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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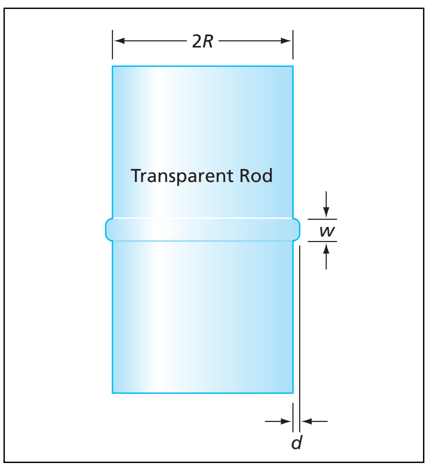
Few-Mode Whispering-Gallery-Mode Resonators

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).*

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