equipped with custom wafer probes (see figure) designed for the noted frequency band, which is that of WR-3 waveguides [waveguides having a standard rectangular cross section of 0.0340 by 0.0170 in. (0.8636 by 0.4318 mm)]. Among other things, the measurements showed a peak gain of 10 dB at a frequency of 235 GHz.

This work was done by Douglas Dawson, King Man Fung, Karen Lee, Lorene Samoska, Mary Wells, Todd Gaier, and Pekka Kangaslahti of Caltech; and Ronald Grundbacher, Richard Lai, Rohit Raja, and Po-Hsin Liu of NGST for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).
NPO-42202

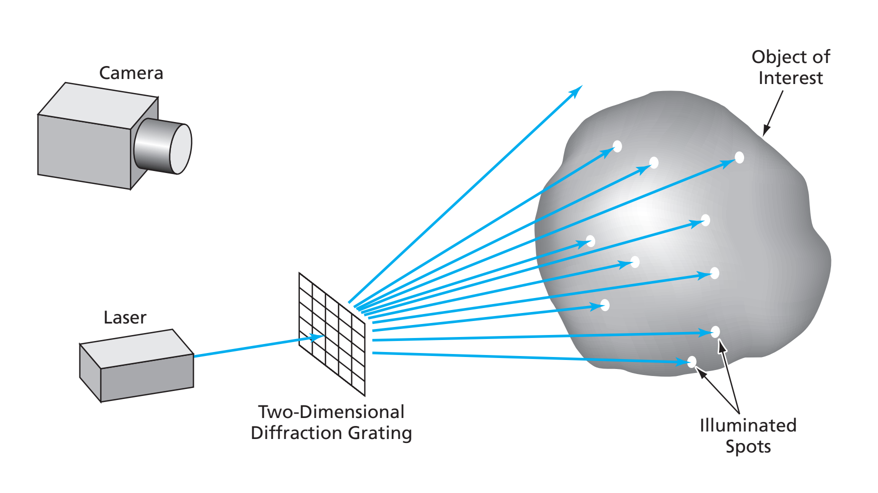
Mapping Nearby Terrain in 3D by Use of a Grid of Laser Spots

A relatively simple system would utilize triangulation.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed optoelectronic system, to be mounted aboard an exploratory robotic vehicle, would be used to generate a three-dimensional (3D) map of nearby terrain and obstacles for purposes of navigating the vehicle across the terrain and avoiding the obstacles. Like some other systems that have been, variously, developed and proposed to perform similar functions, this system would include (1) a light source that would project a known pattern of bright spots onto the terrain, (2) an electronic camera that would be laterally offset from the light source by a known baseline distance, (3) circuitry to digitize the output of the camera during imaging of the light spots, and (4) a computer that would calculate the 3D coordinates of the illuminated spots from their positions in the images by triangulation.

The difference between this system and the other systems would lie in the details of implementation. In this system, the illumination would be provided by a laser. The beam from the laser would pass through a two-dimensional diffraction grating, which would divide the beam into multiple beams propagating in different, fixed, known directions (see figure). These beams would form a grid of bright spots on the nearby terrain and obstacles. The centroid of each bright spot in the image would be computed. For each such spot, the combination of (1) the centroid, (2) the known direction of the light beam that produced the spot, and (3) the known baseline would constitute sufficient information for calculating the 3D position of the spot.



A **Diffraction Grating Would Split a Laser Beam** into multiple beams to project a grid of bright spots onto an object of interest. A camera offset from the laser and diffraction grating would capture an image of the illuminated spots. The 3D positions of the spots would be computed from their positions in the image by triangulation.

Concentrating the illumination into spots, instead of into lines as in some other systems, would afford signal-to-noise ratios greater than those of such other systems and would thereby also enable this system to image terrain and obstacles out to greater distances. The laser could be pulsed to obtain momentary illumination much brighter than ambient illumination, and the camera could be synchronized with the laser to discriminate against ambient light between laser pulses.

This work was done by Curtis Padgett, Carl Liebe, Johnny Chang, and Kenneth Brown of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).
NPO-40611

Digital Beam Deflectors Based Partly on Liquid Crystals

Laser beams are switched to different directions, without using solid moving parts.

John H. Glenn Research Center, Cleveland, Ohio

A digital beam deflector based partly on liquid crystals has been demonstrated as a prototype of a class of optical beam-steering devices that contain no mechanical actuators or solid moving parts. Such beam-steering devices could be useful in a variety of applications, including free-space optical communications, switching in fiber-optic communications, general optical switching, and optical scanning. Liquid crystals are of special interest as active materials in nonmechanical beam steerers and deflectors because of their structural flexibility, low operating voltages, and the relatively low costs of fabrication of devices that contain them. Recent advances in synthesis of liquid-crystal materials and design of the nematic-liquid-crystal cells have resulted in significant improvements in properties (e.g., short response times and birefringence) that are important for effective beam steering.

A beam deflector of this type is a multistage device. Each stage consists mainly of (1) a passive birefringent prism made of yttrium orthovanadate (YVO_4) [alternatively, it could be made of a uniaxial smectic A liquid crystal] and (2) a switchable polarization rotator in the form of a cell containing a twisted nematic liquid crystal. A linearly polarized laser beam that one seeks to deflect travels through the liquid-crystal cell on the way to the passive birefringent prism. If no voltage is applied across the cell ("off" state), passage though the cell changes the direction of polarization by 90°. If a suitable non-zero voltage is applied across the cell ("on" state), then the polarization direction remains unchanged after passage through the cell. Therefore, by virtue of birefringence, depending on which of the two selectable polarizations has been imparted to the beam by the liquid-crystal cell, the beam propagates through the crystal in either of two different directions.

If a beam deflector of this type contained N stages, then it would be possible to switch the input laser beam to any of 2^N different output directions through electrical switching of the liquid-crystal cells. The prototype device operates with an incident 633-nm-wavelength beam from a helium/neon laser. It contains 4 stages and, hence, can deflect the beam to any of $2^4 = 16$ output directions. In this case, the directions are separated by increments of 8 milliradians. To obtain a relatively short response time (0.5 ms), the cells are made from so-called dual-frequency nematic liquid crystals and operated in a special addressing scheme that features amplitude- and frequency-modulated driving voltage.

This work was done by John J. Pouch and Felix A. Miranda of Glenn Research Center; Liubov Kreminska, Oleg Pishnyak, Andrii Golovin, and Oleg D. Lavrentovich of Kent State University; and Bruce K. Winker of Rockwell Scientific Company LLC. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17947-1.

Narrow-Band WGM Optical Filters With Tunable FSRs

Microwave signals generated by optoelectronic oscillators can be tuned.

NASA's Jet Propulsion Laboratory, Pasadena, California

Optical resonators of the whispering-gallery-mode (WGM) type featuring DC-tunable free spectral ranges (FSRs) have been demonstrated. Previously, the FSRs of WGM optical resonators were determined solely by the resonator geometries and materials: hence, the FSR of such a resonator could be tailored by design, but once the resonator was constructed, its FSR was fixed. By making the FSR tunable, one makes it possible to adjust, during operation, the frequency of a microwave signal generated by an optoelectronic oscillator in which an WGM optical resonator is utilized as a narrow-band filter.

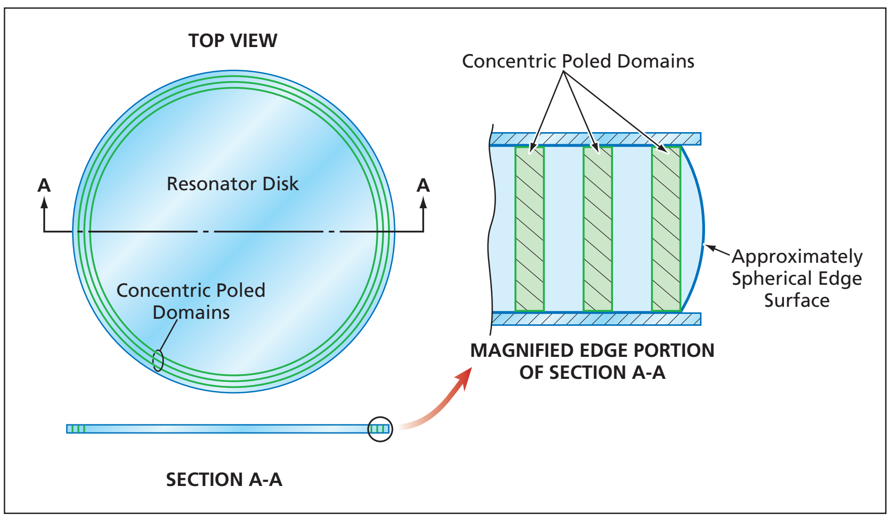


Figure 1. **Concentric Poled Domains** in a ferroelectric electro-optical resonator disk can be engineered to enable relative frequency shifting of adjacent radial resonator modes.

Each tunable WGM resonator was made from a disk of lithium niobate, 2.6 mm in diameter and 120 µm thick. The edge of the disk was rounded by polishing to an approximately spherical surface. A ferroelectric-domain structure characterized by a set of rings concentric with the axis of the disk (see Figure 1) was created by means of a poling process in which a 1-µm-diameter electrode was dragged across the top surface of the disk in the concentric-ring pattern while applying a 2.5-kV bias between the electrode and a conductor in contact with the bottom surface of the disk. After the poling process, the top and bottom surfaces of the disk were placed in contact with metal electrodes that, in turn, were connected to a regulated DC power supply that was variable from 0 to 150 V. When a DC bias electric field is applied in such a structure, the indices of refraction in the positively poled concentric rings and in the unflipped, negatively poled concentric regions change by different amounts.

The concentric-ring ferroelectric-domain structure of such a resonator can be engineered so that it overlaps with one or more radial resonator modes more than it does with other, adjacent modes. As a result, when the indices of refraction change in response to DC bias, some modes shift in frequency by amounts that differ from those of adjacent modes; the difference in frequency shift amounts to the desired change in the FSR between the affected adjacent modes.

A test was performed on each tunable resonator to observe the absorption spectrum of the resonator and the changes in frequencies of adjacent modes of interest as the applied DC bias voltage was varied.