

# Implementation of Large Scale Shadowgraphy in Hydrogen Explosion Phenomena



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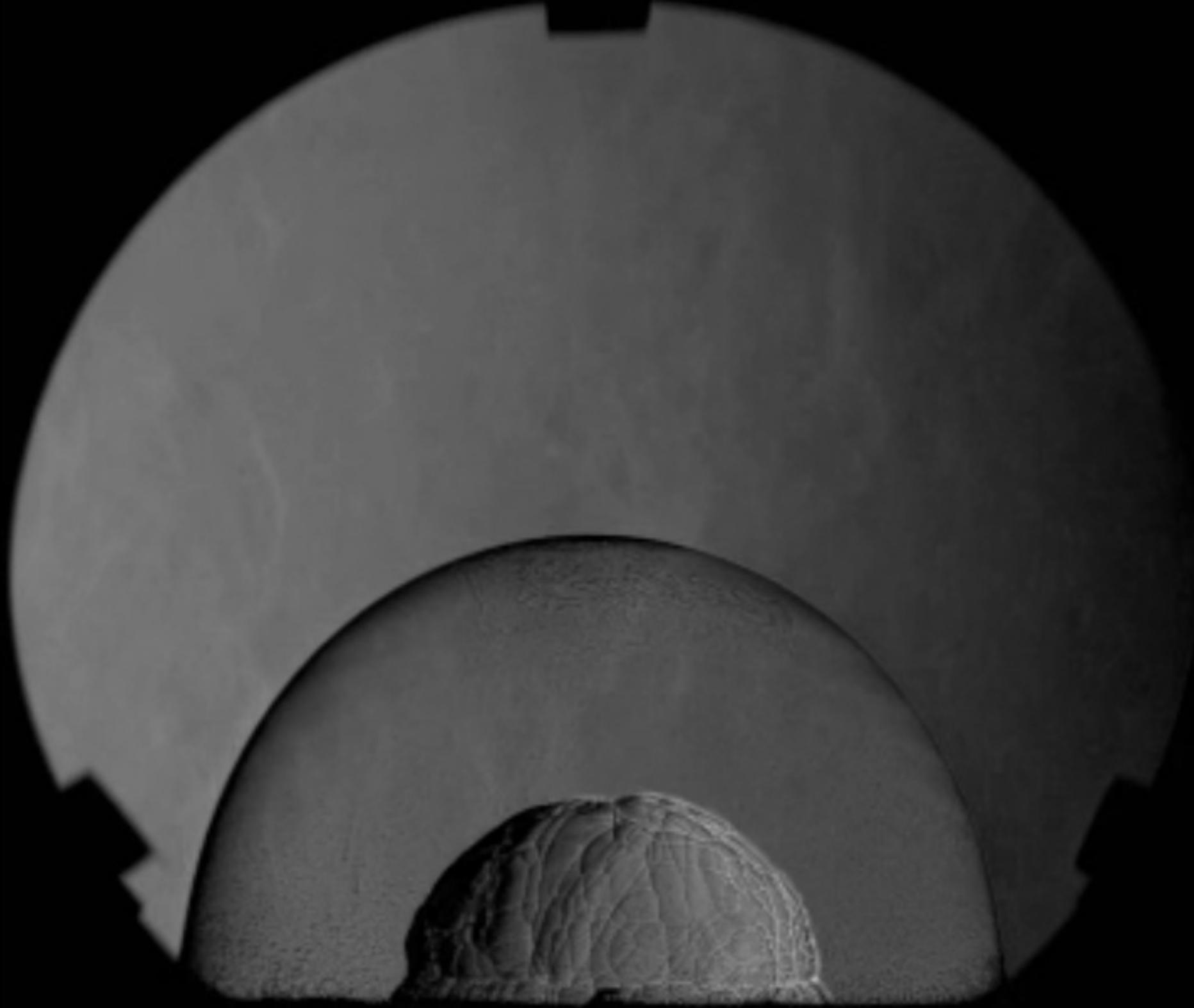
# Purpose



- We want to visualize laboratory combustion experiments
- One meter length scale



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# Background-oriented Schlieren



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J. Hartberger, "BACKGROUND-ORIENTED SCHLIEREN  
PATTERN OPTIMIZATION," Air Force Institute of Technology.  
M.Sc Thesis, 2011.

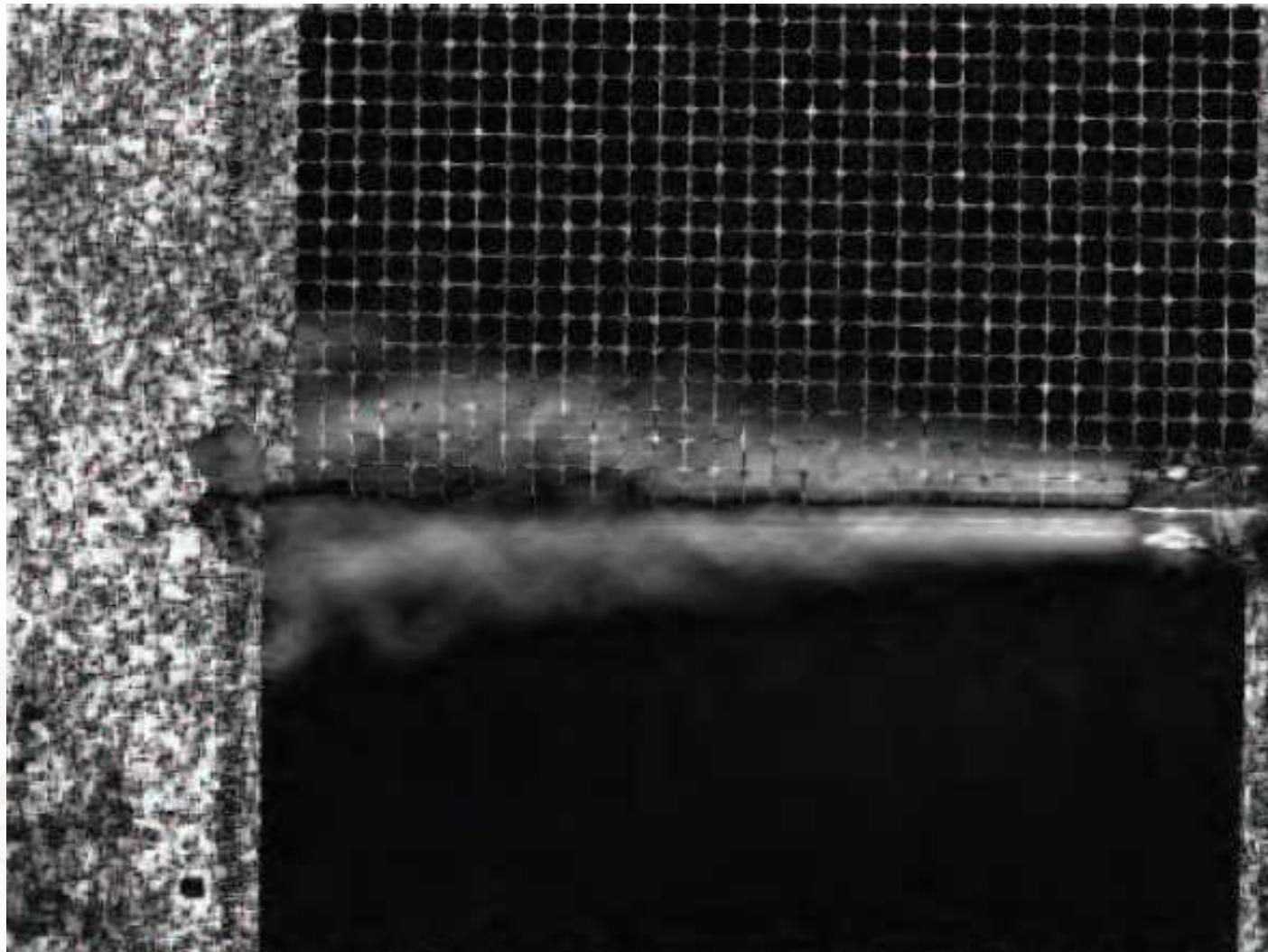
# Background-oriented Schlieren



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J. Hartberger, "BACKGROUND-ORIENTED SCHLIEREN  
PATTERN OPTIMIZATION," M.Sc Thesis, 2011.

# Background-oriented Schlieren

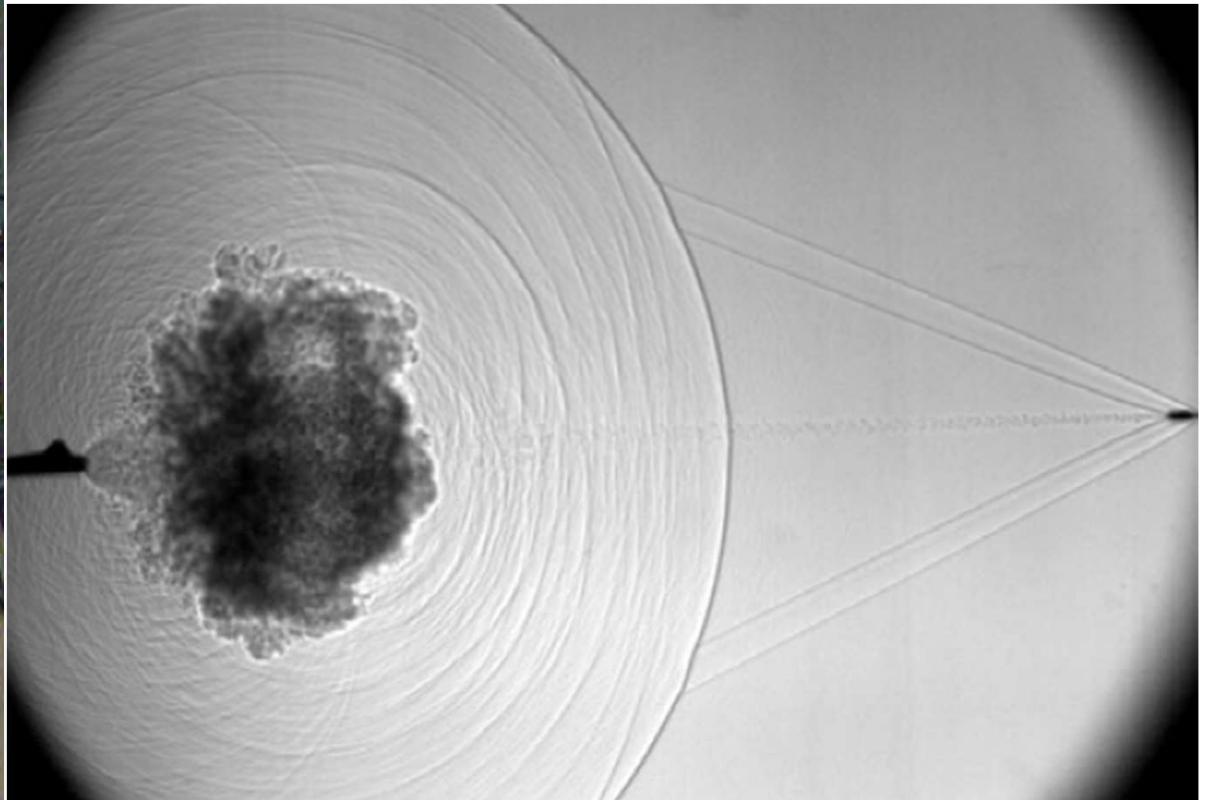


J. Hartberger, "BACKGROUND-ORIENTED SCHLIEREN  
PATTERN OPTIMIZATION," M.Sc Thesis, 2011.



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# Large-scale Shadowgraphy



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G. S. Settles, T. P. Grumstrup, J. D. Miller, M. J. Hargather, L. J. Dodson, and J. A. Gatto, "FULL-SCALE HIGH-SPEED 'EDGERTON' RETROREFLECTIVE SHADOWGRAPHY OF EXPLOSIONS AND GUNSHOTS," presented at the 5th Pacific Symposium on Flow Visualisation and Image Processing

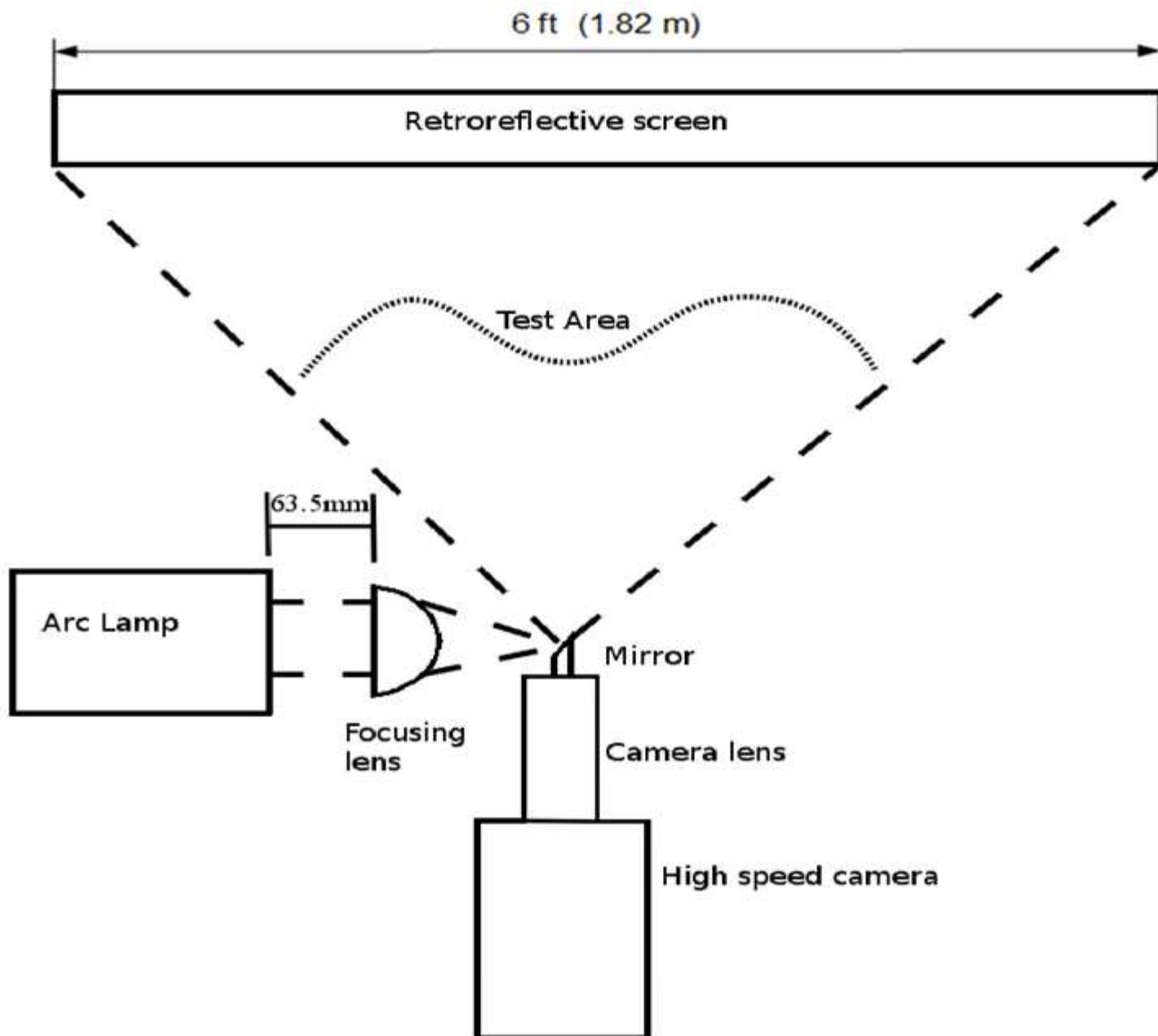
# This study



- Implement Settles' large-scale shadowgraph technique
- Combustion experiments where self-luminosity may be an issue
- Gas dynamics experiments



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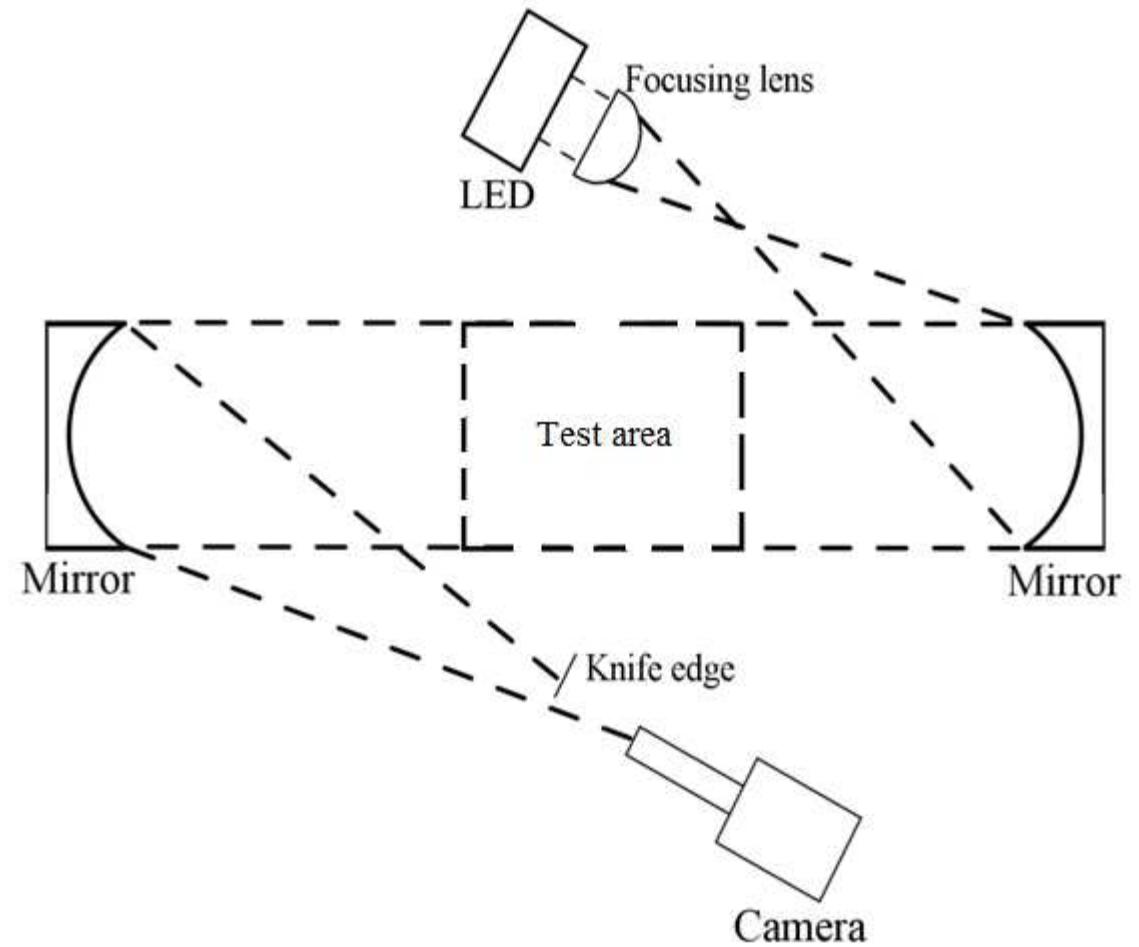
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- Phantom v1210 1,000,000 fps

# Schlieren Visualization



- Z-schlieren
- 300W LED  
16500 lm
- 32cm parabolic f/8  
mirrors



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# Experiments



Jet Releases

Unconfined Flames

Detonations

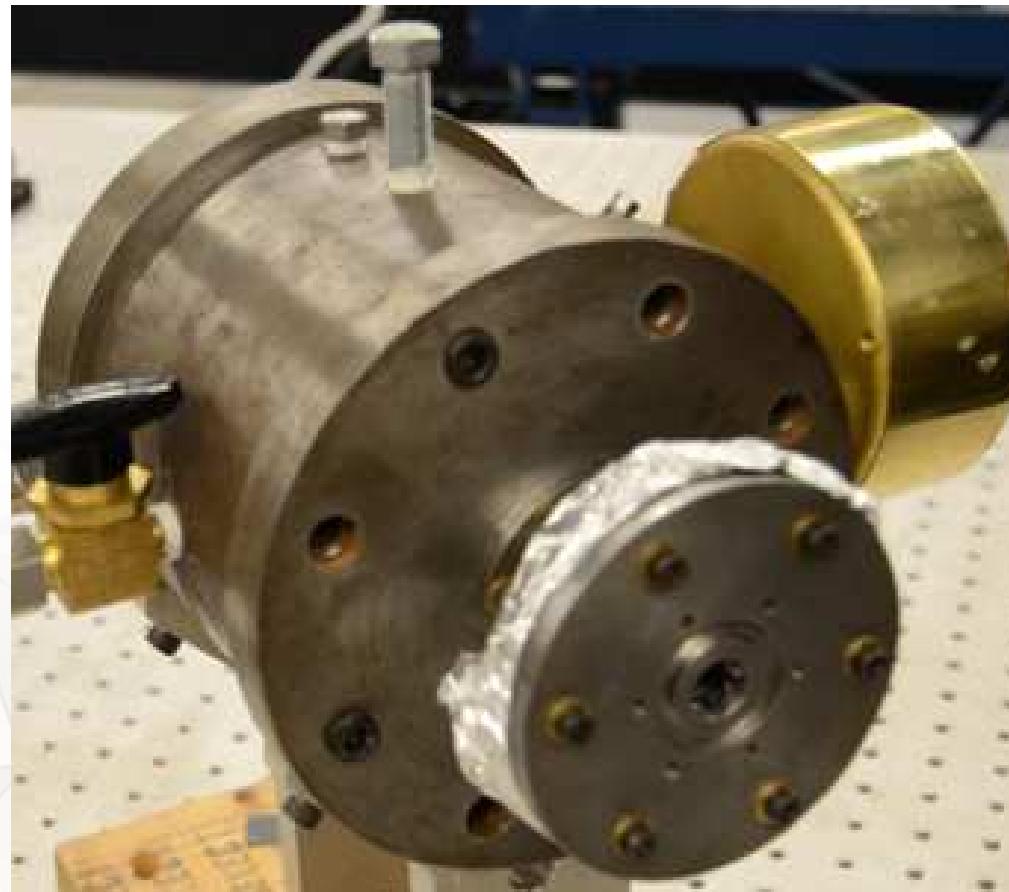


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# Jet Releases

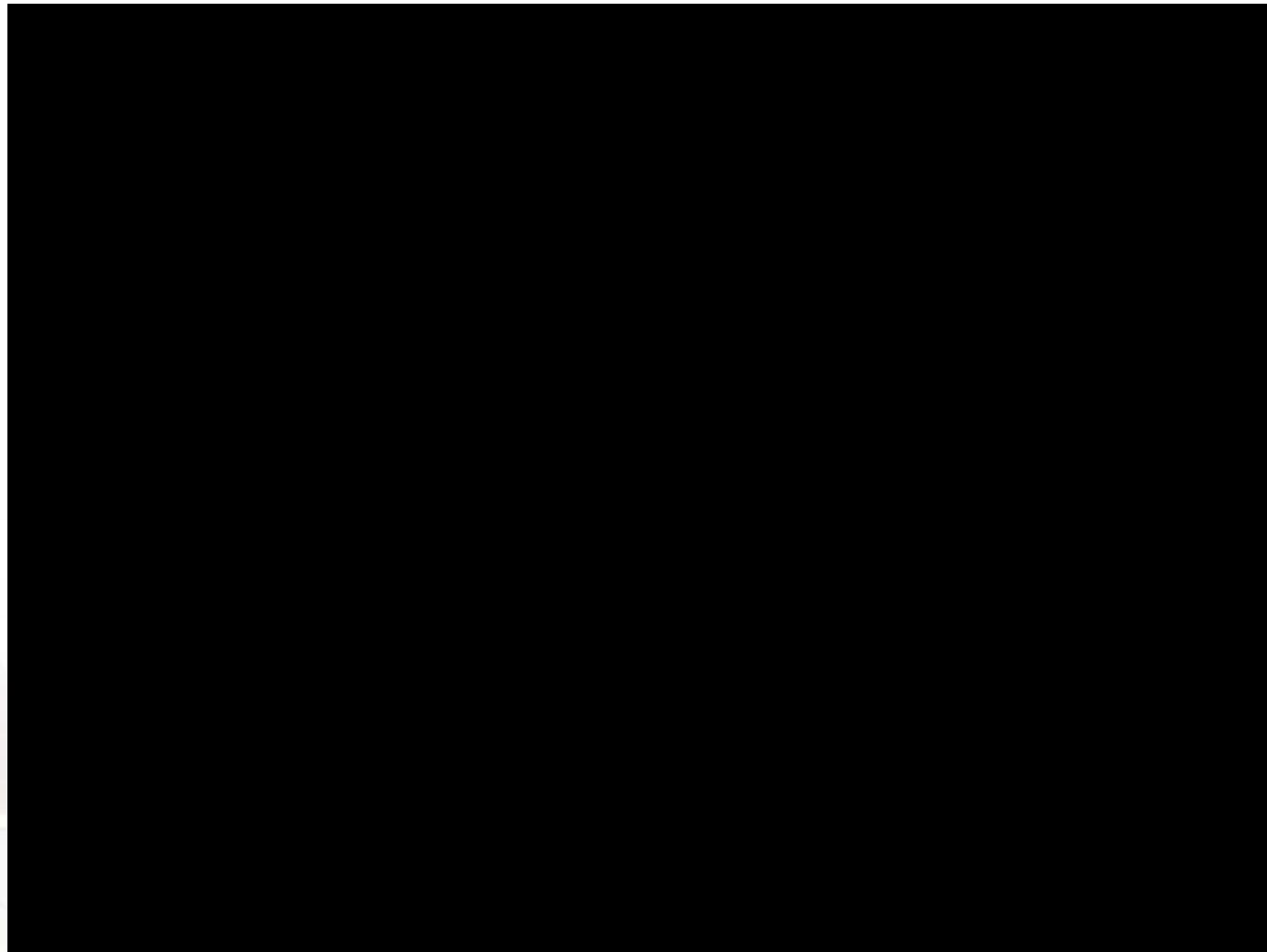


- 850 cm<sup>3</sup> volume



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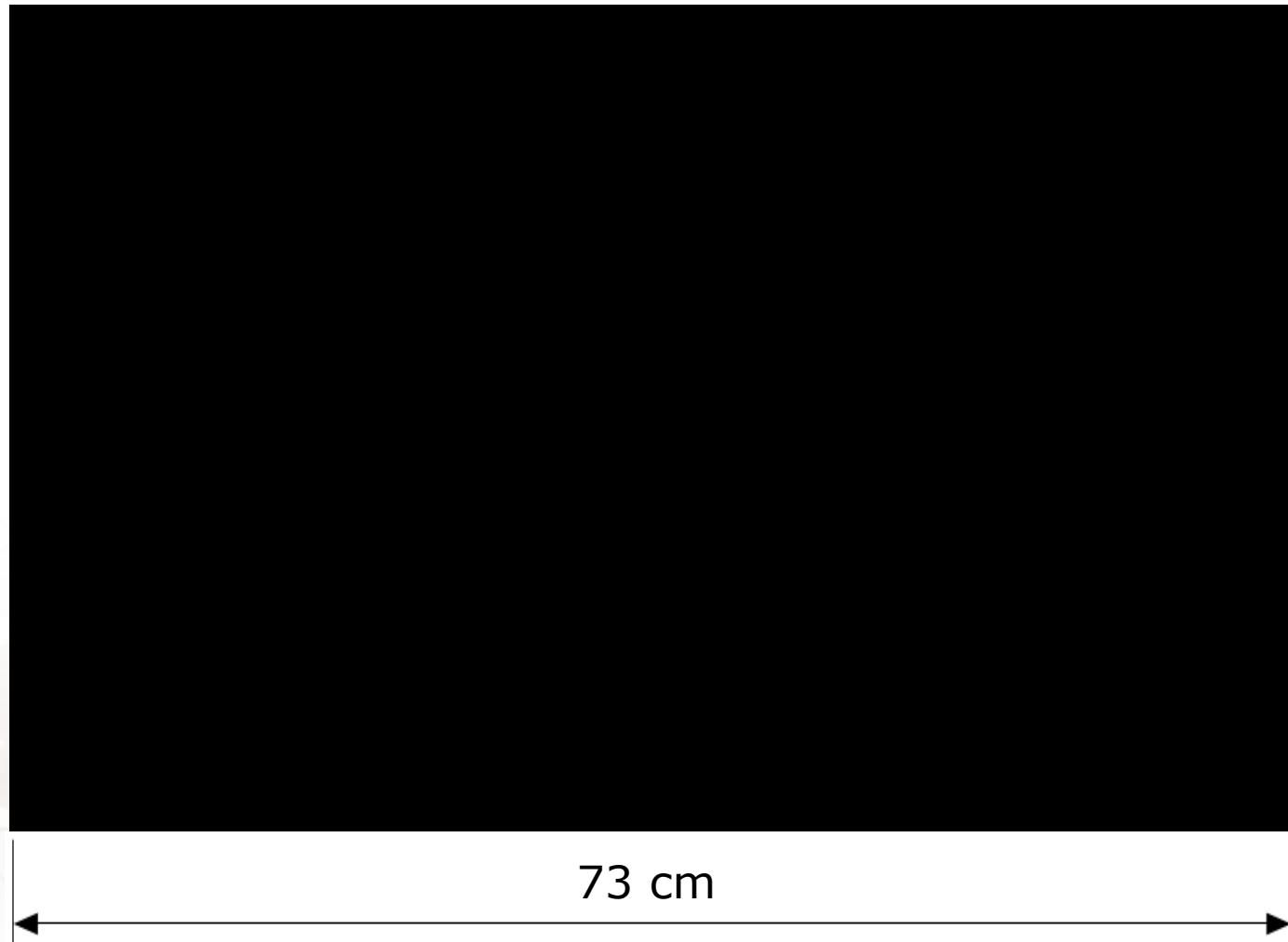
# Jet Release - Schlieren



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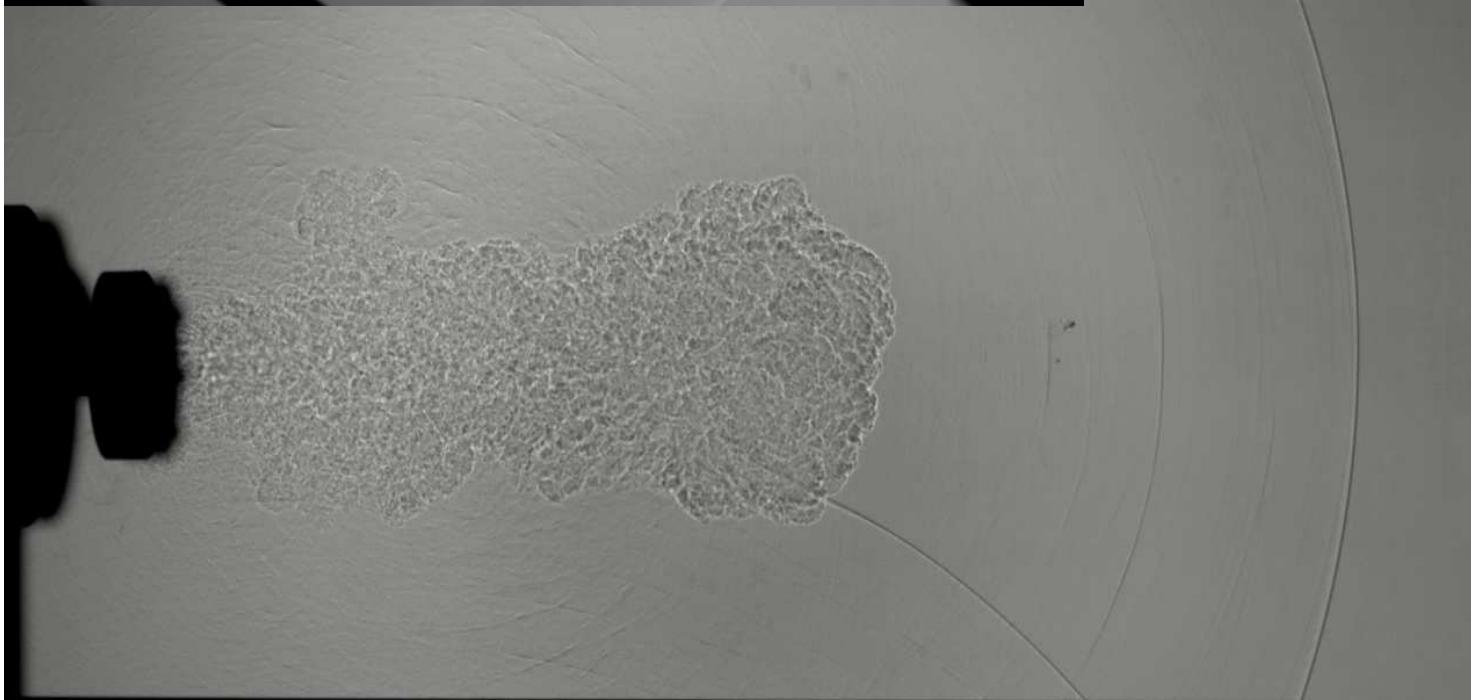
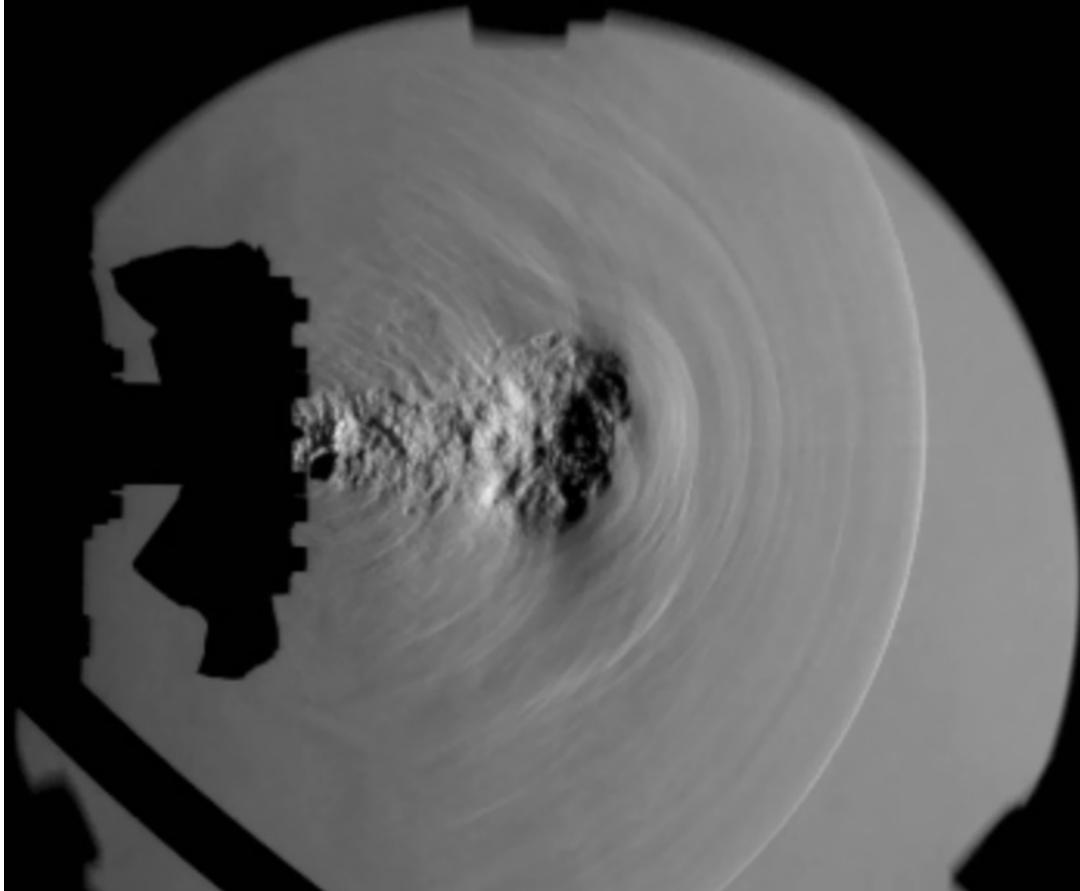
414 kPa H<sub>2</sub>  
13 mm diameter hole  
31 µm aluminum diaphragm

# Jet Releases - Shadowgraph



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1.4 MPa H<sub>2</sub>  
13 mm diameter hole  
0.1 mm aluminum diaphragm



## Jet Releases - Comparison

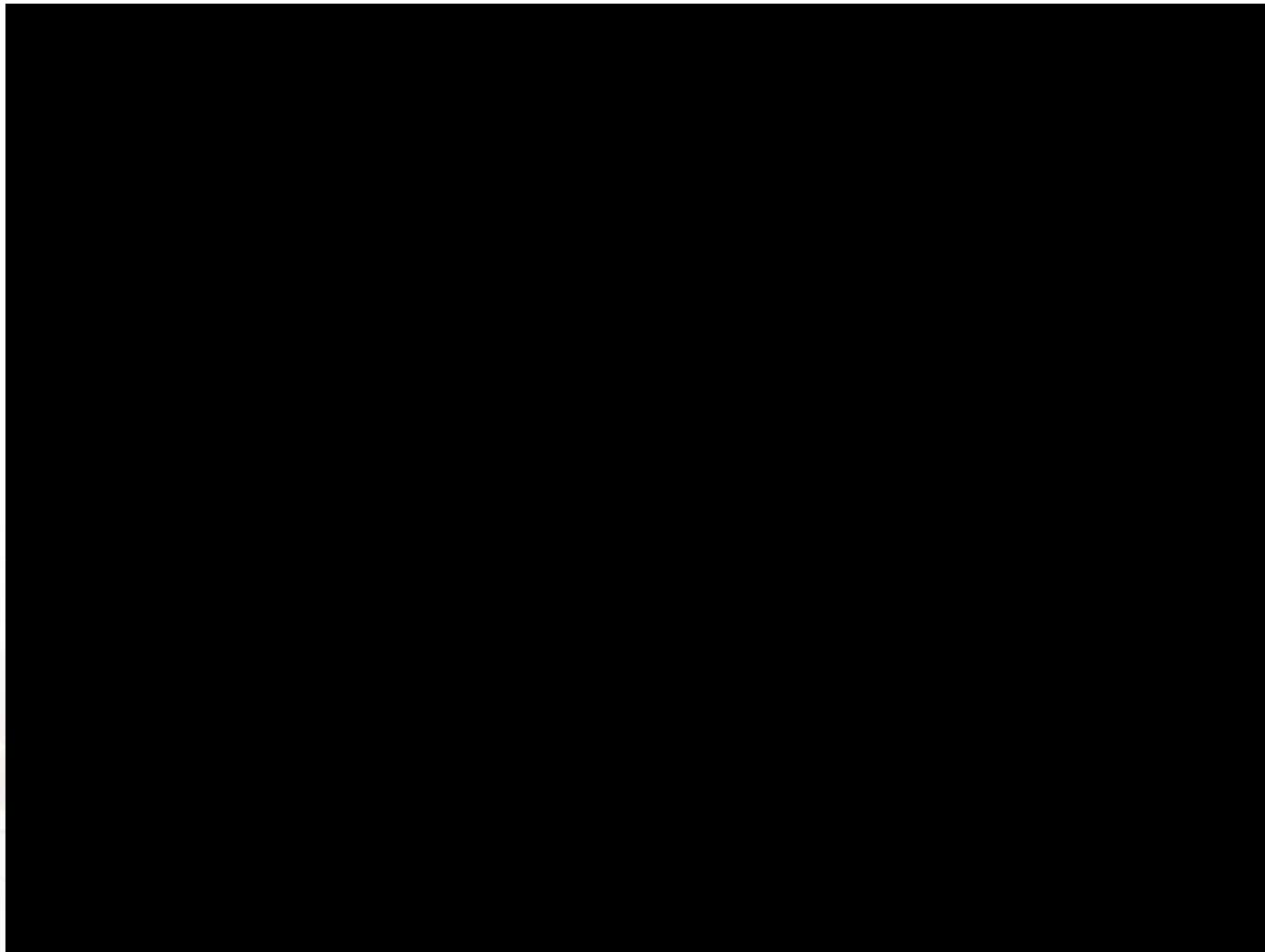


# Soap Bubble Technique



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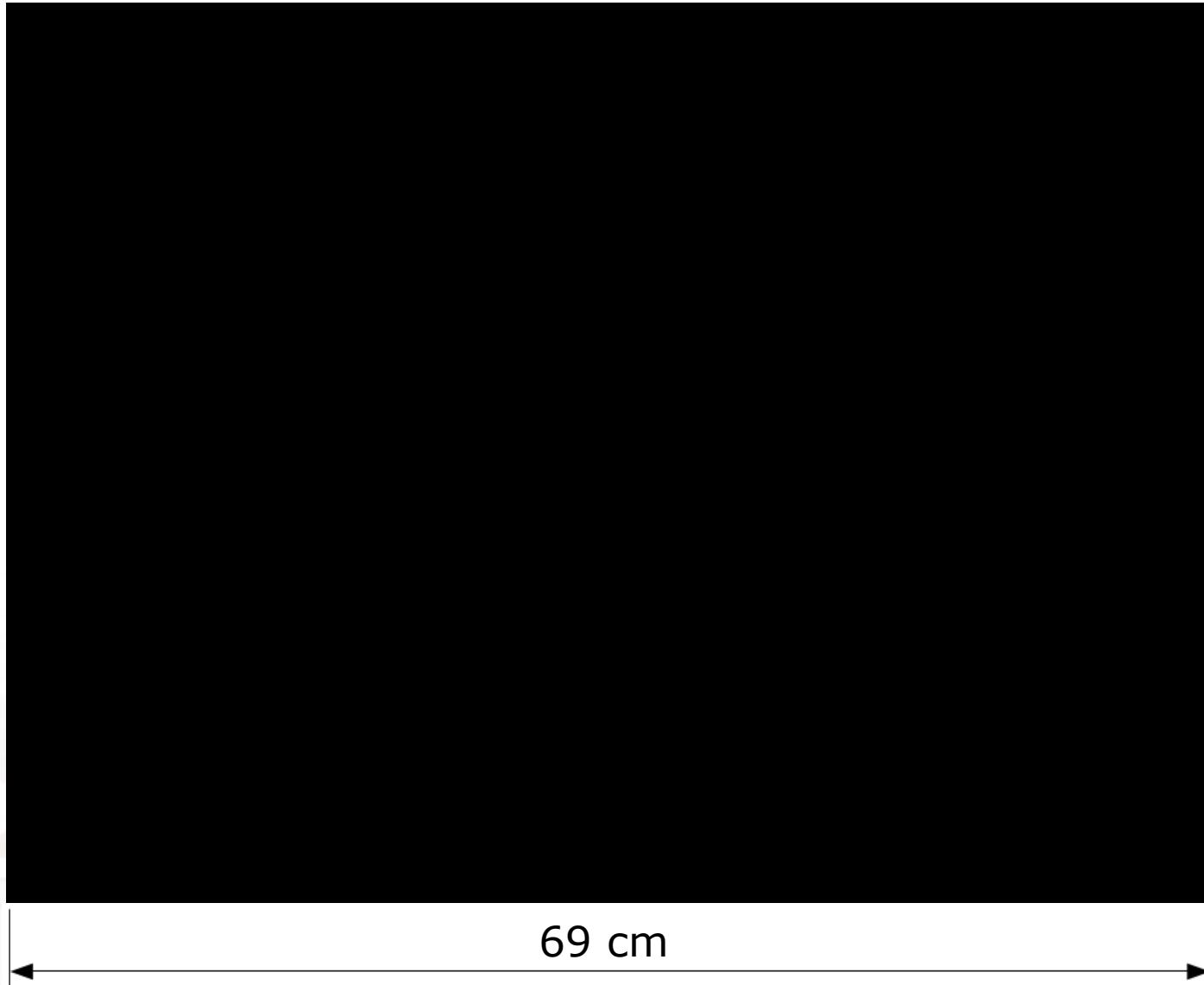
# Unconfined Flames - Schlieren



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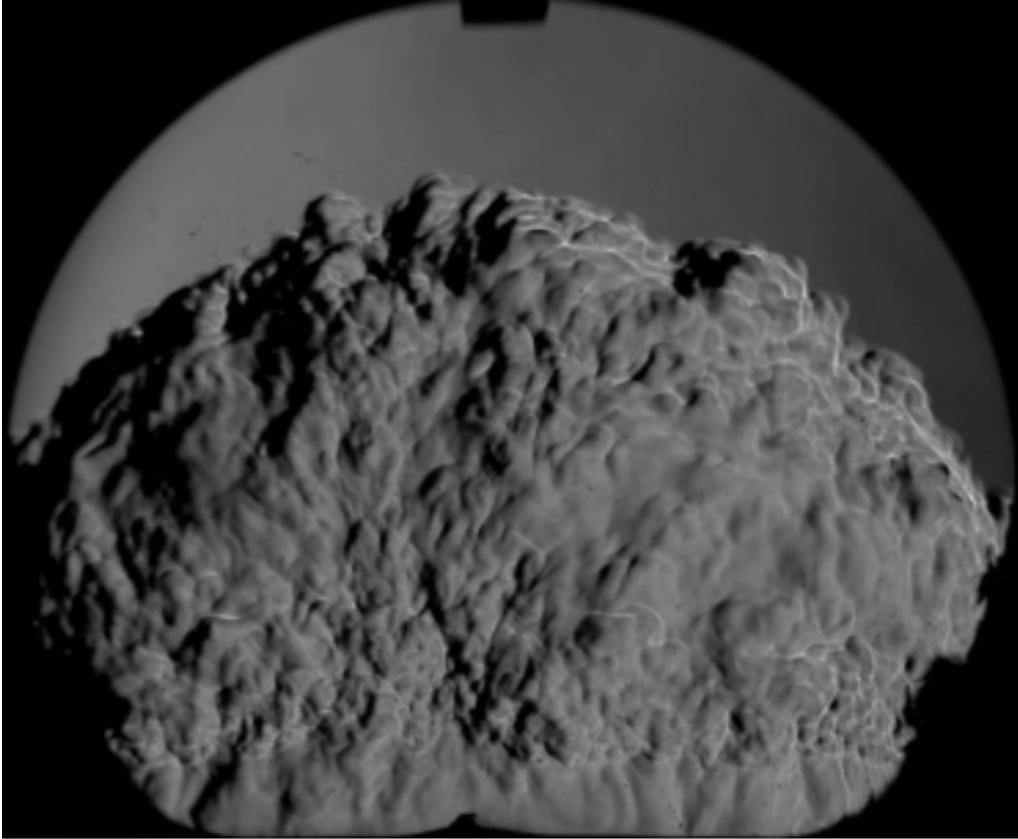
15% H<sub>2</sub> – Air  
 $\Phi = 0.42$   
Soap bubble diameter 22 cm

# Unconfined Flames - Shadowgraph

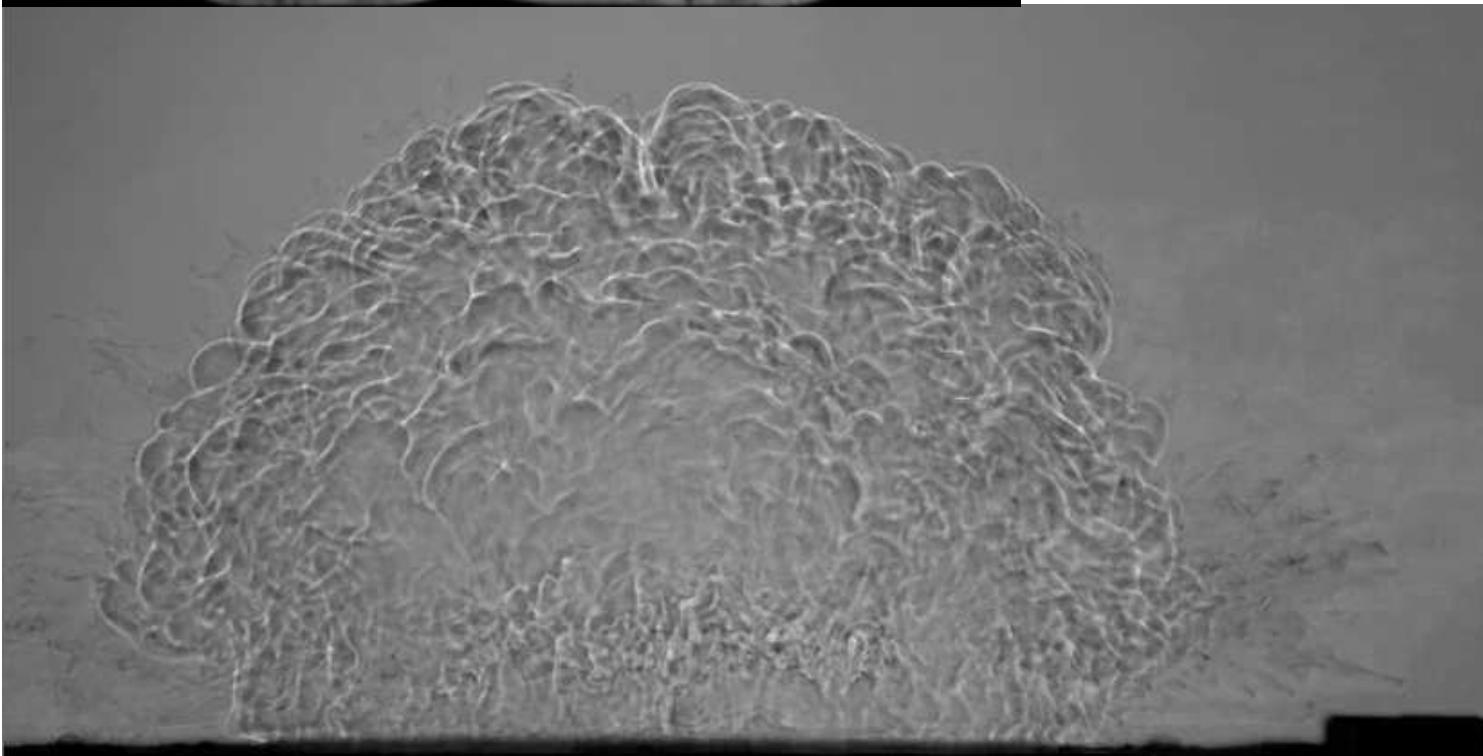


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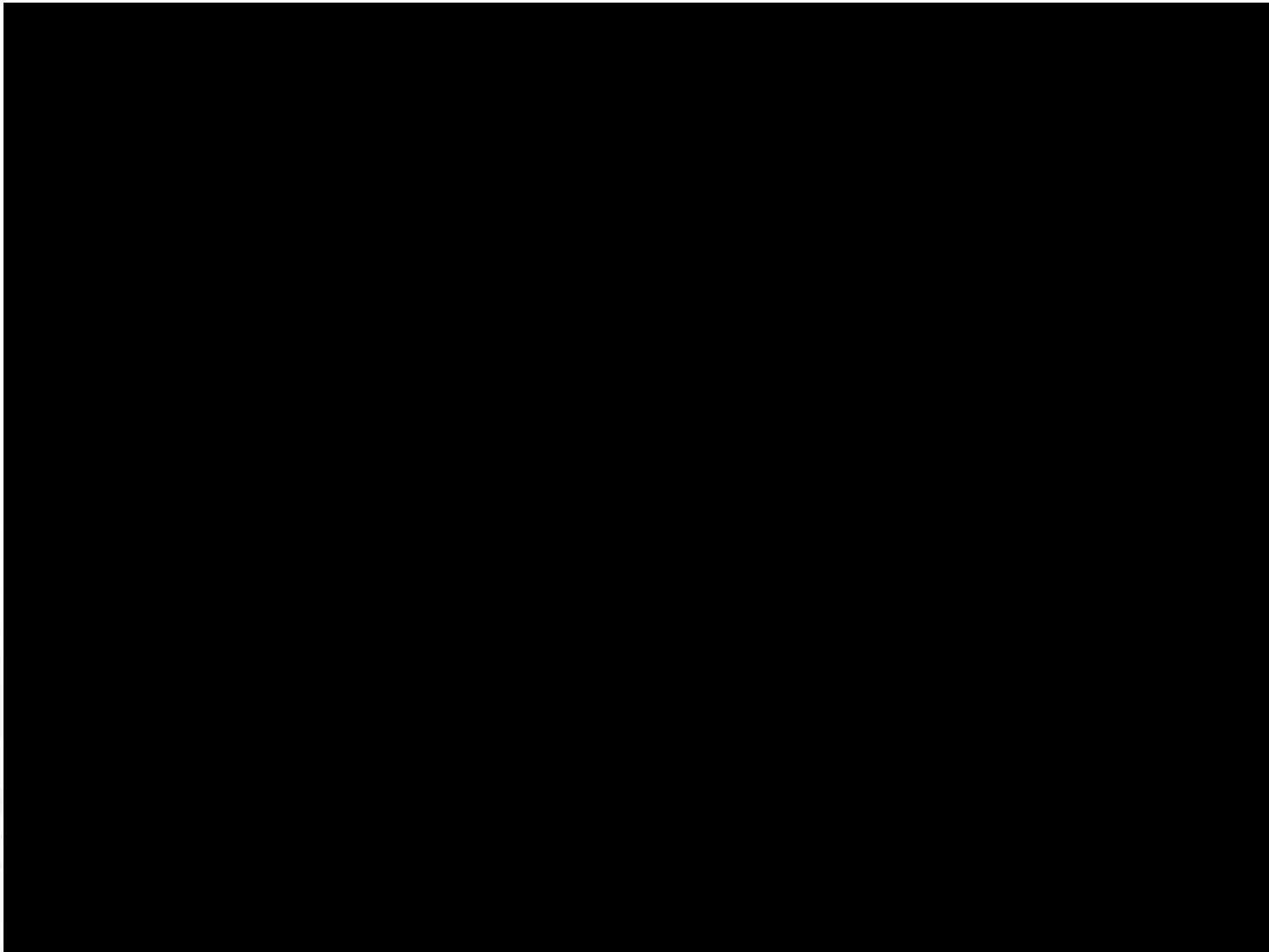
15% H<sub>2</sub> – Air  
 $\Phi = 0.42$   
Soap bubble diameter 33 cm



## Unconfined Flames Comparison



# Unconfined Flames - Methane

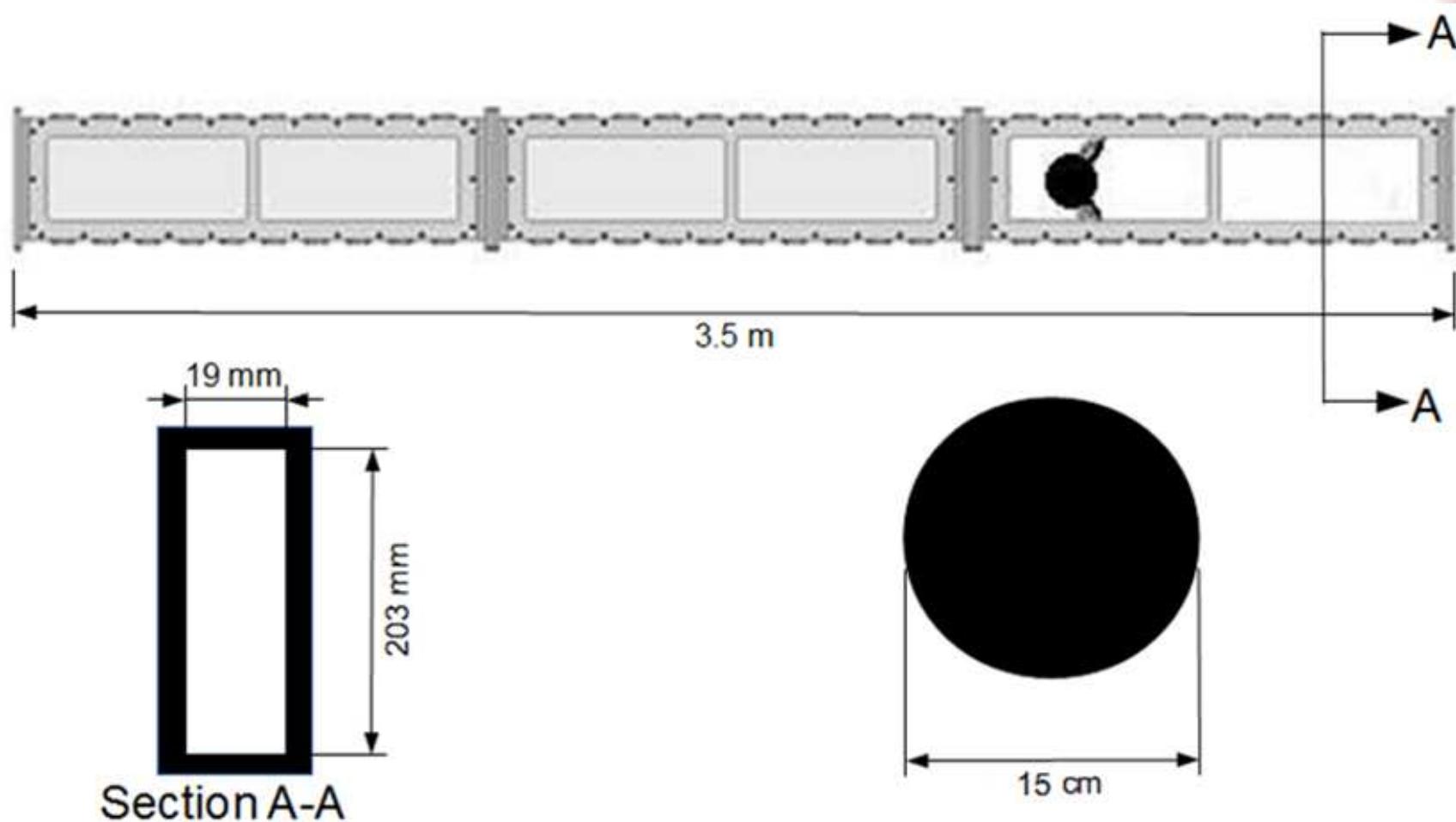


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$\text{CH}_4 + \text{Air}$

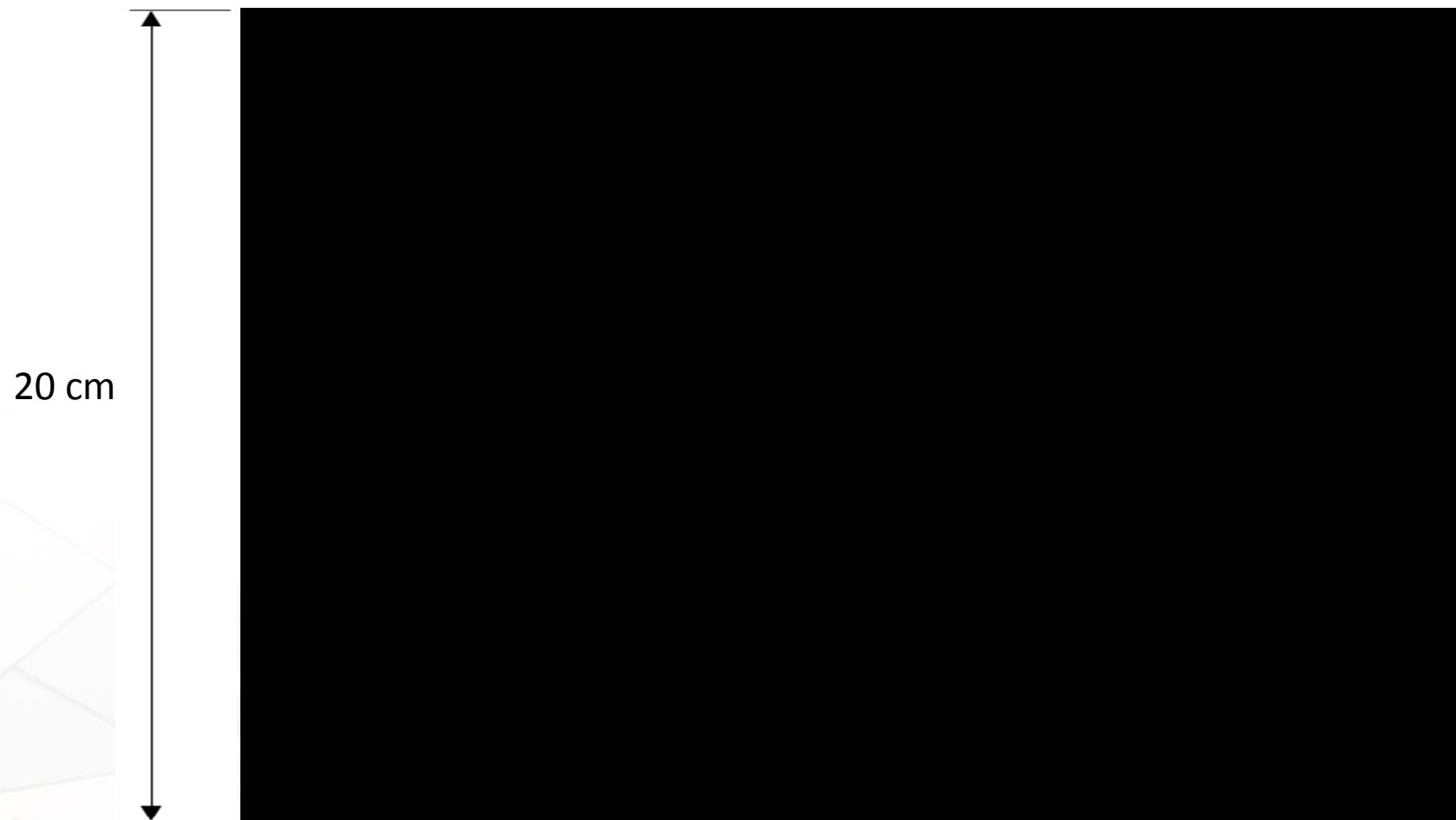
Setup courtesy of P. Julien from McGill University

# Shock Tube



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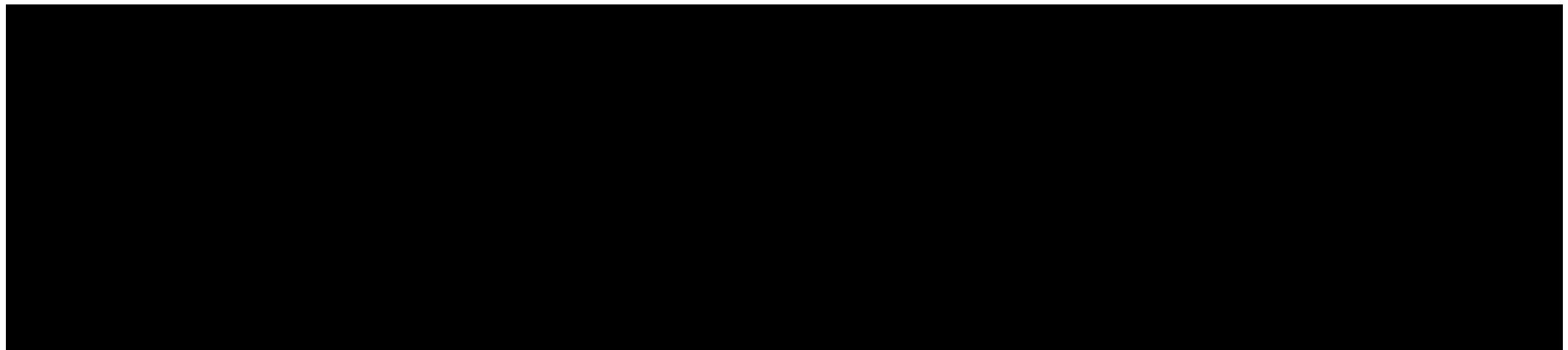
# Methane Detonations - Schlieren



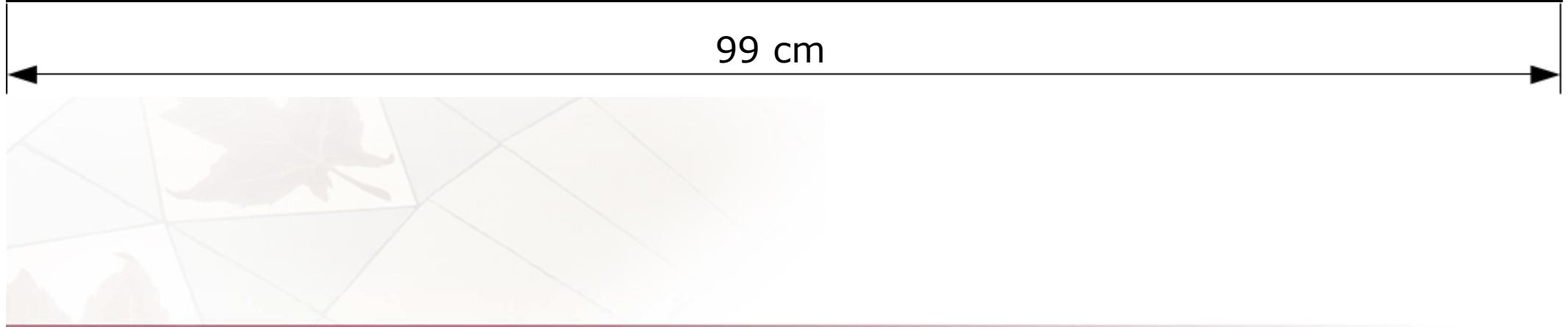
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$\text{CH}_4 + 2\text{O}_2$   
17 kPa

# Methane Detonations - Shadowgraph



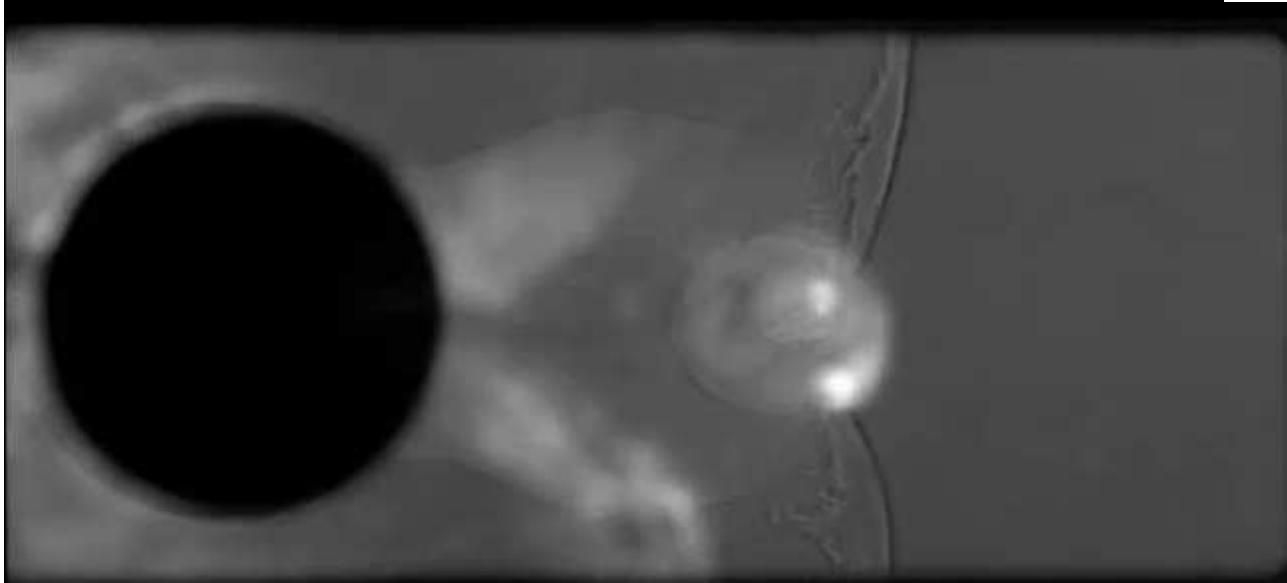
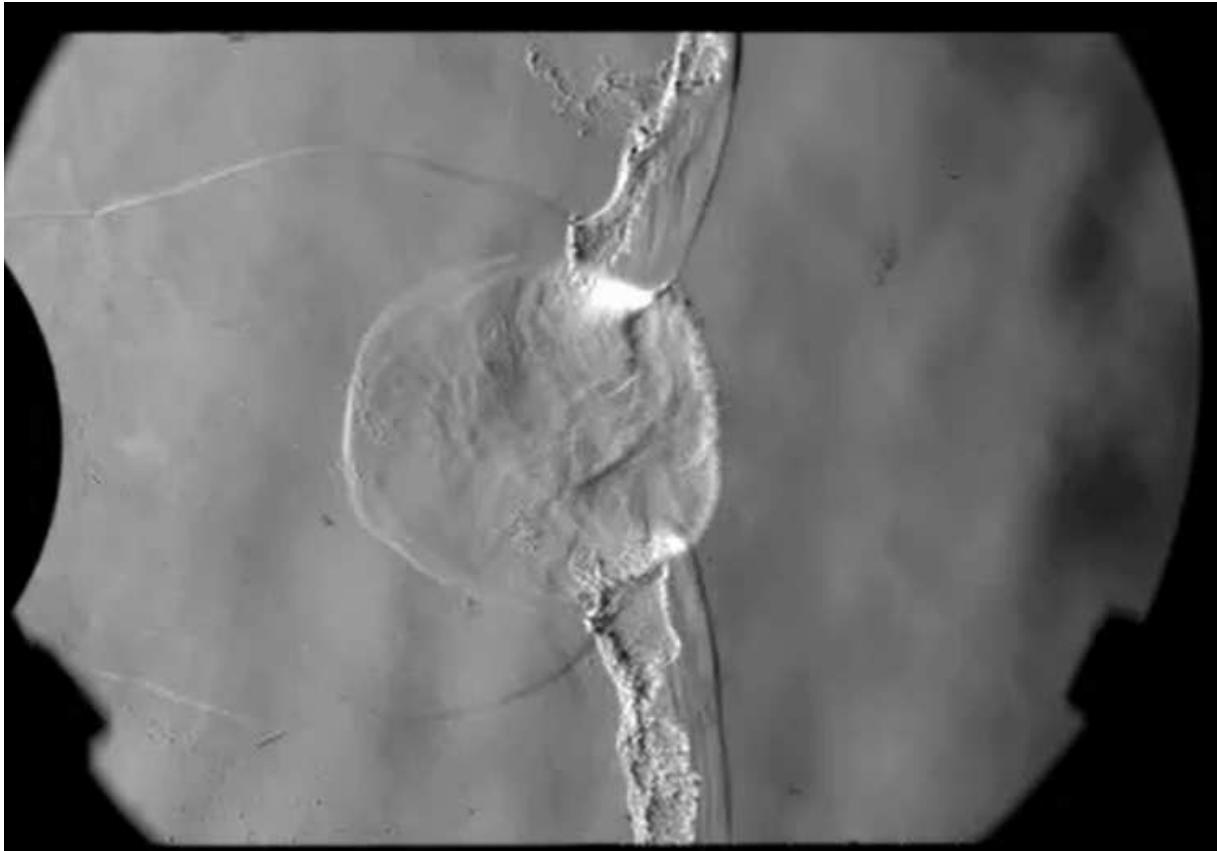
99 cm



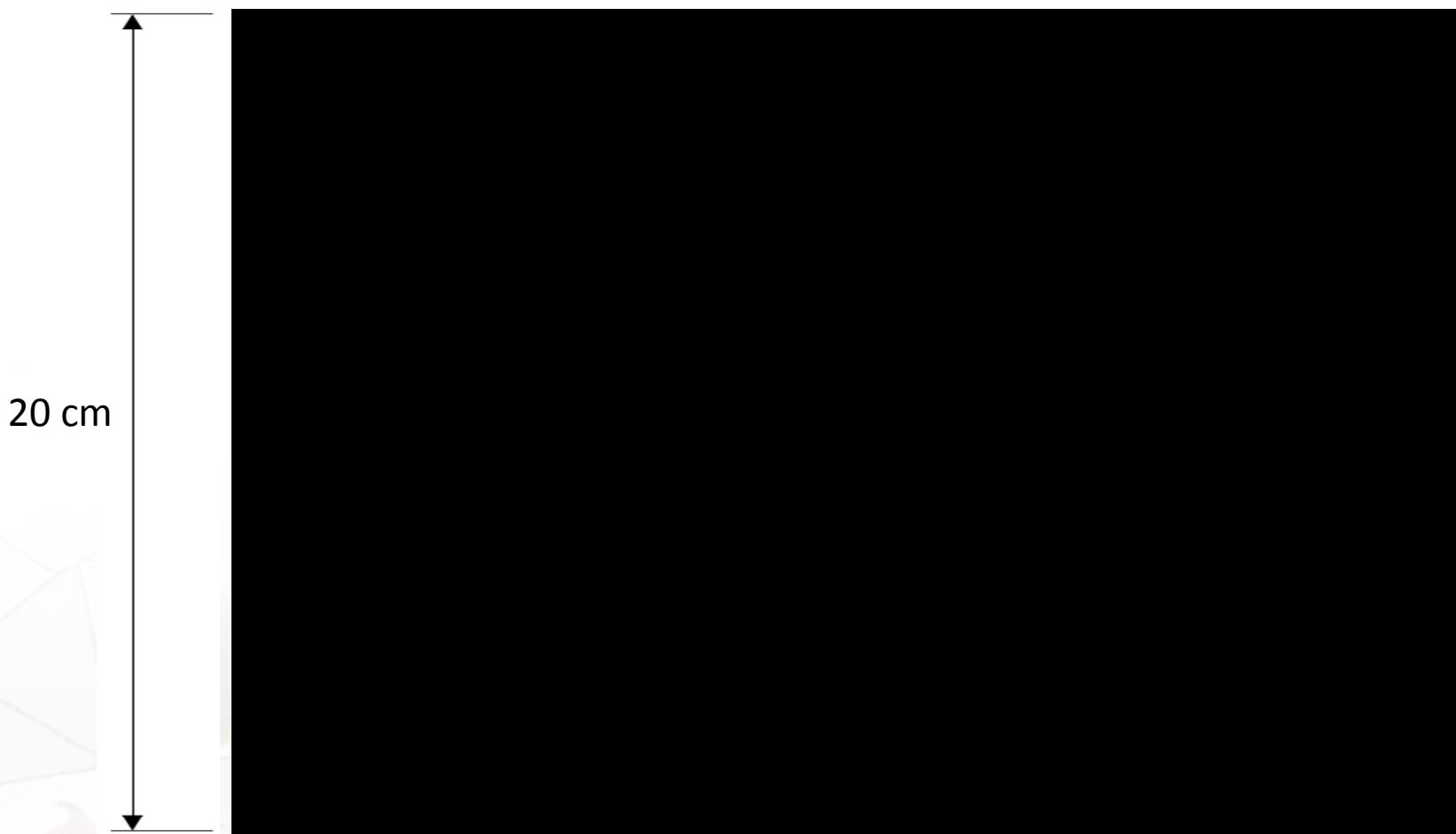
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$\text{CH}_4 + 2\text{O}_2$   
14 kPa

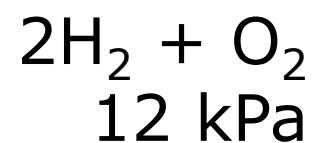
# Methane Detonations - Comparison



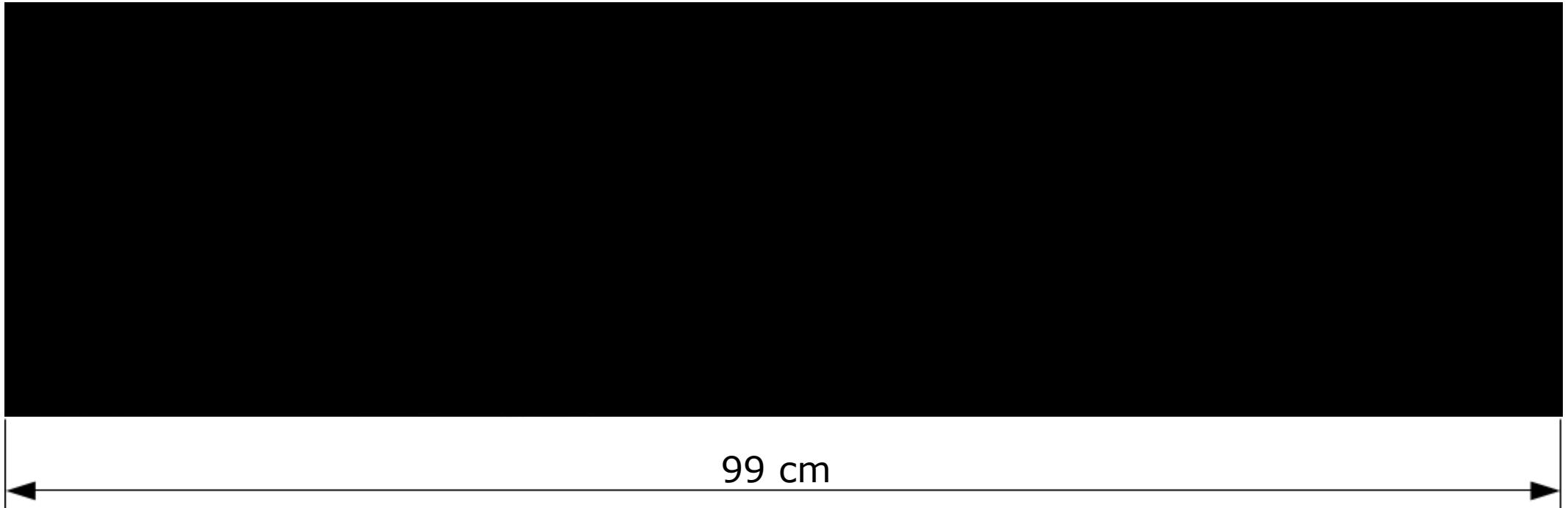
# Hydrogen Detonations - Schlieren



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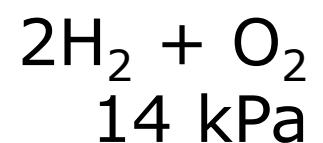
# Hydrogen Detonations - Shadowgraph



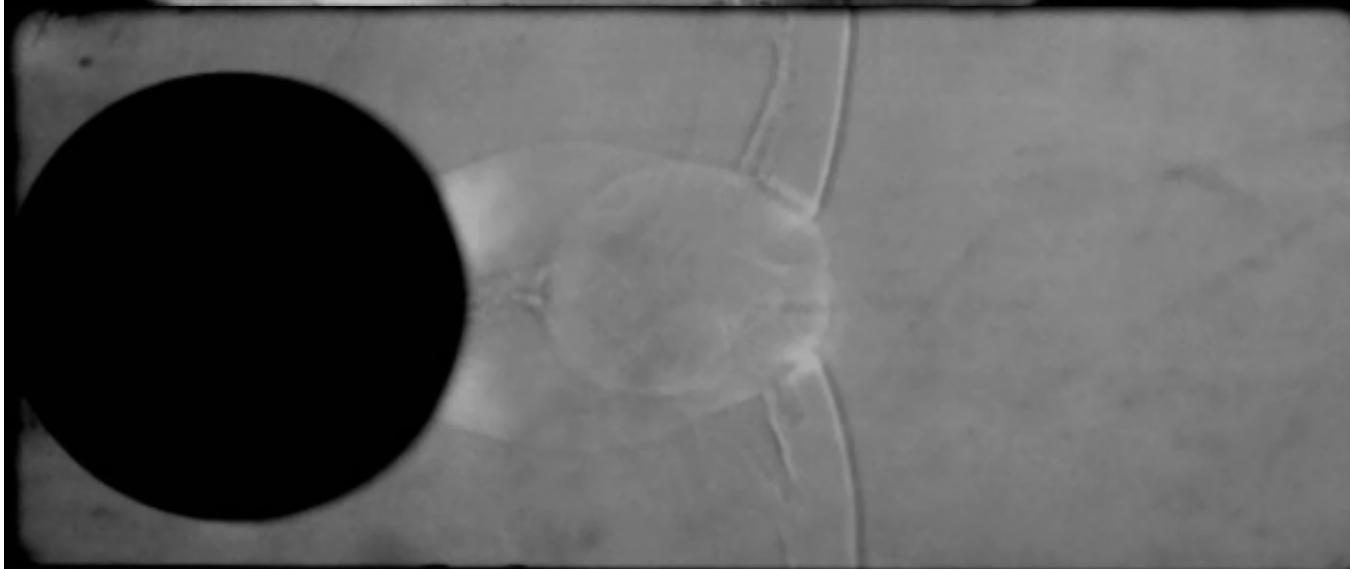
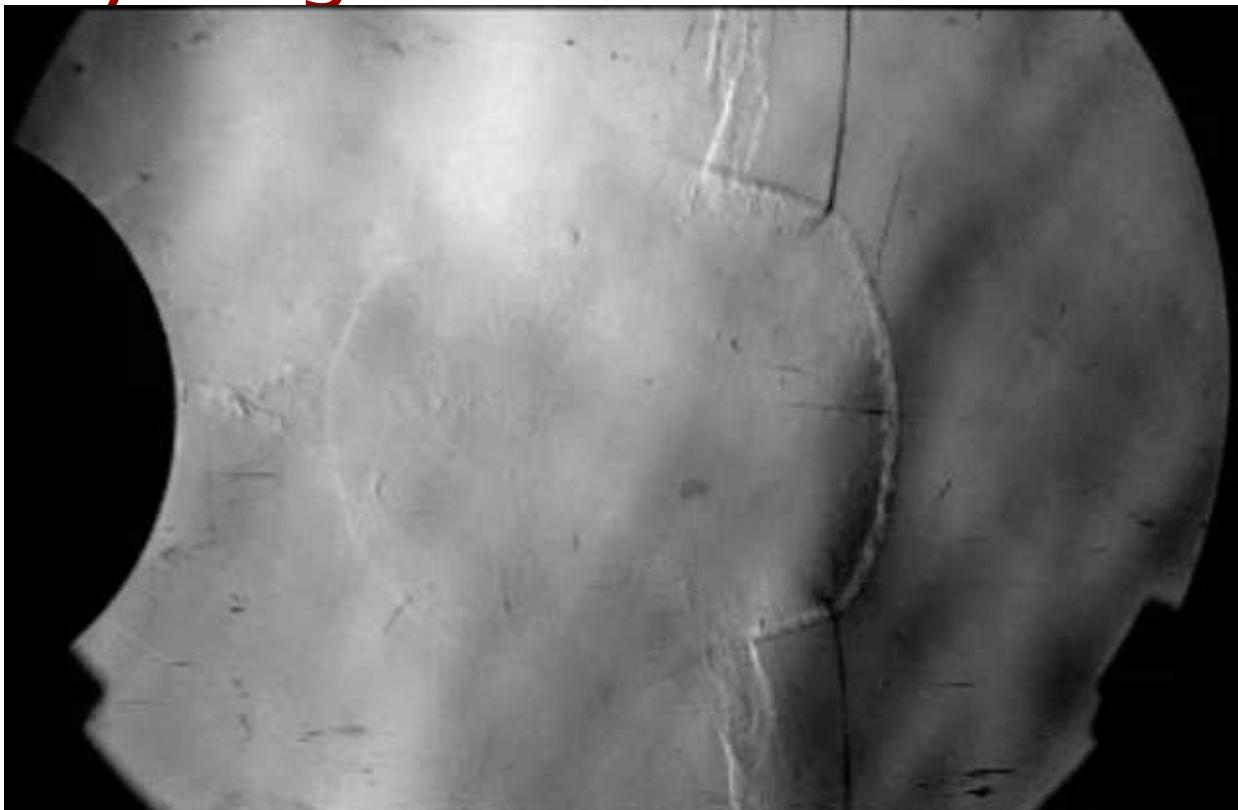
99 cm



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# Hydrogen Detonations - Comparison



# Conclusions



- Strong in all experiments
- Applicable outside of combustion experiments
- Low-cost
- Large-scale analysis
- Loss of detail



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# Future Work



- Flash light source
- Self-luminosity issues



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# Acknowledgements



**AECL  
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