Multilayer Dielectric Transmissive Optical Phase Modulator

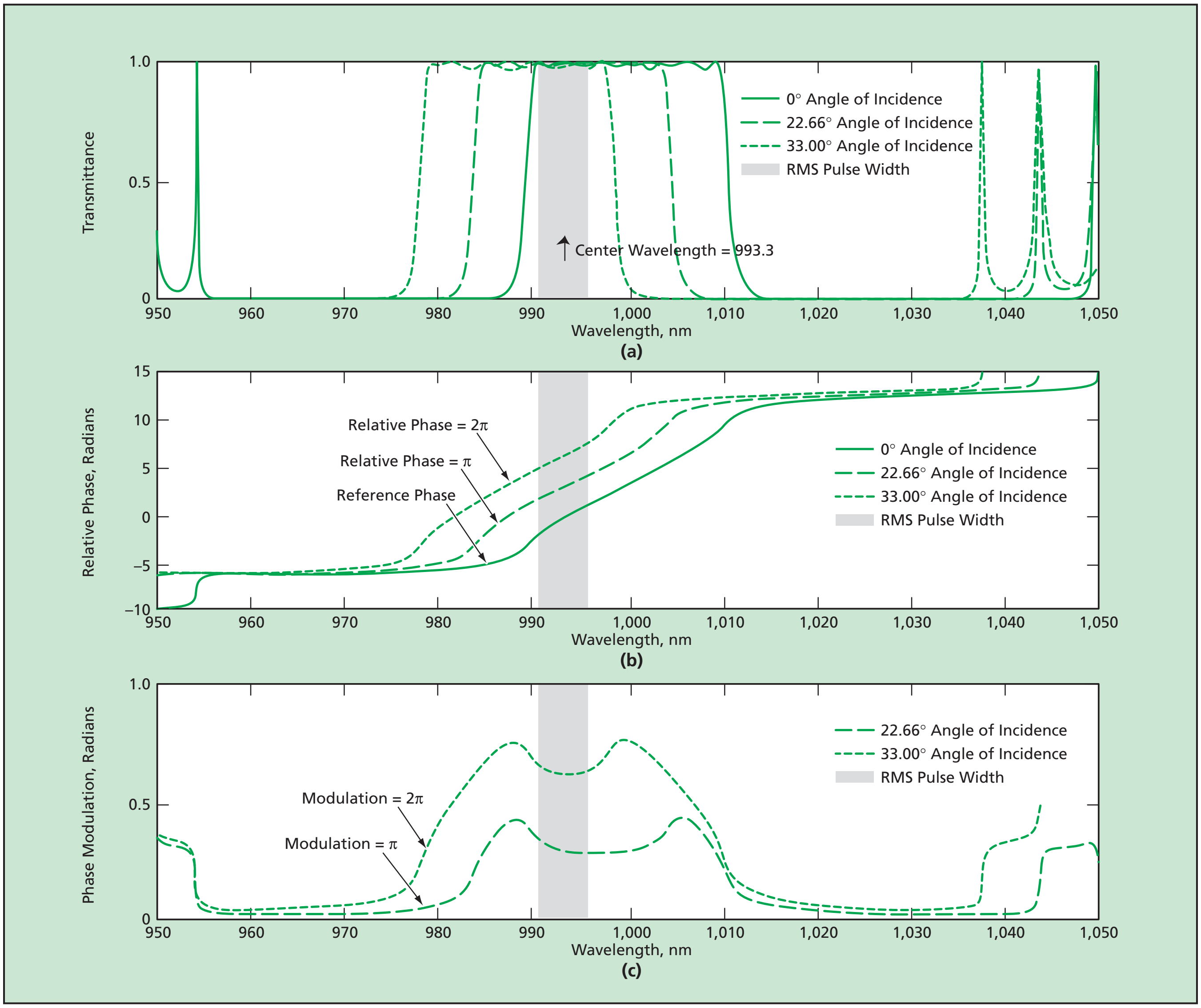
Full-cycle phase change with low distortion would be produced over a terahertz optical bandwidth.

Marshall Space Flight Center, Alabama

A multilayer dielectric device has been fabricated as a prototype of a low-loss, low-distortion, transmissive optical phase modulator that would provide as much as a full cycle of phase change for all frequency components of a transmitted optical pulse over a frequency band as wide as 6.3 THz. Arrays of devices like this one could be an alternative to the arrays of mechanically actuated phase-control optics (adaptive optics) that have heretofore been used to correct for wave-front distortions in highly precise optical systems. Potential applications for these high-speed wave-front-control arrays of devices include agile beam steering, optical communications, optical metrology, optical tracking and targeting, directional optical ranging, and interferometric astronomy.

The device concept is based on the same principle as that of band-pass interference filters made of multiple dielectric layers with fractional-wavelength thicknesses, except that here there is an additional focus on obtaining the desired spectral phase profile in addition to the device's spectral transmission profile. The device includes a GaAs substrate, on which there is deposited a stack of GaAs layers alternating with AlAs layers, amounting to a total of 91 layers. The design thicknesses of the layers range from 10 nm to >1 µm. The number of layers and the thickness of each layer were chosen in a computational optimization process in which the wavelength dependences of the indices of refraction of GaAs and AlAs were taken into account as the design was iterated to maximize the transmission and minimize the group-velocity dispersion for a wavelength band wide enough to include all significant spectral components of the pulsed optical signal to be phase modulated.

The figure depicts the normal-incidence power transmission and relative transmitted phase spectrum computed for the optimized design. The band-pass re-



The **Computed Transmittance Spectrum (a) and Relative Phase Spectrum (b)** of the proposed device indicate the ability to phase-modulate an optical signal without changing transmission levels. The **Phase Modulation Spectrum (c)** shows full cycle phase modulation levels across the full spectral pulse width.

gion — about 21 nm wide in wavelength and 6.3 THz wide in frequency — would feature an edge-to-edge phase change of 2.08 full cycles — slightly greater than 4 radians. The large edge-to-edge phase change would create the potential for any level of phase modulation, provided that one could select a modulation technique that would shift the transmission function far enough in the appropriate direction.

Computational tests were performed for an input optical signal with a Gaussian amplitude envelope, a center wavelength of 993.3 nm, and a root-mean-square (rms) wavelength width of 5 nm, corresponding to pulse duration of 52 fs. One reason for this choice of parameters is that it positions the rms bandwidth of the signal within the shorter-wavelength half of the transmission pass band of the device with the center wavelength at the peak of the second transmission resonance ripple. Another reason for this choice of parameters is that it provides for all significant frequency components of the signal to have access to a full cycle of phase modulation without adversely affecting transmission levels.

An appropriate modulation technique would enable the wavelength shift of the transmission function such that the signal would be shifted from lower half of the pass band to the upper half of the pass band; this amount of shift would bring all significant frequency components of the signal through a complete cycle of phase modulation. In order for this modulation scheme to be successful, the wavelength shift of the transmission must not change the shape of this function in the pass band. The fabricated prototype device has been characterized in its ability to affect transmission phase through a mechanical change in the signal's angle of incidence.

Nonmechanical modulation would likely be effected by an electrorefractive or nonlinear optical technique that would vary the indices of refraction of the GaAs and AlAs layers. The technique has not yet been selected. A computational simulation has shown that a decrease of 1.3 percent in the indices of refraction of the GaAs and AlAs layers would shift the transmission function to shorter wavelengths by an amount sufficient to provide a full cycle of phase modulation for the 993.3-nm test signal. The simulation also showed that a similarly sized increase in the indices of refraction would shift the transmission function to longer wavelengths by an amount sufficient to put the test signal in a wavelength region of high reflectivity; taking advantage of this behavior, one could use the device as an optical switch.

This work was done by Andrew Scott Keys of **Marshall Space Flight Center** *and Richard Lynn Fork of the University of Alabama in Huntsville. Further information is contained in a TSP (see page 1).*

This invention is owned by NASA, and a patent application has been filed. For further information, contact Jim Dowdy, MSFC Commercialization Assistance Lead, at jim.dowdy@nasa.gov. Refer to MFS-31565.

Second-Generation Multi-Angle Imaging Spectroradiometer

NASA's Jet Propulsion Laboratory, Pasadena, California

A report discusses an early phase in the development of the MISR-2 C, a second, improved version of the Multi-angle Imaging SpectroRadiometer (MISR), which has been in orbit around the Earth aboard NASA's Terra spacecraft since 1999. Like the MISR, the MISR-2 would contain a "pushbroom" array of nine charge-coupled-device (CCD) cameras — one aimed at the nadir and the others aimed at different angles sideways from the nadir. The major improvements embodied in the MISR-2 would be the following:

- A new folded-reflective-optics design would render the MISR-2 only a third as massive as the MISR.
- Smaller filters and electronic circuits would enable a reduction in volume to a sixth of that of the MISR.
- The MISR-2 would generate images in two infrared spectral bands in addition to the blue, green, red, and near-infrared spectral bands of the MISR.
- Miniature polarization filters would be incorporated to add a polarization-sensing capability.
- Calibration would be performed nonintrusively by use of a gimbaled tenth camera.

The main accomplishment thus far has been the construction of an extremely compact all-reflective-optics CCD camera to demonstrate feasibility.

This work was done by Steven Macenka, Larry Hovland, Daniel Preston, Brian Zellers, and Kevin Downing of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1). NPO-35097*