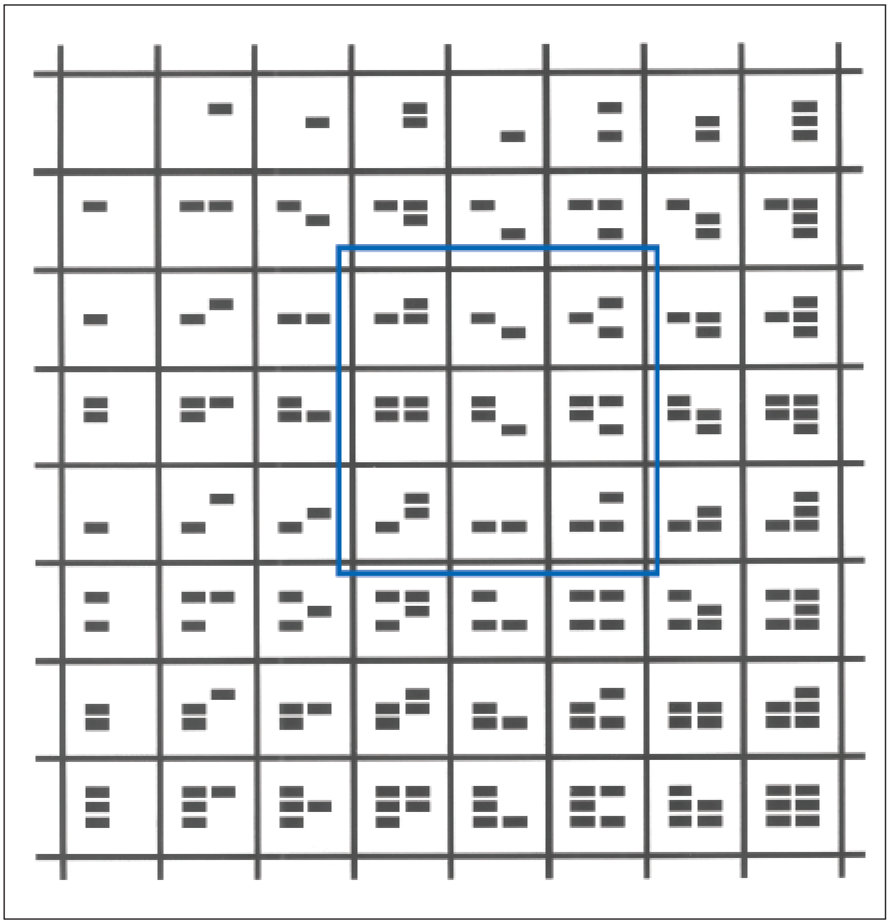


Figure 2. In the **Coded Cartesian Grid**, each grid cell contains a distinct binary image code that identifies that cell. The upper code bits in a cell identify the line at the bottom of the cell, while the lower bits identify the line at the left of the cell. In the instantaneous field of regard (square box), code bits identify vertical lines 2, 3, and 4, and horizontal lines 3, 4, and 5.

which contribute to errors and lack of stability in position measurements. Nonuniformity of the position-sensitive photodetector also contributes to readout nonlinearity.

In the electronic absolute Cartesian autocollimator, the target is a coded Cartesian grid (see Figure 2) and the viewing plane is occupied by an image sensor. Vertical lines in the target image encode azimuthal deflections of the datum mirror from the optical axis, while horizontal lines encode elevational deflections. The planar array of pixels of the image sensor intrinsically constitutes a fixed high-resolution coordinate grid. The outputs from the pixels are digitized, and the resulting digital data are processed to decipher the codes in the target image and to determine locations of centroids of grid lines, which provide angular measurement with a granularity nearly one thousand times finer than the angular extent of a single pixel. Each centroid produces an independent position measurement. Averaging measurements together naturally increases readout accuracy and sensitivity.

The combination of the intrinsic grid structure of the image sensor and the Cartesian grid of the target image ensures linearity of output and a high degree of immunity to any non-uniformity among responses of individual sensor pixels. The coding of the grid ensures unambiguous position readout.

Processing of the target image is not subject to drift as a result of weakness of signals on the image sensor. At worst, weakness of signals increases the proportion of noise. Therefore, the electronic absolute Cartesian autocollimator includes a servo loop that regulates the brightness of illumination to keep signal levels optimum. Finally, the electronic absolute Cartesian autocollimator offers one major additional advantage over a conventional electronic autocollimator: The cells of the Cartesian grid effectively constitute a multiplicity of targets that, collectively, makes the field of regard of this apparatus much larger than that of a conventional electronic autocollimator.

This work was done by Douglas B. Leviton of **Goddard Space Flight Center**. *Further information is contained in a TSP (see page 1).*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center, (301) 286-7351. Refer to GSC-14718-1.

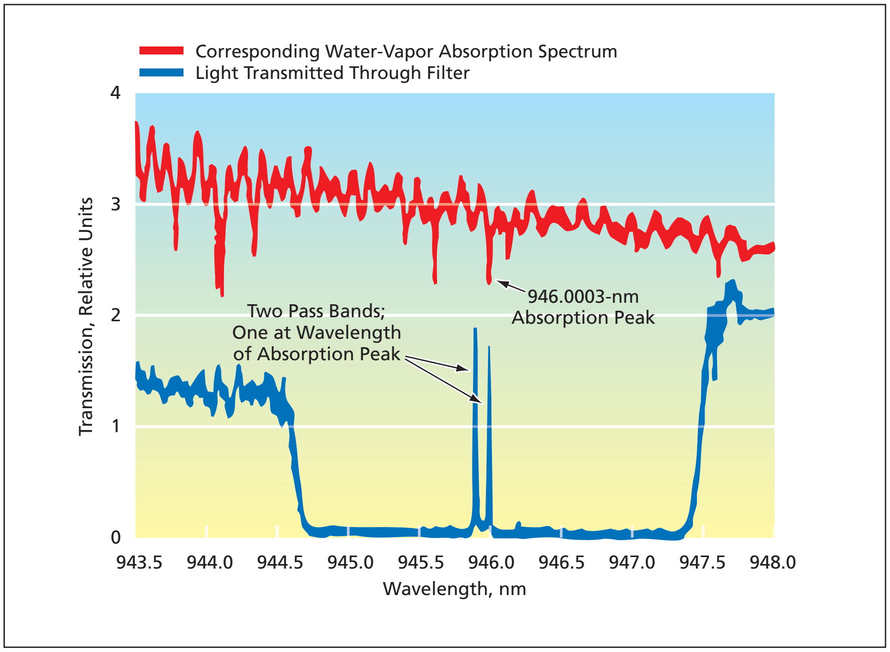
Fiber-Optic Gratings for Lidar Measurements of Water Vapor

These are highly selective, lightweight, tunable optical filters.

Langley Research Center, Hampton, Virginia

Narrow-band filters in the form of phase-shifted Fabry-Perot Bragg gratings incorporated into optical fibers are being developed for differential-absorption lidar (DIAL) instruments used to measure concentrations of atmospheric water vapor. The basic idea is to measure the relative amounts of pulsed laser light scattered from the atmosphere at two nearly equal wavelengths, one of which coincides with an absorption spectral peak of water molecules and the other corresponding to no water vapor absorption. As part of the DIAL measurement process, the scattered light is made to pass through a filter on the way to a photodetector. Omitting other details of DIAL for the sake of brevity, what is required of the filter is to provide a stop band that:

- Surrounds the water-vapor spectral absorption peaks at a wavelength of ≈946 nm,
- Has a spectral width of at least a couple of nanometers,
- Contains a pass band preferably no wider than necessary to accommodate the 946.0003-nm-wavelength water-



The **Transmission Spectrum** of a prototype filter was found to contain the desired two narrow pass bands within a stop band and was tension-tuned to match the 946-nm water vapor absorption line.

vapor absorption peak [which has 8.47 pm full width at half maximum (FWHM)], and

- Contains another pass band at the slightly shorter wavelength of 945.9 nm, where there is scattering of light from aerosol particles but no absorption by water molecules.

Whereas filters used heretofore in DIAL have had bandwidths of ≈300 pm, recent progress in the art of fiber-optic Bragg-grating filters has made it feasible to reduce bandwidths to ≤20 pm and thereby to reduce background noise. Another benefit of substituting fiber-optic Bragg-grating filters for those now in use would be significant reductions in the weights of DIAL instruments. Yet another advantage of fiber-optic Bragg-grating filters is that their transmission spectra can be shifted to longer wavelengths by heating or stretching: hence, it is envisioned that future DIAL instruments would contain devices for fine adjustment of transmission wavelengths through stretching or heating of fiber-optic Bragg-grating filters nominally designed and fabricated to have transmission wavelengths that, in the absence of stretching, would be slightly too short.

Prototype fiber-optic Bragg-grating filters were designed so that their grating structures were chirped and each filter included π-radian phase shifts at two locations along its length. In each filter, the chirp was characterized by 200 uniform-pitch fields concatenated along a total length of about 6 cm. The chirp rate was 0.3 nm/cm, with a pitch centered at 648.9 nm. The π-radian phase shifts were located at lengthwise positions of 29 and 31 cm, respectively. The particular combination of chirping parameters and phase-shift locations was chosen to yield the desired pass bands at wavelengths of 945.9 and 946.0003 nm in a stop band 2.66 nm wide upon stretching of the fiber at a tension equivalent to the terrestrial weight of a mass of 140 mg (see figure). The filters were fabricated in a multistep process, starting with electron-beam patterning of step-chirp corrugations into a mask. Hydrogen-loaded single-mode optical fibers were irradiated through the mask by light from an ultraviolet excimer laser, then the fibers were annealed by heating.

The prototype fiber-optic Bragg-grating filters were subjected to several tests that demonstrated their potential utility for DIAL water-vapor measurements. Measurements of the transmission spectra of the filters were found to be well approximated by theoretical calculations, which were made by use of a piecewise-matrix form of a coupled-mode equation. Tension tuning was also demonstrated.

This work was done by Leila B. Vann and Russell J. DeYoung of **Langley Research Center** *and Stephen J. Mihailov, Ping Lu, Dan Grobnic, and Robert Walker of the Communications Research Centre Canada. Further information is contained in a TSP (see page 1). LAR-17039-1*

Simulating Responses of Gravitational-Wave Instrumentation

NASA's Jet Propulsion Laboratory, Pasadena, California

Synthetic LISA is a computer program for simulating the responses of the instrumentation of the NASA/ESA Laser Interferometer Space Antenna (LISA) mission, the purpose of which is to detect and study gravitational waves. Synthetic LISA generates synthetic time series of the LISA fundamental noises, as filtered through all the time-delay-interferometry (TDI) observables. (TDI is a method of canceling phase noise in temporally varying unequal-arm interferometers.) Synthetic LISA provides a streamlined module to compute the TDI responses to gravitational waves, according to a full model of TDI (including the motion of the LISA array and the temporal and directional dependence of the arm lengths). Synthetic LISA is written in the C++ programming language as a modular package that accommodates the addition of code for specific gravitational wave sources or for new noise models. In addition, time series for waves and noises can be easily loaded from disk storage or electronic memory. The package includes a Python-language interface for easy, interactive steering and scripting. Through Python, Synthetic LISA can read and write data files in Flexible Image Transport System (FITS), which is a commonly used astronomical data format.

This program was written by John Armstrong, Jeffrey Edlund, and Michele Vallisneri of Caltech for **NASA's Jet Propulsion Laboratory**.

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-41001.