



Flowfield Characterization of a Rotating Detonation Engine

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ISSI



Rotating Detonation Engine (RDE)



- **Pressure Gain Combustion**
- **Single initiation event**
- **Steadier outlet flow than PDE**
- **High cycle rates**
- **High power density**
- **Mechanically simple**



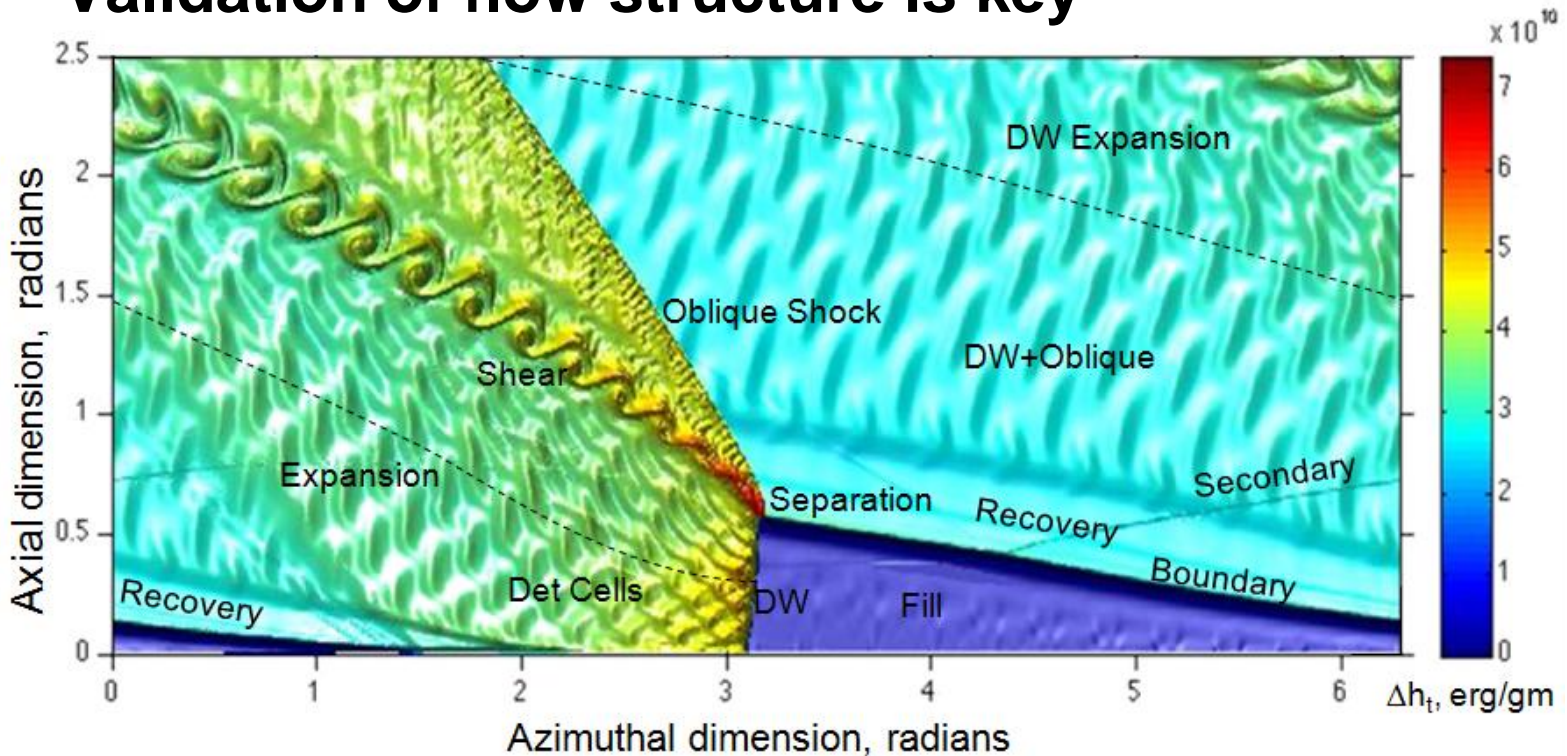
*Video courtesy of K. Kailasanath,
Naval Research Laboratory



RDE Flow Modeling



- Fluid dynamic & Thermodynamic models
 - Determine efficiency, exit flow state
 - Validation of flow structure is key



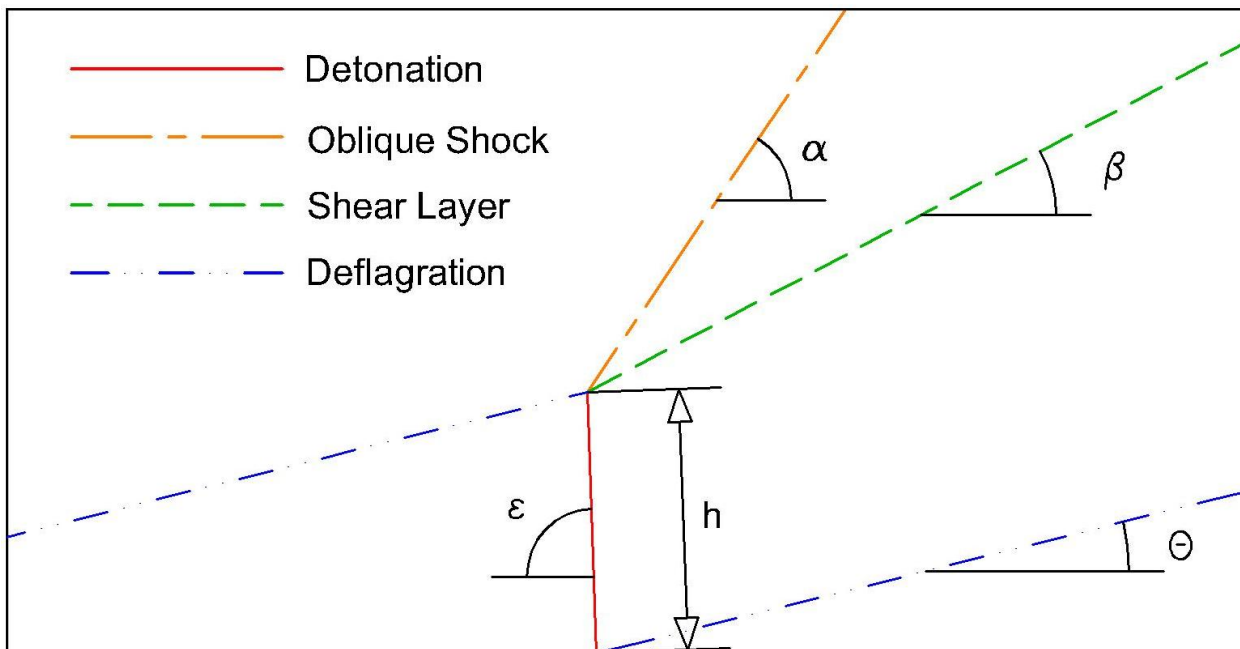
***Nordeen, C.A., et al., *Thermodynamic Modeling of a Rotating Detonation Engine*, in *49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition*. 2011: Orlando, Florida. p. 1-15.



Objective



- **Capture high speed video of operating RDE**
 - **Chemiluminescence**
- **Determine basic flow structure**
- **Measure angles of notable structures**

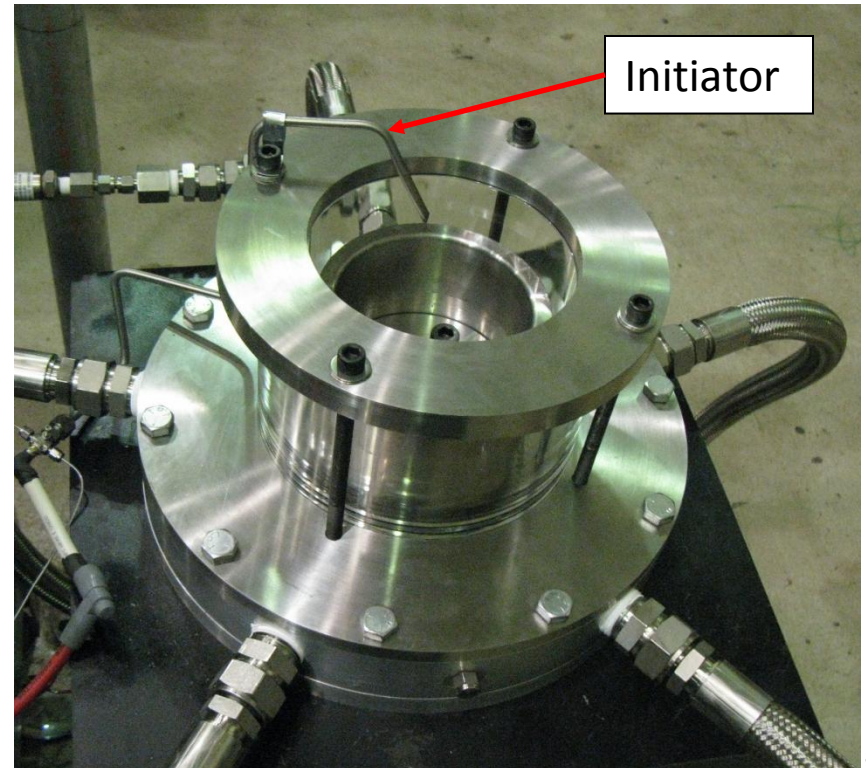
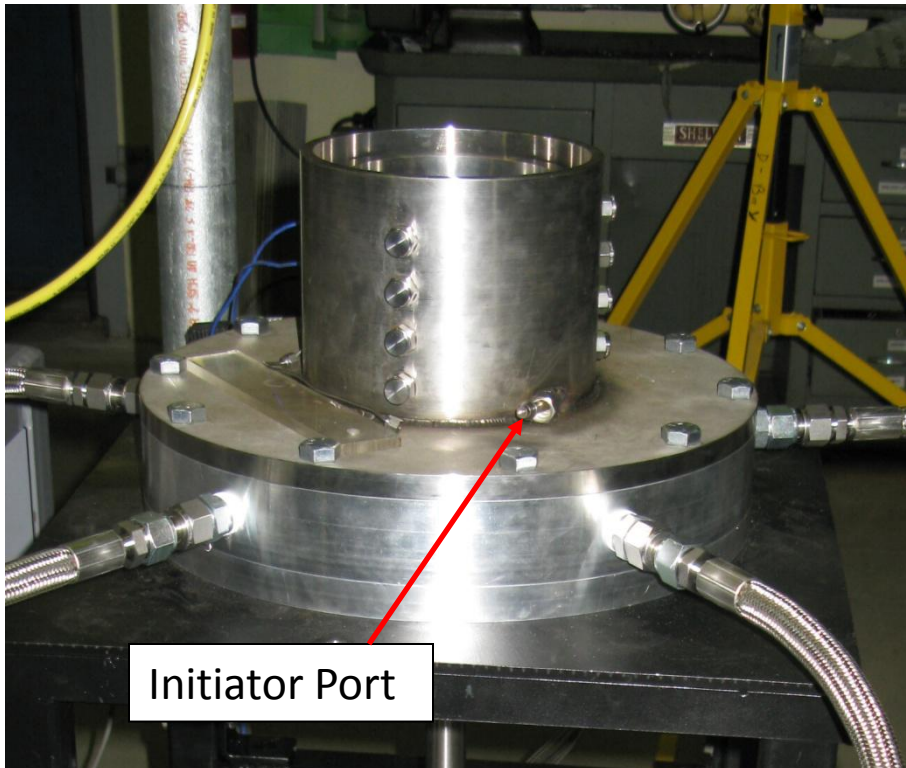




Testing Setup

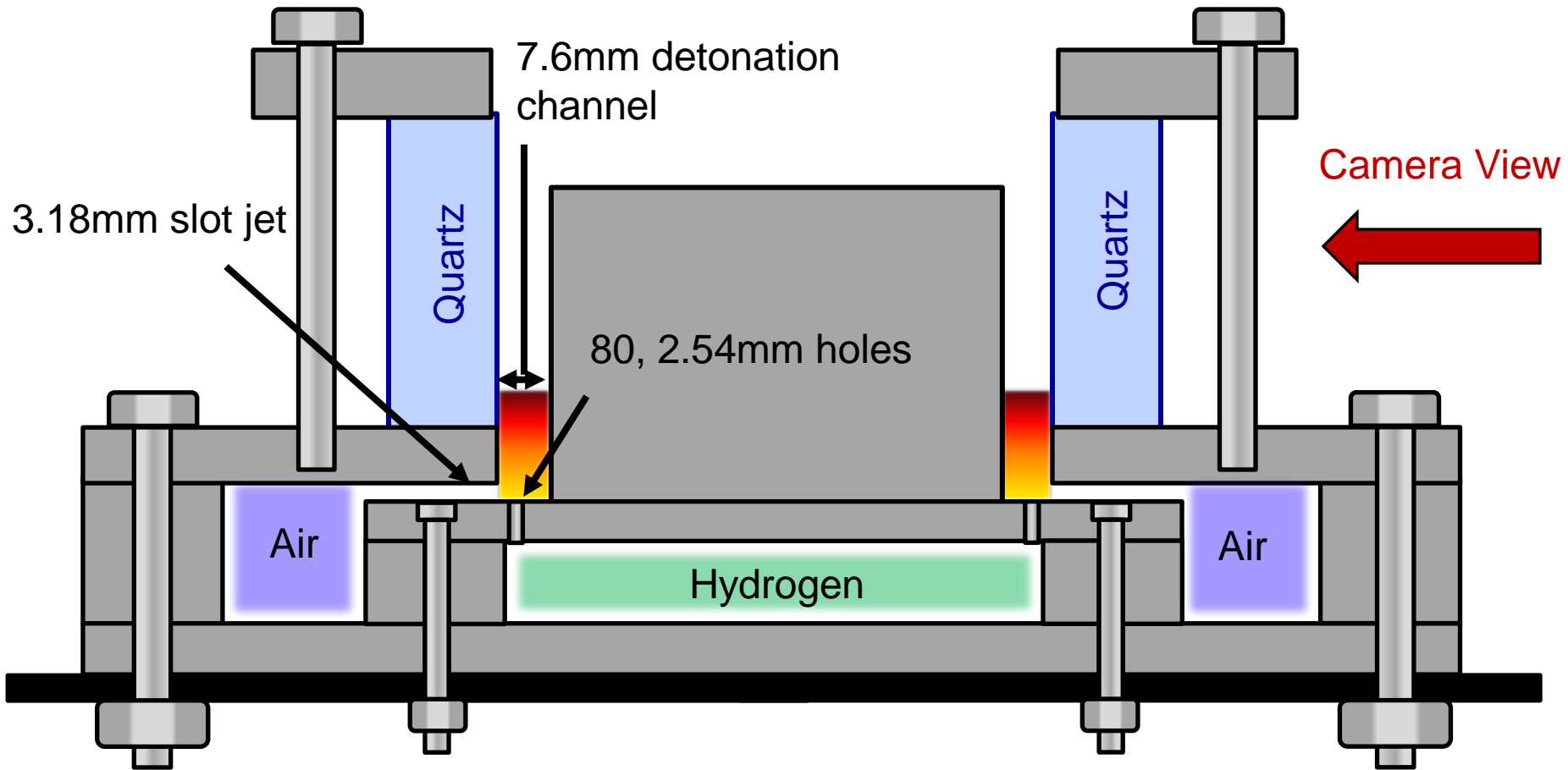


- **Modified RDE developed at AFRL**
 - Quartz outer wall
 - Aft end ignition (H_2/O_2 detonation)
 - 95% H_2 + 5% C_2H_4 Fuel mixture (mass basis)



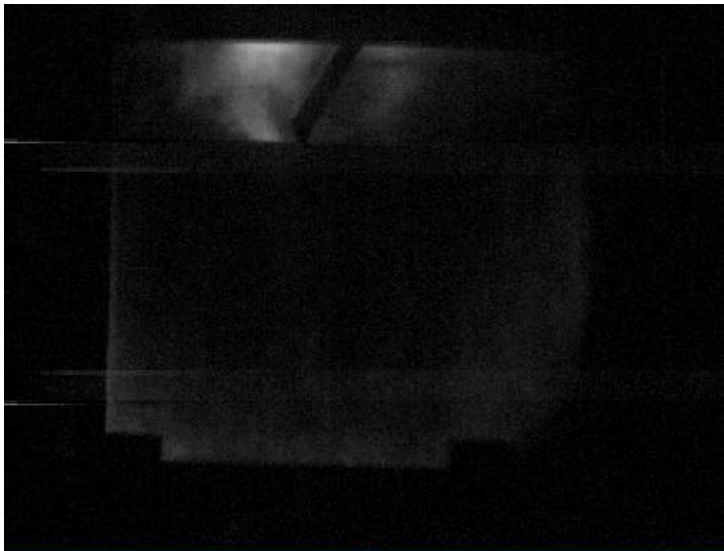


150mm RDE Cross-section





Aft End Ignition





RDE Operation



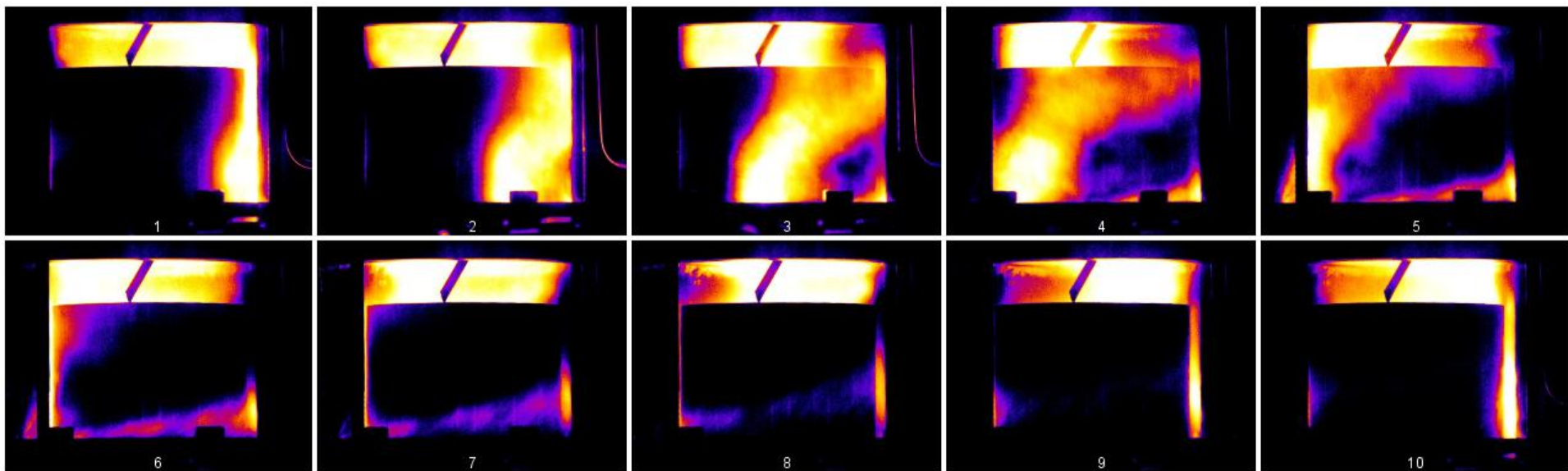
High Speed Video: 33000fps, 19.5 μ s exposure



Average Intensity



- Tracked detonation wave
- Averaged light intensity
- Applied false color to images

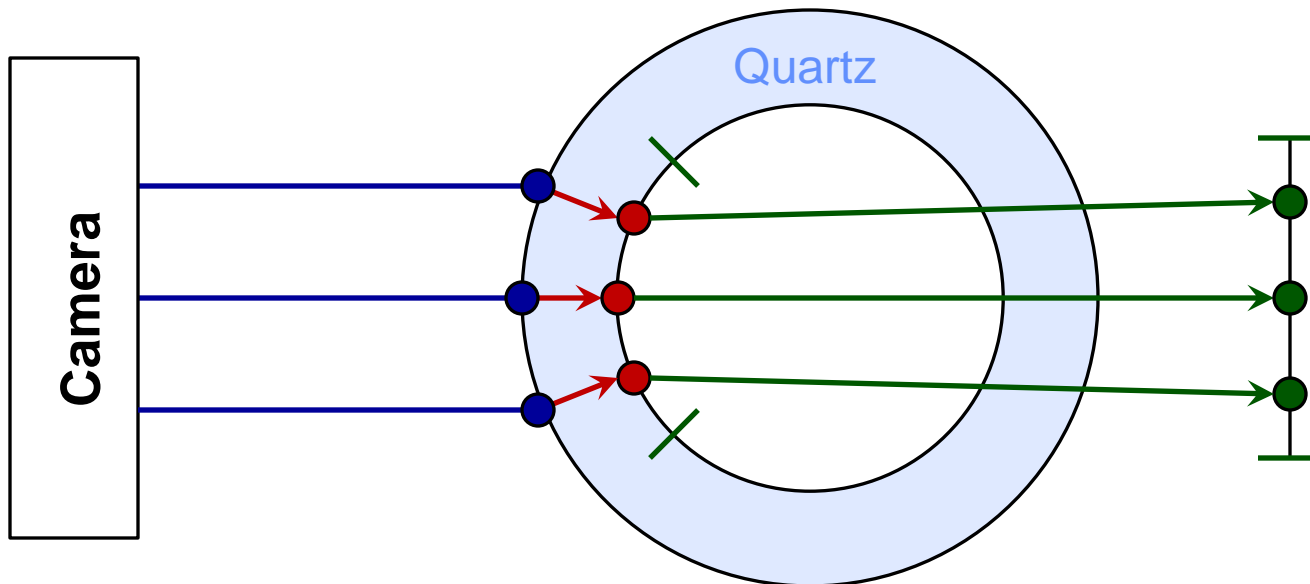




2D RDE Picture Conversion



- Use window within center 10cm of video
- Assume parallel light, optically thin annulus
- Quartz refraction correction
- RDE “unwrapping” to 2 dimensions

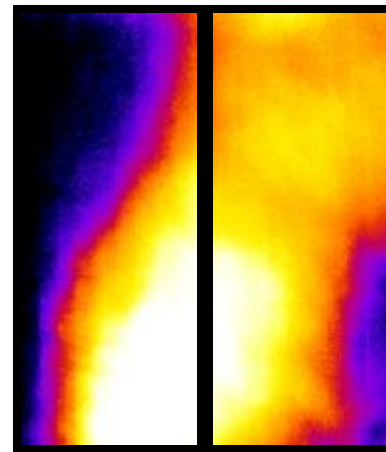
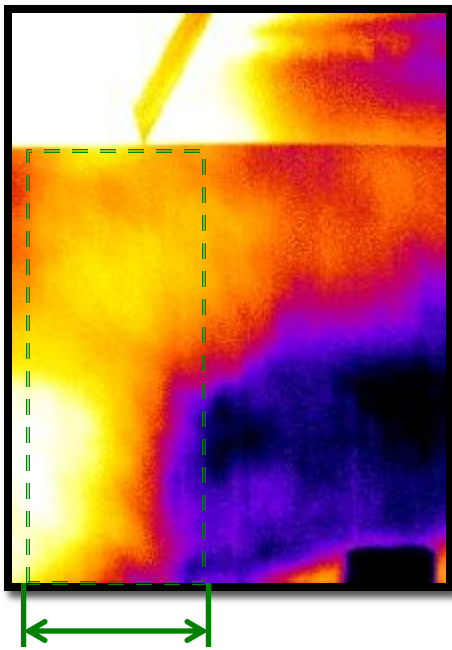




2D RDE Construction



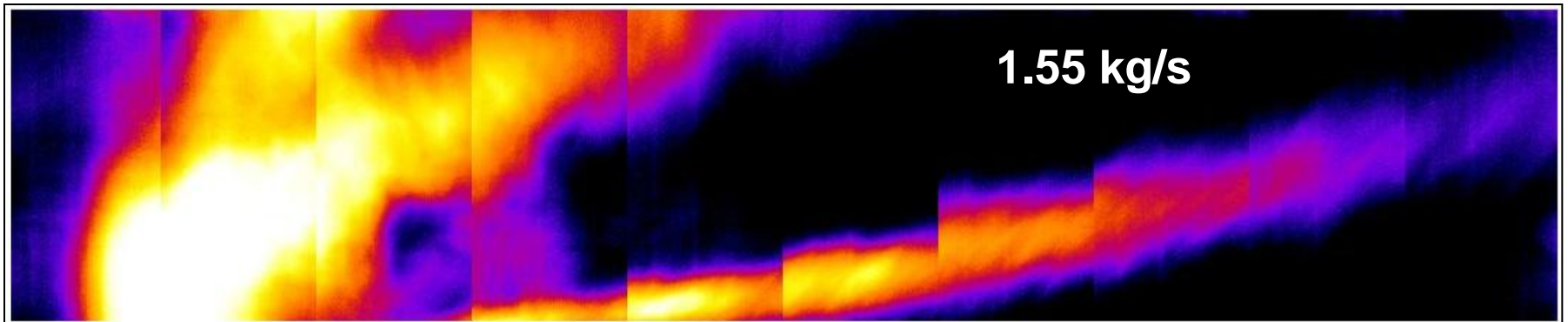
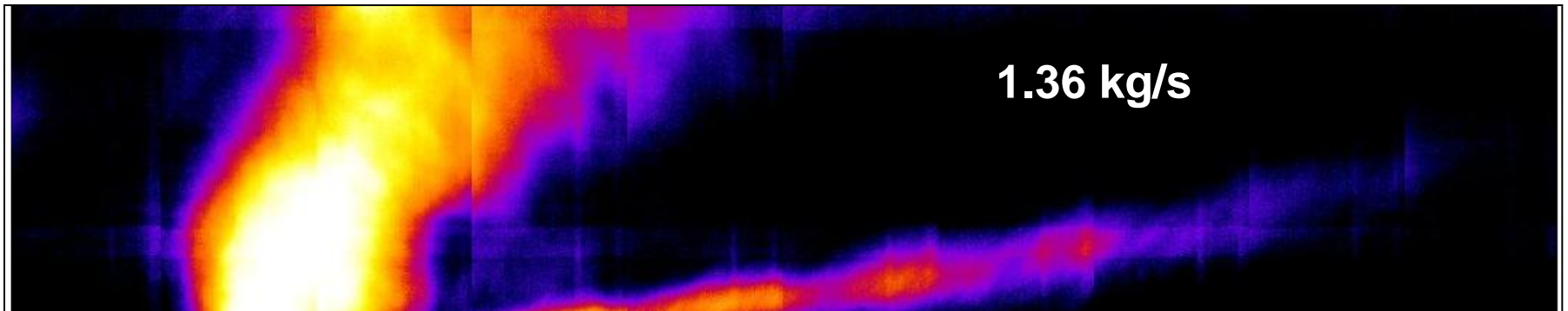
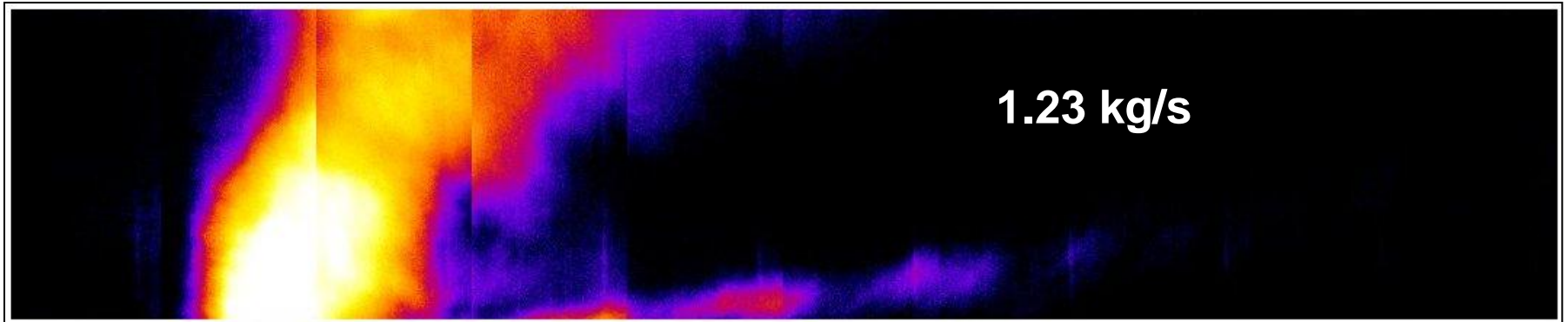
- **Crop small portion of converted video**
- **10 frames for full lap**



Distance Traveled by
detonation between
camera frames

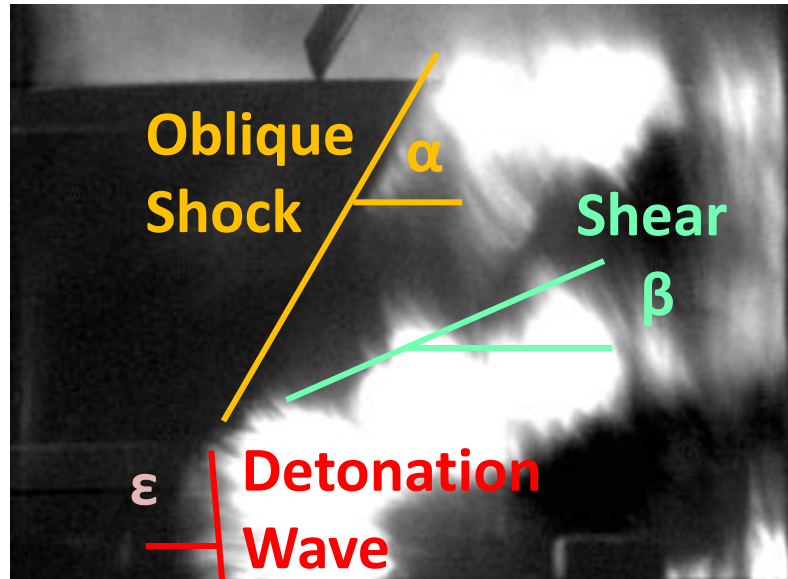


2D RDE

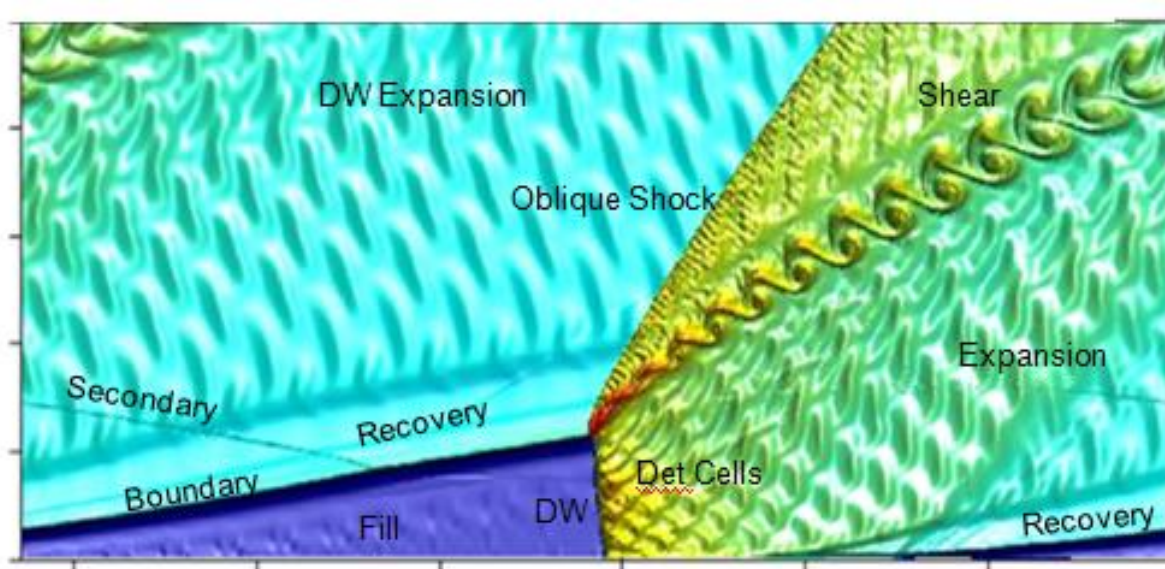
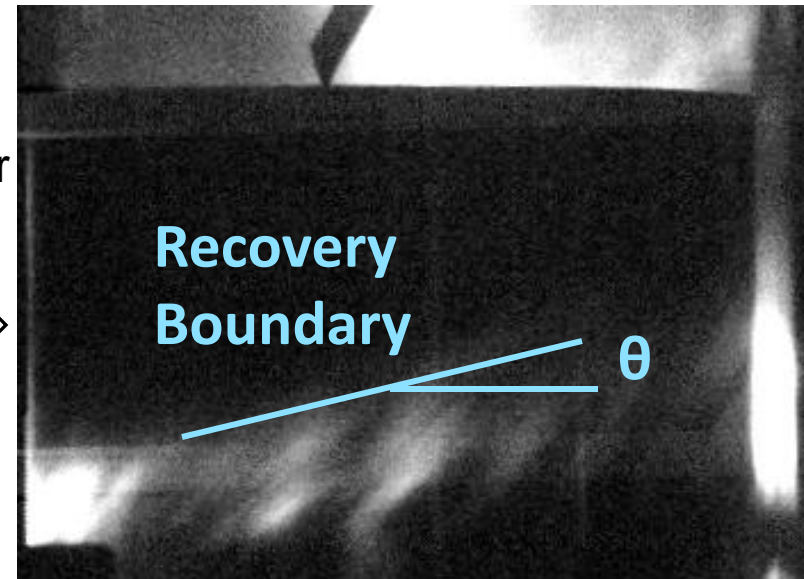
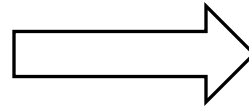




Measured Angles

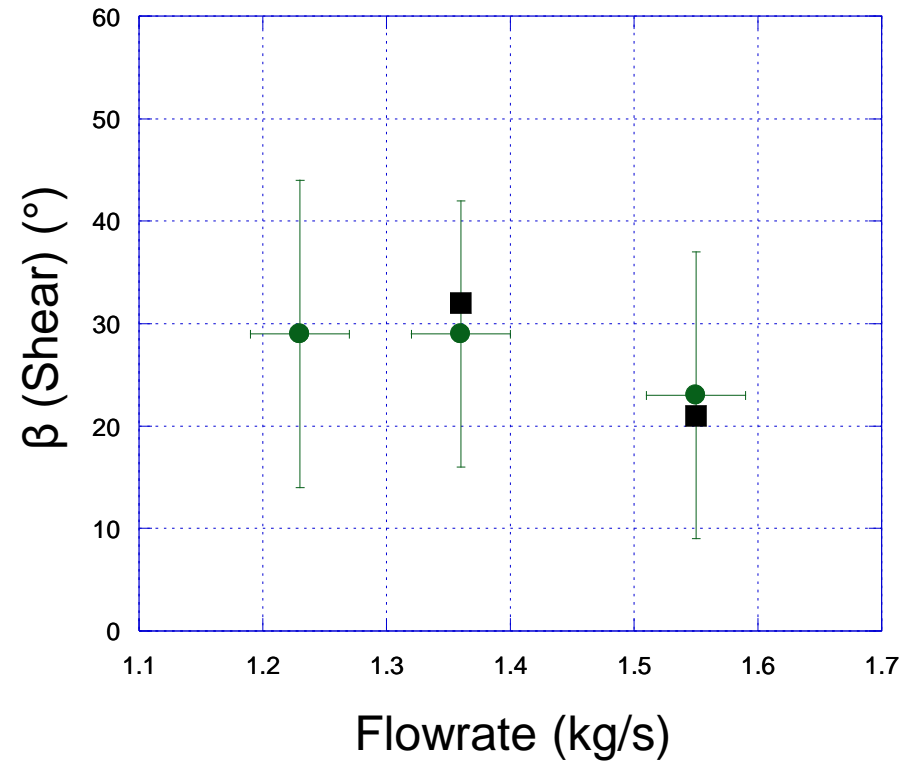
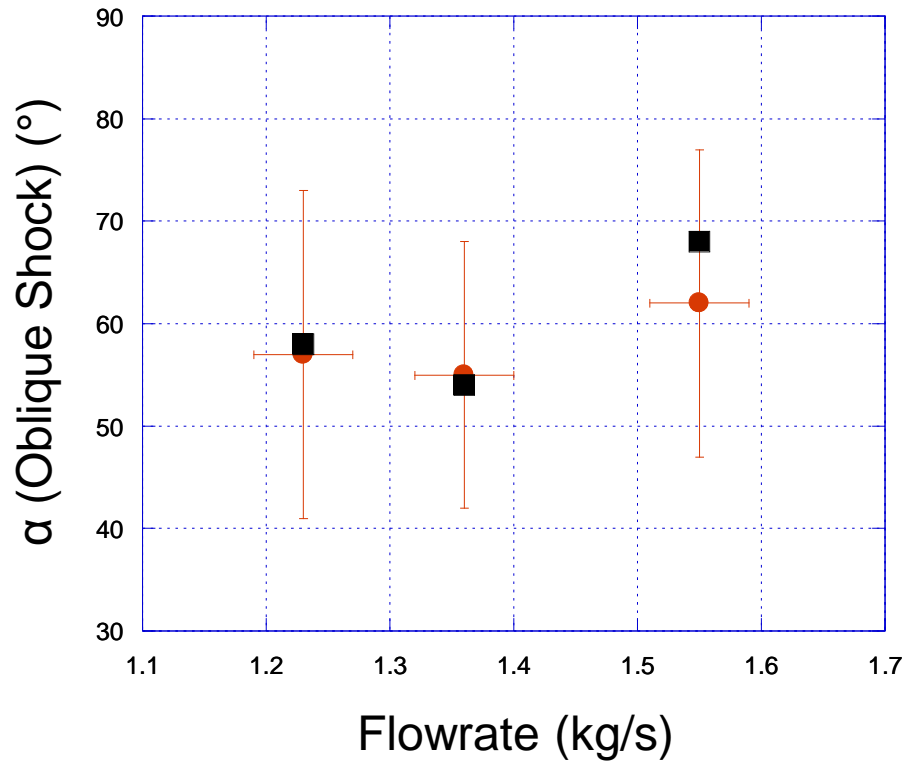


152 μ s Later
(6 frames)





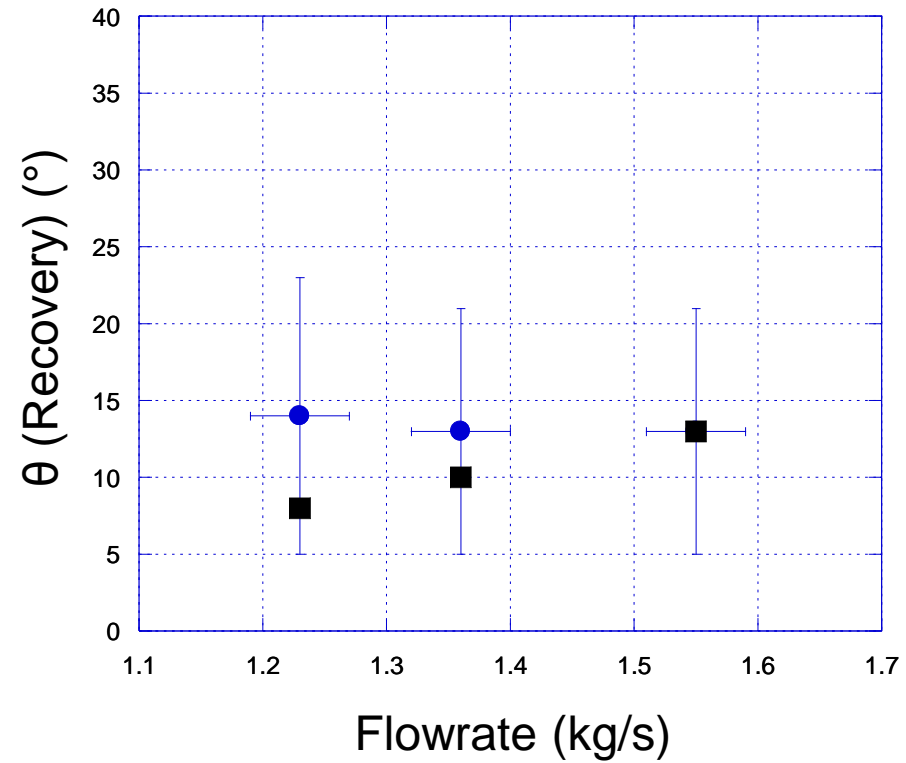
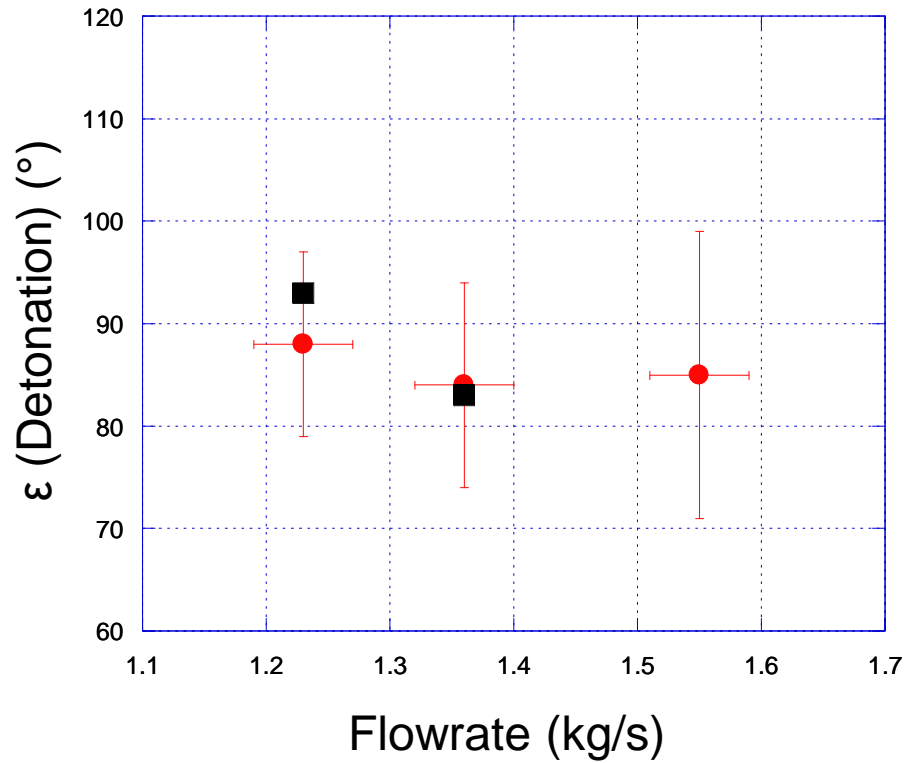
Measured Angles



■ Average Intensity Result



Measured Angles



■ Average Intensity Result



Abnormal behavior



- **Some operation was different than expected**
 - **Wave direction changes**
 - **External startup**

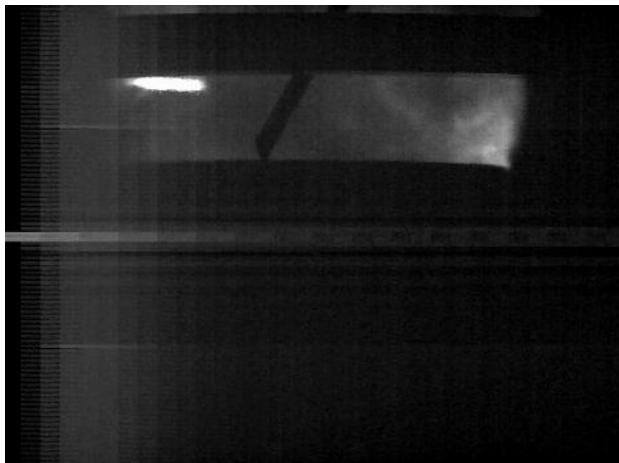
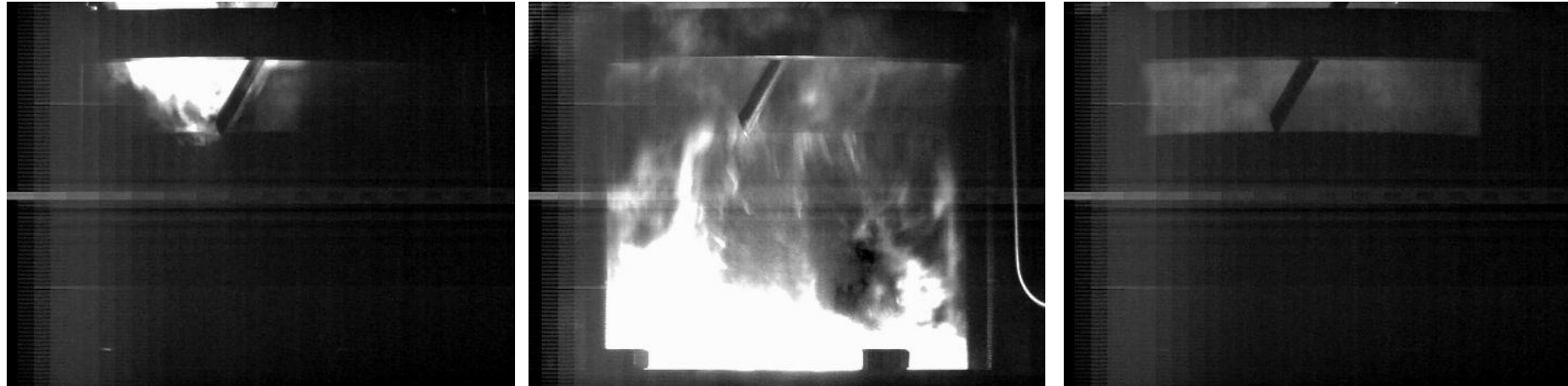


Wave Direction Change



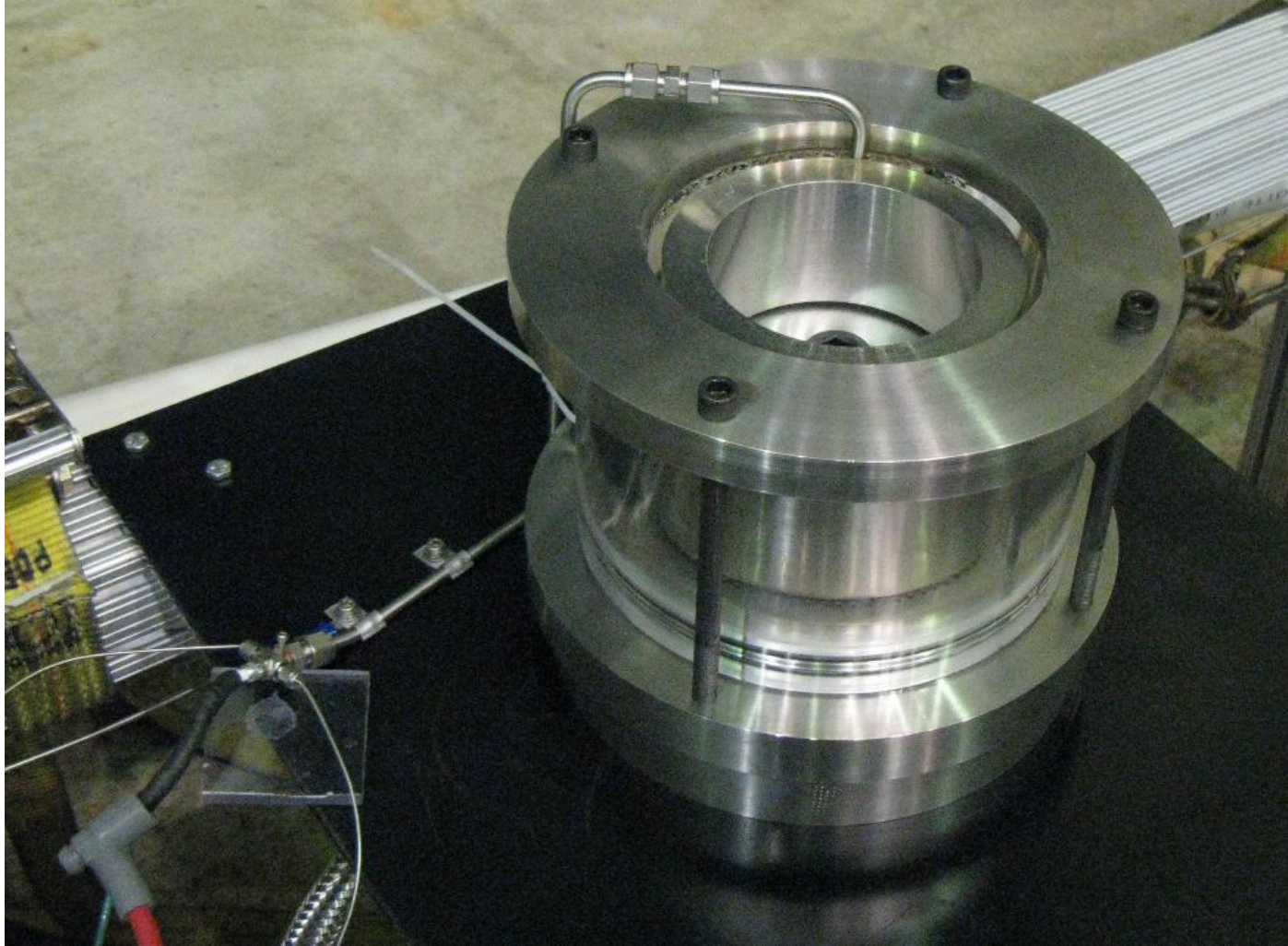


External startup



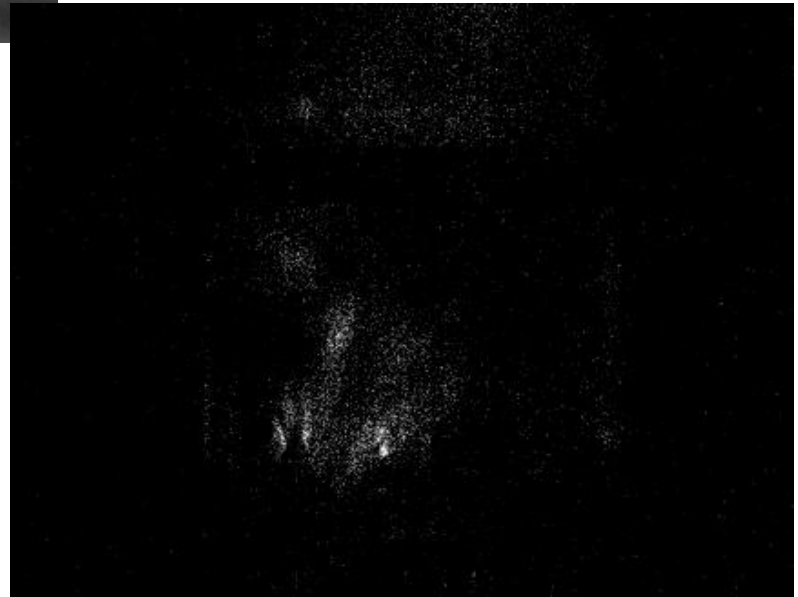
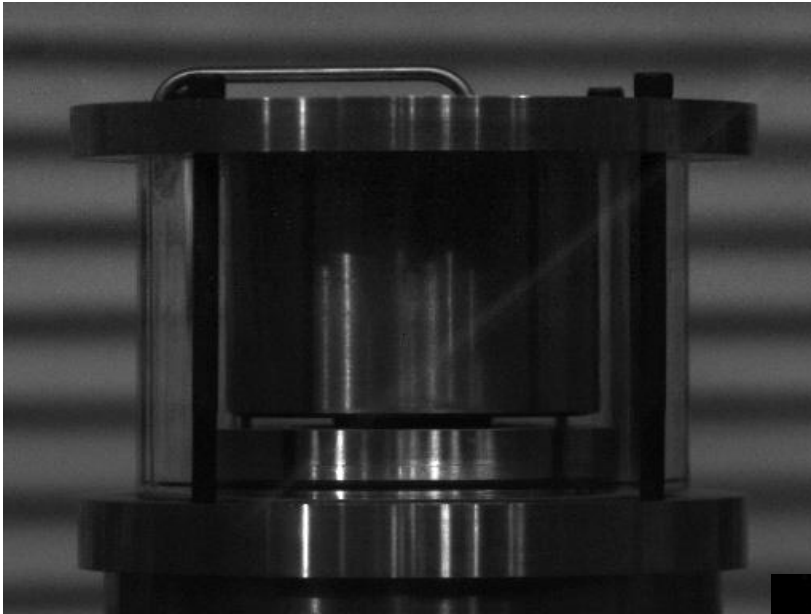


New RDE





New RDE





Conclusions



- **Rough flow structure angles measured**
- **Flowfield is inconsistent**
 - **Chemiluminescence**
 - **Mix variation**
 - **Plenum dynamics, mixing striation**
 - **Detonation channel geometry**
 - **Volume relief, curvature**
- **Need better diagnostic techniques**
 - **PIV, PLIF, Schlieren**