Compact Dielectric-Rod White-Light Delay Lines

Achievable group delays would be limited only by optical losses in materials.

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Optical delay lines of a proposed type would be made from rods of such dielectric materials as calcium fluoride, fused silica, or sapphire. These would offer advantages over prior optical delay lines, as summarized below.

Optical delay lines are key components of opto-electronic microwave oscillators, narrow-band opto-electronic microwave filters, evanescent-field optical biochemical detectors, and some Fourier-Transform spectrum analyzers. Heretofore, optical delay lines used in such applications have been of two types: resonators and coiled long optical fibers, both of which have disadvantages:

- Resonators are compact, but excitation must be provided by narrow-band lasers. Wide-band (including noisy) laser light cannot be coupled efficiently to narrow-band resonators.
- When light is coupled into a narrow-band resonator from a source of reasonably high power, a significant amount of optical energy circulates within the resonator, causing nonlinear loss and significant noise.
- Typically, a coil-type optical delay line is made of fused-silica fiber, which exhibits fundamental loss. To overcome the limit imposed by the optical loss in fused silica, it would be necessary to use fibers having crystalline cores.
- Although space is saved by winding fibers into coils, fiber-coil delay lines are still inconveniently bulky.

The proposed compact dielectric-rod delay lines would exploit the special class of non-diffracting light beams that are denoted Bessel beams because their amplitudes are proportional to Bessel functions of the radii from their central axes. High-order Bessel beams can have large values of angular momentum. They can be generated with the help of whispering-gallery-mode optical resonators, as described, for example, in "Simplified Generation of High-Angular-Momentum Light Beams" (NPO-42965) *NASA Tech Briefs*, Vol. 31, No. 3 (March 2007), page 8a. In a delay line according to the proposal, the dielectric rod would be dimensioned to function as a multimode waveguide. Suitably chosen high-angular-momentum modes in such a waveguide exhibit low group velocity (hence, long delay) and no resonance. Such a delay line could perform well at any wavelength or range of wavelengths within the transparency wavelength band of the dielectric material, and the maximum possible group delay achievable through suitable design would be limited only by the optical loss in the rod material.

This work was done by Lute Maleki, Andrey Matsko, Anatoliy Savchenvkov, and Dmitry Strekalov of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).NPO-43459

Single-Mode WGM Resonators Fabricated by Diamond Turning

Resonators having desired spectral responses can be reproduced efficiently.

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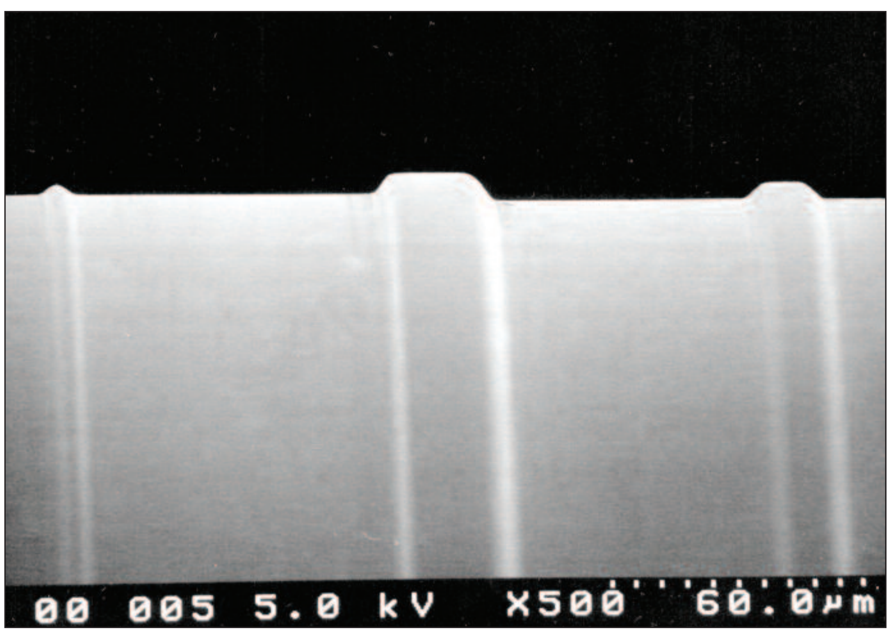
A diamond turning process has made possible a significant advance in the art of whispering-gallery-mode (WGM) optical resonators. By use of this process, it is possible to fashion crystalline materials into WGM resonators that have ultrahigh resonance quality factors (high *Q* values), are compact (ranging in size from millimeters down to tens of microns), and support single electromagnetic modes.

This development combines and extends the developments reported in "Few-Mode Whispering-Gallery-Mode Resonators" (NPO-41256), *NASA Tech Briefs*, Vol. 30, No. 1 (January 2006), page 16a and "Fabrication of Submillimeter Axisymmetric Optical Components" (NPO-42056), *NASA Tech Briefs*, Vol. 31, No. 5 (May 2007), page 10a. To recapitulate from the first cited prior article: A WGM resonator of this special type consists of a rod, made of a suitable transparent material, from which protrudes a thin circumferential belt of the same material. The



Circumferential Belts were formed by diamond turning on the initially cylindrical surface of a CaF_2 rod. The radial depths and axial widths of the belts were chosen to make some of the belts act as single-mode and some as multi-mode WGM resonators.