pable of data rates of 11 Mb/s over distances up to 40 km. The WLAN is configured for remote control of the camera and transmission of acquired imagery to the ground station. A bridge in the airborne network serves as the link between an airborne system payload computer and an omnidirectional stub antenna on the underside of the airplane. A bridge in the ground station serves as a link between the ground antenna and a laptop computer. The remote-control software is installed in both the system payload computer and the portable laptop computer. The ground-based payload operator controls each camera remotely by use of the laptop computer.

Testing and development of the system were continuing at the time of reporting the information for this article. Particularly notable is a flight test, performed in September 2002, to demonstrate safe and effective operation of the system in an agricultural setting in FAA controlled airspace. The airplane was flown for four hours over a 15-km^2 coffee plantation in Hawaii, under supervision by Honolulu air-traffic controllers as though it were a conventionally piloted aircraft. The airplane was shown to be capable of flying planned routes and to perform spontaneous maneuvers to collect imagery in cloud-free areas. The WLAN was capable of downloading image data at rates exceeding 5 Mb/s, making all image data available for viewing, enhancing, and printing within a few minutes of collection. During the latter part of the flight, the payload was operated over an established wide-area network by an operator located on the United States mainland at a distance of 4,000 km.

This work was done by Robert G. Higgins, Steve E. Dunagan, Don Sullivan, Robert Slye, and James Brass of **Ames Research Center***; Joe G. Leung, Bruce Gallmeyer, Michio Aoyagi, and Mei Y. Wei of Dryden Flight Research Center; Stanley R. Herwitz of Clark University; Lee Johnson and Jian Zheng of California State University; and John C. Arvesen of Kauai Airborne Sciences. Further information is contained in a TSP (see page 1).*
ARC-15061

A Resonator for Low-Threshold Frequency Conversion

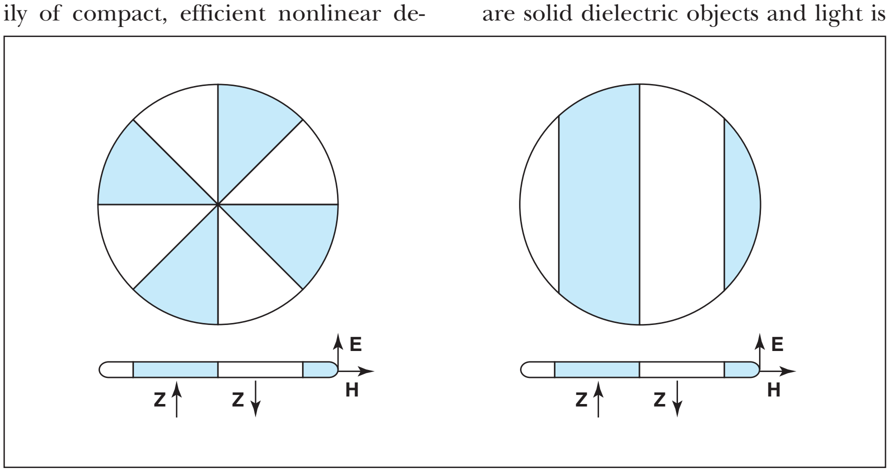
A nonlinear dielectric whispering-gallery resonator would be poled for quasi-phase-matching.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed toroidal or disklike dielectric optical resonator (dielectric optical cavity) would be made of an optically nonlinear material and would be optimized for use in parametric frequency conversion by imposition of a spatially periodic permanent electric polarization. The poling (see figure) would suppress dispersions caused by both the material and the geometry of the optical cavity, thereby effecting quasi-matching of the phases of high-resonance-quality (high-Q) whispering-gallery electromagnetic modes. The quasi-phase-matching of the modes would serve to maximize the interactions among them. Such a resonator might be a prototype of a family of compact, efficient nonlinear devices for operation over a broad range of optical wavelengths.

A little background information is prerequisite to a meaningful description of this proposal:

- Described in several prior *NASA Tech Briefs* articles, the whispering-gallery modes in a component of spheroidal, disklike, or toroidal shape are waveguide modes that propagate circumferentially and are concentrated in a narrow toroidal region centered on the equatorial plane and located near the outermost edge.
- For the sake of completeness, it must be stated that even though optical resonators of the type considered here are solid dielectric objects and light is confined within them by total internal reflection at dielectric interfaces without need for mirrors, such components are sometimes traditionally called cavities because their effects upon the light propagating within them are similar to those of true cavities bounded by mirrors.
- For a given set of electromagnetic modes interacting with each other in an optically nonlinear material (e.g., modes associated with the frequencies involved in a frequency-conversion scheme), the threshold power for oscillation depends on the mode volumes and the mode-overlap integral.
- Whispering-gallery modes are attractive in nonlinear optics because they maximize the effects of nonlinearities by occupying small volumes and affording high Q values.



A **Disk of $LiNbO_3$** or perhaps another suitable optically nonlinear material would be poled periodically, possibly in one of these two patterns. The labels **E** and **H** denote the electric and magnetic field axes, respectively, of a whispering-gallery electromagnetic field. The labels **Z** denote the vectors of permanent electric polarization.

In designing a cavity according to the proposal, one could reduce the mode volume and increase the mode-overlap integral, and thereby reduce the threshold power needed for oscillation, relative to those of a the nonlinear material in bulk form. The amplitude, configuration, and periodicity of the poling would be chosen so that the whispering-gallery modes to be quasi-phased-matched were the modes associated with the pump, signal, and idler frequencies involved in the parametric frequency conversion. It would be necessary to perform some complex computations, including calculation of quantum-mechanical mode

wave functions and evaluation of mode-overlap integrals, in order to analyze the performance of the cavity and design it for quasi-phase-matching.

The nonlinear cavity material would likely be commercially available flat, *Z*-cut $LiNbO_3$. The optimum poling geometry would be the one symmetrical about the center, shown on the left side of the figure. However, the imposition of centrally symmetric poling would be difficult. It would be much easier to use a slice of $LiNbO_3$ as supplied commercially with poling stripes; this would entail an increase in the threshold power for oscillation, relative to the optimum symmetrical poling pattern. On the other hand, the striped poling would enable the parametric generation of oscillations at multiple frequencies.

This work was done by Vladimir Iltchenko, Andrey Matsko, Anatoliy Savchenkov, 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:

Innovative Technology Assets Management
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109-8099
(818) 354-2240
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-30638, volume and number of this NASA Tech Briefs *issue, and the page number.*