stalled in the vacuum manifold to match an electrometer circuit in the control and monitoring unit.

The instrument operates under control by a computer that runs custom software. Included in the software is a module for performing real-time monitoring of selected gases at a chosen update rate (e.g., once per second).

Like commercial instruments, this QITMS utilizes a mass-selective instability for mass analysis. Both commercial ion-trap analyzers from which the parts were taken to build the present unit have low-mass cutoffs of 4 Da. To extend the lower mass limit to 2 Da with the least amount of modification and fabrication, it was decided to increase the upper limit of frequency of the signal applied to coils to generate the trapping radio-frequency field. This decision was implemented through modifications of the signal-generating circuits and construction of replacement coils to provide multiple resonance frequencies from 1 to 4 MHz. Increasing the upper limit of frequency reduced the upper limit of the mass range below that of the unmodified commercial instruments, but this was acceptable because the upper mass limit of 50 Da required for this instrument remained within range.

The QITMS was initially tested at a frequency of 2.8 MHz with a sample gas mixture comprising 1.25 percent, each, of hydrogen, helium, oxygen, and argon in nitrogen. The results of this test showed readily identifiable ion signals at m/Z values of 2, 4, 32, and 40, with an upper m/Z limit only a few tenths above 40 (see figure). In a subsequent test, it was found that the desired m/Z range of 2 to 50 could be attained in operation at a frequency of 2.5 MHz. In other tests, it was found that the relative accuracy and precision in quantitating the four gases of interest were characterized by an error of no more than 10 percent of reading and a deviation of no more than 5 percent of reading, respectively. In still other tests, it was found that the lower limits of detectable concentrations were 25 parts per million (ppm) for hydrogen, 100 ppm for helium, slightly higher than 25 ppm for oxygen, and slightly higher than 10 ppm for argon.

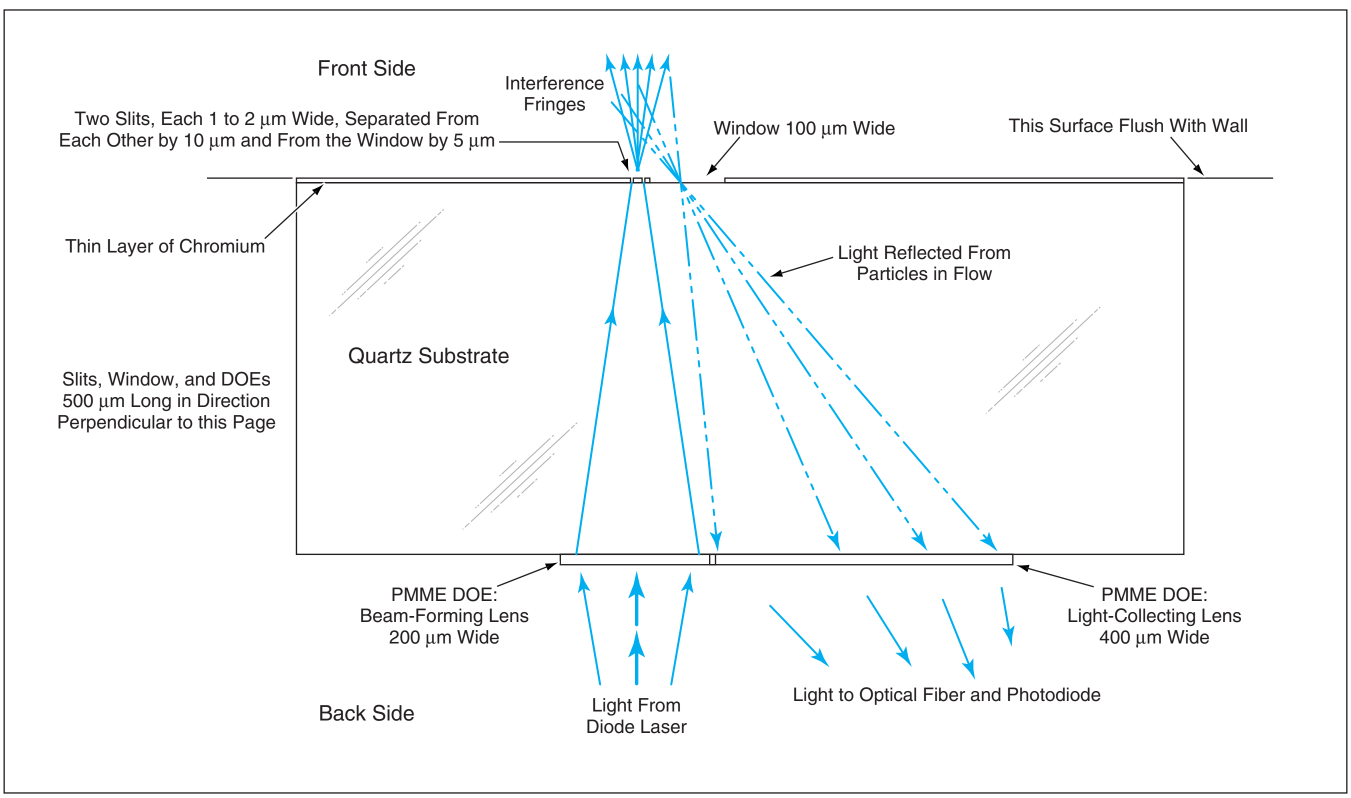
This work was done by William Helms of **Kennedy Space Center***; Timothy P. Griffin of Dynacs, Inc.; and Andrew Ottens and Willard Harrison of the University of Florida. Further information is contained in a TSP (see page 1). KSC-12428*

Miniature Laser Doppler Velocimeter for Measuring Wall Shear

Interference fringes are configured for sensitivity to a velocity gradient.

NASA's Jet Propulsion Laboratory, Pasadena, California

A miniature optoelectronic instrument has been invented as a nonintrusive means of measuring a velocity gradient proportional to a shear stress in a flow near a wall. The instrument, which can be mounted flush with the wall, is a variant of a basic laser Doppler velocimeter. The laser Doppler probe volume can be located close enough to the wall (as little as 100 µm from the surface) to lie within the viscosity-dominated sublayer of a turbulent boundary layer.



A **Unitary Assembly of Optical Components** is fabricated on a quartz substrate. For the sake of simplicity, such non-optical details as alignment marks and mounting features are omitted from this view.

Like other laser Doppler velocimeters, this instrument includes optics that split a laser beam into two parts that impinge on the probe volume from two different directions to form interference fringes in the probe volume. Also like other laser Doppler velocimeters, this instrument measures the frequency of variation of light reflected by particles entrained in the flow as they pass through the fringes (the velocity component that one seeks to measure is simply the product of this frequency and the fringe spacing). What distinguishes this instrument from other laser Doppler velocimeters is its highly miniaturized design and its unique fringe geometry.

The instrument (see figure) includes a diode laser, the output of which is shaped by a diffractive optical element (DOE) into two beams that have elliptical cross sections with very high aspect ratios. The DOE focuses these beams through two slits a few microns apart on a surface that, in use, is mounted flush with the wall that bounds the flow. Light reflected from flow particles that pass through the fringes is collected through a window (essentially, a third, wider slit). Another DOE acts as focusing lens that couples the collected light into an optical fiber that, in turn, couples the light to an avalanche photodiode. The output of the photodiode is processed to measure the frequency of variation in the intensity of the reflected light.

The interference between the laser beams forms fringes that diverge by an amount proportional to the distance from the wall: the fringes appear as radial spokes in the plane that contains a parallel-to-the-wall velocity component to be measured. Because the magnitude of this velocity component also increases linearly with distance from the wall in the viscosity-dominated flow regime and because the corresponding component of shear stress is proportional to the perpendicular-to-the-wall gradient of this velocity component, it follows that the frequency of variation of light reflected by particles entrained in the flow is proportional to the shear-stress component that one seeks to measure.

The critical optical components for manipulating the laser light are fabricated on a 0.5-mm-thick quartz substrate in a sequence of microfabrication steps. The front surface (the top surface in the figure) is coated with a thin film of chromium, then further coated with poly(methyl methacrylate) [PMMA]. The slits and window are formed in the chromium film by electron-beam lithography followed by wet etching. The back surface is coated with PMMA, in which the DOEs are formed by electron-beam lithography. The unitary assembly of optical components thus formed is mounted in a compact housing that also holds the diode laser and the fiber-optic-coupled photodiode.

This work was done by Morteza Gharib, Darius Modarress, Siamak Forouhar, Dominique Fourguette, Federic Taugwalder, and Daniel Wilson 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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Refer to NPO-20851, volume and number of this NASA Tech Briefs *issue, and the page number.*

Coherent Laser Instrument Would Measure Range and Velocity

This lightweight, low-power, compact instrument could have a variety of uses.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed instrument would project a narrow laser beam that would be frequency-modulated with a pseudorandom noise (PN) code for simultaneous measurement of range and velocity along the beam. The instrument performs these functions in a low mass, power, and volume package using a novel combination of established techniques. Originally intended as a low resource-footprint guidance sensor for descent and landing of small spacecraft onto Mars or small bodies (e.g., asteroids), the basic instrument concept also lends itself well to a similar application guiding aircraft (especially, small unmanned aircraft), and to such other applications as ranging of topographical features and measuring velocities of airborne light-scattering particles as wind indicators.

Several key features of the instrument's design contribute to its favorable performance and resource-consumption characteristics. A laser beam is intrinsically much narrower (for the same exit aperture telescope or antenna) than a radar beam, eliminating the need to correct for the effect of sloping terrain over the beam width, as is the case with radar. Furthermore, the use of continuous-wave (CW), erbium-doped fiber lasers with excellent spectral purity (narrow line width) permits greater velocity resolution, while reducing the laser's power requirement compared to a more typical pulsed solid-state laser. The use of CW also takes proper advantage of the increased sensitivity of coherent detection, necessary in the first place for direct measurement of velocity using the Doppler effect. However, measuring range with a CW beam requires modulation to "tag" portions of it for time-of-flight determination; typically, the modulation consists of a PN code. A novel element of the instrument's design is the use of frequency modulation (FM) to accomplish both the PN-modulation and the Doppler-bias frequency shift necessary for signed velocity measurements. This permits the use of a single low-power waveguide electro-optic phase modulator, while simultaneously mitigating the effects of speckle as a noise source in the coherent detection.

The instrument (see figure) would include a narrow-line-width CW laser, the output of which would be split into a local oscillator and signal arm. Within the instrument, optical beams would be routed, split, and combined by use of fiber and planar integrated optics. The signal arm beam would be frequency-modulated by the electro-optic phase modulator, fed by a serrodyne waveform generated either in software or hard-