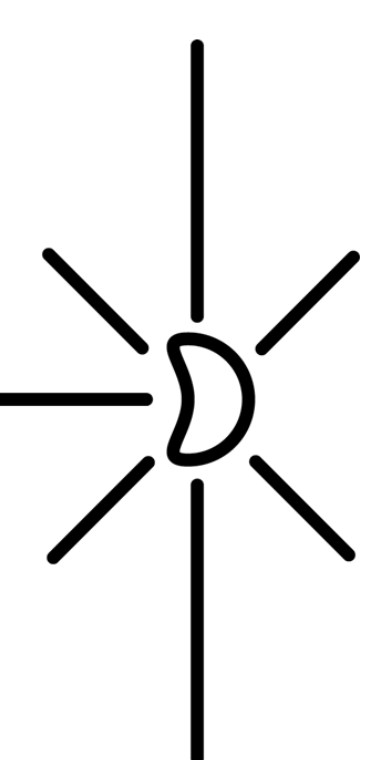




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# Hypervelocity Impact Phenomena

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### Velocimetry

**Photron Camera**  
150,000 fps

Camera FOV

Shot Line

Mirror

Target

0  $\mu$ s    18  $\mu$ s    36  $\mu$ s  
Impactor plasma "streak"

126  $\mu$ s    144  $\mu$ s    162  $\mu$ s  
Impact flash expansion

Impactor ionizes atmosphere, producing a plasma sheath  
Impact speed determined by tracking the plasma sheath

### Small Particle Hypervelocity Impact Range (SPHIR)

#### Two-Stage Light Gas Gun

- Impact velocity: 3 – 10 km/s
- Target chamber: 1 m x 1 m x 2 m
- Chamber pressure: 1 – 50 Torr
- 6" x 6" aluminum 6061-T6 targets
- 22.7 mg 440C steel spheres  $\rightarrow$  2 – 3 km/s
- 5.5 mg nylon 6/6 cylinders  $\rightarrow$  5 – 10 km/s
- 3.6 mg nylon 6/6 spheres  $\rightarrow$  5 – 6 km/s

### Debris Capture Pack

Stack of alternating foam plates and plastic films

Target

Light Box

Film

Camera

Computer Image Analysis

Architectural Foam - 1 lb/ft<sup>3</sup>  
- inexpensive  
- highly engineered (controlled pty)

Opaque plastic film

Film sheet after test

#### Measurements

- X-Y position of debris particle perforations on each film [dispersion of debris]
- Size of debris particle perforations [debris particle size]
- #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]
- Recovery of debris material from selected tests

Perforations measured in 1 cm annular rings

Target D63  
Thickness = 0.5 mm  
Impact Speed = 5.74 km/s

Target D88  
Thickness = 1.5 mm  
Impact Speed = 5.45 km/s

### Laser Side-Lighting Shadowgraphs

Coherent Verdi V6

Beam Expander 1

Free Beam

Beam Expander 2

Target Chamber

Target

Flight Tube

Zoom Lens

Beam Reducer

Cordin 214-8

(Not to scale)

Impactor = Nylon 6/6 cylinder  
Impact velocity = 5.45 km/s  
Target thickness = 1.5 mm  
Chamber pressure = 1.0 Torr

$t_{\text{impact}} + 0.3 \mu$ s     $t_{\text{impact}} + 2.2 \mu$ s

$t_{\text{impact}} + 6.2 \mu$ s     $t_{\text{impact}} + 10.2 \mu$ s     $t_{\text{impact}} + 12.2 \mu$ s

$t_{\text{impact}} + 14.2 \mu$ s     $t_{\text{impact}} + 16.1 \mu$ s     $t_{\text{impact}} + 20.1 \mu$ s

### IR Imaging and UV-vis Spectroscopy

#### Infrared Imaging Camera (OMA V)

- Liquid nitrogen cooled InGaAs detector array
- Spectral coverage of 0.9  $\mu$ m to 1.7  $\mu$ m
- 1  $\mu$ s minimum exposure time
- IR images show a light and dark vapor/plasma cloud expanding at > 10 km/s

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

- 1024 x 256 pixel, gated, intensified CCD camera
- 28 ns minimum exposure time
- Spectral coverage of 275 nm to 825 nm
- Spectra measures relative intensities of atomic/molecular species present in vapor/plasma cloud

#### Acton SP-2560 spectrograph

- 500 mm focal length (0.05 nm resolution)
- All components operated by integrated computer control software
- Utilizes an internal mirror or diffraction grating to generate images or spectra of impact emission
- Lens systems allow various fields of view from 5.3 cm x 4.3 cm to 60.0 cm x 48.5 cm

Strong emission of several small molecular fragments originating from both the aluminum target and Nylon 6/6 impactor

$V_{\text{impact}} = 6.05 \text{ km/s}$   
 $t_{\text{exposure}} = 2.0 \mu$ s  
 $t_{\text{impact}} + 12.3 \mu$ s  
(Artificial color added)

Aluminum Target

Spectrometer Slit for UV-vis

Nylon 6,6

wavelength / nm

#### References and Acknowledgments

[1] J. Mihaly, L. Lamberson, M. Adams, A.J. Rosakis, A Low Cost, Small Bore Light-Gas Gun Facility, Proceedings of the 11<sup>th</sup> Hypervelocity Impact Symposium, pp. 675 – 686, 2010.

[2] M. Adams, A. Lashgari, B. Li, M. McKerns, J. Mihaly, M. Ortiz, H. Owhadi, A.J. Rosakis, M. Stalzer, T.J. Sullivan, Rigorous model-based uncertainty quantification with application to terminal ballistics – Part II. Systems with uncontrollable inputs and large scatter, Journal of the Mechanics and Physics of Solids, pp. 1002 – 1019, 2012

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