

S&T Campaign: Sciences for Lethality and Protection

Kinetic Protection

Soldier Protection

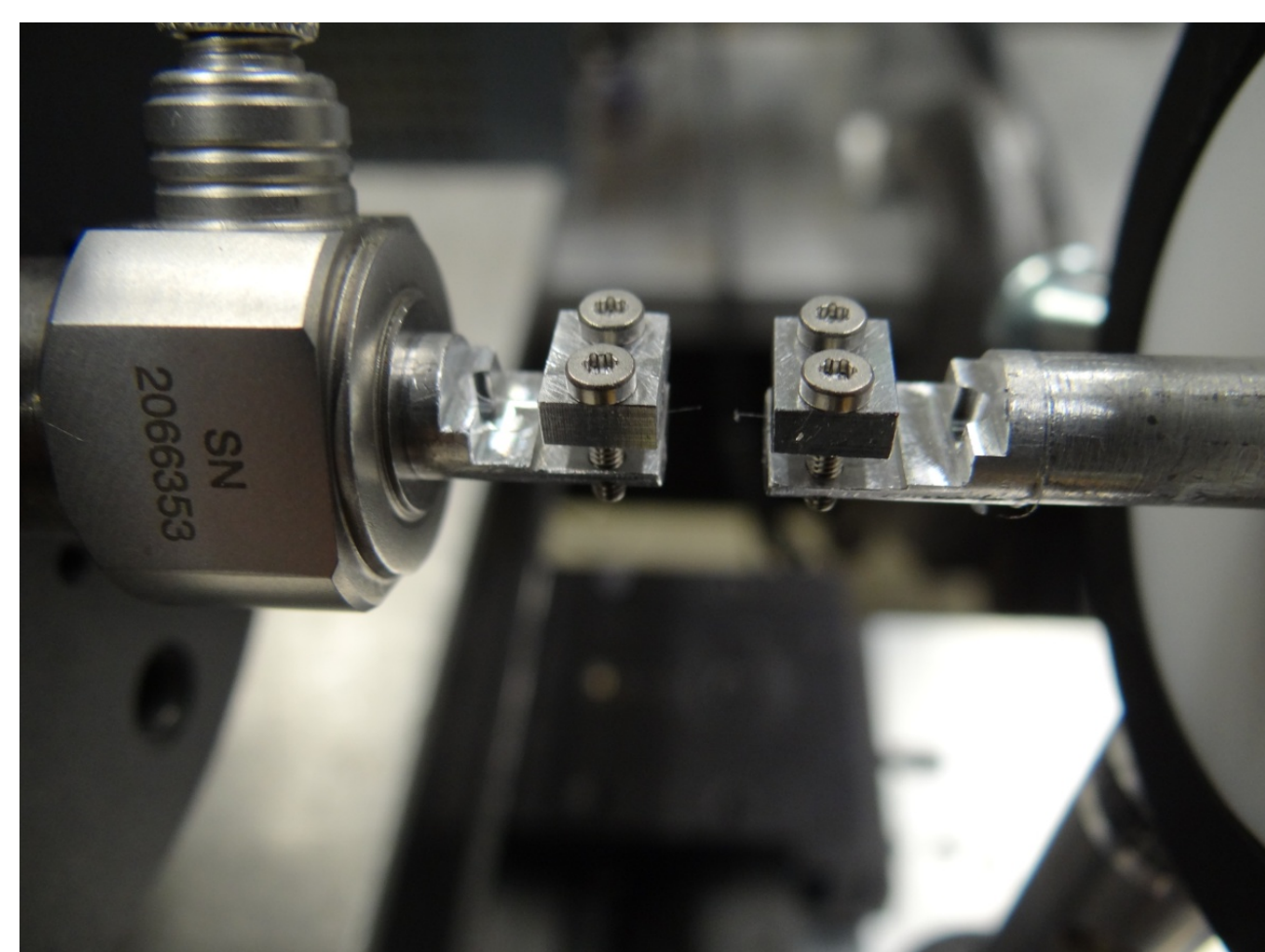
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Research Objective

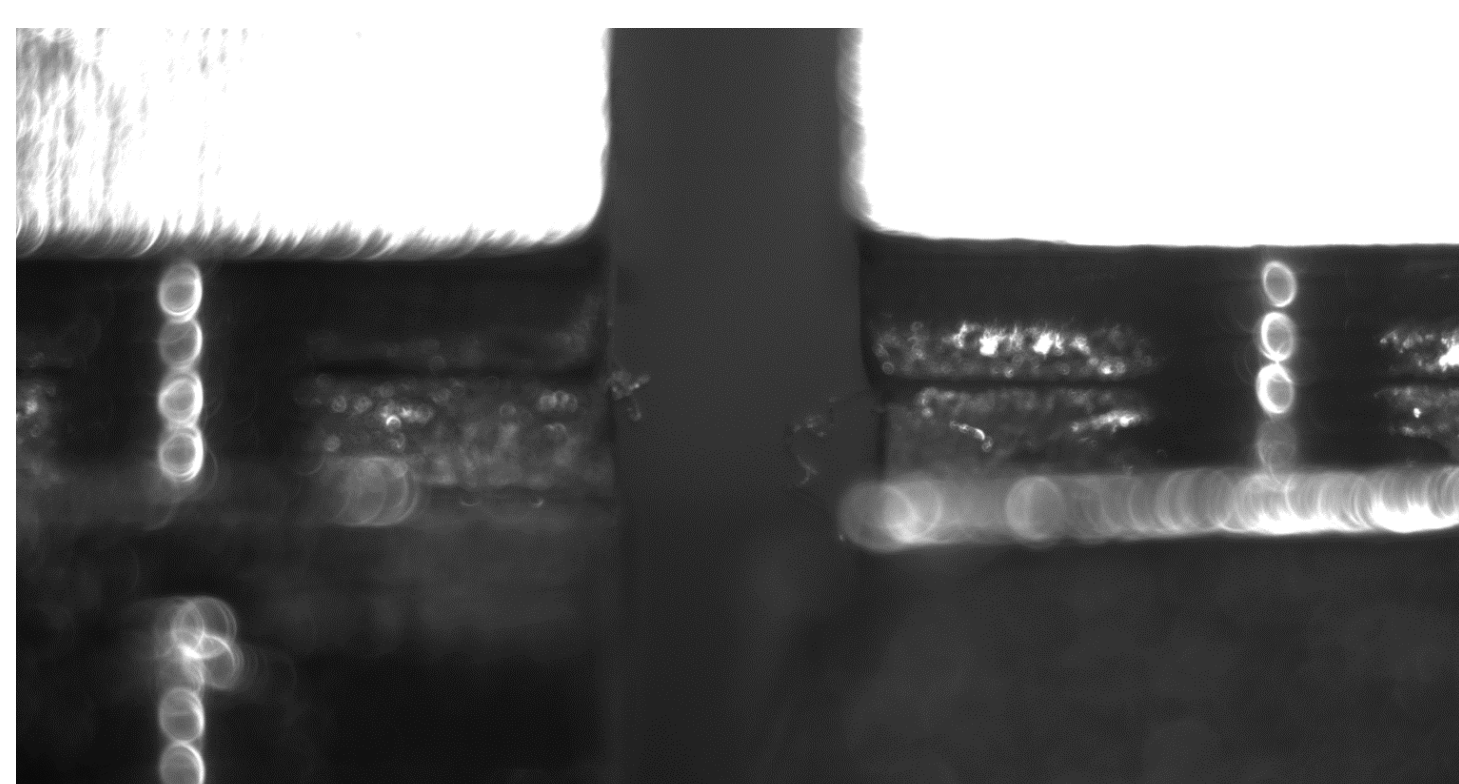
- Goal: Understand the mechanical response of fiber-based materials via fiber and subfiber response
- Currently, constitutive response models are based solely on the uniaxial tensile behavior of single fibers. In reality, the stress-state of a fiber during impact is multiaxial. While the fiber is primarily loaded in uniaxial tension, the fiber is also subjected to transverse compression.
- Multiaxial response of the fiber must be incorporated into mathematical models



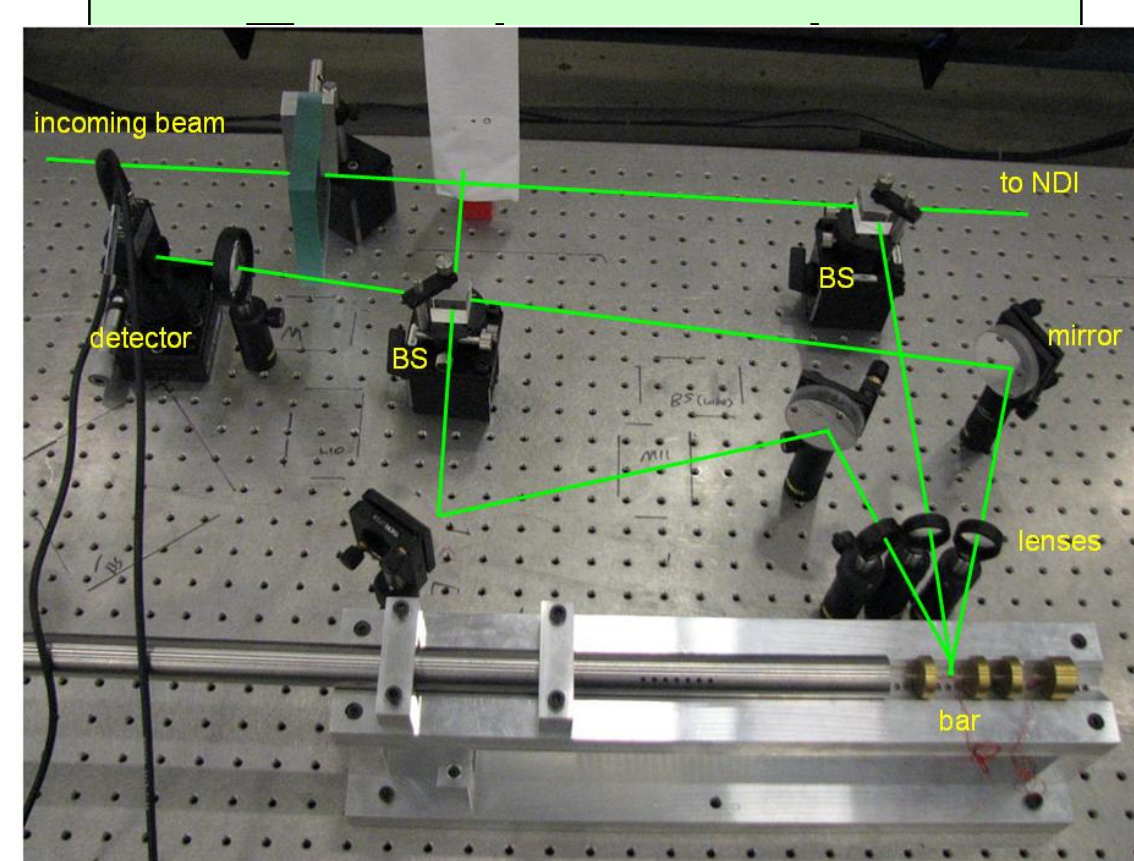
Gripping Method



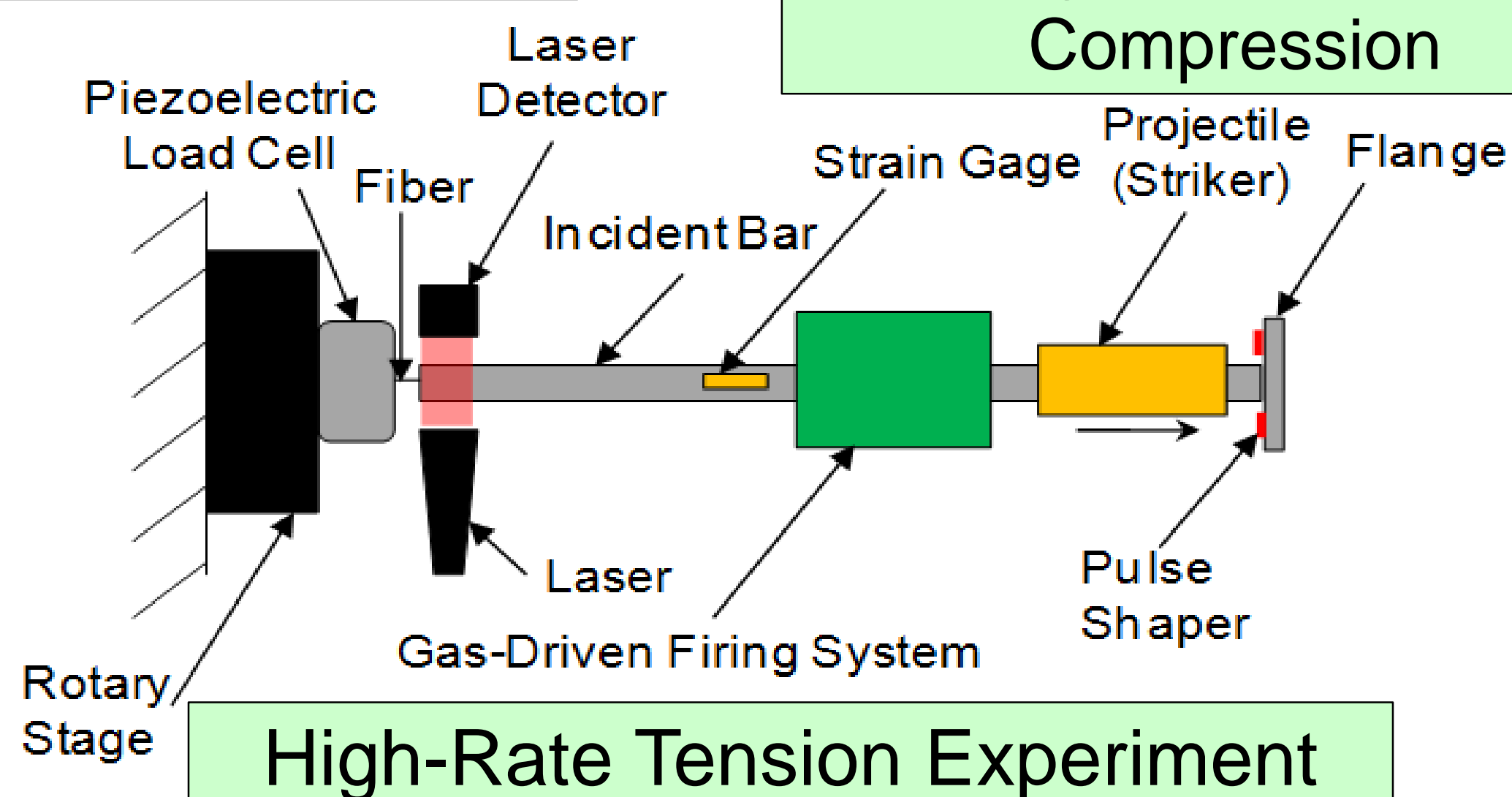
High-Rate Micro
Tensile



Post-Failure Recoil



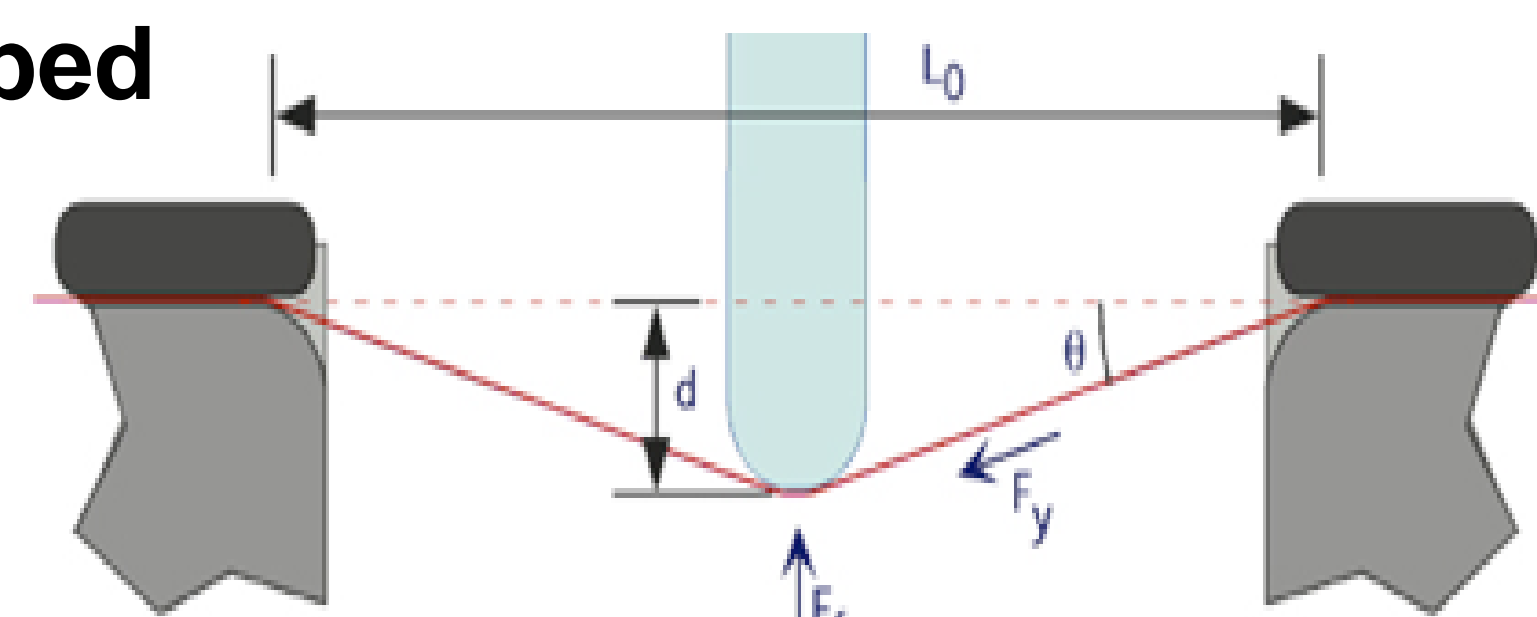
High-Rate Micro
Compression



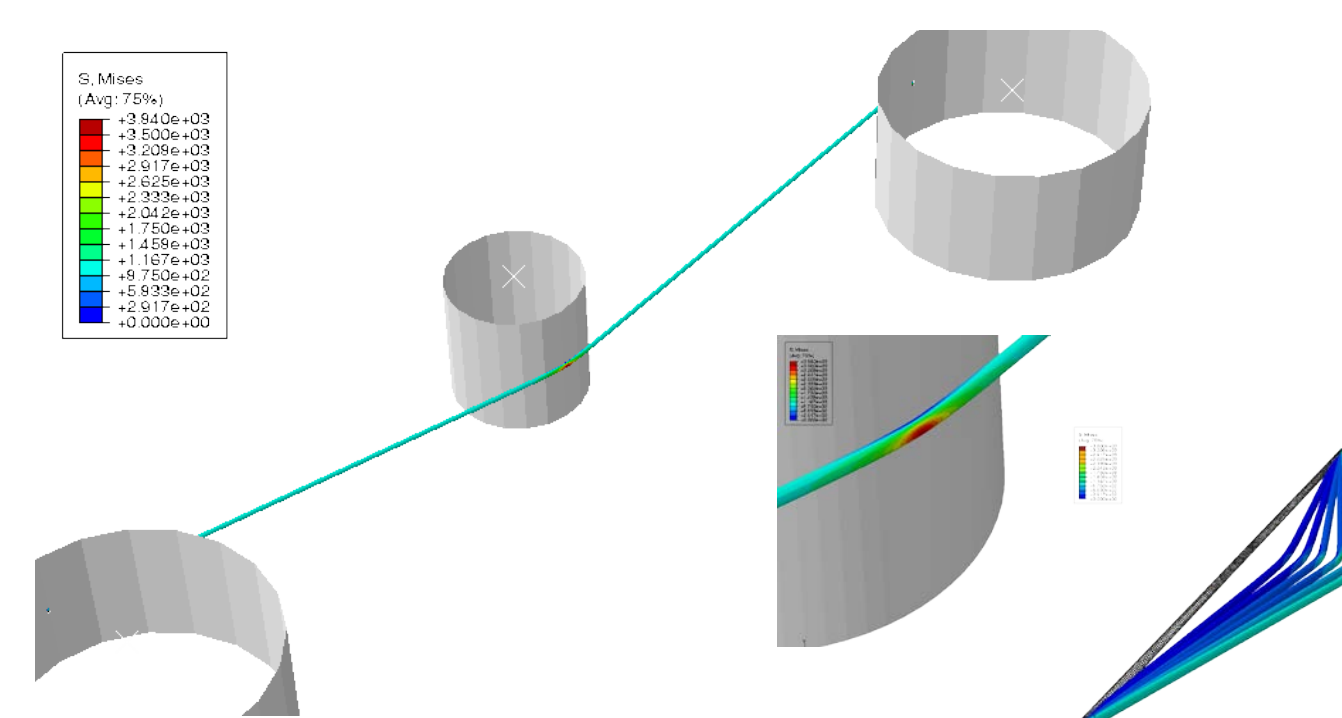
High-Rate Tension Experiment

ARL Facilities and Capabilities Available to Support Collaborative Research

- ARL has the ability to conduct tensile experiments on PPTA [1] and UHMWPE [2] single fibers from low- to high-strain rates
- Currently developing experimental capabilities to conduct transverse compression of single fibers at high rate
- Exploring ways to subject single fibers to both axial tension and transverse compression simultaneously
- In situ SAXS/WAXS loading experimentations are being developed



Schematic of multi-axial loading setup



Initial simulation of mixed mode loading experiment

Complementary Expertise / Facilities / Capabilities Sought in Collaboration

- Develop a constitutive relationship of the transverse compressive response
- Model the anisotropic multiaxial behavior of single fibers
- Model the macro behavior of fiber-based armor using micro-mechanistic relationships from the single fiber scale
- Investigate failure mechanisms and the failure processes of single fibers through in situ microscopy (AFM, SEM, TEM, SAXS/WAXS)
- Micro-mechanistic modeling of fiber substructure – combined crystalline/amorphous regions
- Validation of subfiber modeling via single fiber response
- Synchrotron-based diffraction investigation of failure process to complement SAXS/WAXS studies
- [1] B. Sanborn, T. Weerasooriya. Quantifying Damage at Multiple Loading Rates to Kevlar KM2 Fibers Due to Weaving, Finishing, and Pre-Twist. *International Journal of Impact Engineering*, 71:50-59, 2014.
- [2] B. Sanborn, A.M. DiLeonardi, T. Weerasooriya. Tensile Properties of Dyneema SK76 Single Fibers at Multiple Loading Rates Using a Direct Gripping Method. *Journal of Dynamic Behavior of Materials*, In Review.

Challenges

- Experimental methods to subject single fibers to both axial tension and transverse compression do not exist
- Combined loading must be modeled to extract material behavior
- Dynamic transverse compression of single fibers has not been studied
- Failure process of single fibers is not well understood