Control Program and Optical Improvements of Fresnel Microspectrometer
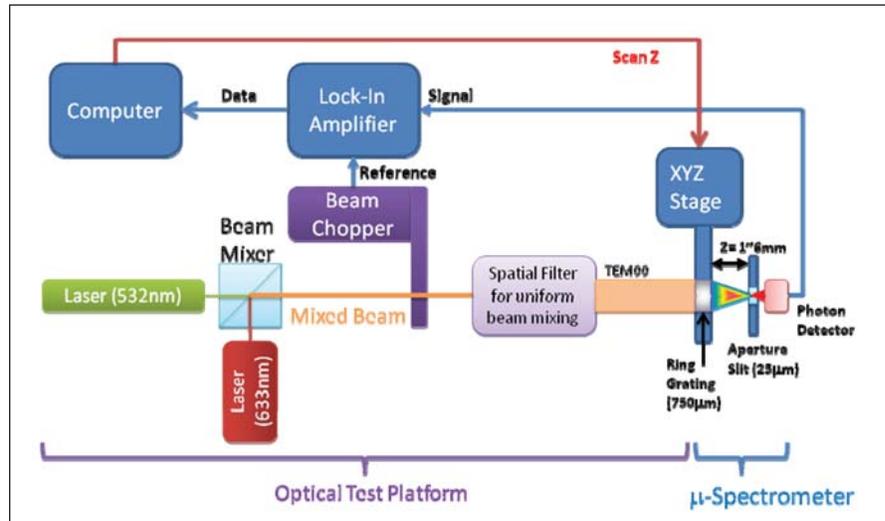
This innovation is suitable for optical fiber communications and medical applications where multiple optical fibers are used.

Langley Research Center, Hampton, Virginia

A microspectrometer has a circular geometry, and is designed with the Fresnel diffraction equation. This enables a dramatic miniaturization of the optical parts of a spectrometer over 100 times by volume. Therefore, it enables the construction of spectrometer arrays such as 100×100 microspectrometers for tunable multispectral or hyper-spectral imaging. It can be used for a massive, simultaneous spectral scan from multiple optical sources such as 10,000 optical fibers.

Two laser beams of 532 nm (green) and 633 nm (red) wavelengths were mixed and combined at a beam mixer. After the beam mixing, the beam looks like a yellow color to a human eye. This mixed pseudo-yellow beam passes a beam chopper operating at 191 Hz to modulate the beam for the lock-in amplification. A spatial filter was used to get a uniformly mixed TEM_{00} beam in a wide beam diameter of about 1 cm. Then, the mixed beam enters the Fresnel ring grating whose diameter is only 750 µm. The ring grating separates the lights according to the wavelengths, and only the selected photons of the desired wavelength can pass the aperture slit of 25 µm in diameter.

The number of passed photons is measured as the current of a photon detector. The signal current is delivered to the lock-in amplifier. The lock-in amplifier picks up only the 191 Hz frequency-locked signal from photon detector with respect to the reference signal from the beam chopper, and it rejects unwanted room lights and other stray lights. The computer receives the data from the lock-in amplifier and sends commands to an XYZ stage actuator to change the optical distance Z, between the ring grating and the aperture slit. A spectral scan is made with the linear actuator movement. The sharpness of the focal point and the spectral resolving power were increased with the increasing numbers of rings in the grating.

Because the size of each microspectrometer is small, a dense array of spectrometers can be fabricated in a small area. Such an array can simultaneously capture the multiple spectral signals from various sources.

This work was done by Yeonjoon Park, Glen King, Sang Choi, and James Elliott of Langley Research Center. Further information is contained in a TSP (see page 1). LAR-17661-1

The configuration of the optical test platform and the **Microspectrometer**.

Miniature Laser Magnetometer

This device can be used for satellite, aircraft, and ground-based magnetic field sensors.

Goddard Space Flight Center, Greenbelt, Maryland

A conceptual design has been developed for a miniature laser magnetometer (MLM) that will measure the scalar magnitude and vector components of near-Earth magnetic fields. The MLM incorporates a number of technical innovations to achieve high-accuracy and high-resolution performance while significantly reducing the size of the laser-pumped helium magnetometer for use on small satellites and unmanned aerial vehicles (UAVs). The MLM will have a dynamic range up to 75,000 nT. The scalar sensitivity will be 1 $pT(Hz)^{-1/2}$ at 1 Hz with an accuracy of 0.2 nT. The vector sensitivity will be 1 $pT(Hz)^{-1/2}$ at 1 Hz with an accuracy of 0.5 nT.

Fluxgates are the most common vector magnetometers used in space applications. They suffer from variable gain and offset drifts that significantly limit absolute accuracy for demanding scientific investigations of magnetic fields. MLM's helium magnetometer technology is significantly more stable and accurate than these fluxgate magnetometers.

On satellites that include vector magnetometers, a separate reference scalar magnetometer is often included to correct the gains, offsets, and alignment errors of the vector instrument. The MLM will provide both scalar and self-calibrated vector measurements of the magnetic fields in a single instrument.

The MLM is a single magnetometer instrument consisting of separate sensor

and electronics sections that has the capability of measuring both the scalar magnetic field magnitude and the vector magnetic field components. Furthermore, the high-accuracy scalar measurements are used to calibrate and correct the vector component measurements in order to achieve superior vector accuracy and stability. The correction algorithm applied to the vector components for calibration and the same cell for vector and scalar measurements are major innovations. The separate sensor and electronics section of the MLM instrument allow the sensor to be installed on a boom or otherwise located away from electronics and other noisy magnetic components.

The MLM's miniaturization will be accomplished through the use of advanced miniaturized components and packaging methods for the MLM sensor and electronics. The MLM conceptual design includes three key innovations. The first is a new non-magnetic laser package that will allow the placement of the laser pump source near the helium cell sensing elements. The second innovation is the design of compact, nested, triaxial Braunbek coils used in the vector measurements that reduce the coil size by a factor of two compared to existing Helmholtz coils with similar field-generation performance. The third innovation is a compact sensor design that reduces the sensor volume by a factor of eight compared to MLM's predecessor.

The MLM design utilizes two distinct methods for performing scalar and vector measurements of magnetic fields. For scalar measurements, the MLM uses the magnetically driven spin precession (MSP) technique where a coil near the helium cell sensing element is driven with a signal oscillating at the Larmor frequency. The signals from three orthogonal cells are summed to obtain omnidirectional sensitivity. For vector measurements, the MLM uses the bias field nulling (BFN) technique where orthogonal coil sets around one cell are used to null the magnetic field. The magnetic vector components are then proportional to the current required to null the field in the cell.