HIGH-STRAIN RATE LABORATORY

Probing and Processing Materials at High Pressures and High Strain Rates

Advisor
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Graduate Students
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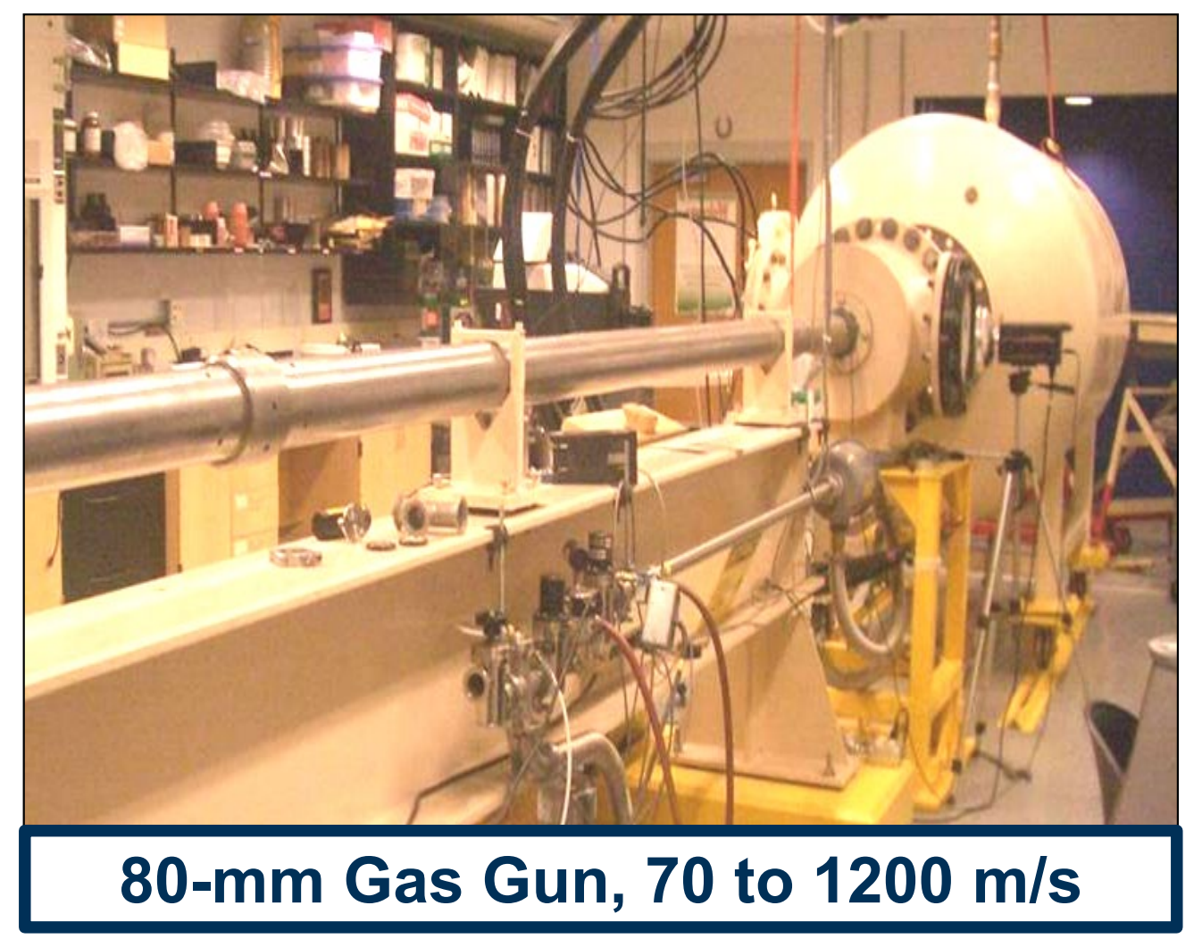
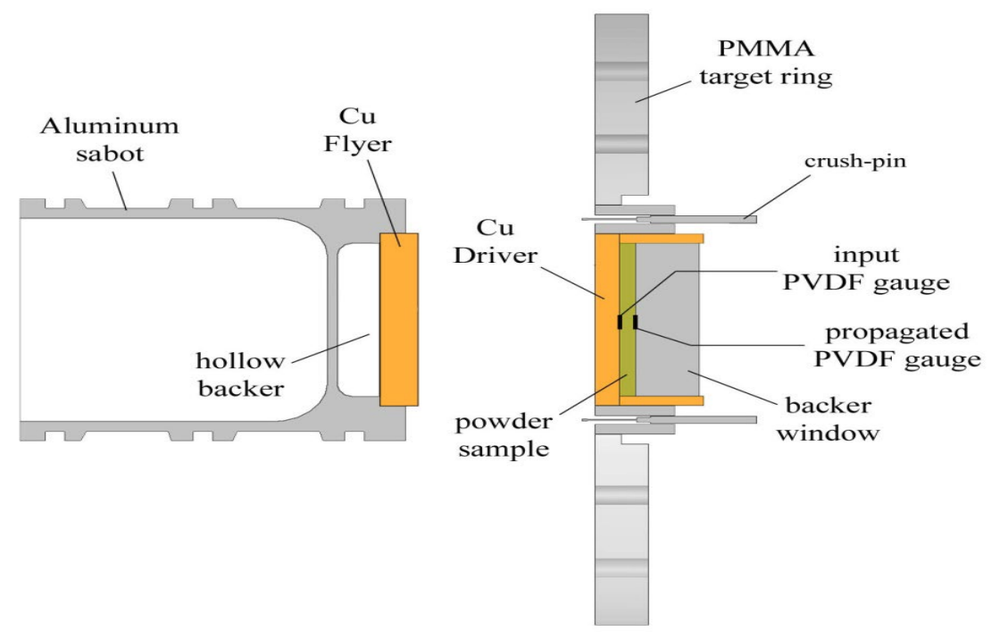
LABORATORY CAPABILITIES

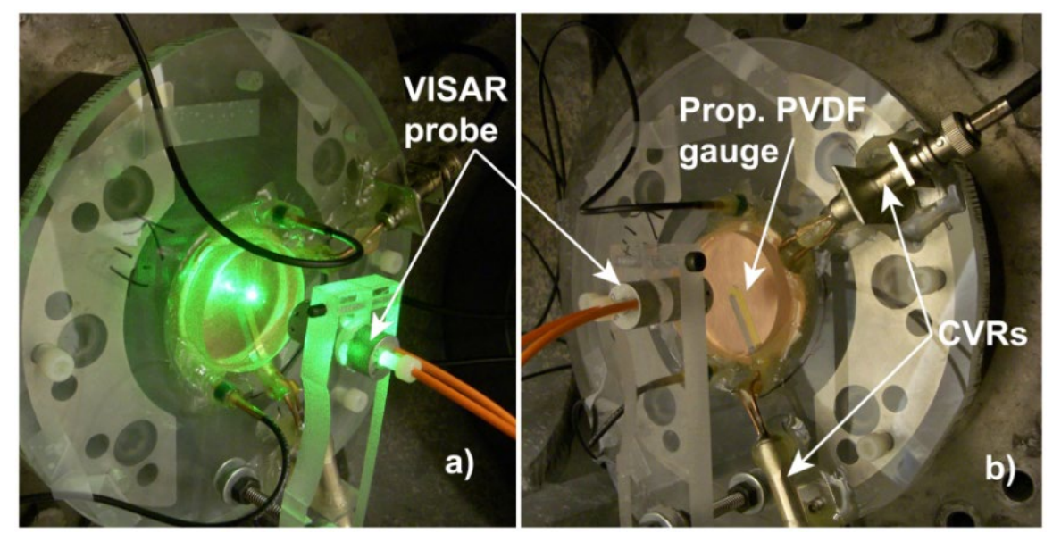
Launch Systems and Diagnostics

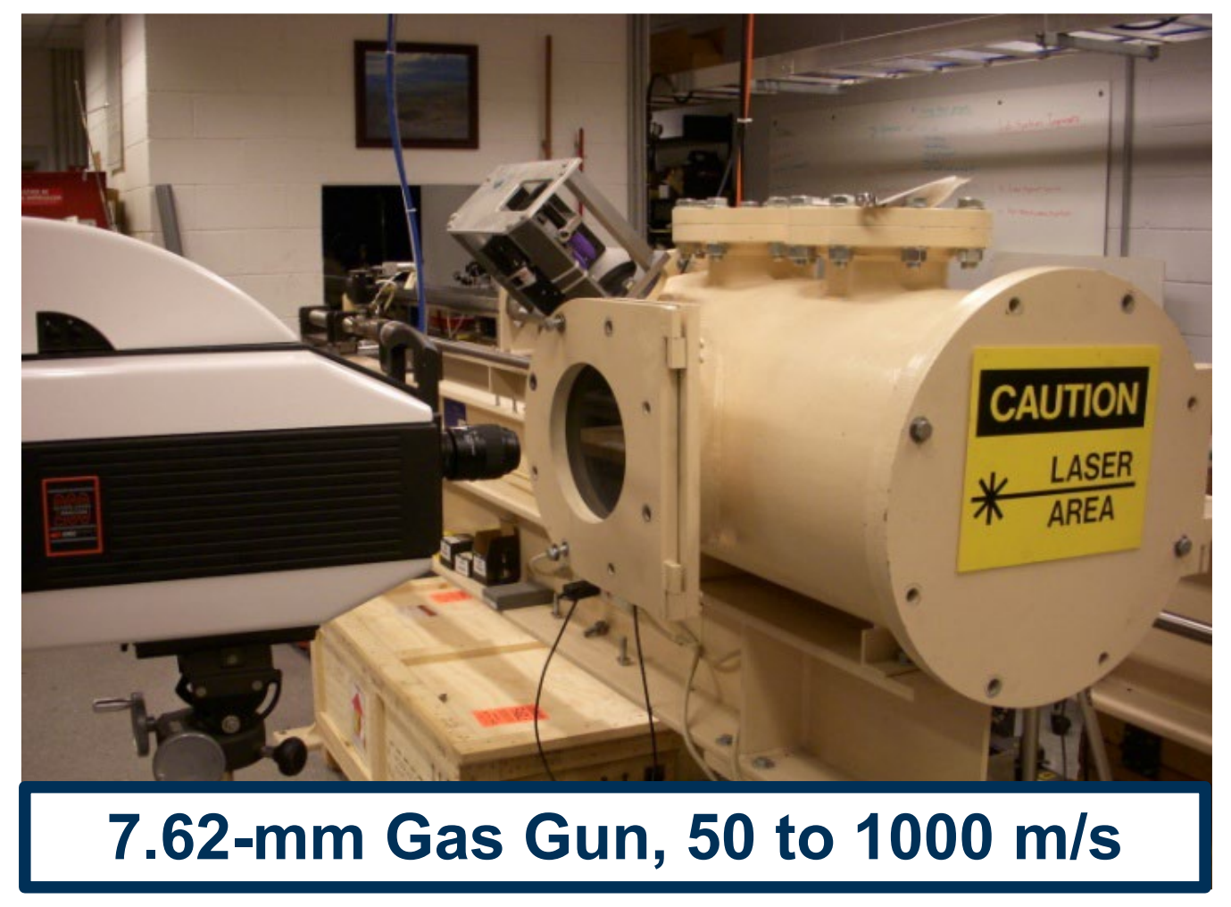
High velocity gas guns, 80 mm and 7.62 mm bore
3-Joule 1064 nm laser for mini-flyer launch or direct exposure

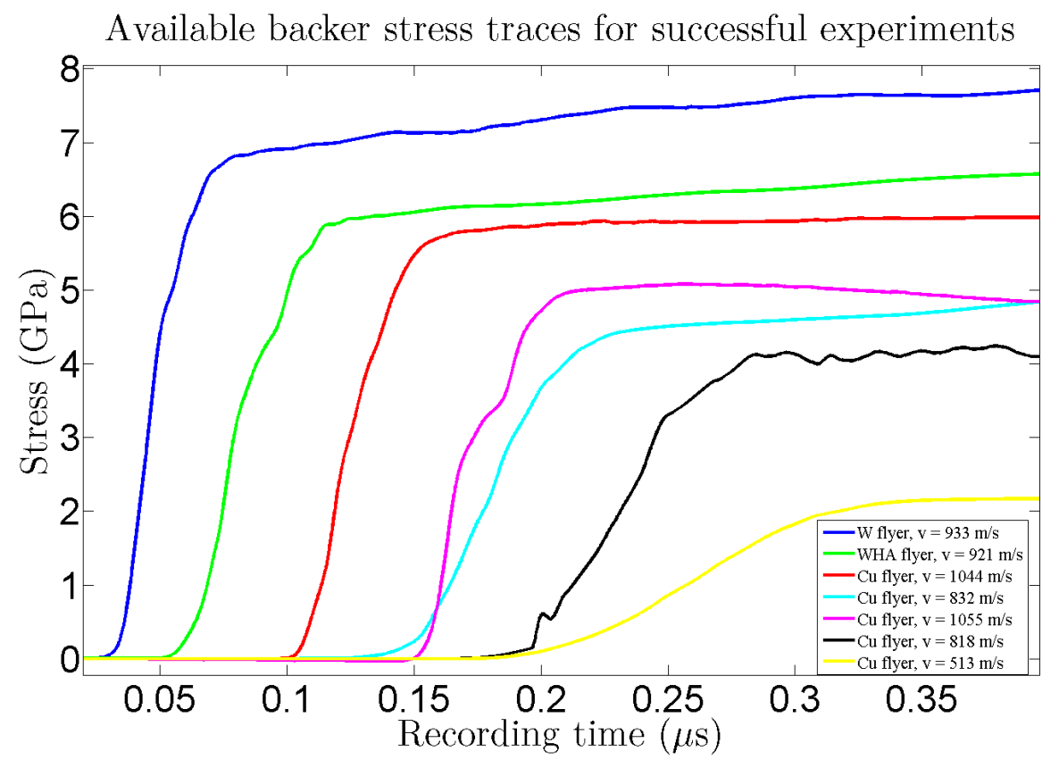
VISAR and PDV (laser interferometry) probes for velocity
PVDF and Manganin stress gauges for pressure
Cameras and spectrography with high time resolution


80-mm Gas Gun, 70 to 1200 m/s

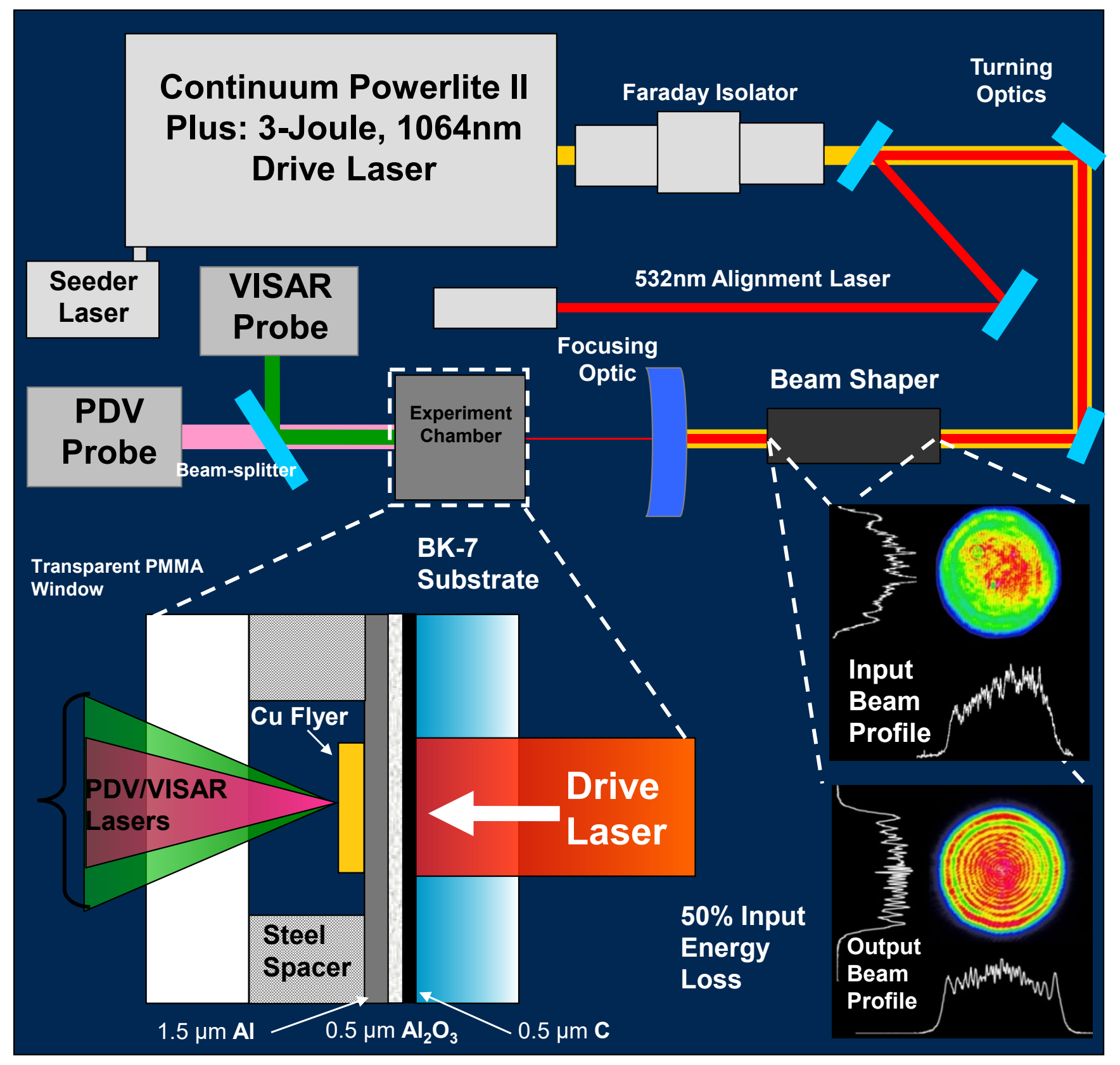


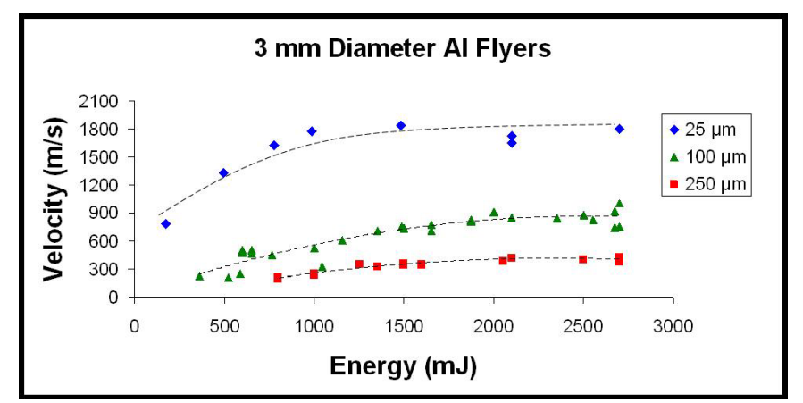



7.62-mm Gas Gun, 50 to 1000 m/s



Gas guns (left) and example experimental setup for 80-mm gas gun experiment (top right). Example PVDF pressure traces for different impact velocities (bottom right).

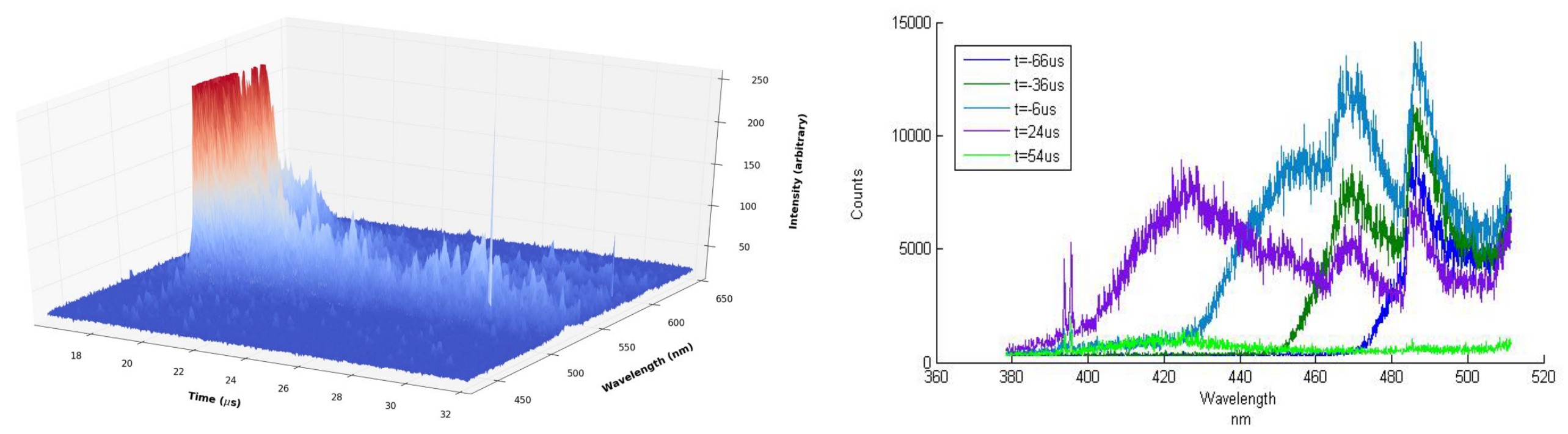




Velocity vs laser energy for Al flyers

3-Joule laser setup

VISAR and PDV velocity measurements can be easily incorporated into experimental setup.

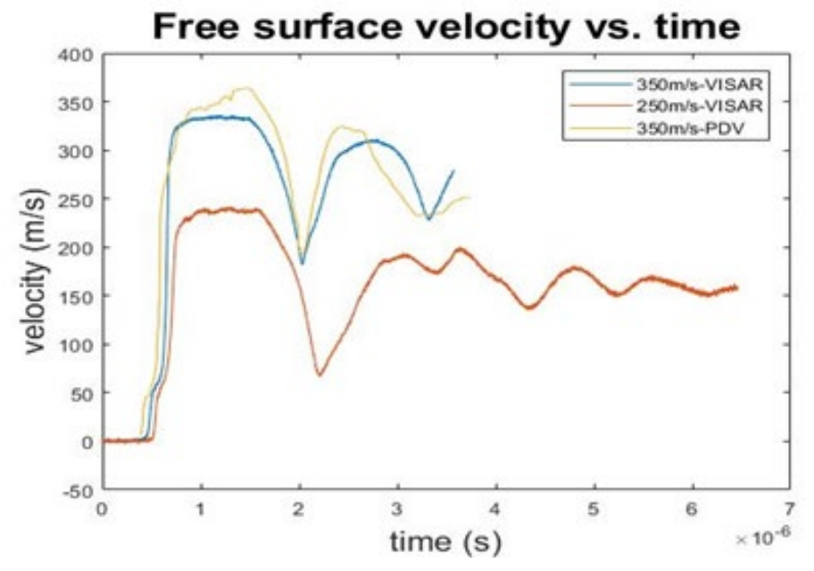


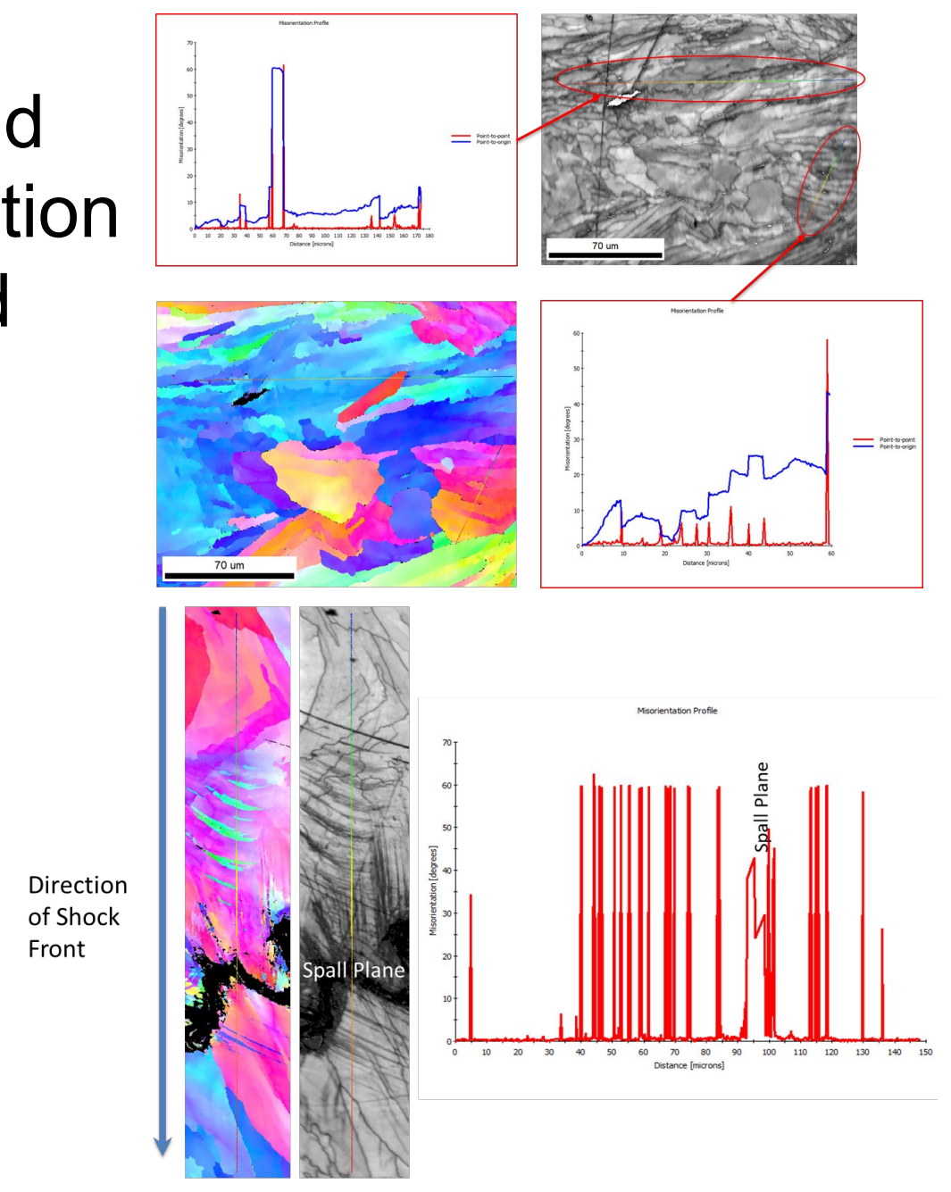
Examples of high time resolution spectroscopy: carbon plasma spectral emission (left), Aluminum reactions during shock compression (right)

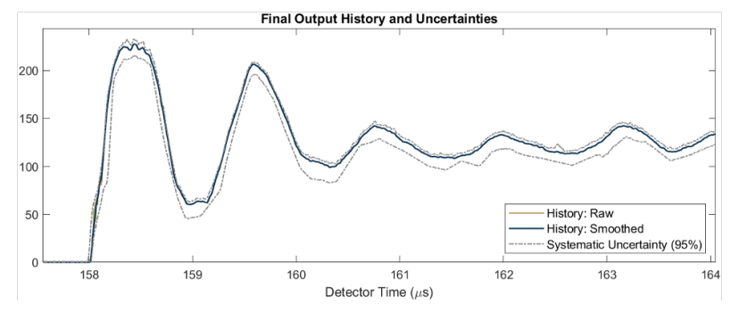
EXPERIMENTAL RESEARCH AREAS

Shock Response of 3D Printed 316L Stainless Steel

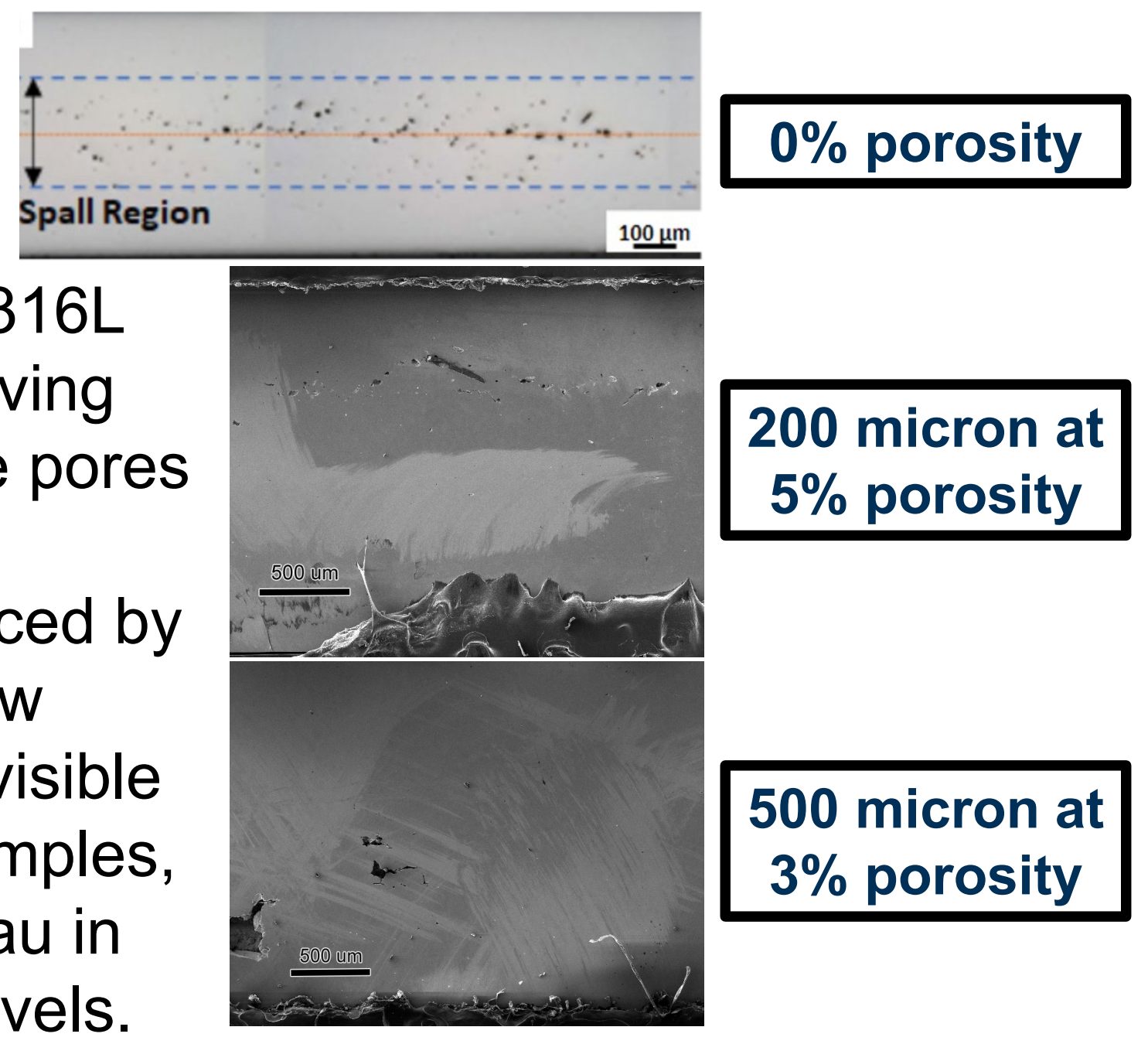
Microstructural response of 3D printed metals to shock tensile and compression depends on the relation between shock front direction and printing orientation. Extensive twinning, grain refinement and misorientation noted at the spall plane.







Porosity can be increased in AM 316L stainless steel by intentionally leaving pores throughout the sample. The pores slow the shock waves' movement through the matrix. This is evidenced by the shifting of the spall plane in low porosity samples and the lack of visible spallation for the high porosity samples, along with a lack of velocity plateau in velocimetry data for all porosity levels.

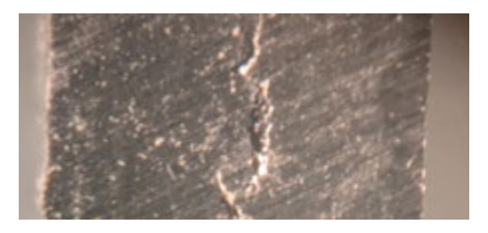


0% porosity

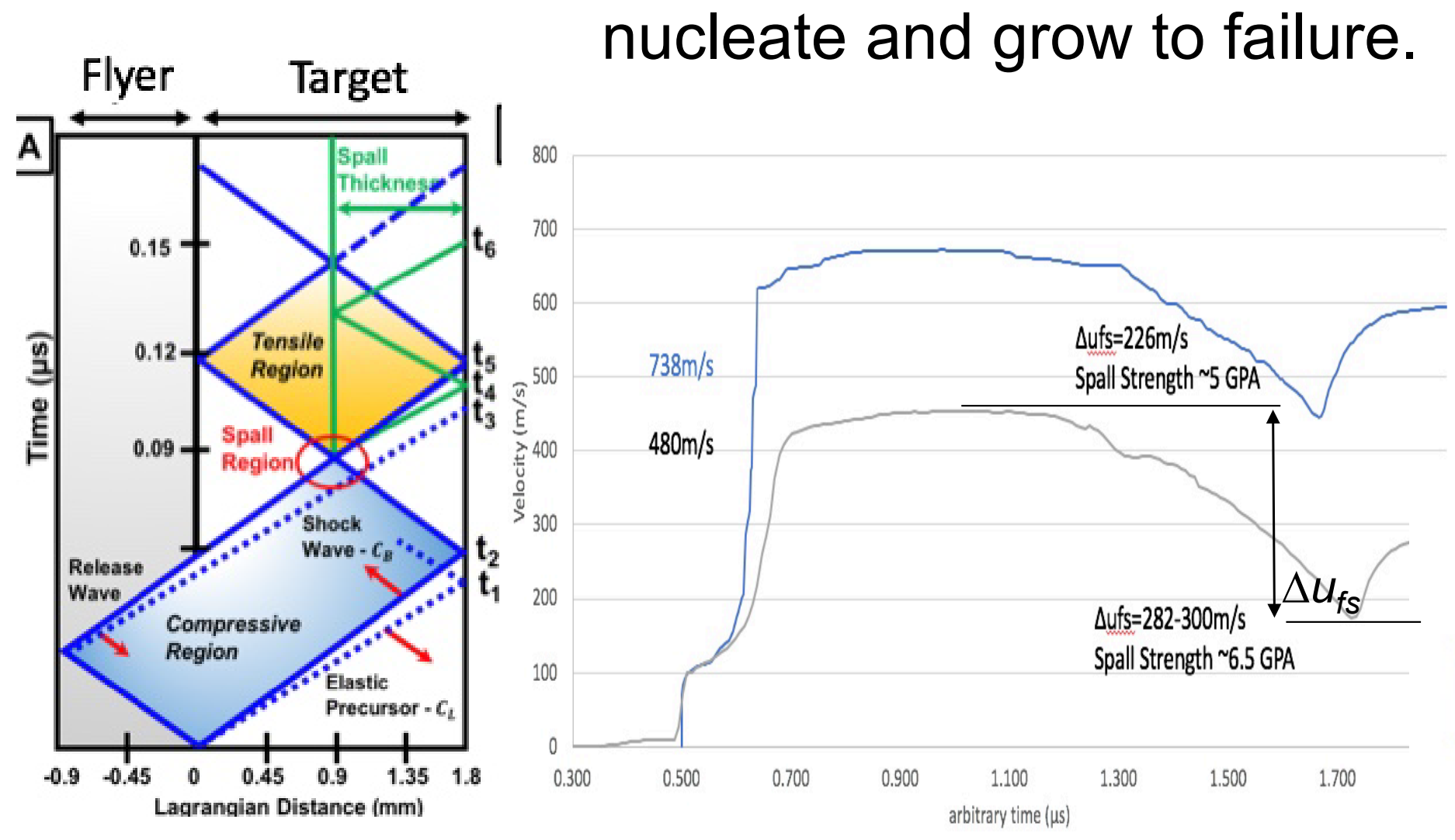
200 micron at 5% porosity

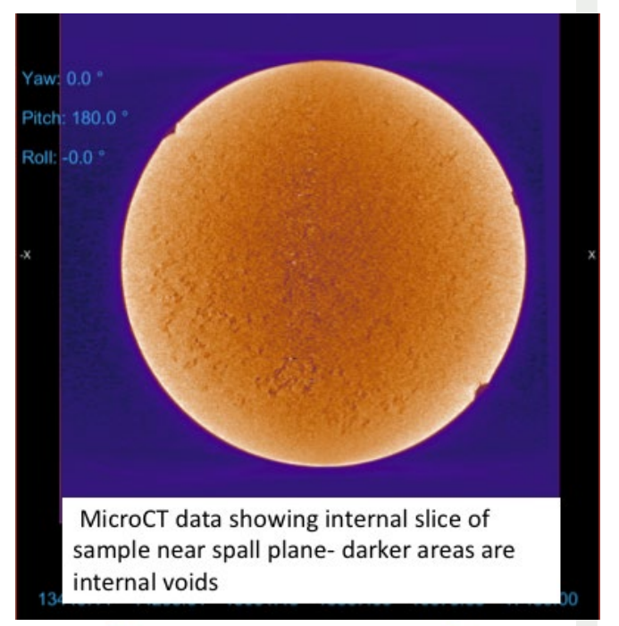
500 micron at 3% porosity

Steels



Spall strength is a measurement of dynamic tensile strength calculated from free surface velocity recorded by PDV. Internal voids nucleate and grow to failure.



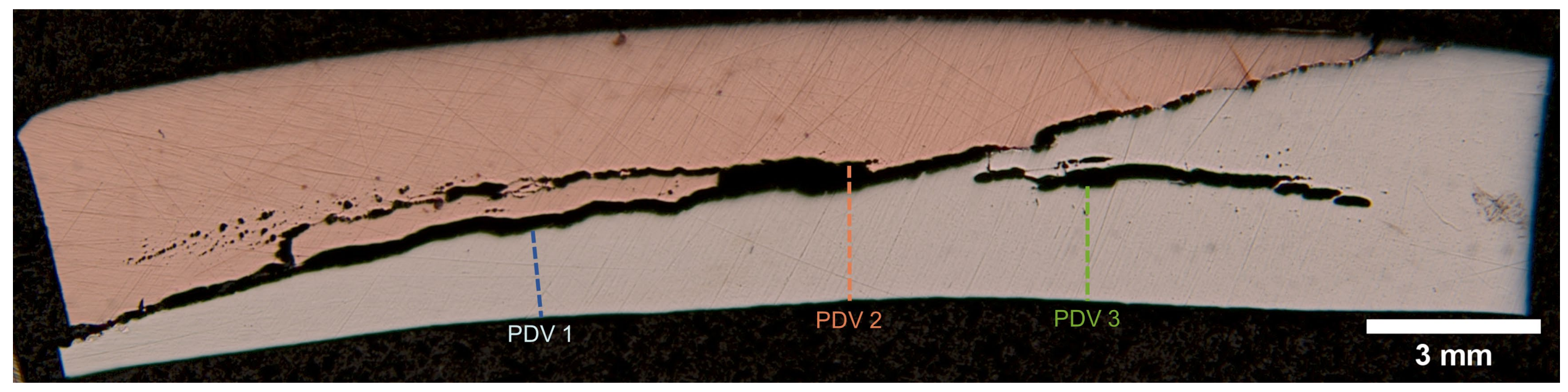

MicroCT data showing internal slice of sample near spall plane- darker areas are internal voids

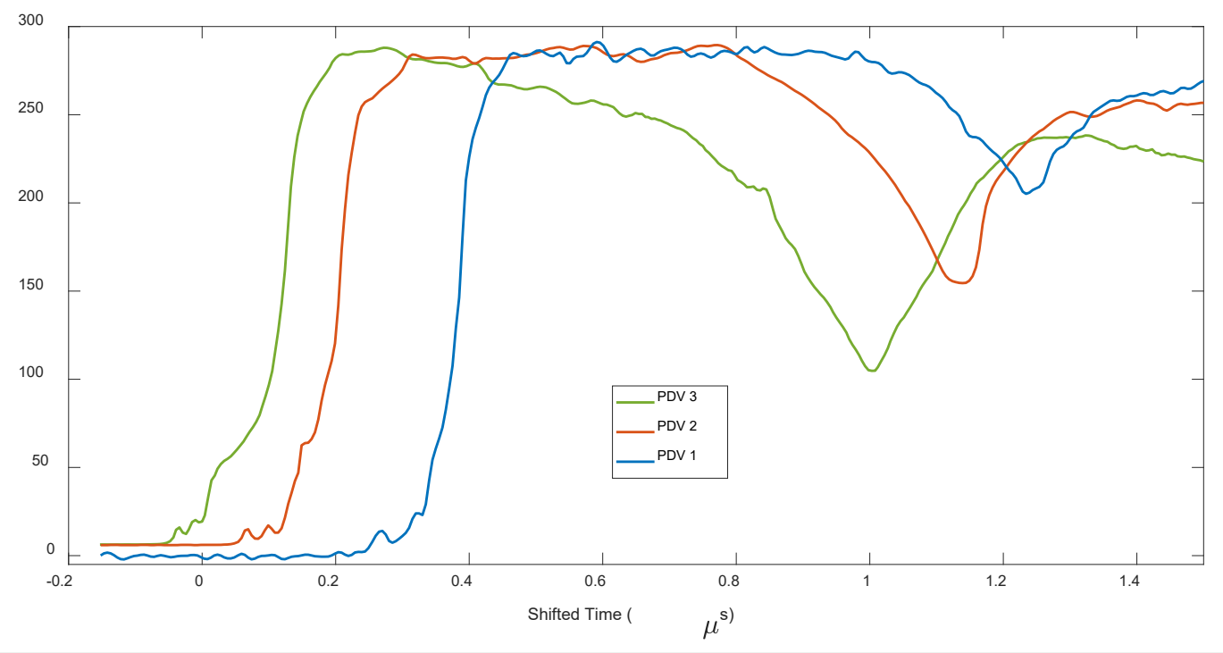
$$\sigma_{HEL} = \frac{1}{2}\rho_0 C_L u_{HEL}$$

$$\sigma_{spall} = \frac{1}{2}\rho_0 C_B(\Delta u_{fs} + \delta)$$

$$\delta = x_{spall}\left(\frac{1}{C_B} - \frac{1}{C_L}\right)\left(\frac{|\dot{u}_1 \dot{u}_2|}{|\dot{u}_1| + \dot{u}_2}\right)$$

AM Cu/Ni Bimetallic Material

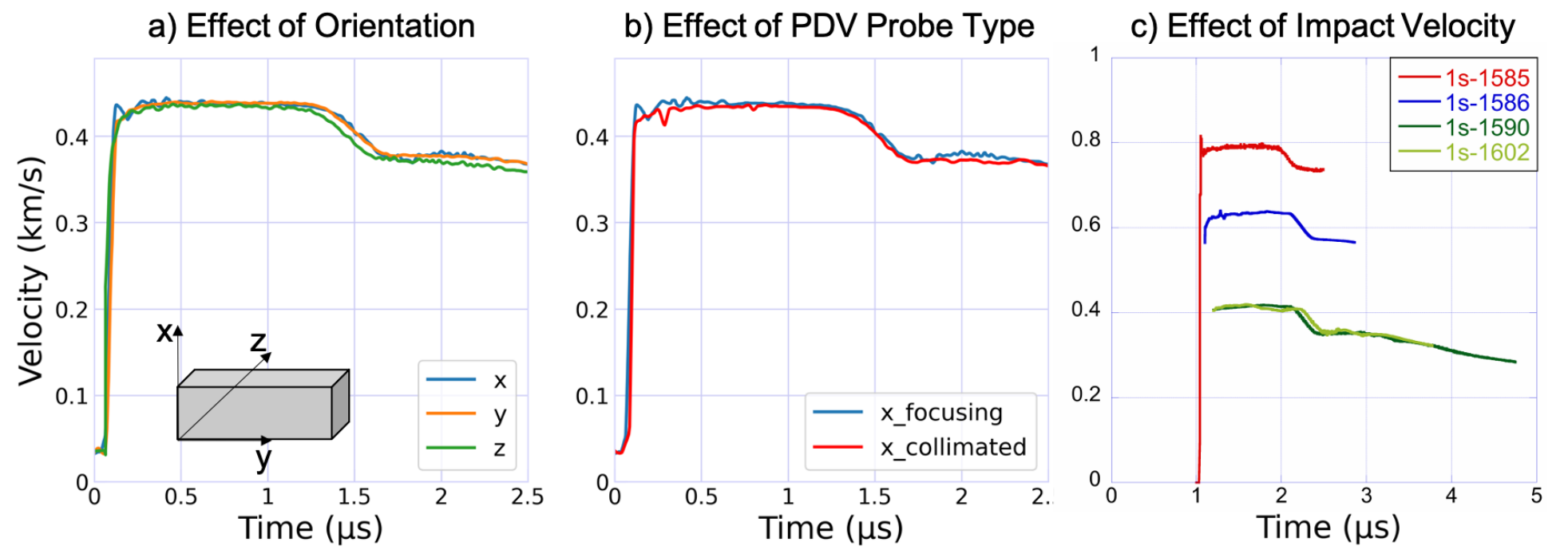




Spall experiments on Cu/Ni bimetallics utilizing multiple PDV probes demonstrates the ability to capture locationally specific pullback signatures from multiple materials in a single sample.

Rational Design of Polymers

Polymers behave differently than metals under high strain rate loading due to their morphological complexity (crystallinity and crystallite sizes/orientations, amorphous-crystalline interfaces, crosslinks and branch structures).



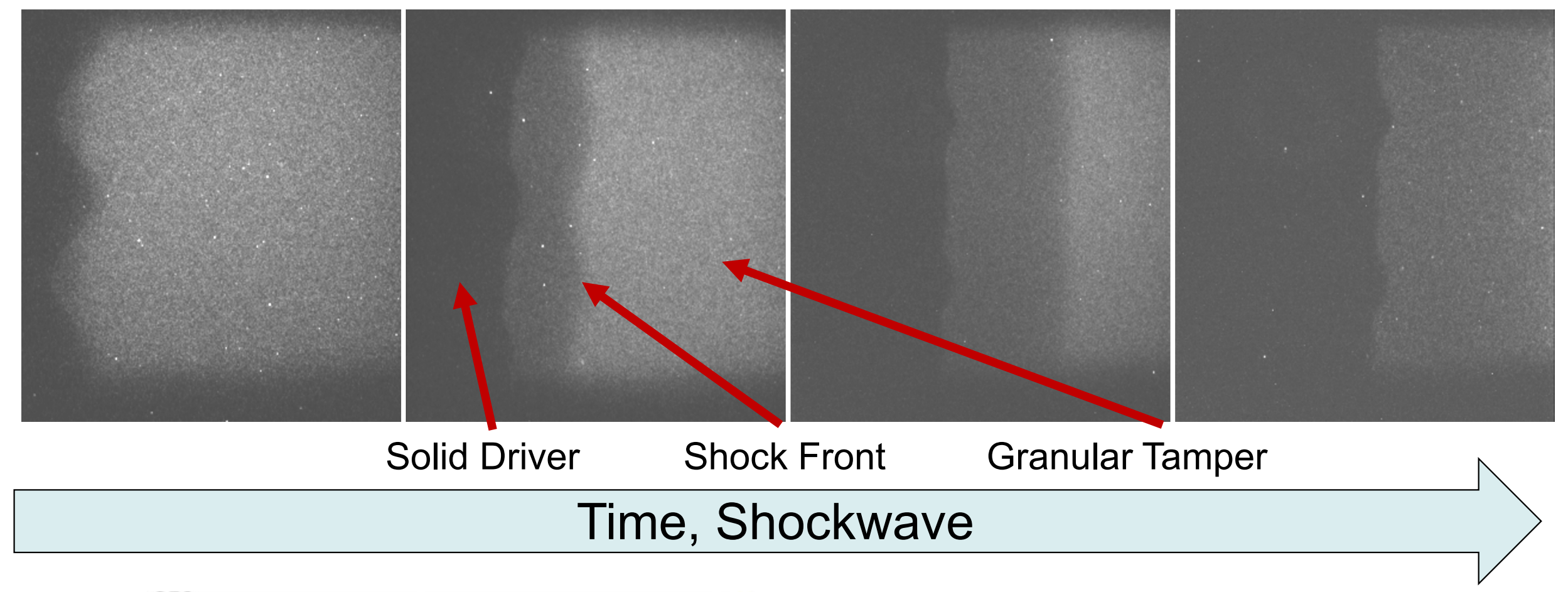
Spall Strength: Free surface velocity vs. time for HDPE

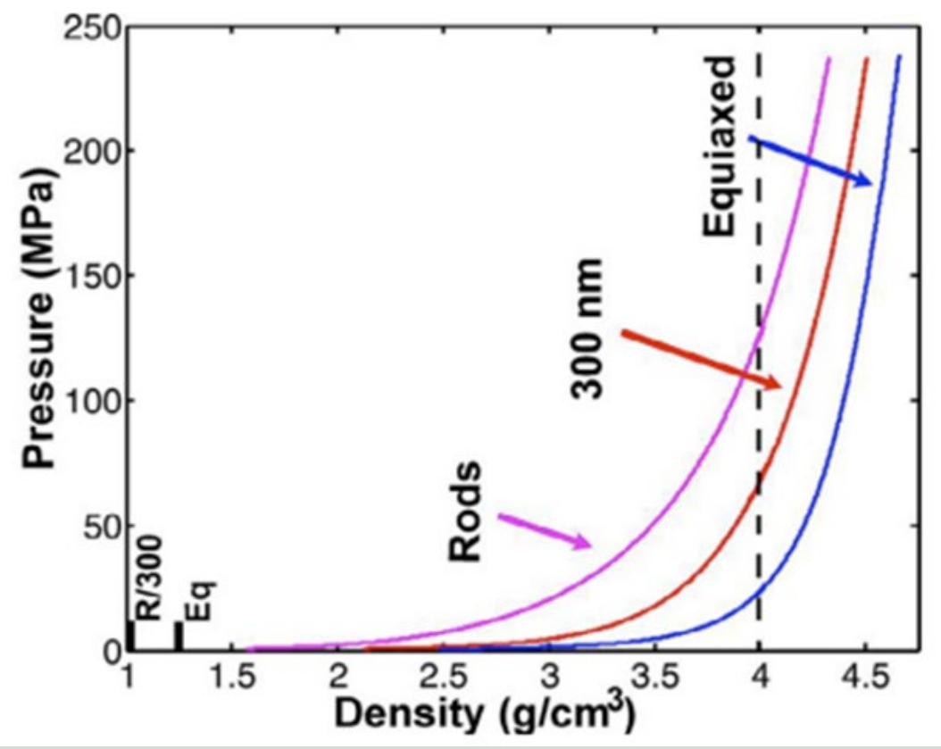
Different impact conditions have no effect on the spall strength of HDPE.

Far right from: Jordan et al., AIP Conference Proceedings (2018)

The goal of this work is to fundamentally understand the behavior of polymers under high-velocity impact conditions through plate-on-plate gas gun experiments. The resulting data will be used to develop predictive models of polymers' spall strengths by utilizing machine learning algorithms.

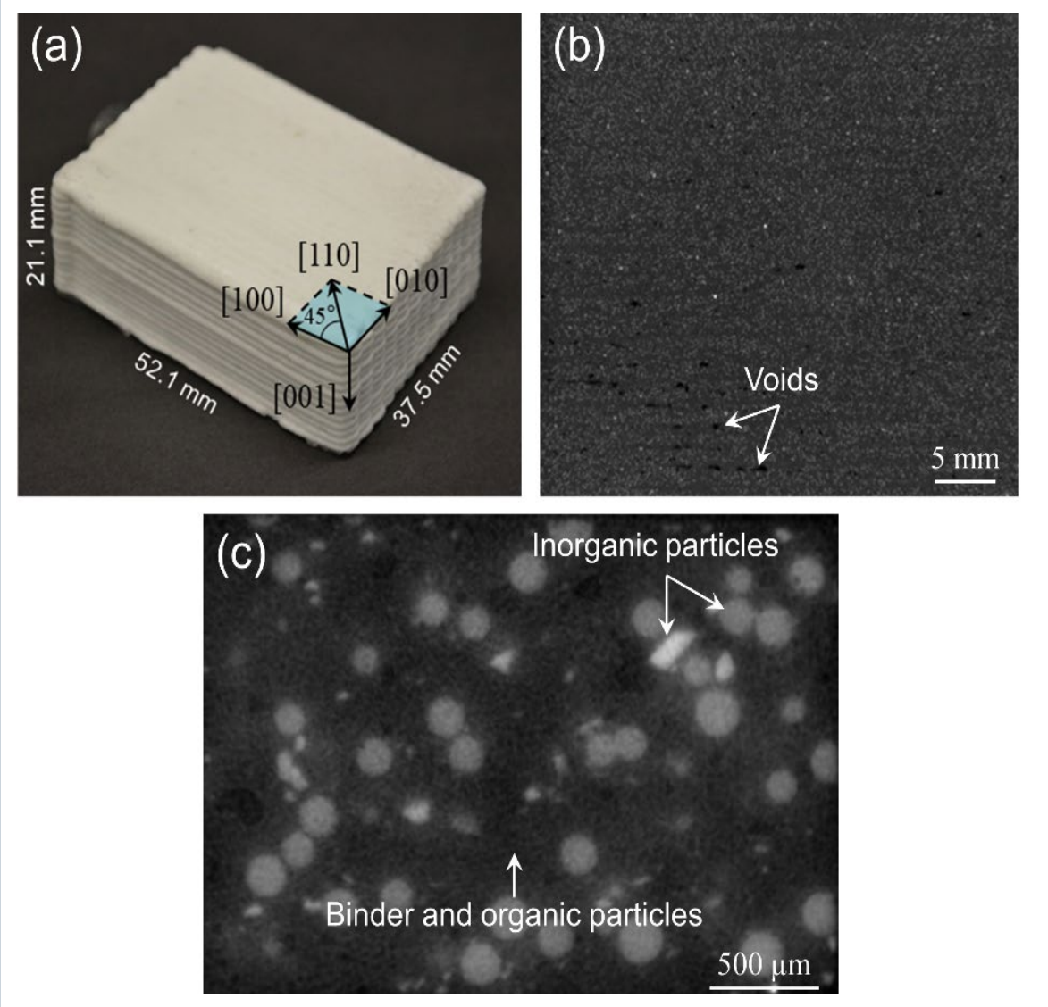
Shock Response of Granular Materials

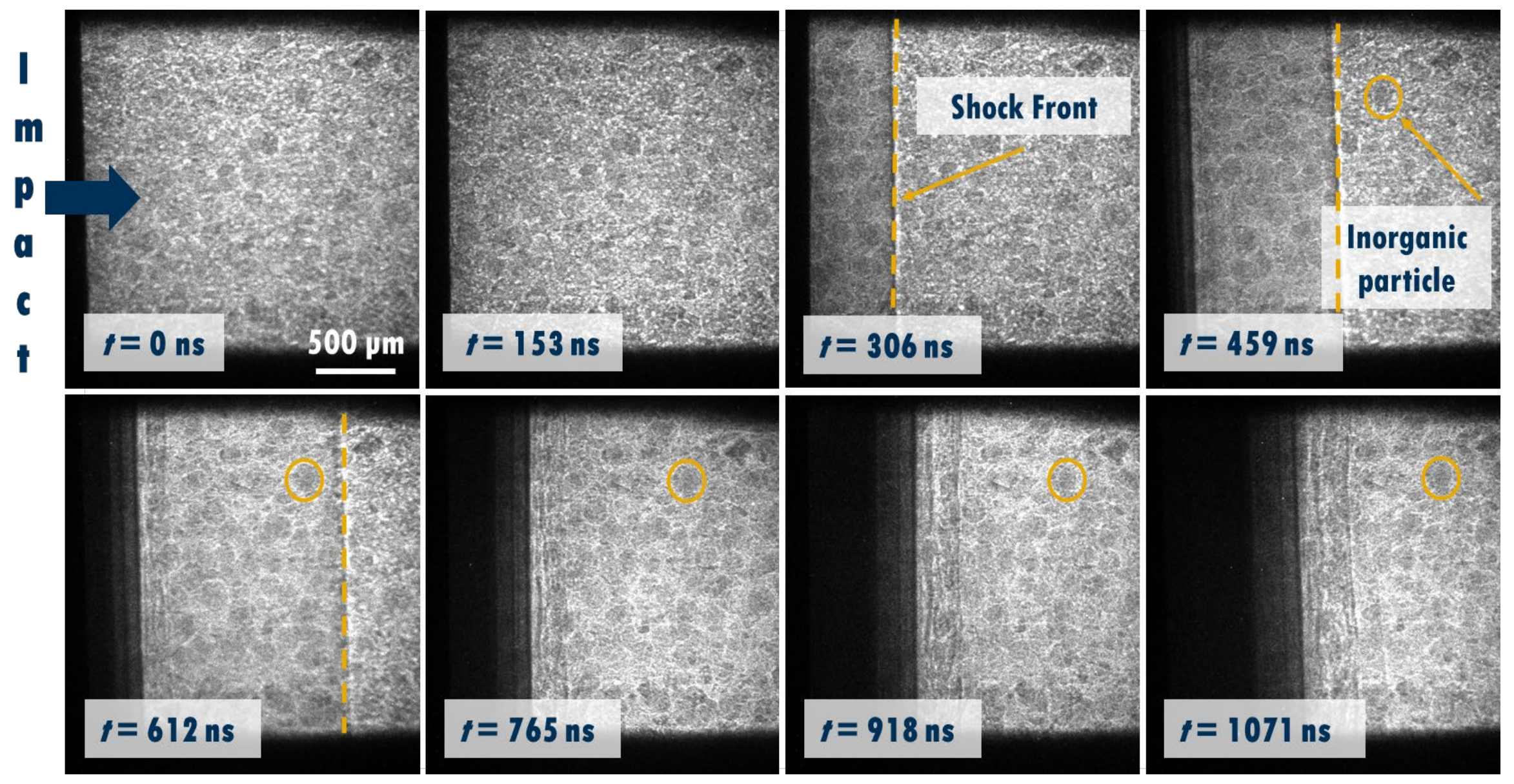


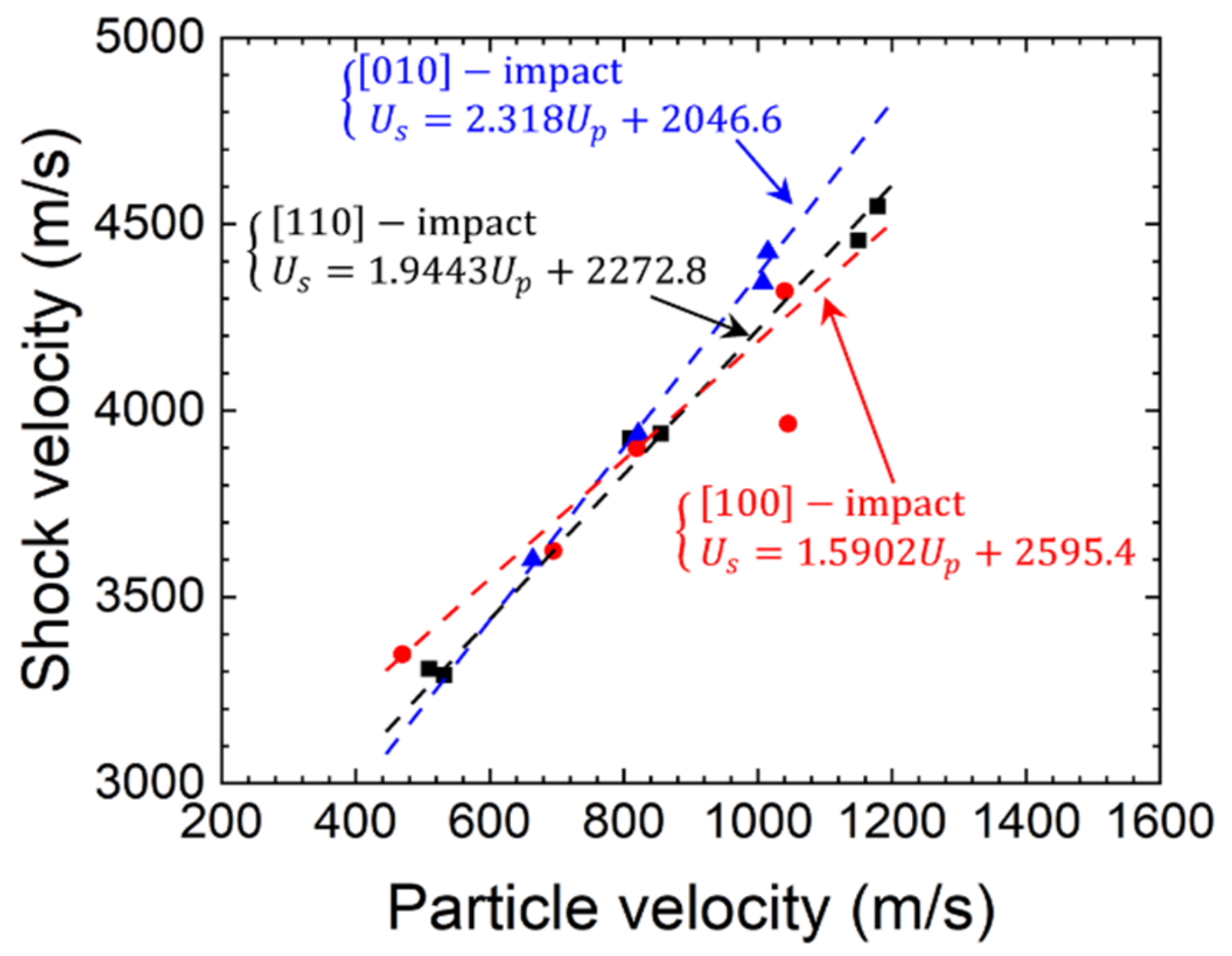


Dynamic compression experiments identifying strength response trends in compaction curves of initially distended granular materials of varying density

Additively Manufactured Heterogeneous Polymer Composites







$$\begin{cases}[010]-\text{impact}\\ U_s = 2.318U_p + 2046.6\end{cases}$$

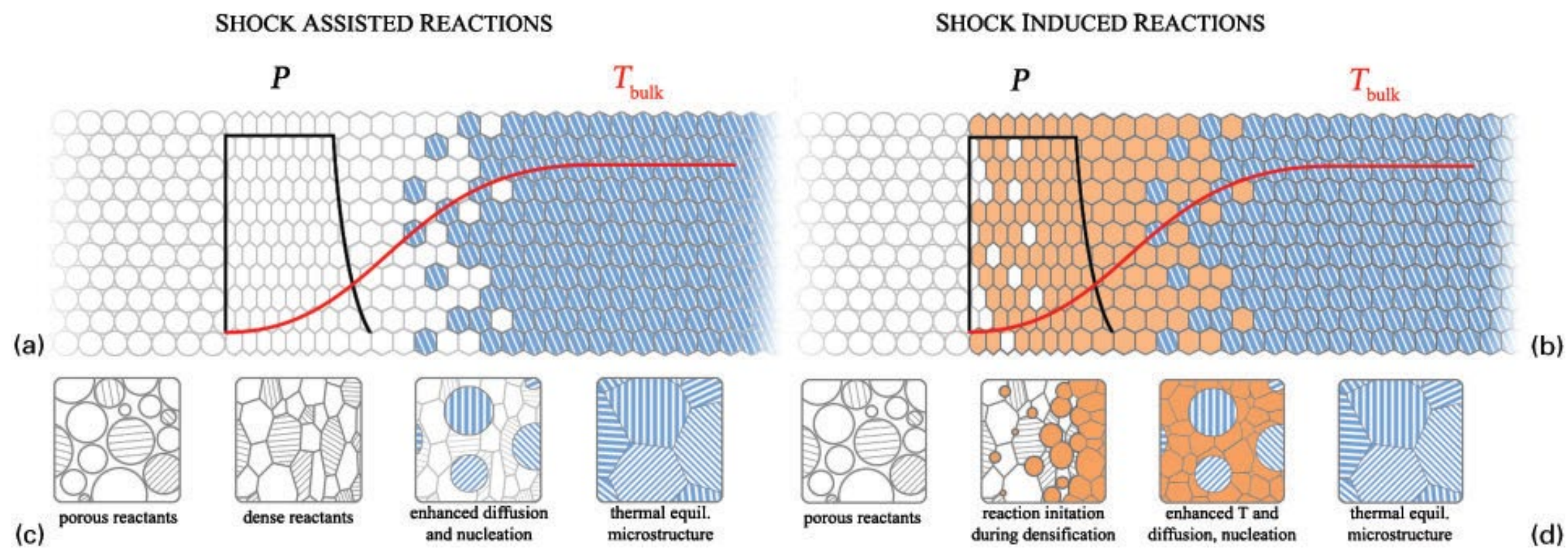
$$\begin{cases}[110]-\text{impact}\\ U_s = 1.9443U_p + 2272.8\end{cases}$$

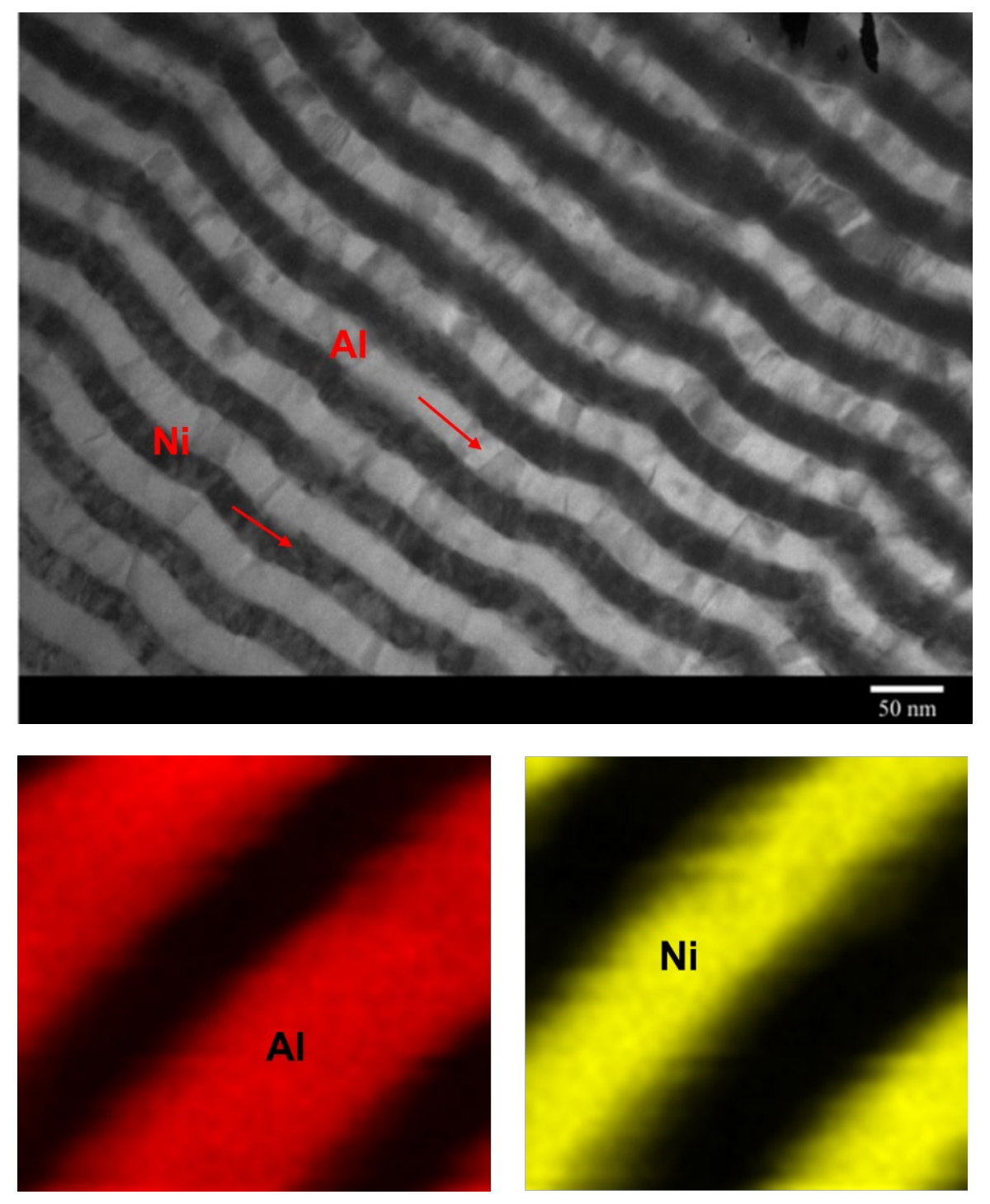
$$\begin{cases}[100]-\text{impact}\\ U_s = 1.5902U_p + 2595.4\end{cases}$$

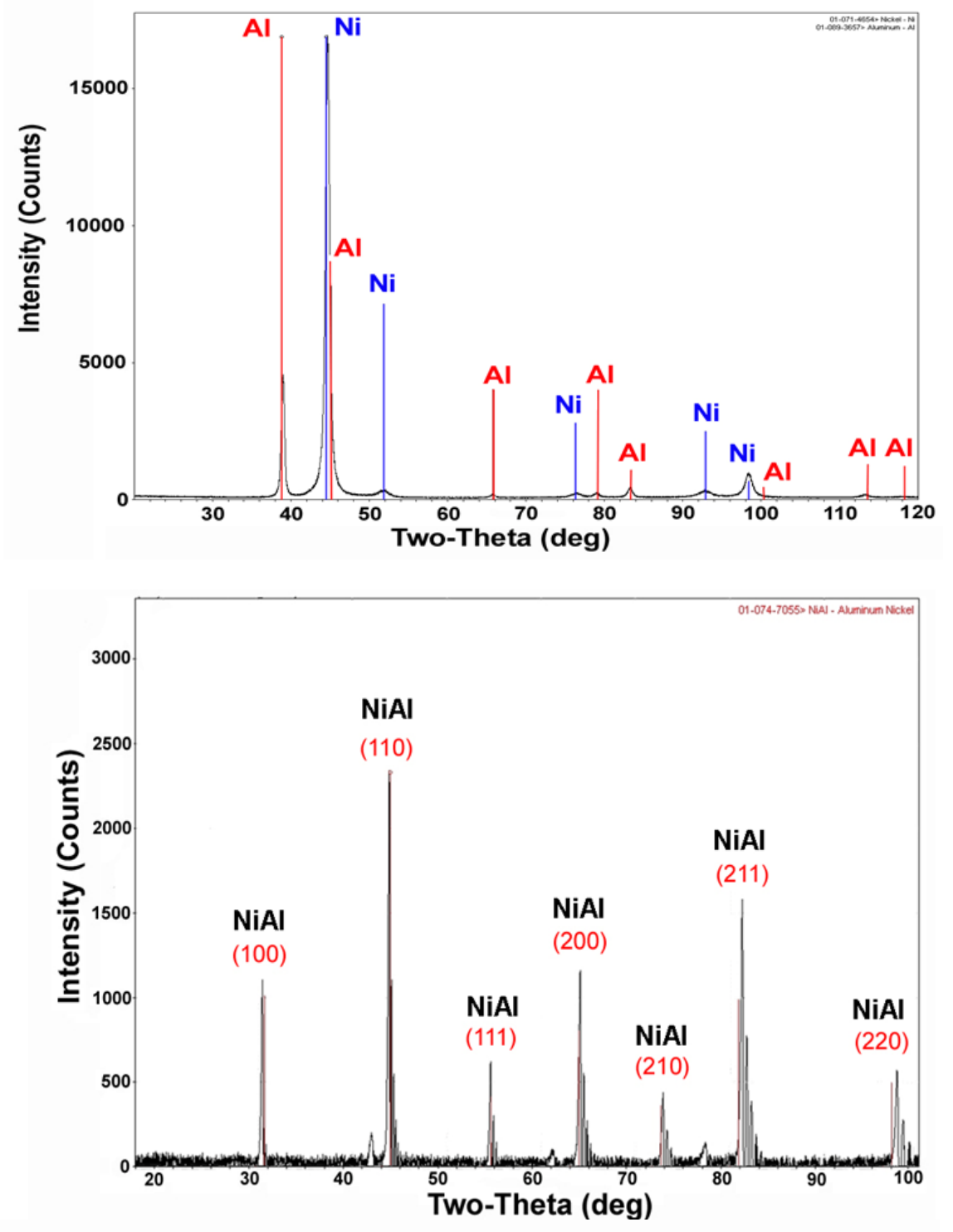
Understanding and controlling heterogeneous microstructures to design new materials , such as for safer energetic materials. New *in-situ* characterization using X-ray Phase Contrast Imaging and Phtoton Doppler Interferometry are utilized to time-resolved measurement of shock compression states..

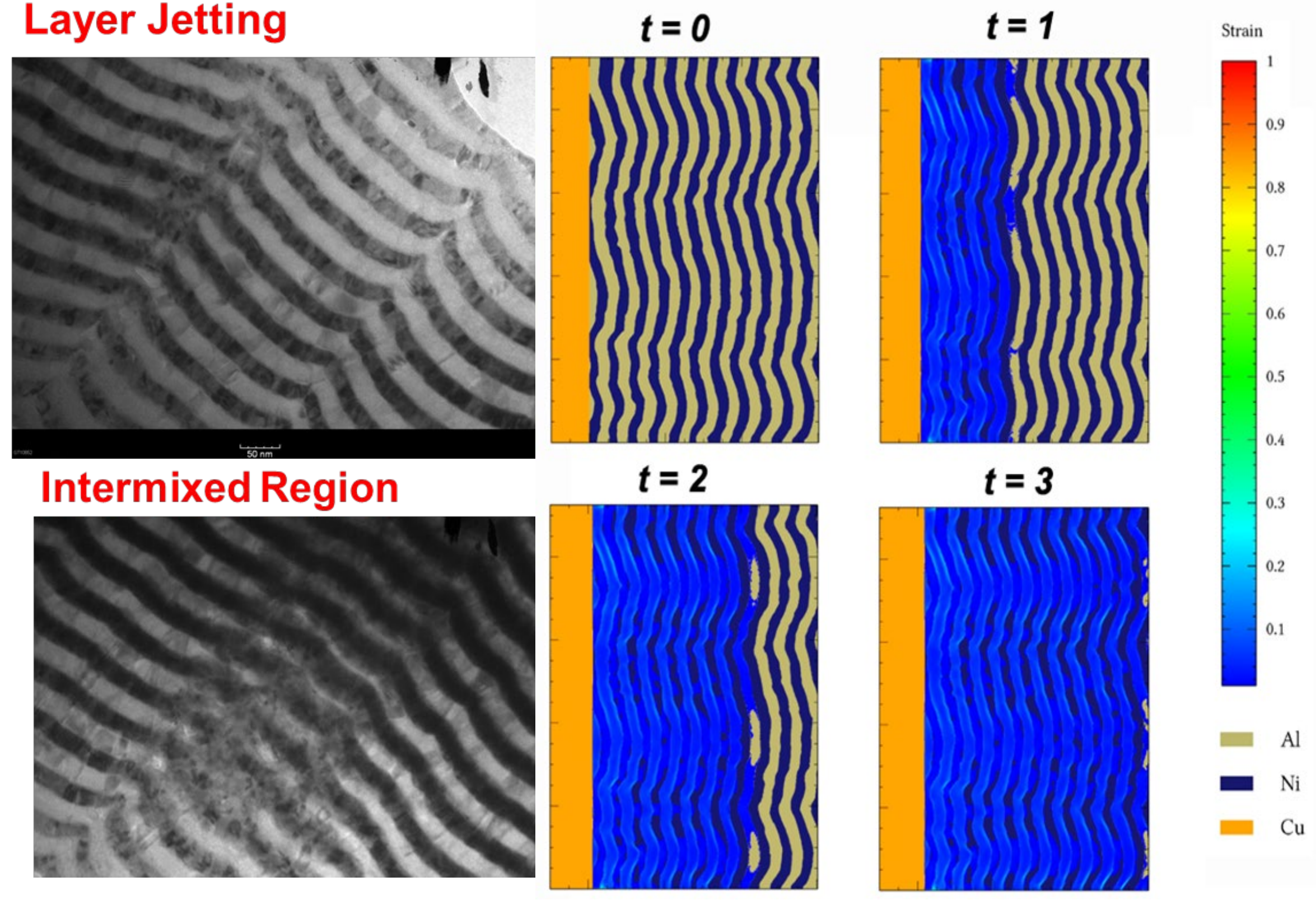
SHOCK CHEMISTRY

Experiments & Mesoscale Simulations



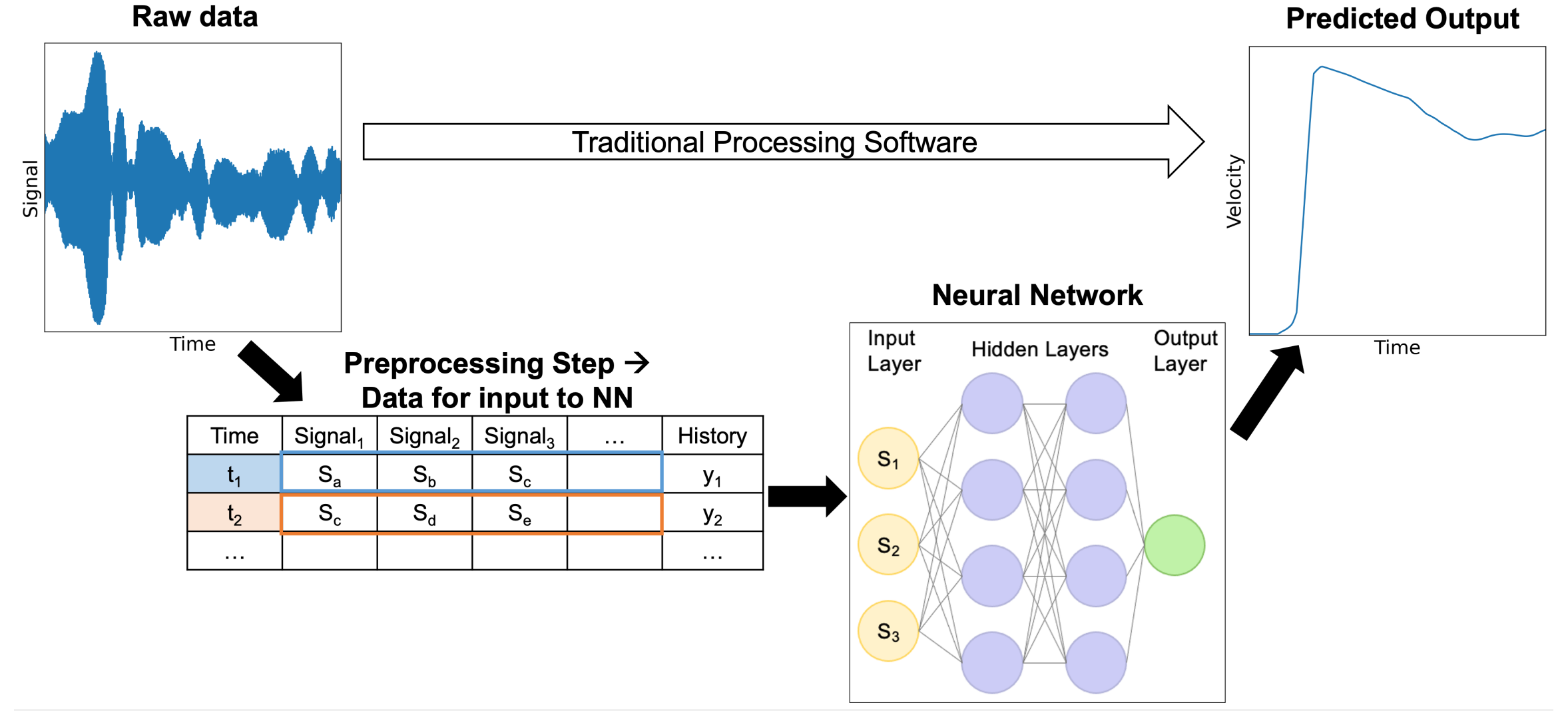






Processing PDV Signals via Neural Networks

How can we ensure consistent PDV signal processing for many probes and determine the error accurately?



Time	$Signal_1$	$Signal_2$	$Signal_3$	…	History
t_1	S_a	S_b	S_c		y_1
t_2	S_c	S_d	S_e		y_2
…					…

Methods that can be used to process PDV signals

Advantages of NN method over traditional processing methods:
- Automatic generation of history profile with no need for human intervention
- Faster than the traditional approach
- Expected to give optimum results because it will learn from past inferences