Experimental Metrology And Techniques For Sub-millimeter Optical Observation Of Detonation Reaction Phenomena And Performance Evaluation Of Crystalline Explosives

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DEM – Department of Mechanical Engineering - University of Coimbra
LEDAP – Laboratory of Energetics and Detonics
ONR – Office of Naval Research, Science & Technology – DON USA

XIII INTERNATIONAL SYMPOSIUM
ON EXPLOSIVE PRODUCTION OF NEW MATERIALS:
Science, Technology, Business and Innovations

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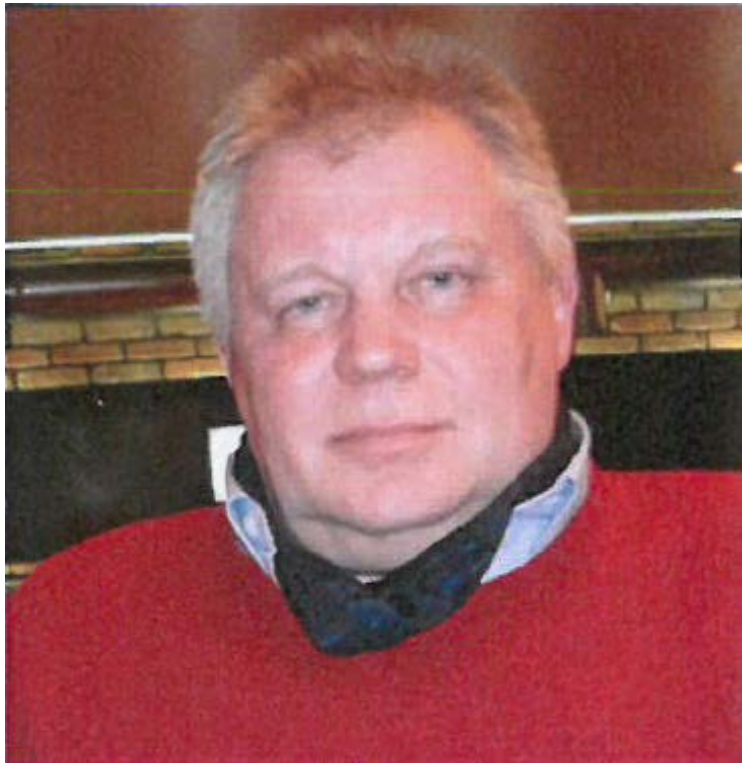


Igor Evgenievich Plaksin
1954 – 2016

1. Experimental Technique Overview

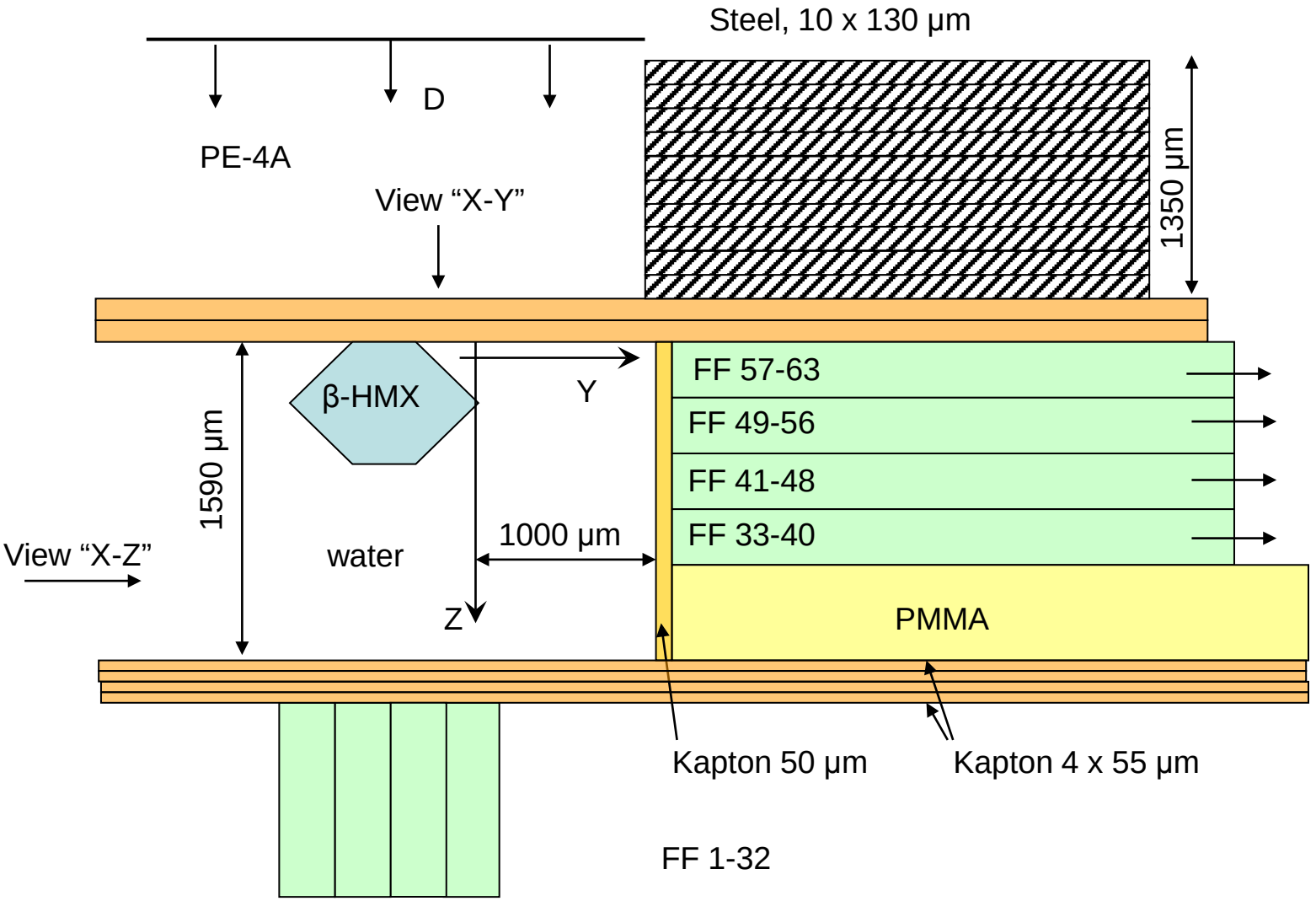
- *Multi-Fiber Optical Probe* (MFOP)
  - Multi-Mode PMMA Fiber Optic Array
  - Spatial Resolution: 250μm
- High-Speed Electronic Streak Camera (ESC)
  - Model: *Thomson TSN 506 N*
  - Temporal Resolution: ~1ns
- +15 Test Setups / Configurations

1. Experimental Technique Overview

- **Products:**
  - Resolution of Reaction Radiation Fields
    - Hotspots, Localizations and Irregularities
  - Resolution of Induced Peak Pressure Fields in Inert Media
  - Correlation Between Reaction Intensity and Induced Pressure
  - Detonation Front Topography
    - Curvature
    - Smoothness / Roughness
  - Resolution of Local Detonation Velocity (*D*) Perturbations
  - Detonation Extinction Critical Diameter
  - Shock-to-Detonation Transition (SDT), etc…

2. Experimental Setups / Configurations Examples

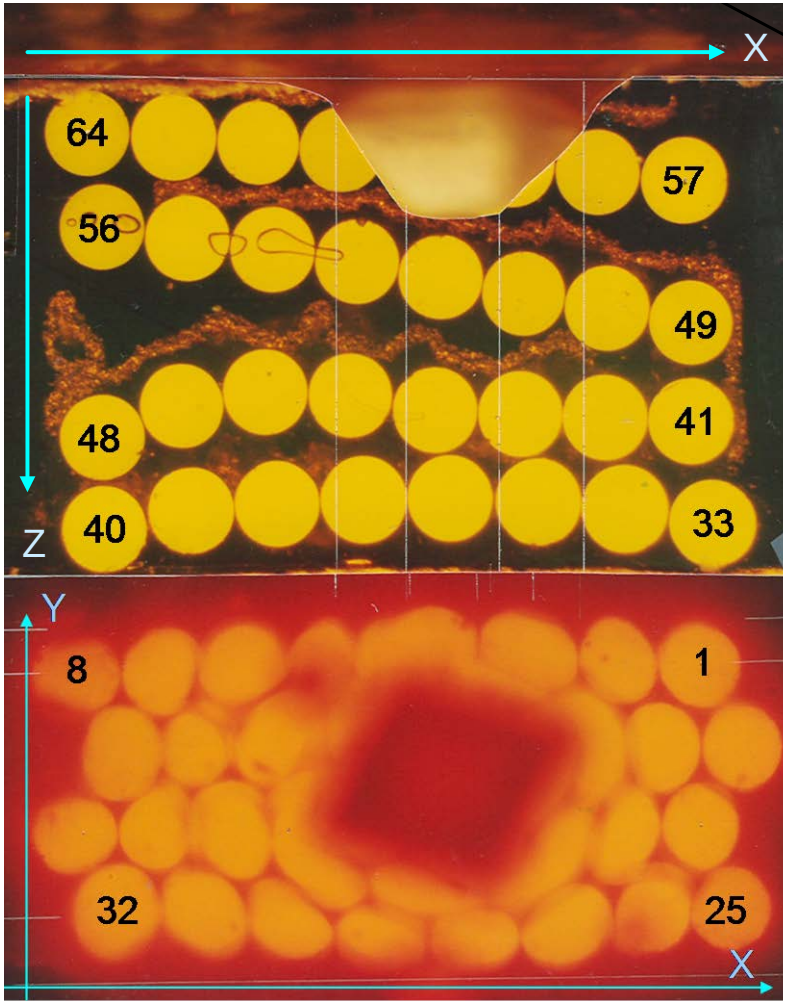
2.1. Single Crystal Reaction



2. Experimental Setups / Configurations Examples

2.1. Single Crystal Reaction

2.1.1. Two-Plane Observation



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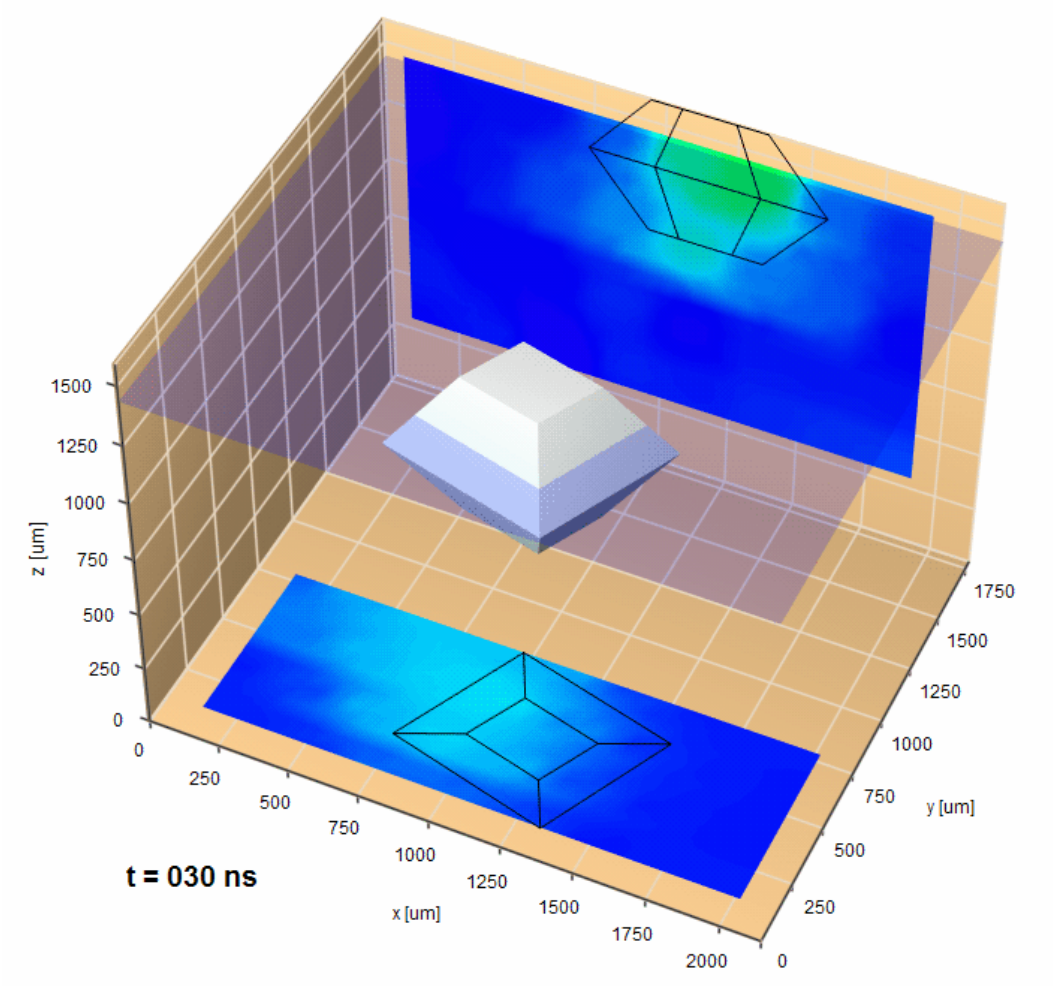
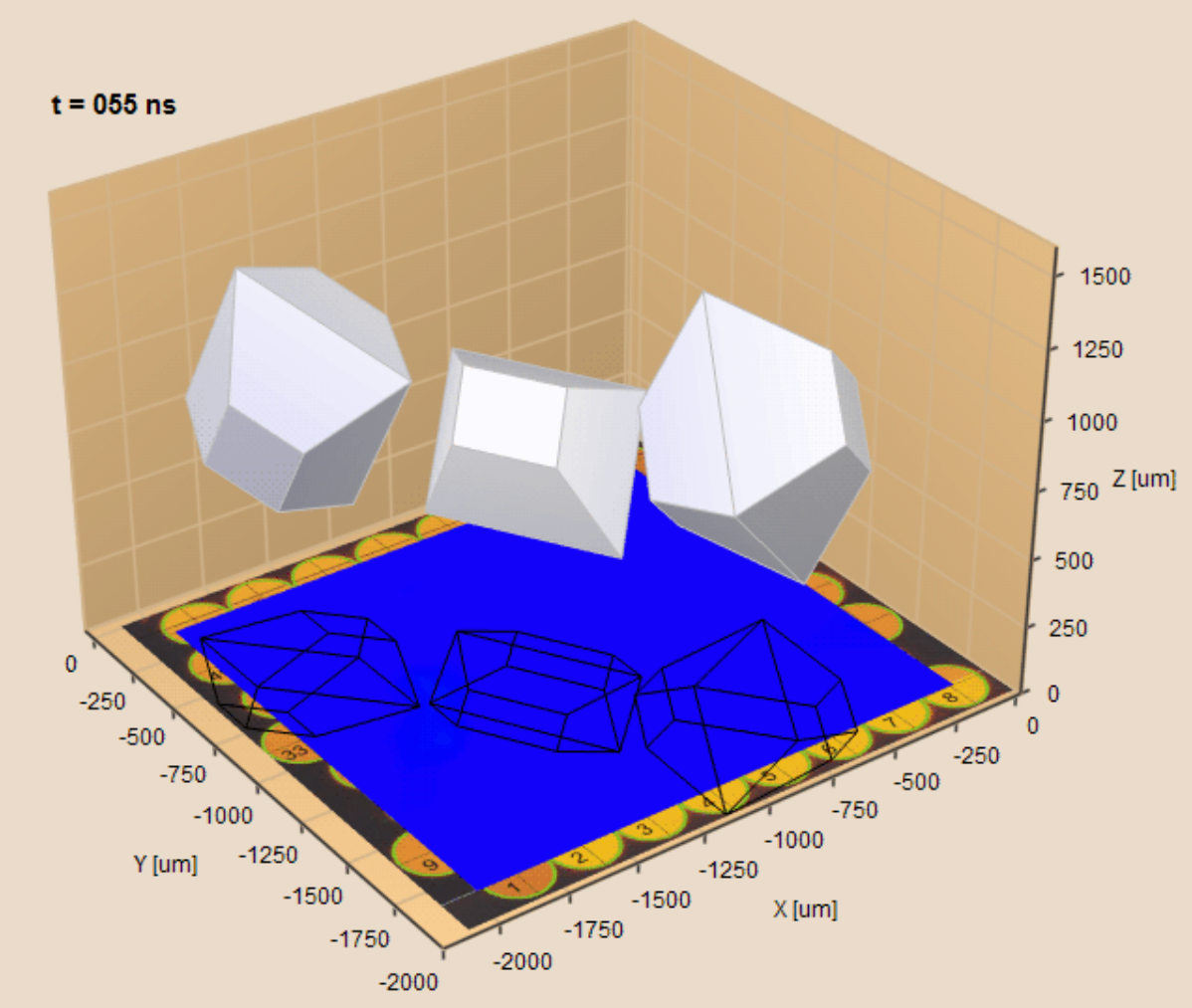


2. Experimental Setups / Configurations Examples

2.1. Single Crystal Reaction

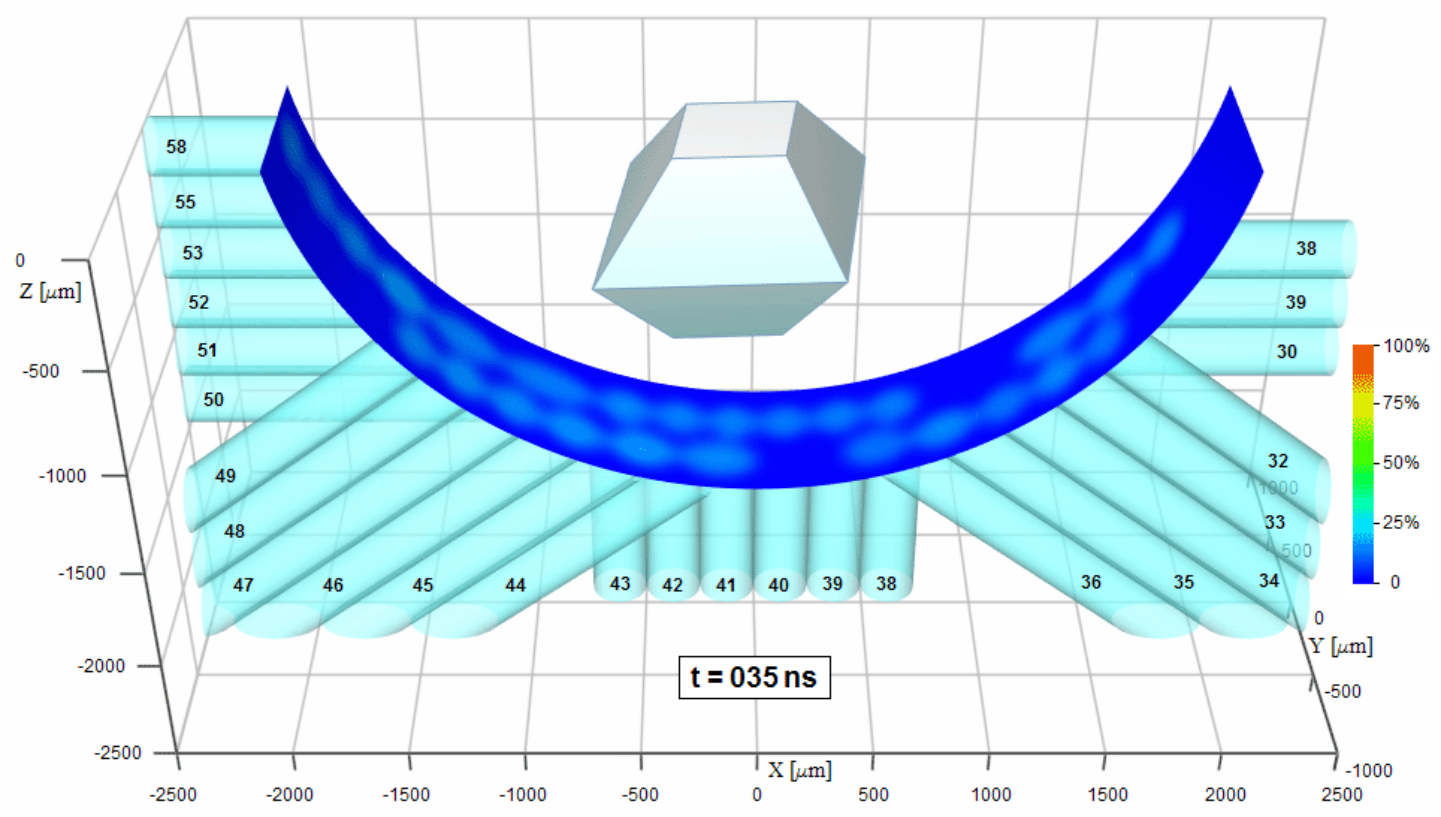
2.1.2. Single-Plane Observation (w/ 3 Crystals)



2. Experimental Setups / Configurations Examples

2.1. Single Crystal Reaction

2.1.3. Panoramic Observation



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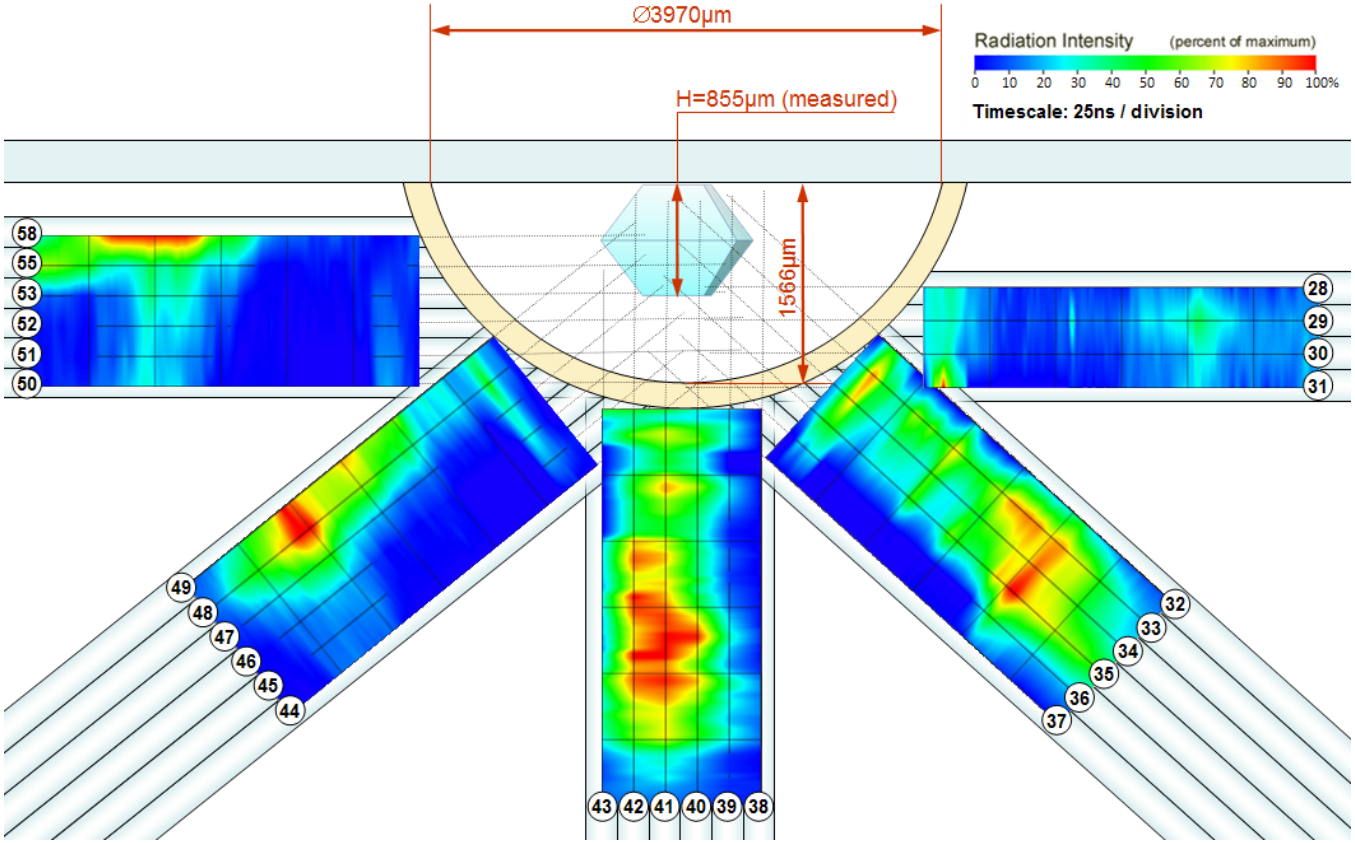
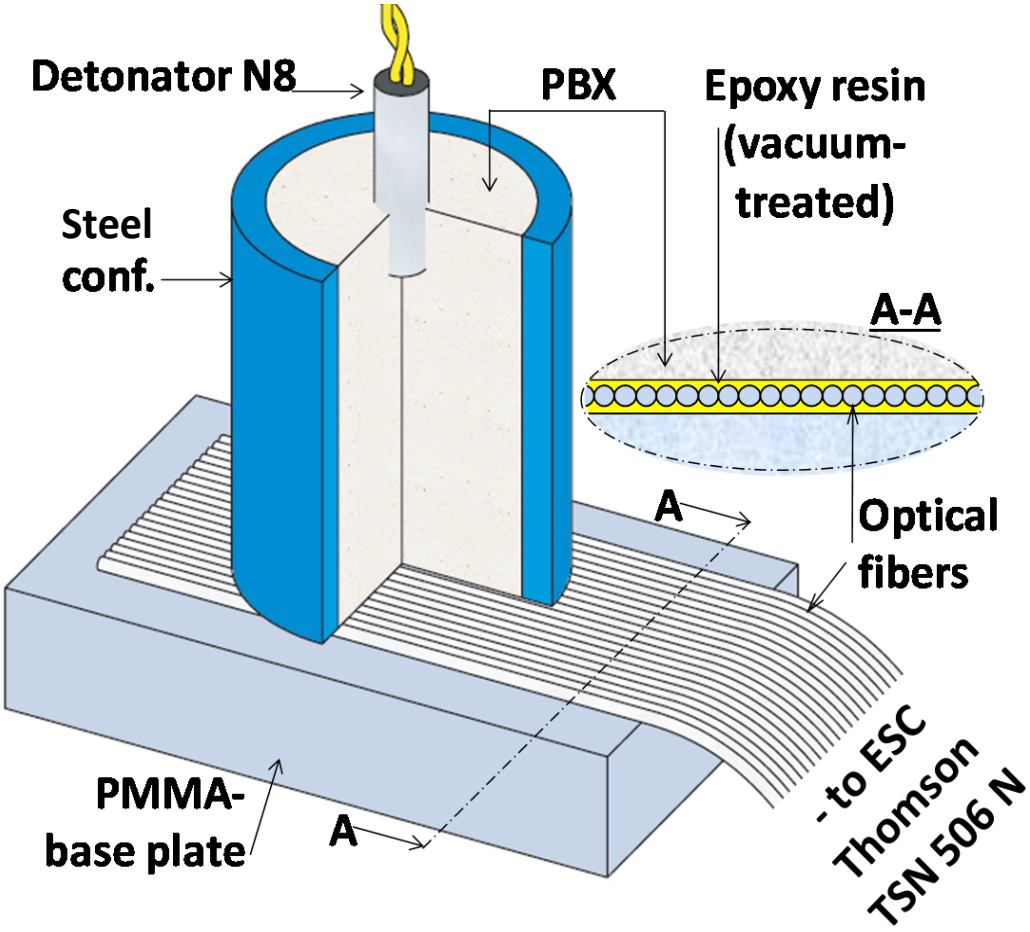
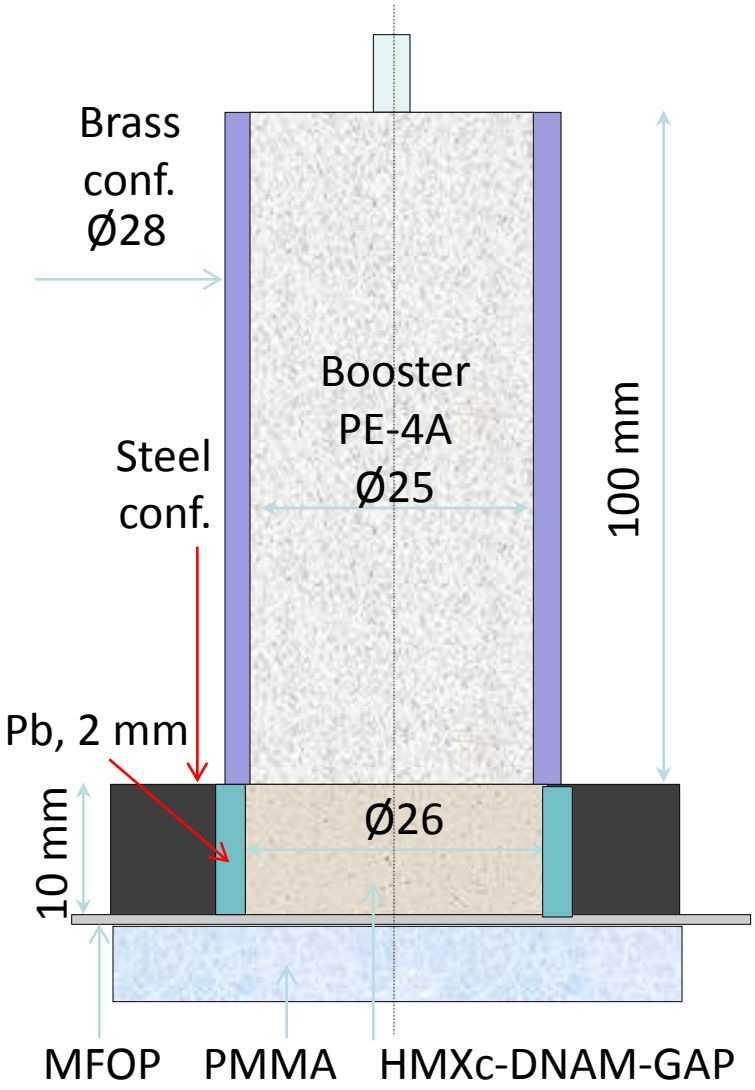


2. Experimental Setups / Configurations Examples

2.2. Long Charge Tests

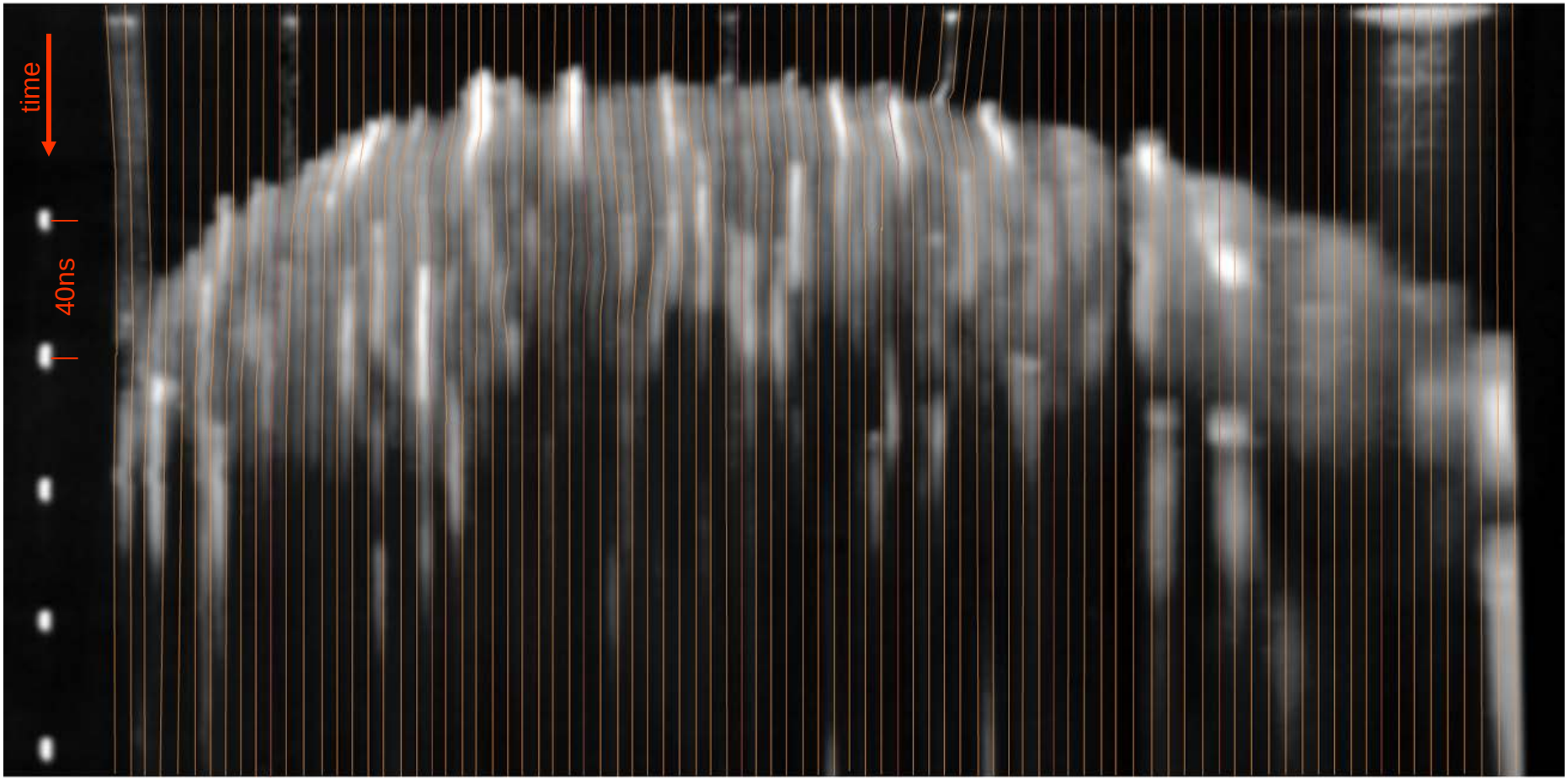




2. Experimental Setups / Configurations Examples

2.2. Long Charge Tests

Streak Record (Photochronogram)



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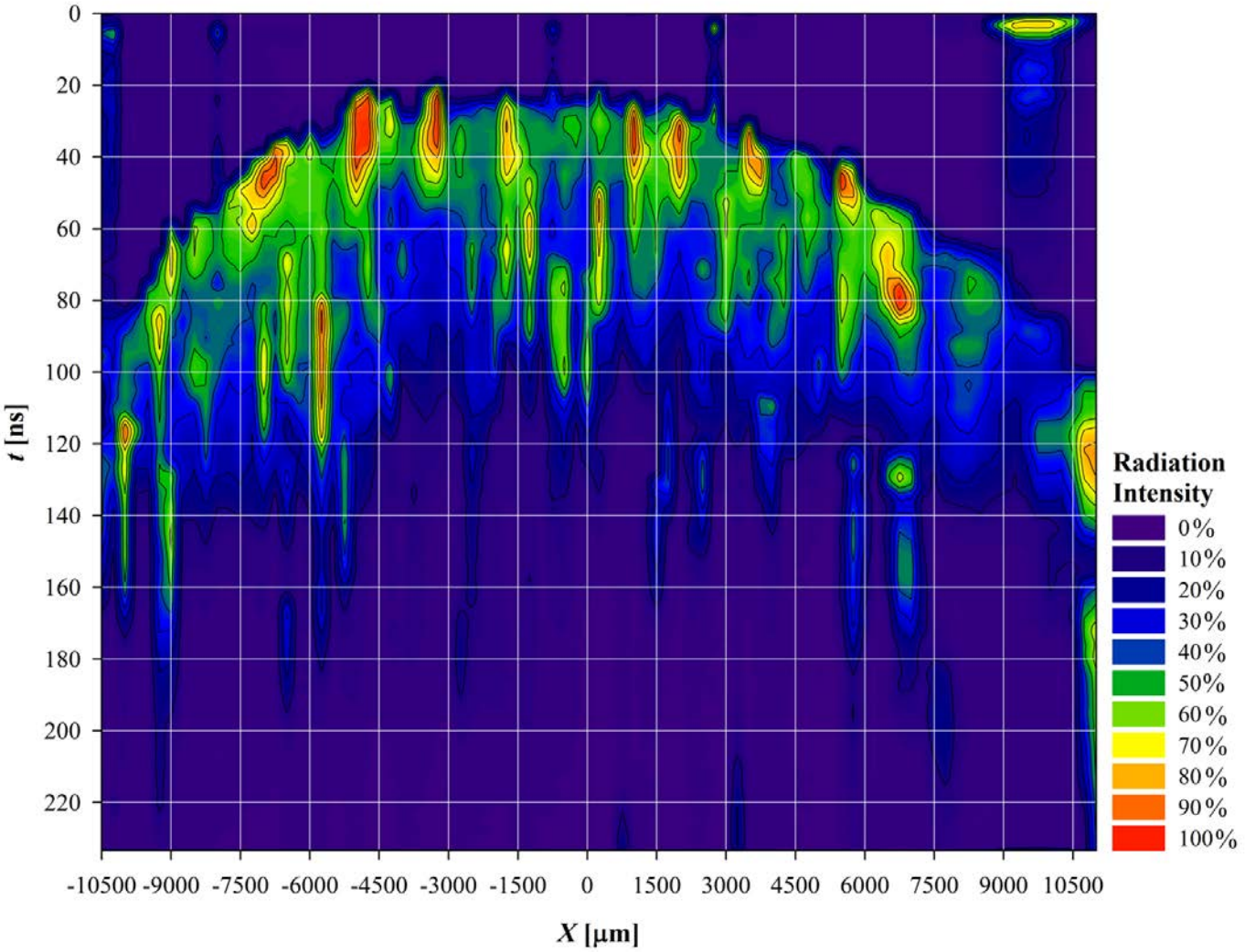

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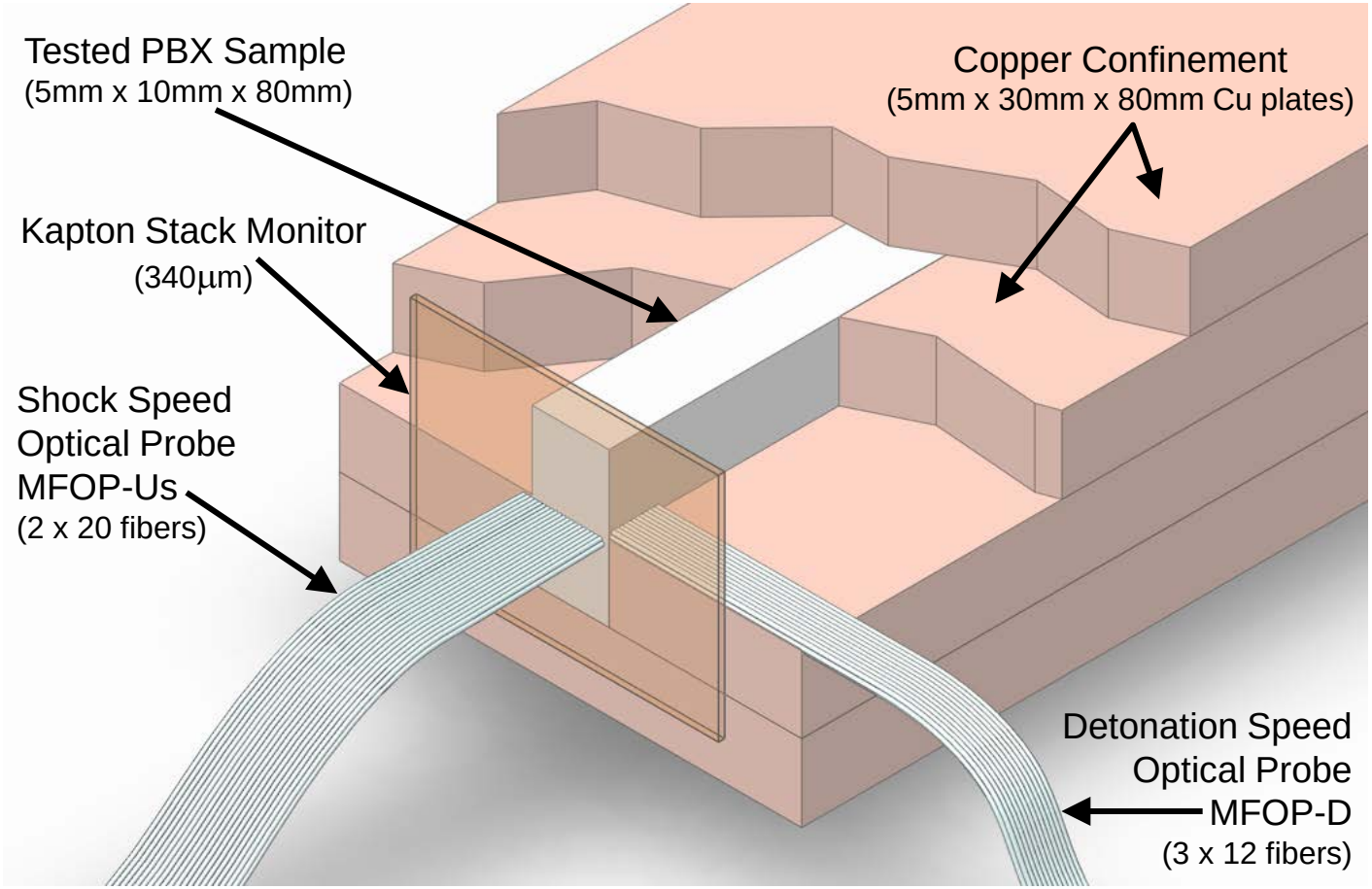

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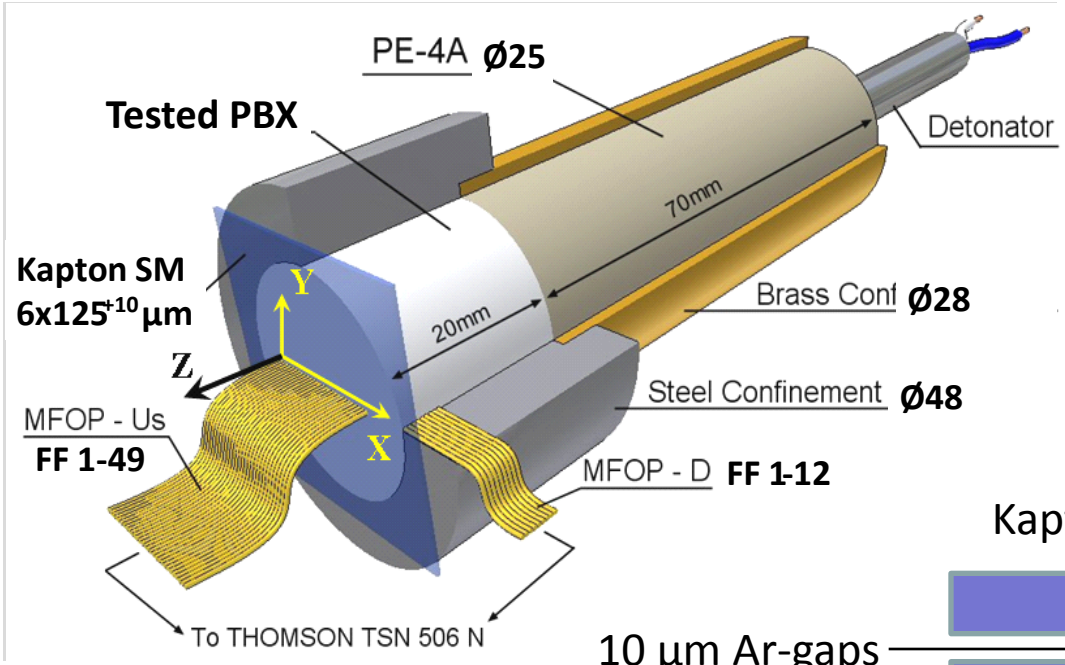
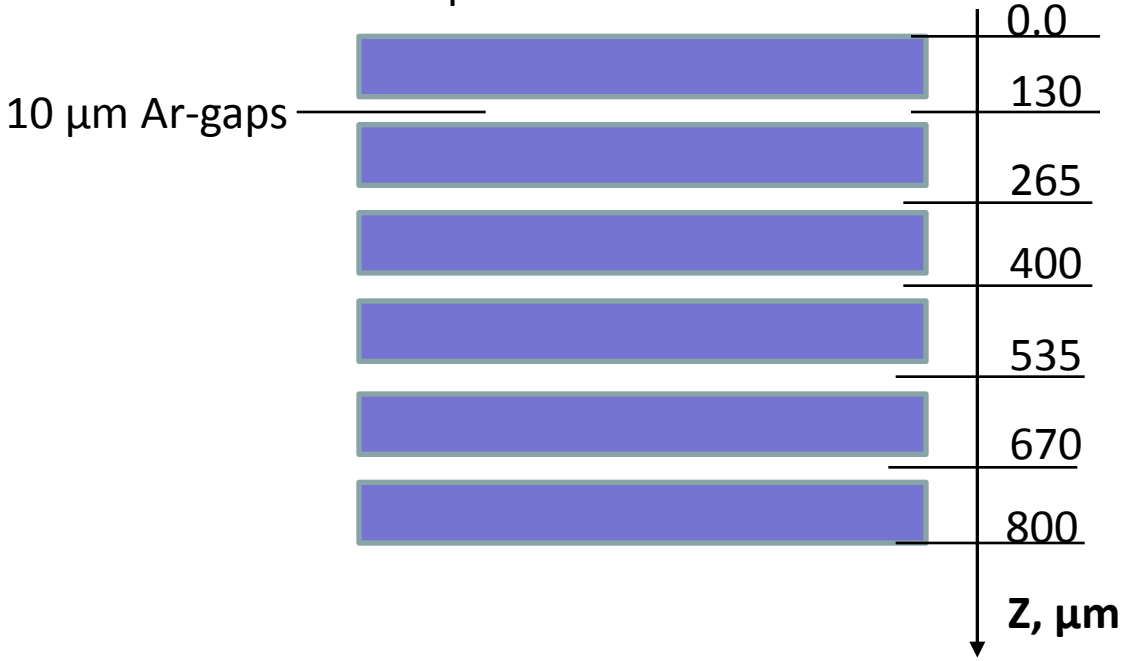


Shock Hugoniot of Kapton:

$P(Us)_{Kapton} \cong 3.7\times(\tanh(4\times(Us-6.24)+1)+0.5\times(\tanh(50\times Us-125)+1)\times(1.009\times Us^2-3.118\times Us+1.547)$

Kapton Stacked Monitor



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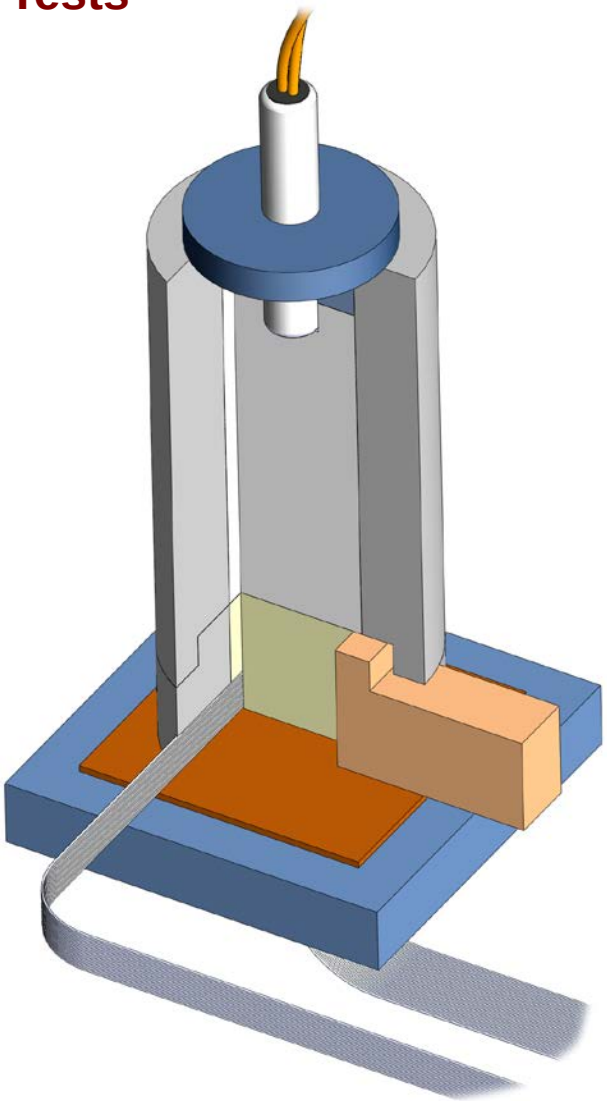
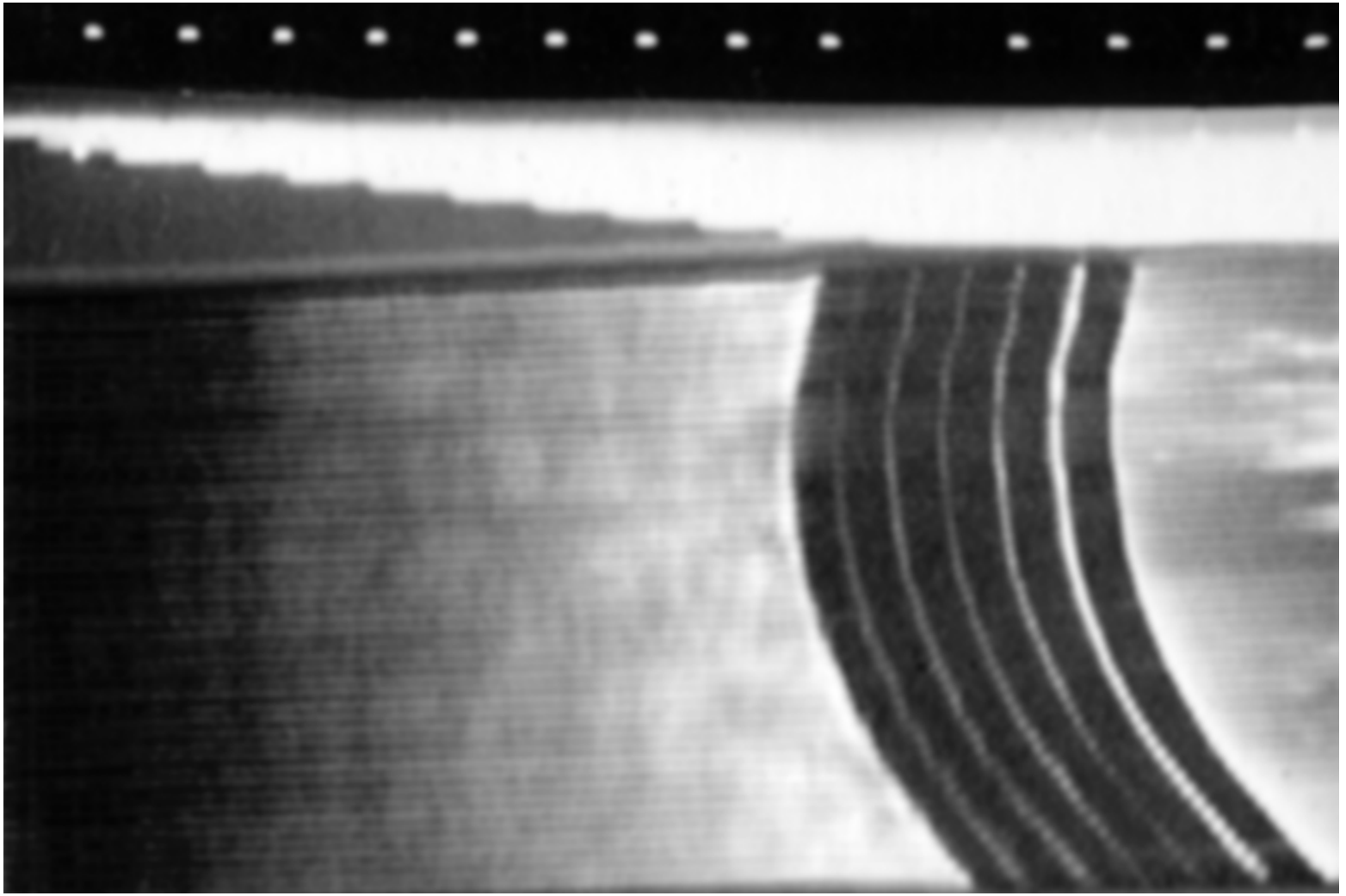


2. Experimental Setups / Configurations Examples

2.2. Long Charge Tests

Long Charge Test (LCT)
RDX 93.0 / 7.0 wt. HTPB



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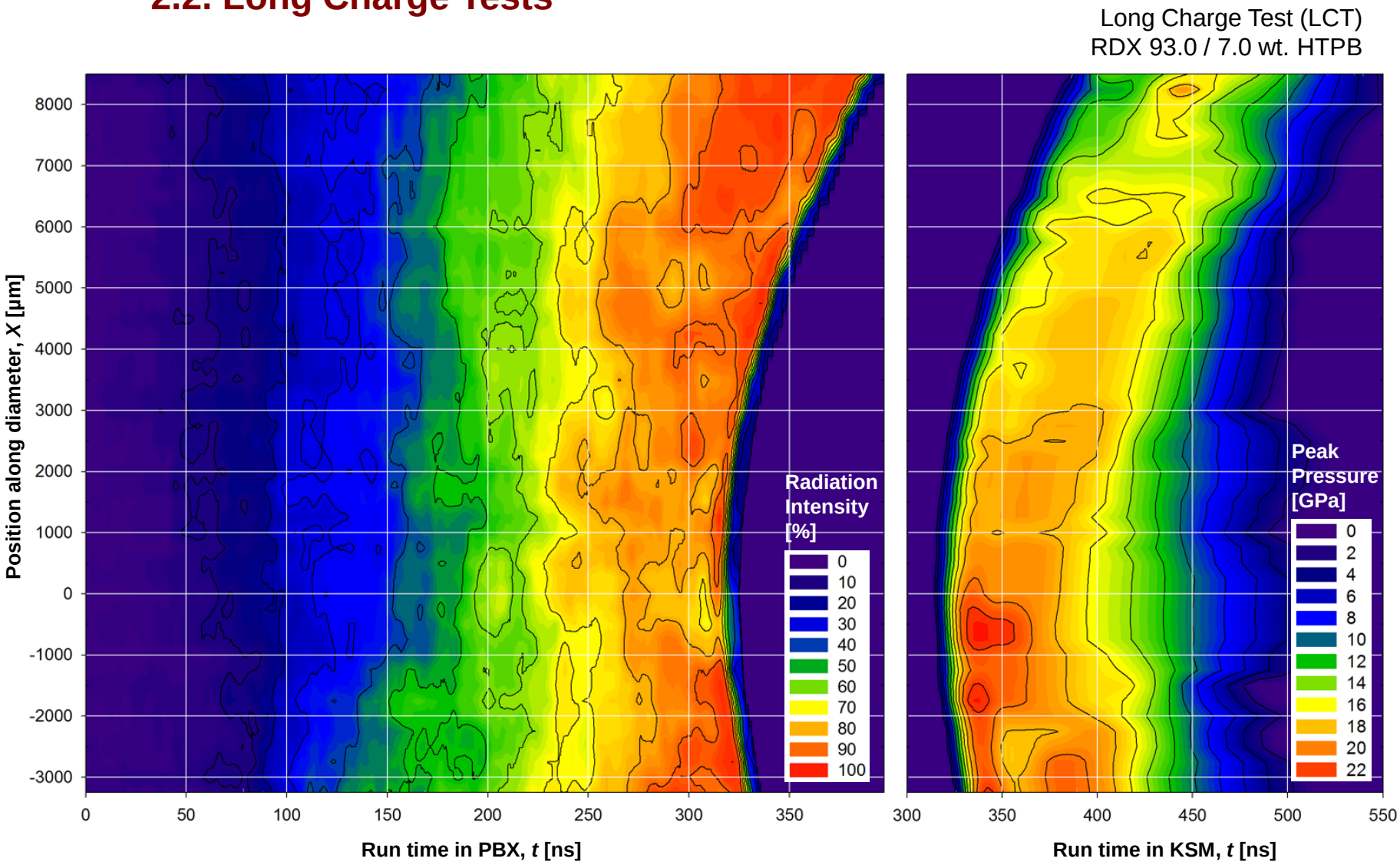

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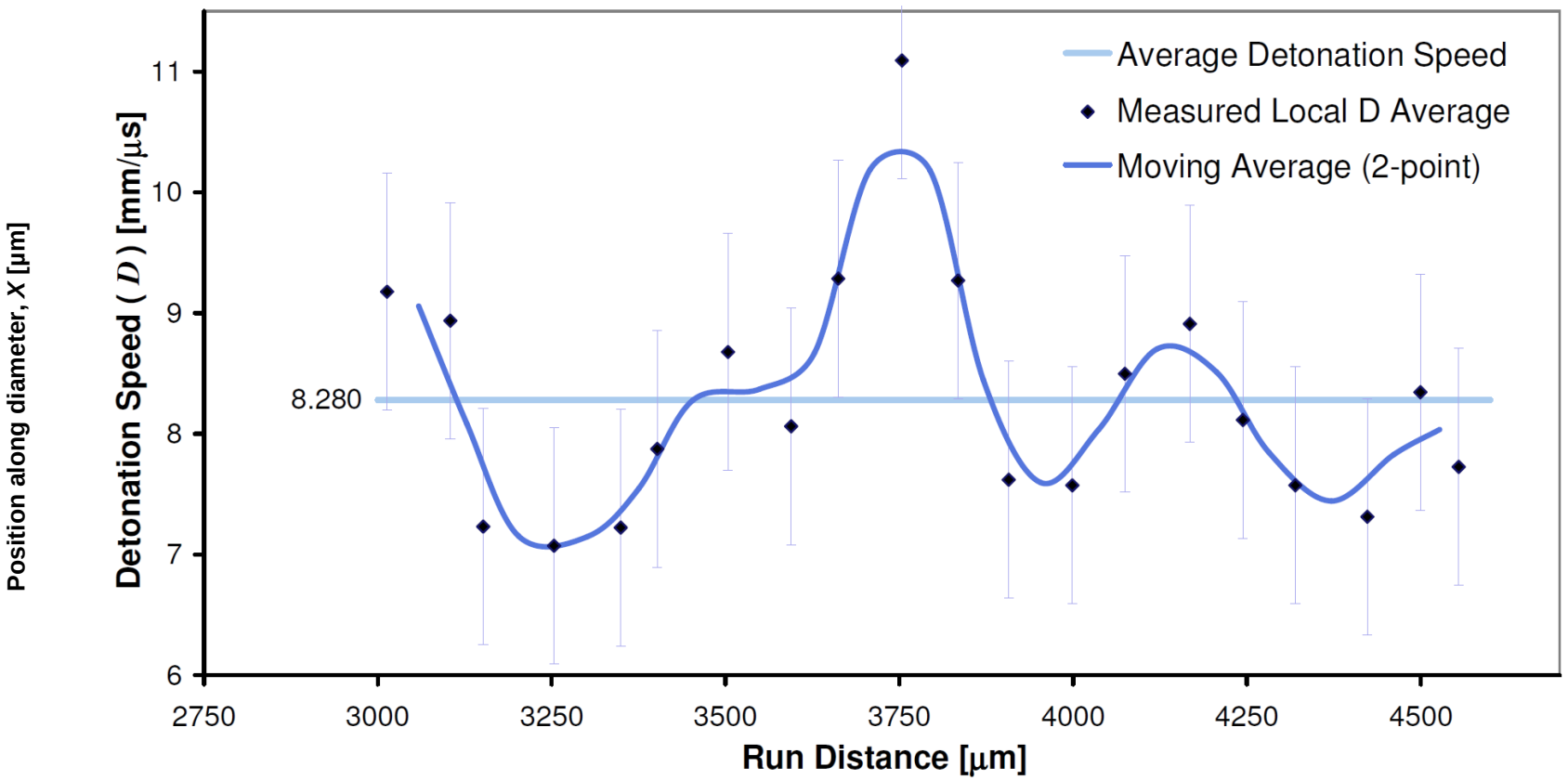

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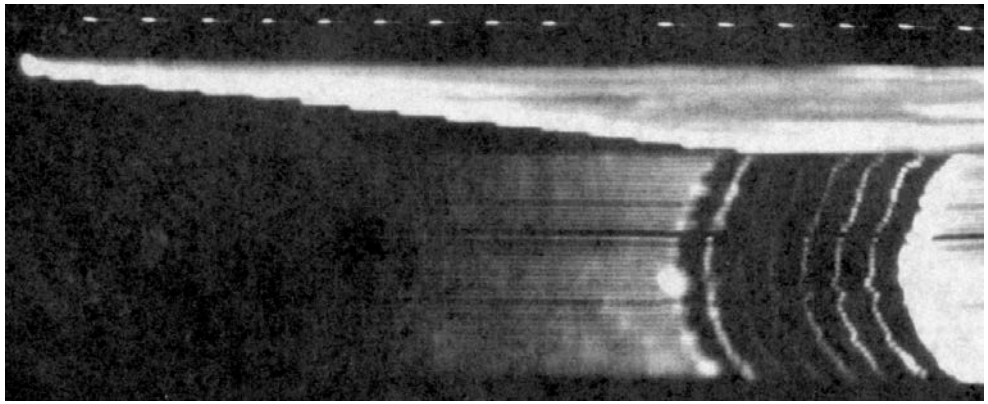
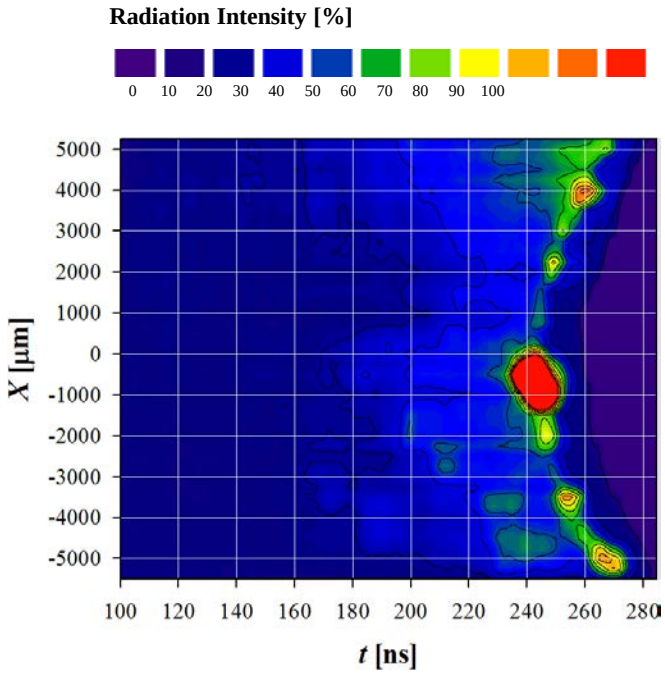
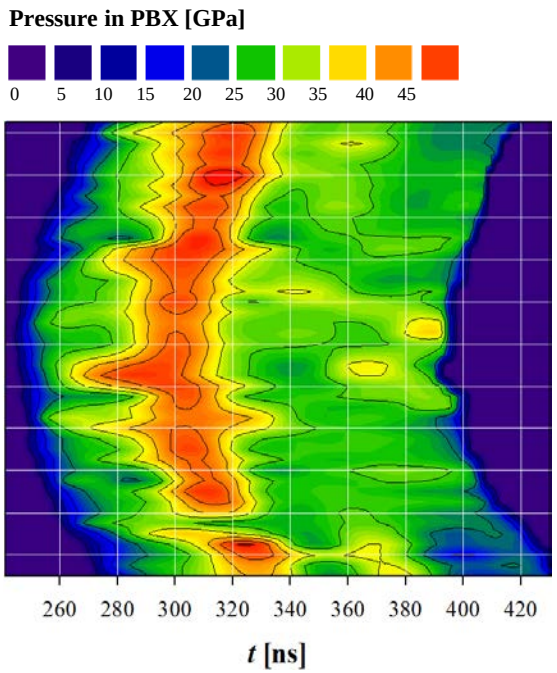


ρ_0(RS-PBX) (g/cm^3)	1.572
D (mm/μs)	7.51
ρ_0(Kapton) (g/cm^3)	1.414

D = 7.51 mm/μs





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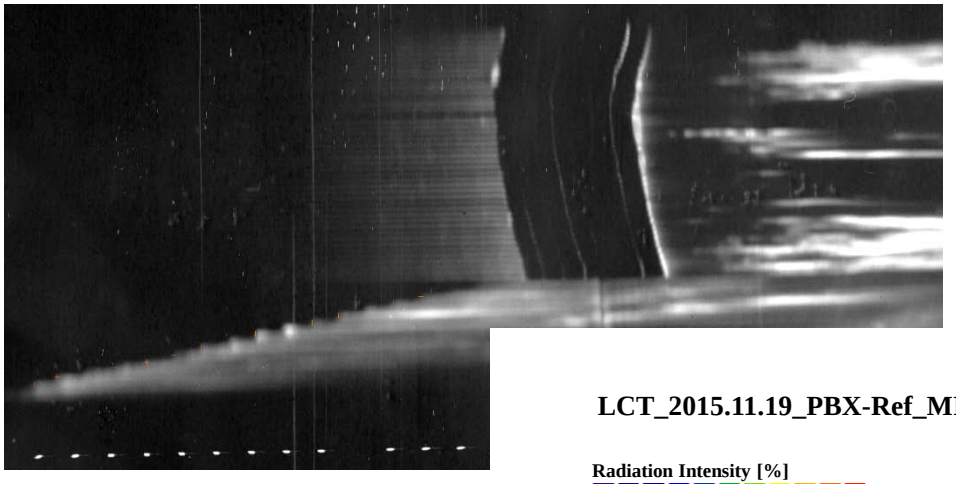
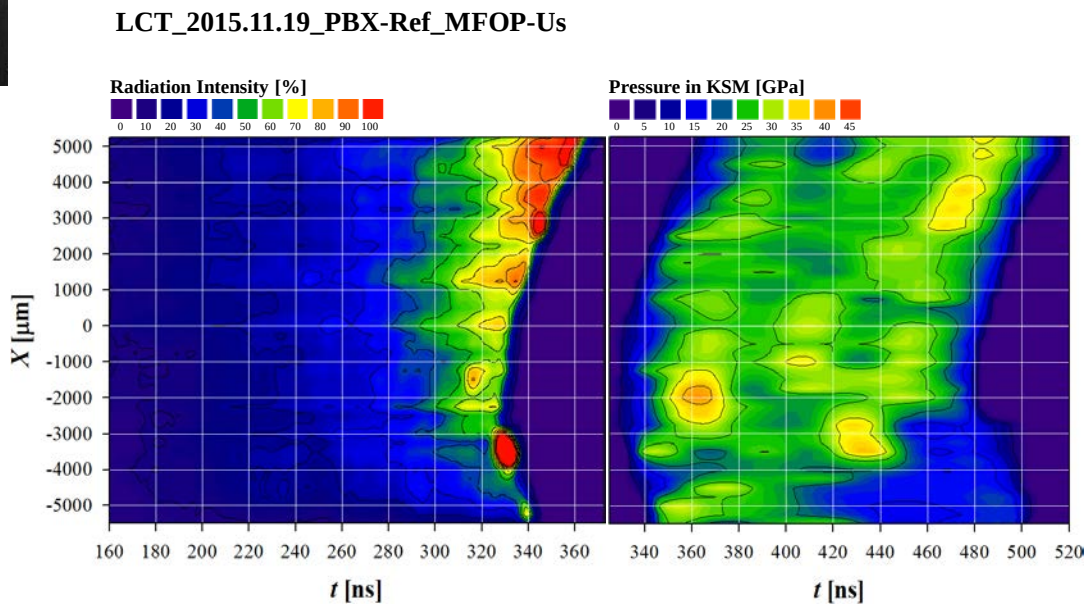


ρ_0 (PBX-Ref) (g/cm^3)	1.54
D (mm/µs)	7.79
ρ_0(Kapton) (g/cm^3)	1.414

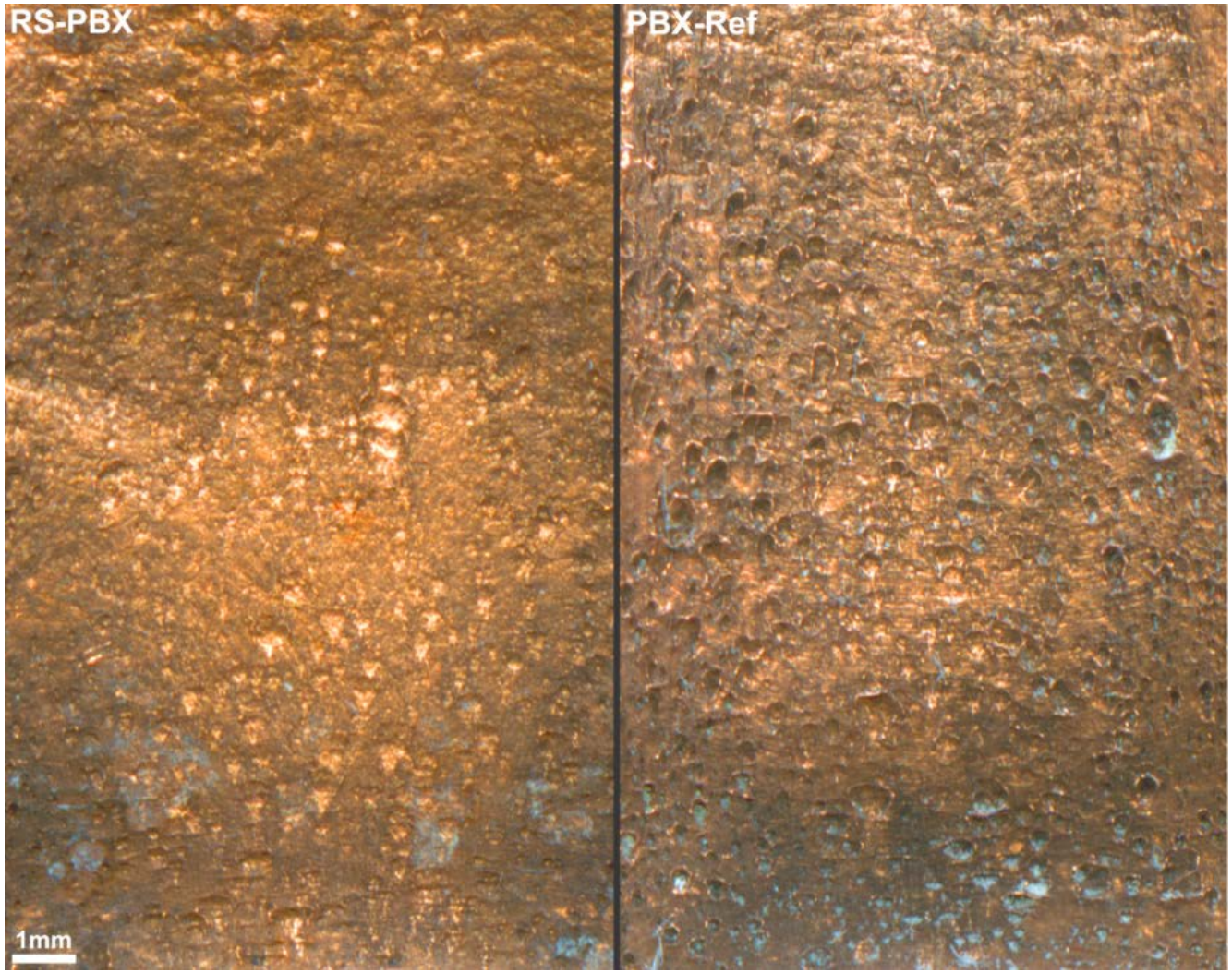
D = 7.79 mm/µs



2. Experimental Setups / Configurations Examples

2.2. Long Charge Tests

Witness Plate (Copper Insert) Surface Analysis



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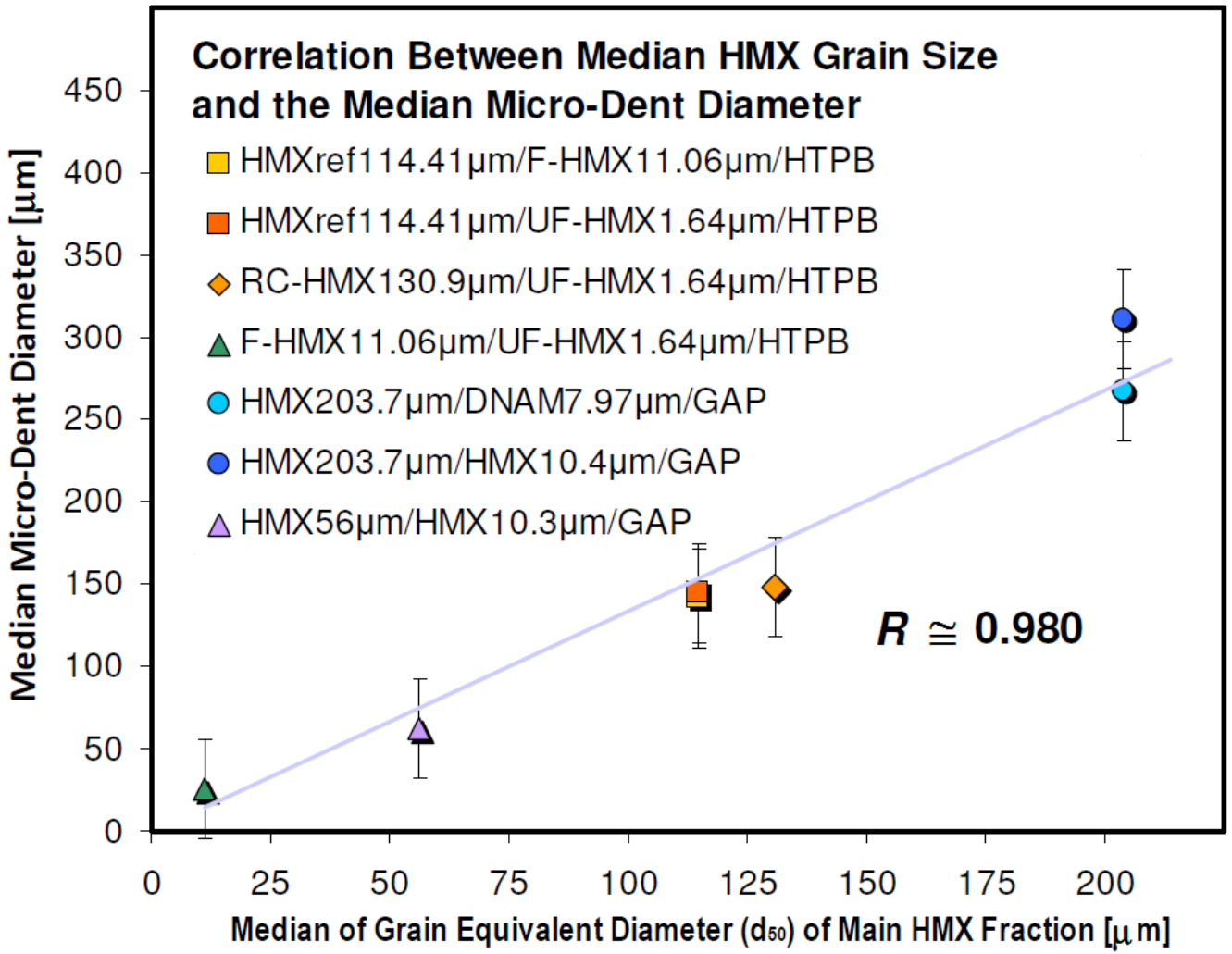

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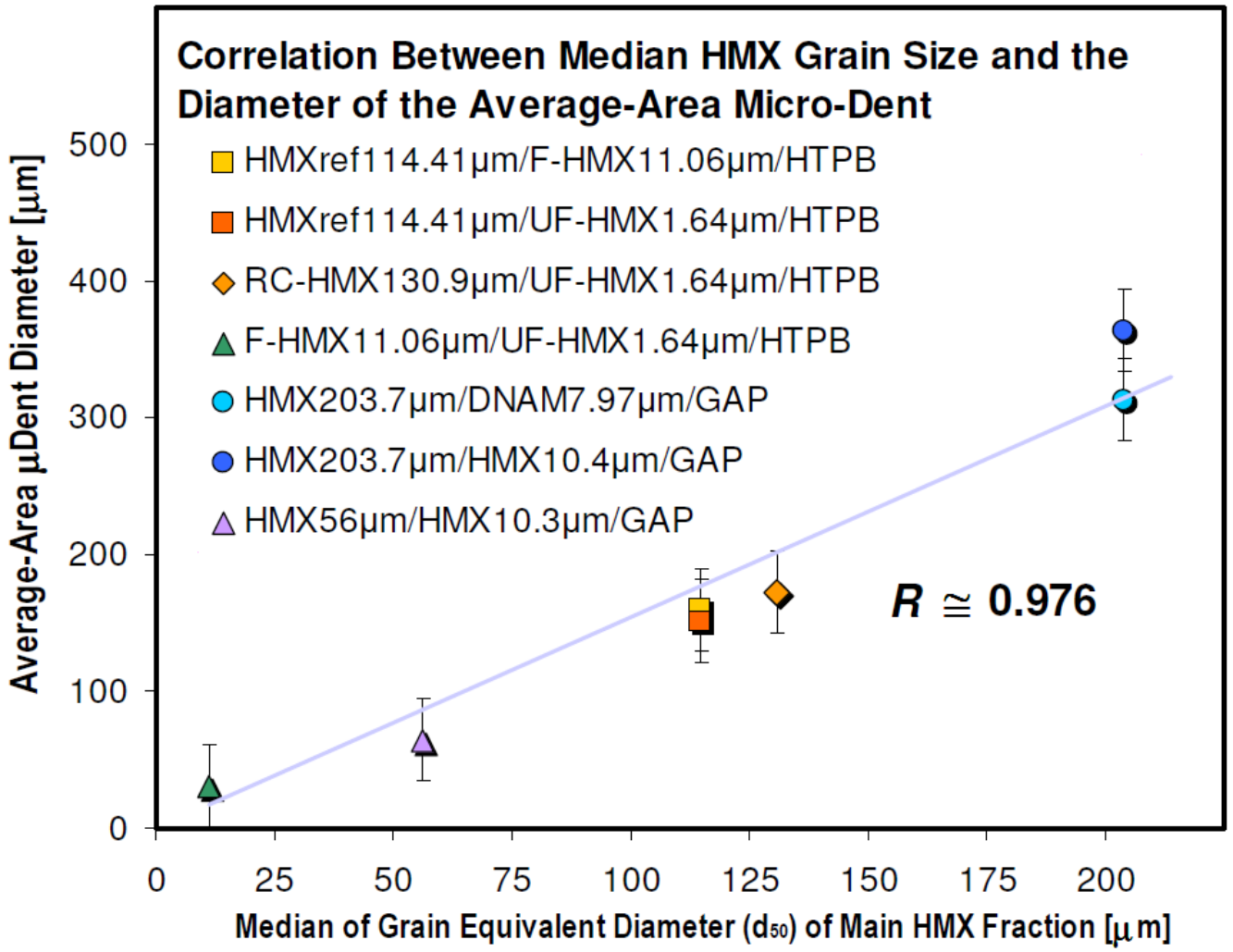
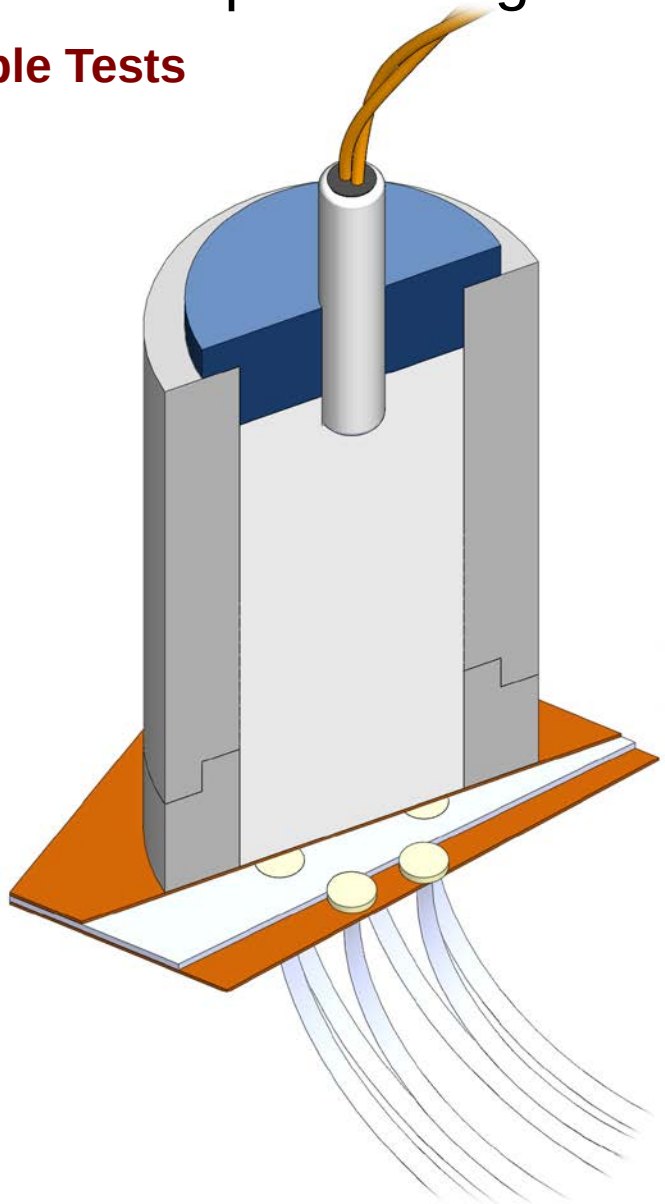


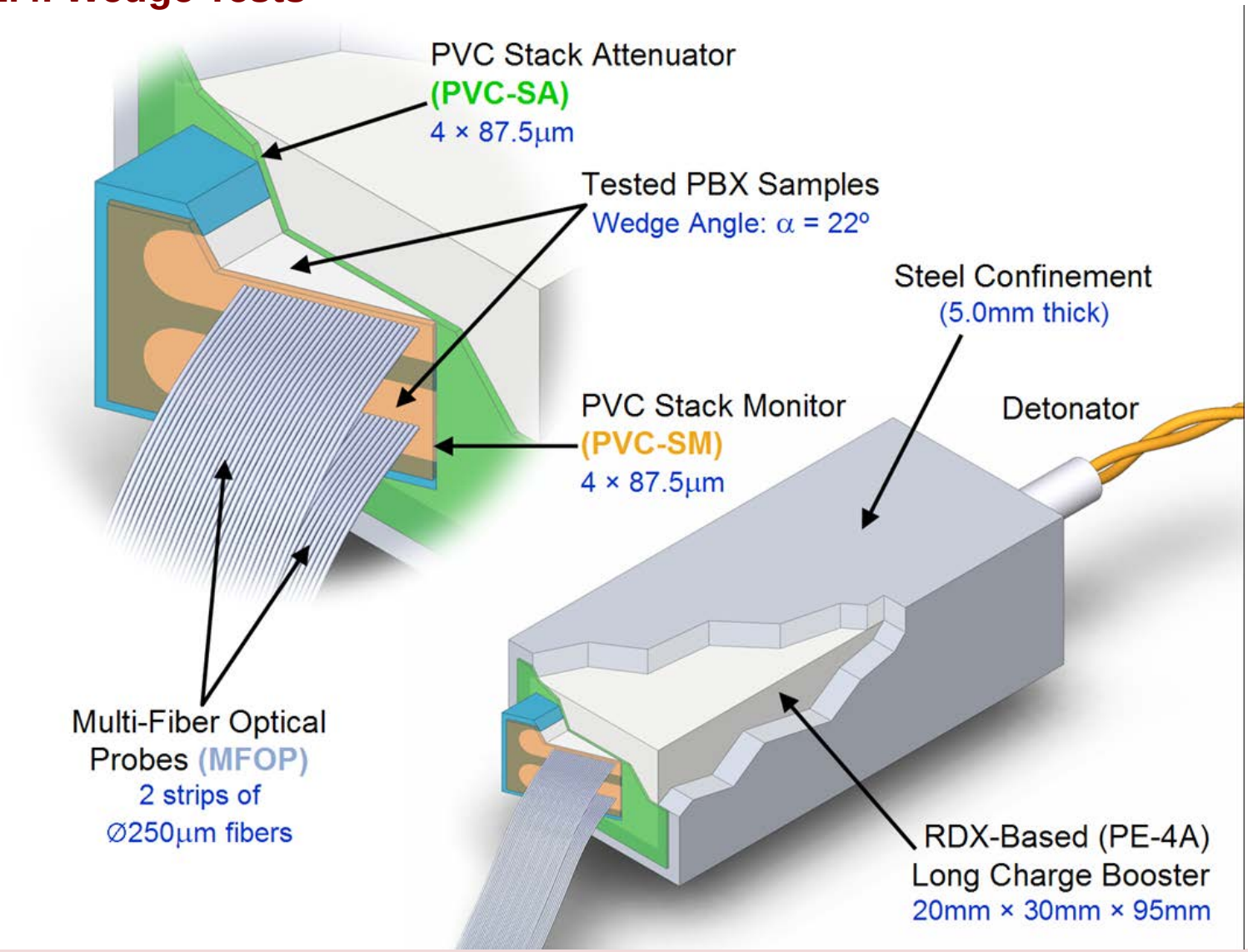
2. Experimental Setups / Configurations Examples

2.2. Multi-Sample Tests



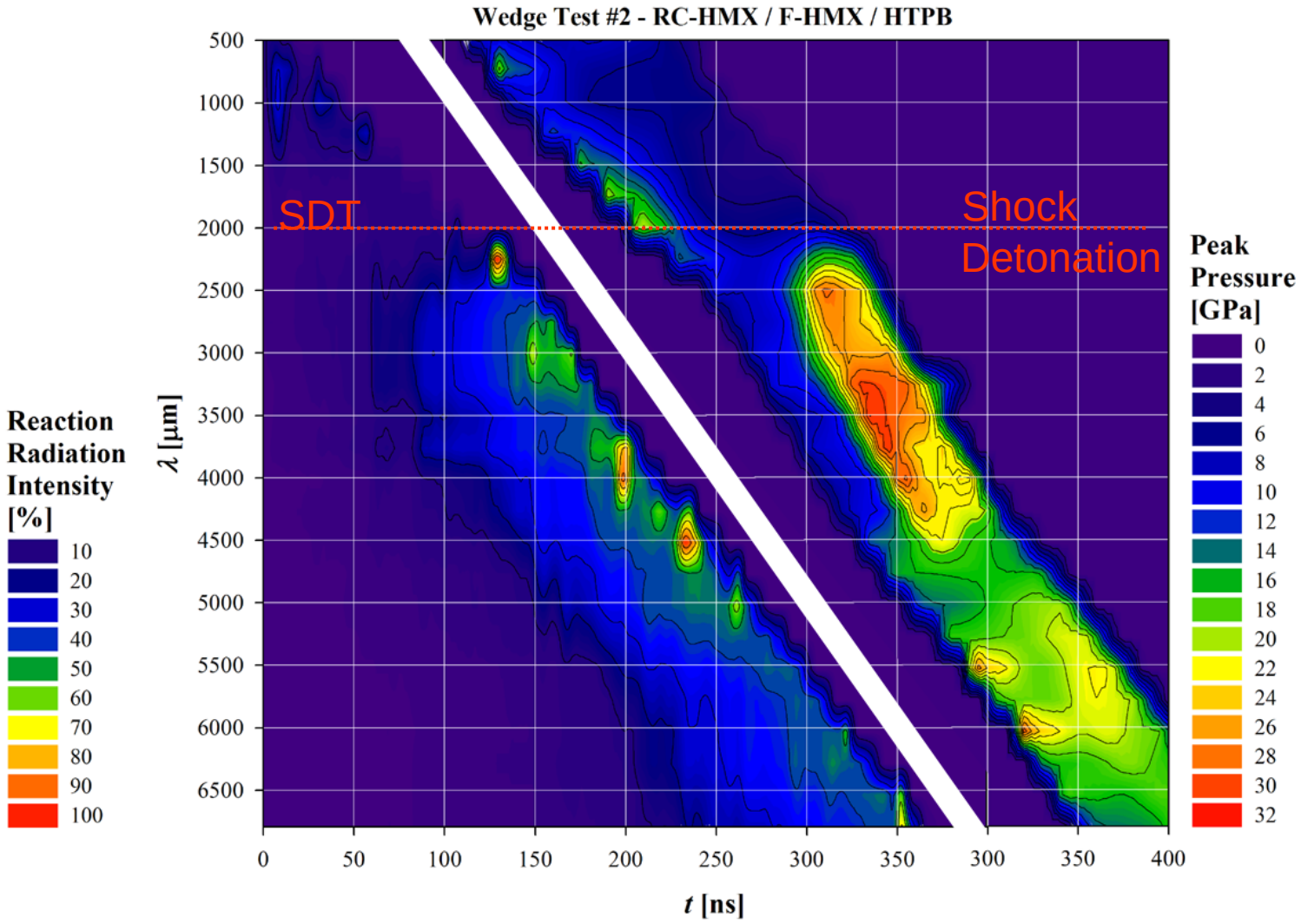
2. Experimental Setups / Configurations Examples

2.4. Wedge Tests



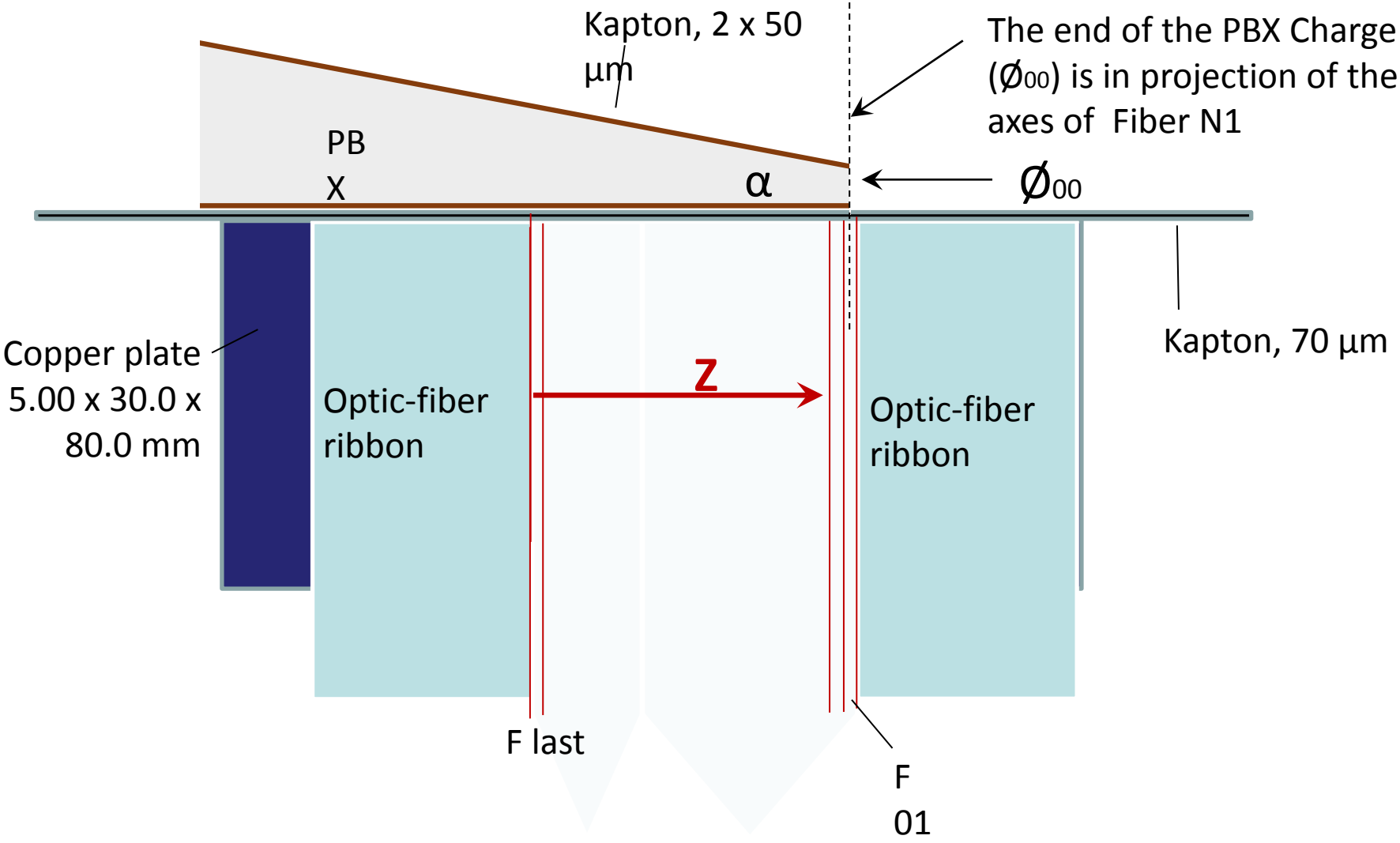
2. Experimental Setups / Configurations Examples

2.4. Wedge Tests – Shock-To-Detonation Transition



2. Experimental Setups / Configurations Examples

2.5. Detonation Extinction Diameter Tests (Conical Failure Tests)



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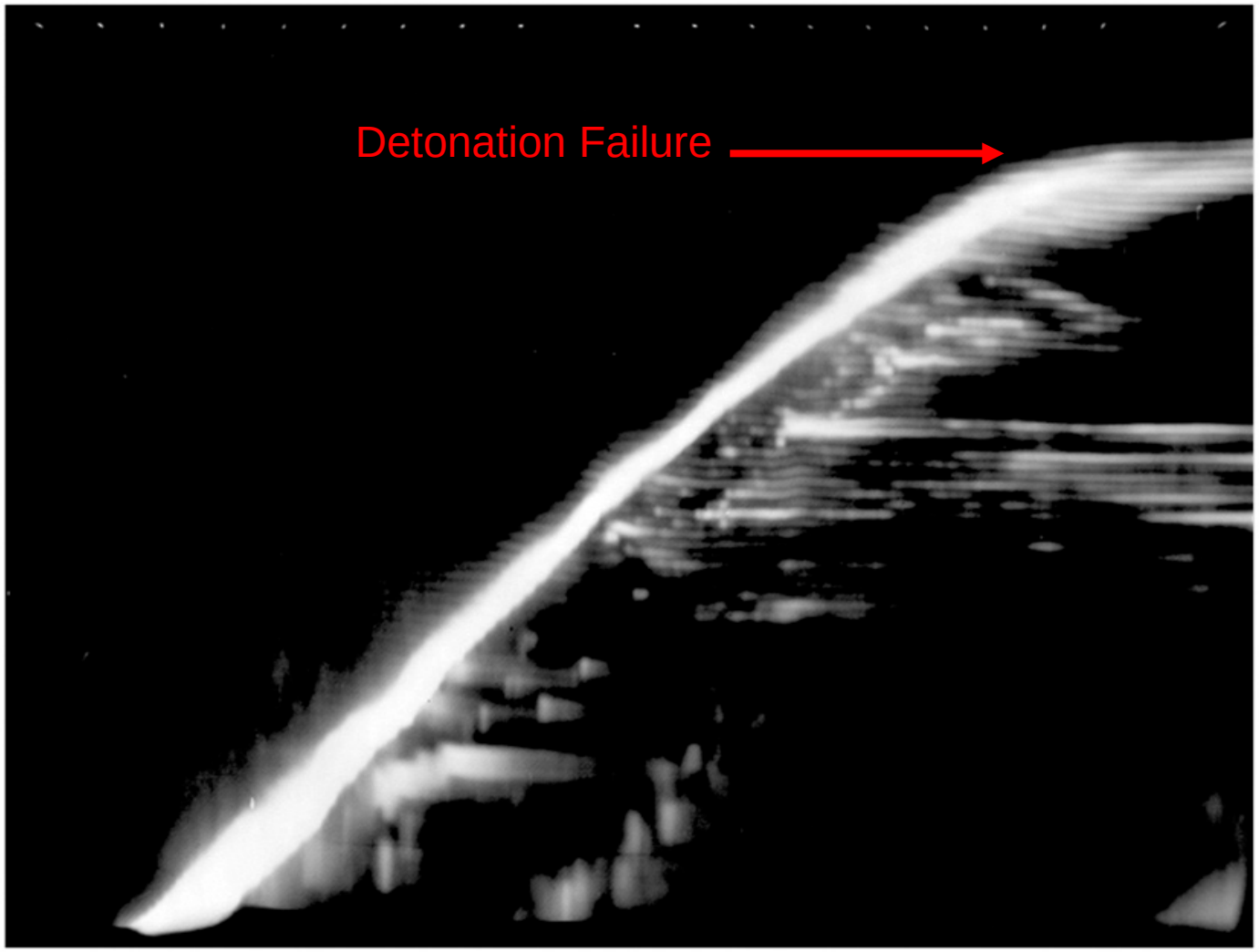
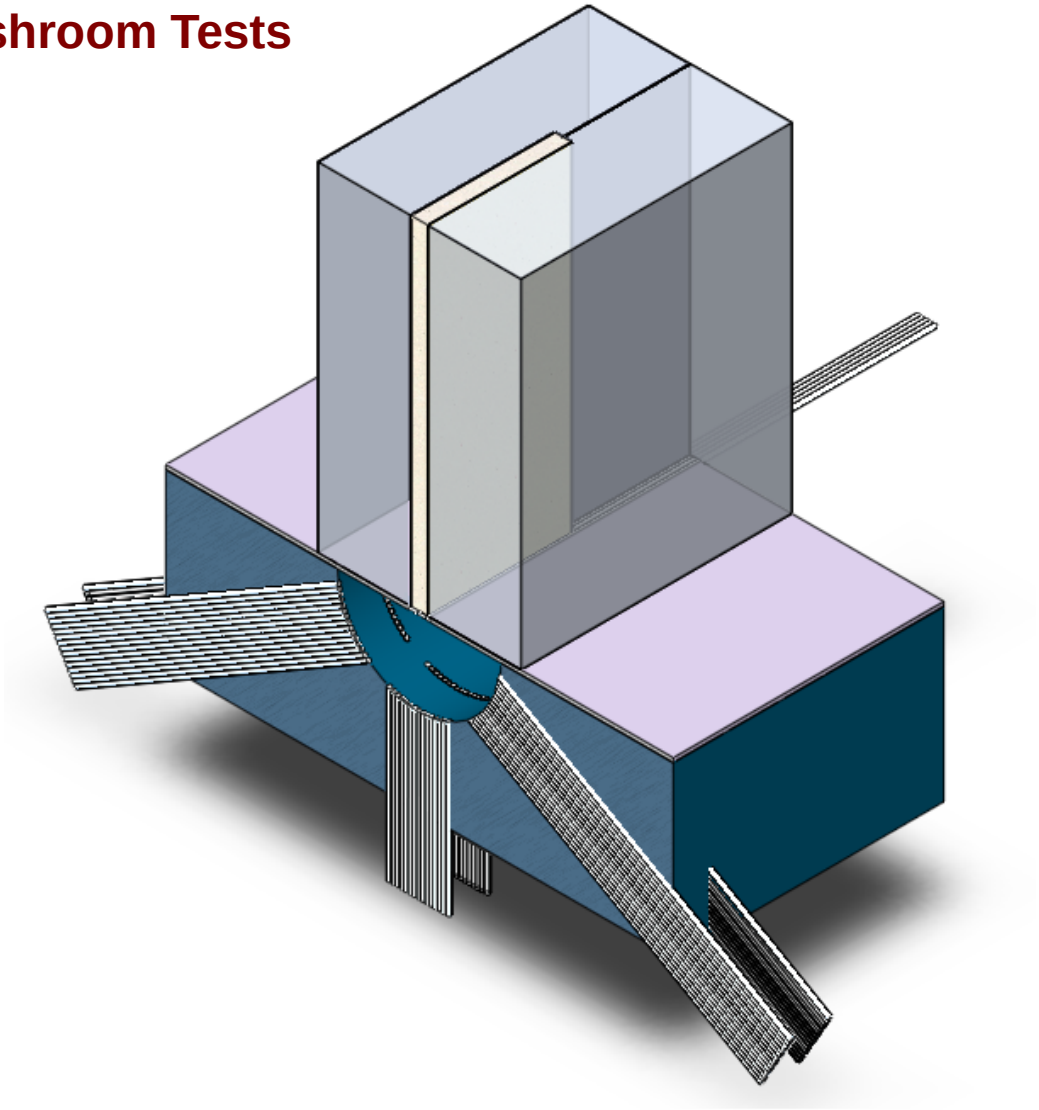


2. Experimental Setups / Configurations Examples

2.6. Mushroom Tests



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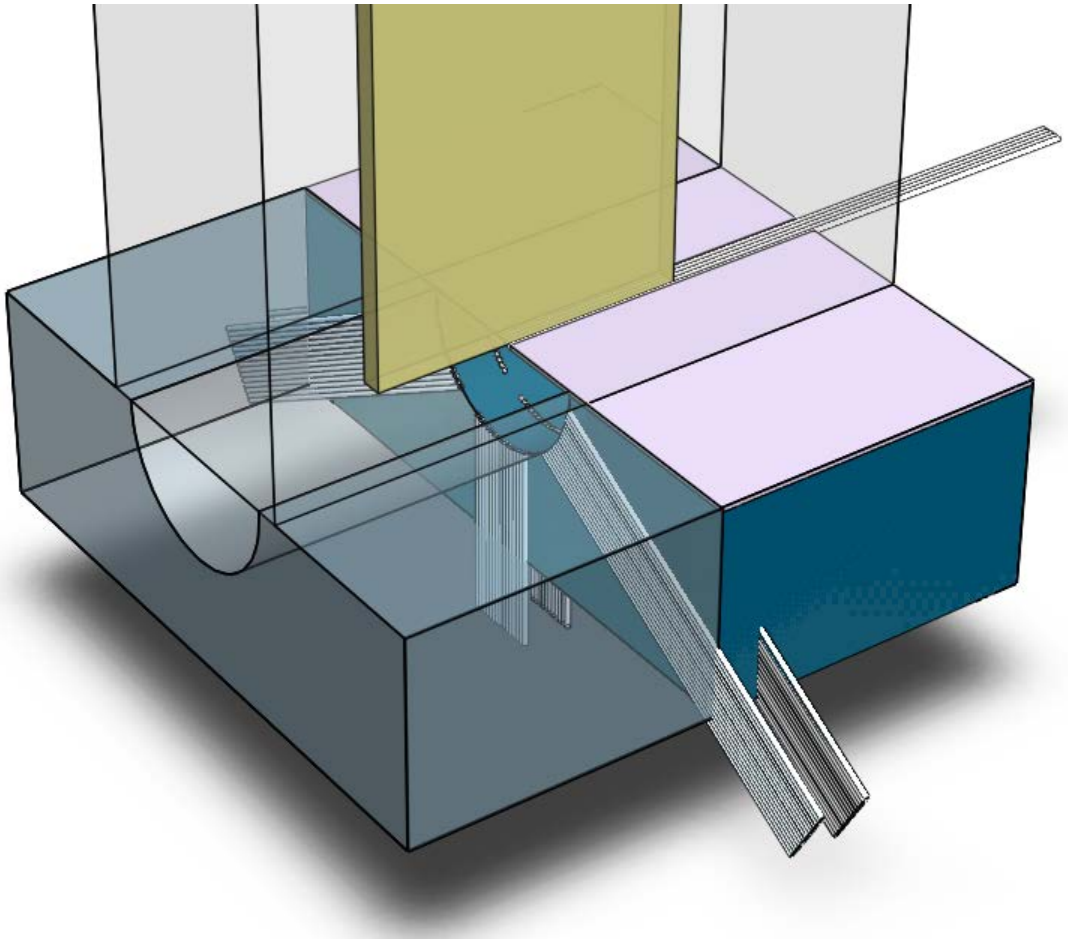

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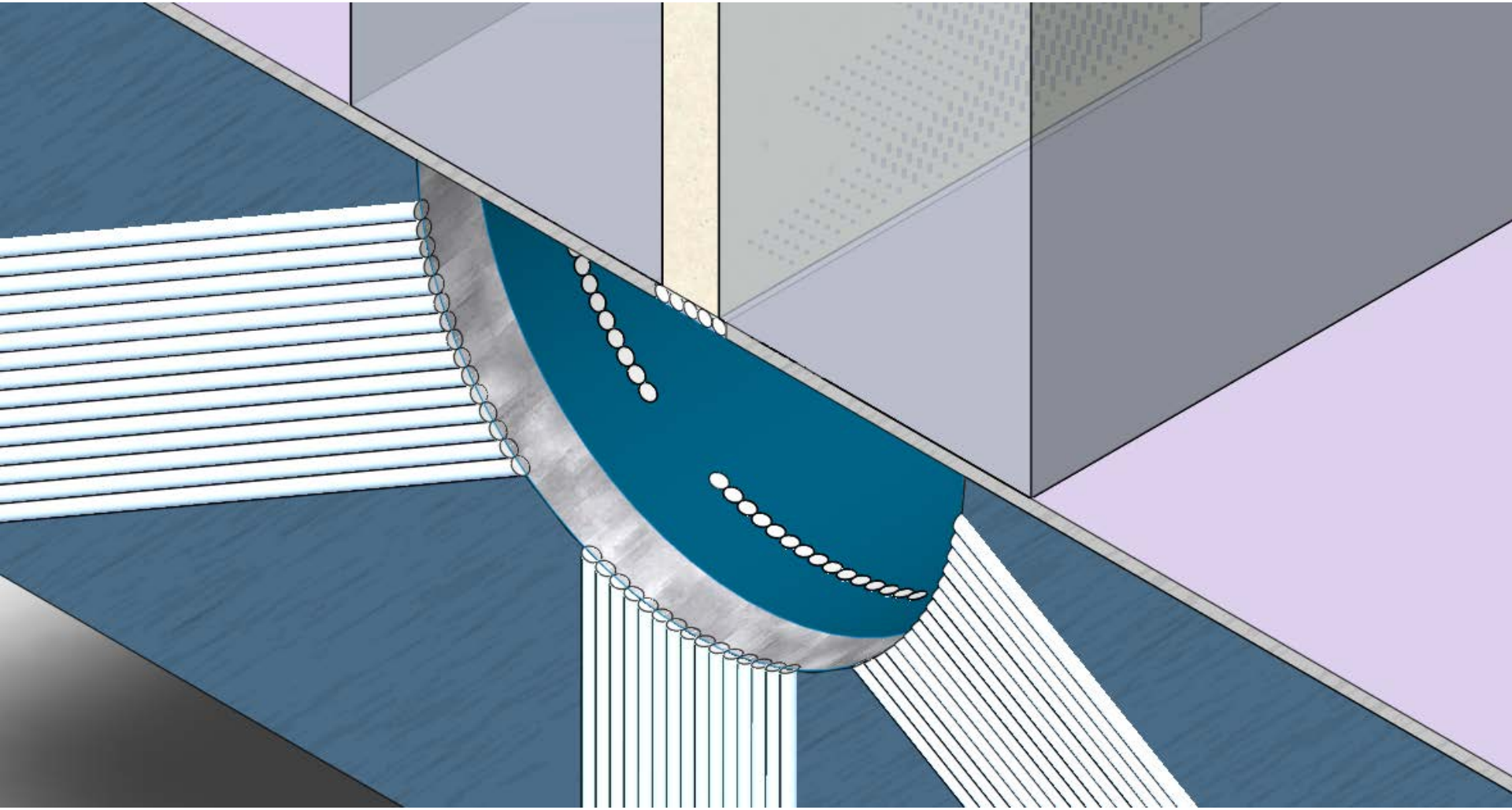

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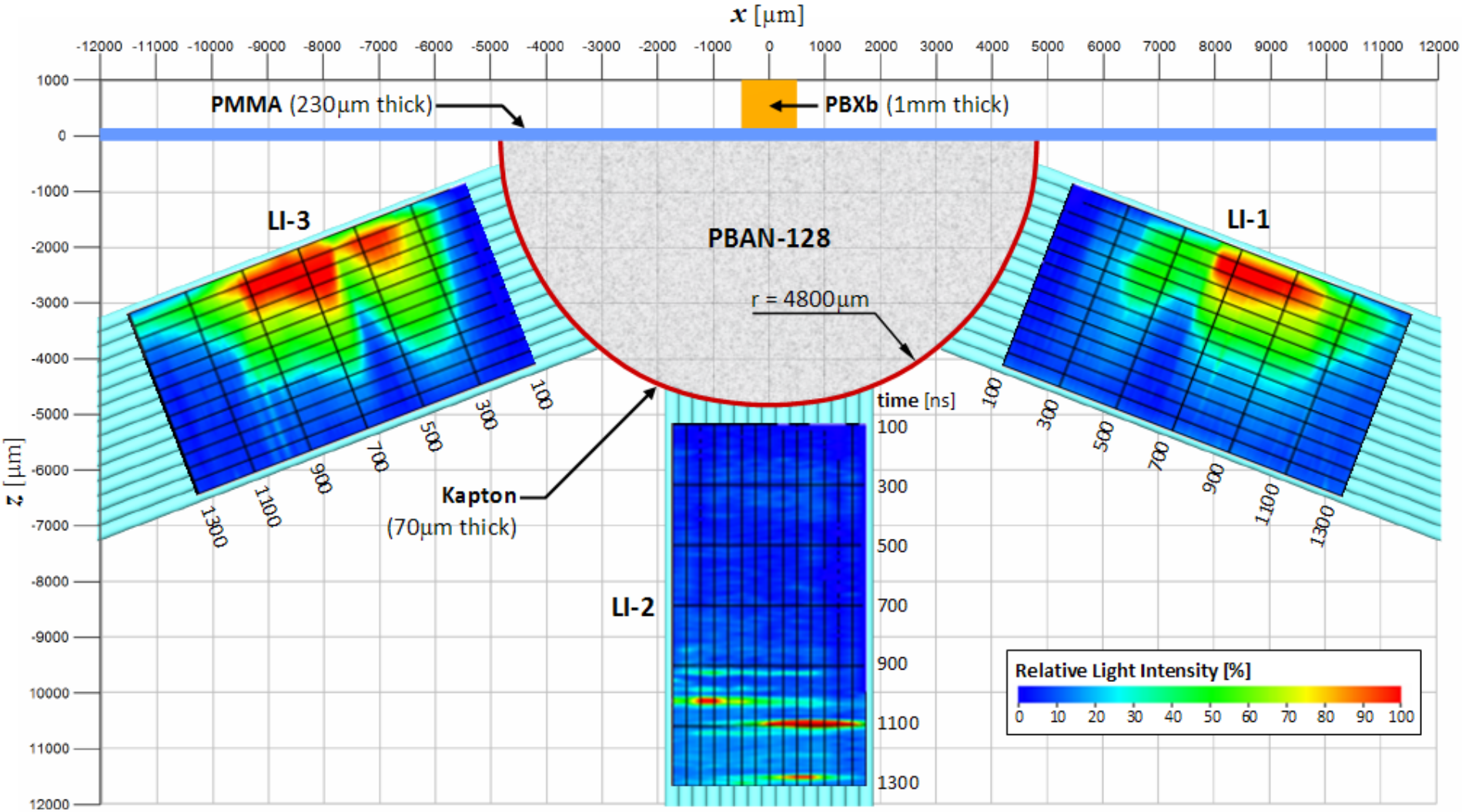

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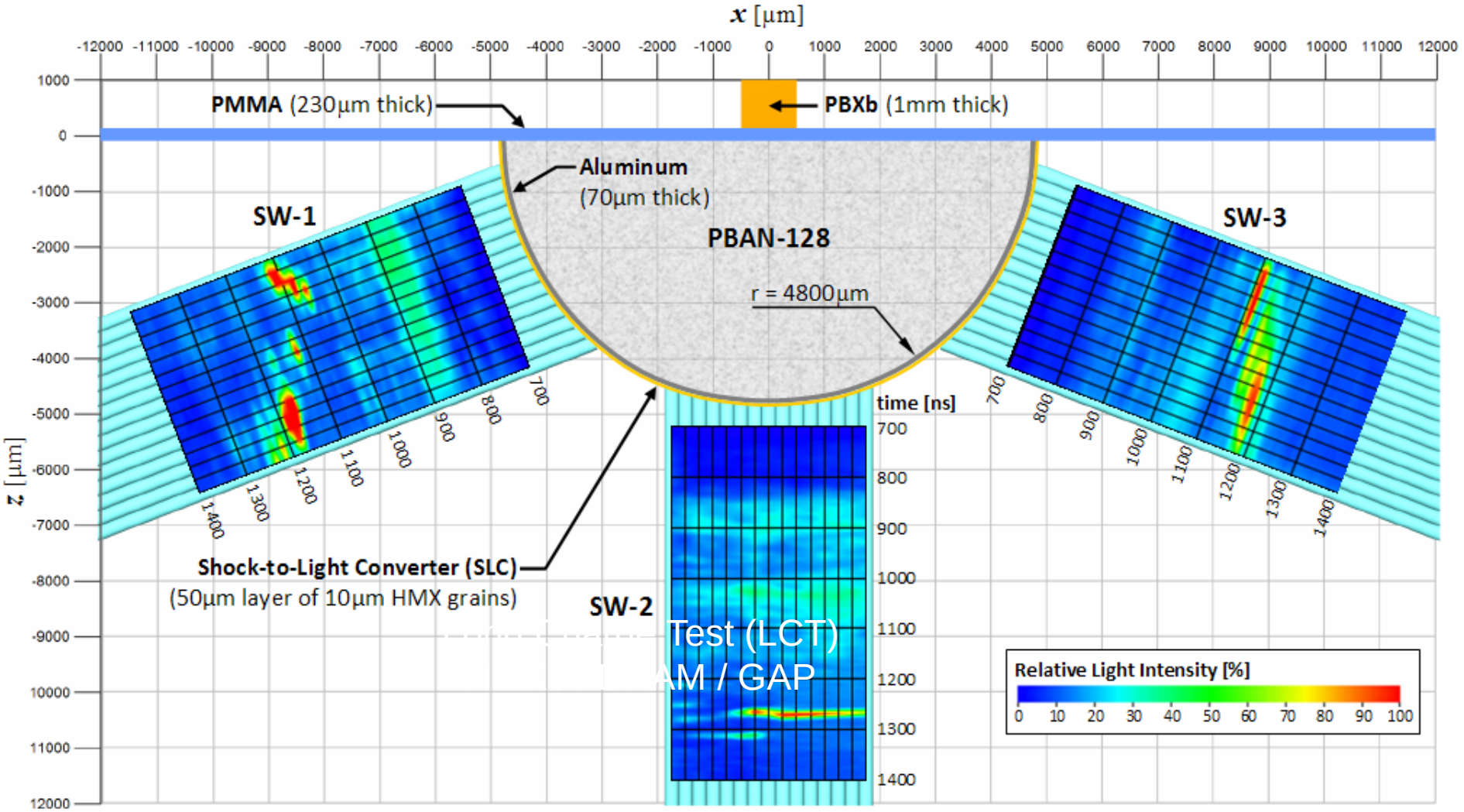

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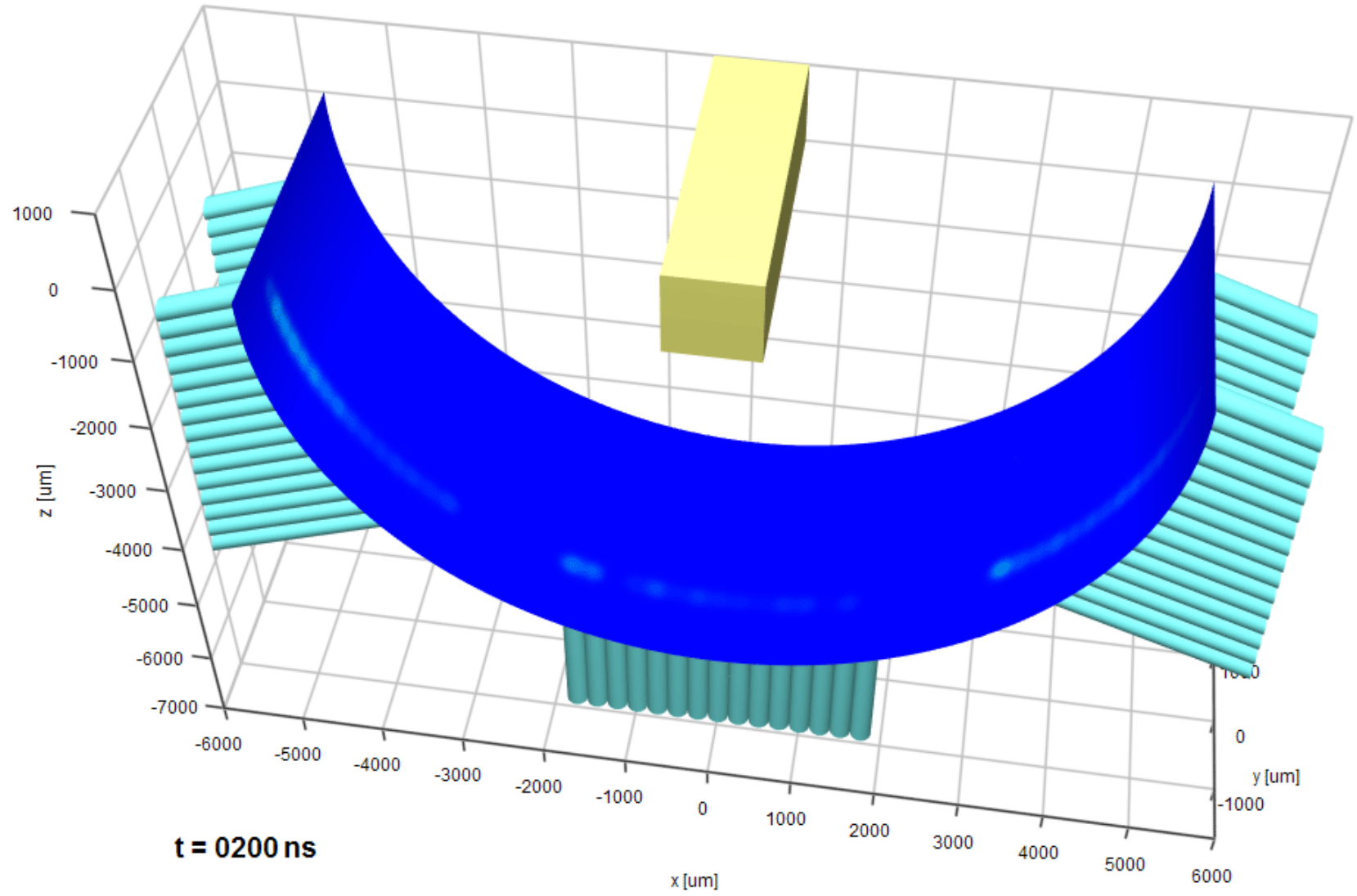

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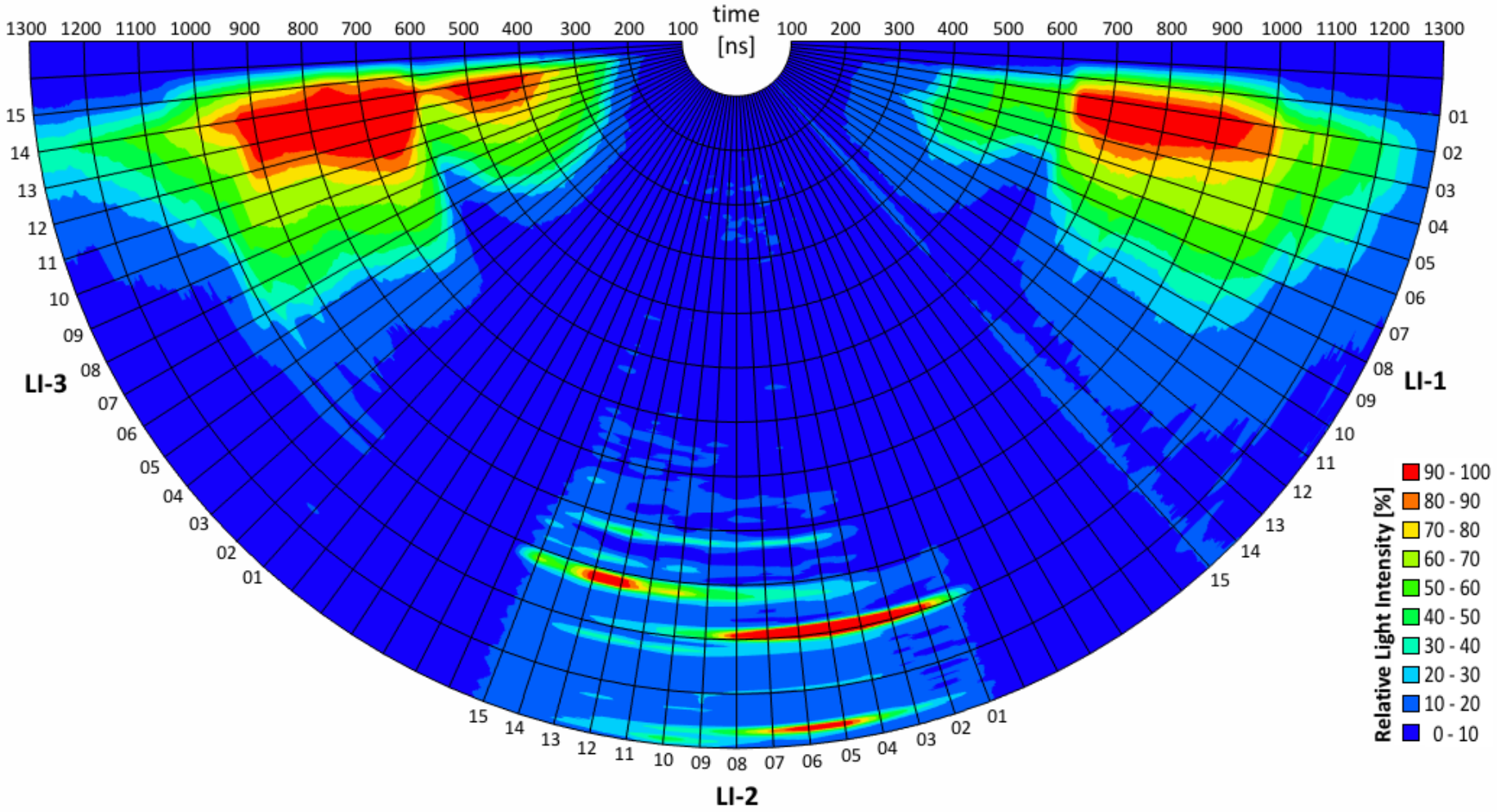

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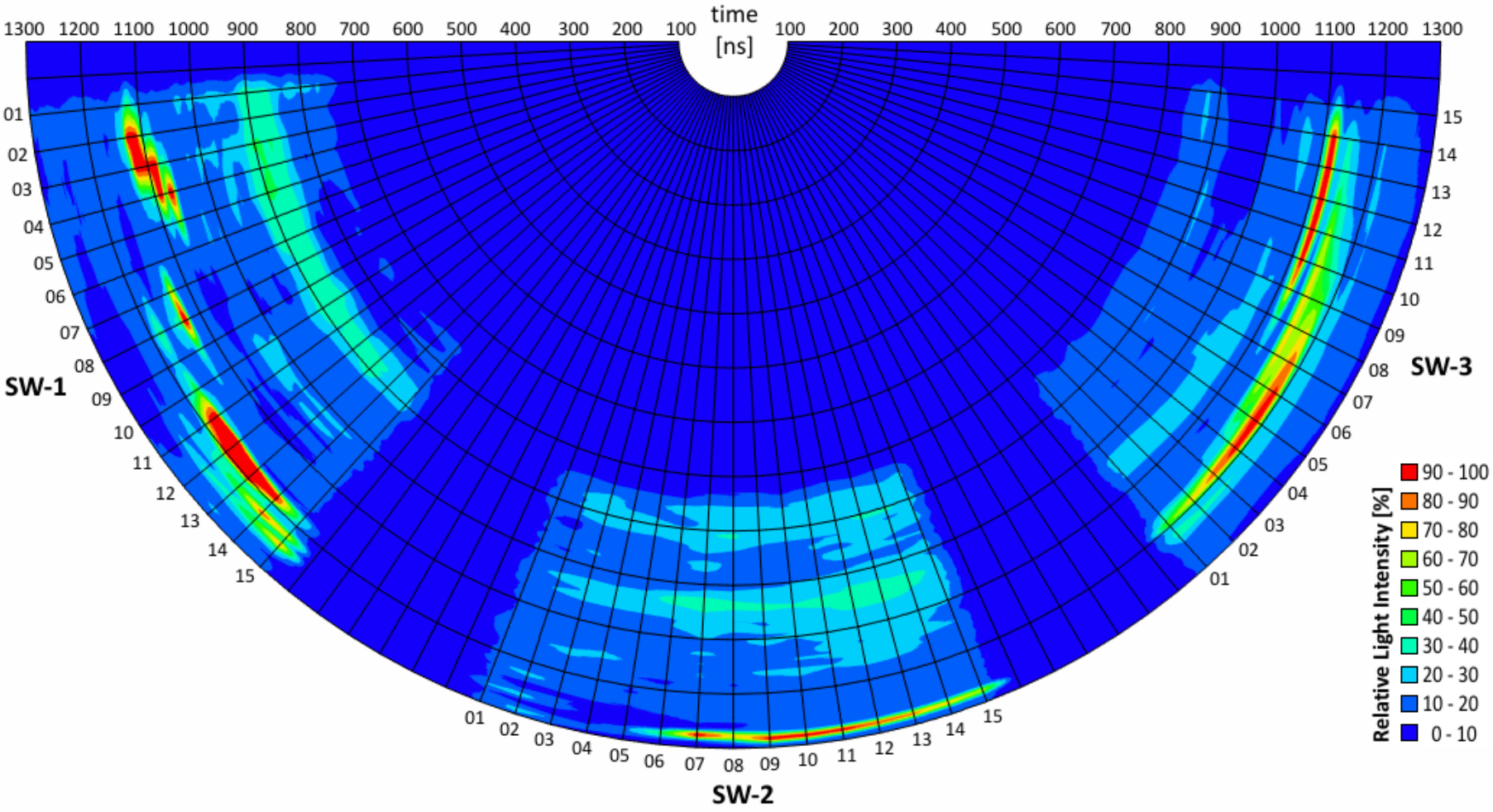
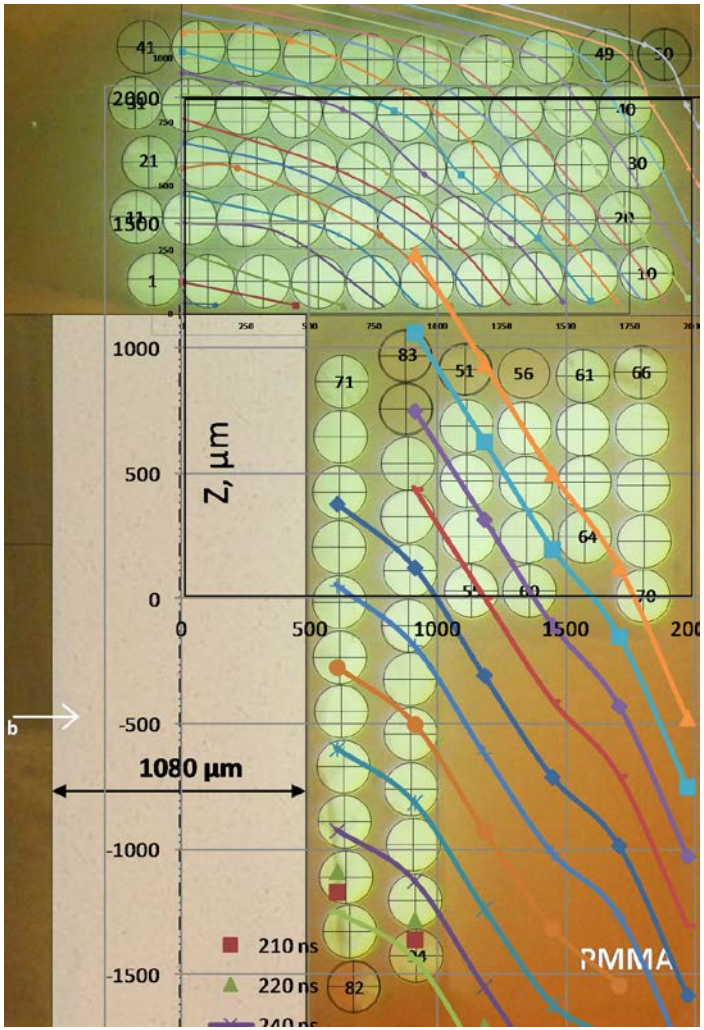


2. Experimental Setups / Configurations Examples

2.7. Shock Input Calibration Tests



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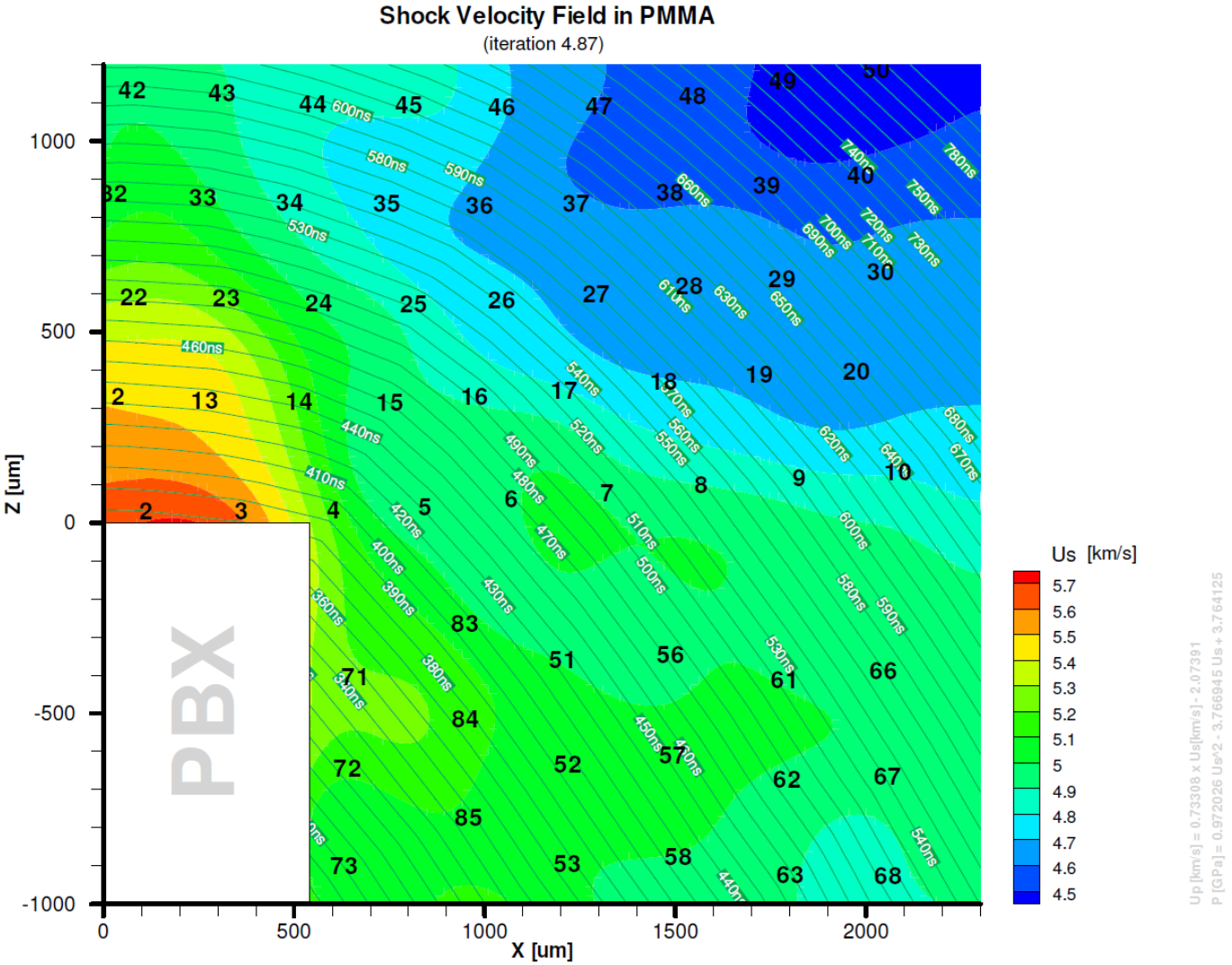

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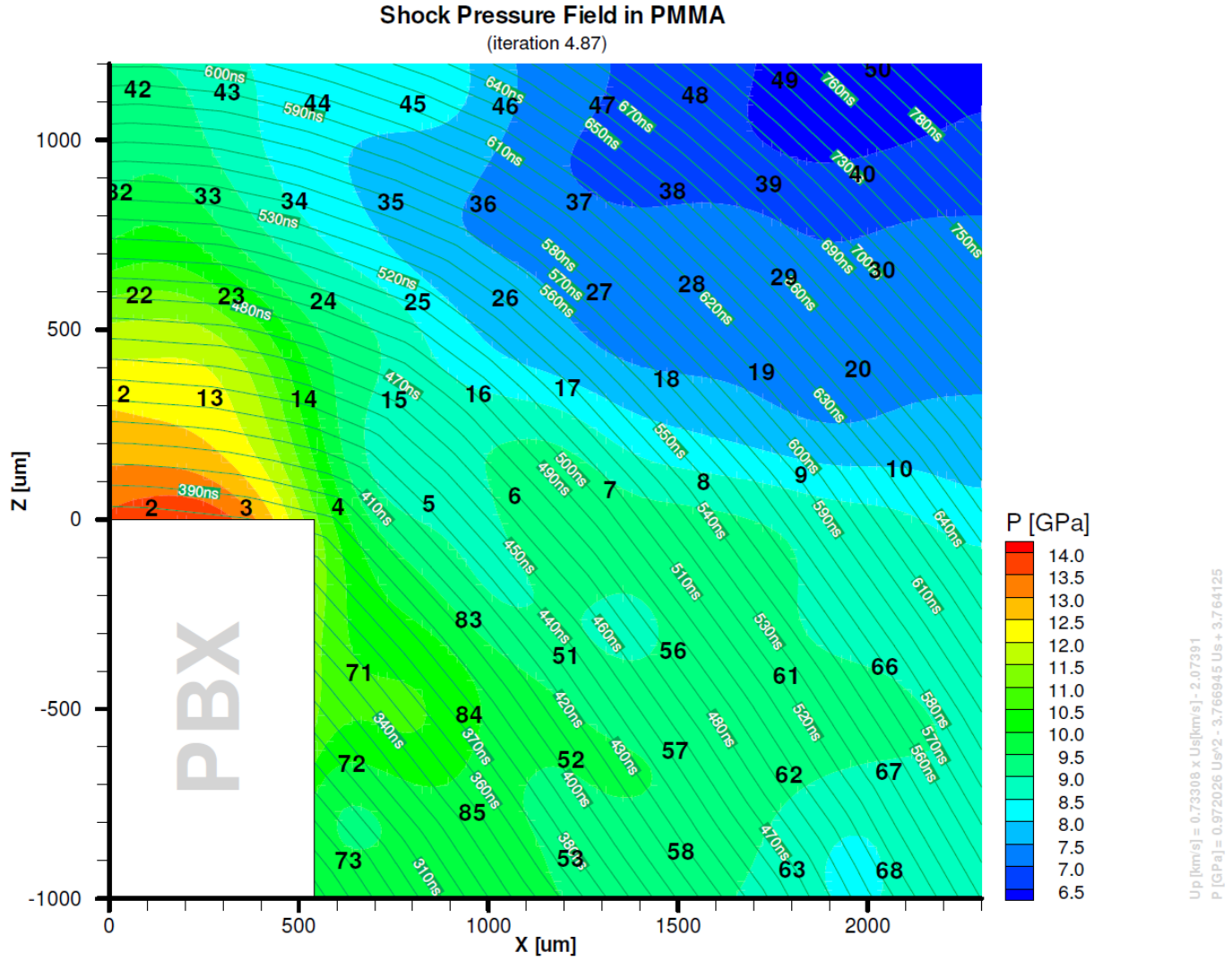

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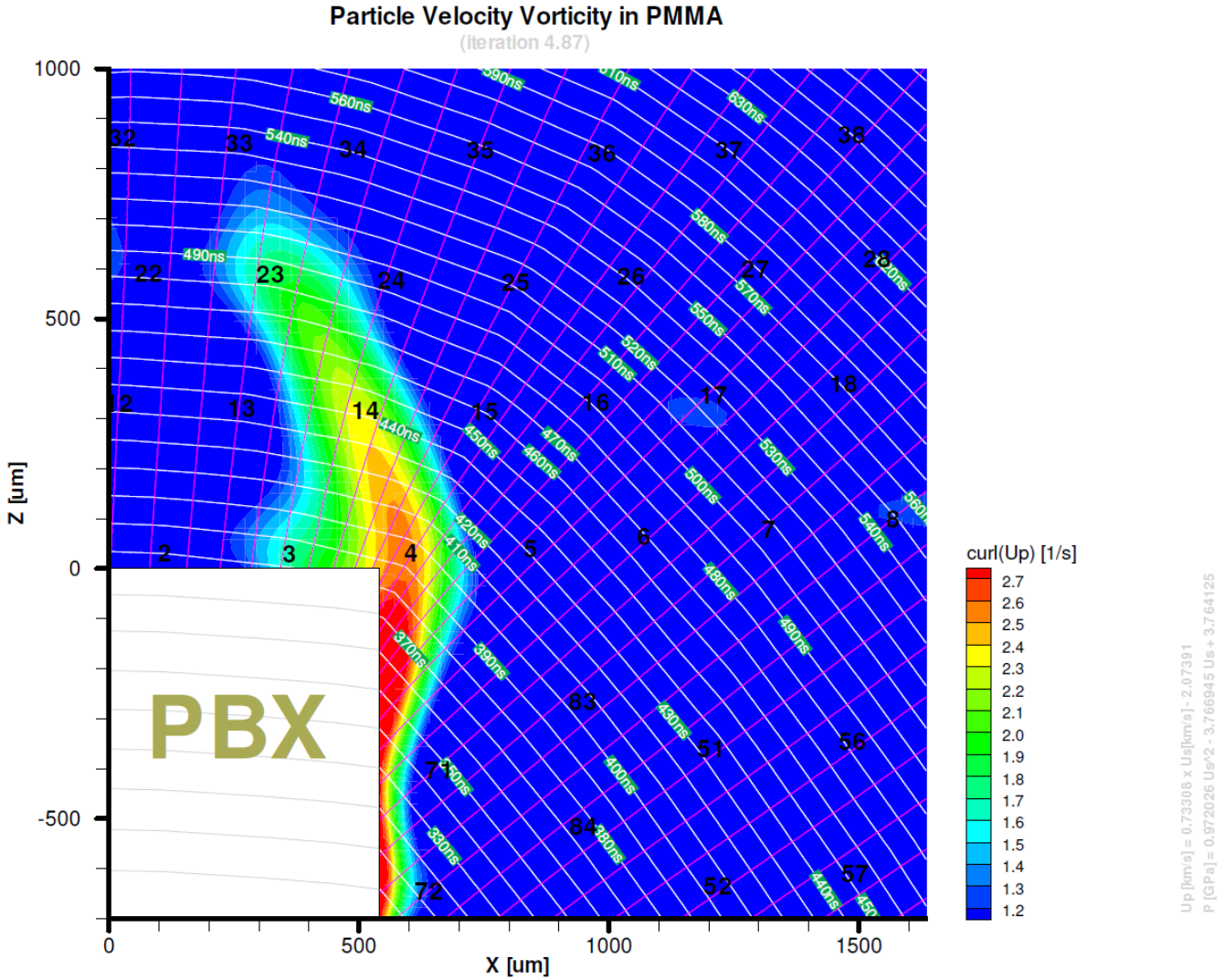

3. Main Conclusions

- Non-ideal behaviour at sub-millimeter scales
- Classical Models not applicable
- Non-Steady State Detonation Propagation
- Perturbations of Detonation Velocity
- Detonation Propagates Non-Continuously (local reaction domains/cells and “hotspots”)
- Evidence of Significcant Perturbations in Reaction Intensity and Induced Pressure Fields
- Detonation Front Roughness
- Non-uniform Acceleration of Liners
- Roughness Inprint on Witness Plates
- Implications for practical applications (explosive welding, shock compaction/sintering, shaped-charges, etc…)