High-Rate Micro-Compression – Micro-Kolsky Bar

S&T Campaign: Sciences for Lethality and Protection
Kinetic Protection
Soldier Protection

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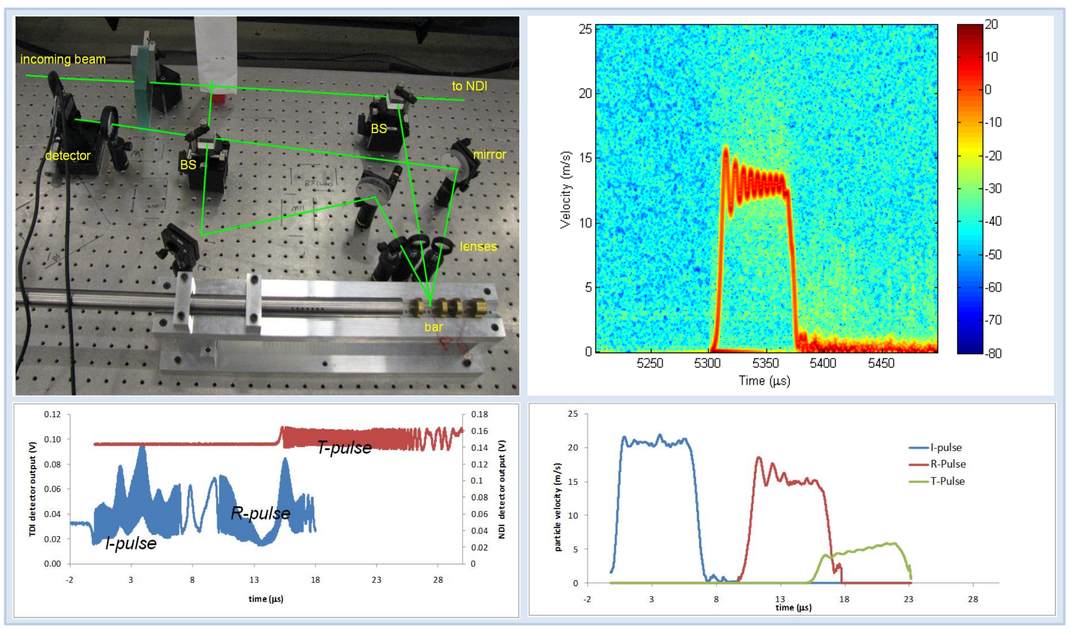
Research Objective

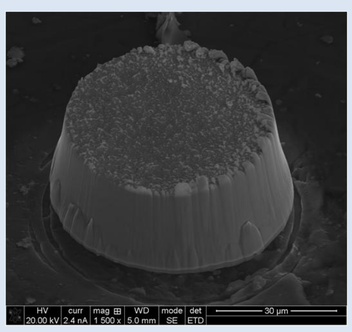
- **Ultra-high-rate mesoscale behavior of materials**
- **Dynamic compression apparatus suitable for specimen dimensions of 10100 mm and strain rates greater than 1M/sec**
- **Linking mesoscale dynamic response with continuum level**



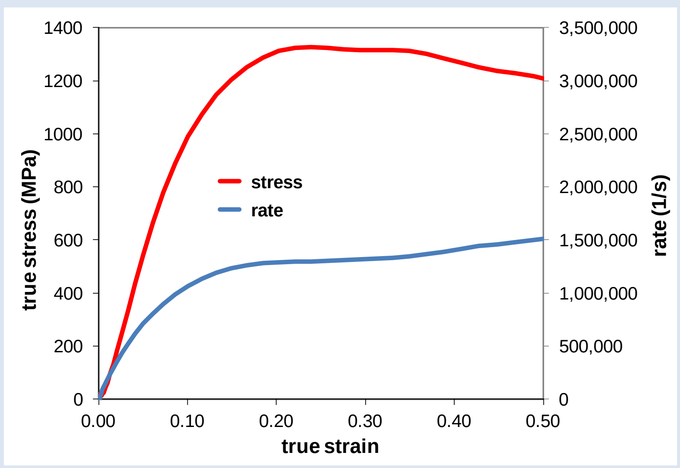
Optical instrumentation (various displacement interferometers) adapted to the Kolsky bar allow miniaturization of the system. Bars with diameters as small as 127 mm have been used successfully, which are compatible with micron-scale samples and can achieve extremely high strain rates.

Challenges

- **Specimen manufacture and characterization can be difficult due to extremely small size**
- **In situ visualization of deformation and fracture needs to be developed (e.g., high-speed photography must be compatible with the small size and short time scales of these experiments)**
- **Recovery of rapidly deformed samples along with associated postmortem analysis**



Nb sample laser-milled/FIB'd from 25 mm thick foil.



Stress-strain response for Nb sample at 1-1.5M/s.

A microKolsky Bar experiment on Nb at a strain rate of 1M/s.

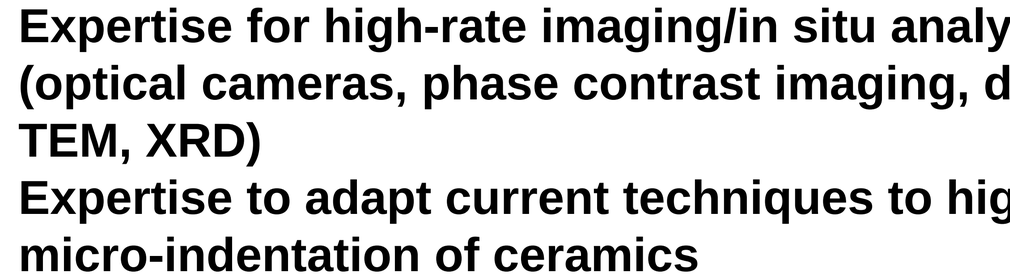
ARL Facilities and Capabilities Available to Support Collaborative Research

- **microKolsky Bar facilities (diameters from 127 mm to 1.6 mm)**
- **Laser interferometers (Normal Displacement Interferometer, Transverse Displacement Interferometer, Photon Doppler Velocimeter, VISAR)**
- **Characterization equipment (SEM, EBSD, optical microscopy)**
- **Standard Kolsky bars, servo-hydraulic load-frames.**
- **Plate impact gas-gun facility (e.g., pressure shear plate impact)**
- **Micro-machining (fs laser mill, Focused Ion Beam)**
- **High-speed cameras with framing rates of 1M frames/sec**
- **Materials successfully investigated to date: ductile metals, individual sand grains, Dyneema and Kevlar individual filaments under transverse compression, polymeric microcapsules**

Casem, D.T., Dwivedi, A.K., Mrozek, R.A., Lenhart, J.L., "Compression Response of a Thermoplastic Elastomer Gel Tissue Surrogate over a Range of Strain-rates," International Journal of Solids and Structures (2014) 51:2037–2046.

Casem, D.T., Zellner, M.B., "Kolsky Bar Wave Separation Using a Photon Doppler Velocimeter," Experimental Mechanics (2013) 53:1467–1473.

Casem, D.T., Grunschel, S.E., Schuster, B.E., "Normal and Transverse Displacement Interferometers Applied to Small Diameter Kolsky Bars," Experimental Mechanics (2012) 52:173–184.



Optical instrumentation eliminates the need for strain gages.

Complementary Expertise / Facilities / Capabilities Sought in Collaboration

- **Numerical approaches to model mesoscale behavior for integrated computational-experimental studies of material behavior**
- **Methods and expertise for post-mortem evaluation of critical high-rate deformation mechanisms**
- **Expertise for high-rate imaging/in situ analysis (optical cameras, phase contrast imaging, dynamic TEM, XRD)**
- **Expertise to adapt current techniques to high rate micro-indentation of ceramics**
- **Extension of techniques to tensile loading**
- **Complementary methods to conduct micro-compression experiments at low and intermediate rates (0.001-100/s)**