of a rod of transparent material or partly melting the tip of the rod. For example, the figure depicts such an optic made from a fused-silica rod of 30-mm length that tapers from 0.45-mm diameter at the narrow end to 3 mm at the wide end. The WGM resonator is a 500-µm axisymmetric bulge at the narrow end, formed by using a hydrogen torch to partly melt the narrow end. In operation, light is coupled into the WGM resonator via the cleaved tip of an optical fiber.

In use of such an optic as a sensor, the rod is dipped into liquid, the absorption spectrum of which one seeks to measure. Interference among the Bessel beams in the far-field region of the waveguide forms a helix-shaped light field. A charge-coupled-device camera is installed at a distance between 2 and 30 mm from the wide end of the optical fiber to observe this field. The dependence of the brightness of this field on the azimuth angle contains information on absorption as a function of wavelength.

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

Loading of desired modes is reduced, relative to loading of undesired modes.

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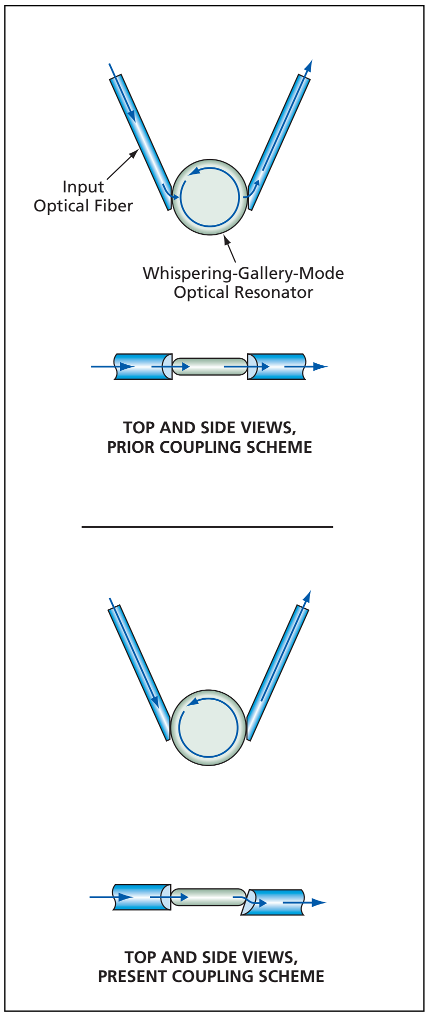
A Raman-scattering-suppressing input/ output coupling scheme has been devised for a whispering-gallery-mode optical resonator that is used as a four-wave-mixing device to effect an all-optical parametric oscillator. Raman scattering is undesired in such a device because (1) it is a nonlinear process that competes with the desired nonlinear four-wave conversion process involved in optical parametric oscillation and (2) as such, it reduces the power of the desired oscillation and contributes to output noise.

An all-optical parametric oscillator potentially offers the advantages of a narrow output spectral peak with a low overall noise floor. Often, undesirably, the threshold power for Raman scattering is lower than that for optical parametric oscillation, partly because phase matching is not a necessary precondition for Raman scattering. On the other hand, phase matching is necessary for four-wave mixing, in which pump power in fundamental modes of the resonator is converted to only fundamental modes of a different frequency. Some of the pump laser power needed for optical parametric oscillation can be Raman-scattered to non-fundamental modes of the resonator. The resonance quality factors (*Q* values) of these non-fundamental modes are not reduced by the presence of input and output fiber-optic couplers designed according to a prior coupling scheme, and the threshold power levels of both competing nonlinear processes decrease with increasing *Q* values. Moreover, when the pump power reaches the Raman-scattering threshold, the *Q* values of the pump modes decrease, with consequent increase in the oscillator output noise. For these reasons, it is highly desirable to utilize a modified coupling scheme to suppress the Raman modes without significantly suppressing the fundamental modes.



These Two Input/Output Coupling Schemes differ in the position and orientation of the output optical fiber. In the present scheme, the output fiber is tilted to reduce coupling to the fundamental modes of the resonator.

The essence of the present input/output coupling scheme is to reduce output loading of the desired resonator modes while increasing output loading of the undesired ones. The figure illustrates the prior and present coupling schemes. In the prior scheme, the input and output couplers are both positioned and oriented to effect coupling to the fundamental modes of the resonator. The *Q* of the fundamental modes is reduced by this coupling — especially by output coupling to the load. In the present scheme, the input coupler is still positioned and oriented to effect coupling to the fundamental modes, but the output coupler is tilted to greatly reduce coupling to the fundamental modes without reducing coupling to the Raman modes. As a result, the *Q* values of the fundamental modes are increased while the output loading reduces the *Q* values (and thereby increases the threshold power) of the Raman modes.

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

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