

## Waveguide Harmonic Generator for the SIM

NASA's Jet Propulsion Laboratory, Pasadena, California

A second-harmonic generator (SHG) serves as the source of the visible laser beam in an onboard calibration scheme for NASA's planned Space Interferometry Mission (SIM), which requires an infrared laser beam and a visible laser beam coherent with the infrared laser beam. The SHG includes quasi-phase-matched waveguides made of MgO-doped, periodically poled lithium niobate, pigtailed with polarization-maintaining optical fibers. Frequency doubling by use of such waveguides affords

the required combination of coherence and sufficient conversion efficiency for the intended application. The spatial period of the poling is designed to obtain quasi-phase-matching at a nominal middle excitation wavelength of 1,319.28 nm.

The SHG is designed to operate at a warm bias (ambient temperature between 20 and 25 °C) that would be maintained in its cooler environment by use of electric heaters; the heater power would be adjusted to regulate

the temperature precisely and thereby maintain the required precision of the spatial period. At the state of development at the time of this reporting, the SHG had been packaged and subjected to most of its planned space-qualification tests.

*This work was done by Daniel Chang, Ilya Poberezhskiy, and Jerry Mulder of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-45253*

## Whispering Gallery Mode Resonator With Orthogonally Reconfigurable Filter Function

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An optical resonator has been developed with reconfigurable filter function that has resonant lines that can be shifted precisely and independently from each other, creating any desirable combination of resonant lines. This is achieved by changing the axial distribution of the effective refractive index of the resonator, which shifts the resonant frequency of particular optical modes, leaving all the rest unchanged. A reconfigurable optical filter is part of

the remote chemical detector proposed for the Mars mission (Planetary Instrument Definition and Development Program — PIDDP), but it is also useful for photonic communications devices.

*This work was done by Lute Maleki, Andrey Matsko, Dmitry Strelakov, and Anatoliy Savchenkov of Caltech for NASA's Jet Propulsion Laboratory.*

*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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*Refer to NPO-44948, volume and number of this NASA Tech Briefs issue, and the page number.*

## Stable Calibration of Raman Lidar Water-Vapor Measurements

Data from occasional radiosonde campaigns and routine laboratory lamp measurements are utilized.

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A method has been devised to ensure stable, long-term calibration of Raman lidar measurements that are used to determine the altitude-dependent mixing ratio of water vapor in the upper troposphere and lower stratosphere. Because the lidar measurements yield a quantity proportional to the mixing ratio, rather than the mixing ratio itself, calibration is necessary to obtain the factor of proportionality. The present method involves the use of calibration data from two sources: (1) absolute calibration data from *in situ* radiosonde measurements made during occasional campaigns and (2) partial calibration data obtained by use, on a regular schedule, of a lamp that emits in a known spectrum de-

termined in laboratory calibration measurements.

In this method, data from the first radiosonde campaign are used to calculate a campaign-averaged absolute lidar calibration factor ( $t_l$ ) and the corresponding campaign-averaged ratio ( $L_l$ ) between lamp irradiances at the water-vapor and nitrogen channel wavelengths. Depending on the scenario considered, this ratio can be assumed to be either constant over a long time ( $L = L_l$ ) or drifting slowly with time.

The absolutely calibrated water-vapor mixing ratio ( $q$ ) obtained from the  $i$ th routine off-campaign lidar measurement run is given by

$$q_i = P_i / t_i = LP_i / P'_i$$

where  $P_i$  is water-vapor/nitrogen measurement signal ratio,  $t_i$  is the unknown and unneeded overall efficiency ratio of the lidar receiver during the  $i$ th routine off-campaign measurement run, and  $P'_i$  is the water-vapor/nitrogen signal ratio obtained during the lamp run associated with the  $i$ th routine off-campaign measurement run. If  $L$  is assumed constant, then the lidar calibration is routinely obtained without the need for new radiosonde data. In this case, one uses  $L = L_l = P'_1 / t_1$ , where  $P'_1$  is the water-vapor/nitrogen signal ratio obtained during the lamp run associated with the first radiosonde campaign.

If  $L$  is assumed to drift slowly, then it is necessary to postpone calculation of  $q_i$  until after a second radiosonde campaign. In this case, one obtains a new value,  $L_2$ , from the second radiosonde

campaign, and for the  $i$ th routine off-campaign measurement run, one uses an intermediate value of  $L$  obtained by simple linear time interpolation between  $L_1$  and  $L_2$ .

*This work was done by Thierry Leblanc and Iain S. McDermid of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-45955*

## Bimaterial Thermal Compensators for WGM Resonators

Net thermal drifts of spectra would be cancelled to first order.

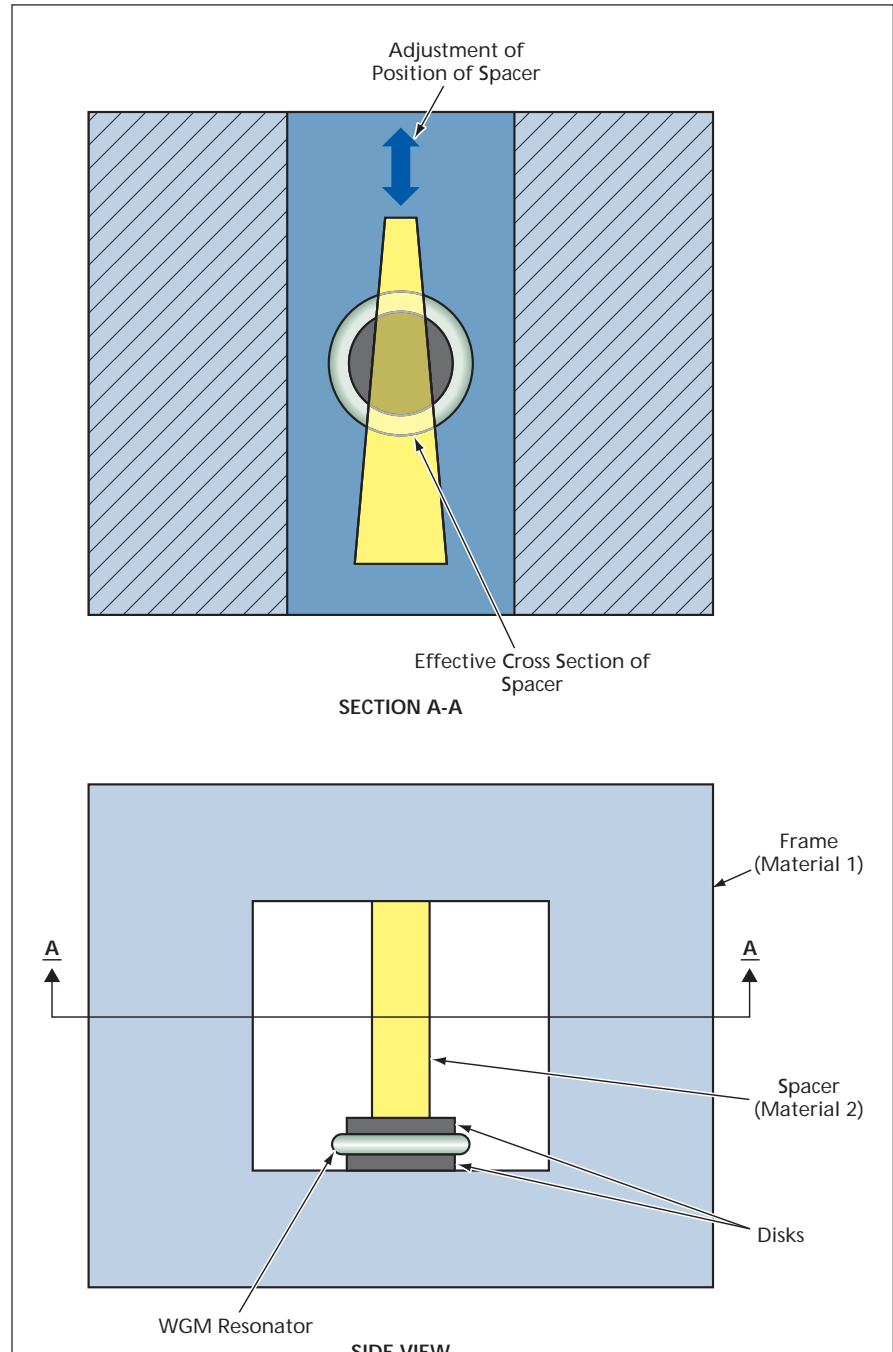
NASA's Jet Propulsion Laboratory, Pasadena, California

Bimaterial thermal compensators have been proposed as inexpensive means of preventing (to first order) or reducing temperature-related changes in the resonance frequencies of whispering-gallery-mode (WGM) optical resonators. A bimaterial compensator would apply, to a WGM resonator, a pressure that would slightly change the shape of the resonator and thereby change its resonance frequencies. Through suitable choice of the compensator dimensions and materials, it should be possible to make the temperature dependence of the pressure-induced frequency shift equal in magnitude and opposite in sign to the temperature dependence of the frequency shift of the uncompensated resonator so that, to first order, a change in temperature would cause zero net change in frequency.

A bimaterial compensator as proposed (see figure) would include (1) a frame made of one material (typically, a metal) having a thermal-expansion coefficient  $\alpha_1$  and (2) a spacer made of another material (typically, a glass) having a thermal-expansion coefficient  $\alpha_2$ . The WGM resonator would be sandwiched between disks and the resulting sandwich would be squeezed between the frame and the spacer (see figure). Assuming that the cross-sectional area of the frame greatly exceeded the cross-sectional area of the spacer and that the thickness of the sandwich was small relative to the length of the spacer, the net variation in a resonance frequency as a function of temperature would be given by

$$df/dT \approx \partial f/\partial T + (\partial f/\partial F) S_2 E_2 (\alpha_2 - \alpha_1)$$

where  $f$  is the resonance frequency,  $T$  is temperature,  $\partial f/\partial T$  is the rate of change of frequency as a function of temperature of the uncompensated resonator,  $\partial f/\partial F$  is the rate of change of frequency as a function of applied force  $F$  at constant temperature,  $S_2$  is the effective cross-sectional area of the



The Bimaterial Compensator would apply a temperature-dependent stress to counteract the temperature dependence of the spectrum of the uncompensated resonator.