



U.S. ARMY  
**RDECOM**

Multi-scale Experimental Framework to Understand  
Rate Dependent Fiber-based Material Response

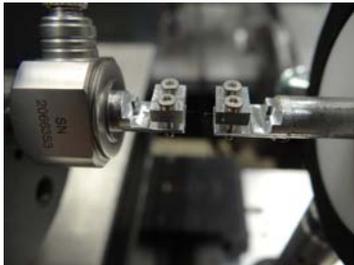


## S&T Campaign: Sciences for Lethality & Protection Battlefield Injury Mechanisms

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## Research Objective

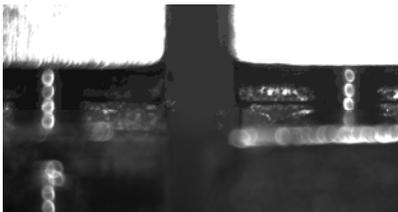
- Goal: Understand the mechanical response of fiber-based materials via fiber and sub-fiber response
- Currently, constitutive response models are based solely on the uniaxial tensile behavior of single fibers. In reality, the stress-state of a fiber during impact is **multiaxial**. While the fiber is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



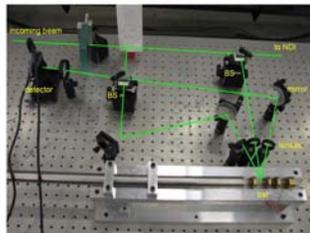
Gripping Method



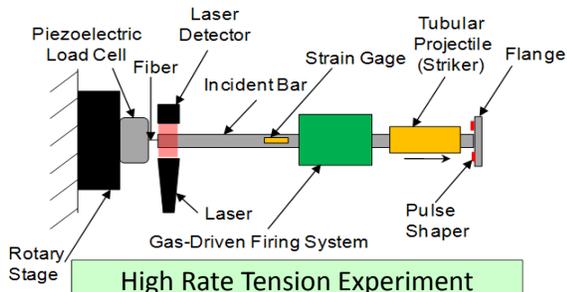
High-Rate Micro Tensile Experimentation



Post-Failure Recoil



High-Rate Micro Compression



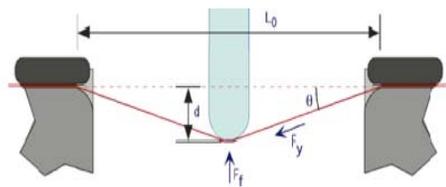
High Rate Tension Experiment

## Challenges

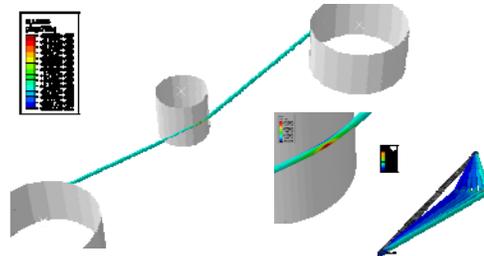
- Experimental methods to subject single fibers to both axial tension and transverse compression do not exist
- **Combined loading** must be modeled to extract material behavior
- **Dynamic transverse compression** of single fibers has not been studied
- **Failure process** of single fibers is not well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

## 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 multiaxial 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** multi-axial 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 sub-fiber 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.