radius. The modeled data indicates distinct spectral features for both the real and the imaginary part of the dielectric function. An ellipsometric measurement would determine this distinct feature and thus can be used to measure nanoparticle concentration. By "ellipsometric responses" is meant the intensities of light measured in various polarization states as functions of the angle of incidence and the polarization states of the incident light. These calculated ellipsometric responses are used as calibration curves: Data from subsequent ellipsometric measurements on real specimens are compared with the calibration curves. The concentration of the nanoparticles on a specimen is assumed to be that of the calibration curve that most closely matches the data pertaining to that specimen.

*This work was done by Srivatsa Venkatasubbarao and Lothar U Kempen of Intelligent Optical Systems, Inc. and Russell Chipman of the University of Arizona for Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. MFS-32506-1*

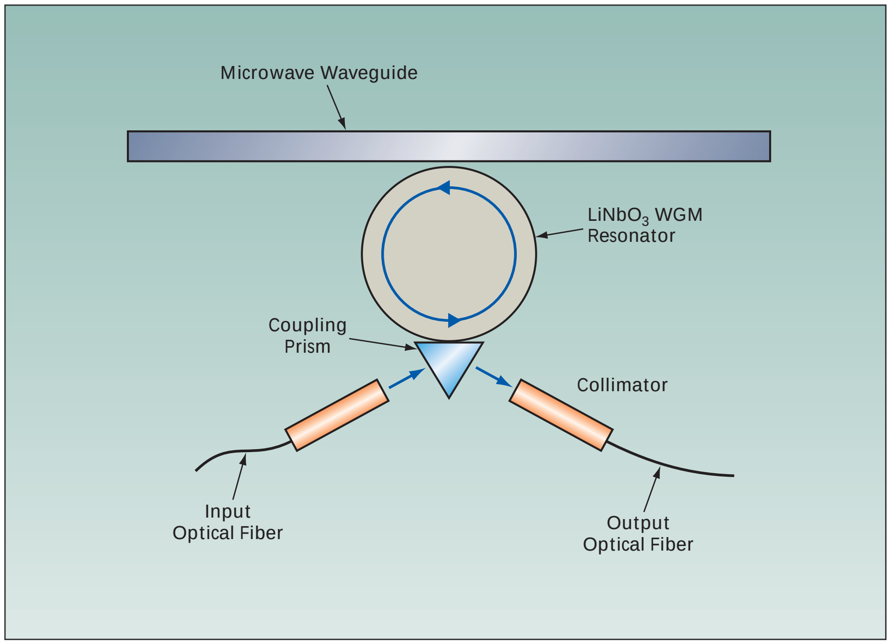
# Microwave-to-Optical Conversion in WGM Resonators

## Three-wave mixing, resonance, and low loss would result in high efficiency.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Microwave-to-optical frequency converters based on whispering-gallery-mode (WGM) resonators have been proposed as mixers for the input ends of microwave receivers in which, downstream of the input ends, signals would be processed photonically. A frequency converter as proposed (see figure) would exploit the nonlinearity of the electromagnetic response of a WGM resonator made of $LiNbO_3$ or another suitable ferroelectric material. Up-conversion would take place by three-wave mixing in the resonator.

The WGM resonator would be designed and fabricated to obtain (1) resonance at both the microwave and the optical operating frequencies and (2) phase matching among the input and output microwave and optical signals as described in the immediately preceding article. Because the resonator would be all dielectric — there would be no metal electrodes — signal losses would be very low and, consequently, the resonance quality factors (*Q* values) of the microwave and optical fields would be very large. The long lifetimes associated with the large *Q* values would enable attainment of high efficiency of nonlinear interaction with low saturation power. It is anticipated that efficiency would be especially well enhanced by the combination of optical and microwave resonances in operation at input signal frequencies between 90 and 300 GHz.




This **Frequency Up-Converter** would exploit three-way mixing among a microwave and two optical signals.

*This work was done by Anatoliy Savchenkov, Dmitry Strekalov, Nan Yu, Andrey Matsko, and Lute Maleki of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-45121*

# Four-Pass Coupler for Laser-Diode-Pumped Solid-State Laser

## A smaller laser slab can be made to perform comparably to a larger one.

*Goddard Space Flight Center, Greenbelt, Maryland*

A four-pass optical coupler affords increased (in comparison with related prior two-pass optical couplers) utilization of light generated by a laser diode in side pumping of a solid-state laser slab. The original application for which this coupler was conceived involves a neodymium-doped yttrium aluminum garnet (Nd:YAG) crystal slab, which, when pumped by a row of laser diodes at a wavelength of 809 nm, lases at a wavelength of 1,064 nm.

Heretofore, typically, a thin laser slab has been pumped in two passes, the second pass occurring by virtue of re-