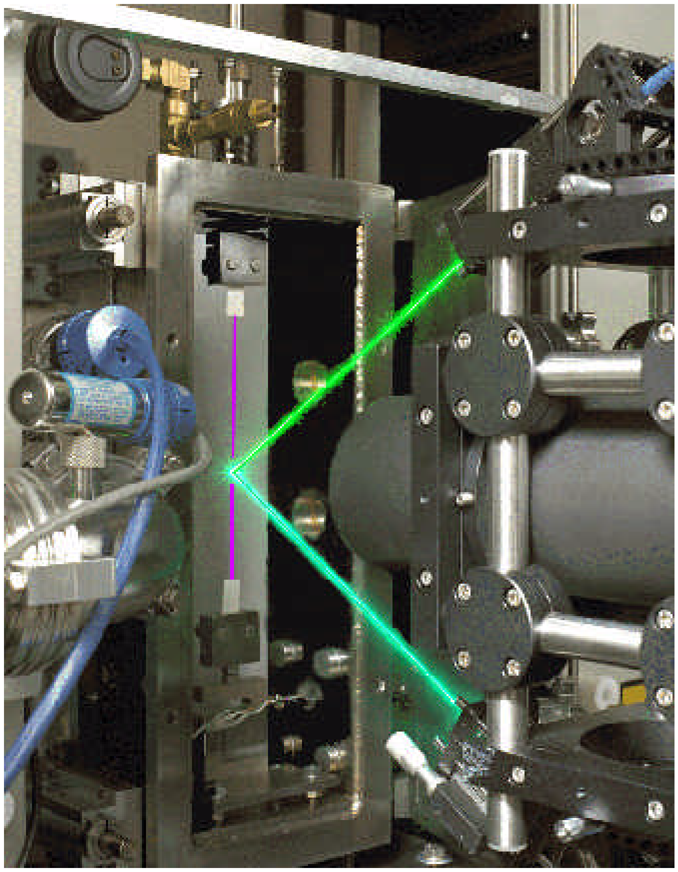
Nondestructive Strain Measurement System Used to Determine Surface Strain on Fibers

Small-diameter structural fibers are being considered as reinforcements for high-temperature ceramic matrix composite materials, and thus they require characterization. At the NASA Lewis Research Center, a nondestructive optical technique was used to determine surface strain on a structural fiber, in real time, as it was pulled in a tensile test machine.

With this technique, interference or speckle patterns from the laser illuminated fiber test specimen are recorded. As the fiber is pulled, its speckle pattern shifts in proportion to the strain, translation, and rotation components of the sample deformation. Shifting speckle patterns are detected in real time by two linear charge-coupled discharge (CCD) camera arrays, and the images are processed by a hardware correlator. Surface strain is selectively detected on fibers with diameters on the order of 100 µm and can be resolved to 19 microstrain.

This system was designed to be robust and compact and generally does not require surface preparation of the structural fibers. For strain detection, two laser beams are positioned incident on the structural fiber being tested, as shown in the photograph, where the test specimen is mounted in a tensile test machine via two coupons. As the fiber is pulled, the speckle pattern produced from each laser beam is detected by one of two CCD arrays located inside the tube on the right side of the photograph.



Sensor head optics of laser speckle-shift strain measurement system illuminating test specimen.

Data obtained from three standard specimens (silica, silicon carbide, and tungsten) using the real-time two-color laser speckle-shift system compared well with published values. A linear fit of the raw data was performed to determine the experimental modulus of each specimen (the slope of the stress versus the strain curve). Errors between the known and experimental values were 5.2 percent or less. Numerical results for silica, silicon carbide, and tungsten fibers are given in the following table.

COMPARISON OF EXPERIMENTAL STRAIN MEASUREMENTS TO ACCEPTED VALUES

Sample	Fiber diameter,µm	Accepted modulus, GPa	Experimental modulus, Gpa	Error, percent
Silica	142	73.1	76.9	5.2
Silicon carbide	143	410.0	418.0	2.0
Tungsten	177	380.0	389.0	2.4

The key feature of this system, which separates it from current strain detection systems, is the real-time data analysis. This allows for closed-loop system control based on the detected strain value. Some other advantages of this system follow:

1. It is easy to use.

2. Generally, it does not require preparation of specimen surface.

3. It does not require post-processing.

4. It will operate at elevated temperatures without modifications.

Because the strain of three standard structural fibers was measured successfully, this system can be used with confidence to characterize unknown samples.

Lewis contacts: Dr. Margaret L. Tuma, (216) 433-8665, Margaret.L.Tuma@grc.nasa.gov; and Lawrence G. Oberle, (216) 433-3657, Lawrence.G.Oberle@grc.nasa.gov
Author: Dr. Margaret L. Tuma
Headquarters program office: OAT
Programs/Projects: HITEMP