The dopant and its concentration are chosen to optimize the performance of the bolometer, taking account of the bolometer operating temperature, the temperature of the source of infrared radiation to be detected, and other relevant environmental factors.

An important practical advantage of the use of silicon, in contradistinction to other semiconductors, is that the art of fabrication of electronic devices from silicon is mature, enabling mass production at low cost per device. An additional advantage accrues when indium is used as the dopant: Indium can be incorporated into silicon over a wide range of concentrations with little consequent change in the basic structure of the silicon matrix. Hence, with impunity, the concentration of indium dopant can be set at almost any desired value in an effort to obtain the desired electrical impedance.

This work was done by John Goebel and Robert McMurray of **Ames Research Center**. *Further information is contained in a TSP (see page 1).*

This invention has been patented by NASA (U.S. Patent No. 6,838,669). Inquiries concerning rights for the commercial use of this invention should be addressed to the Ames Technology Partnerships Division at (650) 604-2954. Refer to ARC-14577.

Multichannel X-Band Dielectric-Resonator Oscillator

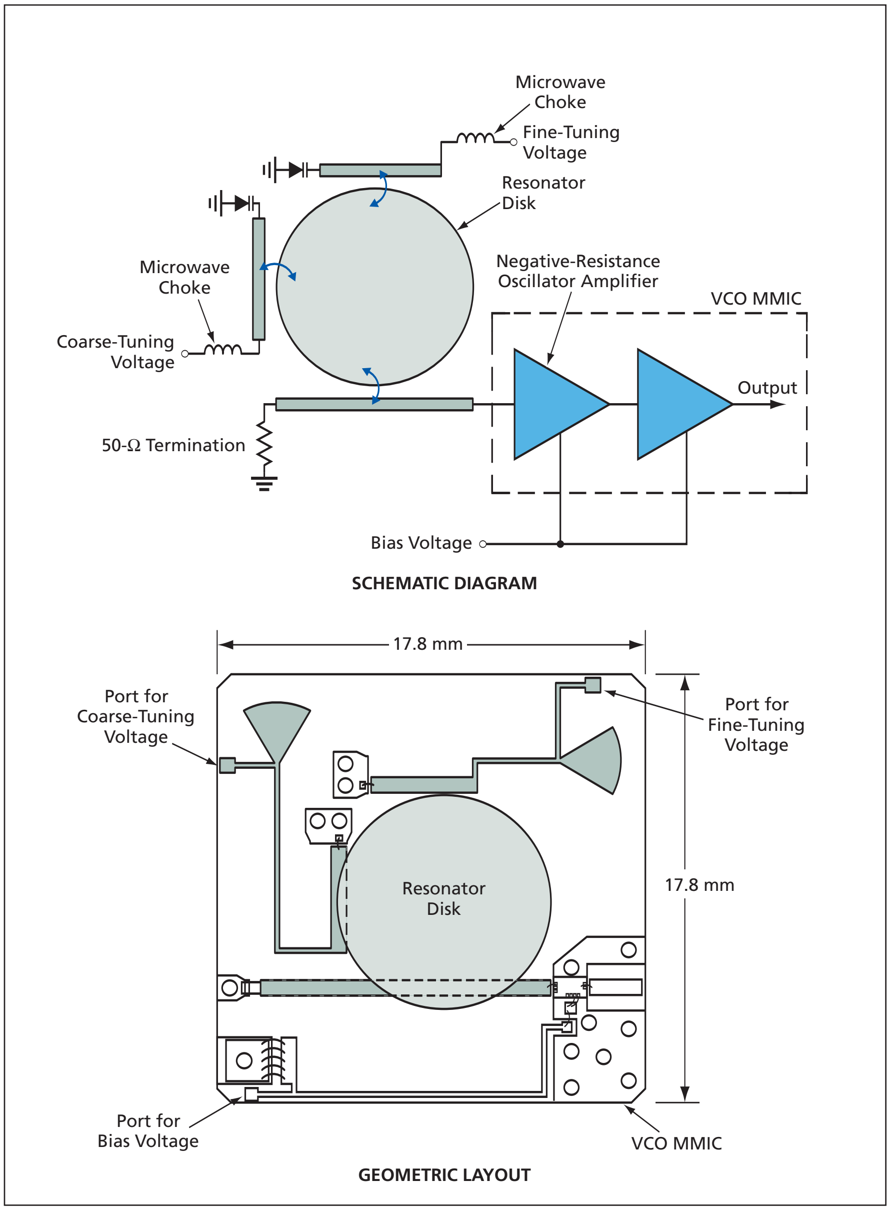
Unlike other DROs, this one is electrically tunable.

NASA's Jet Propulsion Laboratory, Pasadena, California

A multichannel dielectric-resonator oscillator (DRO), built as a prototype of a local oscillator for an X-band transmitter or receiver, is capable of being electrically tuned among and within 26 adjacent frequency channels, each 1.16 MHz wide, in a band ranging from ≈7,040 to ≈7,070 GHz. The tunability of this oscillator is what sets it apart from other DROs, making it possible to use mass-produced oscillator units of identical design in diverse X-band applications in which there are requirements to use different fixed frequencies or to switch among frequency channels.

The oscillator (see figure) includes a custom-designed voltage-controlled-oscillator (VCO) monolithic microwave integrated circuit (MMIC), a dielectric resonator disk ("puck"), and two varactor-coupling circuits, all laid out on a 25-mil (0.635-mm)-thick alumina substrate having a length and width of 17.8 mm. The resonator disk has a diameter of 8.89 mm and a thickness of 4.01 mm. The oscillator is mounted in an 8.9-mm-deep cavity in a metal housing.

The VCO MMIC incorporates a negative-resistance oscillator amplifier along with a buffer amplifier. The resonator disk is coupled to a microstrip transmission line connected to the negative-resistance port of the VCO MMIC. The two varactor-coupling circuits include microstrip lines, laid out orthogonally to each other, for coupling with the resonator disk. Each varactor microstrip line is DC-coupled to an external port via a microwave choke. One varactor is used for coarse tuning to select a channel; the other varactor is used (1) for fine tuning across the 1.16-MHz width of each channel and (2) as a feedback port for a phase-lock loop. The resonator disk is positioned to obtain (1) the most desir-



SCHEMATIC DIAGRAM

GEOMETRIC LAYOUT

Microstrip Lines provide coupling among the resonator disk, the tuning varactors, and the VCO MMIC.

able bandwidth, (2) relatively tight coupling with the microstrip connected to the coarse-tuning varactor, and (3) relatively loose coupling with the microstrip connected to the fine-tuning varactor.

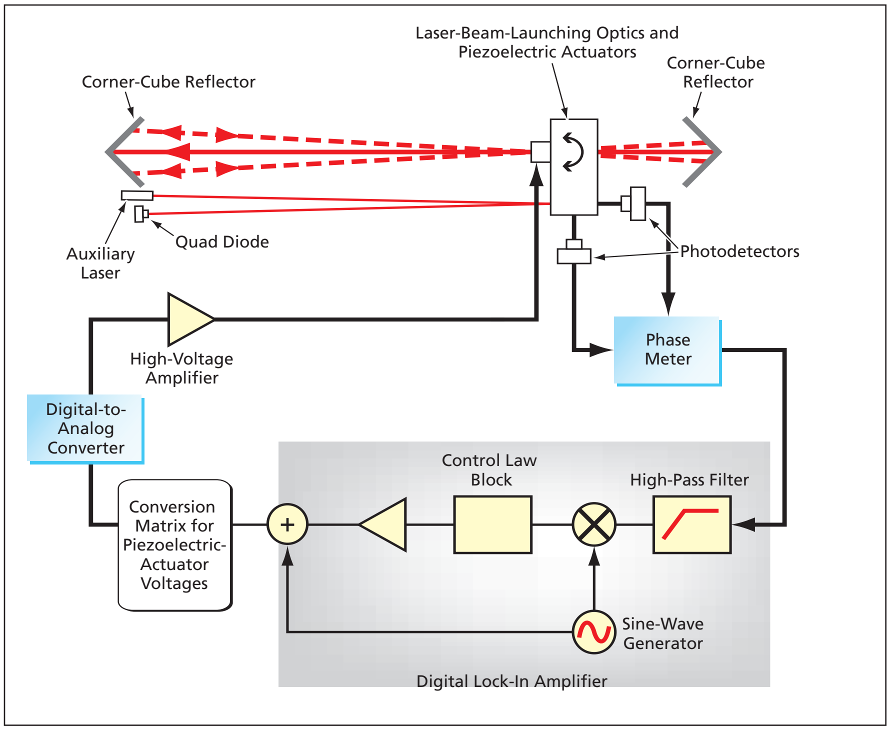
Measurements of performance showed that the oscillator can be switched among any of the 26 channels and can be phase-locked to a nominal frequency in any channel. The degree of nonlinearity of tuning was found not to exceed 2.5 percent. The tuning sensitivity was found to be 6.15 MHz/V at a bias offset of –2 V on the phase-lock-loop varactor. The phase noise of the oscillator in free-running operation was found to be –107 dBc/Hz (where "dBc" signifies decibels relative to the carrier signal) at 100 kHz away from the carrier frequency.

This work was done by Narayan Mysoor, Matthew Dennis, and Brian Cook of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-41275

Automatic Alignment of Displacement-Measuring Interferometer

Corrections are derived from fluctuations associated with circular dithering of a laser beam.

NASA's Jet Propulsion Laboratory, Pasadena, California



This **Simplified Schematic Diagram** of the control system illustrates the control of the tilt of the laser beam about one of two orthogonal tilt axes.

A control system strives to maintain the correct alignment of a laser beam in an interferometer dedicated to measuring the displacement or distance between two fiducial corner-cube reflectors. The correct alignment of the laser beam is parallel to the line between the corner points of the corner-cube reflectors: Any deviation from parallelism changes the length of the optical path between the reflectors, thereby introducing a displacement or distance measurement error.

On the basis of the geometrical optics of corner-cube reflectors, the length of the optical path can be shown to be $L = L_0\cos\theta$, where L_0 is the distance between the corner points and θ is the misalignment angle. Therefore, the measurement error is given by $\Delta L = L_0(\cos\theta - 1)$. In the usual case in which the misalignment is small, this error can be approximated as $\Delta L \approx -L_0\theta^2/2$.

The control system (see figure) is implemented partly in hardware and partly in software. The control system includes three piezoelectric actuators for rapid, fine adjustment of the direction of the laser beam. The voltages applied to the piezoelectric actuators include components designed to scan the beam in a circular pattern so that the beam traces out a narrow cone (60 microradians wide in the initial application) about the direction in which it is nominally aimed. This scan is performed at a frequency (2.5 Hz in the initial application) well below the resonance frequency of any vibration of the interferometer.

The laser beam makes a round trip to both corner-cube reflectors and then interferes with the launched beam. The interference is detected on a photodiode. The length of the optical path is measured by a heterodyne technique: A 100-kHz frequency shift between the launched beam and a reference beam imposes, on the detected signal, an interferometric phase shift proportional to the length of the optical path. A phase meter comprising analog filters and specialized digital circuitry converts the phase shift to an indication of displacement, generating a digital signal proportional to the path length.

If the axis of the conical scan is correctly aligned, then the path-length signal is steady and the path-length error remains constant at about $-L_0\theta_0^2/2$, where, in this case, θ_0 is the half cone angle. If, however, the axis of the conical scan is slightly misaligned, then the misalignment angle consists of a steady component θ_0 plus a small fluctuating component $\Delta\theta$. In this case, the optical-path length fluctuates by approximately $-L_0\theta_0\Delta\theta$. In a lock-in amplifier, the digital path-length signal is high-pass-filtered to eliminate the steady component, then the remaining fluctuating component is synchronously demodulated to generate DC signals proportional to the two tilt angles that characterize the misalignment. These signals are superimposed upon the voltages applied to the piezoelectric actuators to counteract the misalignment.

This work was done by Peter Halverson, Martin Regehr, Robert Spero, Oscar Alvarez-Salazar, Frank Loya, and Jennifer Logan of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40957