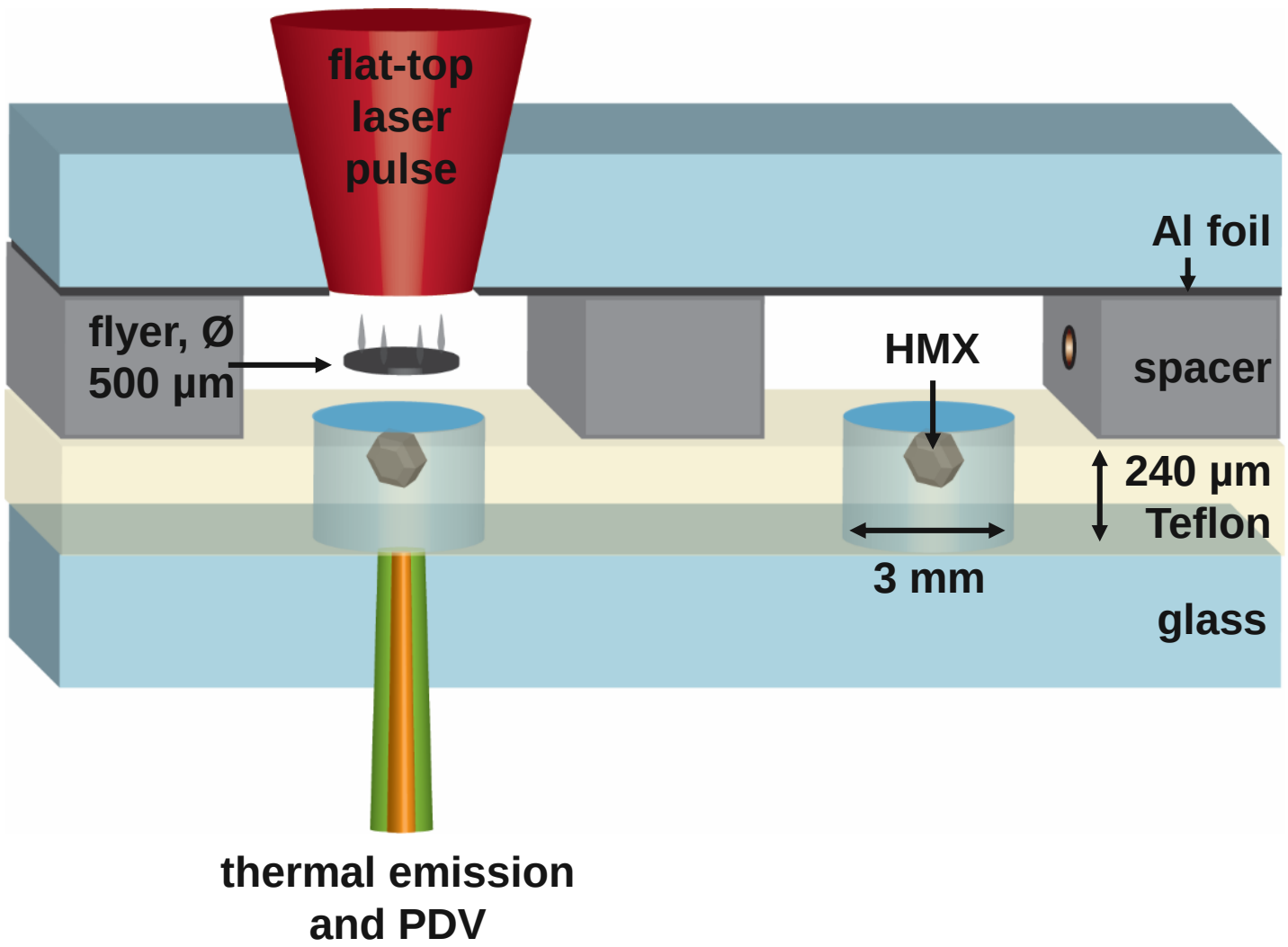
The “Grand Challenge” Problem





Fried, L. E., *et al.*, *Prop., Explos., Pyrotech.* **2020,** *45* (2), 168-168.

Experimental Concept

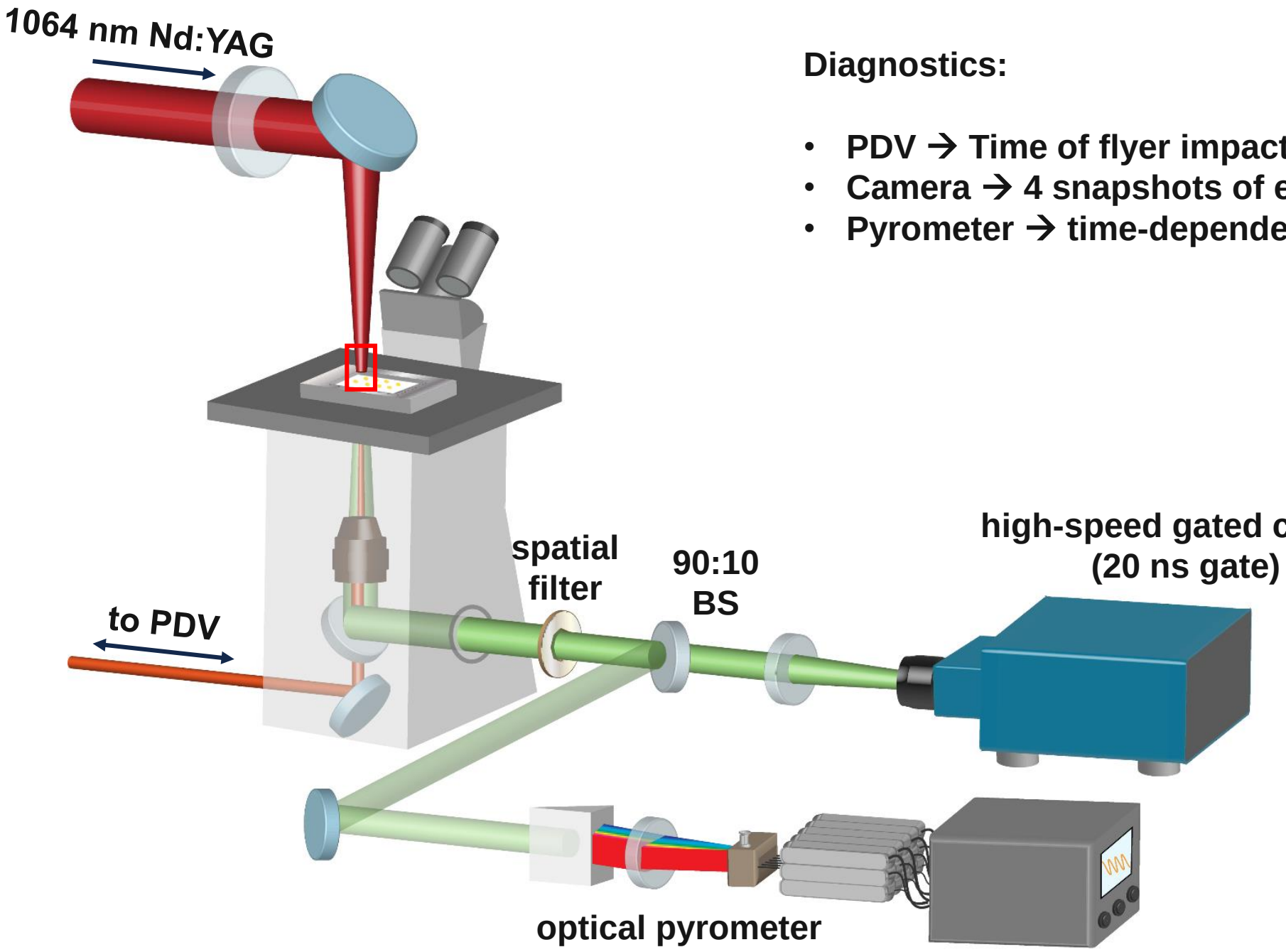


Variables:

- Single vs. defective crystals
- Impact velocity

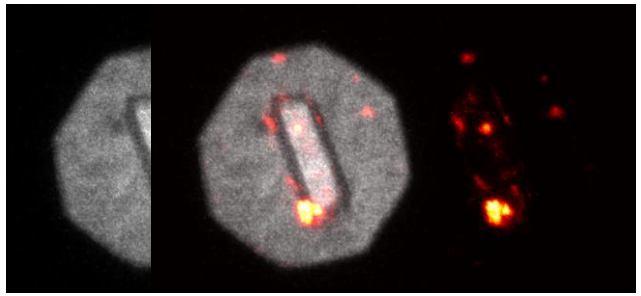
U_p=1.8-3.0 km/s (polymer)

Pressures: 16-34 GPa (crystal)



Diagnostics:

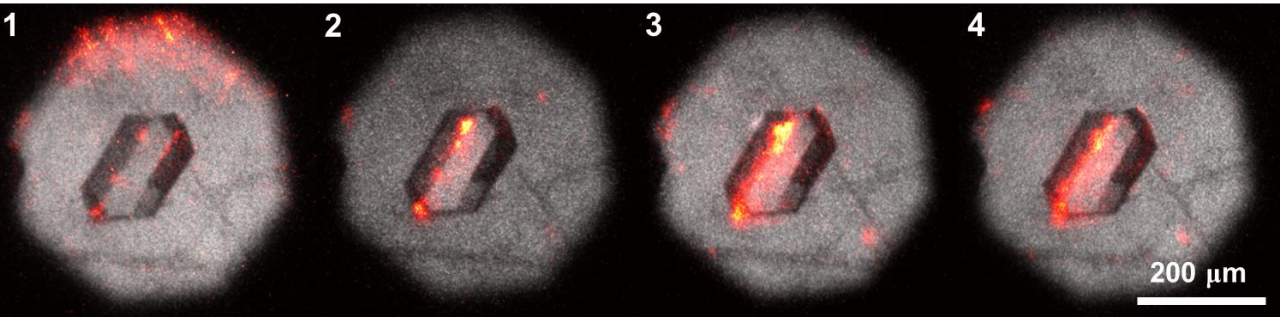
- **PDV → Time of flyer impact on polymer (t=0)**
- **Camera → 4 snapshots of emission**
- **Pyrometer → time-dependent temperatures**

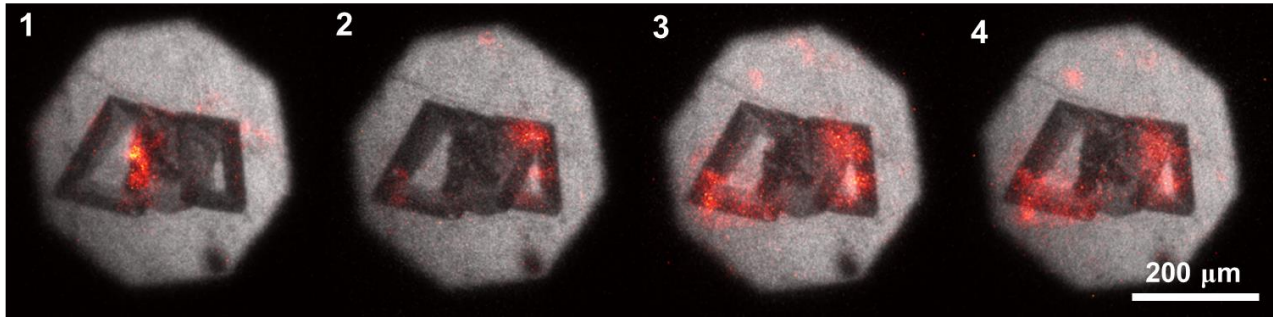


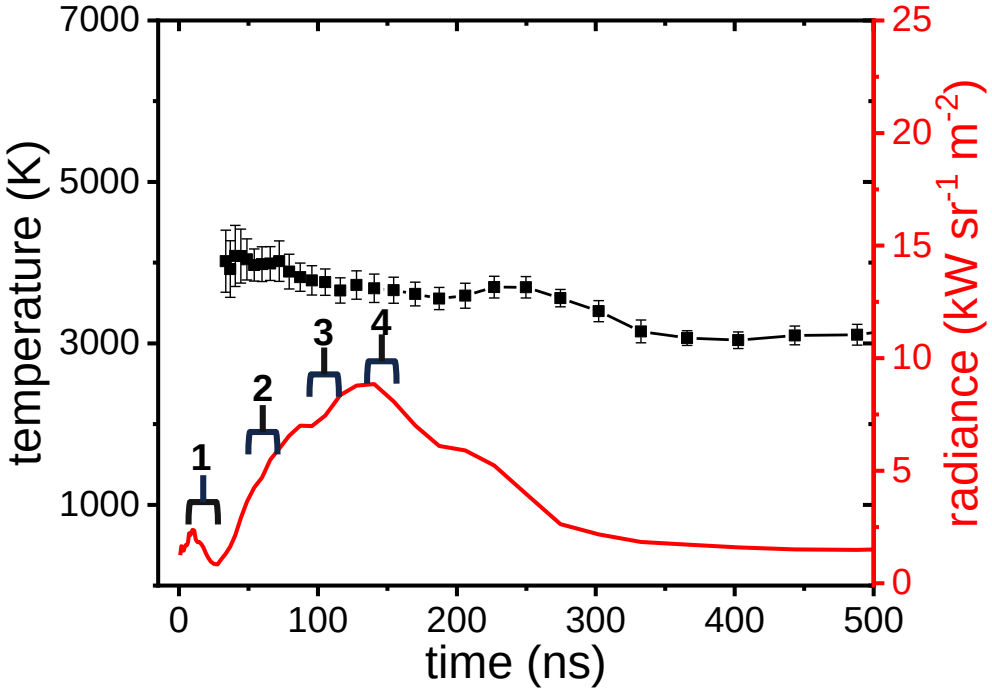
Experimentally Observing Hot Spots in Individual HMX Grains

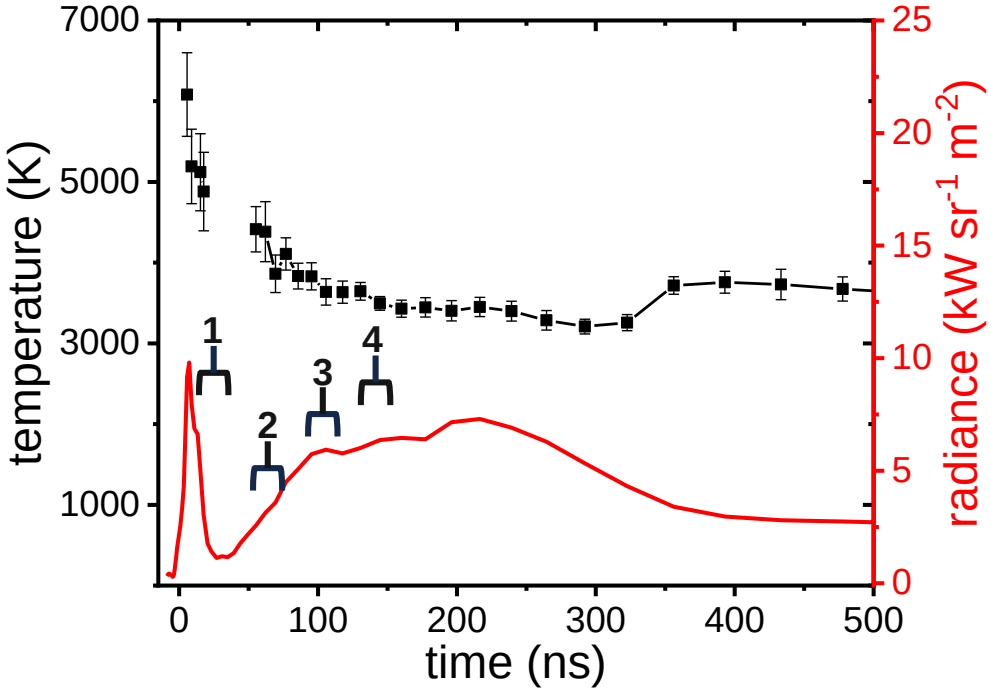
Johnson, B. P., Zhou, X., Ihara, H., Dlott, D. D., *J. Phys. Chem. A* **2020**, *124* (23), 4646-4653.

Single vs Defective Crystals







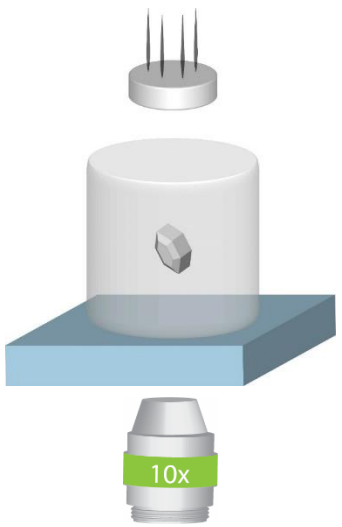


Johnson, B. P., *et al. J. Phys. Chem. A* **2020,** *124* (23), 4646-4653.

Hot Spot Formation in a Model PBX: Simulations and Experiments

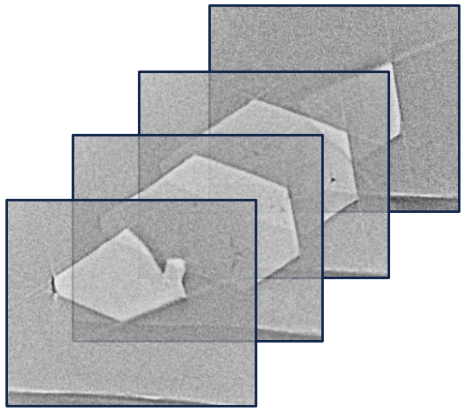
Shobhan Roy, Yen Nguyen, Pratik Das, Prof. H.S. Udaykumar (Iowa)
Belinda P. Johnson, Xuan Zhou, Prof. Dana Dlott (UIUC)

Methodology for Simulating Model PBX

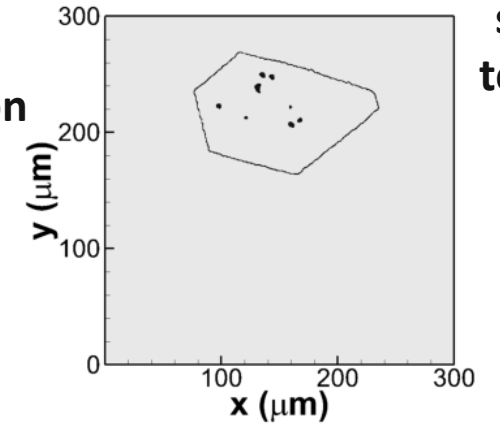


shock experiment configuration

n-CT

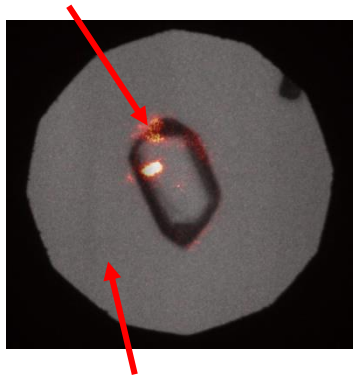


import cross section



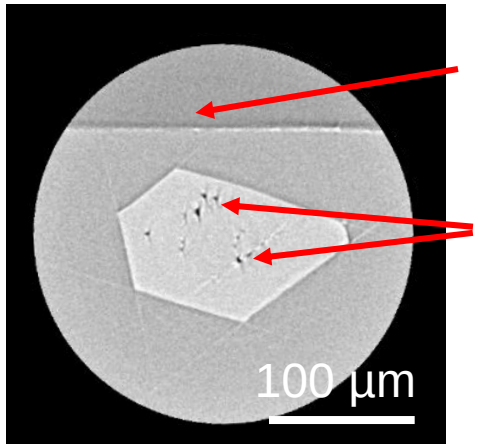
run simulation to find U_p of interest

Superimposed HS emission



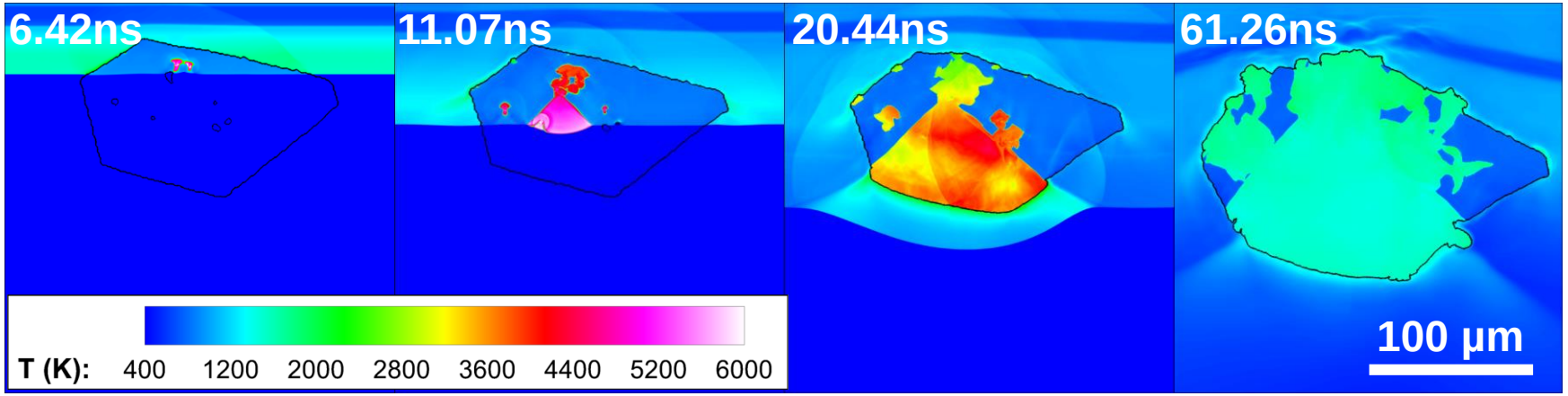
Static, background image

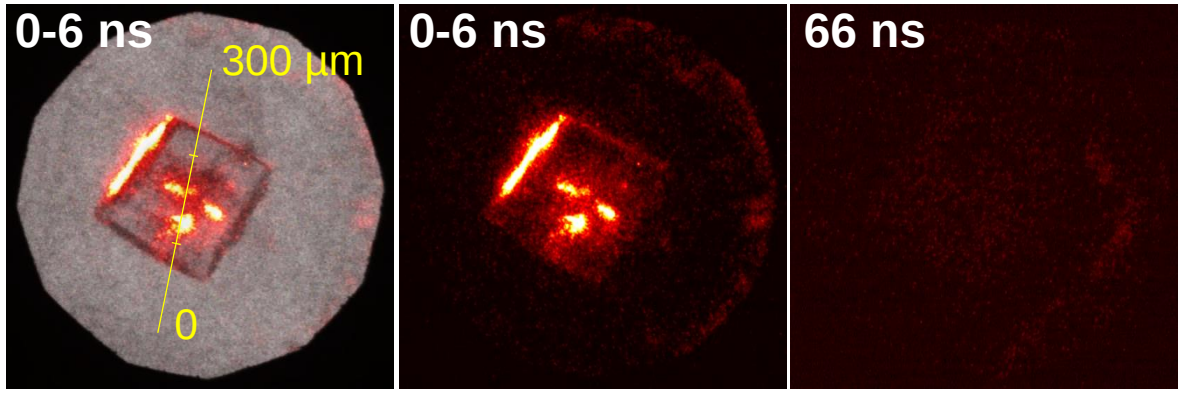
Qualitative HS Formation Comparison



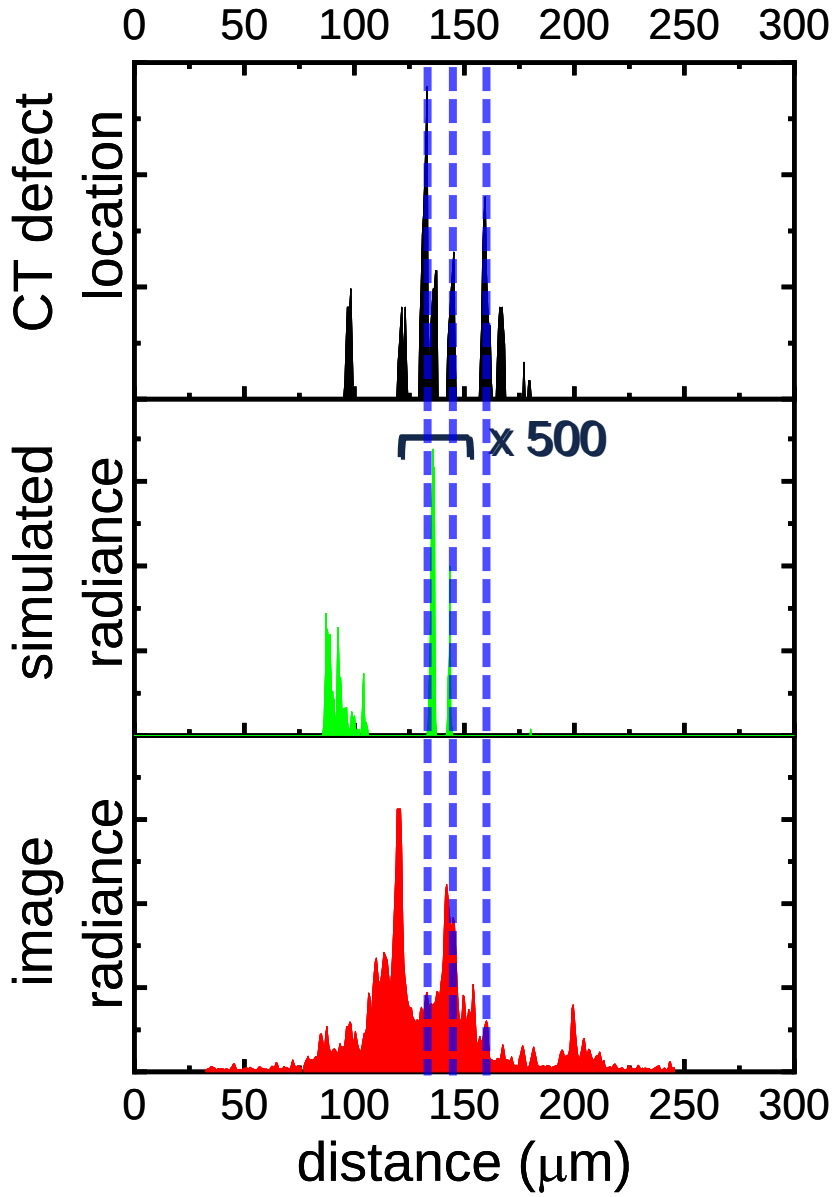
binder-air interface

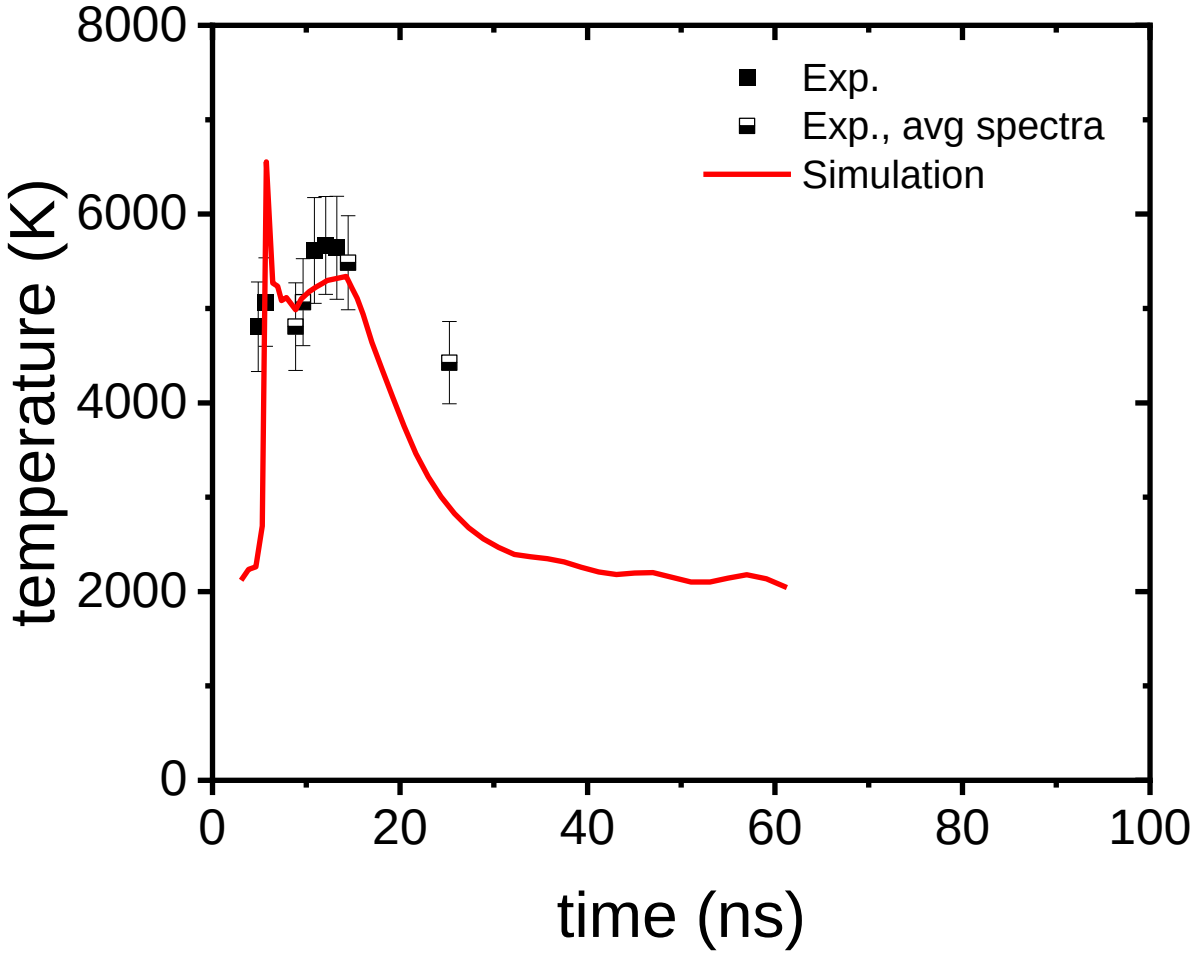
internal voids



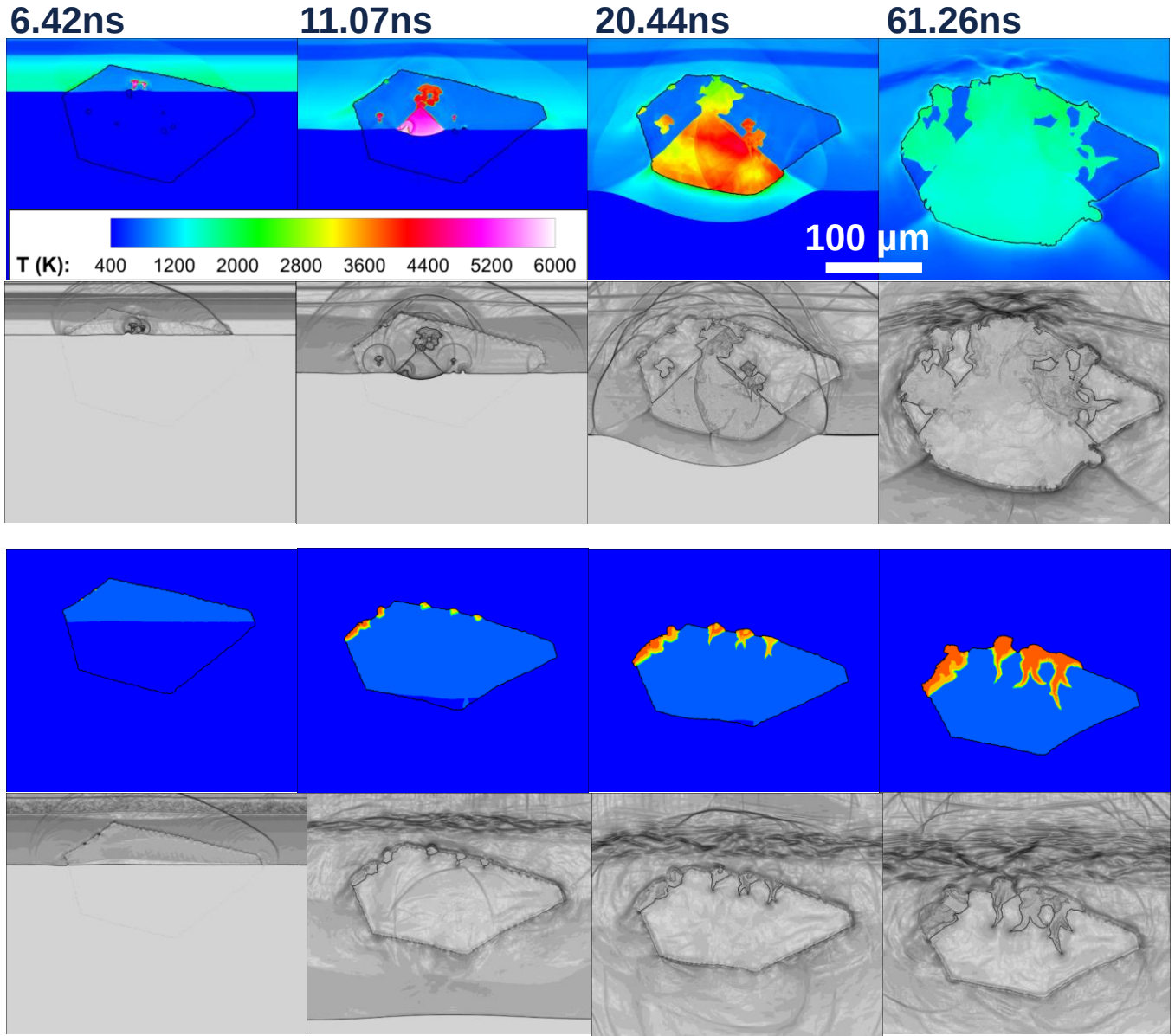


Quantitative HS Temperature Comparison





Hot Spot Formation Mechanisms



with internal voids

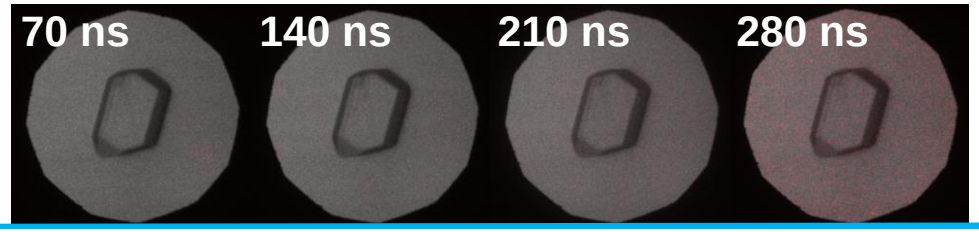
voids artificially removed

Hot Spot Formation in a Model PBX: Simulations and Experiments

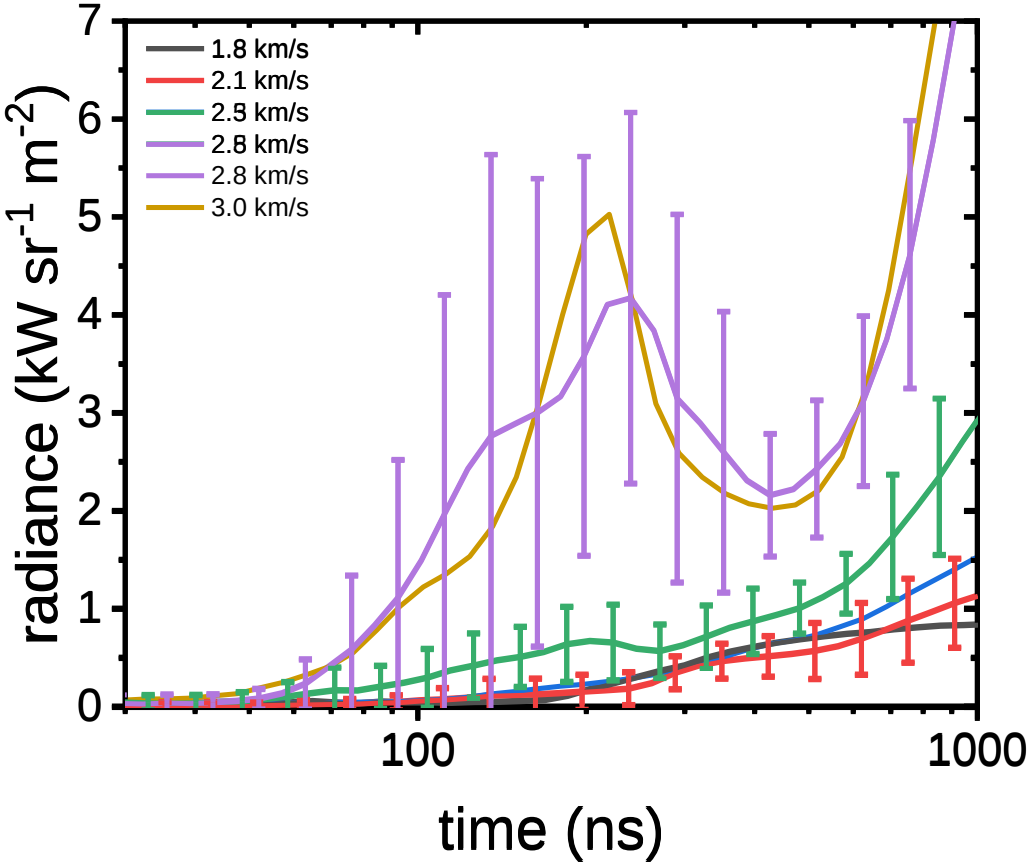
Johnson, B. P., Zhou, X., Ihara, H., Dlott, D. D., *J. Phys. Chem. A* **2021,** *Accepted*.

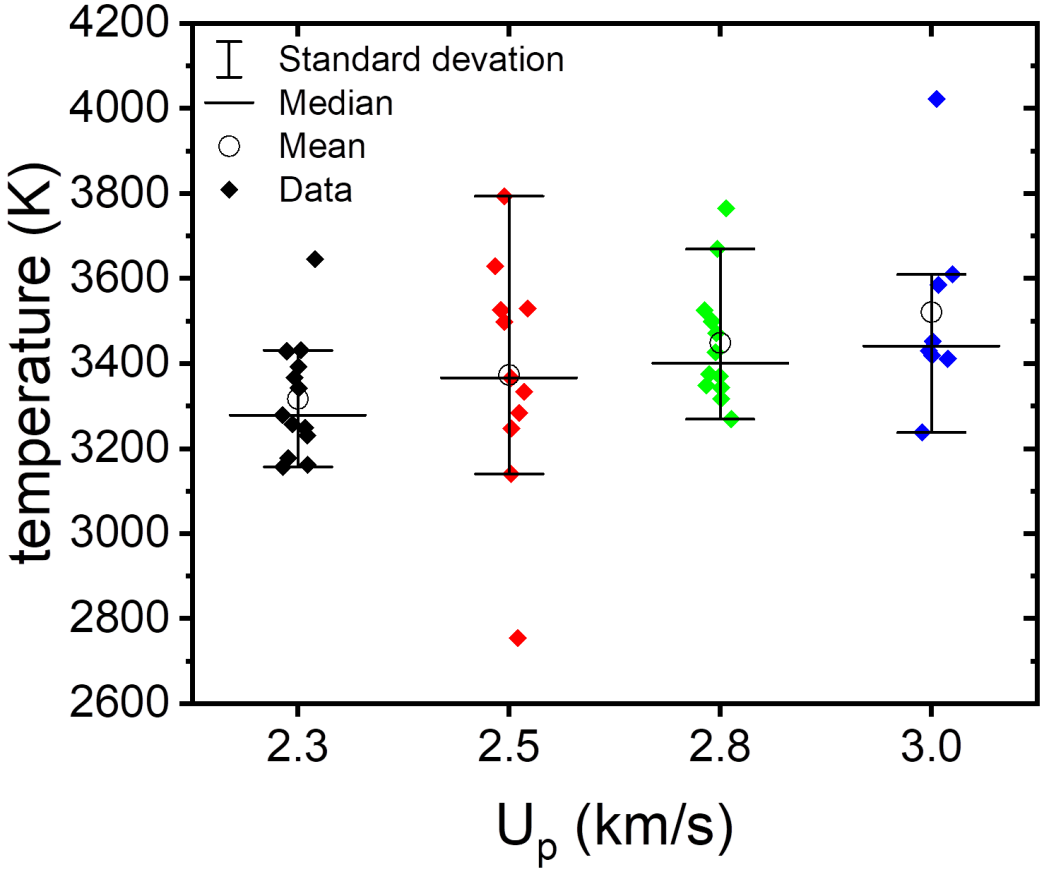
U_p

1.8 km/s



Early Time Pyrometry





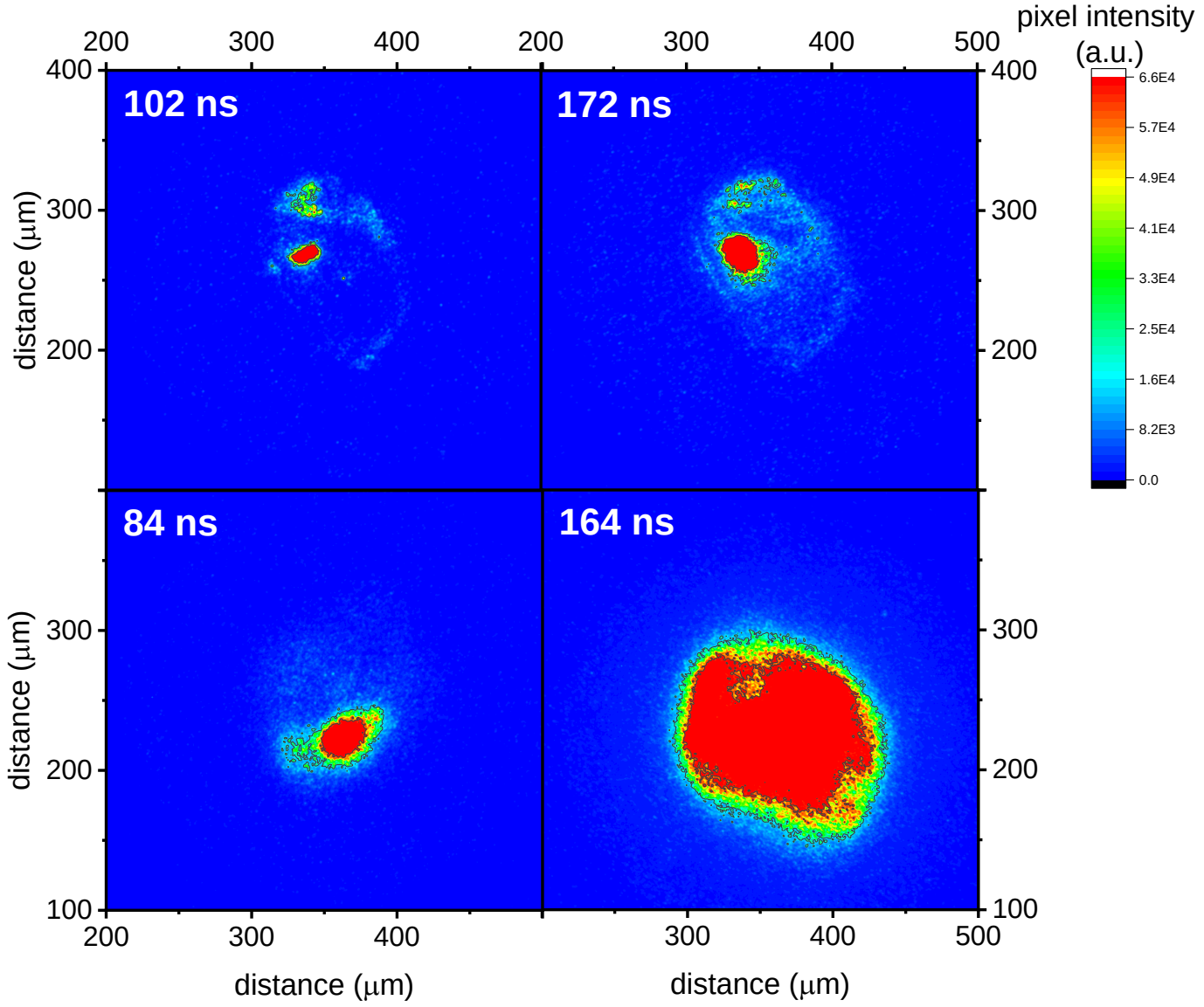
Growth Rates of Individual Hot Spots

U_p=2.3 km/s

E_r= 149 m/s

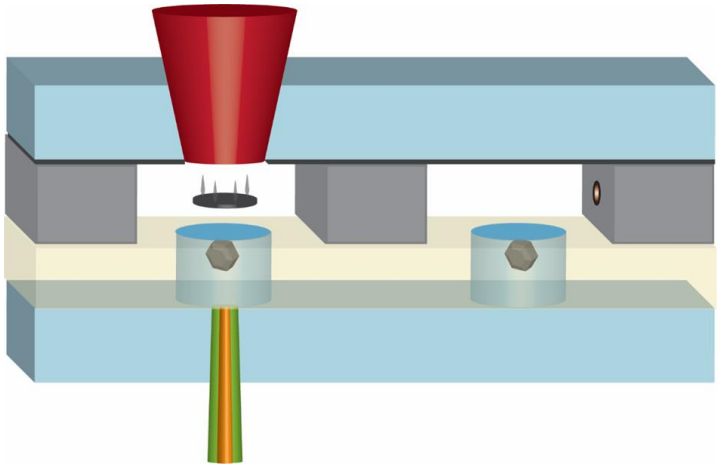
U_p=3.0 km/s

E_r= 556 m/s

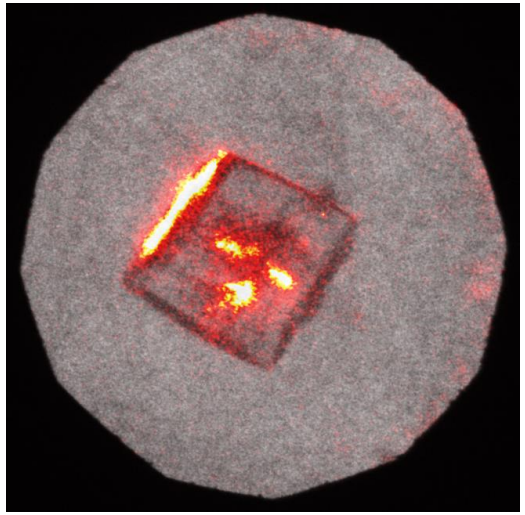


Summary and Future Directions

- Tabletop platform for systematic study of hot spots in model PBXs:
  - Experimentally observe HS formation, location, temperature, and propagation
  - Impact pressure thresholds and growth behavior



- Ongoing Efforts
  - Direct comparison to reactive simulations (Shobhan Roy, Iowa)
  - Quantify HS growth
  - Varying binder
  - Time-resolved temperature maps



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- Dr. Xuan Zhou
- Hoya Ihara
- Shobhan Roy & Udaykumar group (Iowa)
- Dr. Will Bassett
- Dlott group

Graduate Research Fellowship Program

Alfred P. Sloan FOUNDATION

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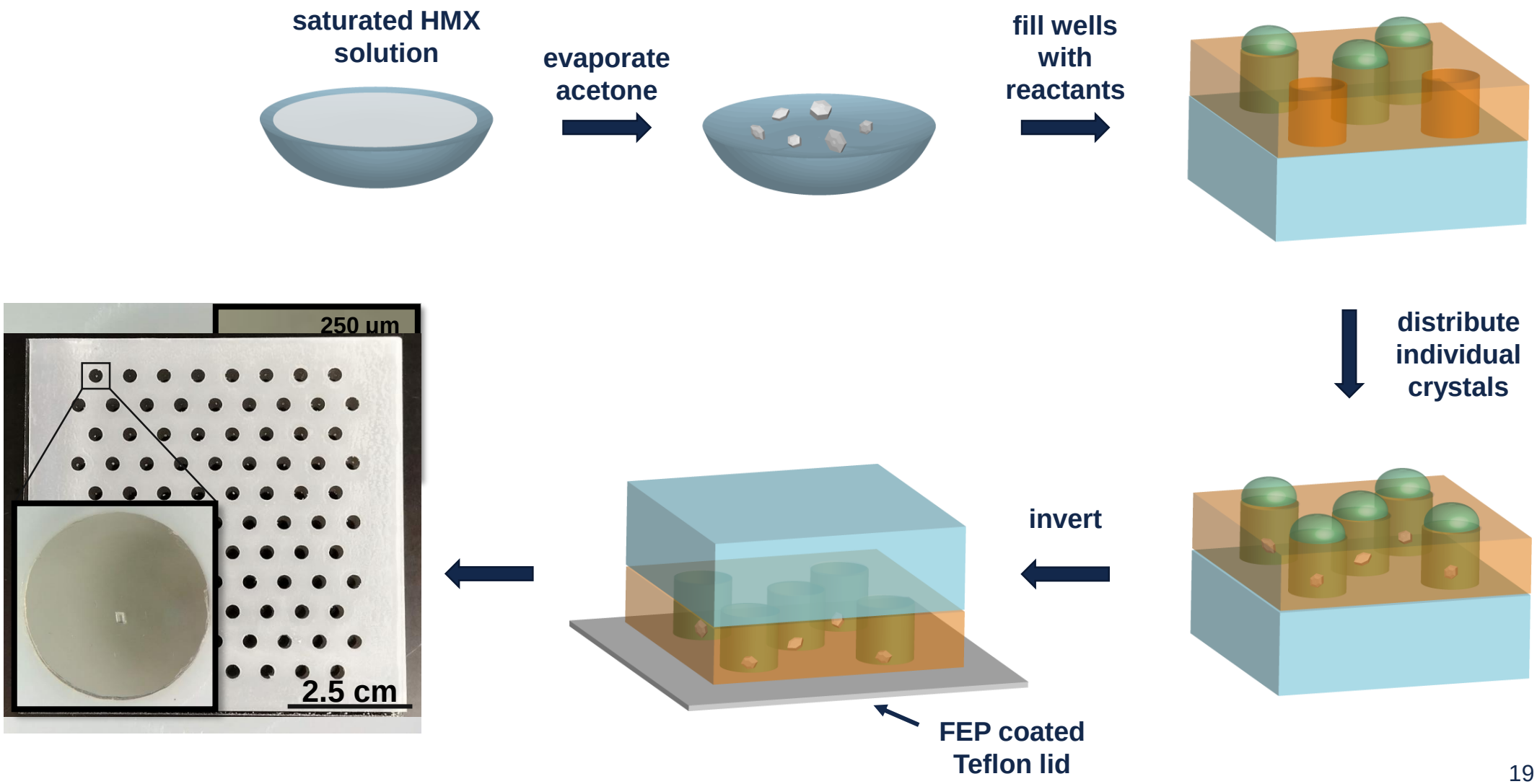
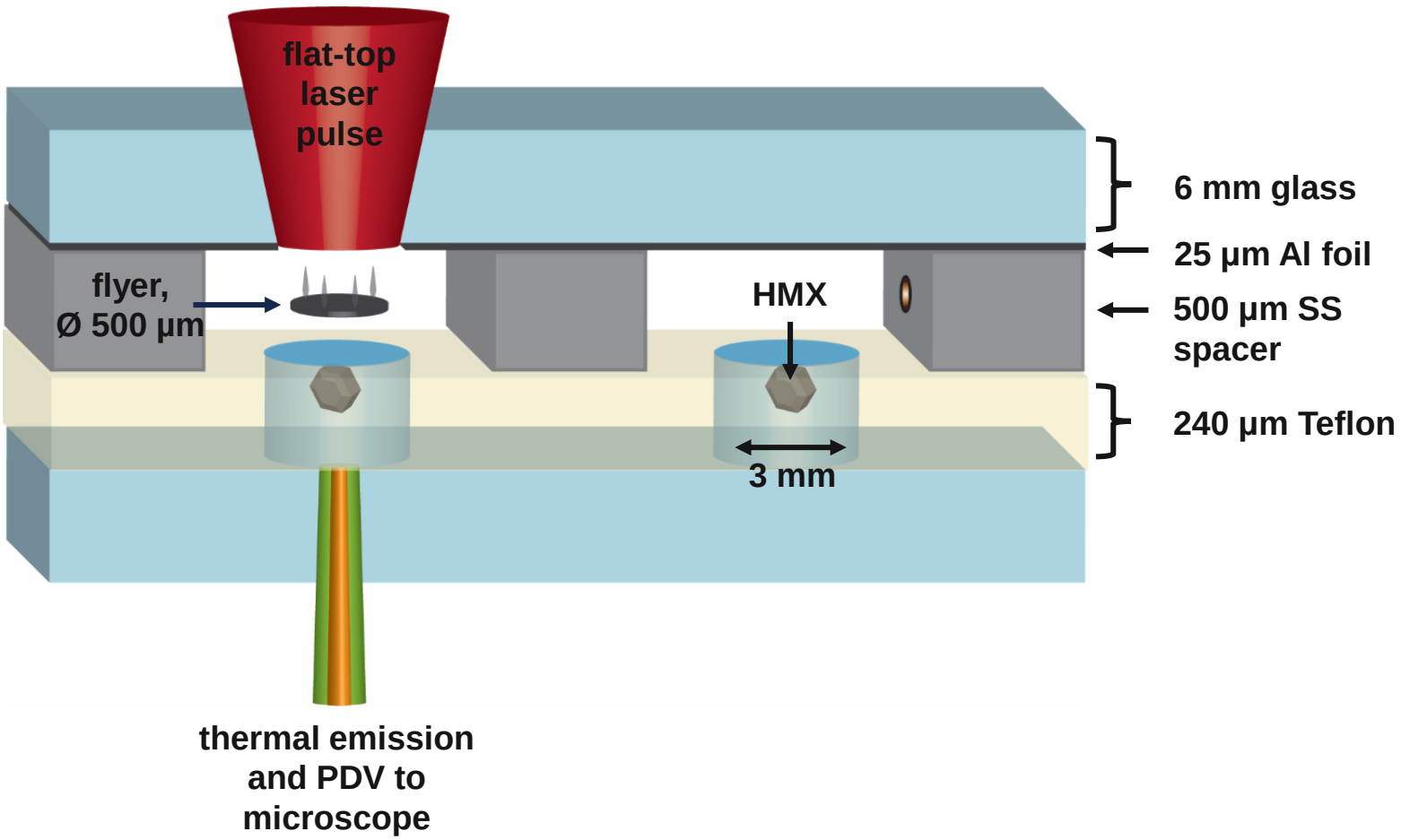
SCIENCE TO SHAPE THE FUTURE OF THE ARMY ARMY RESEARCH OFFICE 1951

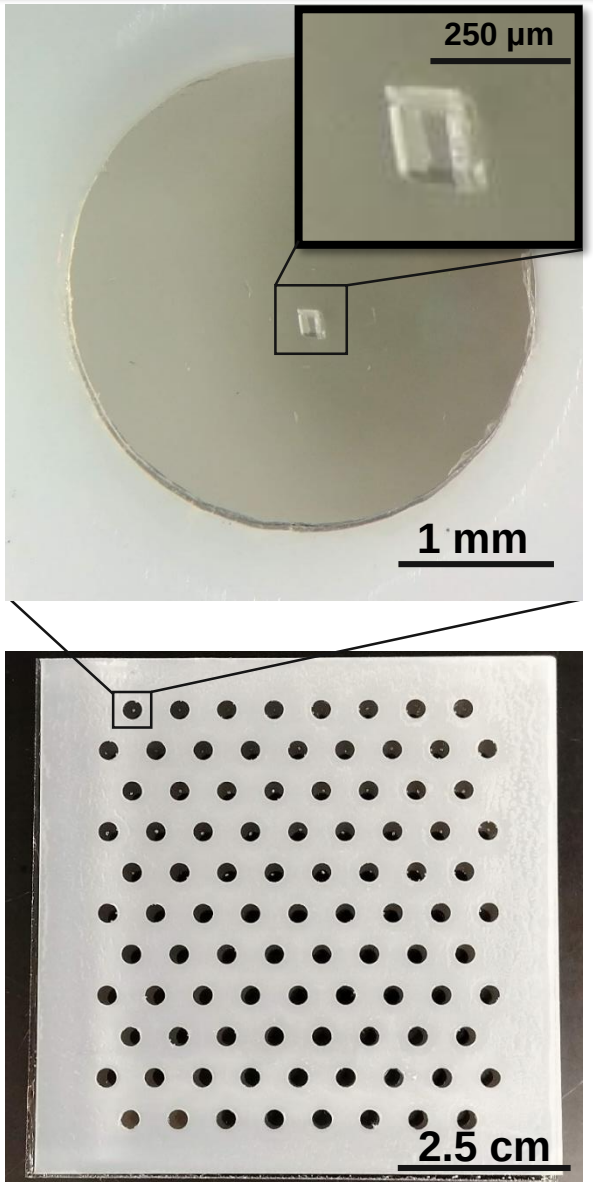
Supplementary Slides

Synthesis of a Model PBX

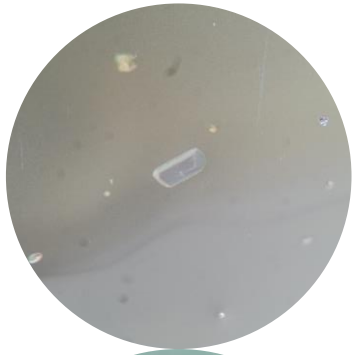
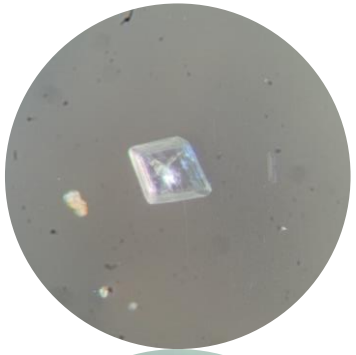
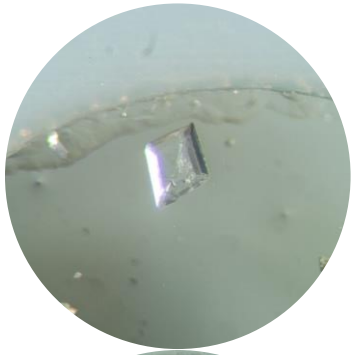
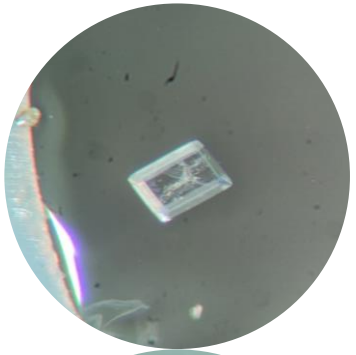
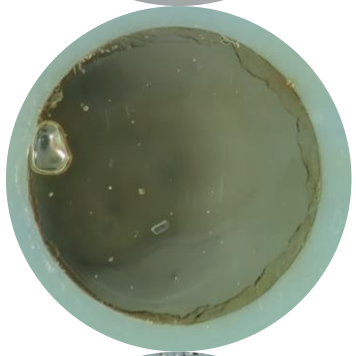
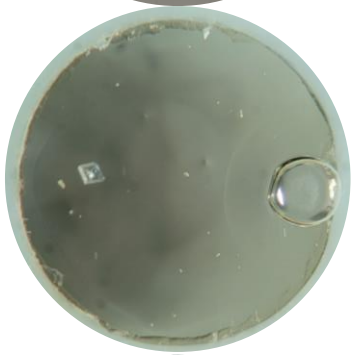
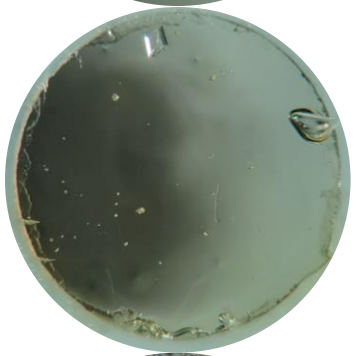
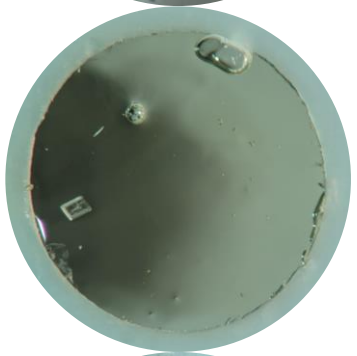
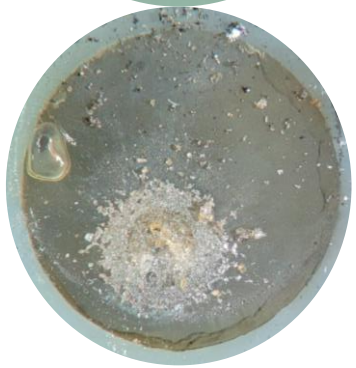
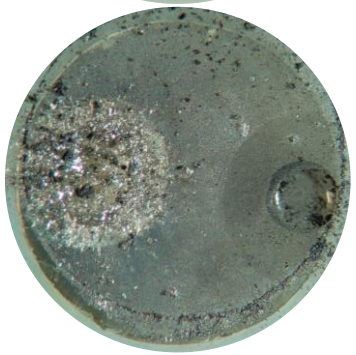
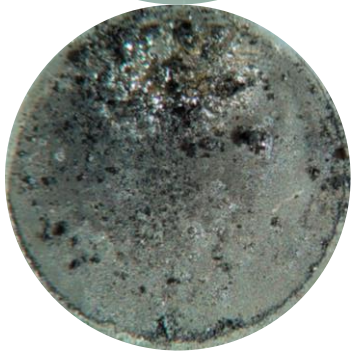
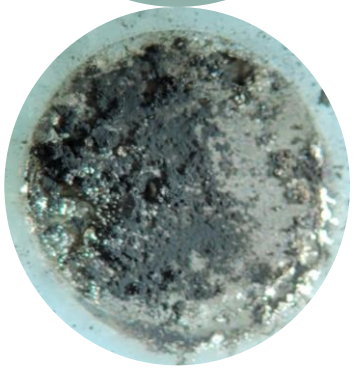


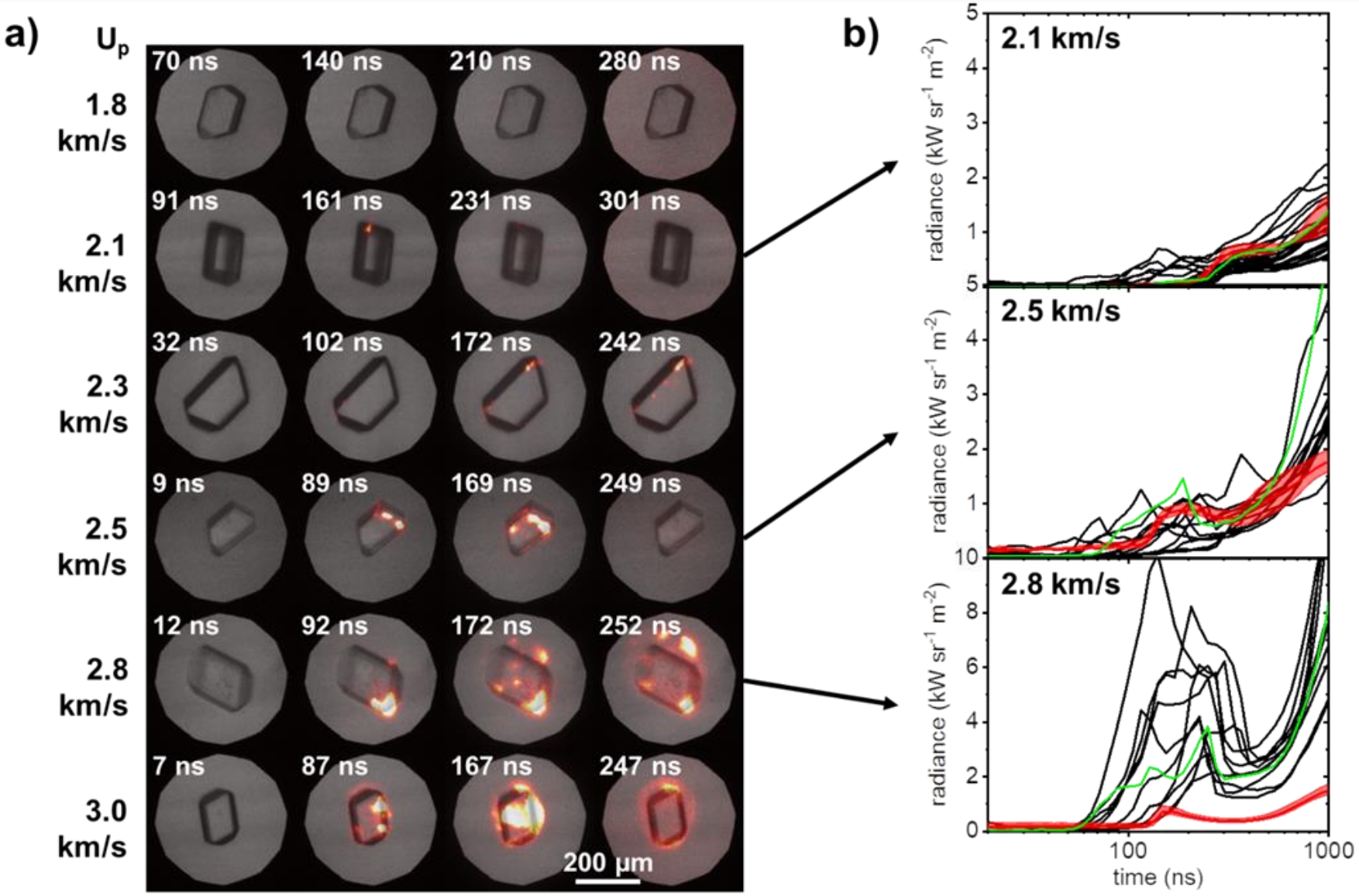
Sample Configuration



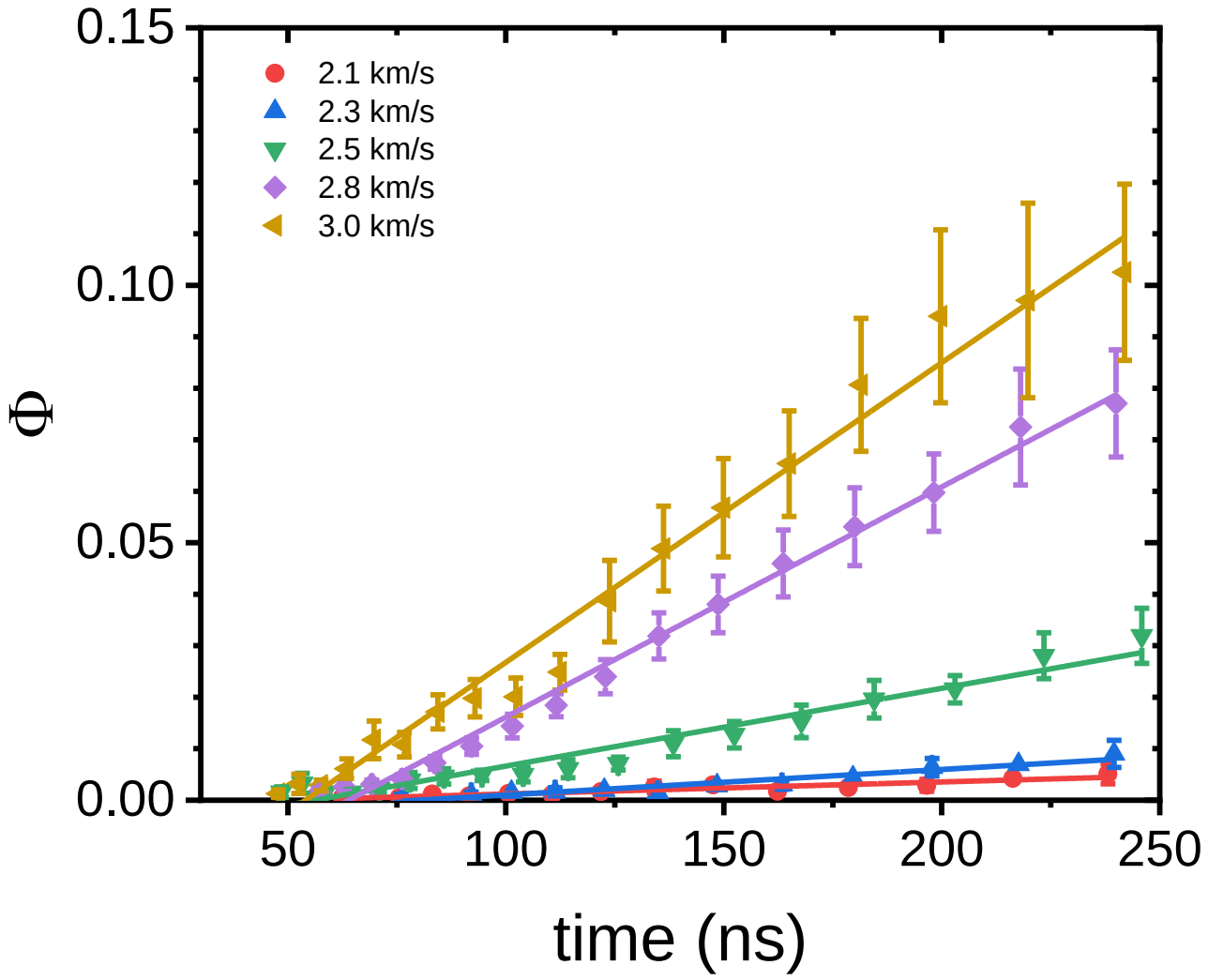


Post-Mortem Images

U_p	2.1 km/s	2.5 km/s	2.8 km/s	3.0 km/s
Zoomed in				
Pre-Shock				
Post-Shock				

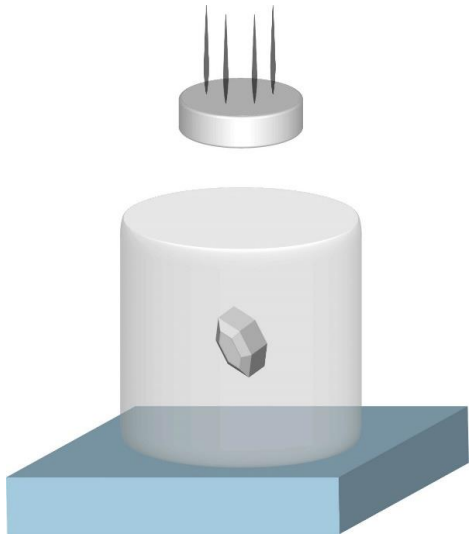

a)
U_p
1.8 km/s
2.1 km/s
2.3 km/s
2.5 km/s
2.8 km/s
3.0 km/s
70 ns
140 ns
210 ns
280 ns
91 ns
161 ns
231 ns
301 ns
32 ns
102 ns
172 ns
242 ns
9 ns
89 ns
169 ns
249 ns
12 ns
92 ns
172 ns
252 ns
7 ns
87 ns
167 ns
247 ns
200 µm
b)
2.1 km/s
2.5 km/s
2.8 km/s
radiance (kW sr^{-1} m^{-2})
time (ns)
100
1000

U_p-Dependent Spatially Averaged Emissivity

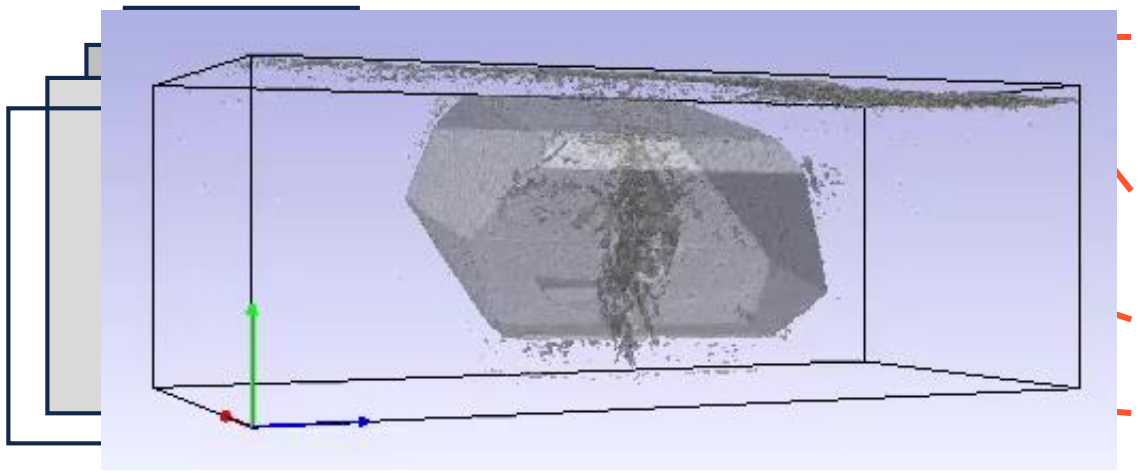


Imaging Configuration

CT scan and simulation configuration



cross sections



shock experiment configuration

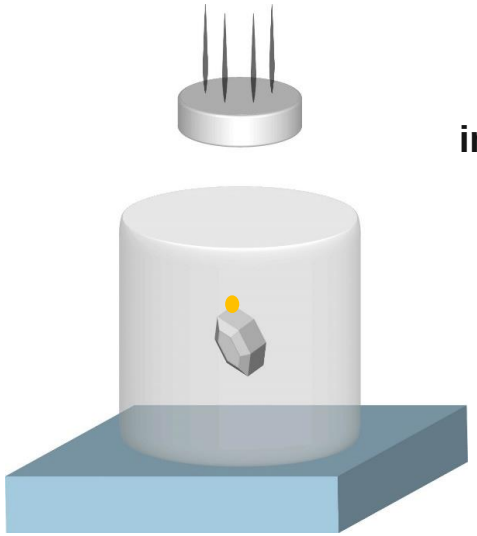
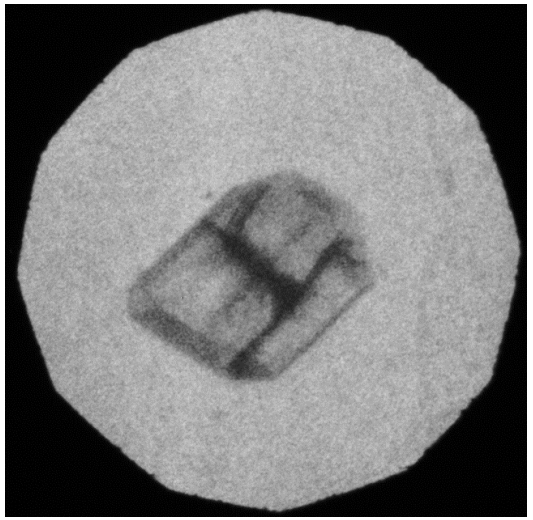
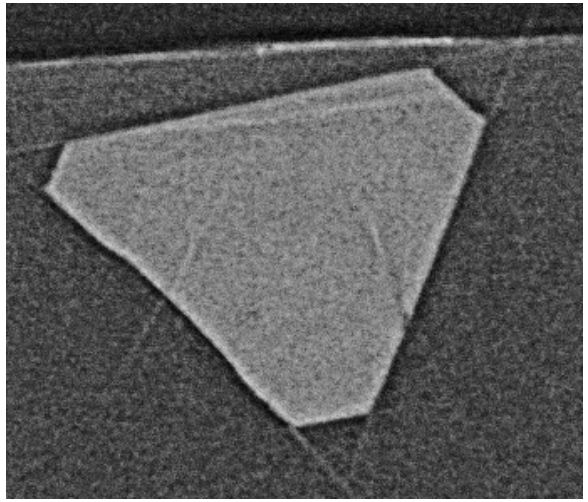


image focused on crystal top



CT Scanned Crystals (Xuan)

#1



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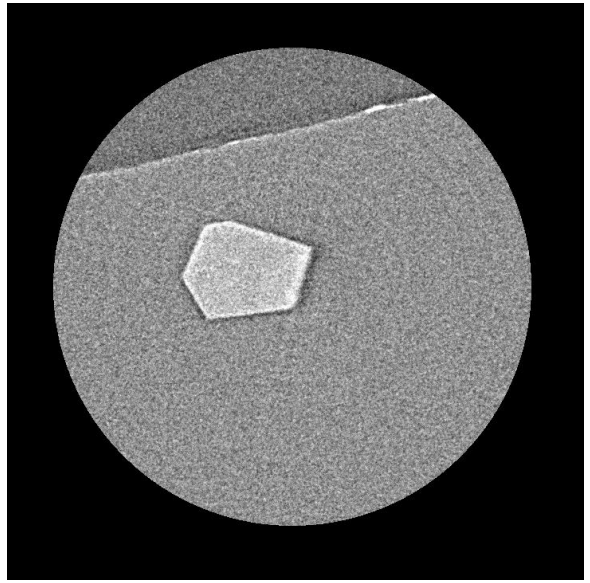

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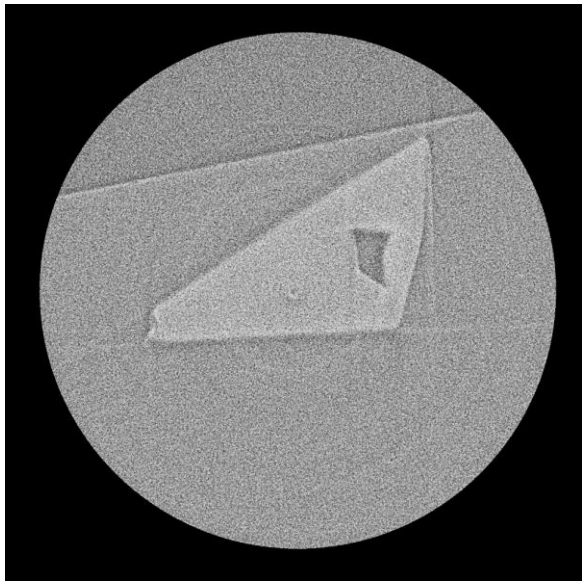

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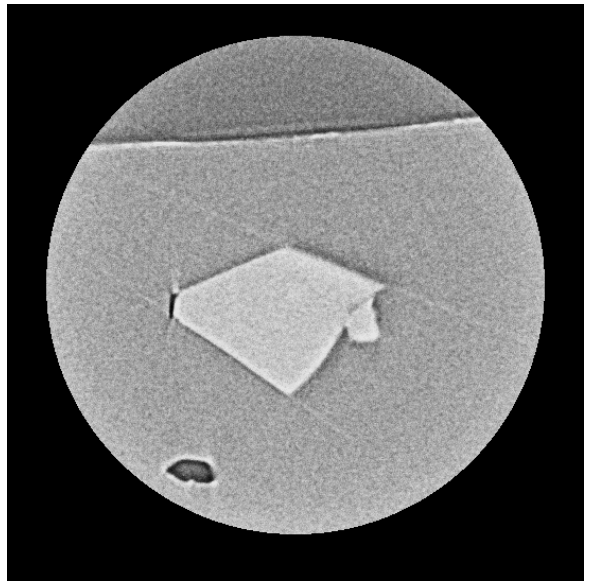
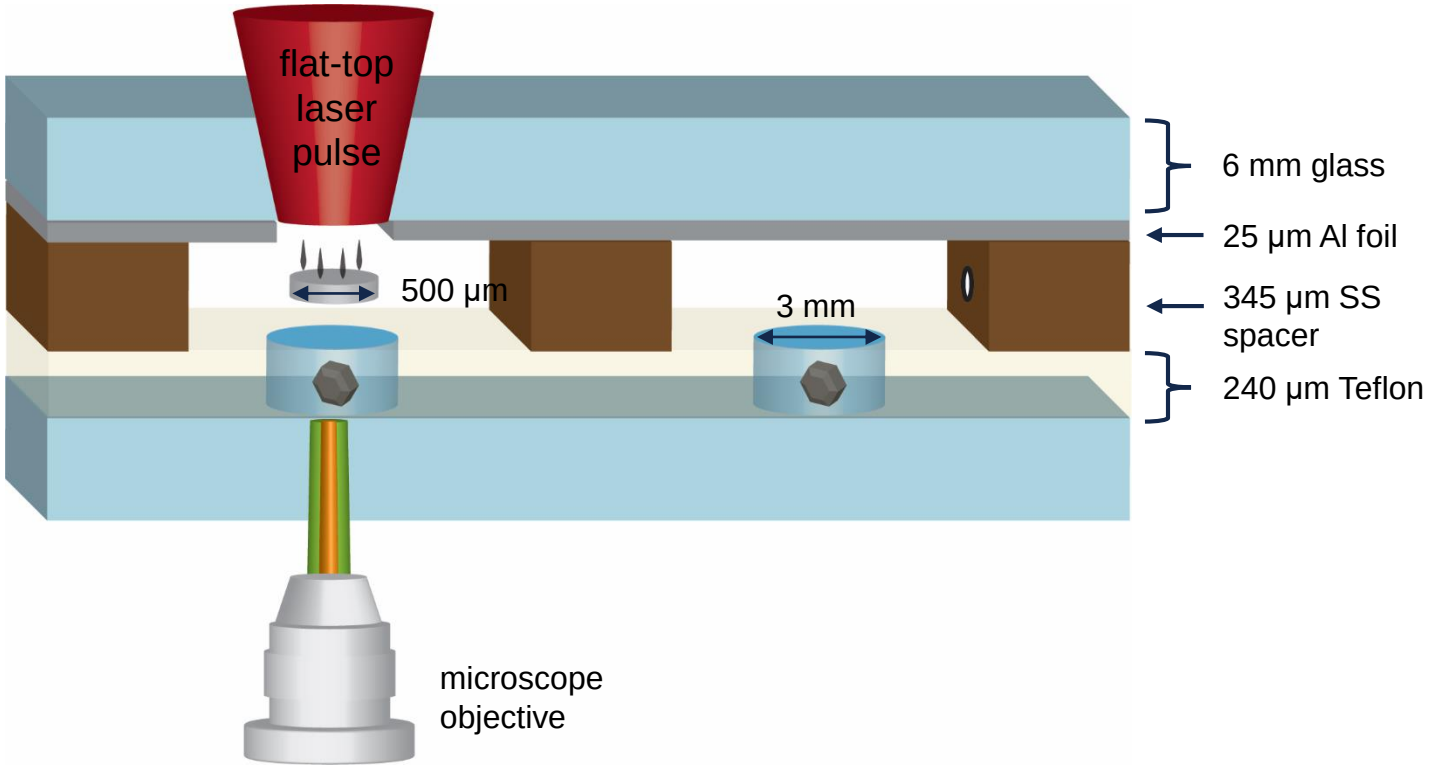
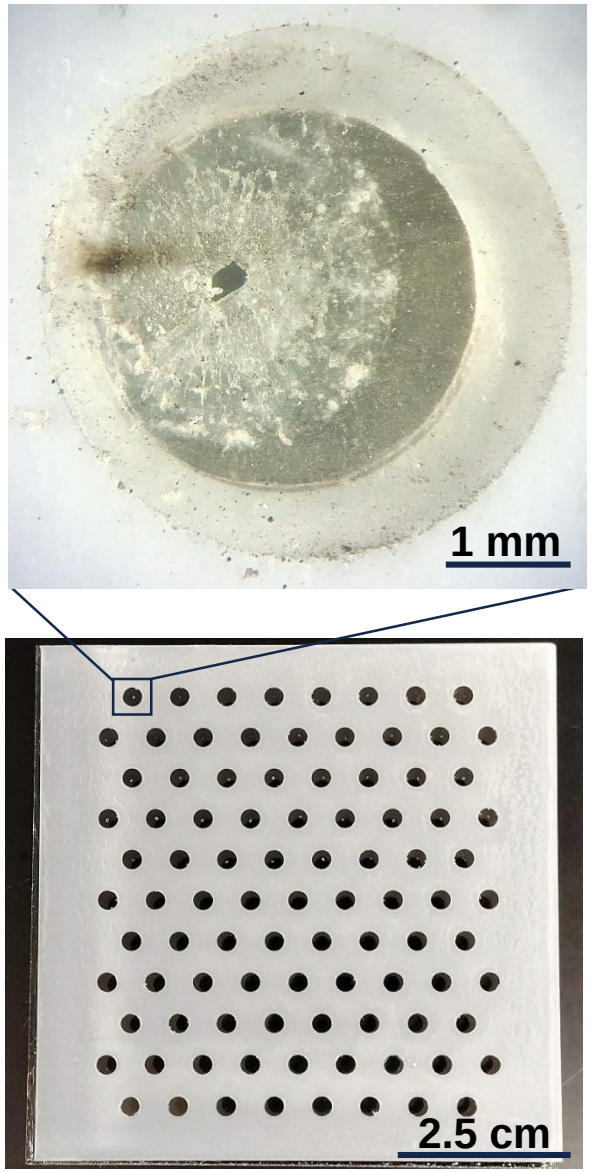
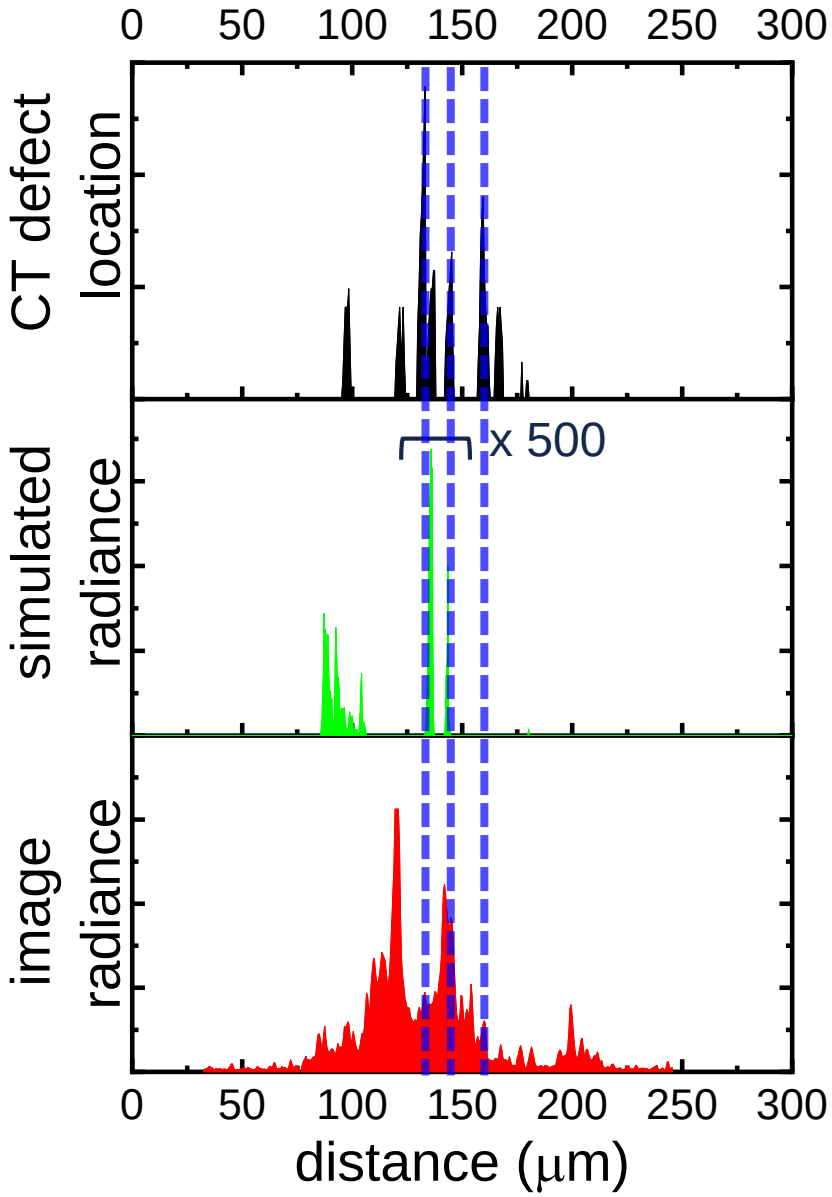


Sample Configuration






0
50
100
150
200
250
300
CT defect location
simulated radiance
x 500
image radiance
distance (μm)