Probing and Processing Materials

at High Pressures and High Strain-Rates

Advisor
Dr. Naresh Thadhani

Research Scientists
Dr. Greg Kennedy
Dr. Sungwoo Jang (Post-doc)

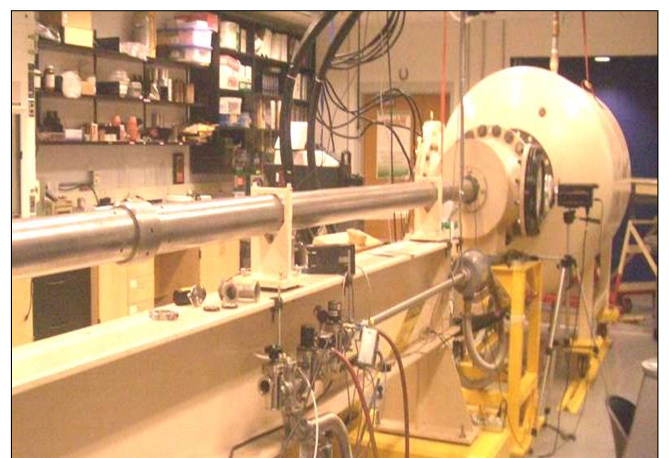
Students
Andrew Boddorff, Keara Frawley, Katie Koube, Leah O'Rourke, Karla Wagner, Tyler Knapp, Taylor Sloop, and Ben Zusmann

Laboratory Capabilities

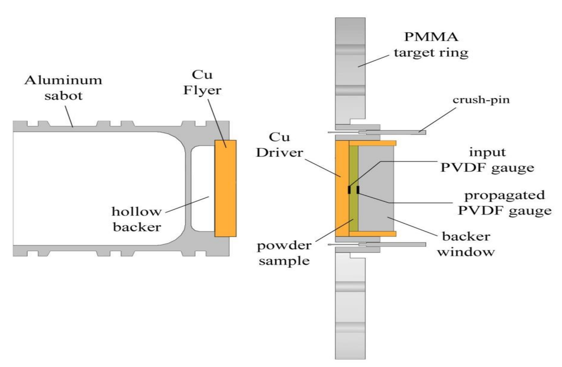
Launch Systems and Diagnostics

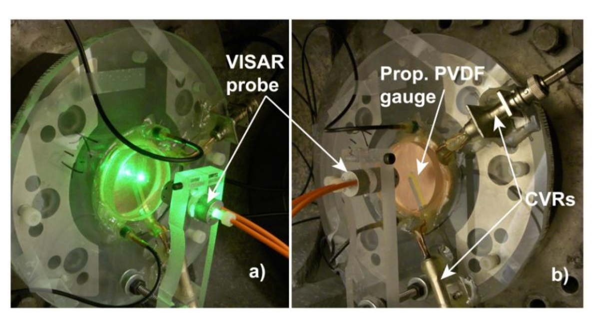
High velocity gas guns, 80 mm and 7.62 mm bore
3-Joule 1064 nm laser for mini-flyer launch or direct exposure

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

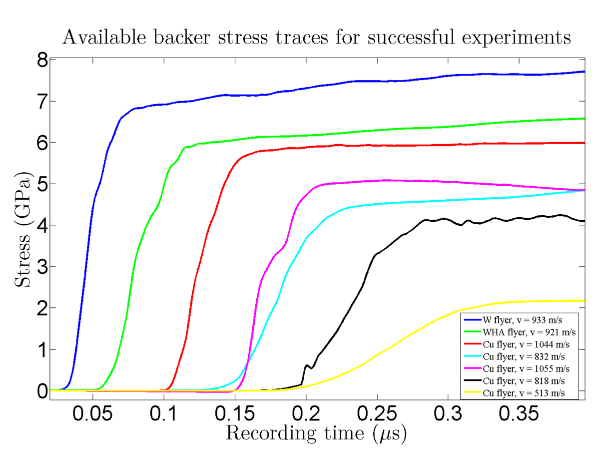


80-mm Gas Gun, 70 to 1200 m/s

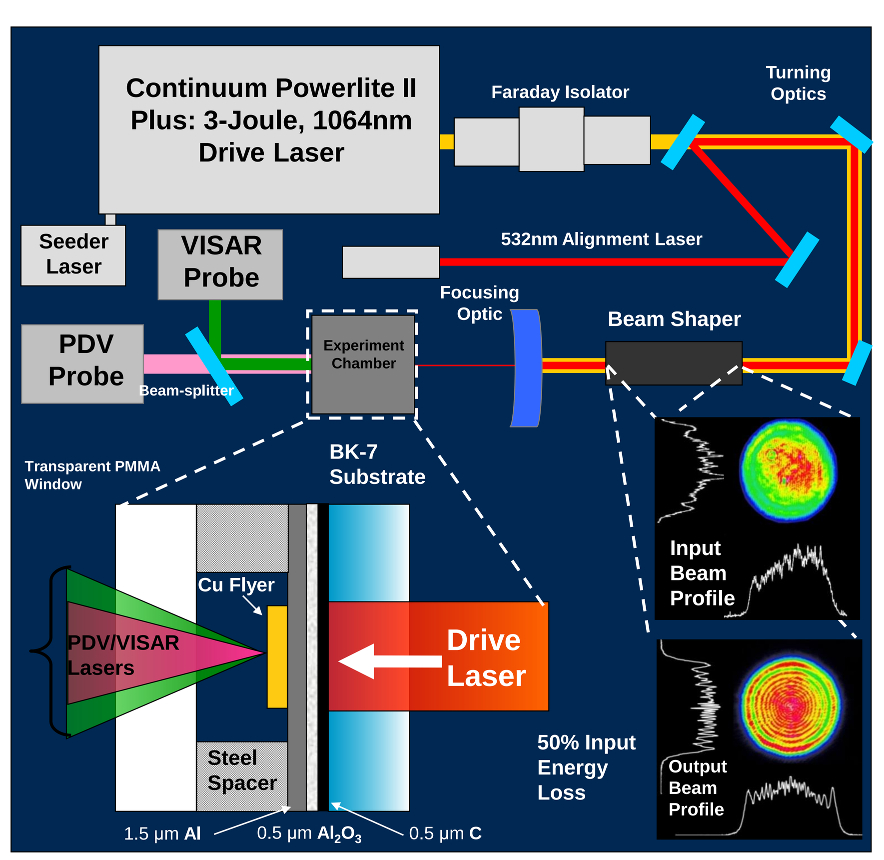


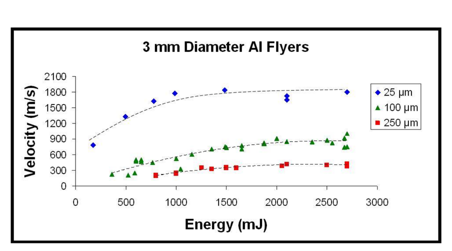


7.62-mm Gas Gun, 50 to 1000 m/s



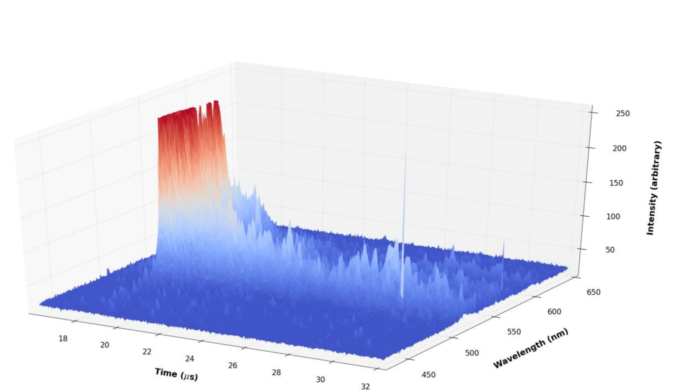
Gas guns (left) and example experimental setup for 80-mm gas gun experiment (right top). Example PVDF pressure traces for different impact velocities (right bottom).

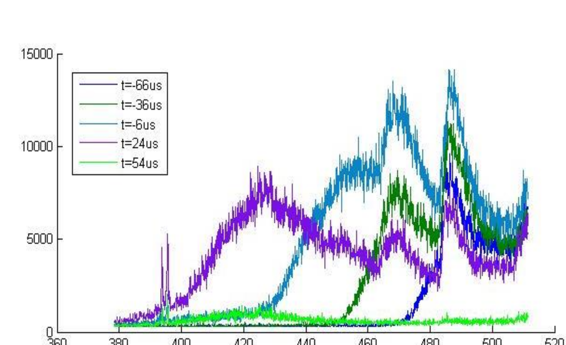




Velocity vs laser energy for Al flyers

3-Joule laser setup. VISAR and PDV velocity measurements can be easily incorporated into experimental setup.



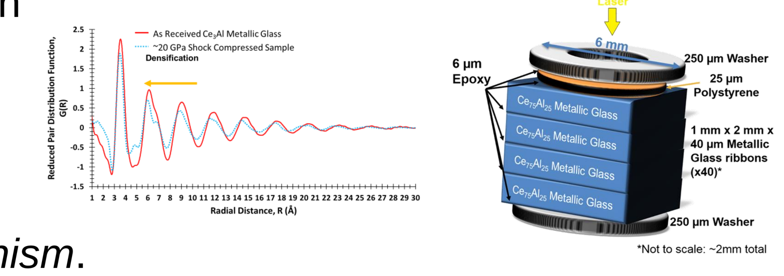


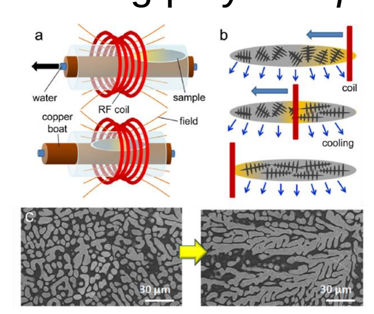
Examples of high time resolution spectroscopy: carbon plasma spectral emission (left), Aluminum reactions during shock compression (right).

Experimental Research Areas

Shock Response of Metallic Glass

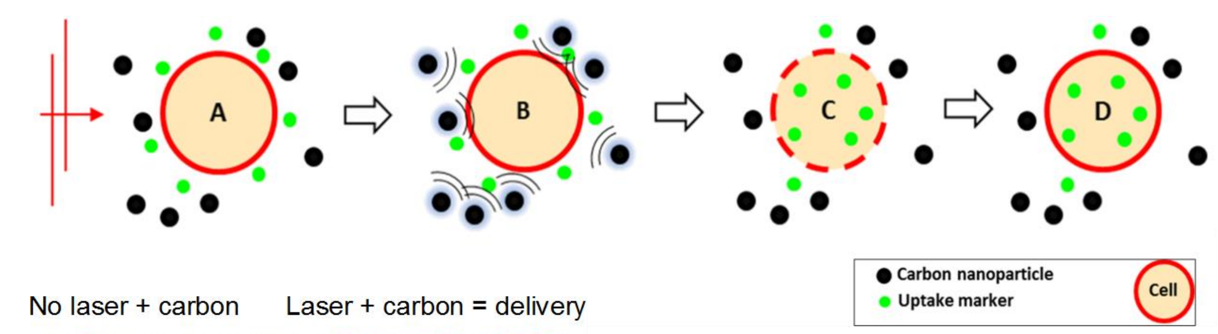
Schematic of LLE high energy laser impact experiment setup. Synchrotron pair distribution function indicating poly*amorphism*.

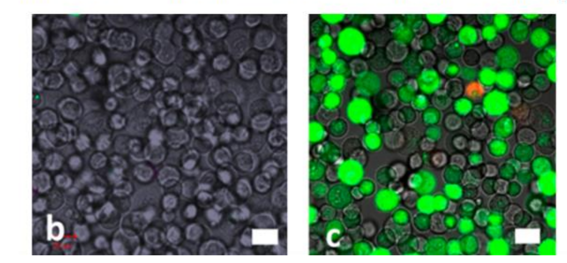




Dendrite-reinforced Bulk Metallic Glasses provided by NASA JPL offer increased toughness and tunable mechanical properties.

Laser-Activated Nanoparticles for Drug Delivery



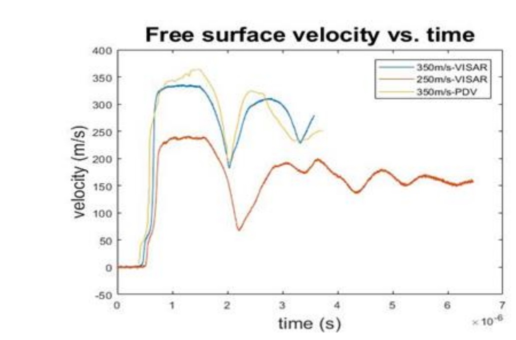


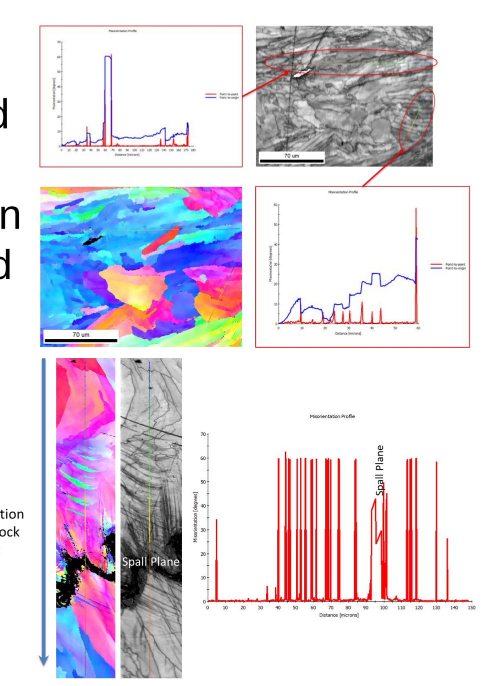
No laser + carbon   Laser + carbon = delivery

Significant increase in uptake (green) with energy transfer generated from laser + carbon black interaction.

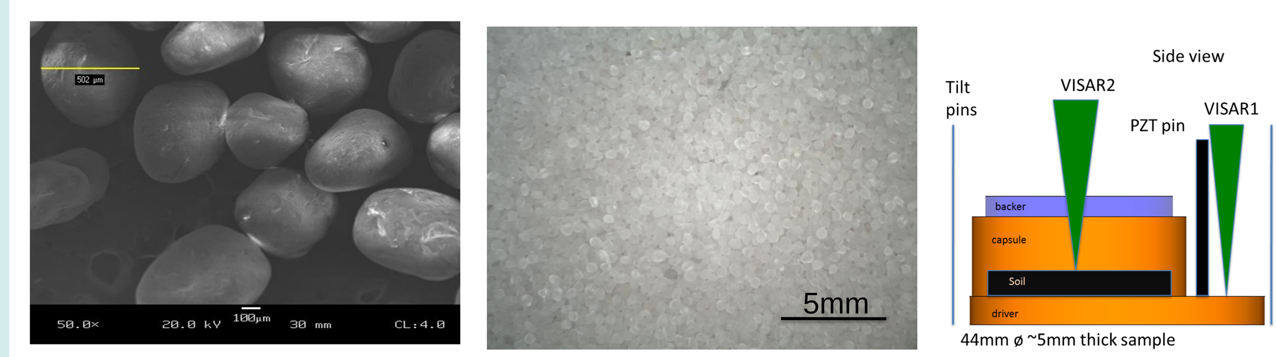
Shock Response of 3D Printed Metals

Microstructural response of 3D printed metals to shock tensile and compression. Extensive twinning, grain refinement and misorientation noted at the spall plane of shocked 3D printed 316L.





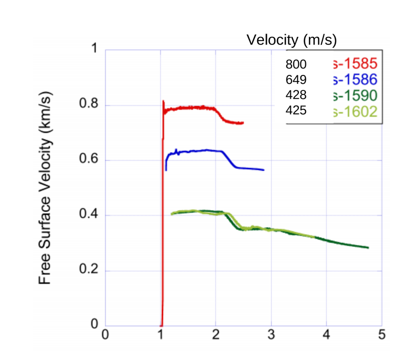
Shock Response of Geologic Materials



Dynamic behavior of hetergeneous geologic materials is not well understood. Parallel plate impact experiments with multiple diagnostics used to generate empirical Equation of State for sand.

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).



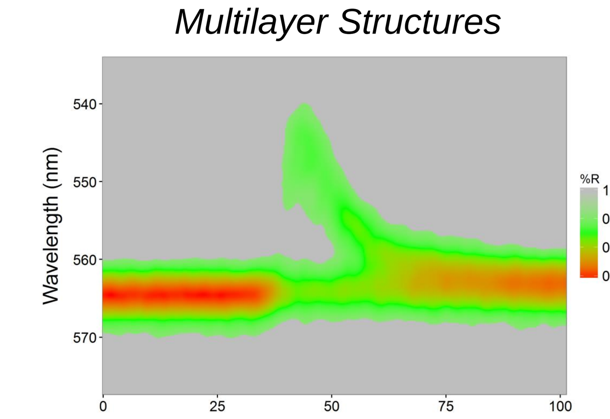
Spall: Free surface velocity vs. time for HDPE
Jordan et al., AIP Conference Proceedings 1979, 090006 (2018)

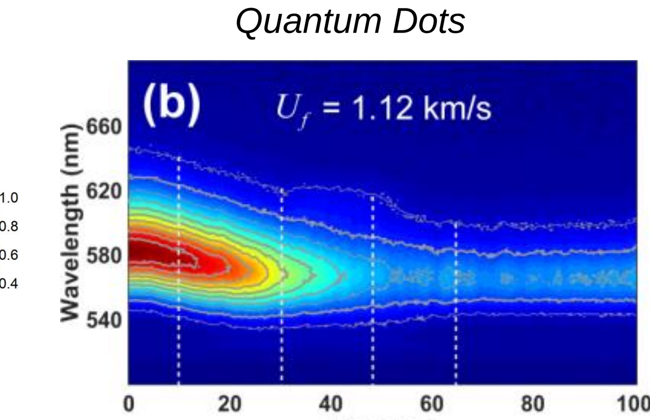
(1) Understand fundamentally the behavior of model polymers (e.g., polyethylene) under high strain rate and shock loading through gas gun experiments and molecular dynamics simulations.
(2) Develop predictive models of mechanical properties by utilizing machine learning algorithms.

Mesoscale Experimental Diagnostics

Multilayer Structures

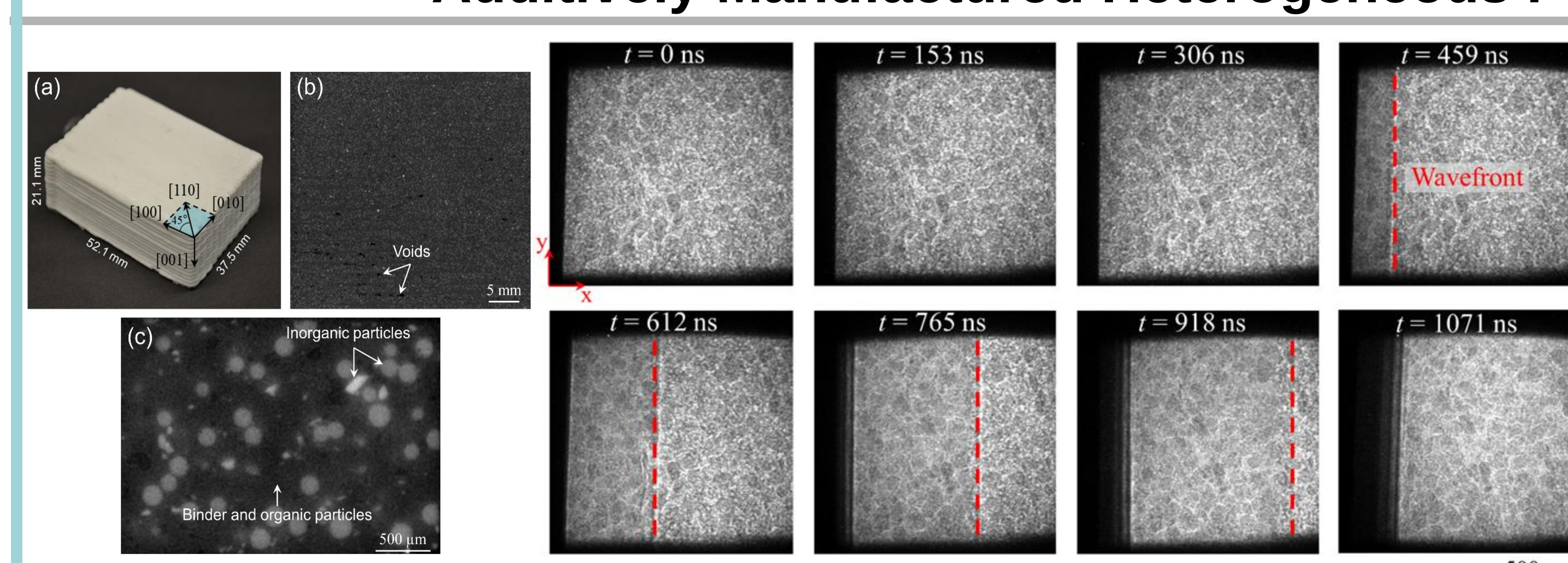
Quantum Dots

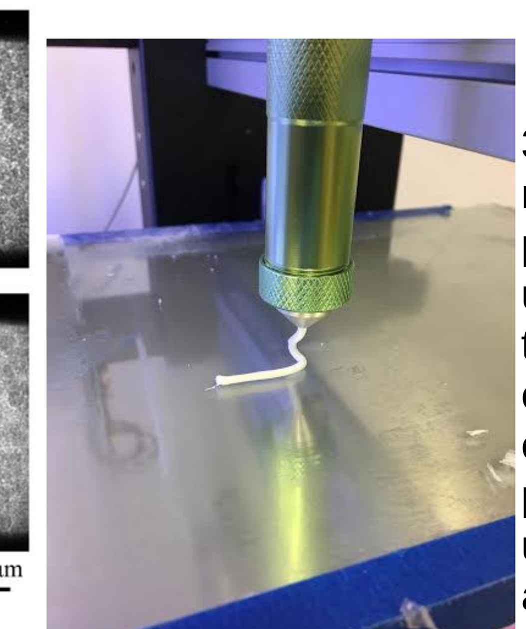




Leveraging the unique behavior of nano-scale photonic structures to create high temporal and spatial resolution diagnostics to study the dynamic response of heterogeneous materials.

Additively Manufactured Heterogeneous Polymer Composites



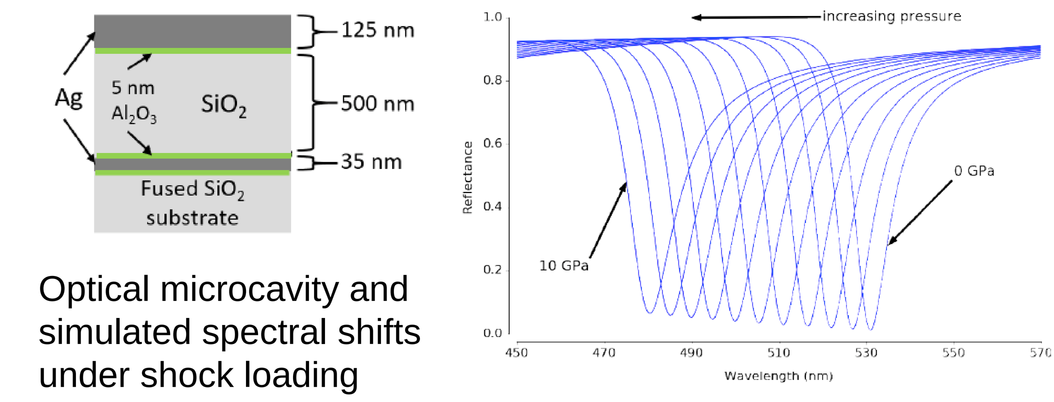


3D printing custom-made inks results in precision objects that undergo mechanical testing like shock compression to connect the material properties to the unique processing and structure.

By understanding and controlling a heterogeneous microstructure, predicting and designing new materials is possible, such as safer energetic materials. Quantitative characterization of microstructure will allow process-structure-property linkages to be created. New *in-situ* characterization techniques, like X-ray Phase Contrast Imaging, are utilized to make such linkages.

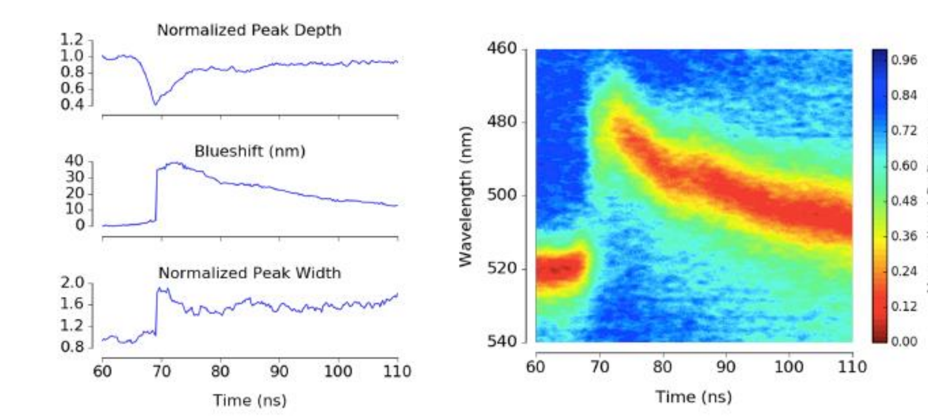
Computational Modeling

Mesoscale Simulations



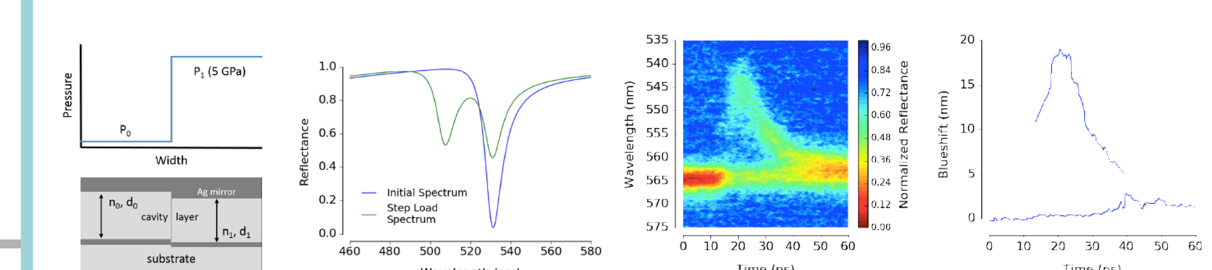
Optical microcavity and simulated spectral shifts under shock loading

Coupled optical-mechanical simulations explore use of multilayered optical microstructures as pressure gauges.

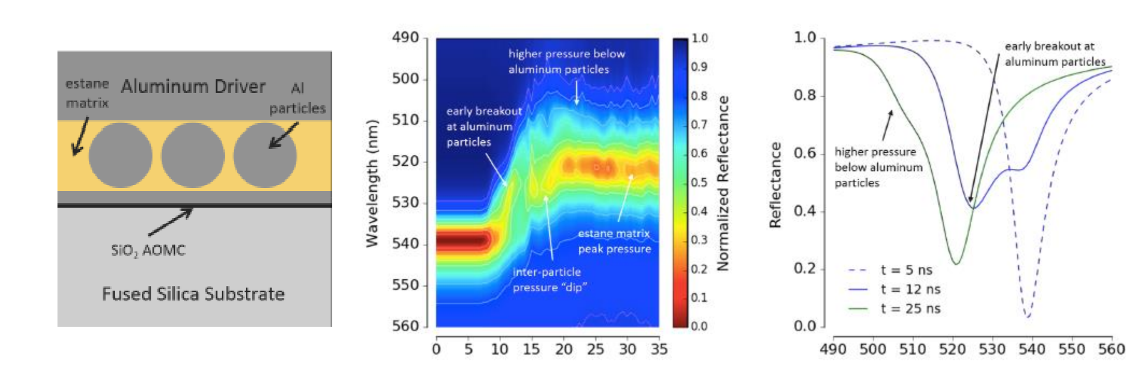


Spectral response of SiO_2-based AOMC under "steady-state" pressure of ~8.5 GPa

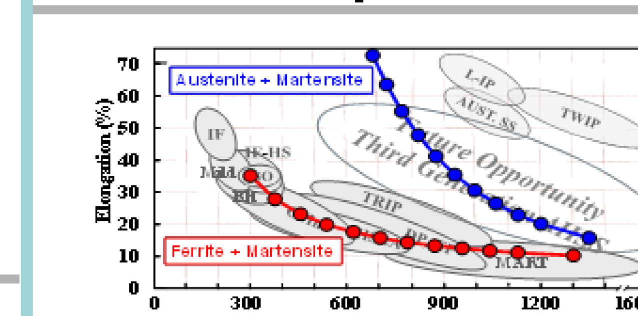
Shock loading produces distinct shifts in multilayer's optical behavior; paired velocimetry and time-resolved spectroscopy allow experimental correlation of mechanical phenomena and spectral features.

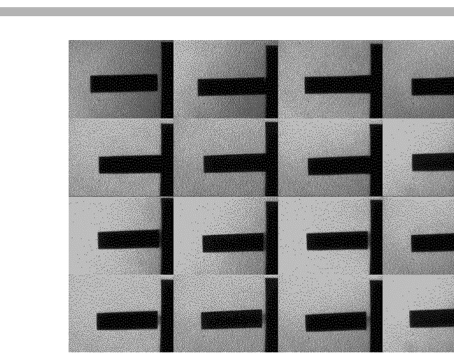


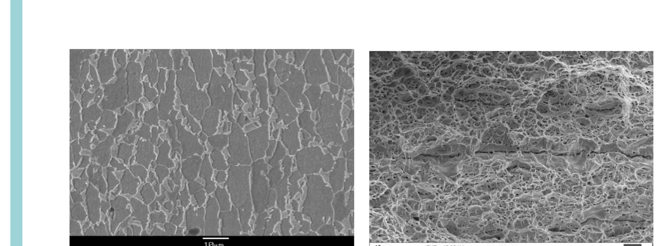
Simulations + experiments indicate multilayers' ability to resolve heterogeneous loading conditions

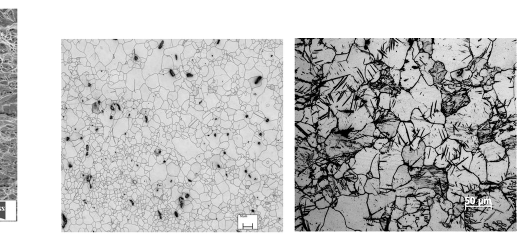


Shock Response of Automotive Materials









Dual Phase Steels are strain rate sensitive. Quasi-static to high strain rate experiments to understand the fracture mechanism and characterize the sensitivity as a function of strain rate and underlying microstructures.

The dynamic behavior of Magnesium alloys are still not understood. Impact experiments to understand the effect of microstructure on their mechanical response.