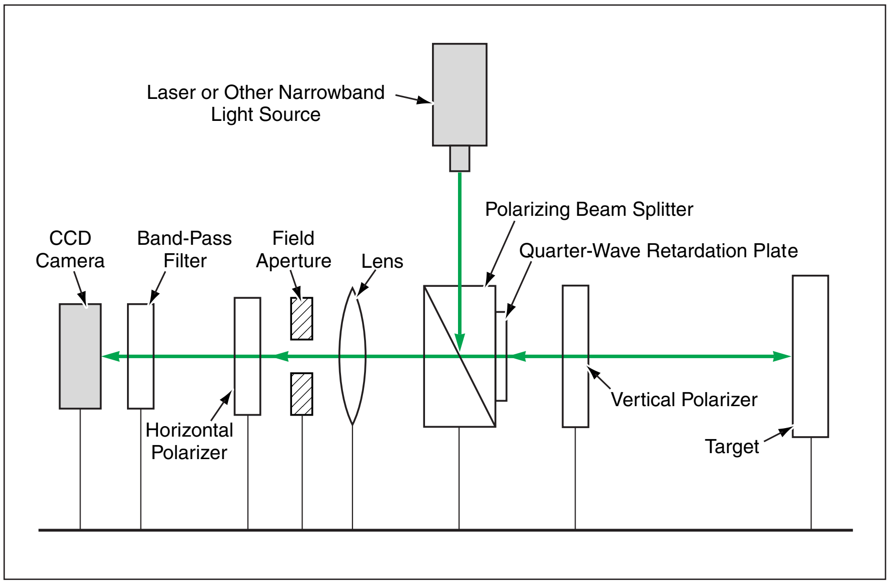

Only One Optical Path is used for both illuminating and viewing the target with laser light. Blackbody radiation from the target is suppressed by the crossed (horizontal and vertical) polarizers.

circularly polarized. The circularly polarized laser light passes undisturbed through a vertical polarizer, then travels along the optical axis to the target. Reflection from the target reverses the circular polarization. The reflected laser light passes again through the vertical polarizer and then through the quarter-wave retardation plate, which converts the reverse circular polarization to horizontal polarization.

The polarizing beam splitter passes the horizontally polarized reflected laser light, which then passes through a lens, a field aperture (which helps to increase contrast by blocking background light), a horizontal polarizer, and a filter having a 20-nm-wide wavelength pass band. The reflected laser light ultimately comes to focus in a charge-coupled-device (CCD) camera. At the same time, the crossed polarizers and the band-pass filter discriminate the wideband, randomly polarized blackbody light from both the target and the background.

Because the intensity of blackbody radiation is proportional to the fourth power of absolute temperature, it could be necessary to increase the laser power to maintain adequate contrast at higher temperatures. A prototype LICES has been found to yield high-contrast images at temperatures 1,500 °C.

This work was done by William K. Witherow and Richard R. Holmes of **Marshall Space Flight Center** *and Robert L. Kurtz of Pace & Waite, Inc.*

This invention has been patented by NASA (U.S. Patent No. 6,366,403). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31561-1.

Electrically Tunable Terahertz Quantum-Cascade Lasers

These devices would supplant gas lasers as far-infrared sources.

NASA's Jet Propulsion Laboratory, Pasadena, California

Improved quantum-cascade lasers (QCLs) are being developed as electrically tunable sources of radiation in the far infrared spectral region, especially in the frequency range of 2 to 5 THz. (Heretofore, the wavelengths of QCLs have been adjusted by changing temperatures, but not by changing applied voltages or currents.) In comparison with gas lasers now used as far-infrared sources, these QCLs would have larger wavelength tuning ranges, would be less expensive, and would be an order of magnitude less massive and power-hungry. It is planned to use the improved QCLs initially as the active components of local oscillators in spaceborne heterodyne instruments for studying infrared spectral lines of molecules of scientific interest. On Earth, the QCLs could be used as far-infrared sources for medical glucose-monitoring and heart-monitoring instruments, chemical-analysis and spectral-imaging systems, and imaging instruments that exploit the ability of terahertz radiation to penetrate cloth and walls for detection of contraband weapons.

The structures of QCLs and the processes used to fabricate them have much in common with those of multiple-quantum-well infrared photodetectors described in numerous previous *NASA Tech Briefs* articles. In one of four approaches being followed in the present development effort, the focus is upon designing and fabricating the structures to obtain heterogeneous cascades for different electric fields and different wavelengths in order to enable electrical tuning of laser emission wavelengths. Both the variation of the emission wavelength and the targeted range of the electric-field strength for each cascade would be kept small so the spectral gains of adjacent cascades at any given electric-field strength in the target range would overlap. This approach is expected to afford the desired variation of the gain maximum with electric-field strength, so that a change in applied bias voltage would result in a wavelength change.

In the second approach, layers of a QCL structure are to be graded to modify the shapes and depths of quantum wells, such that the electronic wave functions in the quantum wells and the transition energies between them would change with an intentional variation of the applied bias electrical field. A change of the bias applied to such a structure would result in a change in the energy and, hence, of the wavelength of the lasing transition.

In the third approach, the focus is on exploiting distributed-feedback and distributed-Bragg-reflector QCL architectures to achieve wavelength tuning through variation of applied electric current.

In the fourth approach, which is complementary to the other three, the focus is on increasing maximum operating temperatures and output power levels in continuous-wave operation. In a given QCL, this approach may involve one or more of the following changes: reducing the threshold current density, improving mounting and packaging to enhance removal of heat and reduce stresses, and optimizing designs of the active regions, injectors, and waveguide. Moreover, optimization of design for increasing maximum operating temperature and output power must include finding the most advantageous combination of the designs of the active regions and waveguide for optimal tuning performance.

This work was done by Sarath Gunapala, Alexander Soidel, and Kamjou Mansour of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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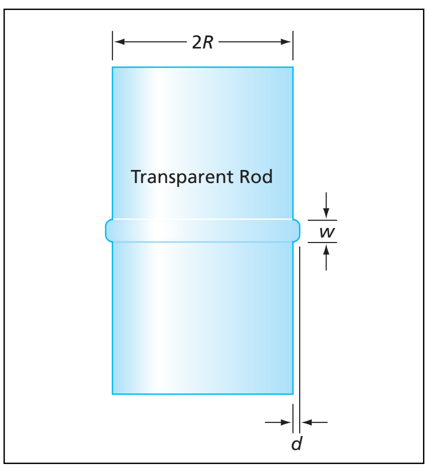
Refer to NPO-41611, volume and number of this NASA Tech Briefs *issue, and the page number.*

Few-Mode Whispering-Gallery-Mode Resonators

Simple structures function similarly to single-mode optical fibers.

NASA's Jet Propulsion Laboratory, Pasadena, California

Whispering-gallery-mode (WGM) optical resonators of a type now under development are designed to support few well-defined waveguide modes. In the simplest case, a resonator of this type would support one equatorial family of WGMs; in a more complex case, such a resonator would be made to support two, three, or some other specified finite number of modes. Such a resonator can be made of almost any transparent material commonly used in optics. The nature of the supported modes does not depend on which material is used, and the geometrical dispersion of this resonator is much smaller than that of a typical prior WGM resonator. Moreover, in principle, many such resonators could be fabricated as integral parts of a single chip.



An **Integral Thin, Narrow Belt** around a transparent rod acts as a circumferential optical waveguide. With suitable choice of *d* and *w* in conjunction with *R*, this structure can be made to act as a single- or few-mode WGM resonator.

Basically, a resonator of this type consists of a rod, made of a suitable transparent material, from which protrudes a thin circumferential belt of the same material. The belt is integral with the rest of the rod (see figure) and acts as a circumferential waveguide. If the depth (d) and width (w) of the belt are made appropriately small, then the belt acts as though it were the core of a single-mode optical fiber: the belt and its adjacent supporting rod material support a single, circumferentially propagating mode or family of modes.

It has been shown theoretically that the fiber-optic-like behavior of the belt-on-rod resonator structure can be summarized, in part, by the difference, Δn, between (1) an effective index of refraction of an imaginary fiber core and (2) the index of refraction (n) of the transparent rod/belt material. It has also been shown theoretically that for a given required value of Δn, the required depth of the belt can be estimated as $d \approx R\Delta n$, where R is the radius of the rod. It must be emphasized that this estimated depth is independent of n and, hence, is independent of the choice of rod material.

As in the cases of prior WGM resonators, input/output optical coupling involves utilization of evanescent fields. In the present case, there are two evanescent fields: one at the belt/air interface and one in the boundary region between the belt and the rest of the rod.

This work was done by Anatoliy Savchenkov, Dmitry Strekalov, Andrey Matsko, Vladimir Iltchenko, and Lute Maleki of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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