SPHIR Facility and Recently added Diagnostics

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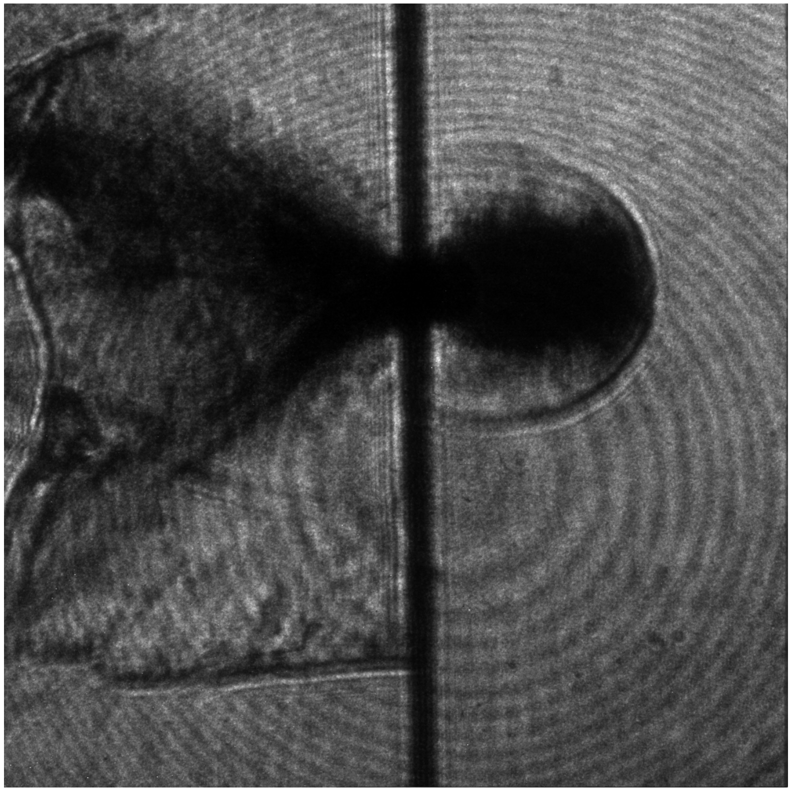

Ares Rosakis, Jon Mihaly, Marc Adams, Jon Tandy

PSAAP Site Visit
October 3rd, 2011

Overview: Major push in instrumentation

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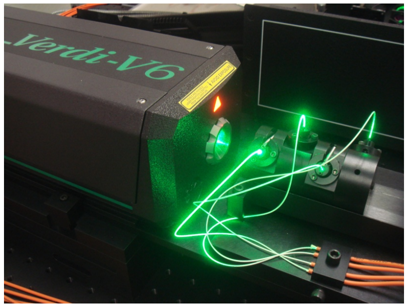
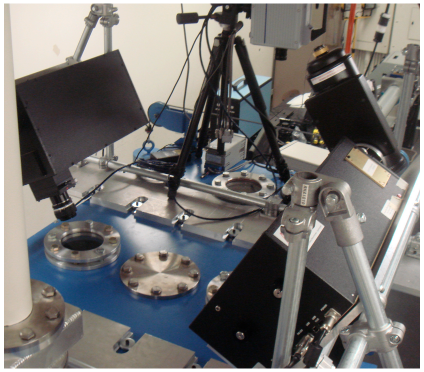
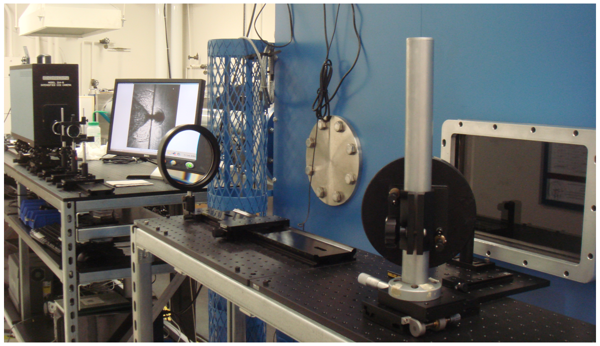
- Facility Overview and major instrumentation Improvements



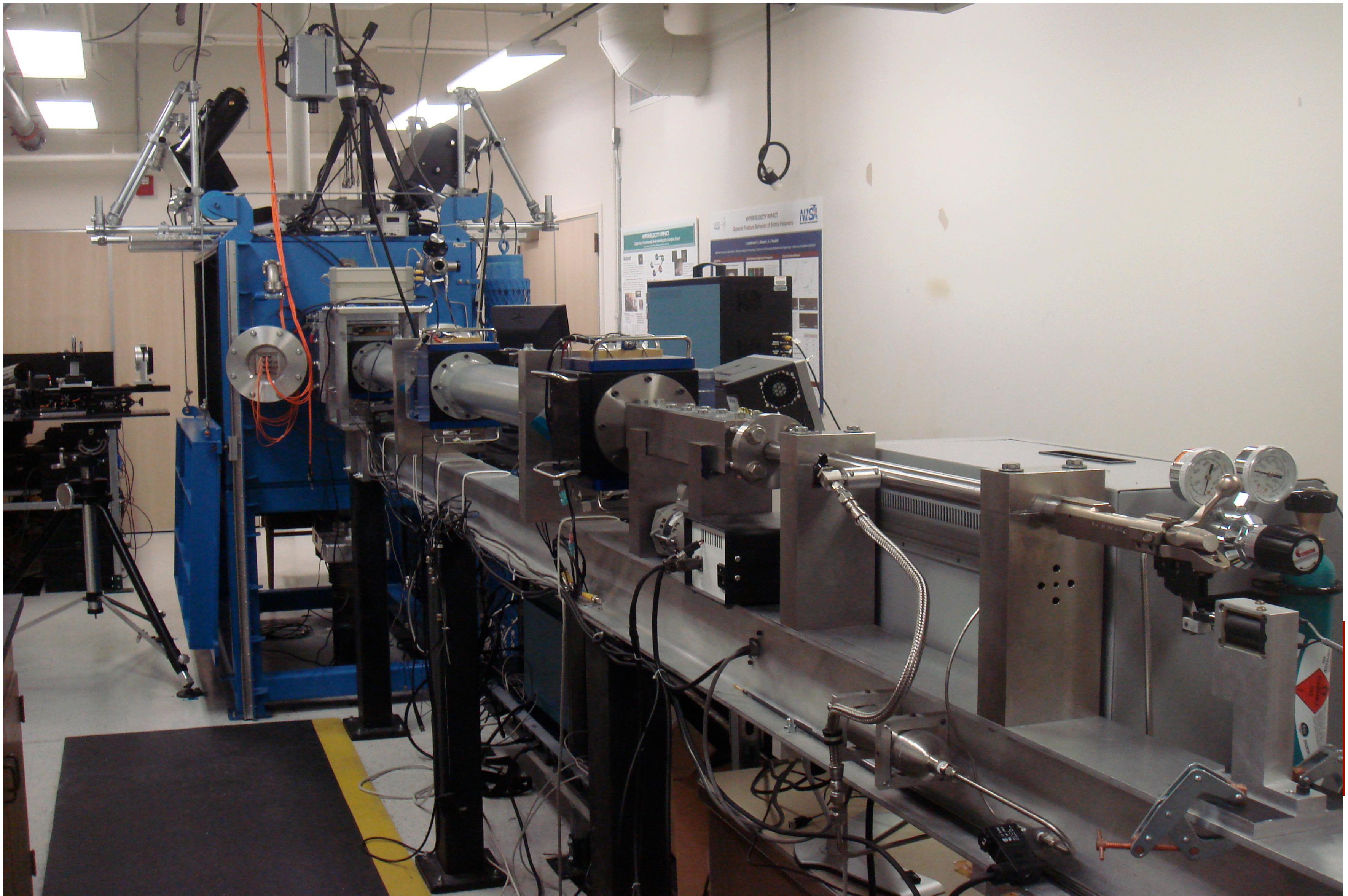
- Laser Side-lighting and CGS Results
- Preliminary Side-Lighting Analysis



- Preliminary Capture Pack Results
- Spectrometer Update
- Legacy Data Database Update



Experimental Facility



Velocimetry: 5 – 10 km/s

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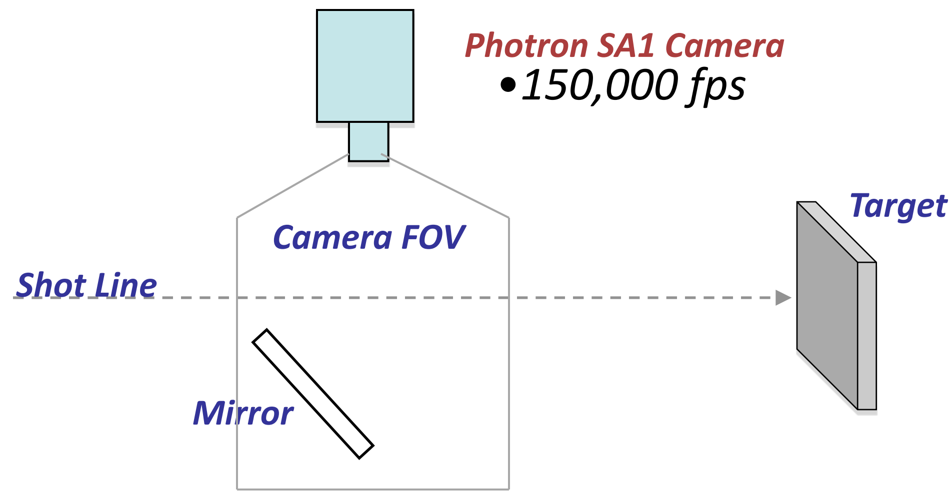
- Impactor ionizes atmosphere, producing plasma sheath
- Impact speed determined from tracking of plasma sheath



Laser Side-Lighting Facility Setup

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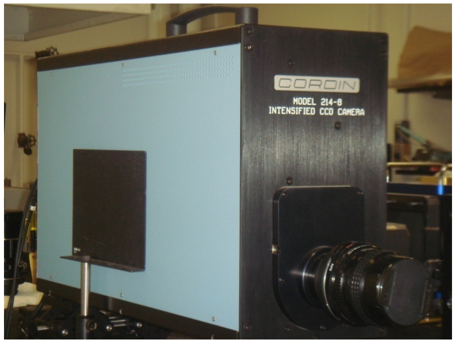
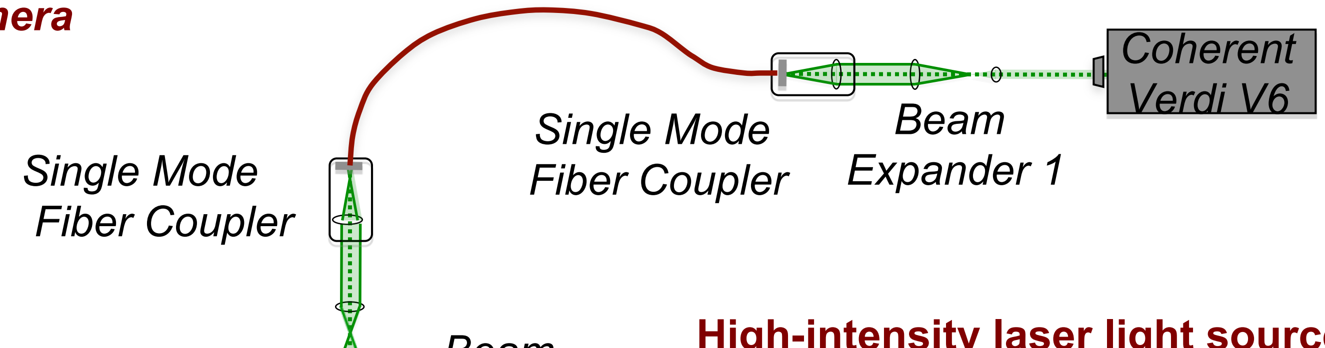
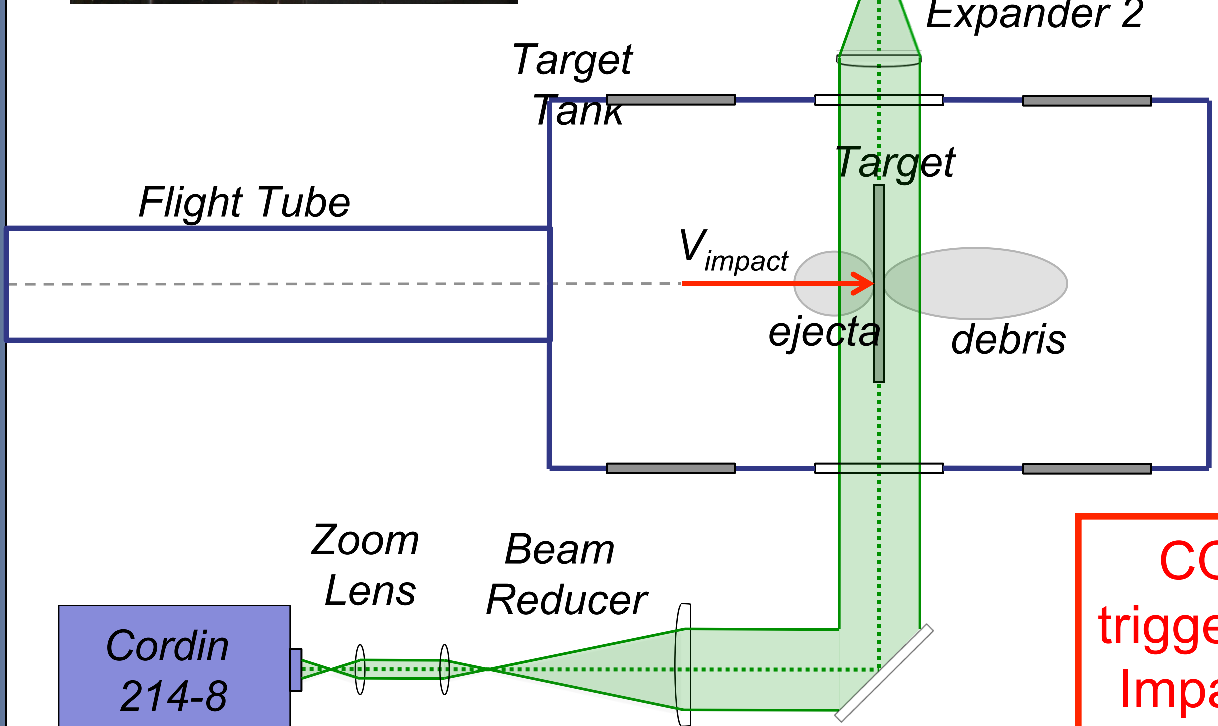
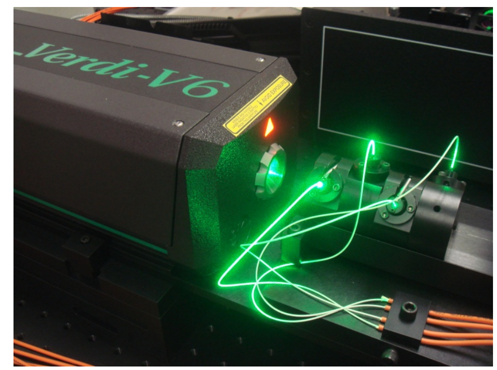
CORDIN 214-8 Model Camera







High-intensity laser light source



CORDIN triggered off of Impact Flash

(Not to scale)

Laser Side-Lighting Facility Setup

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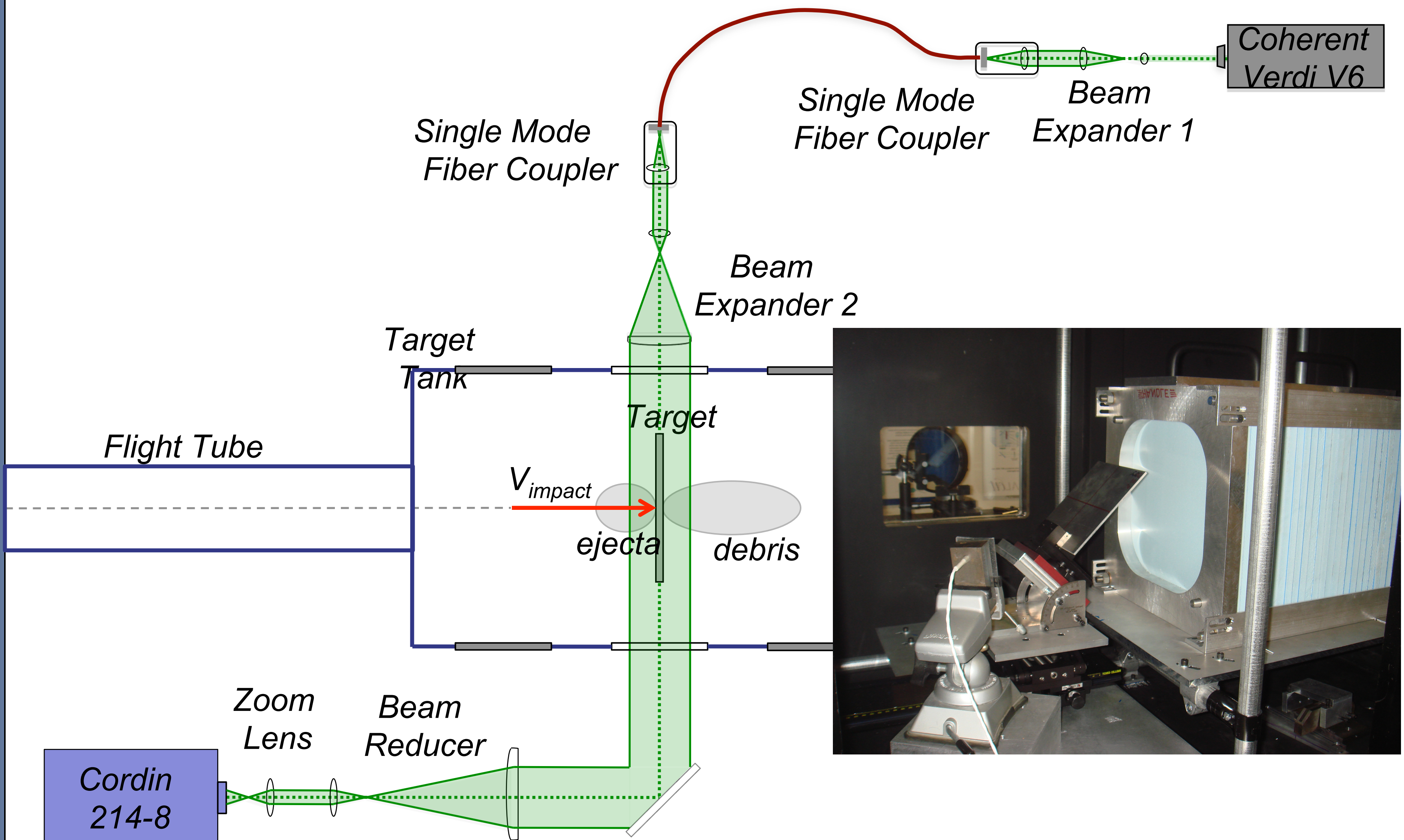

(Not to scale)

Laser Side-Lighting Facility Setup

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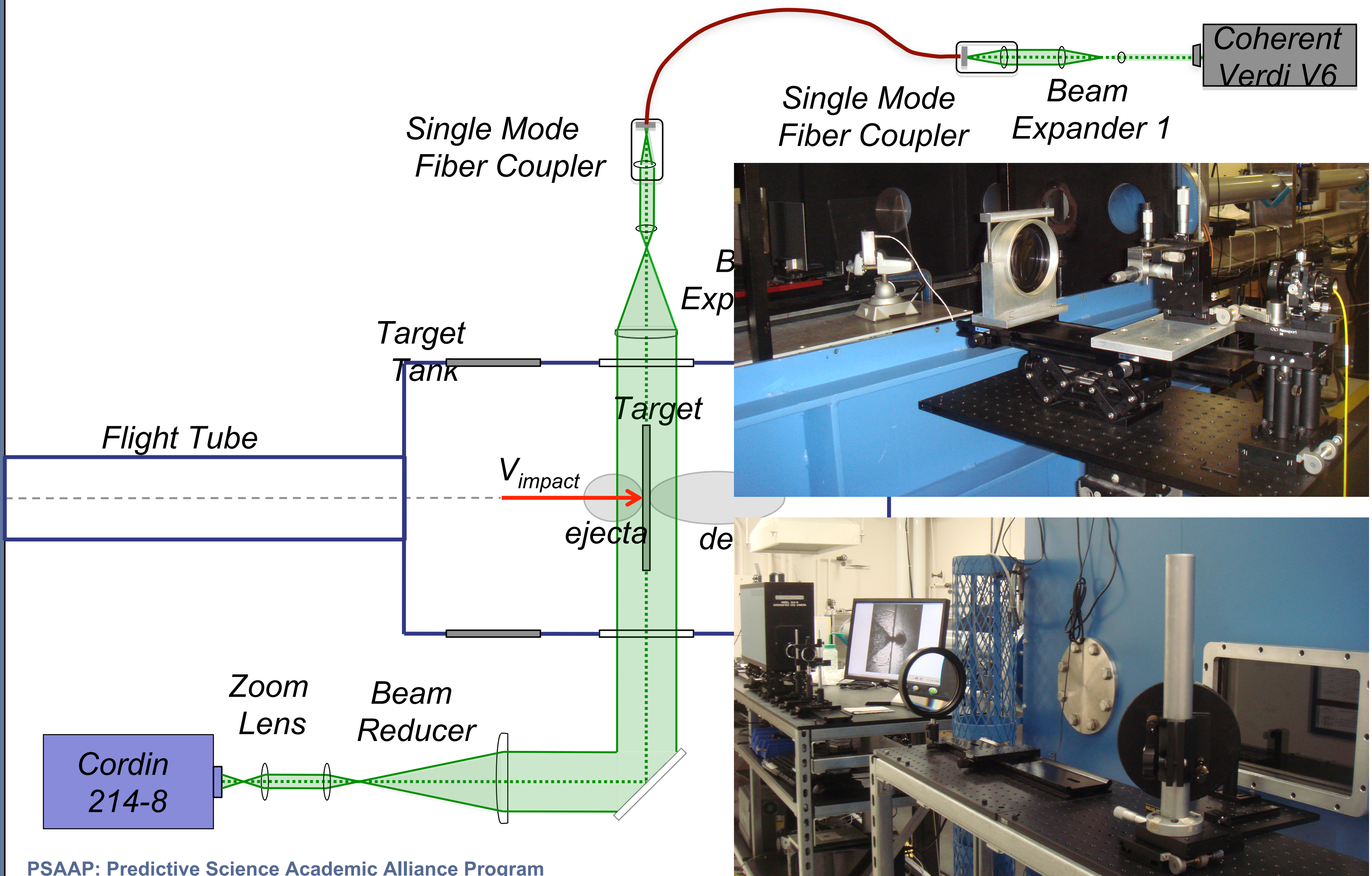
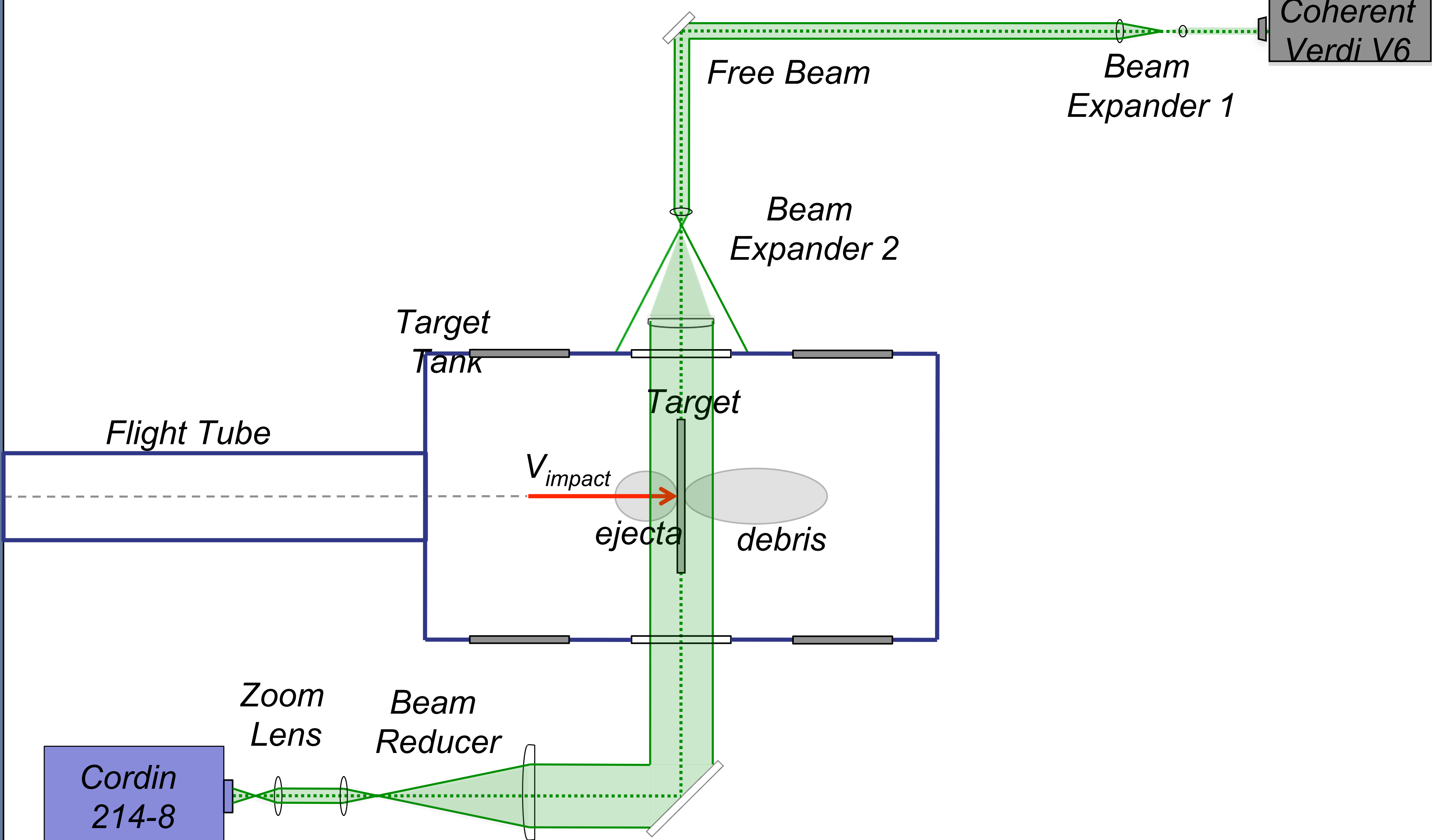


Laser Side-Lighting Facility Setup

CALTECH PSAAP



(Not to scale)

Side-Lighting: Thick vs. Thin

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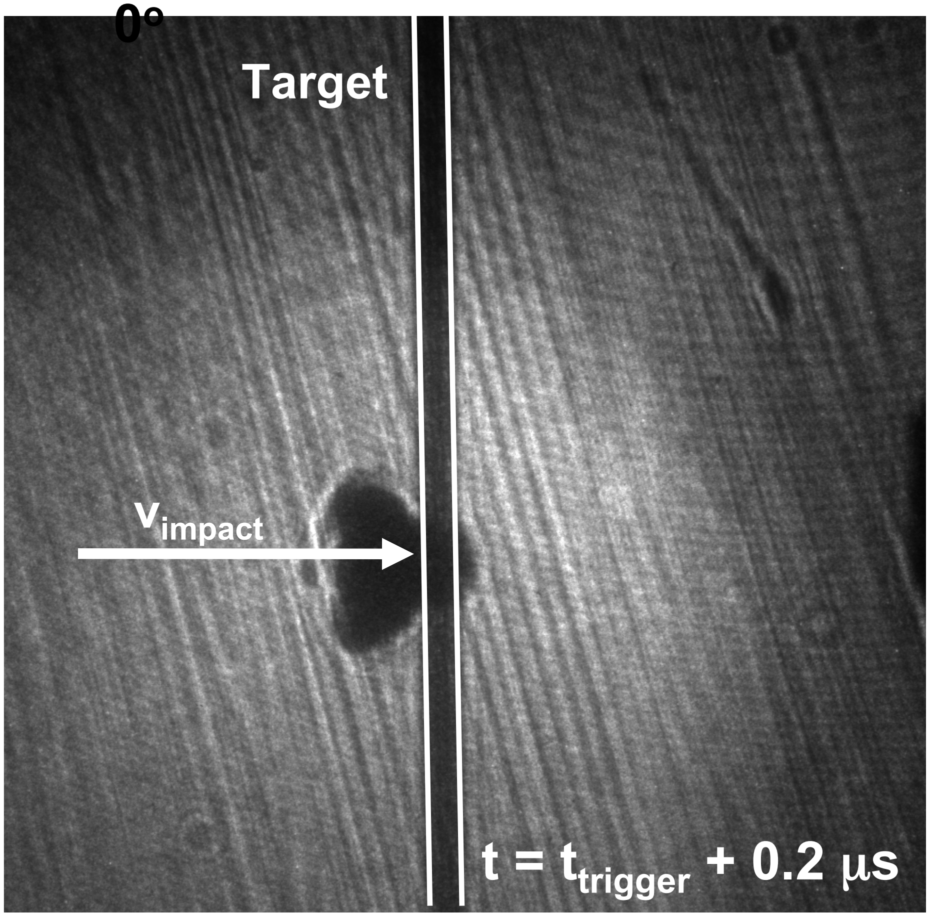
V_{impact} = 5.4 km/s

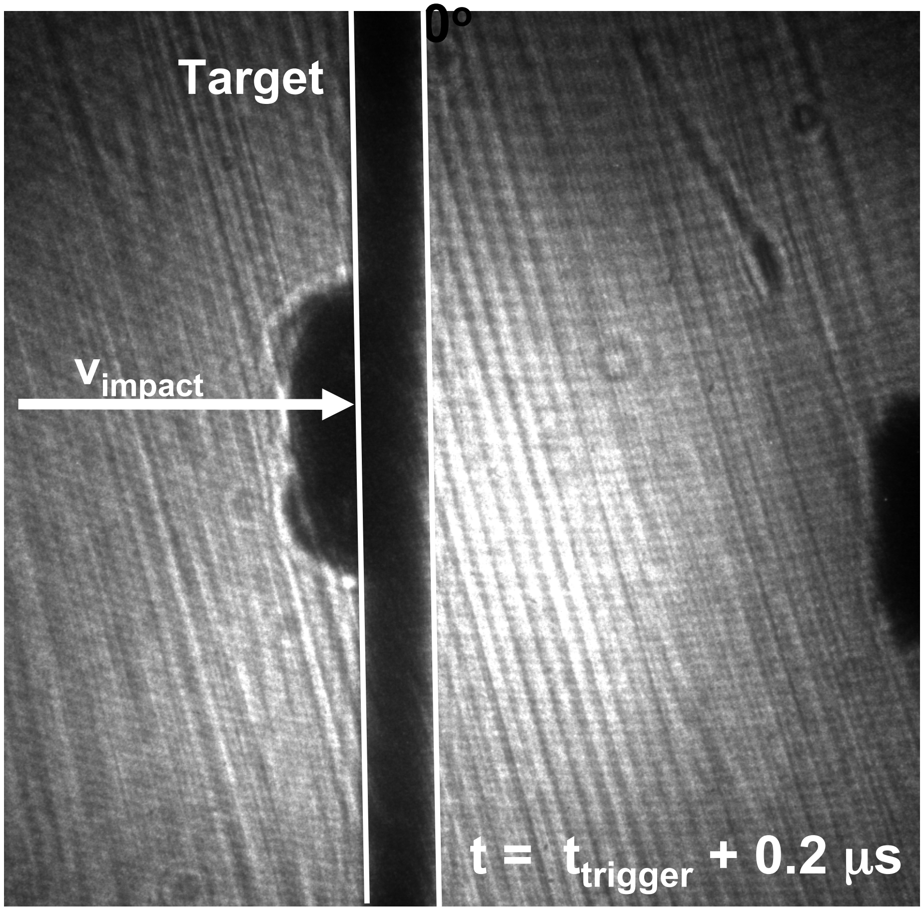
h = 1.5 mm, α = 0°

$t_{exposure}$= 25ns

V_{impact} = 5.4 km/s

h = 3.0 mm, α = 0°





Laser Side-Lighting Results

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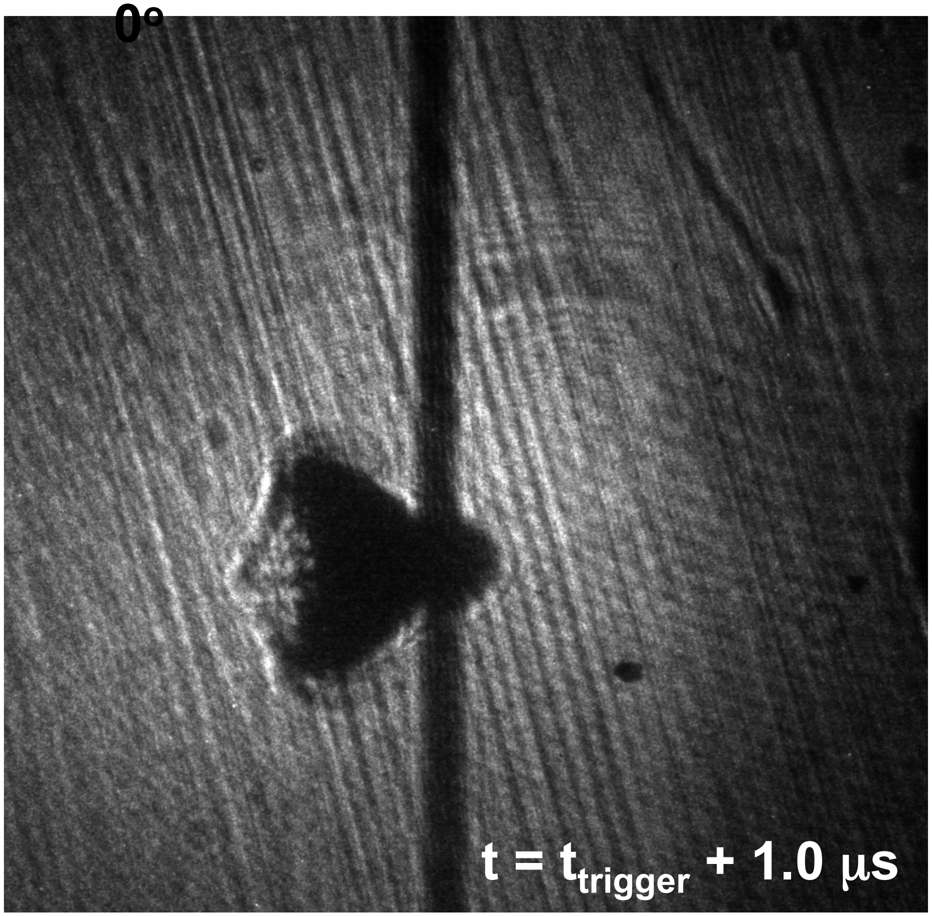

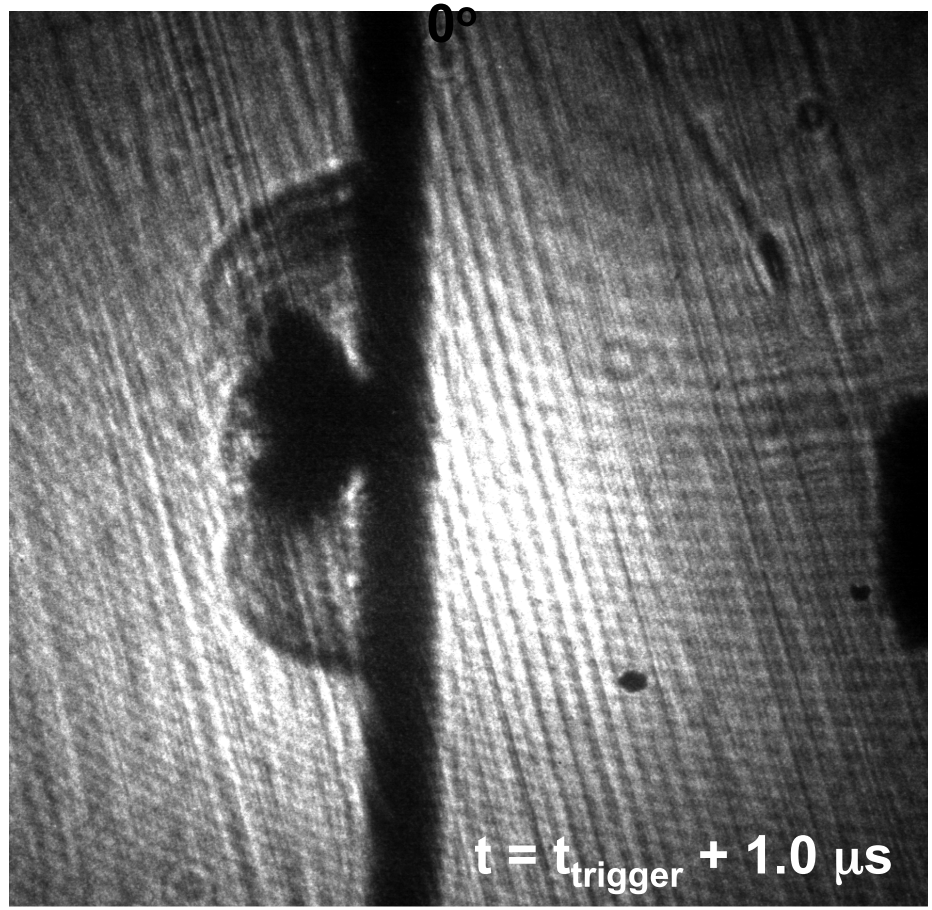

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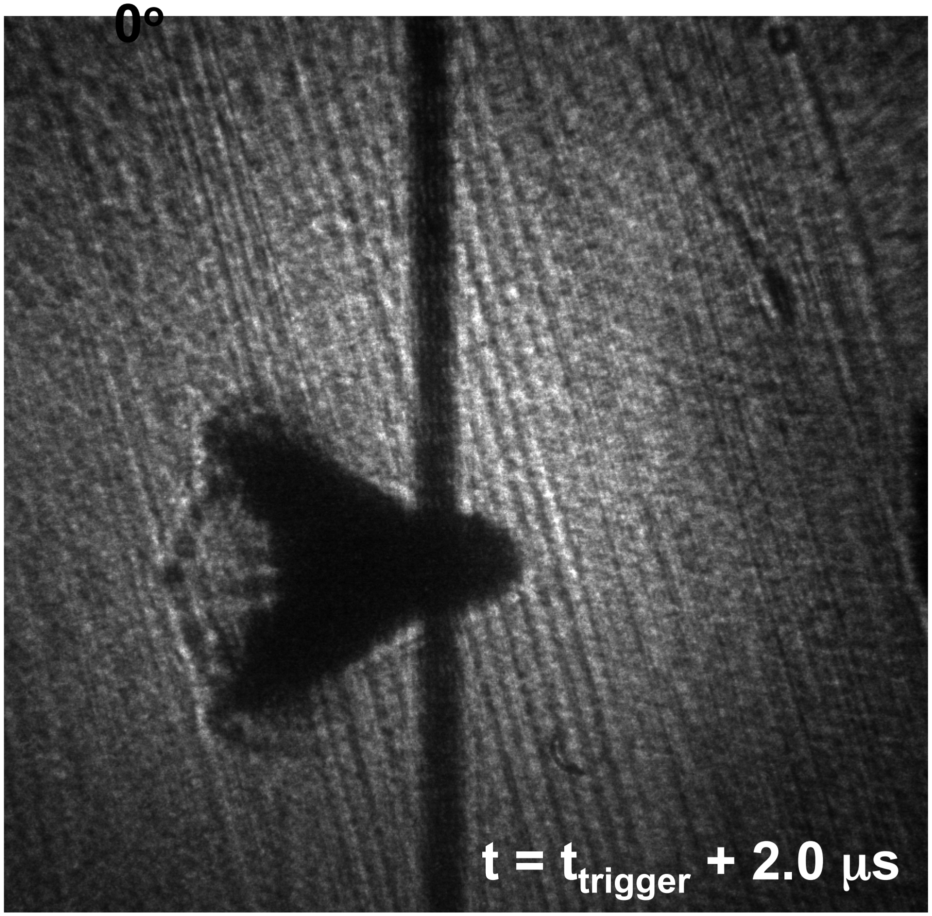

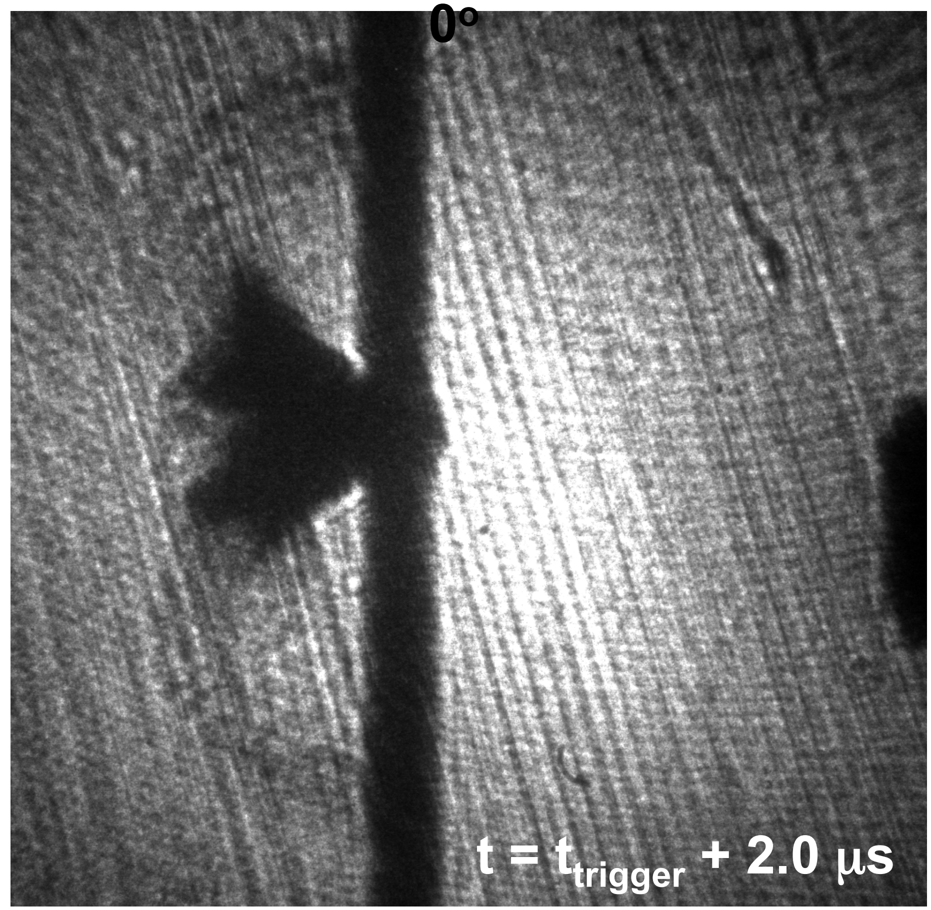

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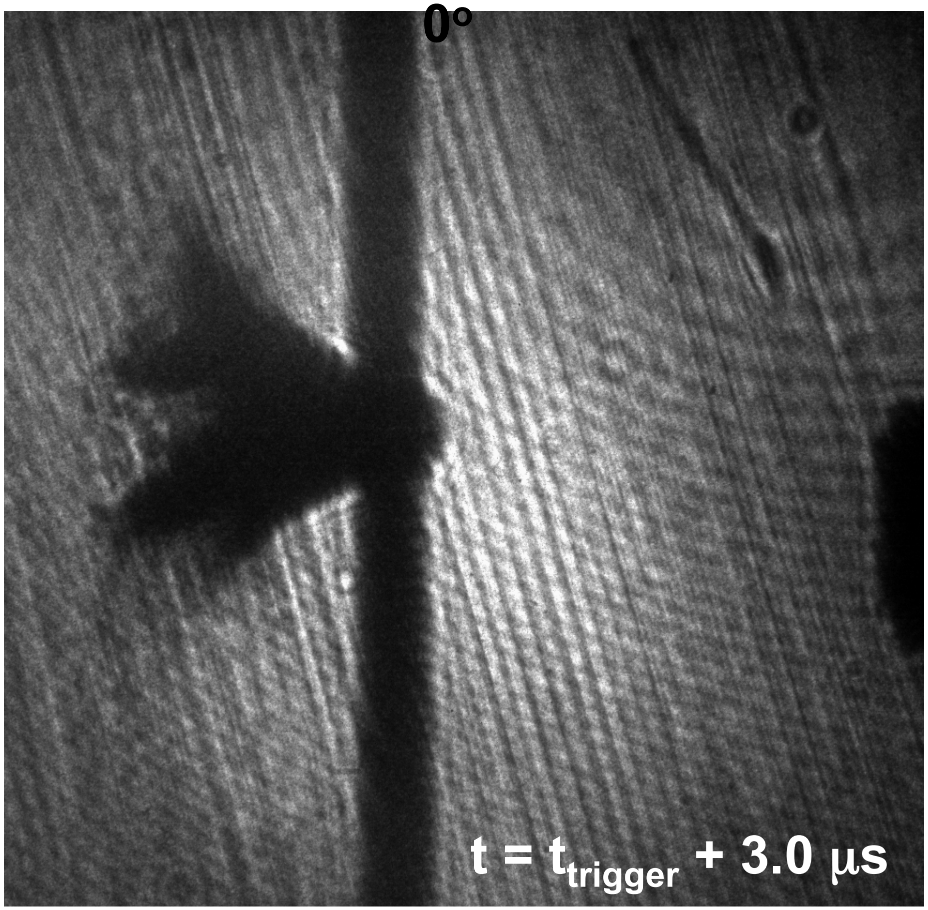

Laser Side-Lighting Results

CALTECH PSAAP

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V_{impact} = 5.4 km/s

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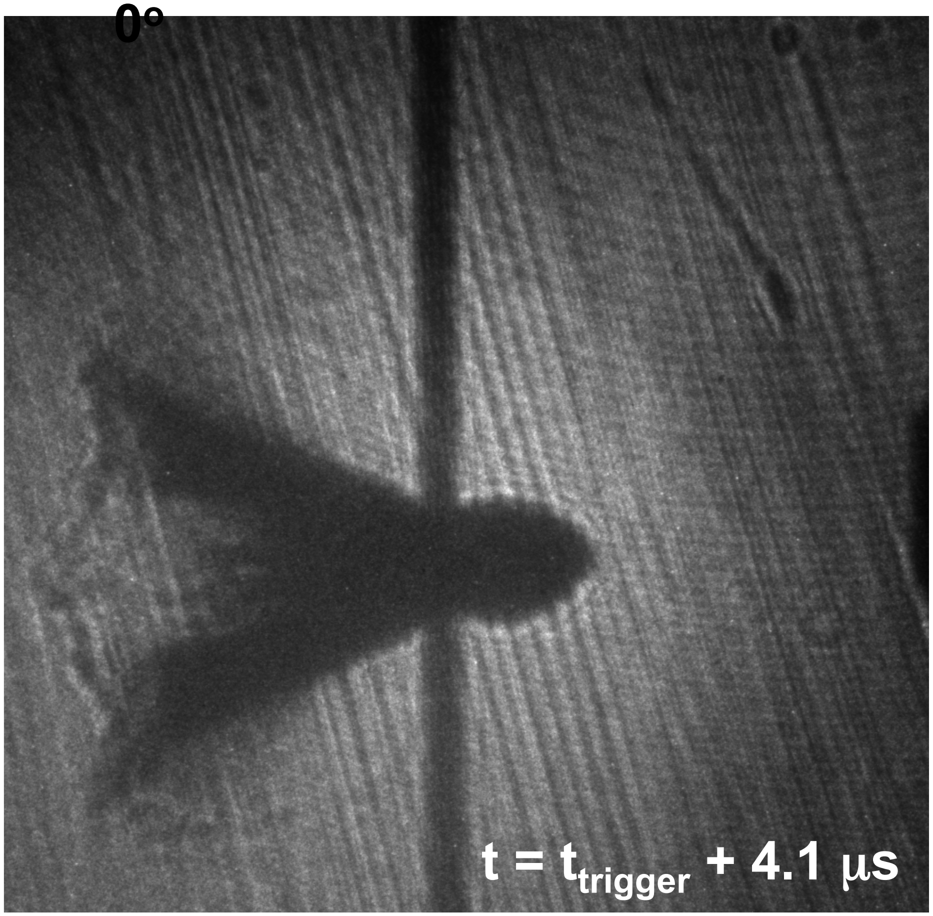

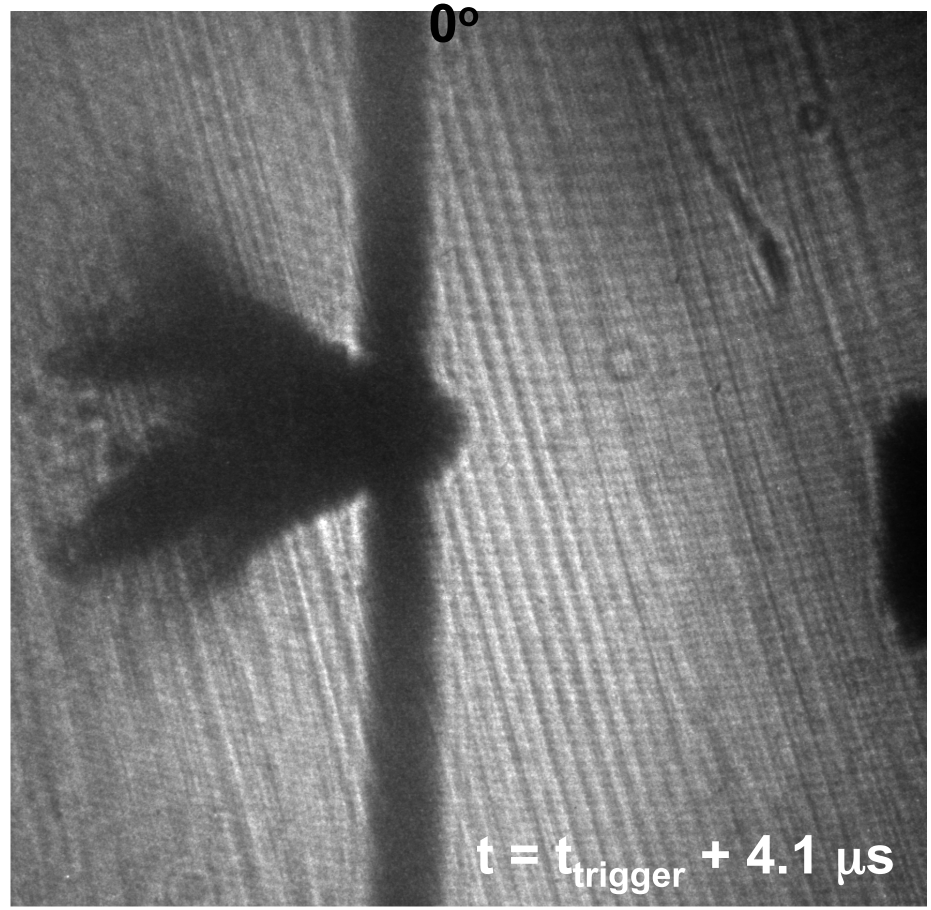

Laser Side-Lighting Results

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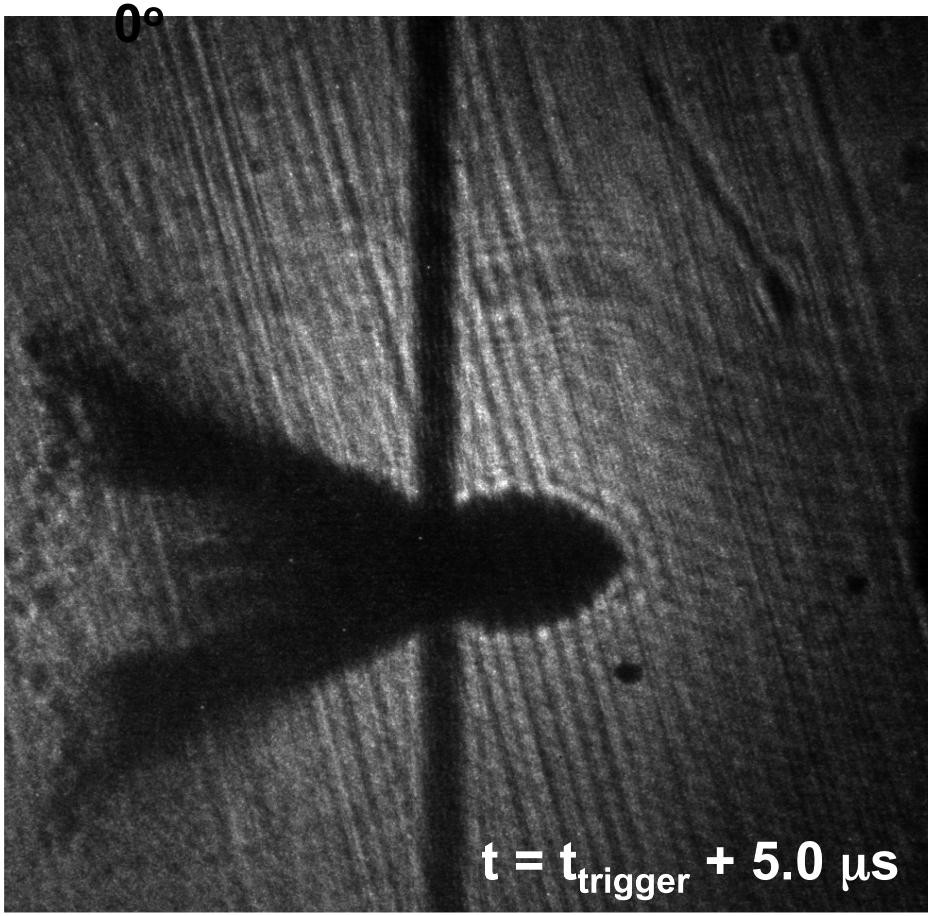

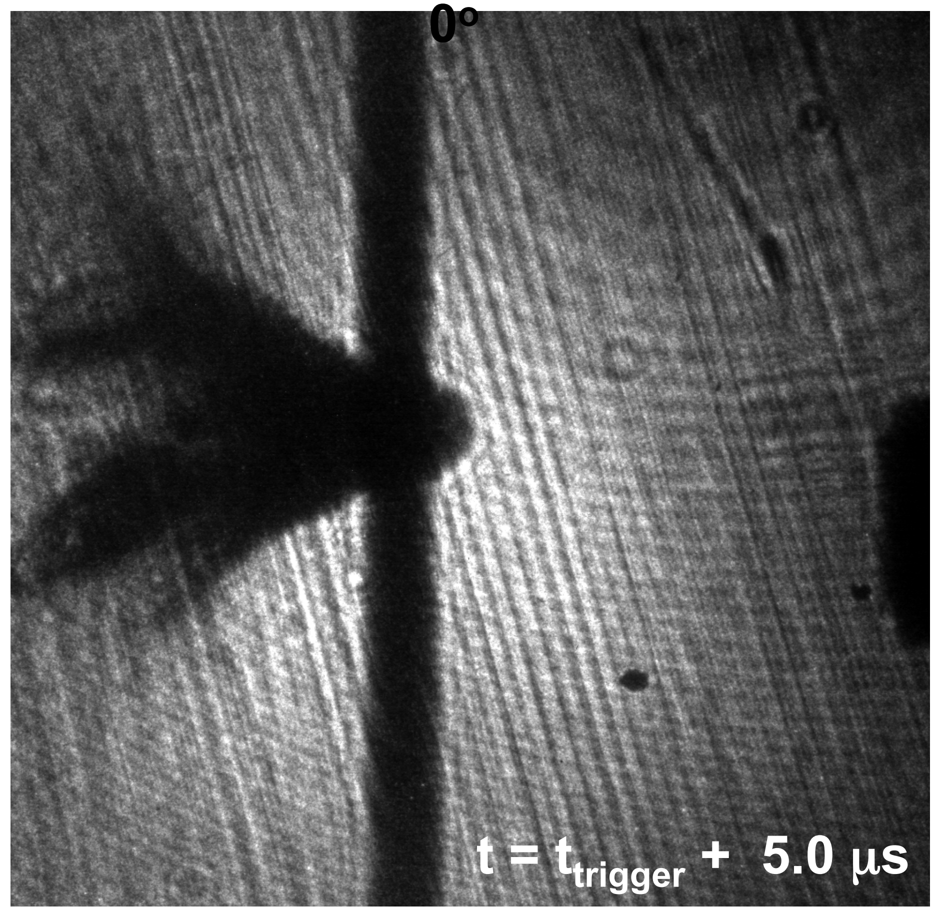

Laser Side-Lighting Results

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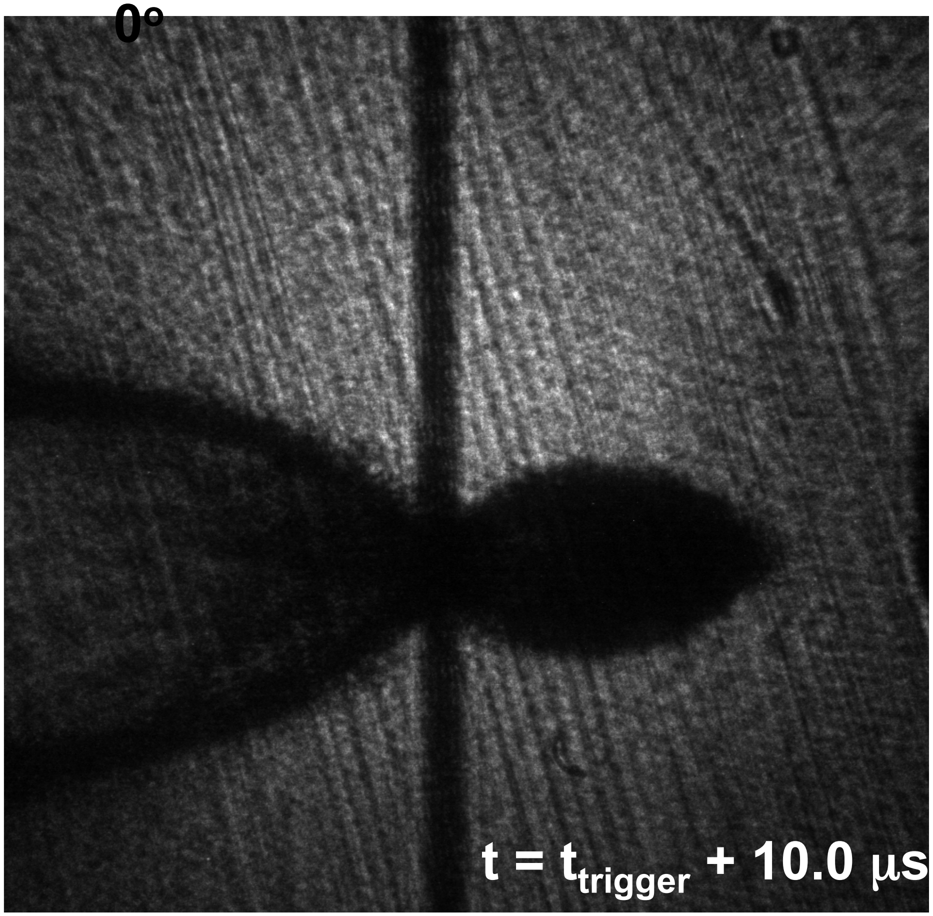

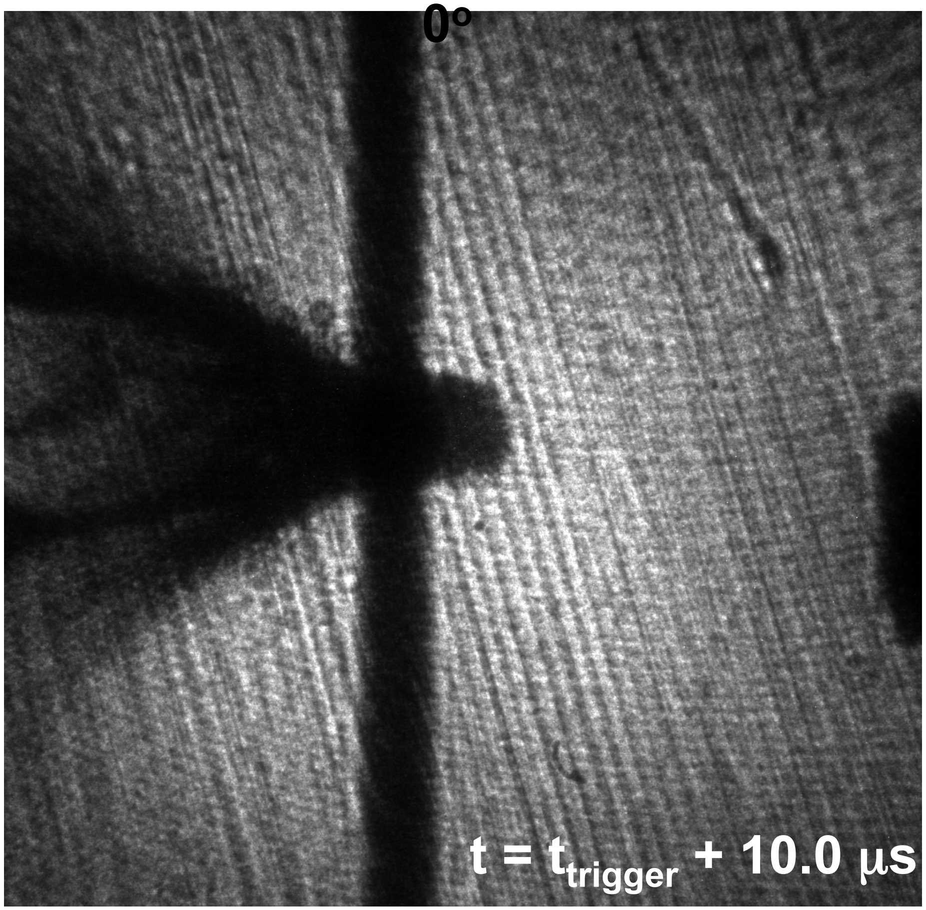

Laser Side-Lighting Results

CALTECH
PSAAP

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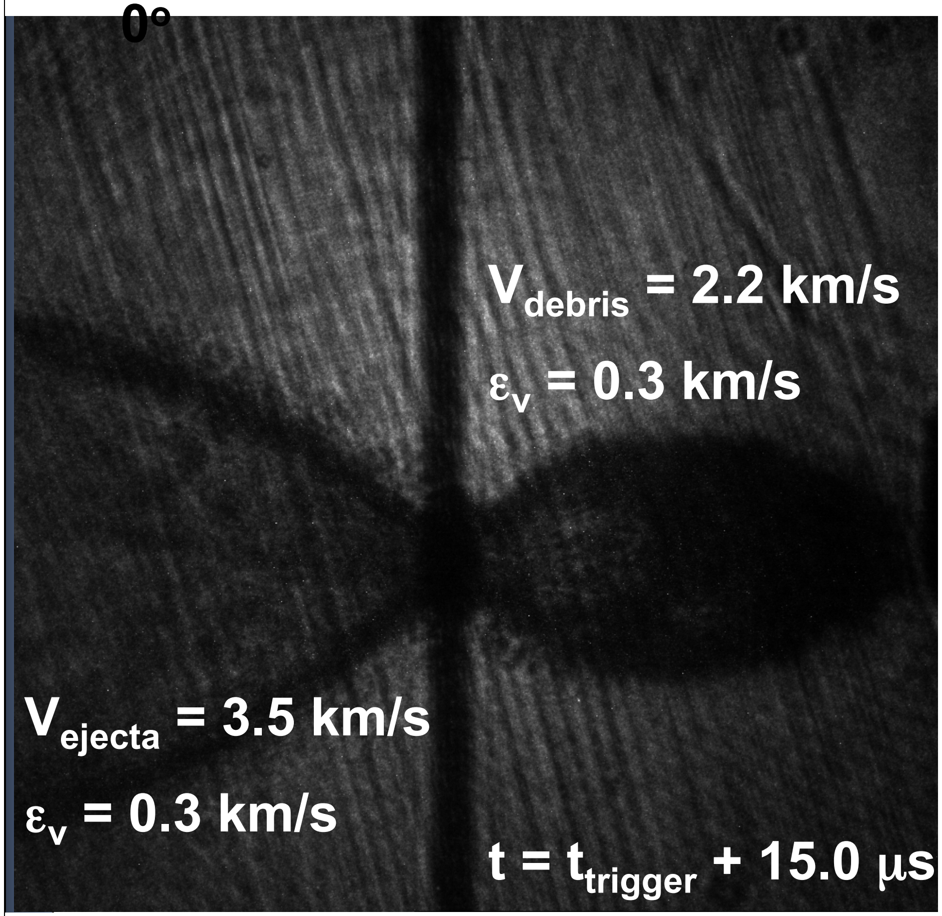
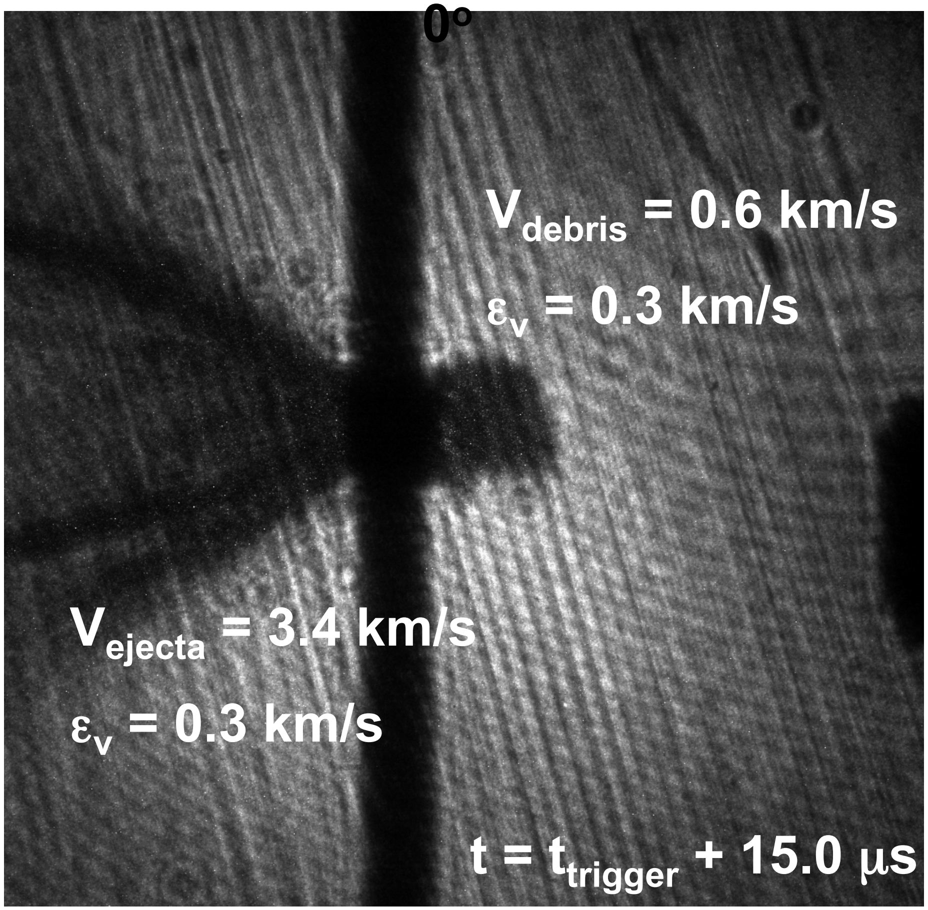
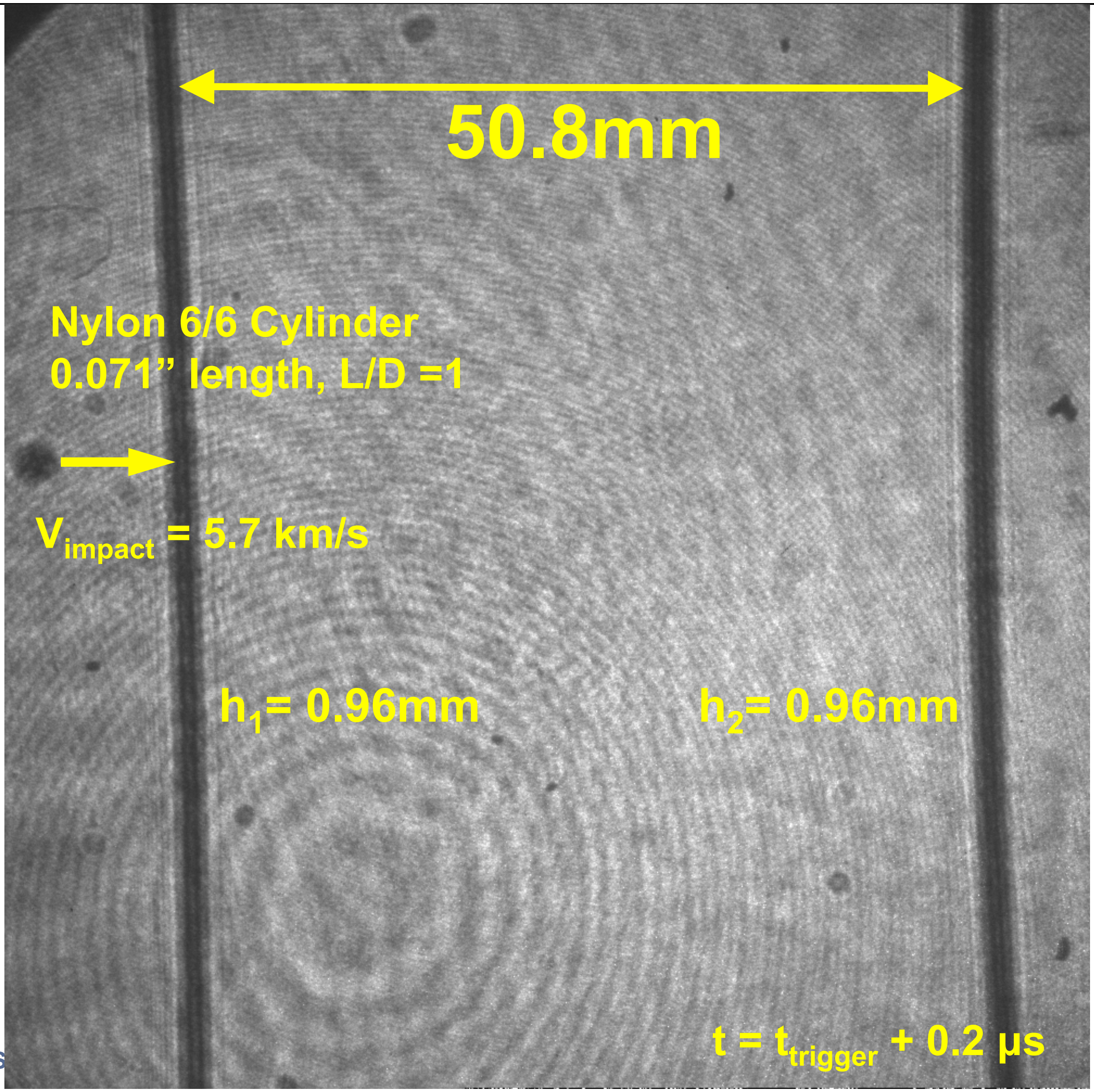




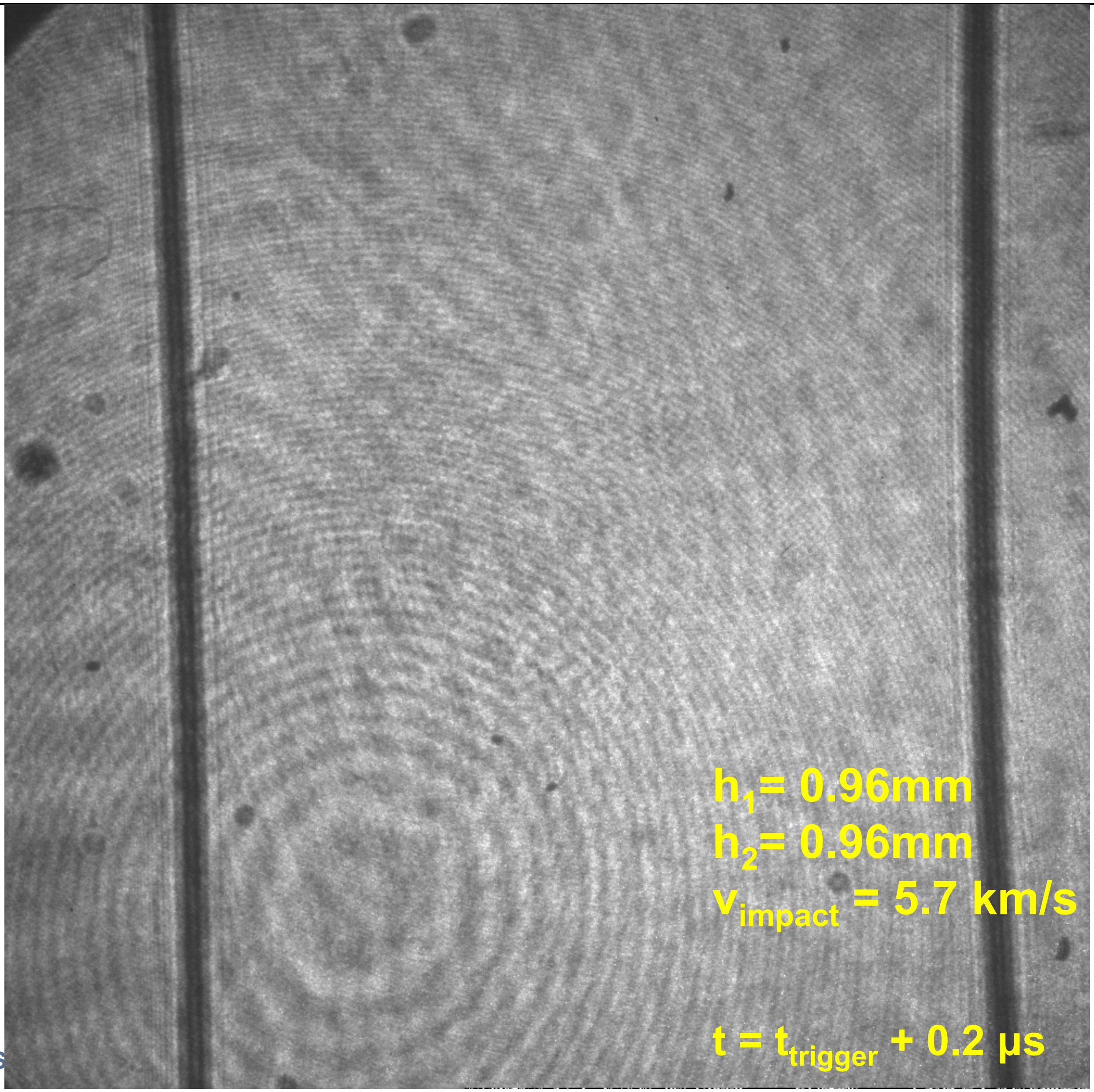
Side-Lighting Results: Thin Plates

CALTECH PSAAP

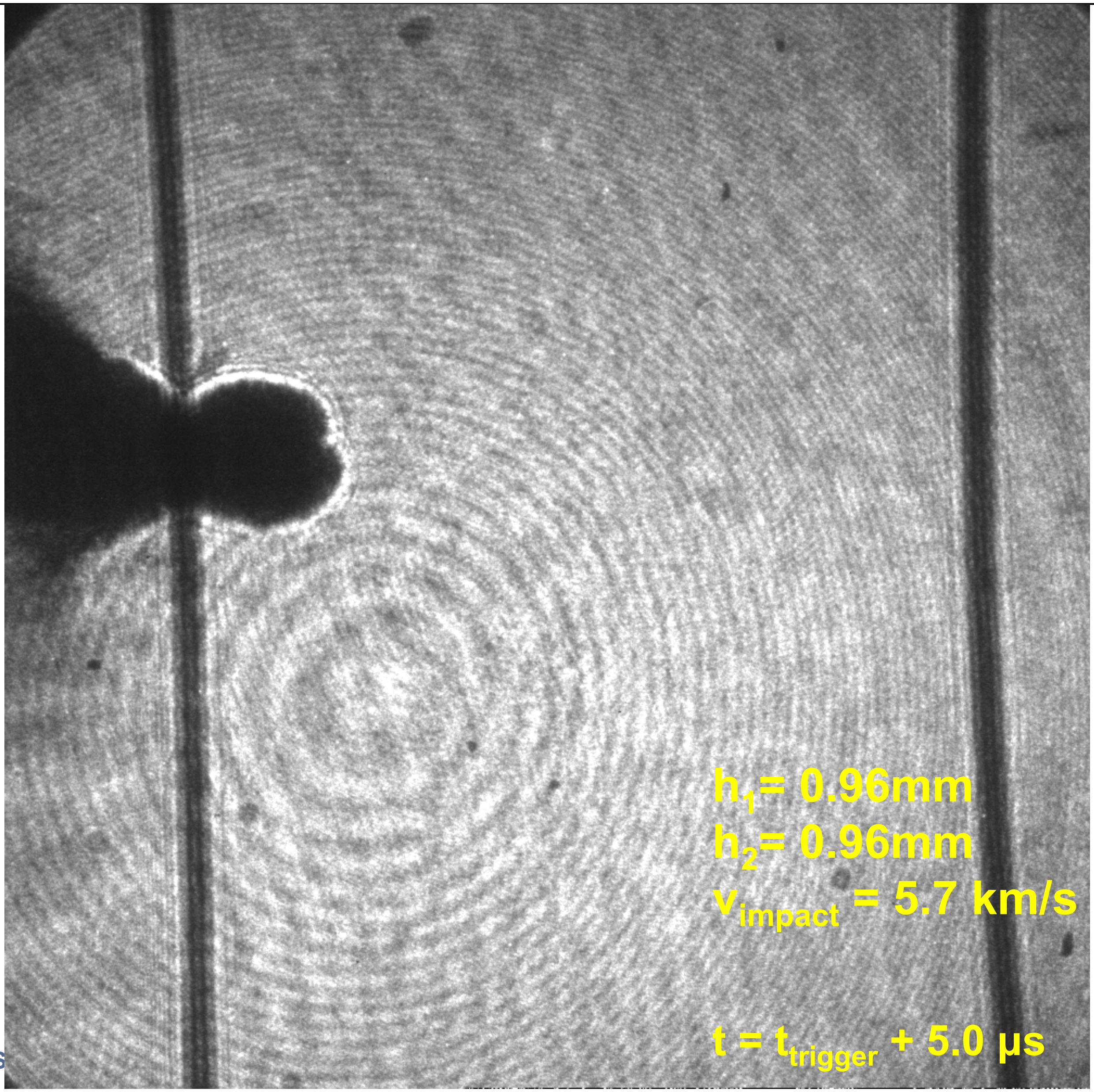


Side-Lighting Results: Thin Plates

CALTECH
PSAAP

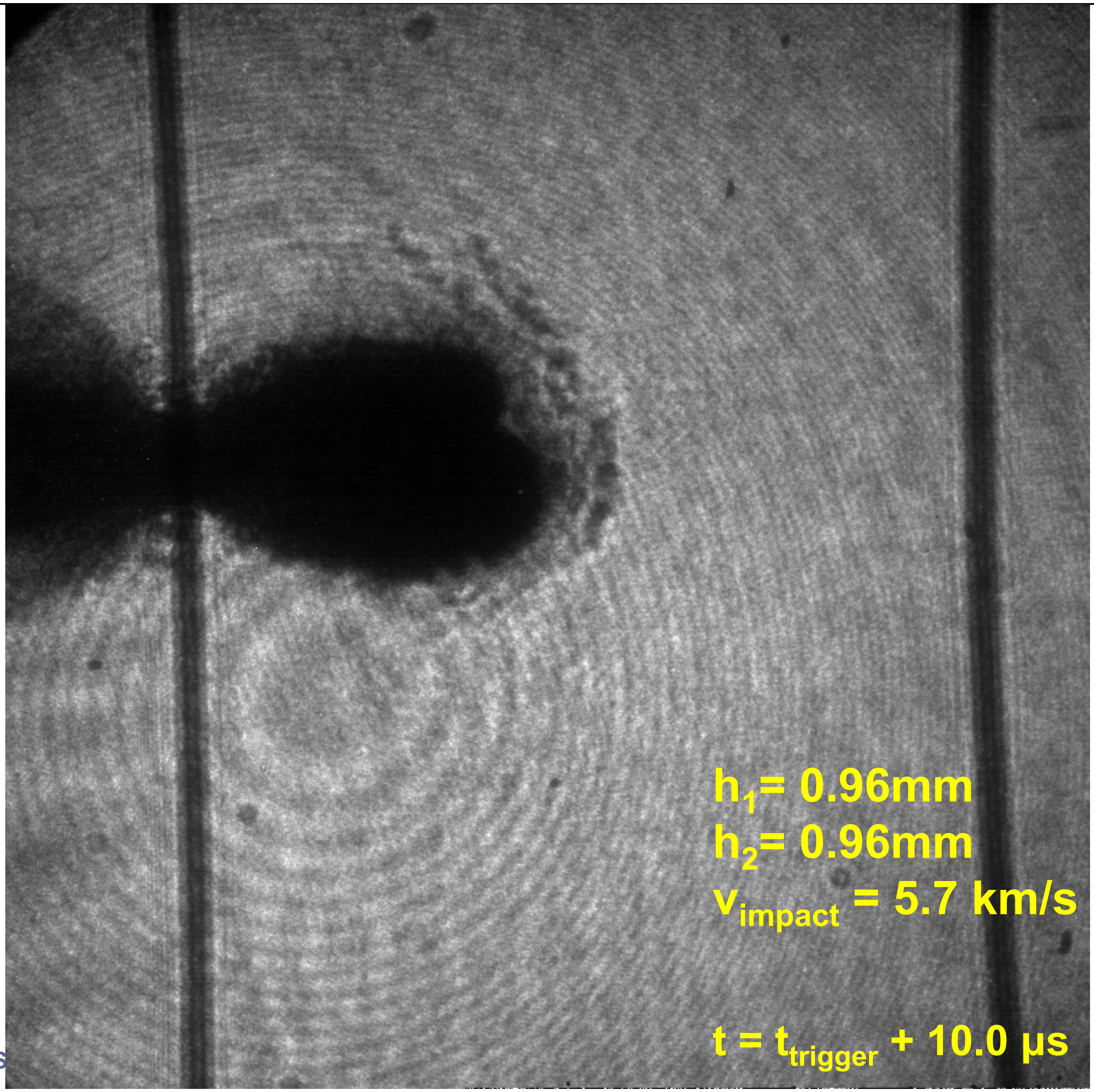


Side-Lighting Results: Thin Plates



Side-Lighting Results: Thin Plates

CALTECH PSAAP



Side-Lighting Results: Thin Plates

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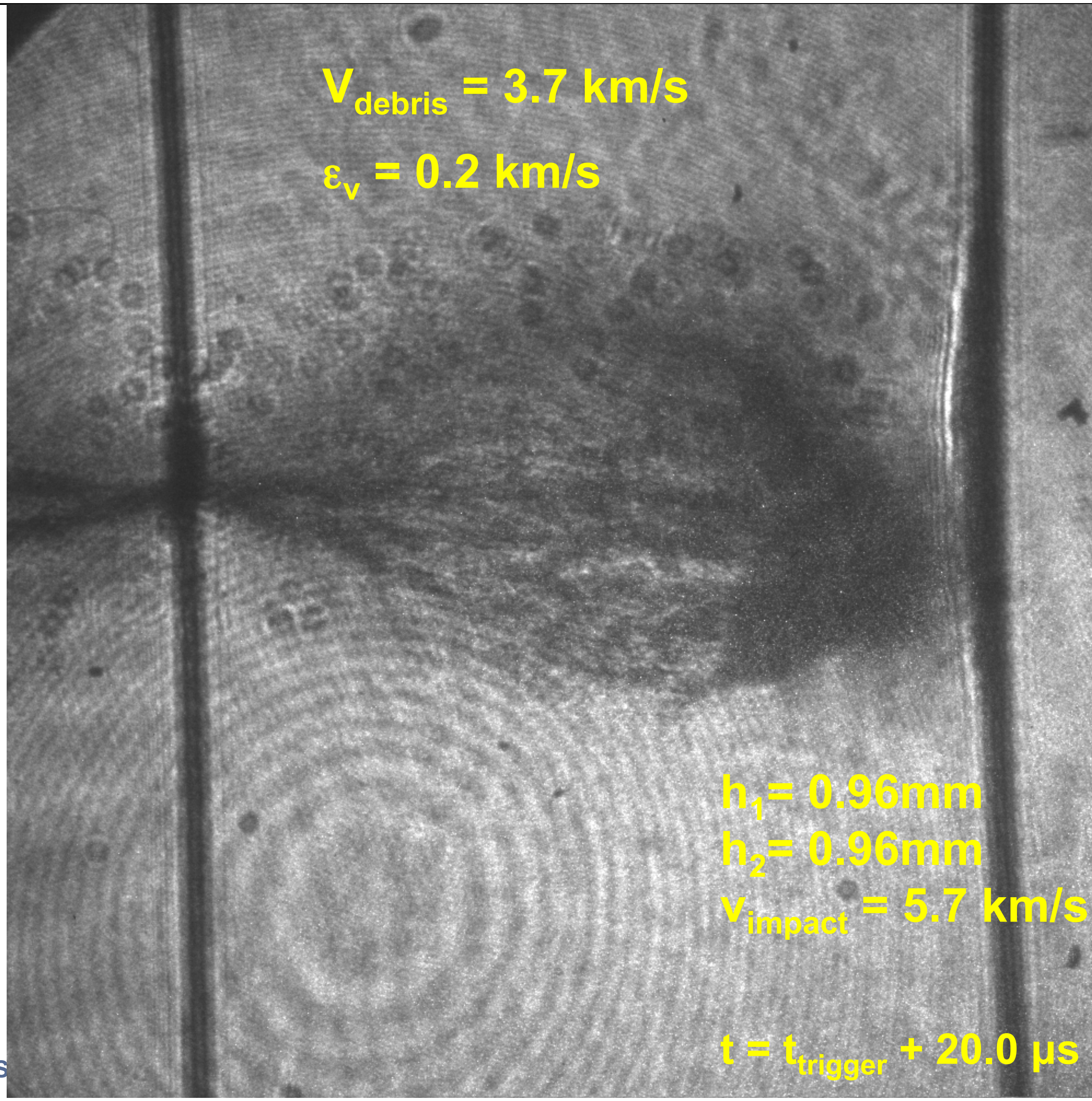

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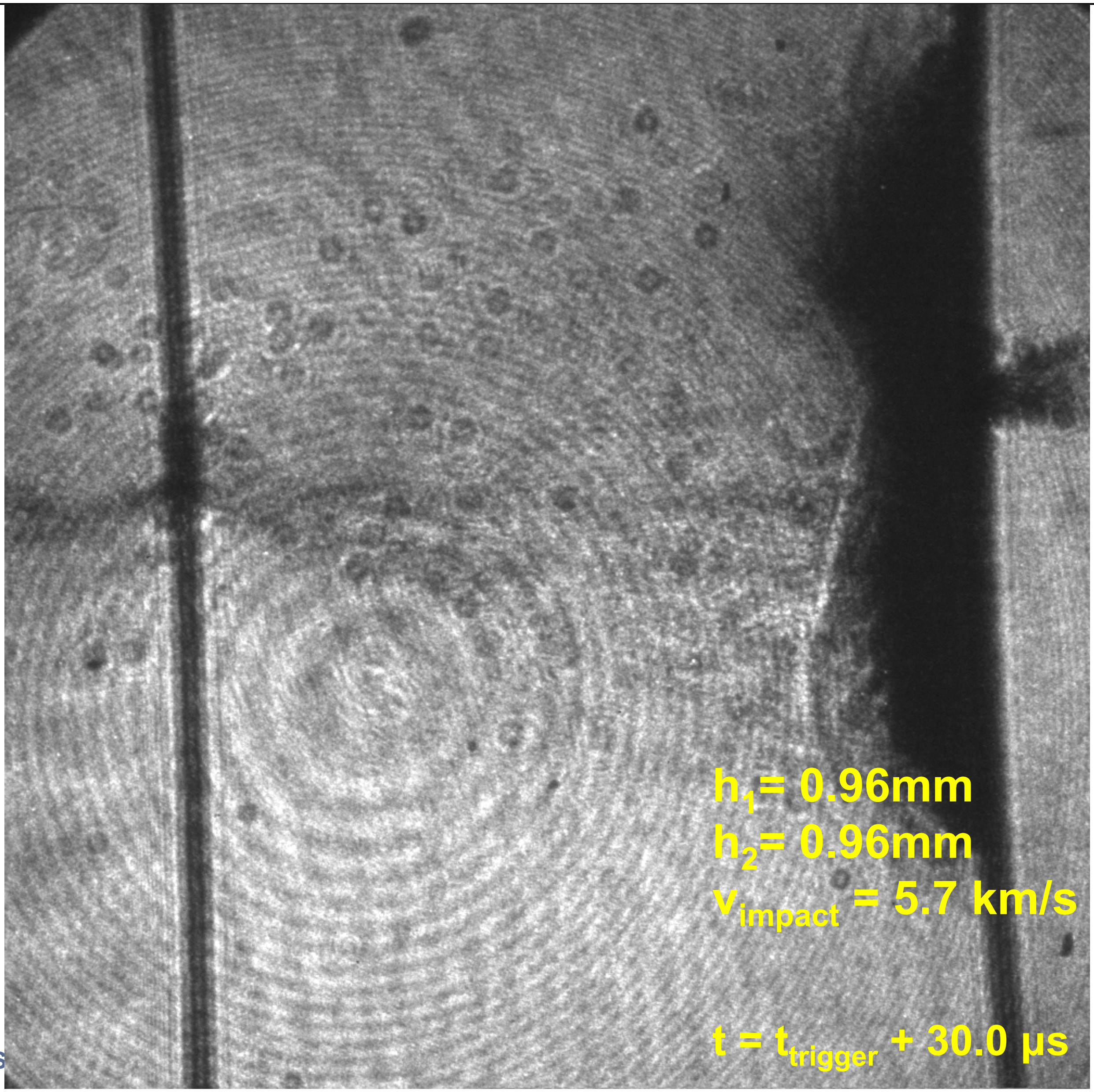
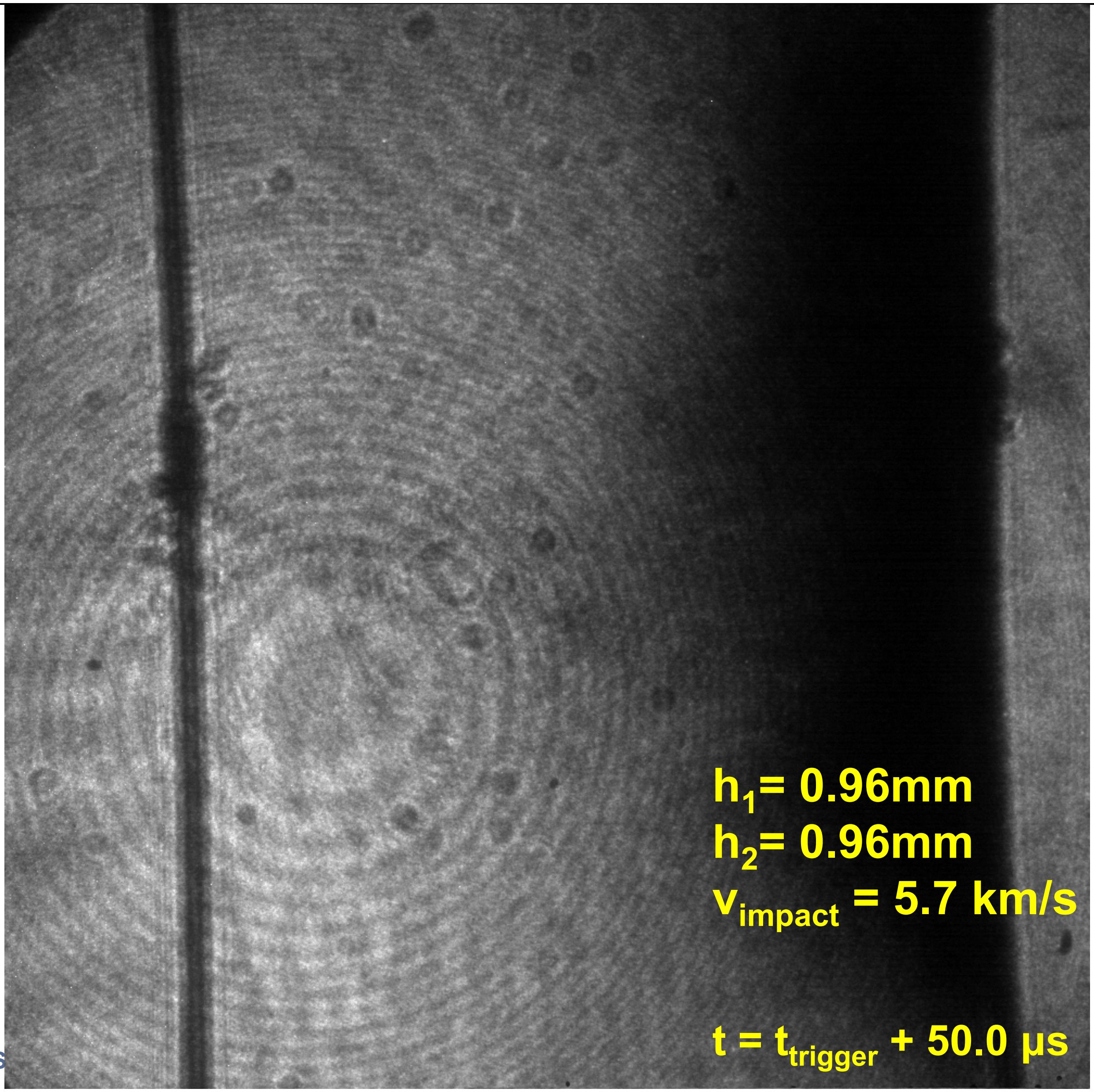


Side-Lighting Results: Thin Plates



Metirc: Debris Cloud Shot-Line Velocity

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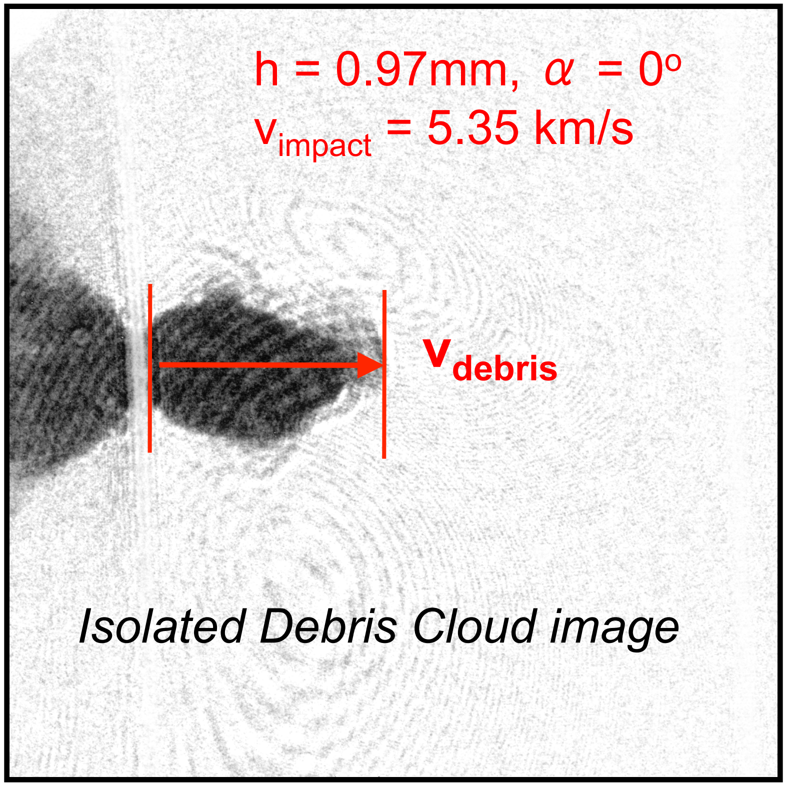
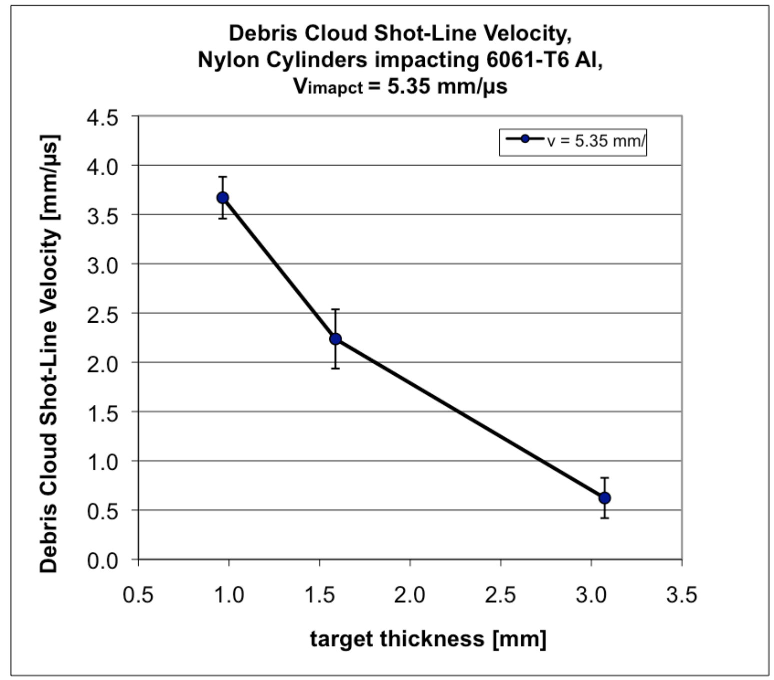


Preliminary Results



$$v_{debris} = \frac{pS}{t}$$

p = inter-frame distance
S = mm/pixel scale
T = inter-frame time

$$\varepsilon_v = \sqrt{\left(\frac{p}{t}\varepsilon_S\right)^2 + \left(\frac{S}{t}\varepsilon_p\right)^2 + \left(\frac{pS}{t^2}\varepsilon_t\right)^2}$$

ε_v conservatively between 0.1 km/s and 0.3 km/s

Side-Lighting Results: Obliquity

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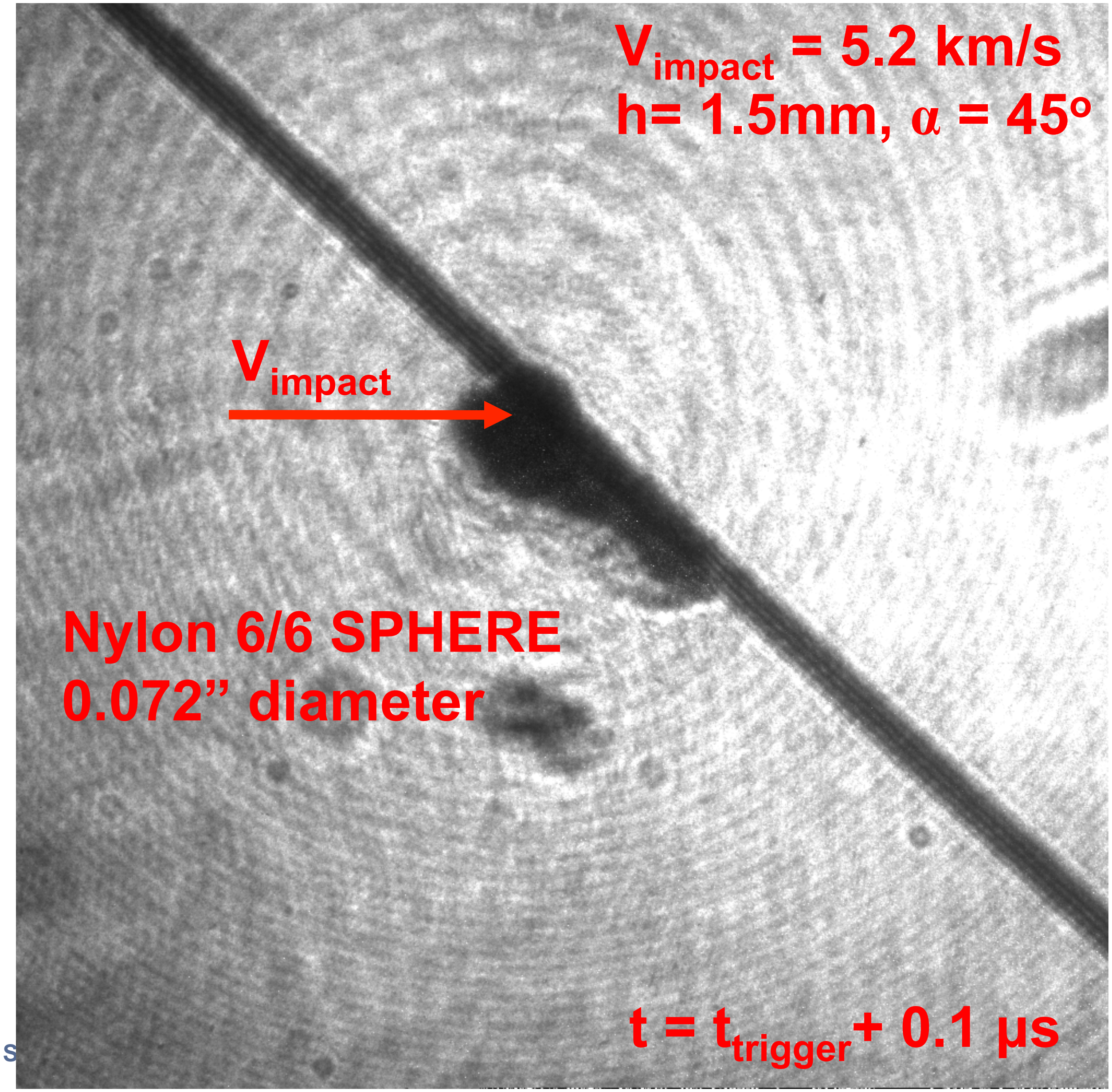
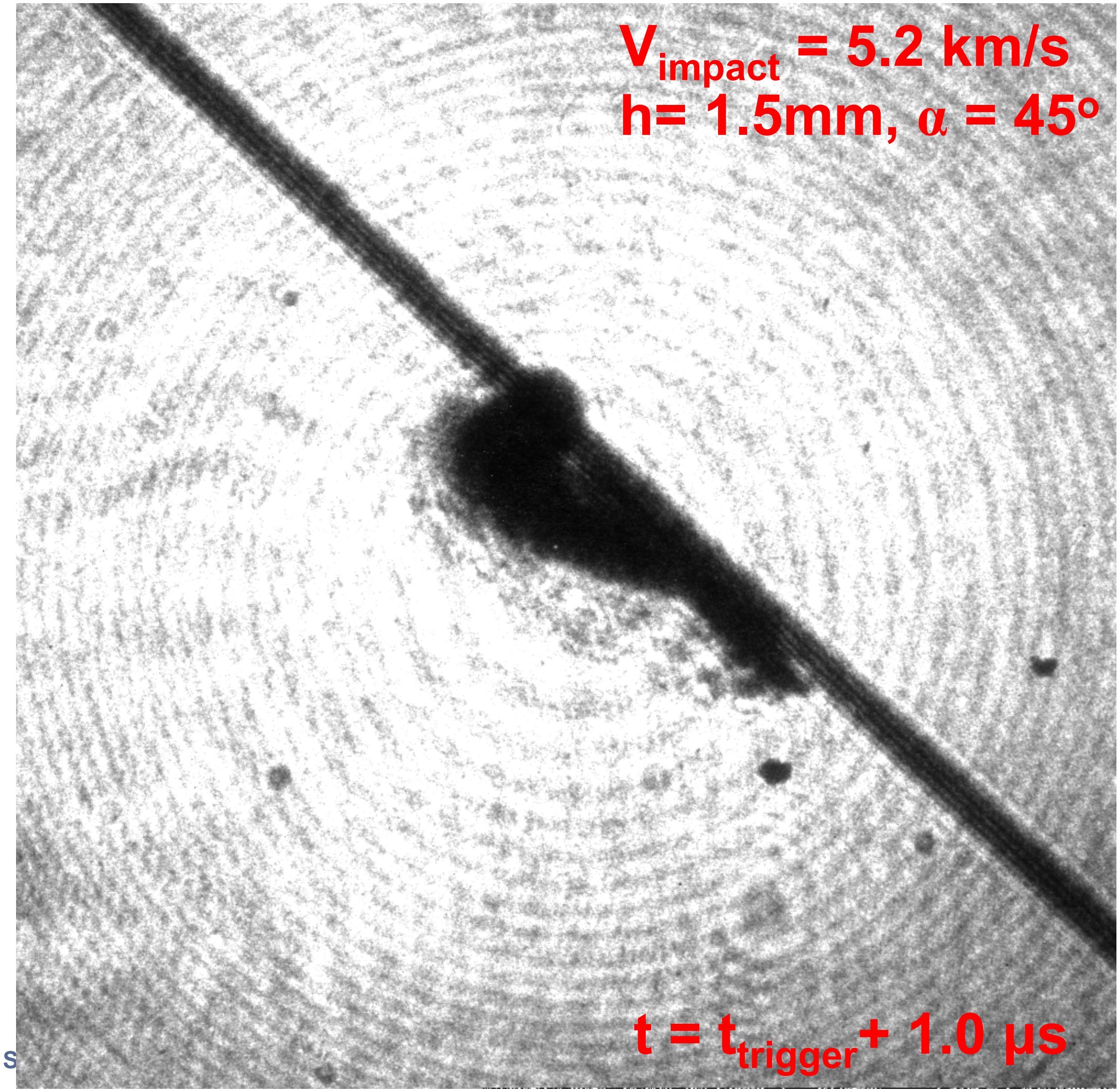
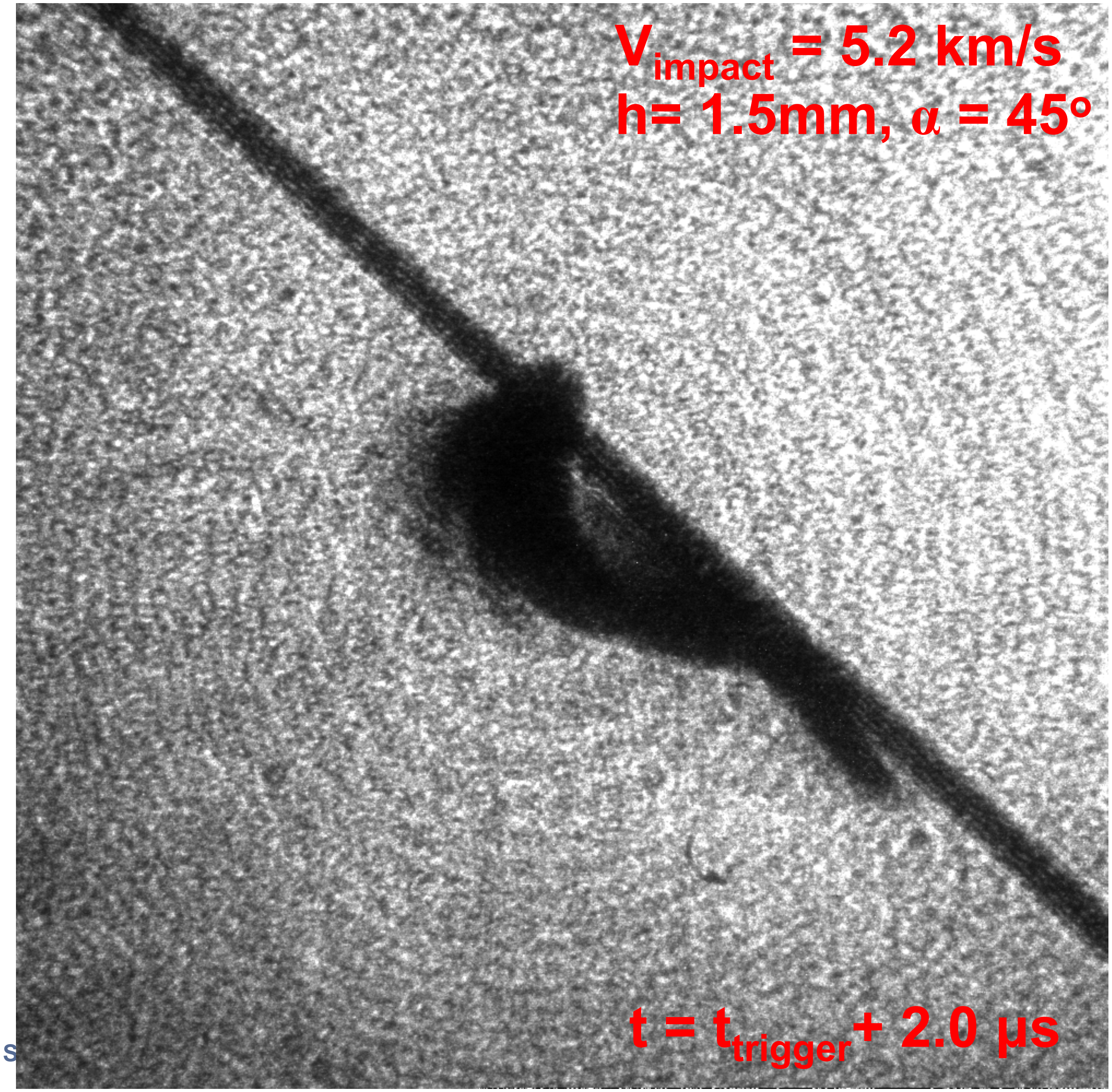


Side-Lighting Results: Obliquity

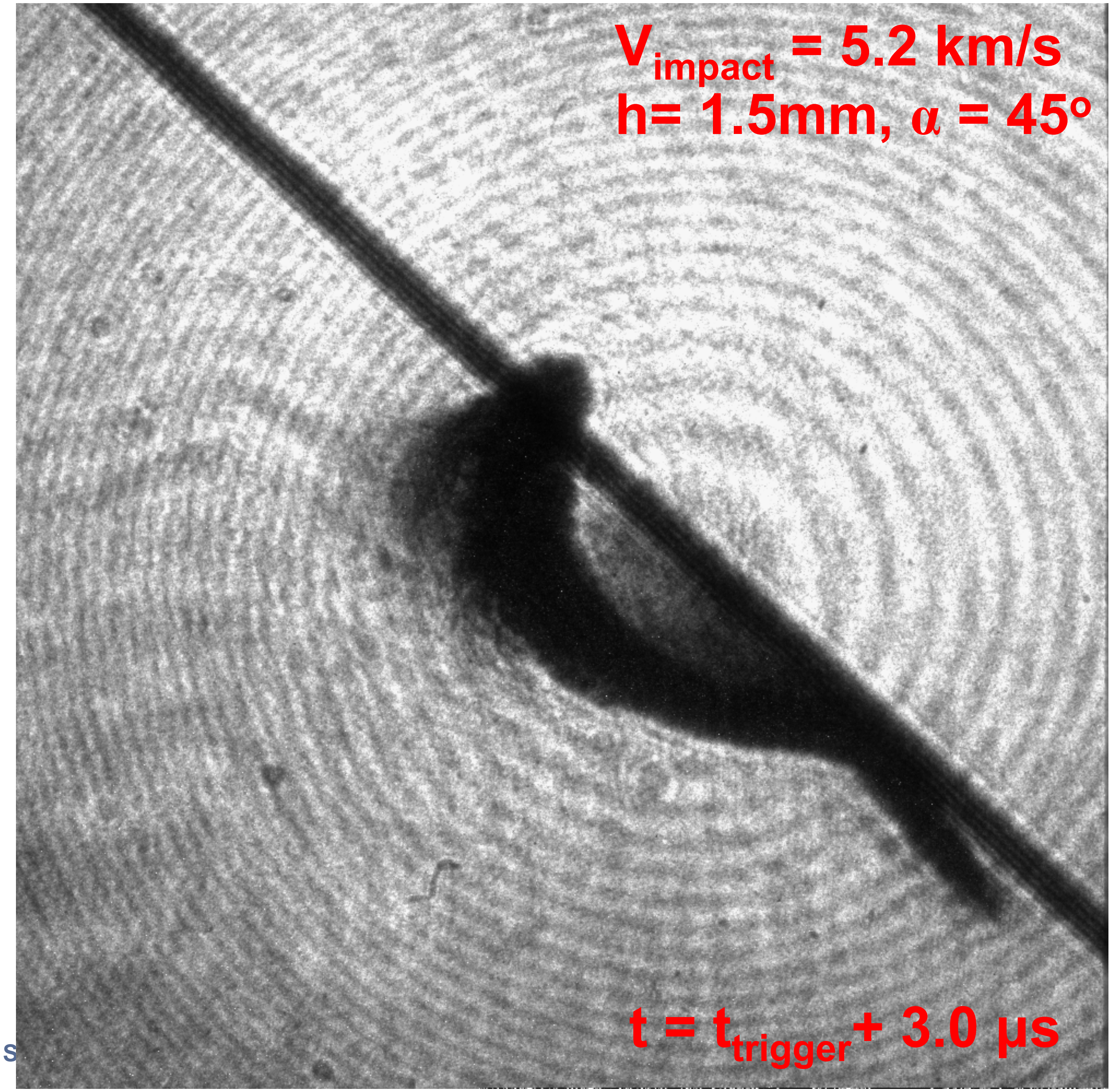
CALTECH PSAAP



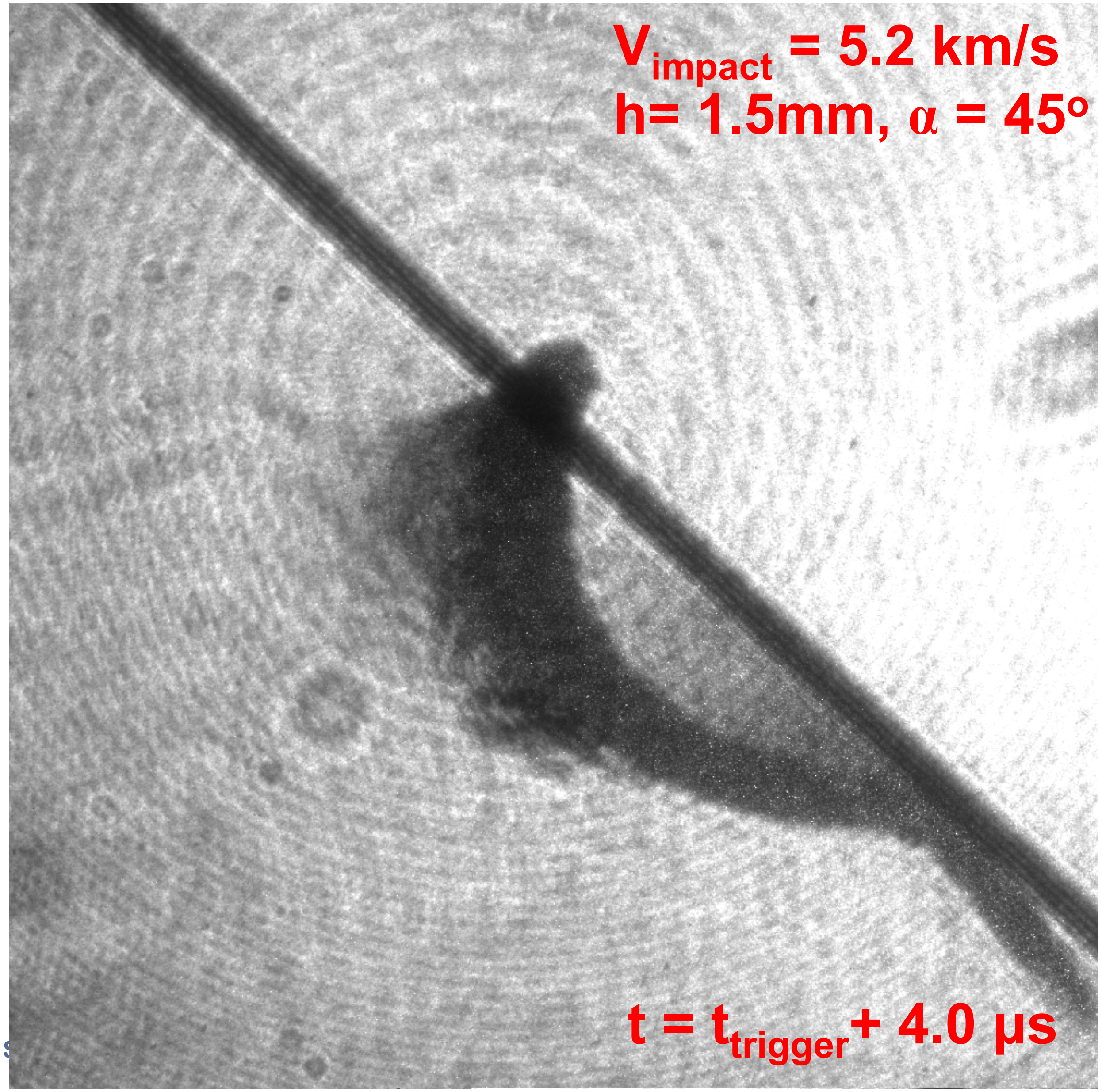
Side-Lighting Results: Obliquity



Side-Lighting Results: Obliquity

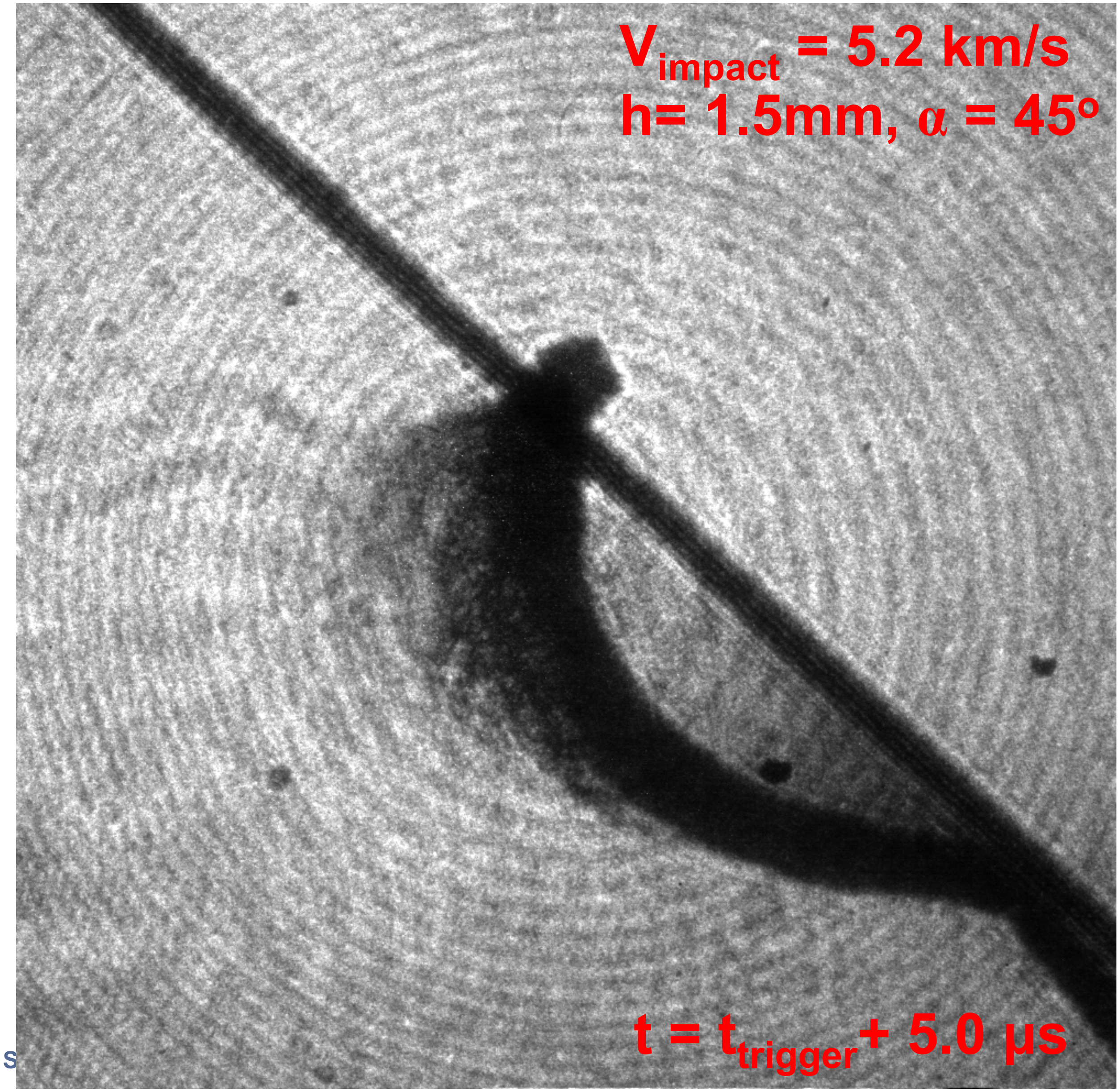


Side-Lighting Results: Obliquity



Side-Lighting Results: Obliquity

CALTECH PSAAP



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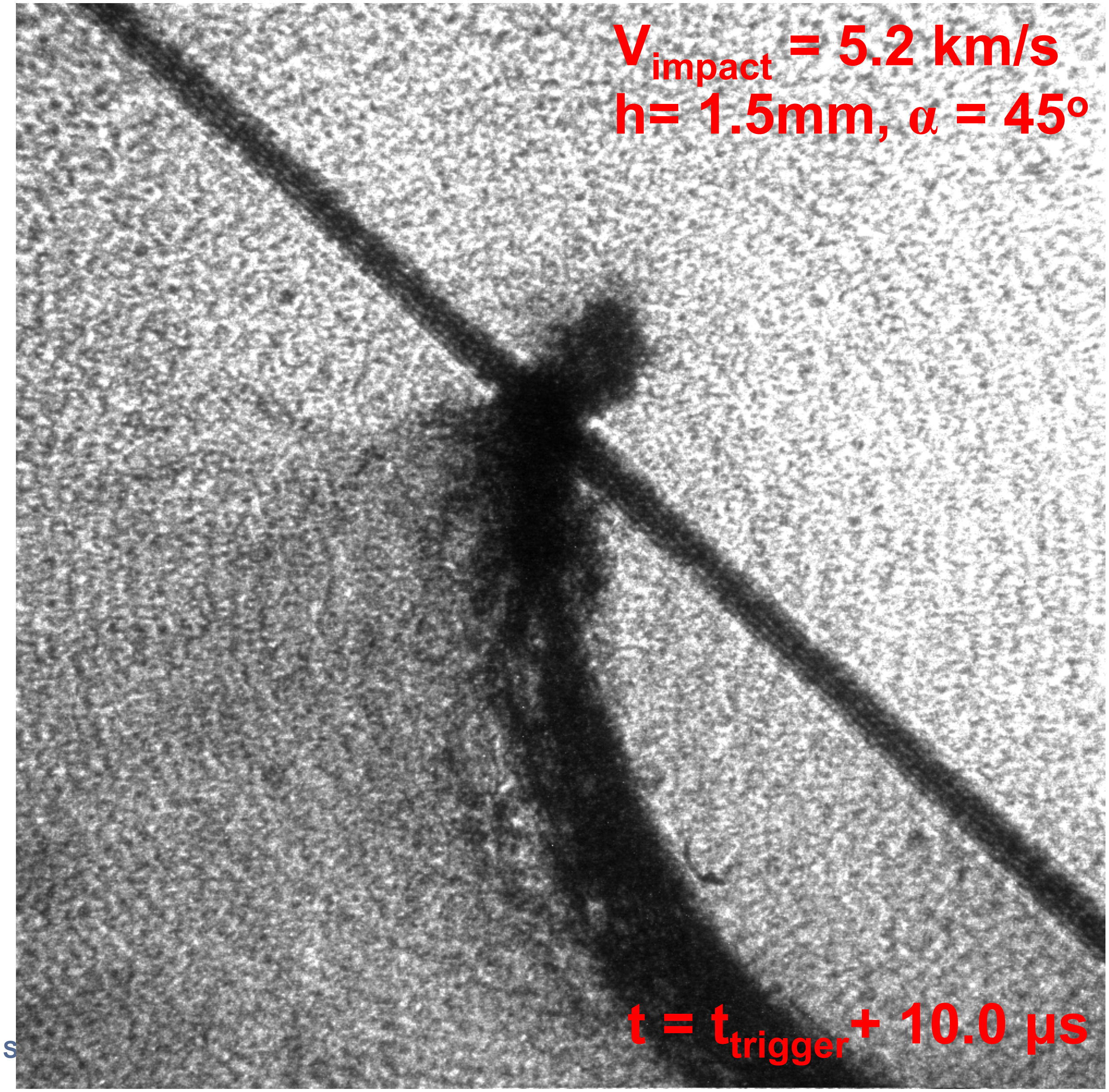
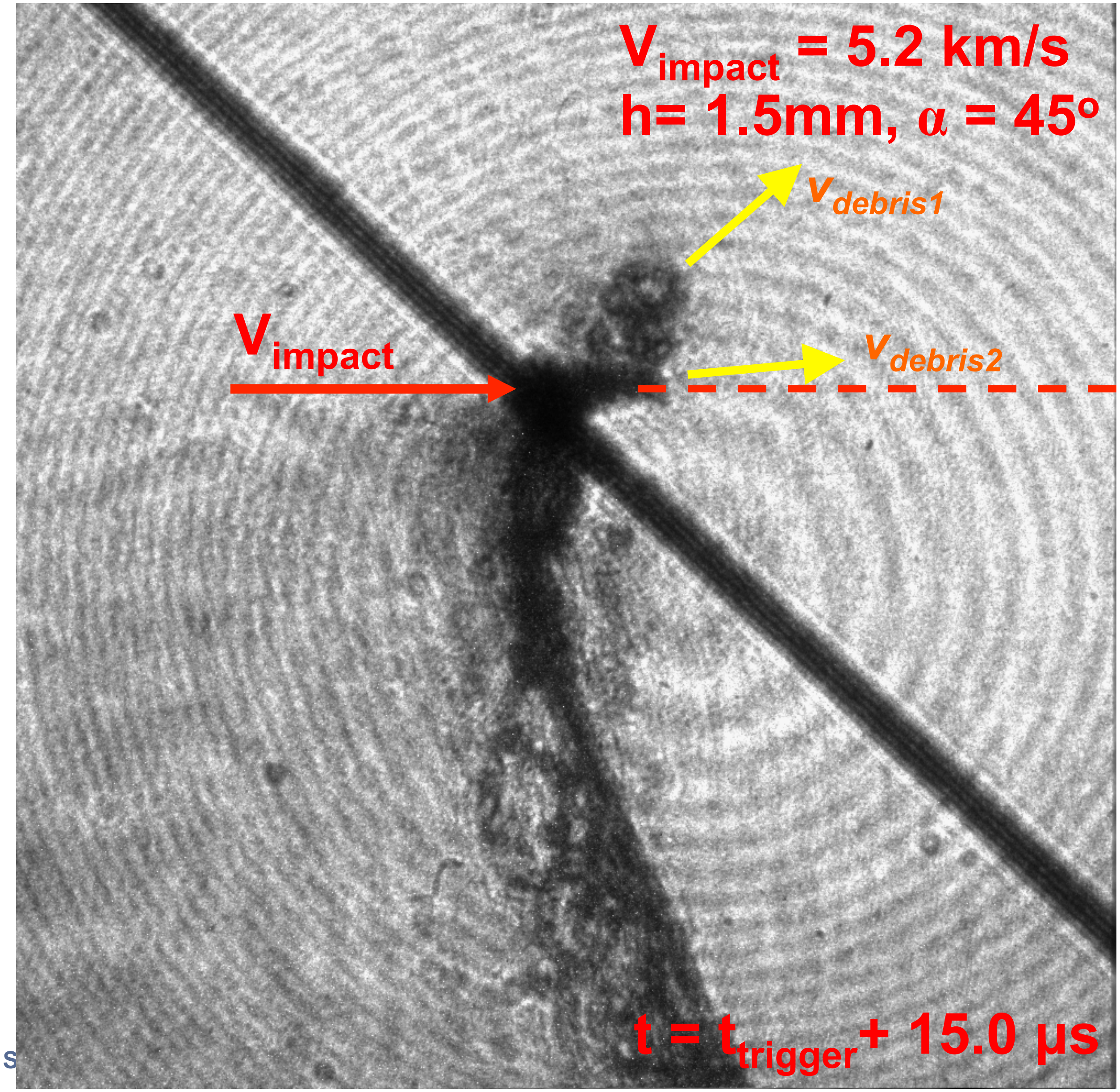
CALTECH PSAAP



Side-Lighting Results: Obliquity

CALTECH PSAAP



CGS by Transmission

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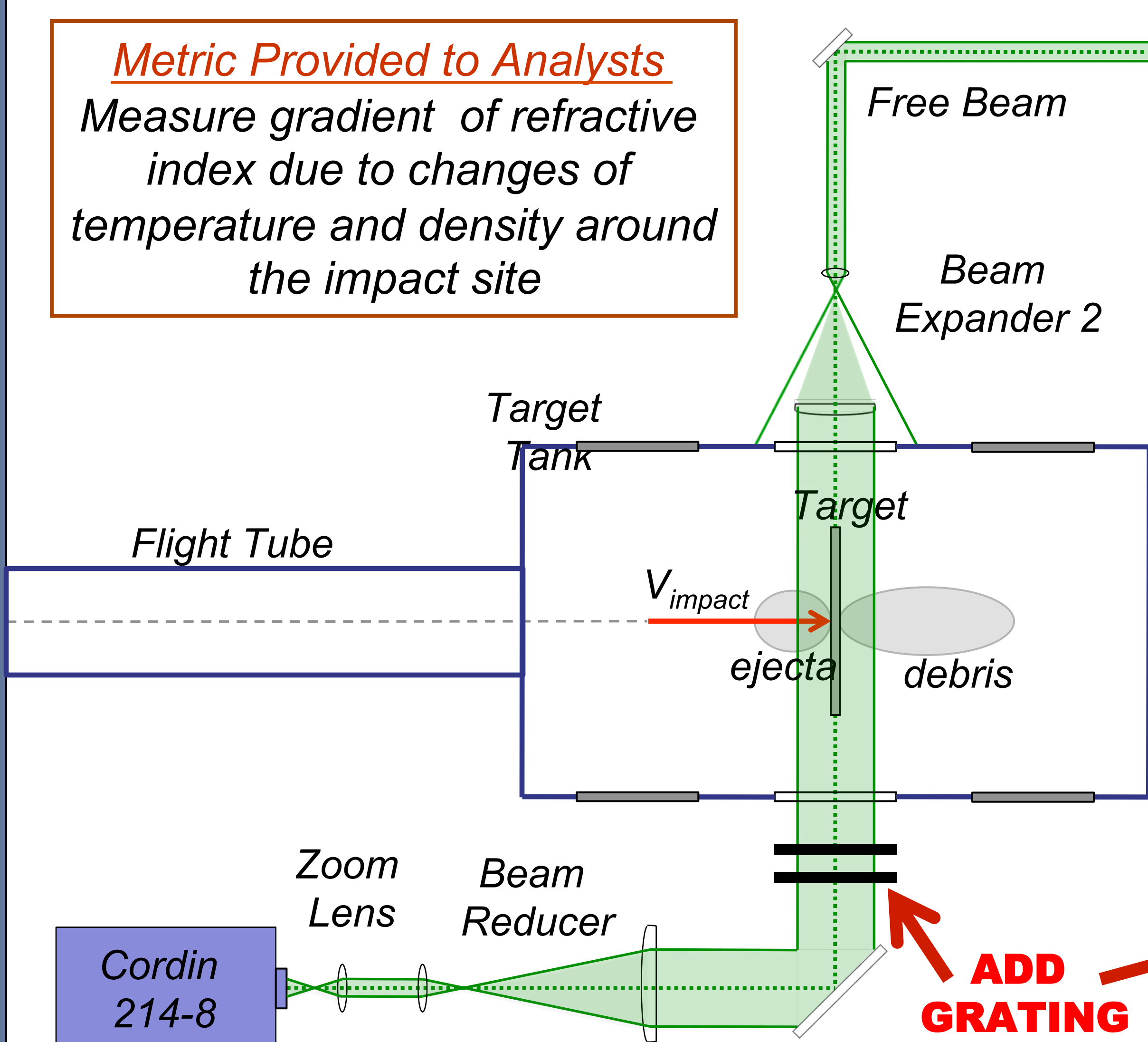
Metric Provided to Analysts

Measure gradient of refractive index due to changes of temperature and density around the impact site

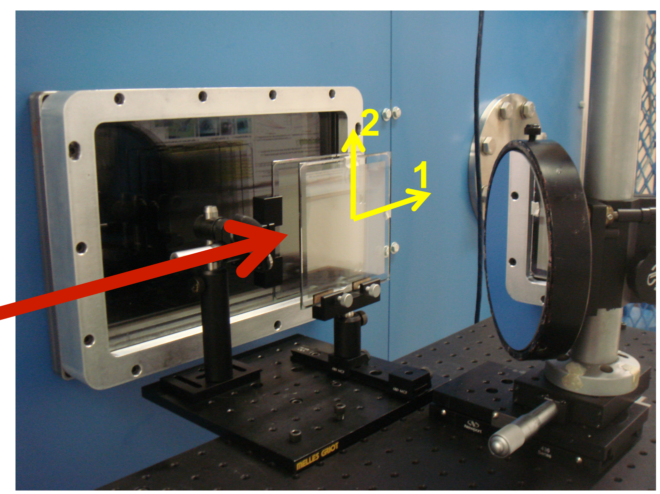


S = optical path difference

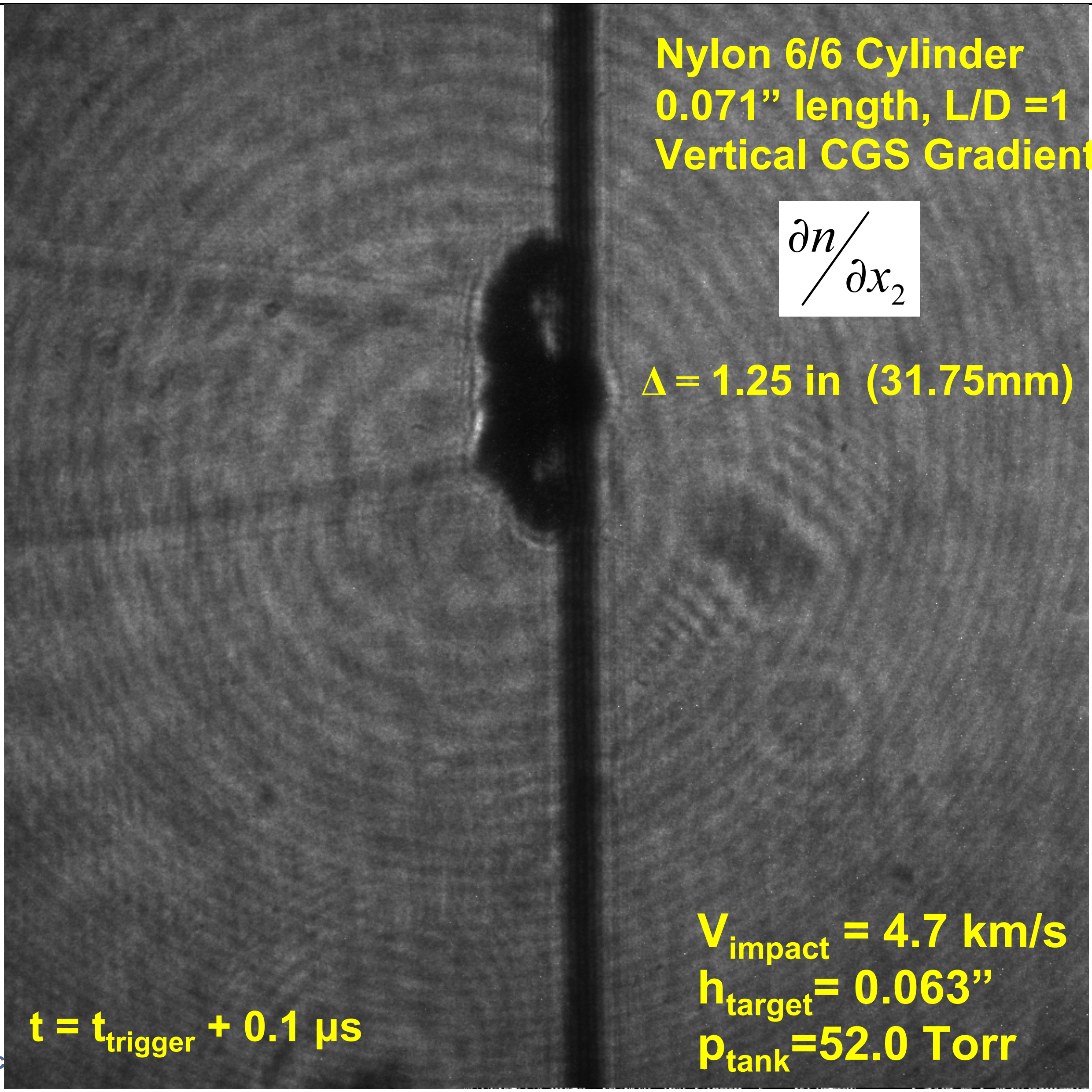
Δ = grating spacing

p = pitch of grating

$$\frac{\partial S}{\partial x_\alpha} = \frac{n\Delta}{p} \qquad \alpha = \{1,2\}$$

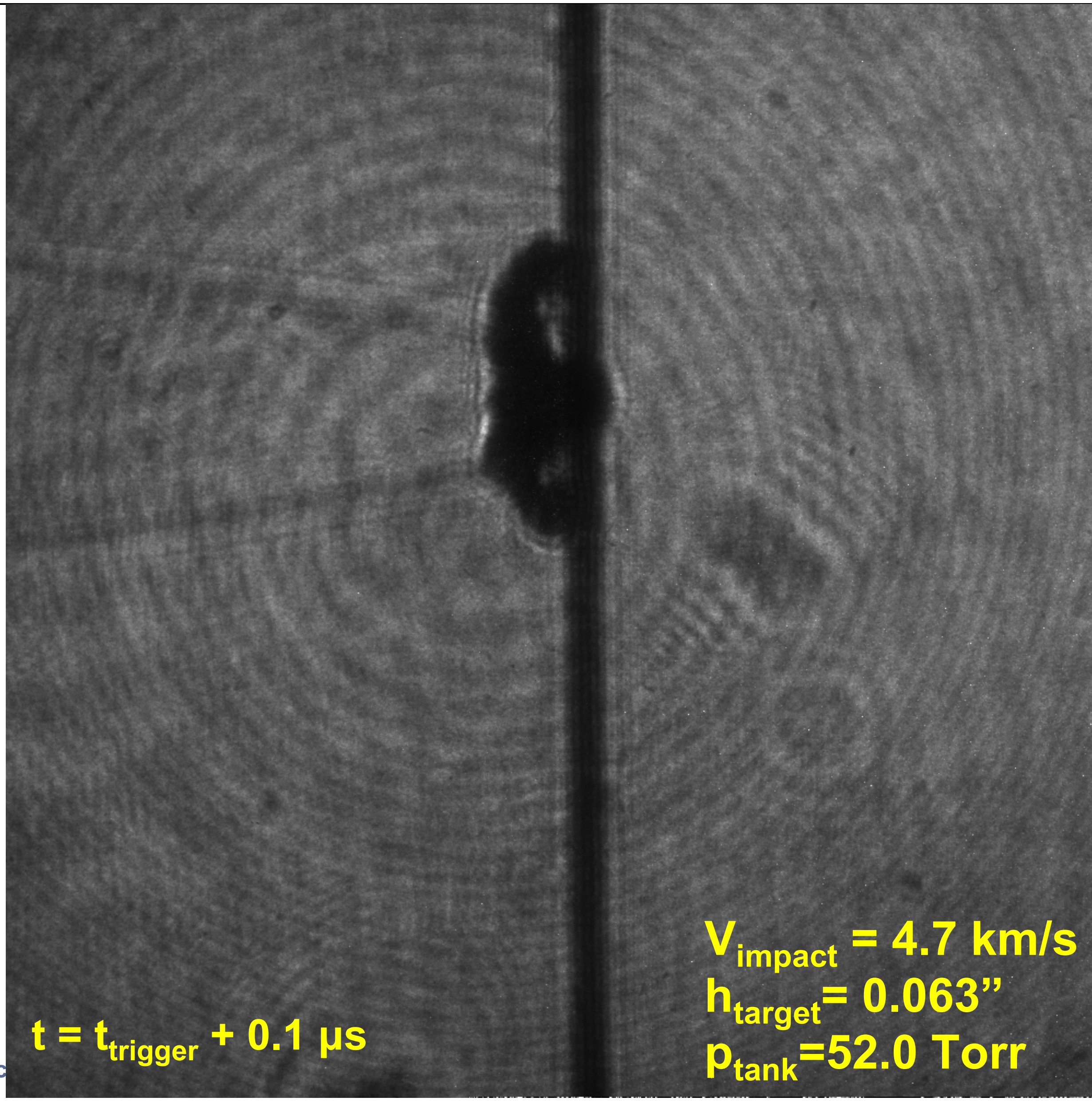


CGS by Transmission Results



CGS by Transmission Results

CALTECH PSAAP



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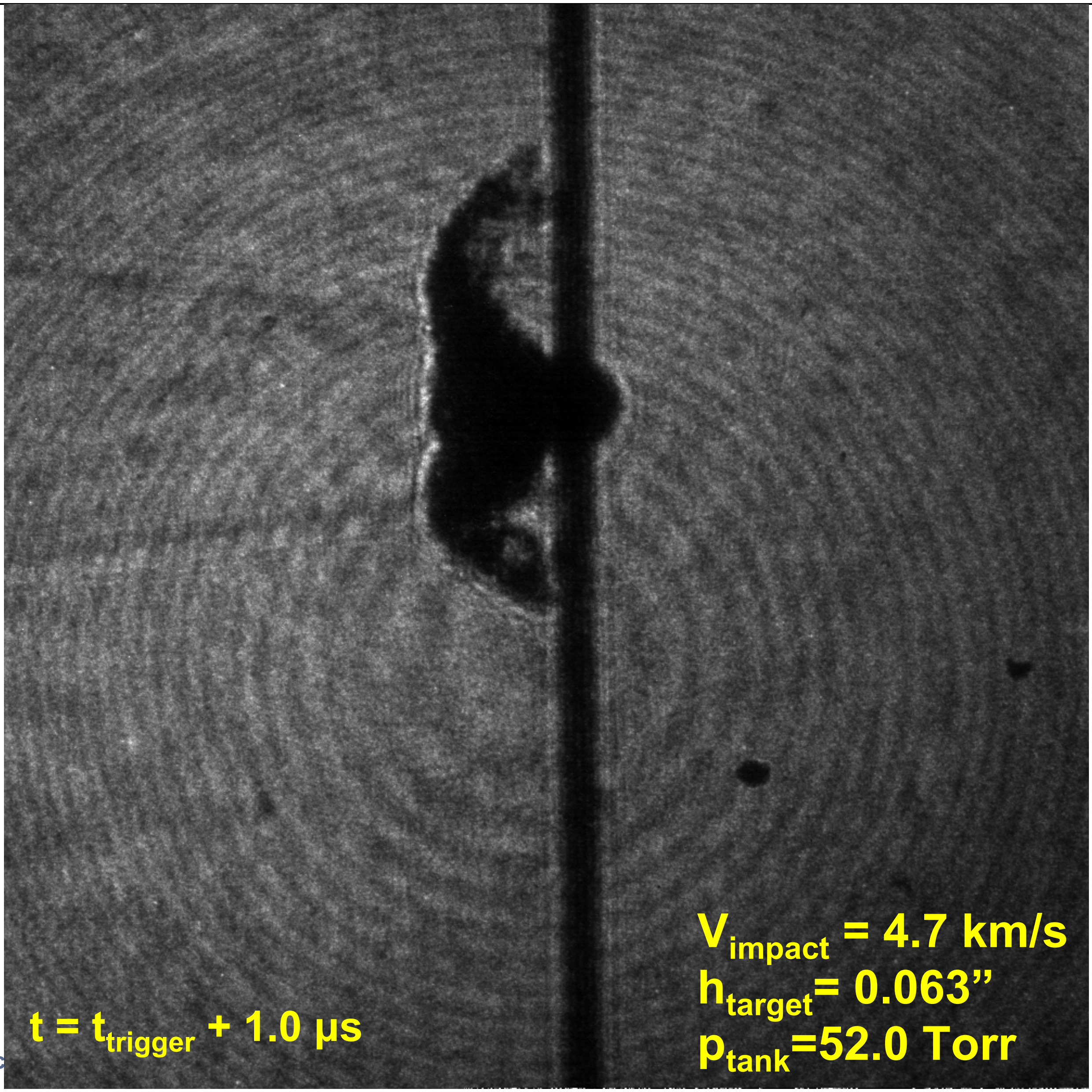
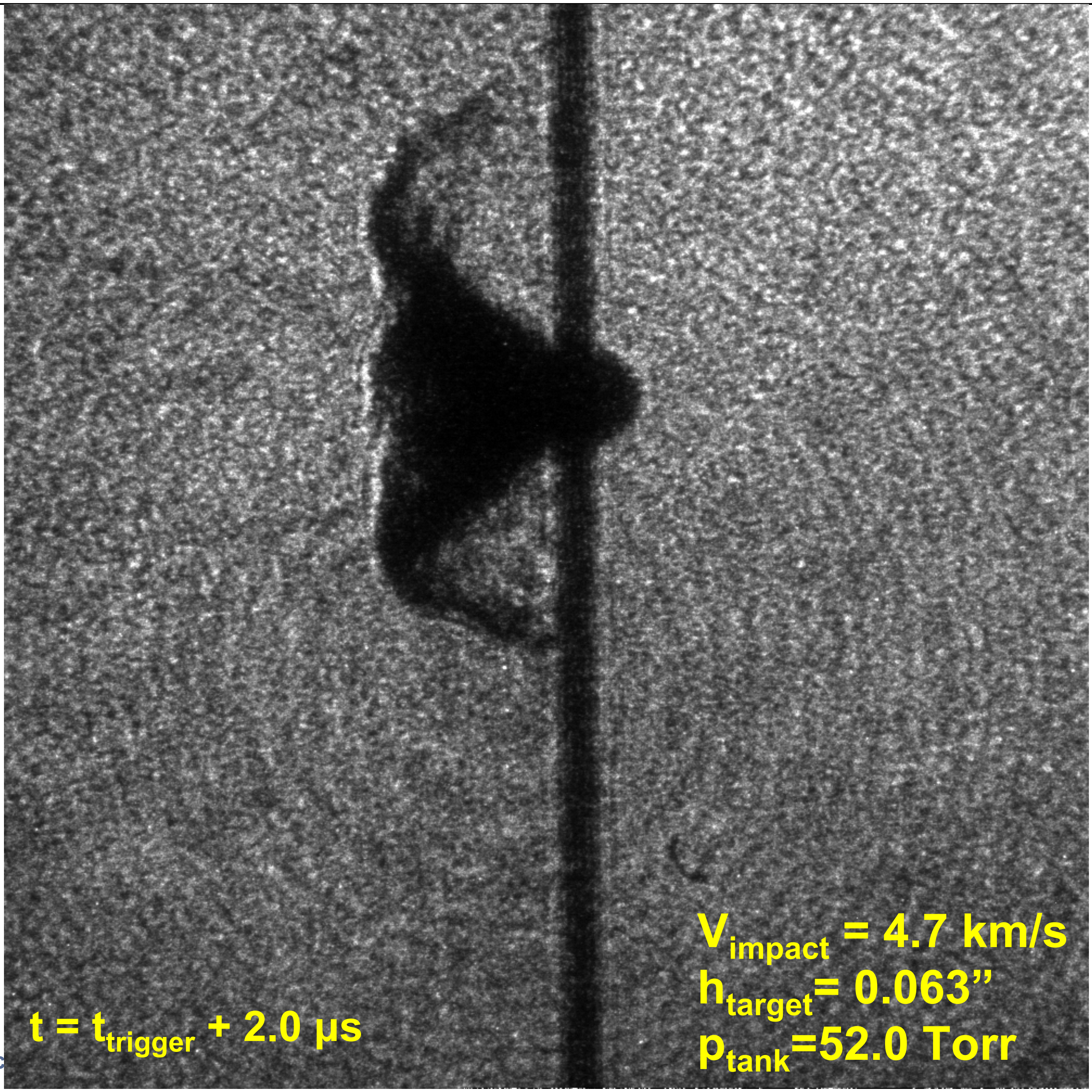


CGS by Transmission Results

CALTECH PSAAP



CGS by Transmission Results

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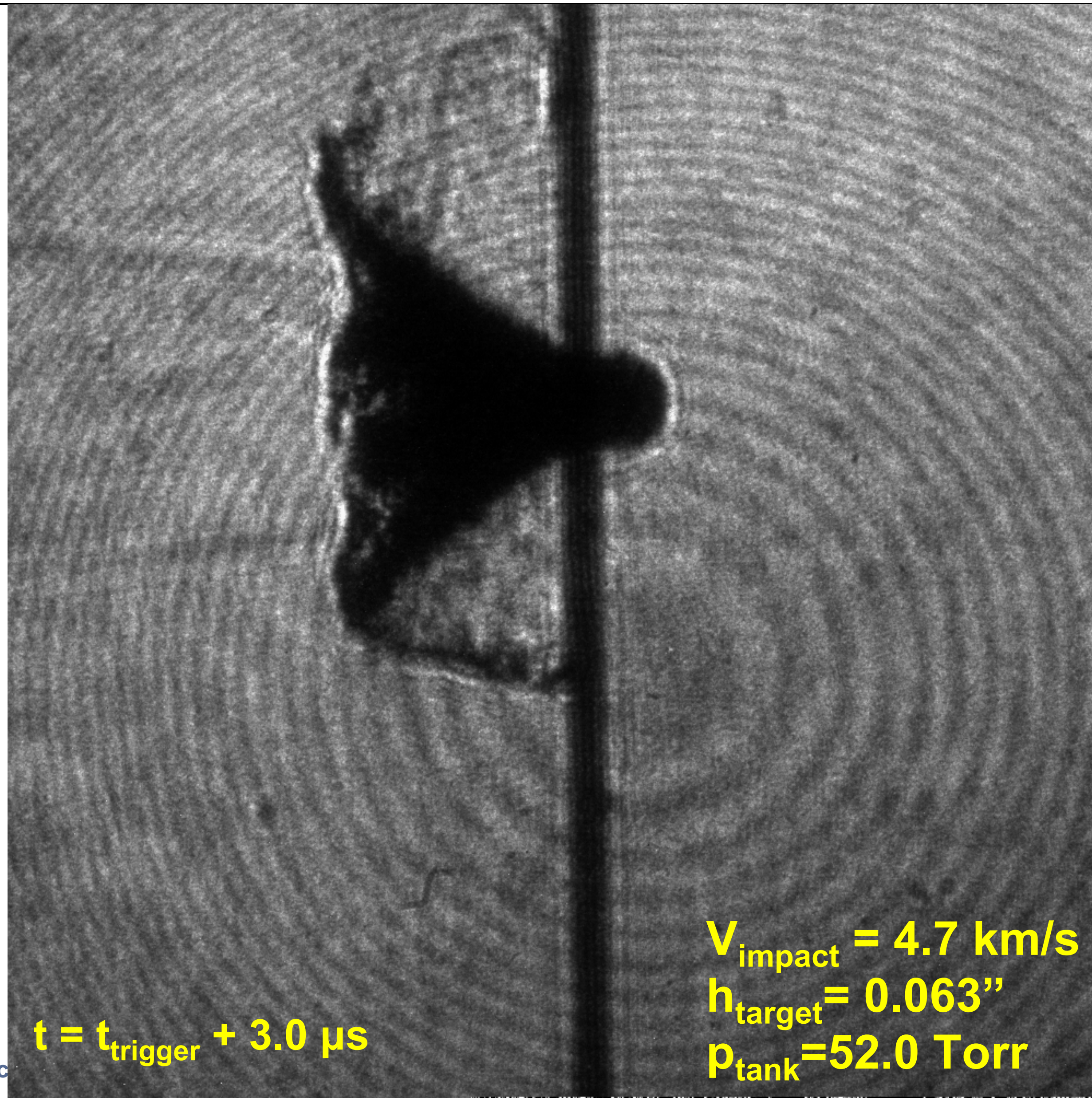

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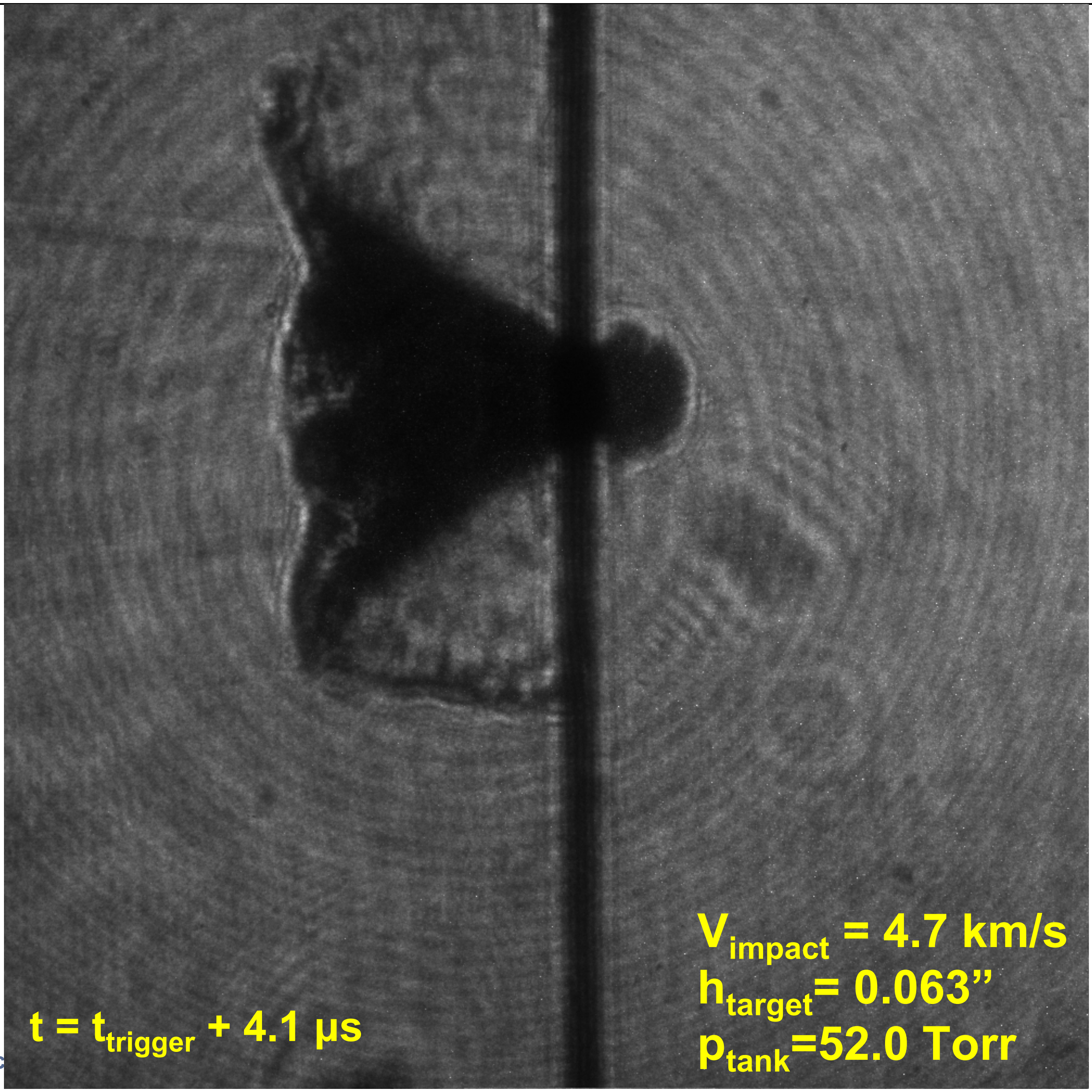

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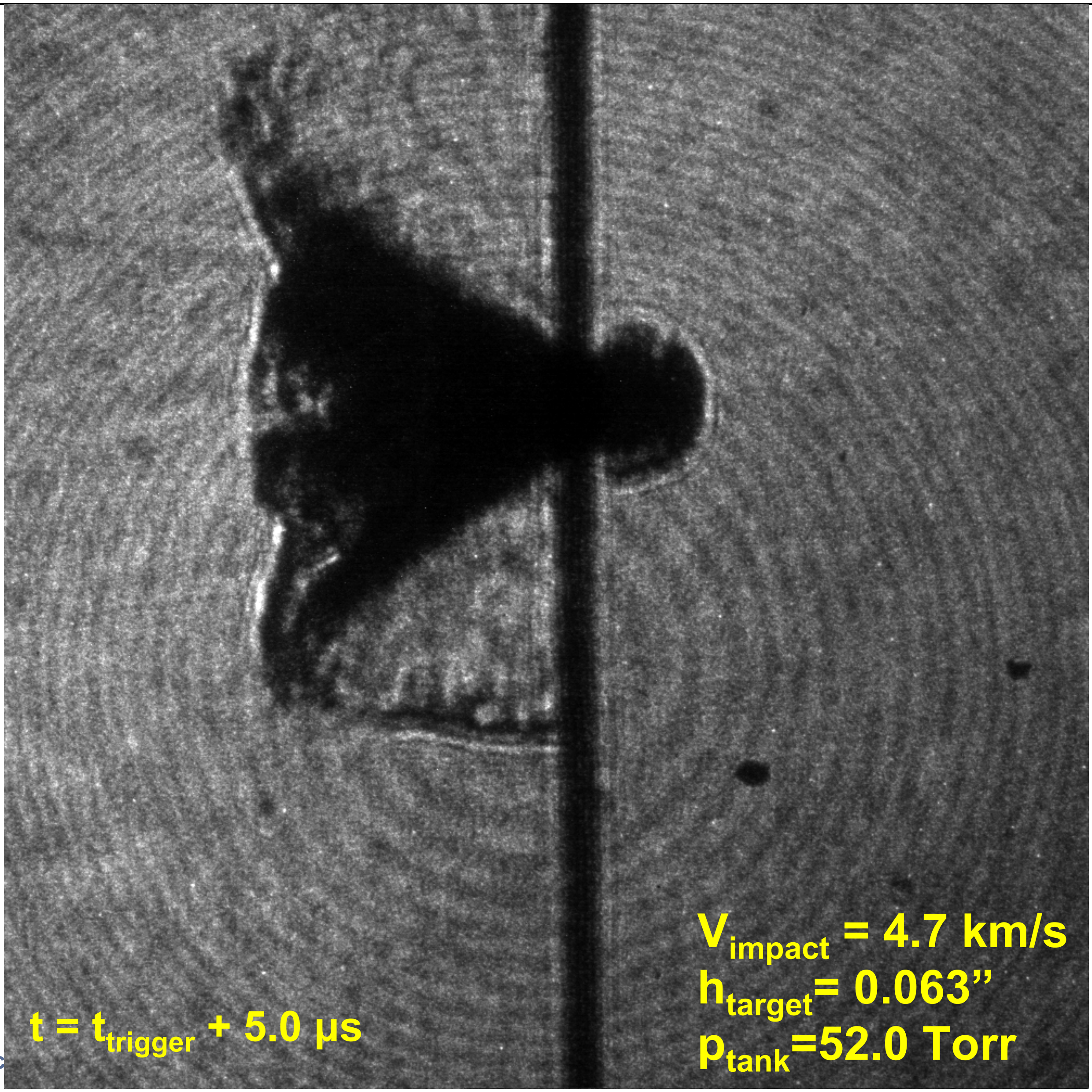

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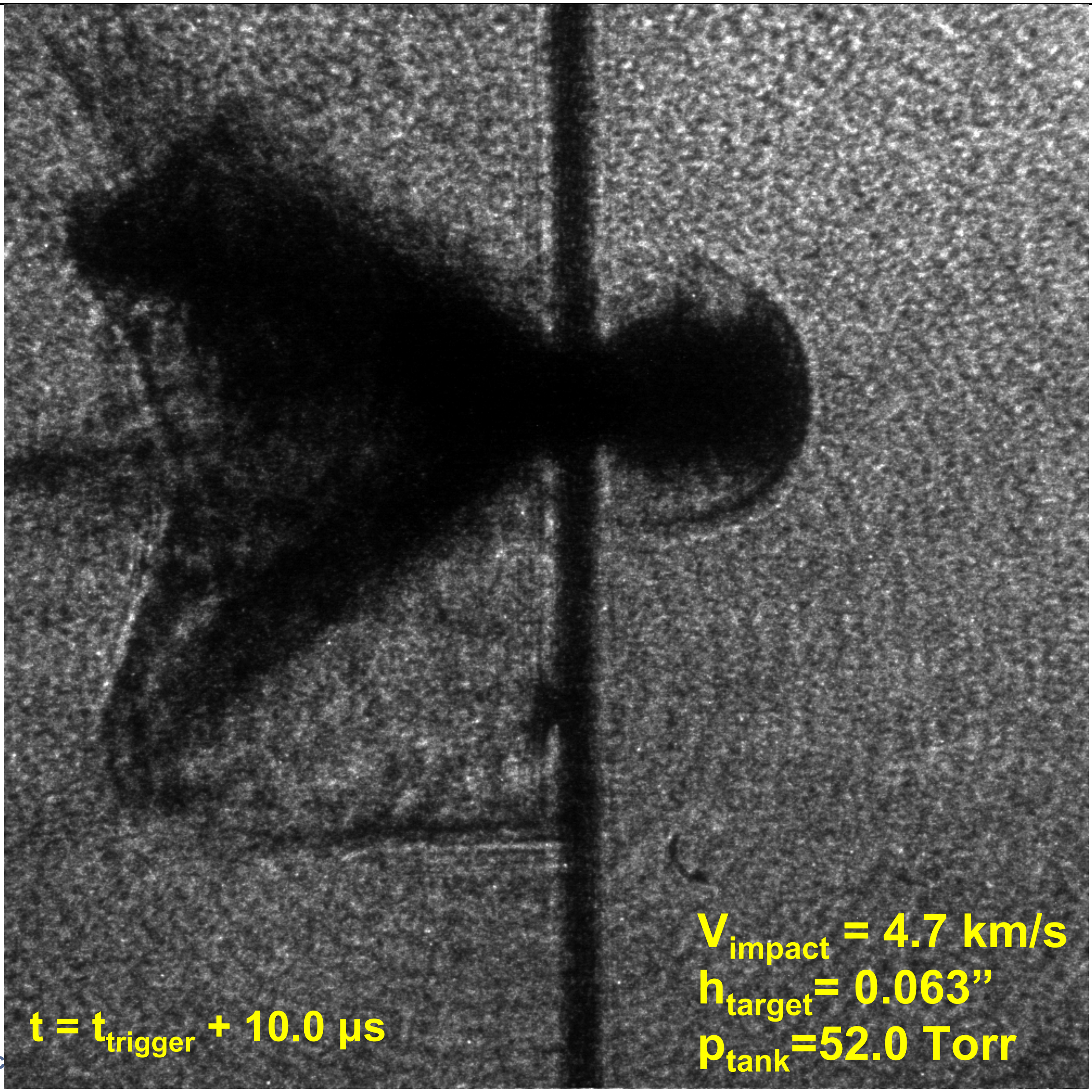

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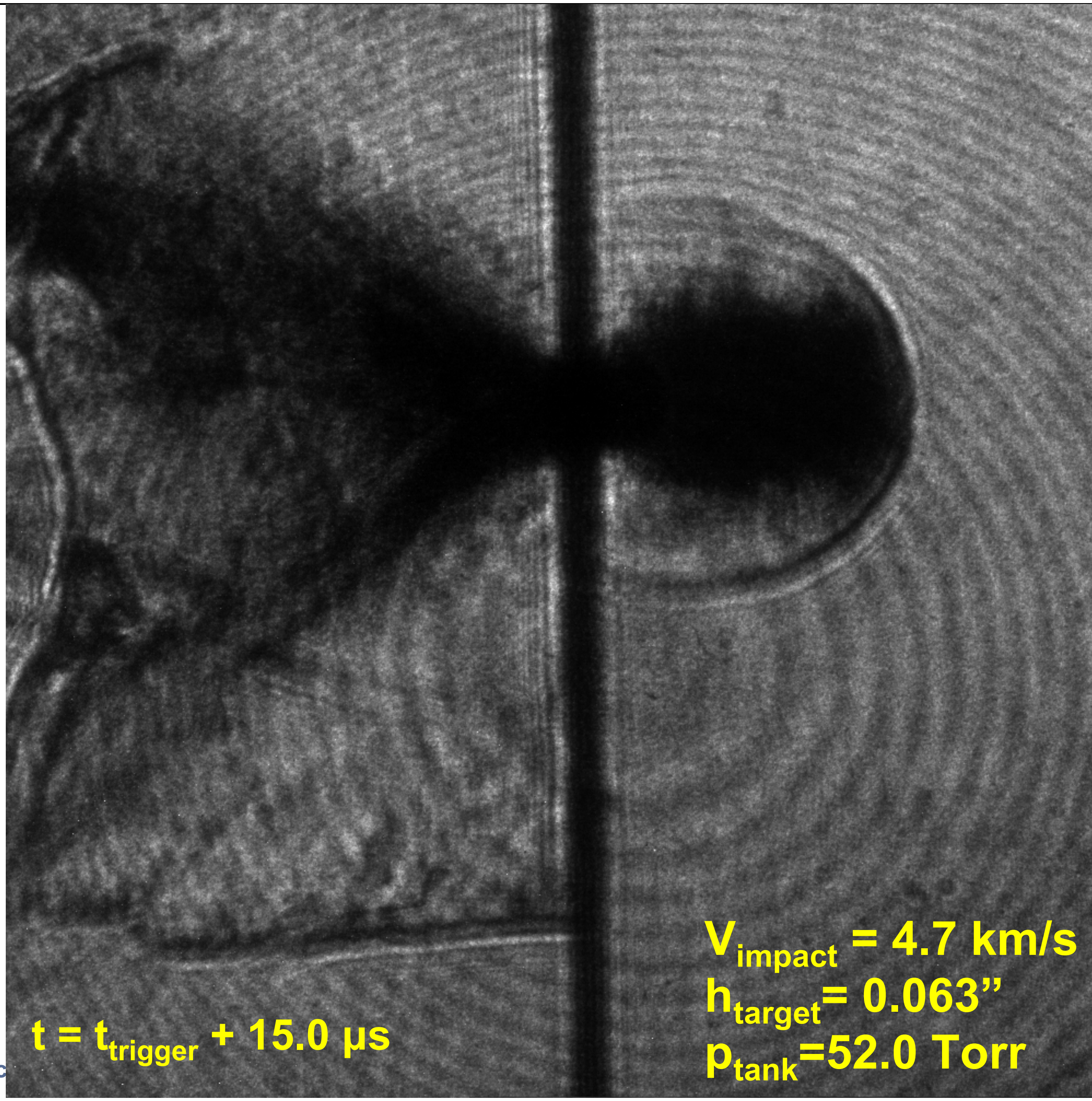

CGS by Transmission Results

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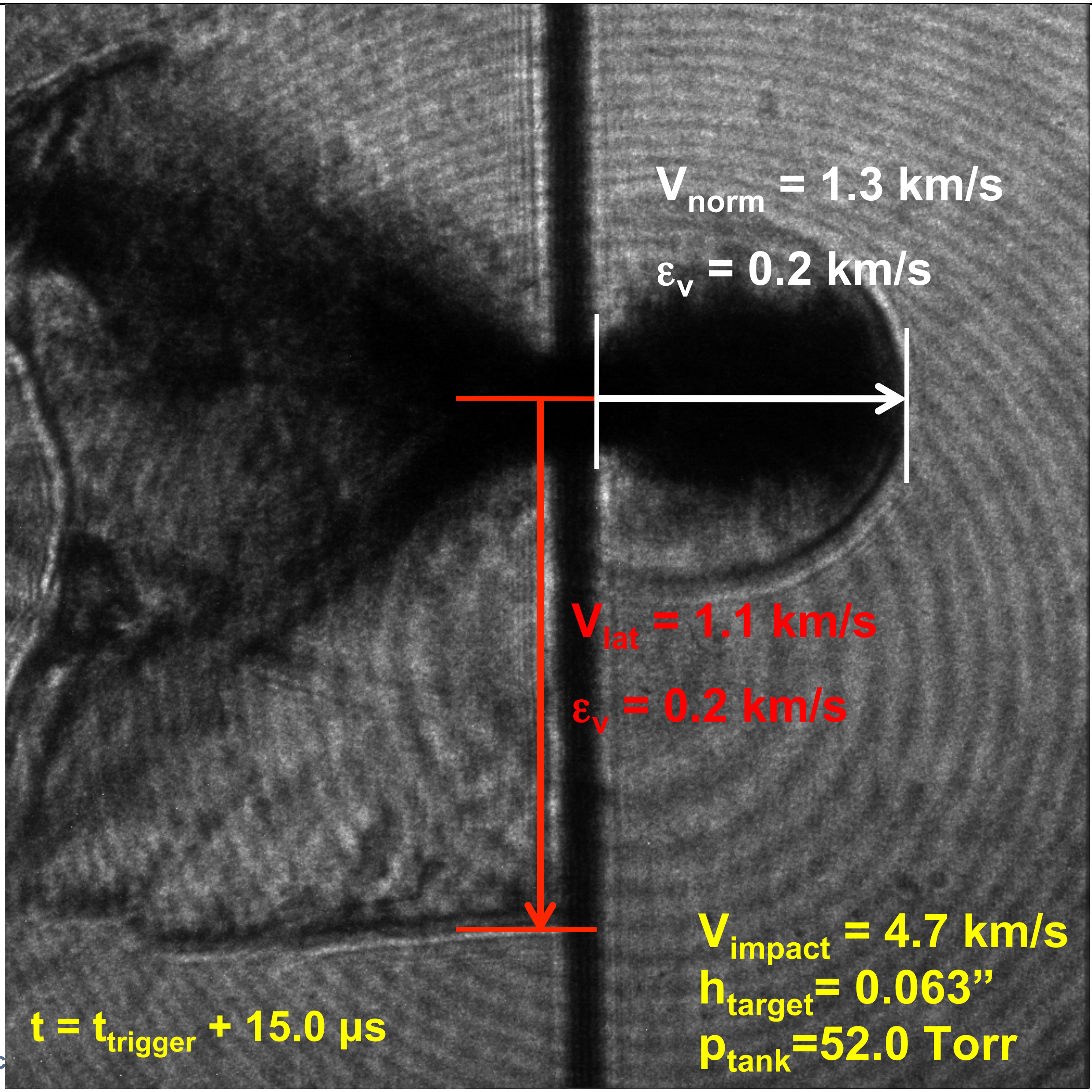

Debris Capture Diagnostic

Capture Pack and Measurement

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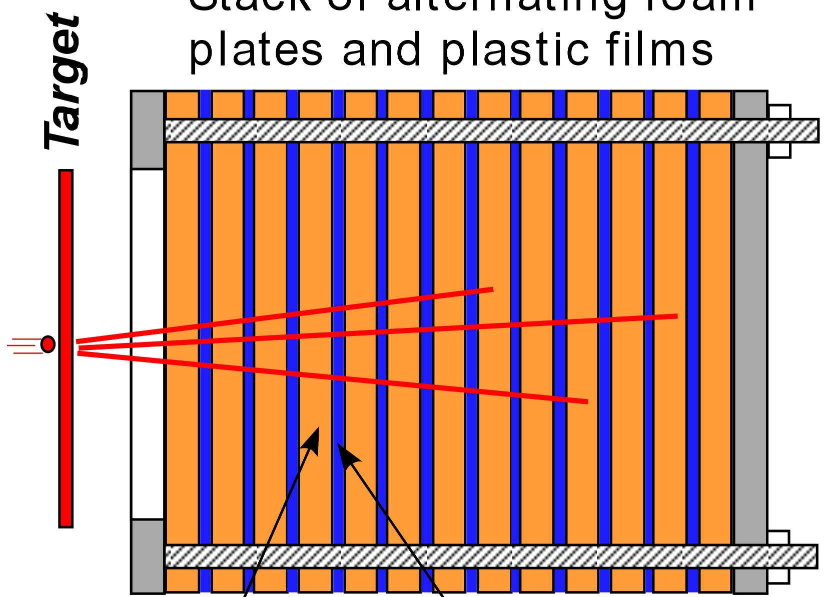
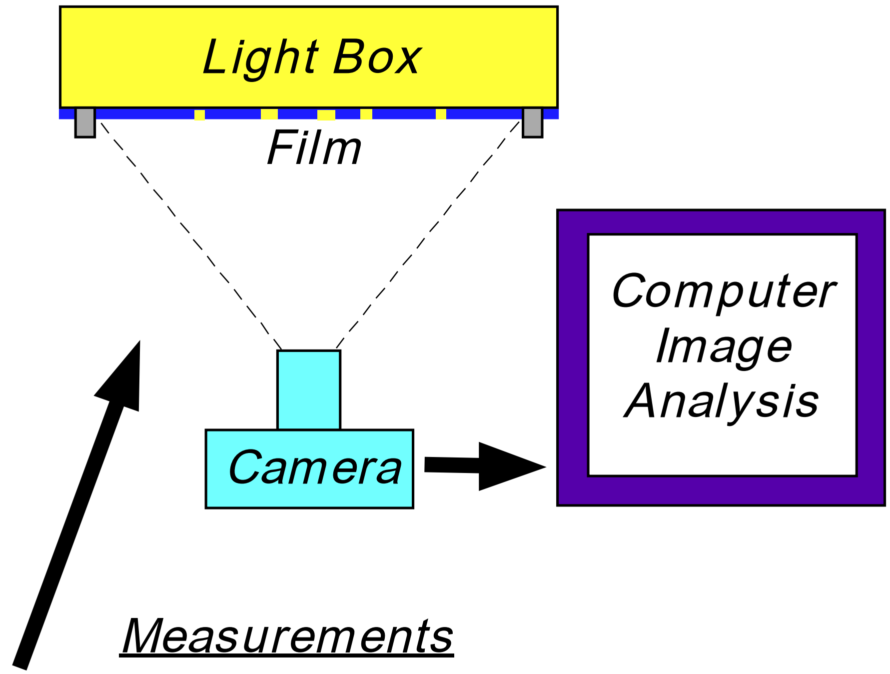
Stack of alternating foam plates and plastic films

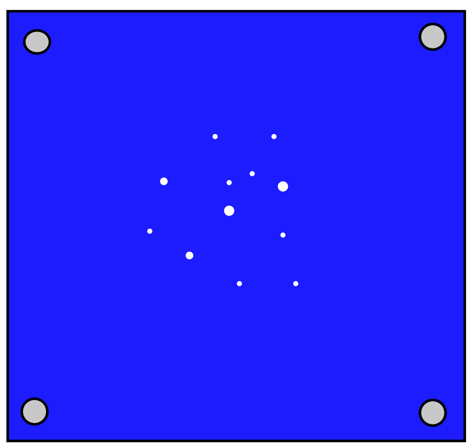


- Architectural Foam
  - 1 lb/ft3
  - inexpensive
  - highly engineered (controlled ptys)

Opaque plastic film



Film sheet after test



Measurements

(1) X-Y position of debris particle perforations on each film [dispersion of debris]
(2) Size of debris particle perforations [debris particle size]
(3) #1 combined with film distance from target perforation site gives debris particle direction and penetration path length in foam [related to mass & velocity of debris particle]
(4) Recovery of debris material from selected tests

Characterizing Debris Cloud Mass & Trajectory

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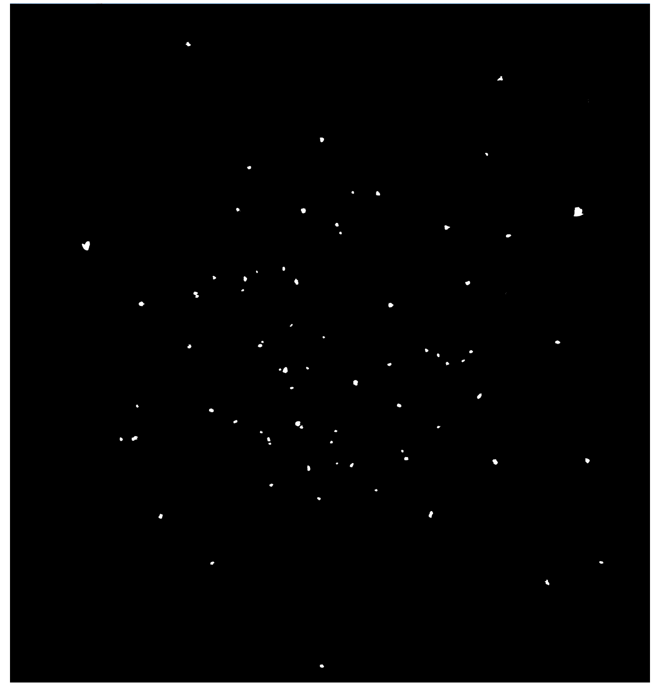
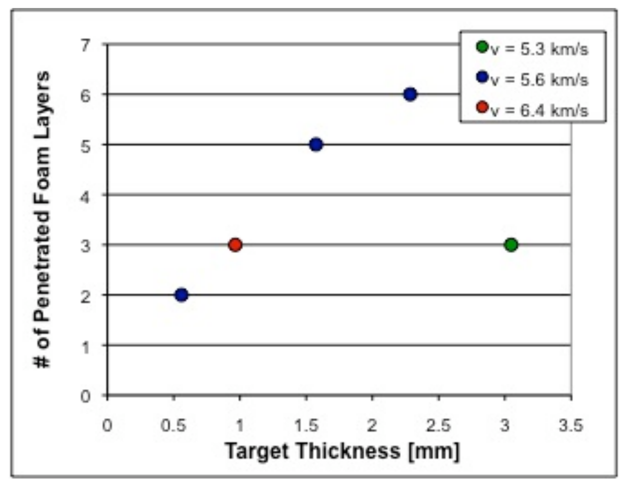
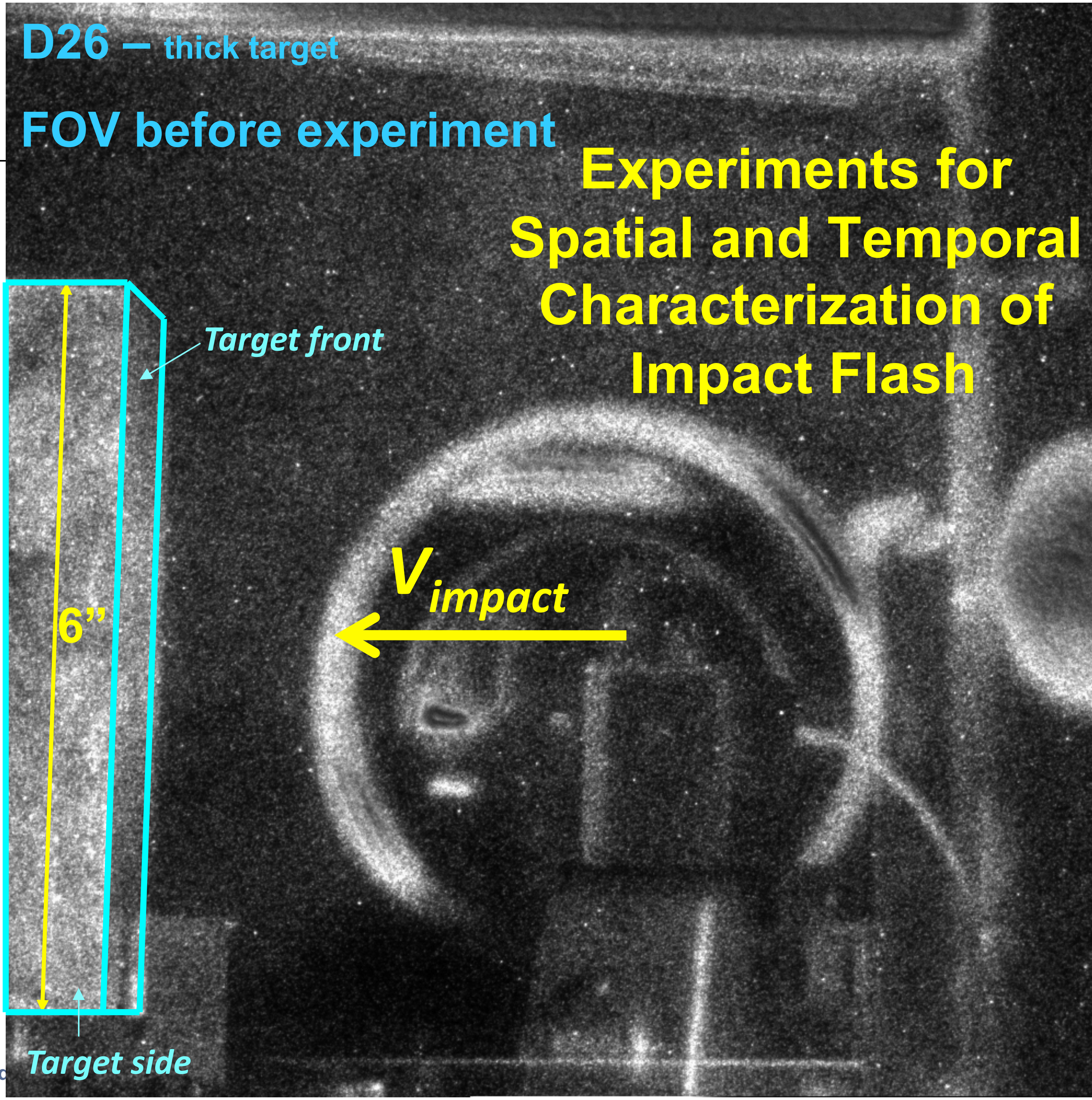
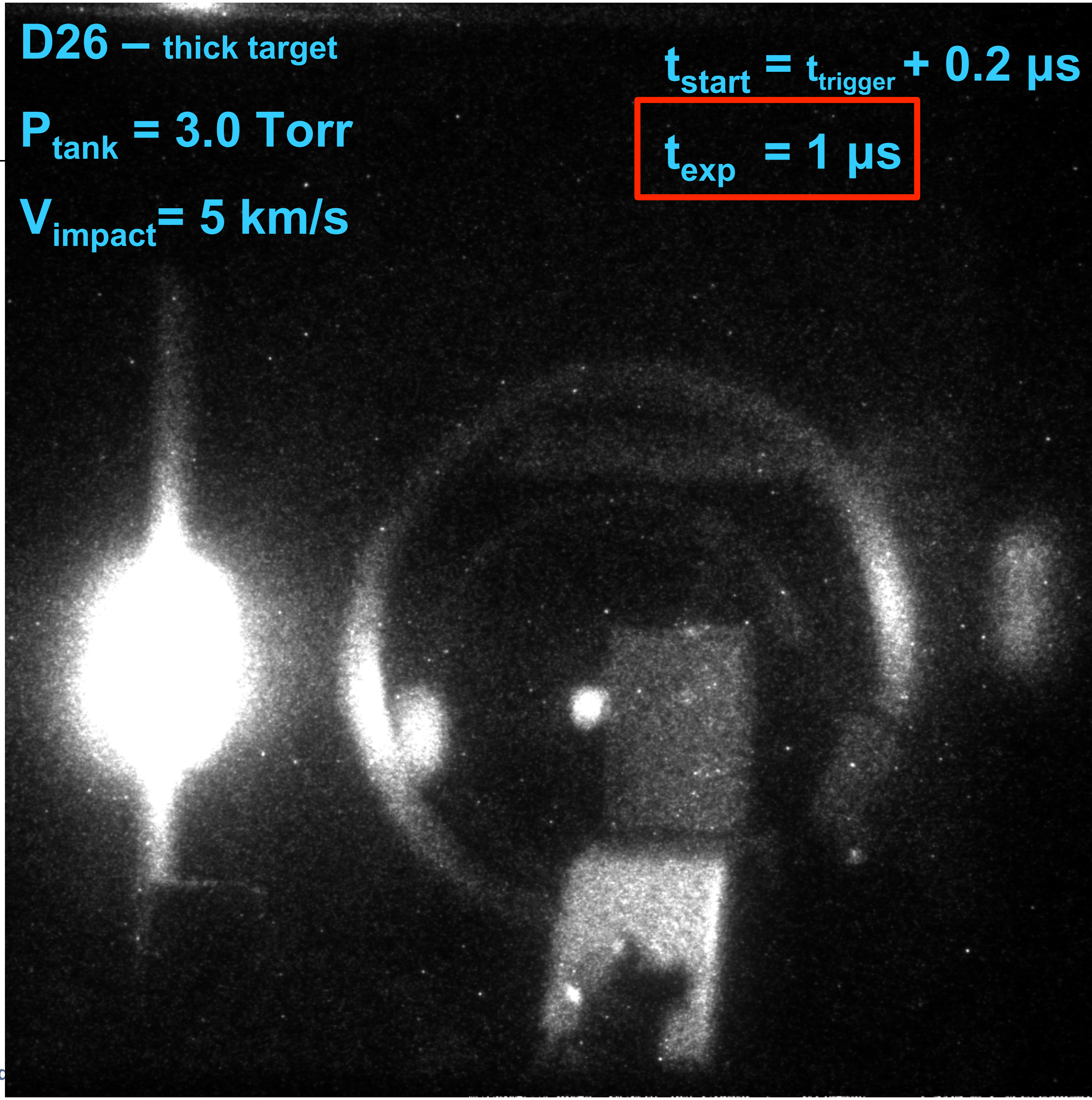


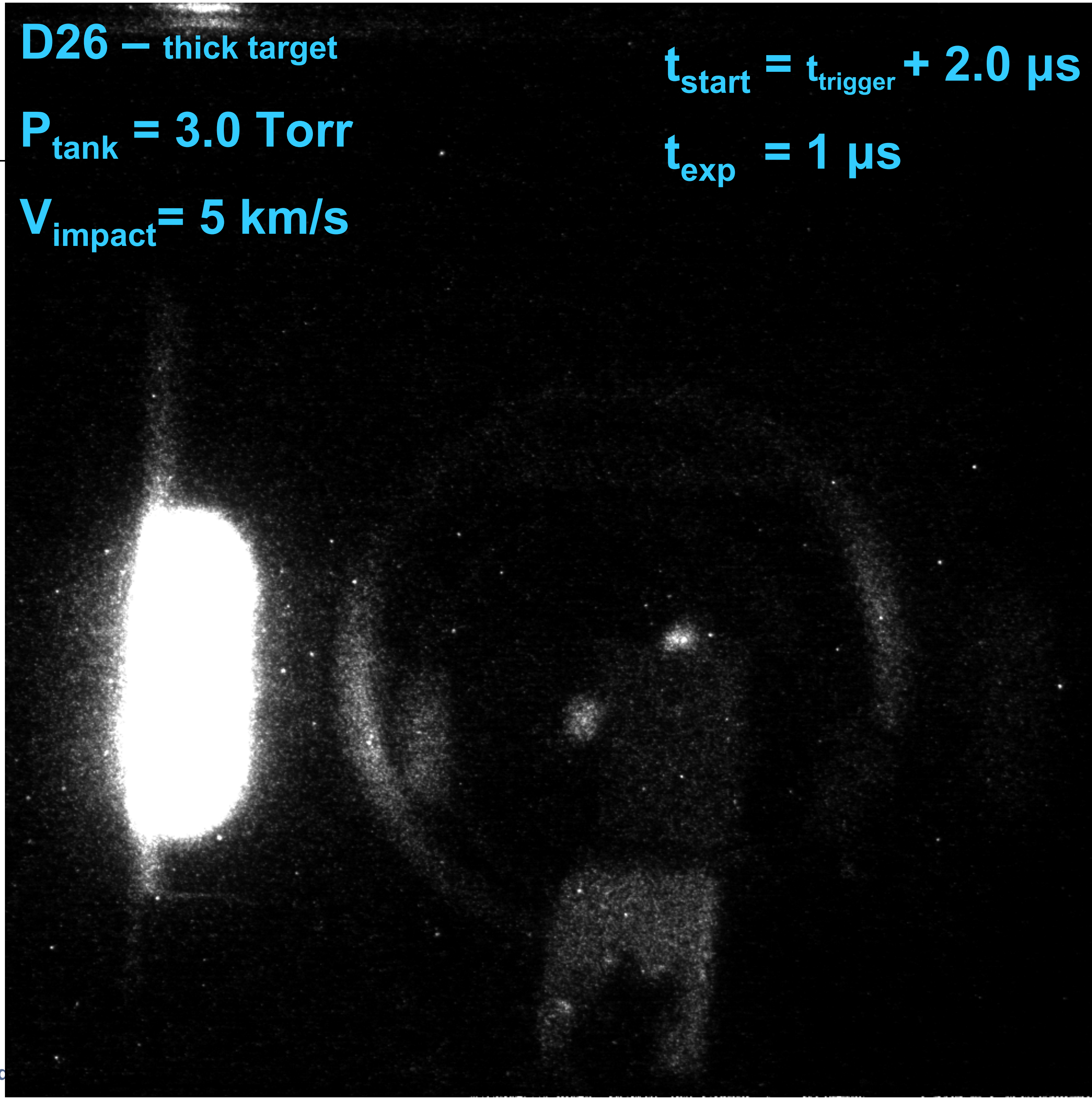


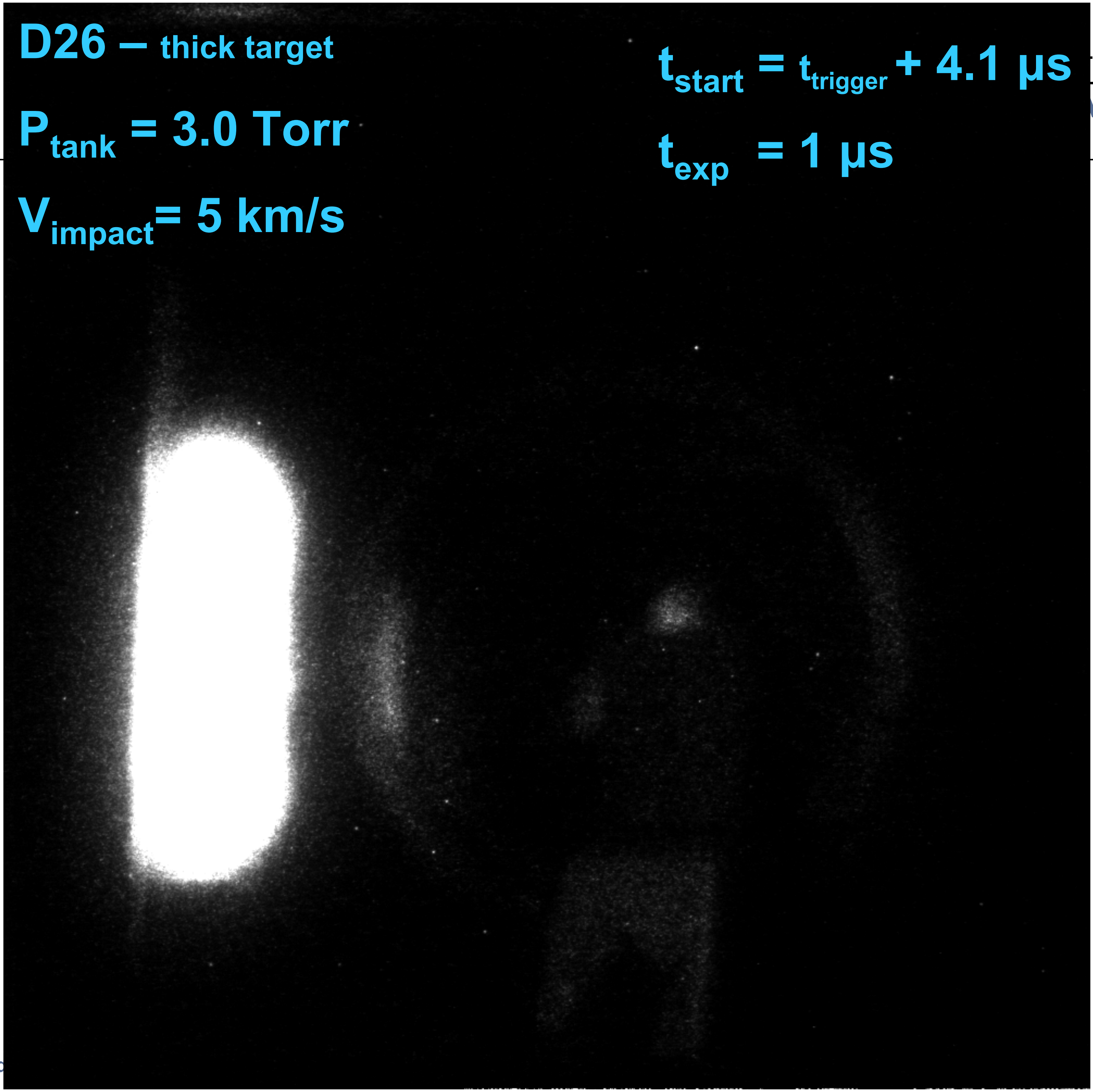
PSAAP: Predictive Science Academic Alliance Program

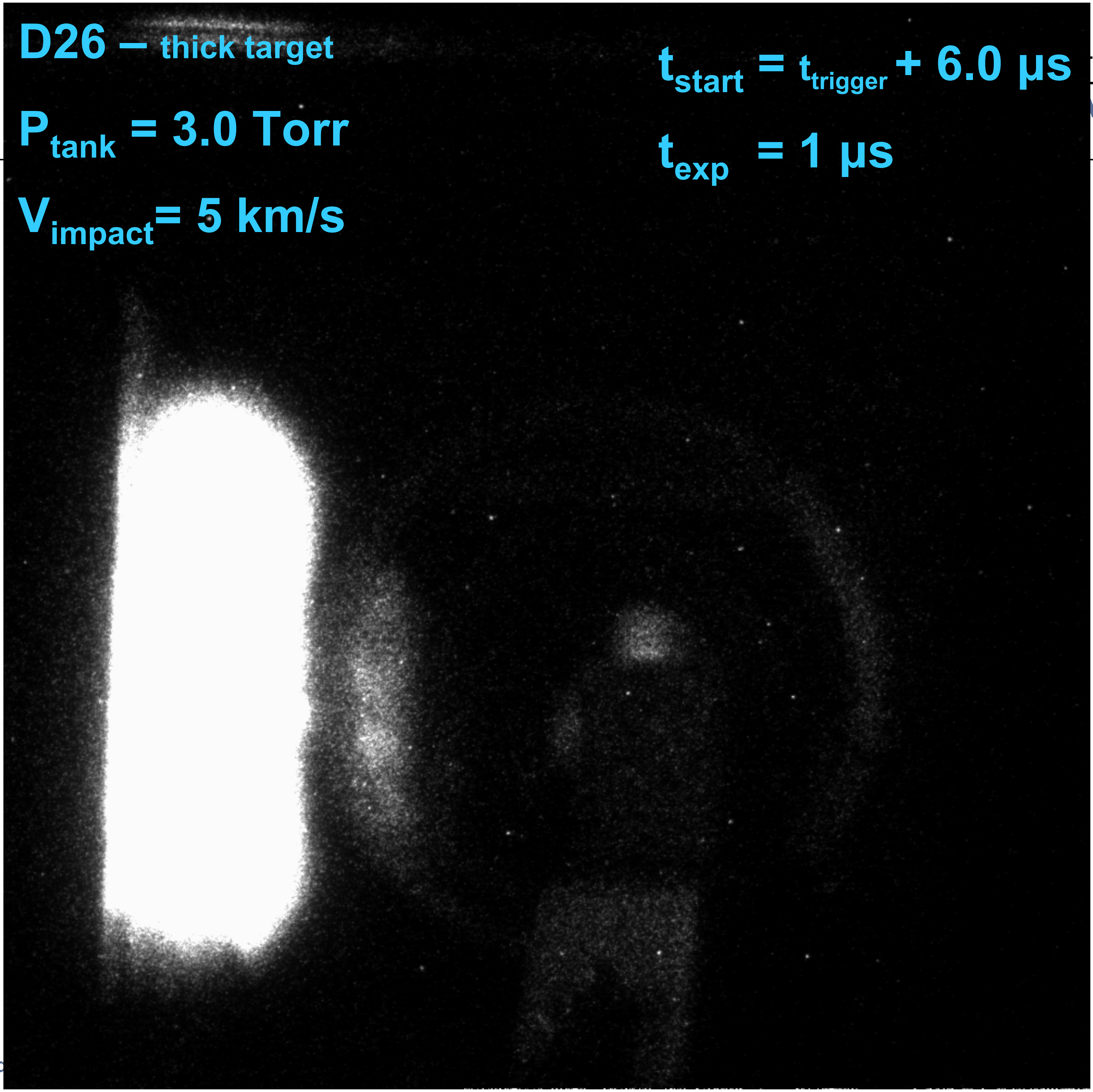
Experiments for Spatial and Temporal Characterization of Impact Flash

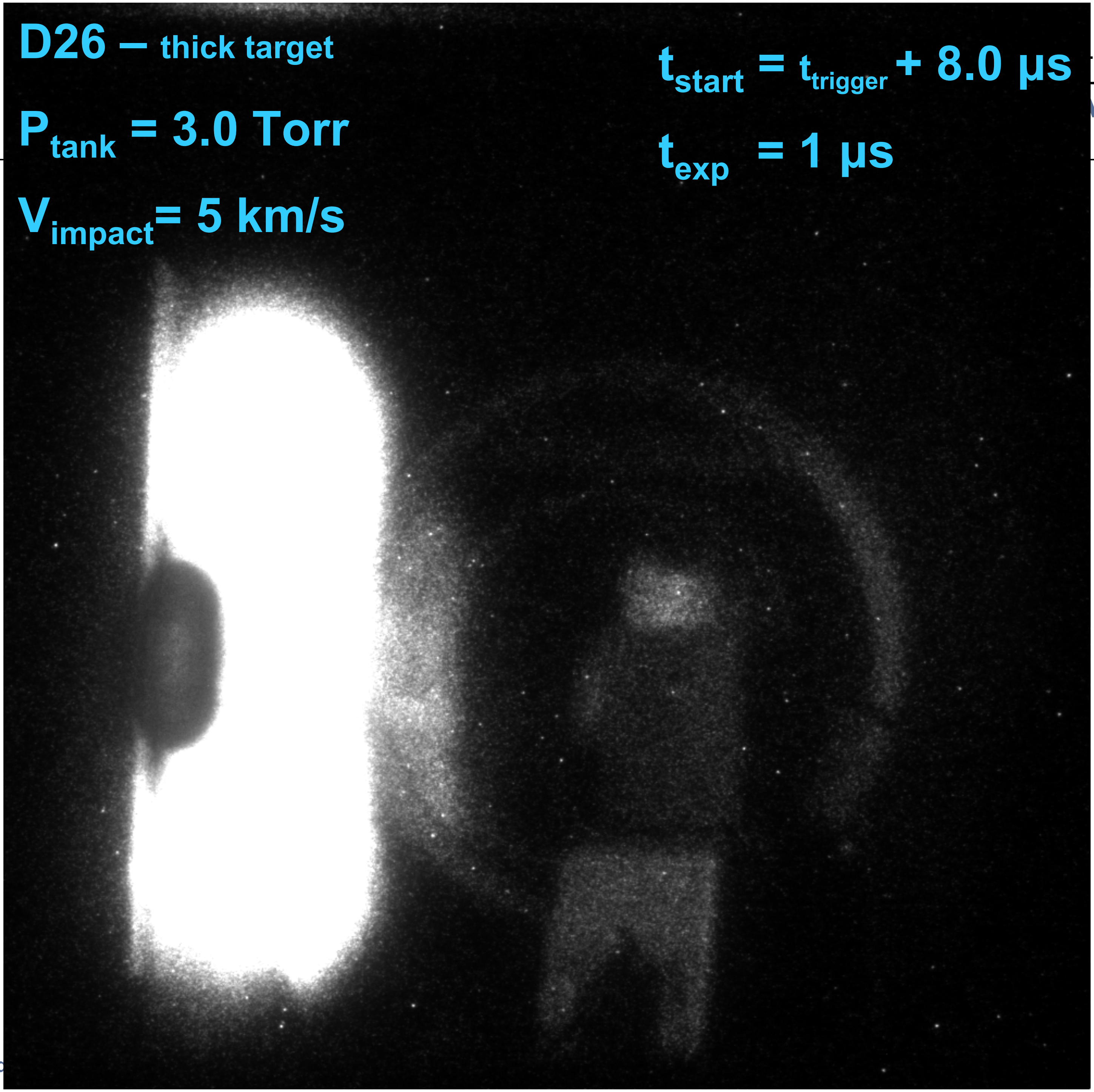


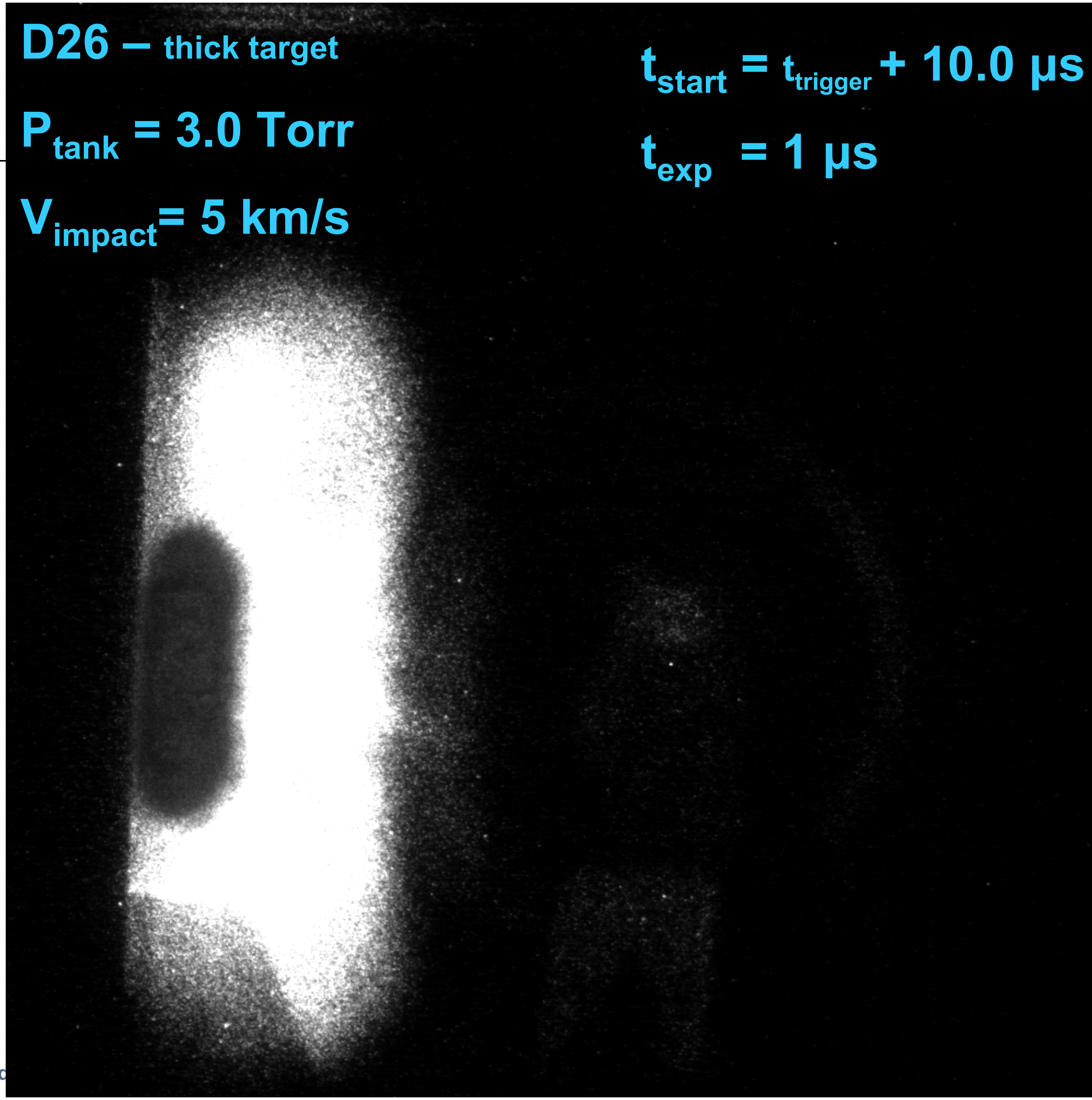

D26 – thick target
P_{tank} = 3.0 Torr
V_{impact}= 5 km/s
$t_{start} = t_{trigger} + 0.2$ μs
t_{exp} = 1 μs

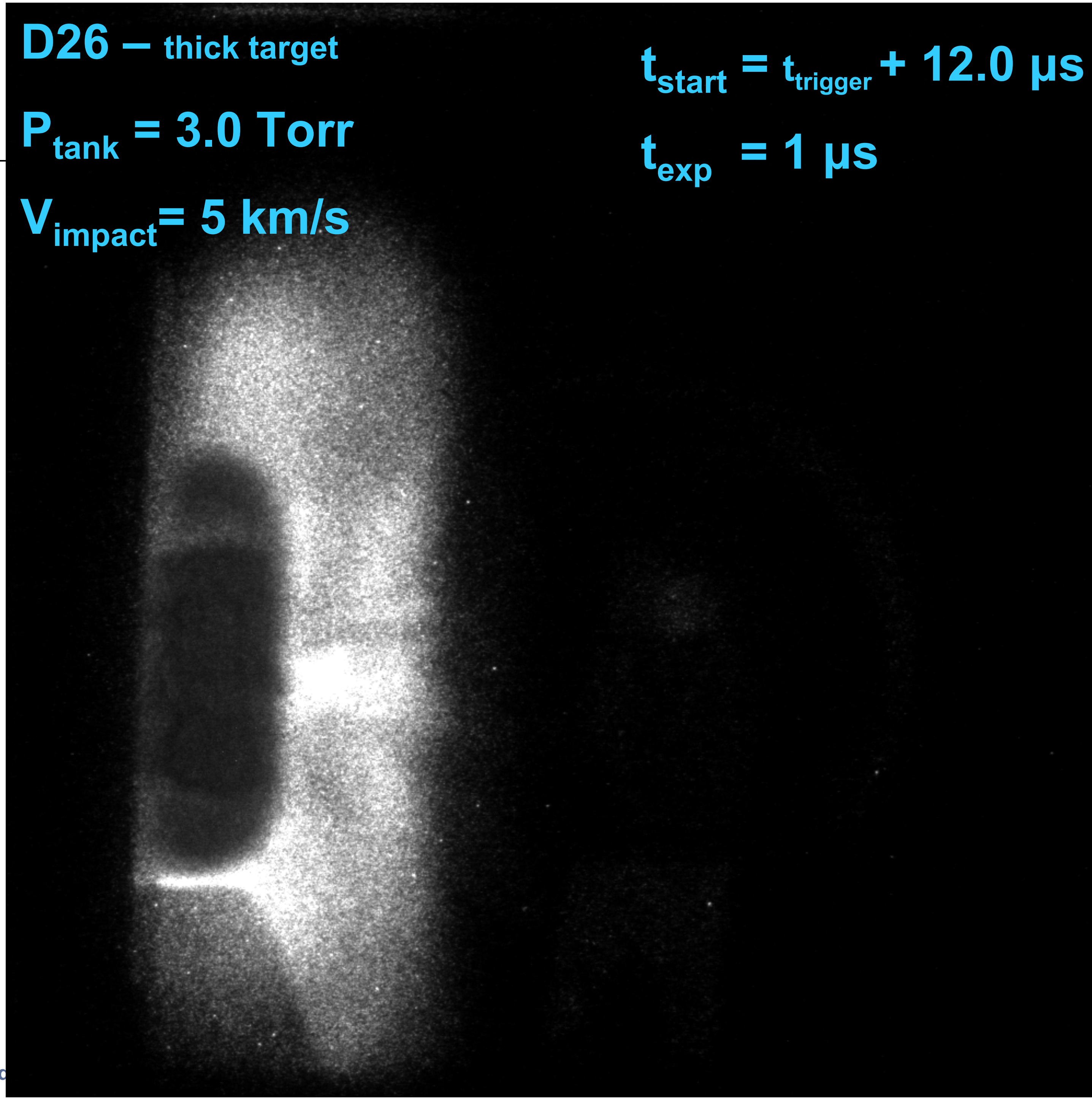

D26 – thick target
P_{tank} = 3.0 Torr
V_{impact}= 5 km/s
$t_{start} = t_{trigger}$ + 2.0 μs
t_{exp} = 1 μs

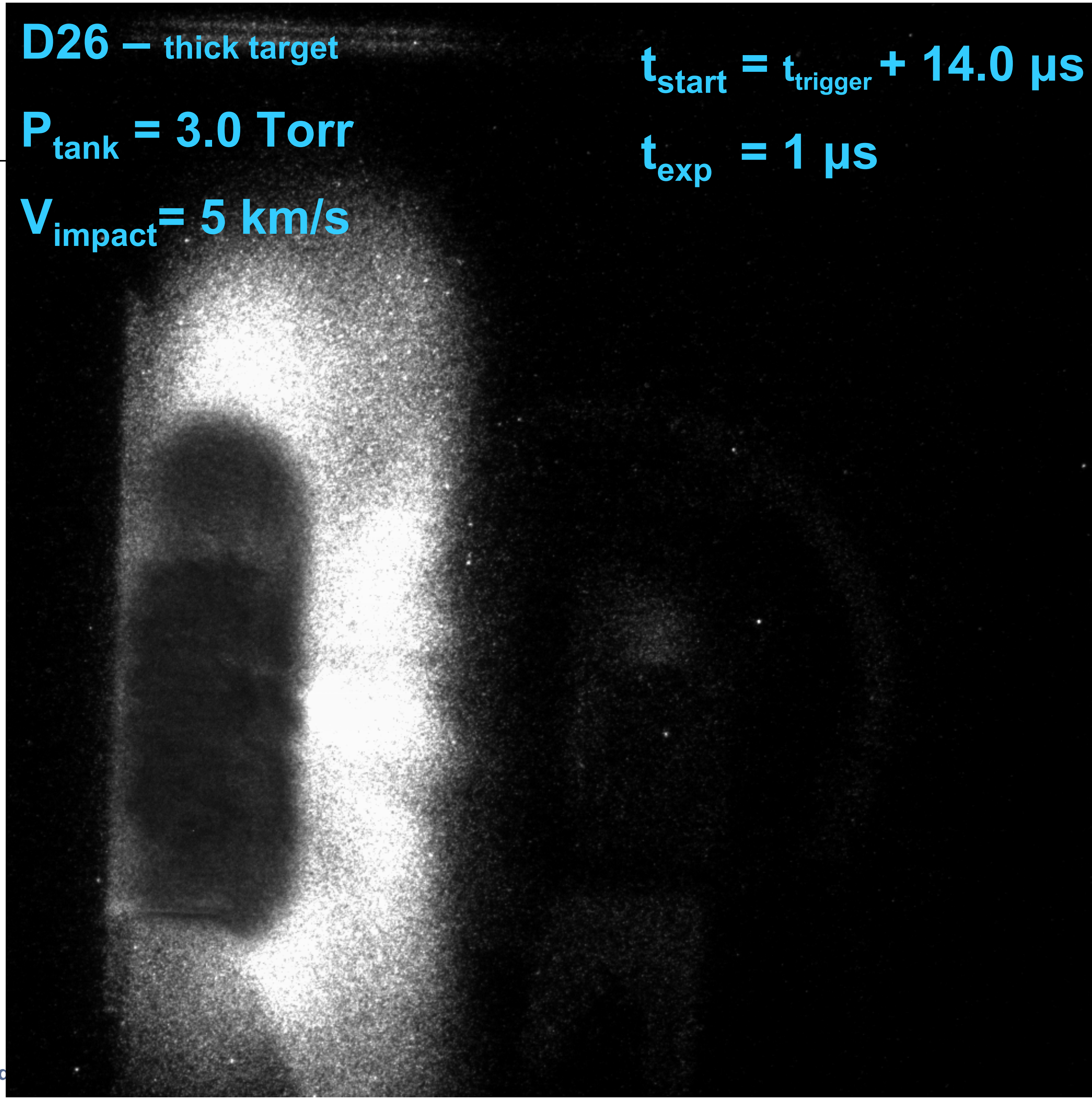

D26 – thick target
P_{tank} = 3.0 Torr
V_{impact}= 5 km/s
$t_{start} = t_{trigger} + 4.1\ \mu s$
$t_{exp} = 1\ \mu s$

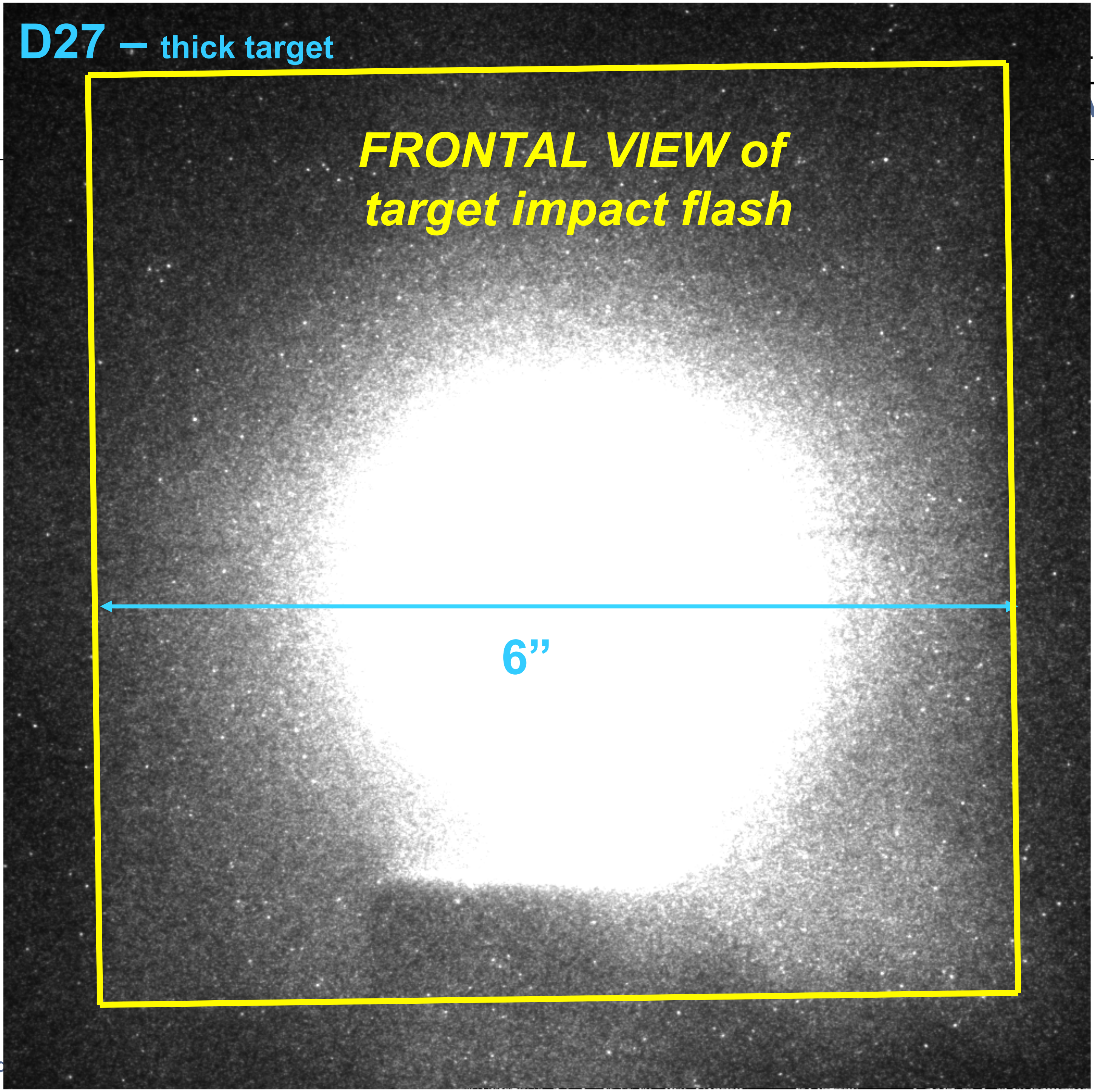

D26 – thick target
P_{tank} = 3.0 Torr
V_{impact}= 5 km/s
$t_{start} = t_{trigger}$ + 6.0 μs
t_{exp} = 1 μs

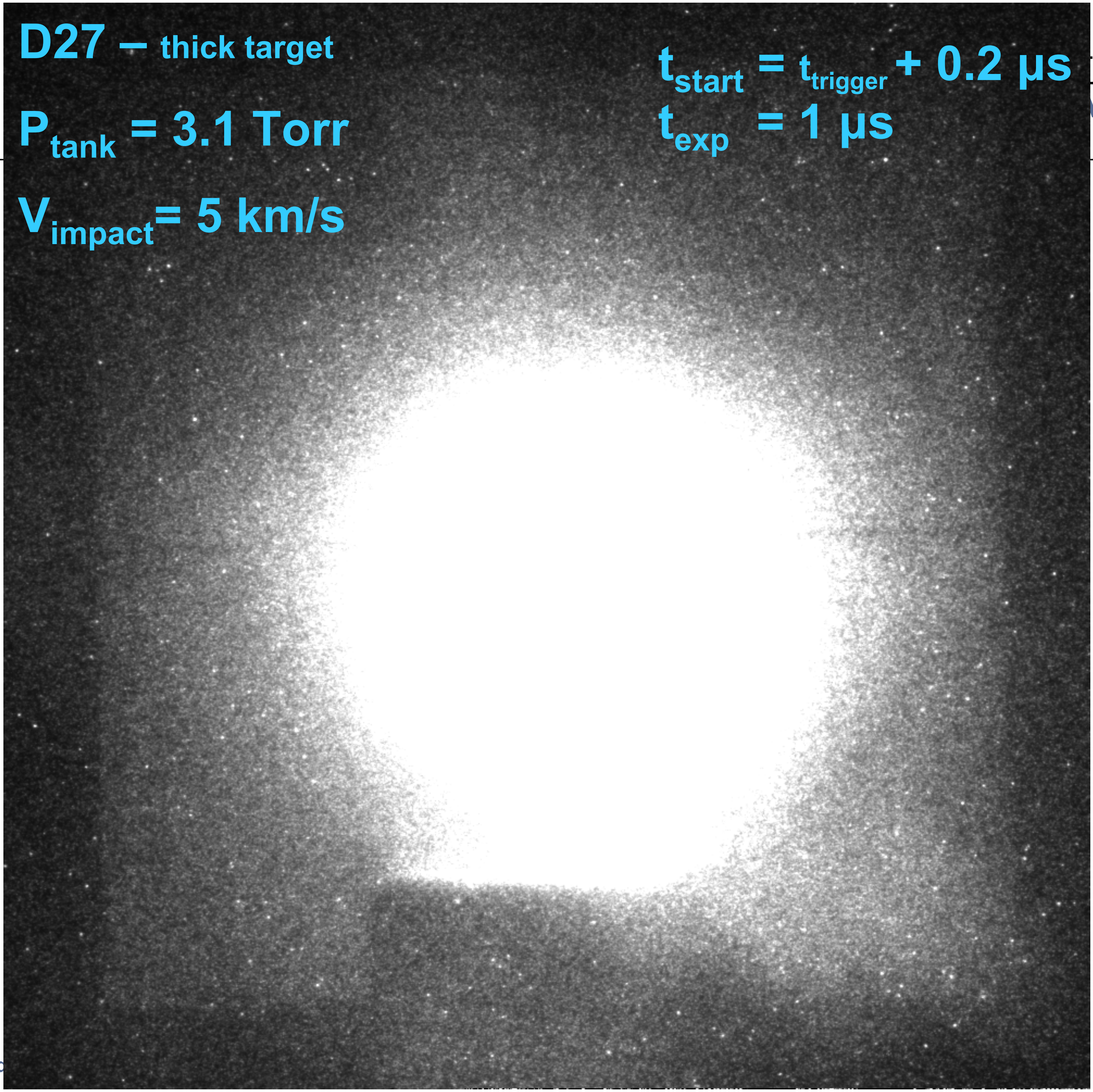

D26 – thick target
P_{tank} = 3.0 Torr
V_{impact}= 5 km/s
$t_{start} = t_{trigger}$ + 8.0 μs
t_{exp} = 1 μs

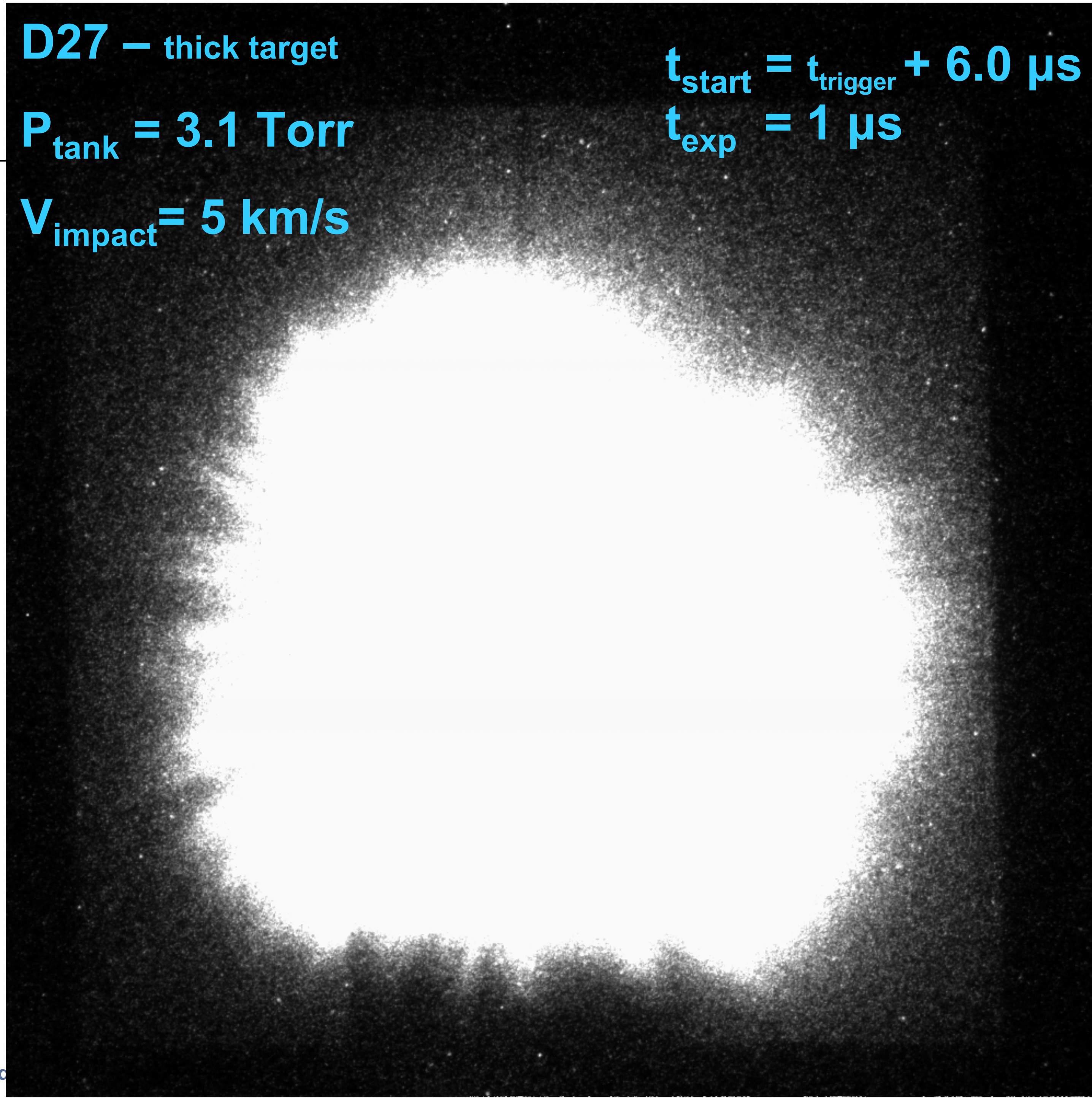

D26 – thick target
P_{tank} = 3.0 Torr
V_{impact} = 5 km/s
$t_{start} = t_{trigger}$ + 10.0 µs
t_{exp} = 1 µs

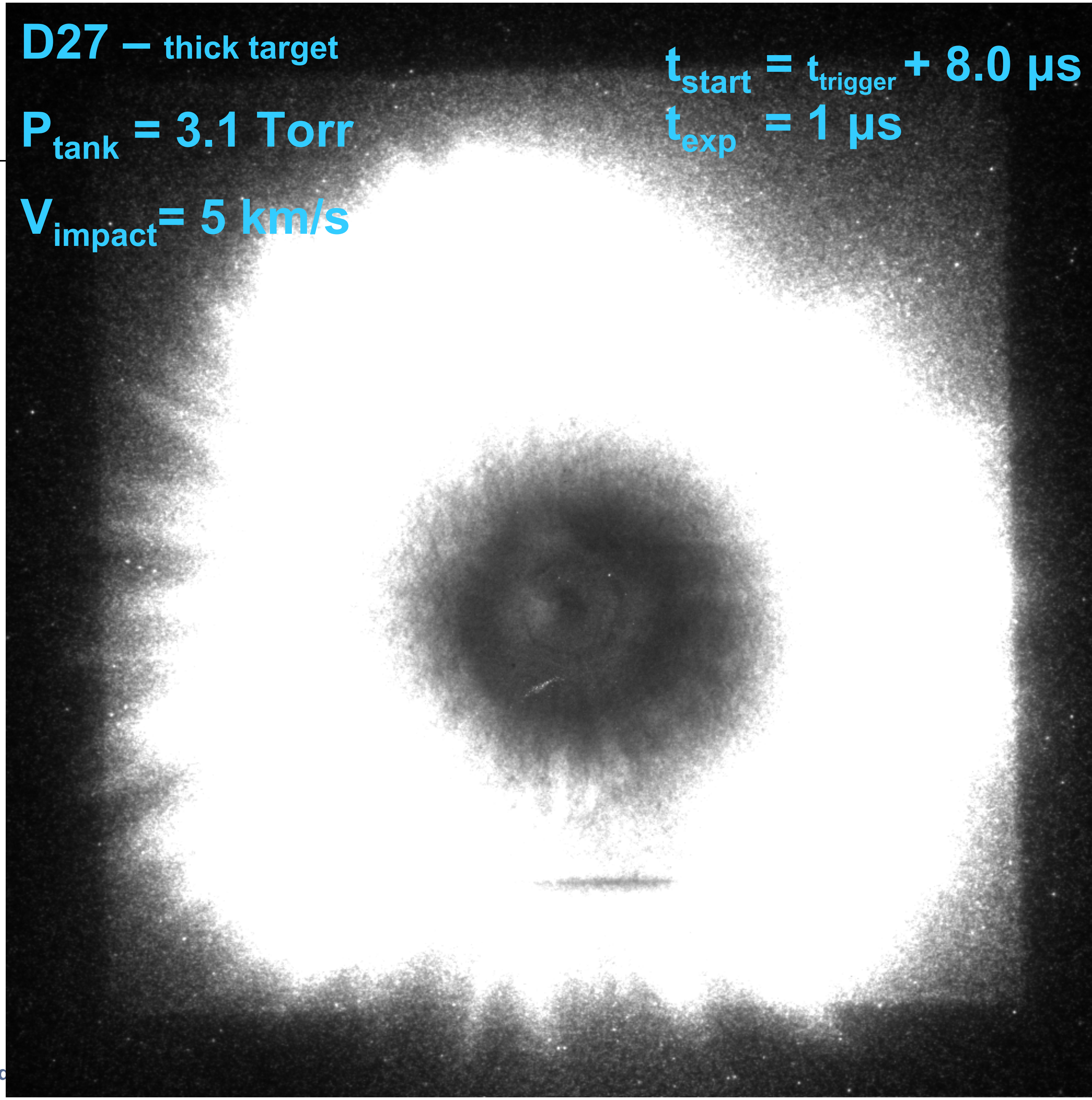

D26 – thick target
P_{tank} = 3.0 Torr
V_{impact}= 5 km/s
$t_{start} = t_{trigger}$ + 12.0 μs
t_{exp} = 1 μs

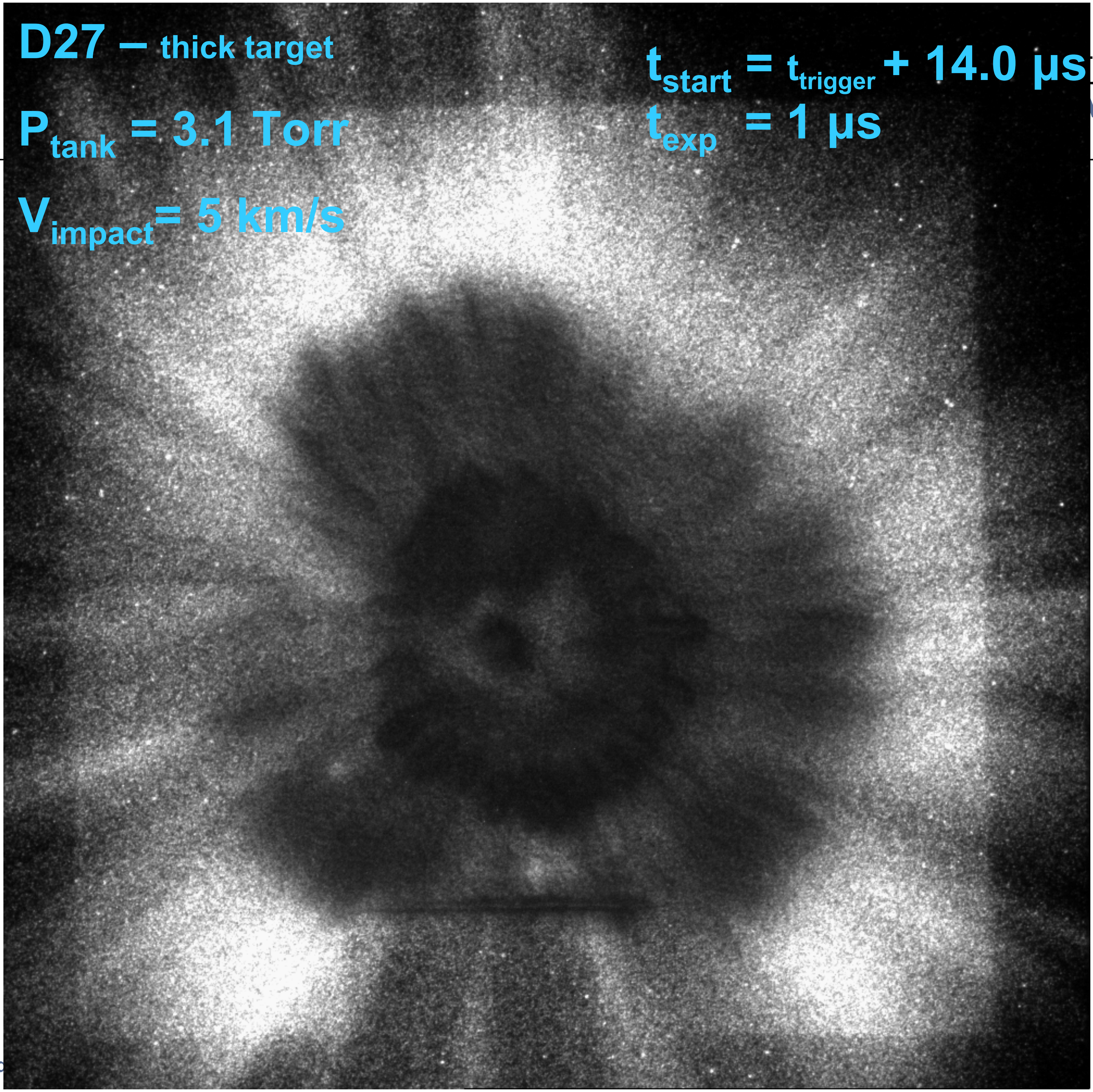

D26 – thick target
P_{tank} = 3.0 Torr
V_{impact}= 5 km/s
t_{start} = $t_{trigger}$ + 14.0 μs
t_{exp} = 1 μs


D27 – thick target
FRONTAL VIEW of
target impact flash
6”


D27 – thick target
P tank = 3.1 Torr
V impact = 5 km/s
t start = t trigger + 0.2 µs
t exp = 1 µs


D27 – thick target
P_{tank} = 3.1 Torr
V_{impact} = 5 km/s
$t_{start} = t_{trigger}$ + 6.0 μs
t_{exp} = 1 μs


D27 – thick target
P_{tank} = 3.1 Torr
V_{impact} = 5 km/s
$t_{start} = t_{trigger}$ + 8.0 μs
t_{exp} = 1 μs



D27 – thick target
P_{tank} = 3.1 Torr
V_{impact} = 5 km/s
$t_{start} = t_{trigger}$ + 14.0 μs
t_{exp} = 1 μs

Spectrometer Instrumentation

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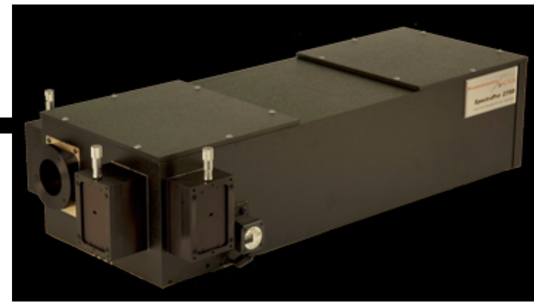
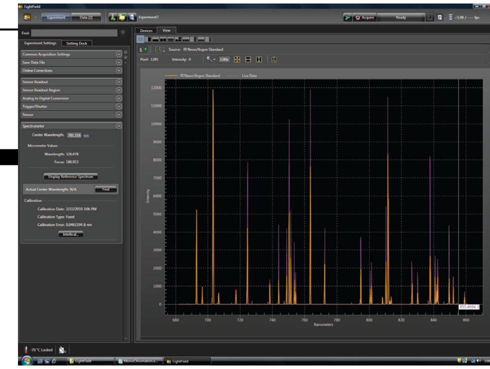
Visible-UV High-Speed Camera (PI-MAX 3)

-1024 x 256 pixel, gated, intensified CCD camera
- 3 ns fast gate
- Spectral coverage of 200 nm to 850 nm



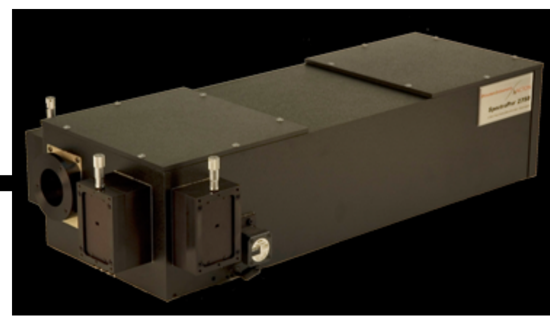
Acton VM-504 500 mm focal length (0.05 nm resolution) spectrograph



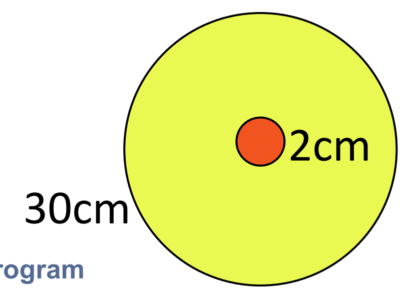
LightField 64 bit Data Acquisition Software

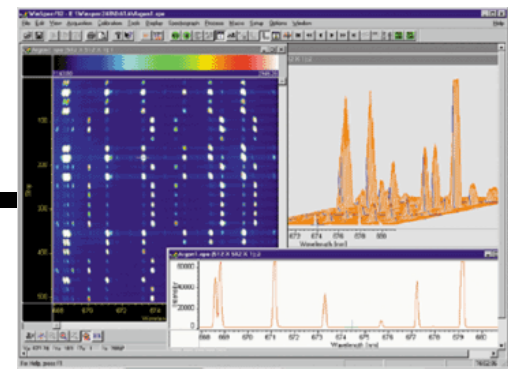
Infrared Imaging Camera (OMA V)

-Spectral coverage of 0.9 µm to 1.7 µm
-2.2 µs response time



Lens systems for field of view





WinSpec 32 bit Data acquisition software

All components operated by integrated computer control software

Spectrometers Installed

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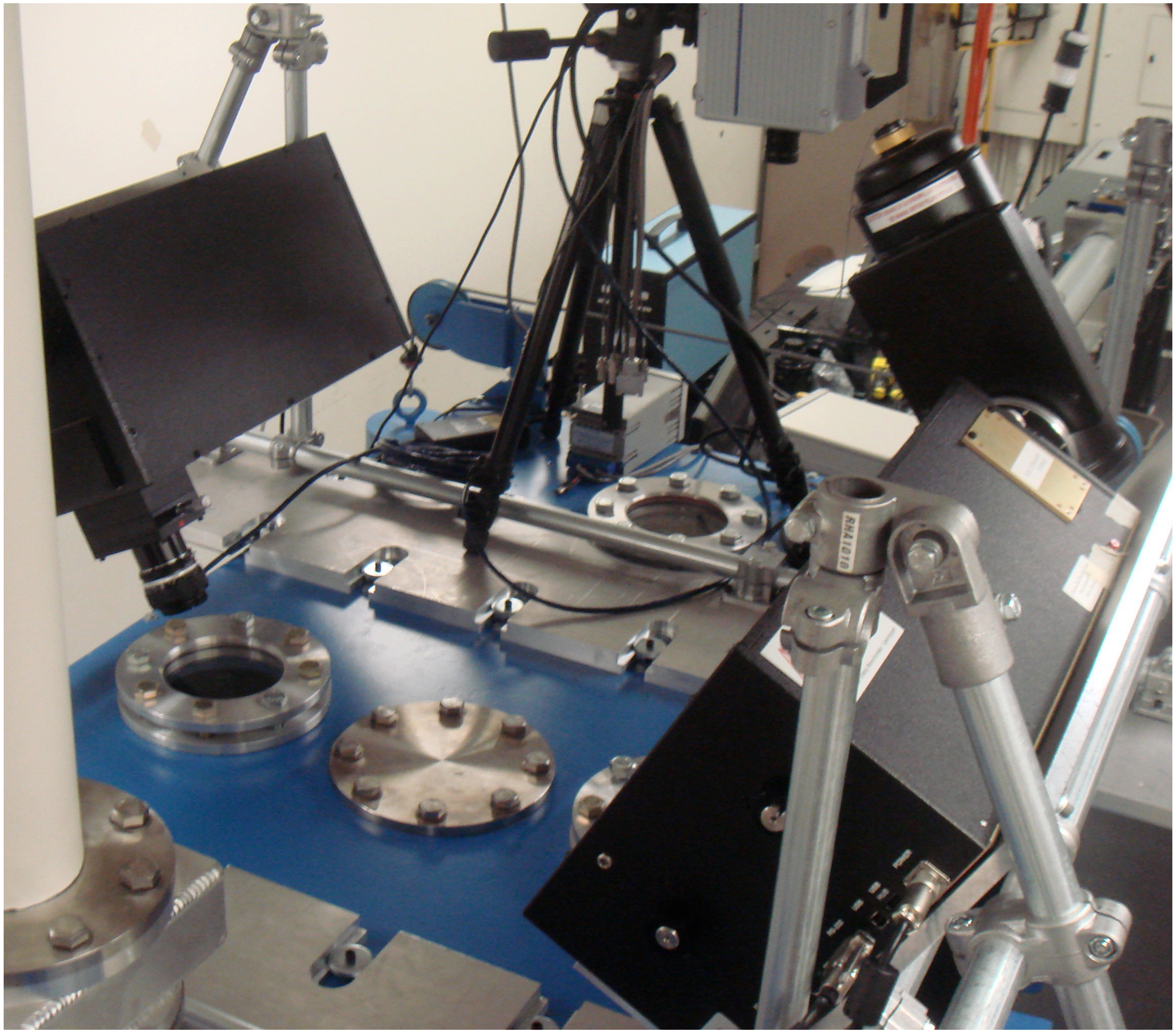

Post Mortem Profilometry

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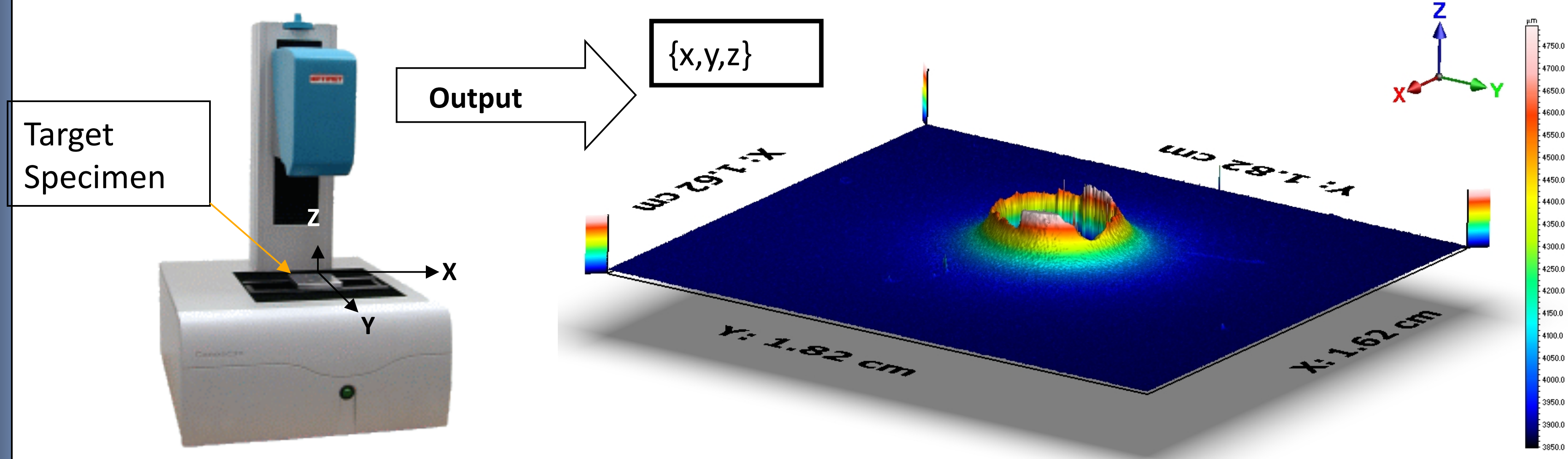
Optimet MiniConoscan 3000



•Produces surface map as {x,y,z} coordinate table

•Scans 101*mm* x 101*mm* area

•25 *micron* resolution in x, y, & z

Accurately measures post-test target deformation features for comparison with numerical simulation

•Target Perforation area
•Back-surface slope map

MiniConoscan Image courtesy of Optimet Optical Metrology

Legacy Data Progress

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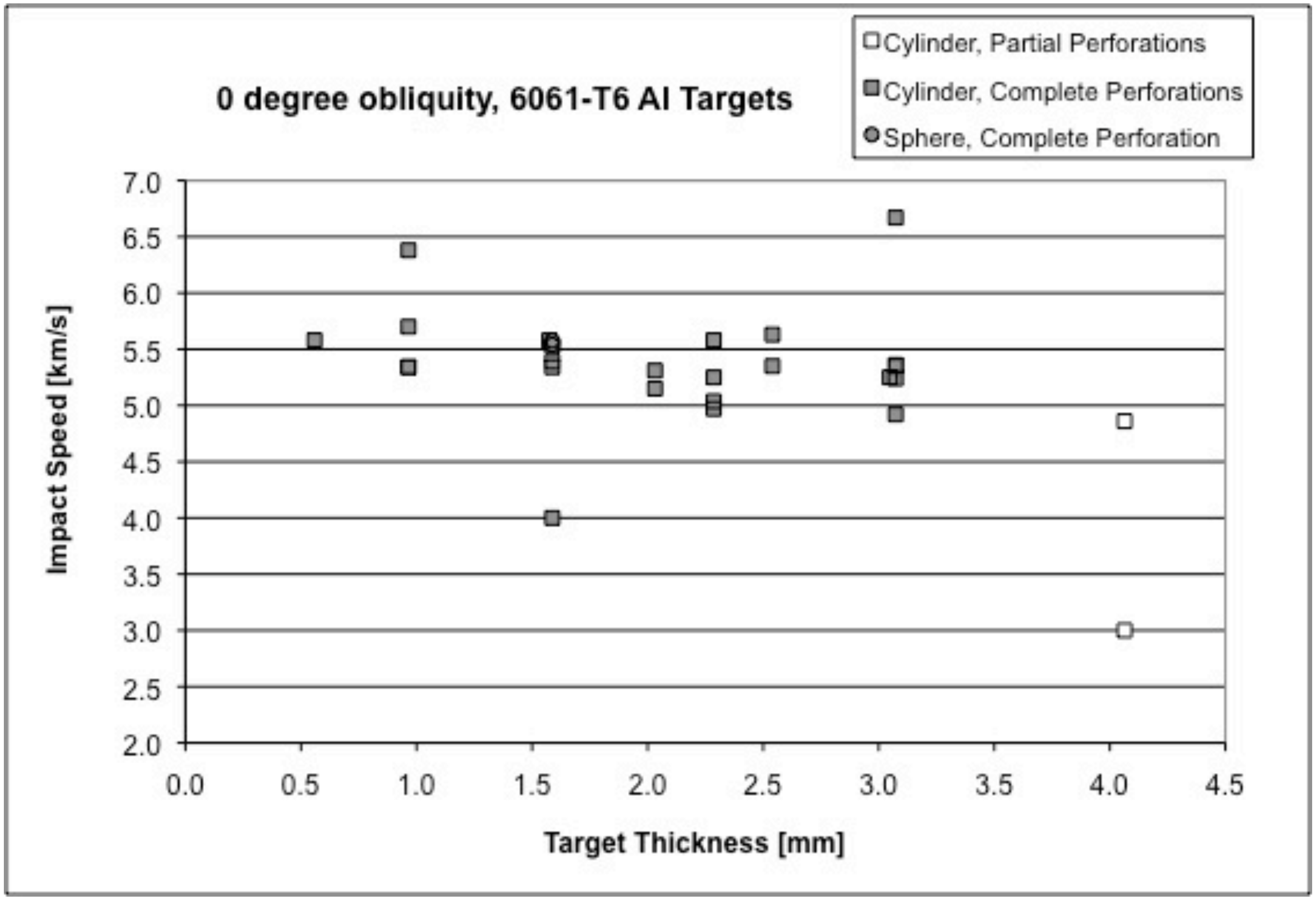
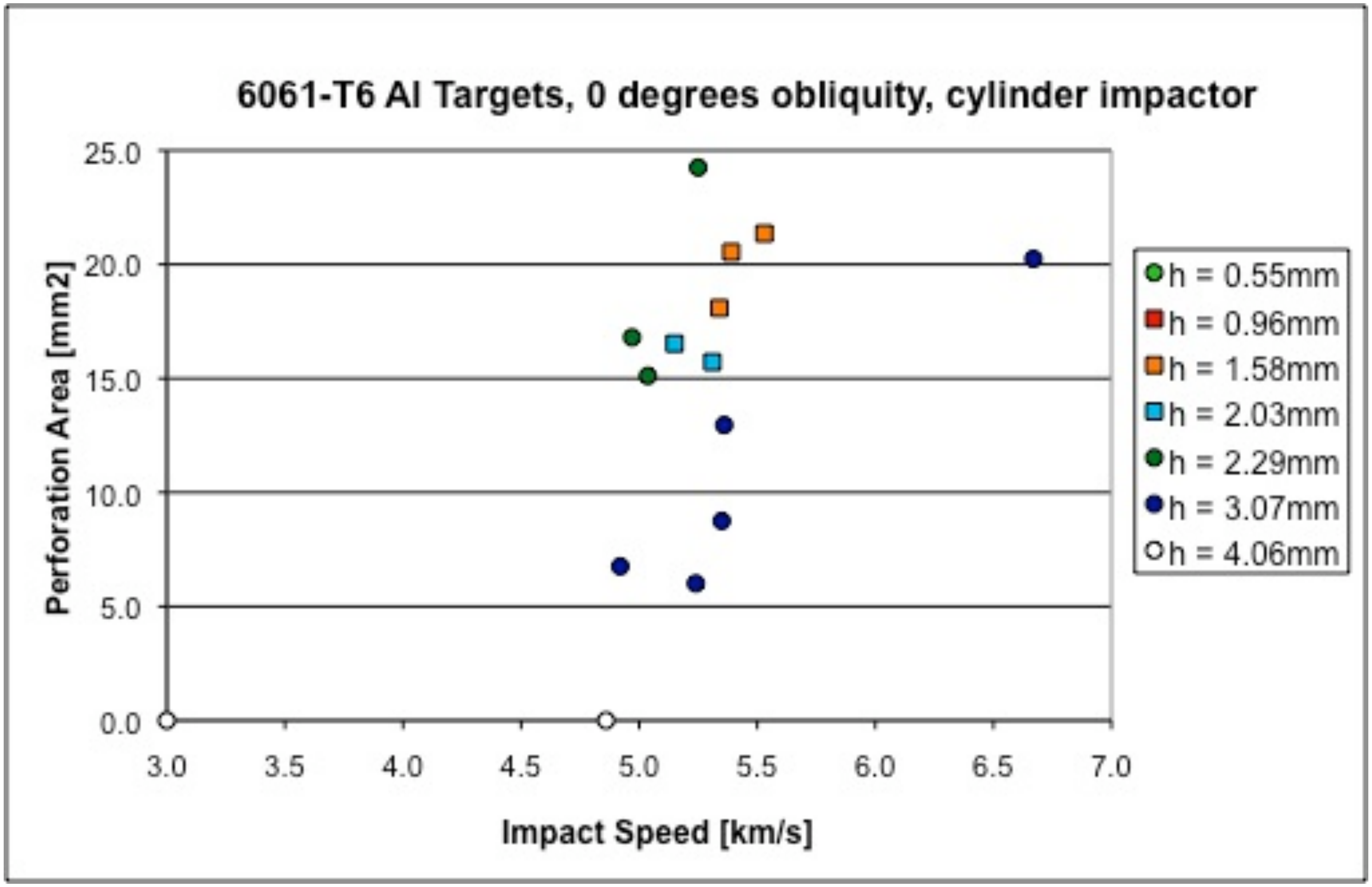
Nylon Impactor on 6061-T6 Aluminum Targets



45 experiments, 40 useful perforation area data points

Legacy Perforation Area Data



VISAR (Recently Operational)

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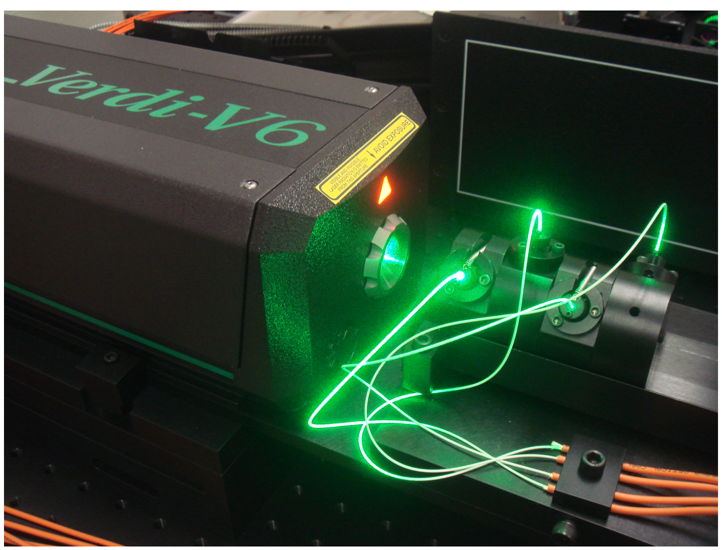
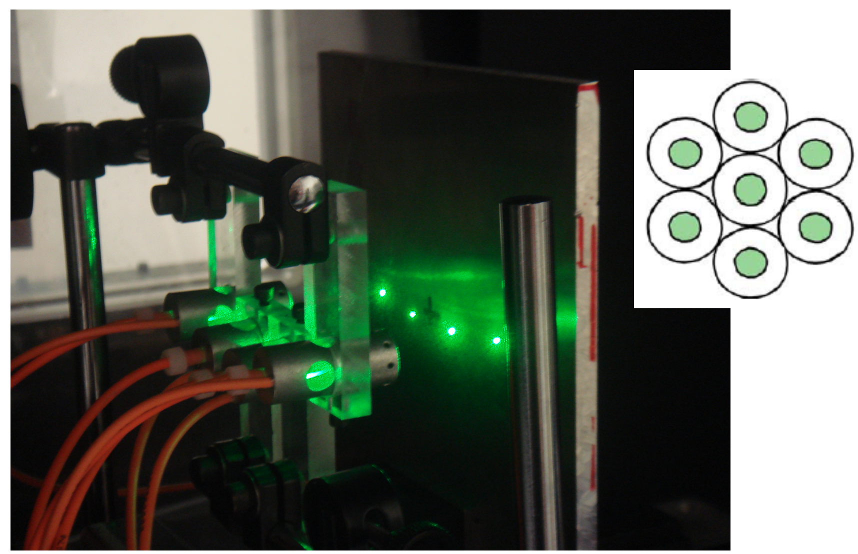
Velocity Interferometer System for Any Reflector

Metric Provided to Analysts
*Normal surface velocity of entire deformation event at **4 selected points** with high < 10 ns resolution*

- **High temporal definition** (entire impact event with <1 μs resolution)
- **Limited spatial resolution** (data taken at 4 points)

***Coherent Verdi-V6* 6 Watt, 532 nm laser**





Current Diagnostics Summary

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Diagnostic Technique	Status	***Performance Measures***
Post Mortem Profilometry	**Routine**	•Perforation Area •Target back-surface slope •…
In Situ Side-Lighting Shadowgraphs	**Operational**	•Bulge formation •Ejecta/debris cloud formation •Ejecta/debris cloud distribution
In Situ CGS by Transmission	**Operational**	•Index of refraction gradient of Ejecta and Debris cloud
In Situ VISAR	**Delivered**	•Back-surface normal velocity
In Situ Spectrometry	**Delivered**	•Emission spectra •Thermal distribution of target/ debris cloud

Metrics for Hypervelocity Campaign

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The following metrics will be used on each experiment and delivered:

- Perforation Area
- Debris Cloud Shot-Line Velocity
- Debris Cloud Trajectory
- Debris Cloud Penetration Depth
- Ejecta Velocity
- Debris Cloud Temperature
- Emission Spectra