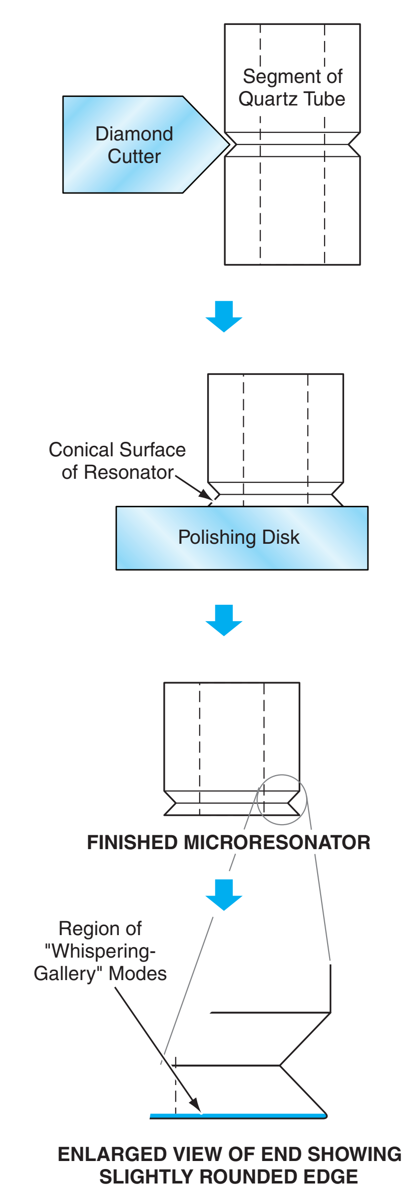

A **Microresonator Would Be Fabricated** from a length of silica tube by a process of diamond cutting, mechanical polishing, and fire polishing.

rication process are expected to be amenable to production of multiple microresonators having reproducible spectral parameters — including, most notably, high values of the resonance quality factor (Q) and reproducible resonance frequencies.

High-Q optical microresonators are key components in many contemplated advanced optoelectronic applications, including high-stability, narrow-line-width microlasers; spectrometers; remote-sensing systems; memory devices; and optical delay lines. In all such applications, there are requirements for stable and repeatable spectra that contain the resonance spectral lines of interest and do not contain unwanted lines: in other words, there are requirements for microresonators that exhibit high Q with reproducible sparse spectra. Although prior microsphere and microtorus optical resonators have been shown to have the potential to satisfy these requirements, the techniques used heretofore to fabricate them, involving melting individual resonators under manual control, do not yield reproducible spectral parameters and, therefore, are not suitable for production of multiple, functionally identical units.

The figure depicts a microresonator and the fabrication thereof according to the proposal. In preparation for fabrication of a batch of microresonators, one would choose a silica tube of precisely calibrated diameter (typically about 6 mm), so that all the resonators in the batch could be relied upon to have the same diameter. One would cut the tube into shorter segments — one for each resonator. By use of a diamond cutter, a circumferential V groove would be made on the outer surface of each segment. By polishing with a diamond disk, all the material would be removed from one end of the segment (the lower end in the figure), up to the edge of the groove. Thus, what would remain at the polished end of the tube would be a quasi-toroidal resonator structure having a conical outer surface.

The edge region would be fire-polished by use of a hydrogen/oxygen torch to eliminate the roughness of the cut edge and conical surface and the residual roughness of the mechanically polished end face of the tube segment. This smoothing of the surface would reduce the loss of light propagating in whispering-gallery modes, thereby helping to ensure high Q (anticipated to be 10^9). The fire polishing would also round the edge slightly, but the radius of curvature of the edge would be small enough that the spectrum would remain sparse.

This work was done by Anatoliy Savchenkov, Vladimir Iltchenko, Lute Maleki, and Dimitri Kossakovski 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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Exact Tuning of High-Q Optical Microresonators by Use of UV

Resonance frequencies can be shifted permanently by controlled amounts.

NASA's Jet Propulsion Laboratory, Pasadena, California

In one of several alternative approaches to the design and fabrication of a "whispering-gallery" optical microresonator of high resonance quality (high Q), the index of refraction of the resonator material and, hence, the resonance frequencies (which depend on the index of refraction) are tailored by use of ultraviolet (UV) light. The principles of operation of optical microresonators, and other approaches to the design and fabrication of optical microresonators, have been described in prior *NASA Tech Briefs* articles, including the two immediately preceding this one.

In this approach, a microresonator structure is prepared by forming it from an ultraviolet-sensitive material. Then the structure is subjected to controlled exposure to UV light while its resonance frequencies are monitored. This approach is applicable, for example, to the fabrication of optical microresonators from silica doped with germanium. This material exhibits low optical loss at a wavelength of 1,550 nm — a wavelength often used in optical communication systems. It is also highly sensitive to UV light: its peak sensitivity occurs at a wavelength of 334 nm, and

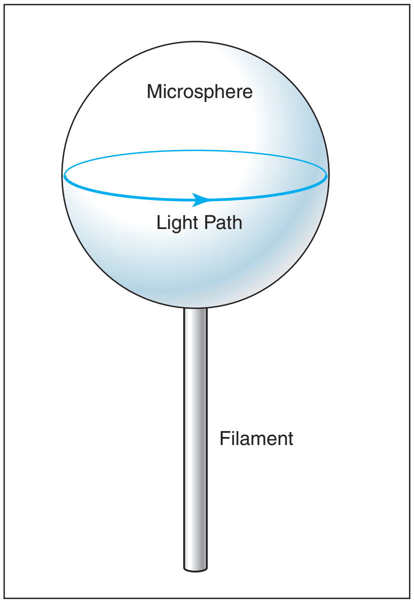

Figure 1. A **Spherical Optical Microresonator** (microsphere) is formed by melting one end of a Ge-doped SiO_2 filament.

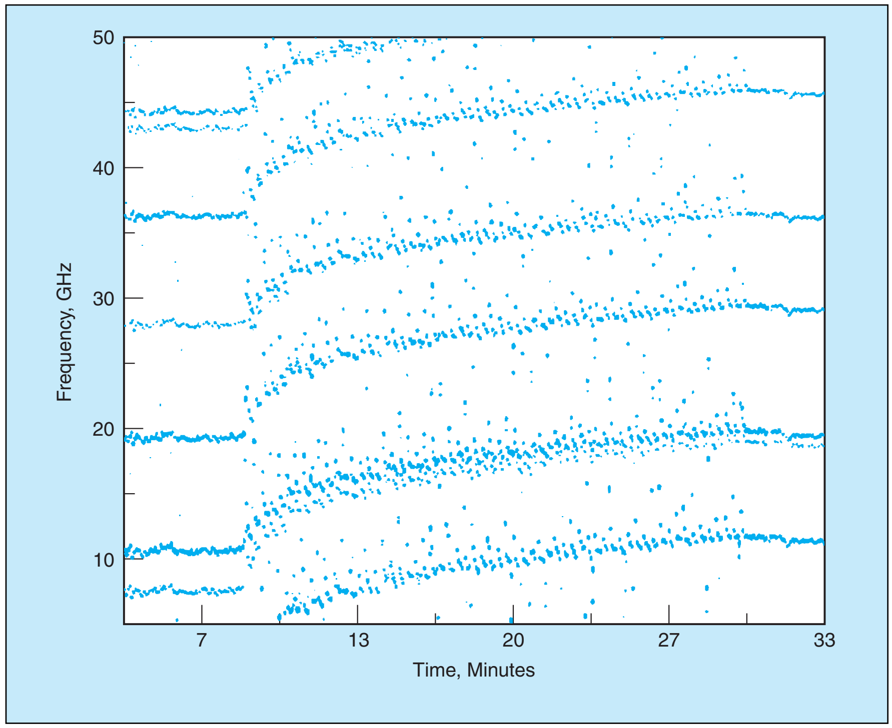

Figure 2. The **Shift in Resonance Frequencies** of a Ge-doped SiO_2 microsphere of 240-μm diameter was measured as a function of time of exposure to laser light at a wavelength of 351 nm.

its index of refraction can be shifted by as much as 10^{-2} by irradiating it at an argon-ion-laser wavelength of 351 nm.

Fabrication begins with softening a Ge-doped SiO_2 rod by use of a hydrogen/oxygen microburner and stretching the rod into a filament ≈30 μm wide. The tip of the filament is heated in the hydrogen/oxygen flame to form a sphere having a diameter between about 100 μm and about 1 mm (see Figure 1). Then the resonance frequencies of the sphere used as a microresonator are measured while the sphere is irradiated with UV light at a power of 1.5 W from an argon-ion laser that can be operated at either of two wavelengths: 379 or 351 nm. Irradiation at the longer wavelength heats the sphere and thereby temporarily shifts the resonance frequencies but does not cause a permanent change in the index of refraction. Irradiation at the shorter wavelength changes the index of refraction permanently.

At first, for the purpose of adjusting the optics that focus the laser light on the sphere, the laser is operated at the longer wavelength and the adjustments performed to maximize the shift of resonance frequencies. Then the laser is operated at the shorter wavelength while the resonance frequencies are monitored. The UV radiation is terminated when the resonance frequencies have shifted by the desired amount. For example, a typical shift of ≈10 GHz can be achieved in a microsphere of 240-μm diameter (see Figure 2).

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

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