hence, do not distort samples in most cases. The techniques used in fabrication are amenable to fabrication in batches, thereby enabling production at relatively low cost.

Silicon microleaks have potential for additional device functionality. For example, resistance heaters could be integrated into silicon microleak structures to enable heating of inlets to vaporize droplets to prevent clogging. Thermistors could also be integrated into silicon microleak structures for monitoring their temperatures. Yet another device concept is that of a one-shot-closing valve: an integrated resistance heater would be used to momentarily melt a microscopic piece of a suitable metal positioned near a channel to cause the metal to flow into, and thus plug, the channel. If all of the multiple channels in a silicon microleak structure were equipped with one-shot-closing valves, then the valves could be actuated, one at a time, to effect stepped reductions in the overall conductance of the microleak.

Silicon microleaks could contribute to the feasibility of proposed small, field-deployable mass spectrometers for homeland-security and point-of-care medical diagnostic applications. Silicon microleaks might also be useful as very-low-conductance calibrated leaks that could enable different approaches to environmental gas sampling. Orifices that support leak rates ranging from 0.1 to 5 standard cubic centimeters per minute are currently available for use in environmental sampling. Silicon microleaks, which can be made to support flow rates many orders of magnitude lower, would enable gas sampling with much smaller volumes.

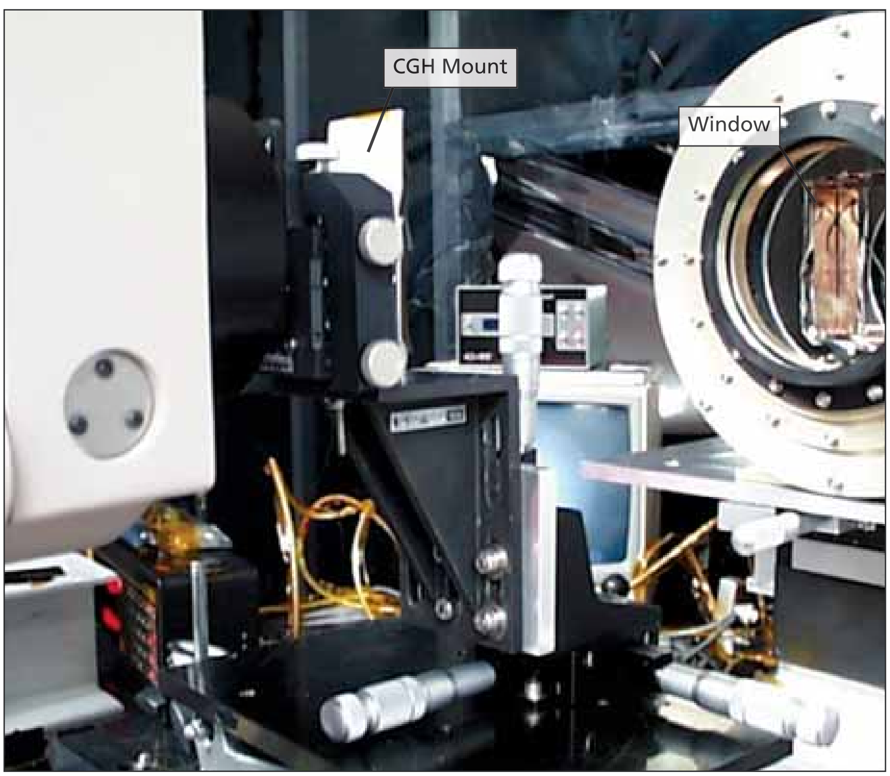
This work was done by Dan Harpold, Hasso Niemann, and Brian G Jamieson of Goddard Space Flight Center and Bernard A Lynch of MEI Technologies, Inc. Further information is contained in a TSP (see page 1). GSC-15341-1

CGH Figure Testing of Aspherical Mirrors in Cold Vacuums

Room-temperature and cryogenic tests yield complementary data on surface-figure errors.

Goddard Space Flight Center, Greenbelt, Maryland

An established method of room-temperature interferometric null testing of mirrors having simple shapes (e.g., flat, spherical, or spheroidal) has been augmented to enable measurement of errors in the surface figures of off-axis, non-axisymmetric, aspherical mirrors when the mirrors are located inside cryogenic vacuum chambers. The established method involves the use of a computer-generated hologram (CGH), functionally equivalent to a traditional null lens, to modify the laser beam of an imaging interferometer to obtain a reference wavefront that matches the ideal surface figure of a mirror under test. The CGH is inserted at the appropriate position and orientation in the optical path of the imaging interferometer, which, in turn, is appropriately positioned and oriented with respect to the mirror under test. Deviations of the surface figure of the mirror from the ideal surface figure manifest themselves as interference fringes. Interferograms are recorded and analyzed to deduce figure errors.



A **CGH Is Positioned** to modify a test laser beam that travels, via a window, to and from a mirror under test inside a cryogenic vacuum chamber. The optical effects of the window, including the effects of any temperature gradient through the window, must be taken into account in analyzing test data.

The need for the present augmented method arises because testing an off-axis, non-axisymmetric, aspherical mirror in a cryogenic environment entails the following complications that are not present in room-temperature testing of simpler mirrors:

- There are commercial off-the-shelf CGHs for the simpler mirror shapes, but not for the more-complex aspherical, off-axis shapes.
- The wall of a typical cryogenic vacuum chamber blocks access to optomechanical alignment fiducial objects that are incorporated into or attached to the mirror.
- Thermal contraction from room temperature to the cryogenic test temperature changes gives rise to a change in the mirror surface, relative to the reference wavefront, that can be confused with a change in surface-figure error.
- The interferometer is located outside the cryogenic vacuum chamber and gains optical access to the mirror in the chamber via a window in the wall of the chamber (see figure). It is necessary to take account of the optical effects of the window, including any changes in these effects caused by imposition of

the ambient-to-cryogenic temperature gradient across the window.

The augmented method includes elements of laboratory implementation and data reduction that go beyond those of the established room-temperature-only method. The most straightforward aspect of the method is the use of an off-the-shelf interferometer and, to match the complex shape of the mirror under test, a custom CGH. Other aspects of the method, too complex to describe in detail, can be summarized as follows: The method calls for a complex combination of room-temperature and cryogenic test procedures and associated data-reduction procedures formulated to minimize systematic test errors and reveal subtle thermomechanical and optical effects, and thereby to characterize surface-figure errors at ambient and cryogenic temperatures. One notable feature of the method is the use of interferometric techniques to quickly align the mirror under test when it is in the cryogenic chamber. Once the mirror has been aligned and thermal equilibrium has been established, measurements are performed on both mirror and window surfaces to obtain the data needed to computationally eliminate the optical effects of the window.

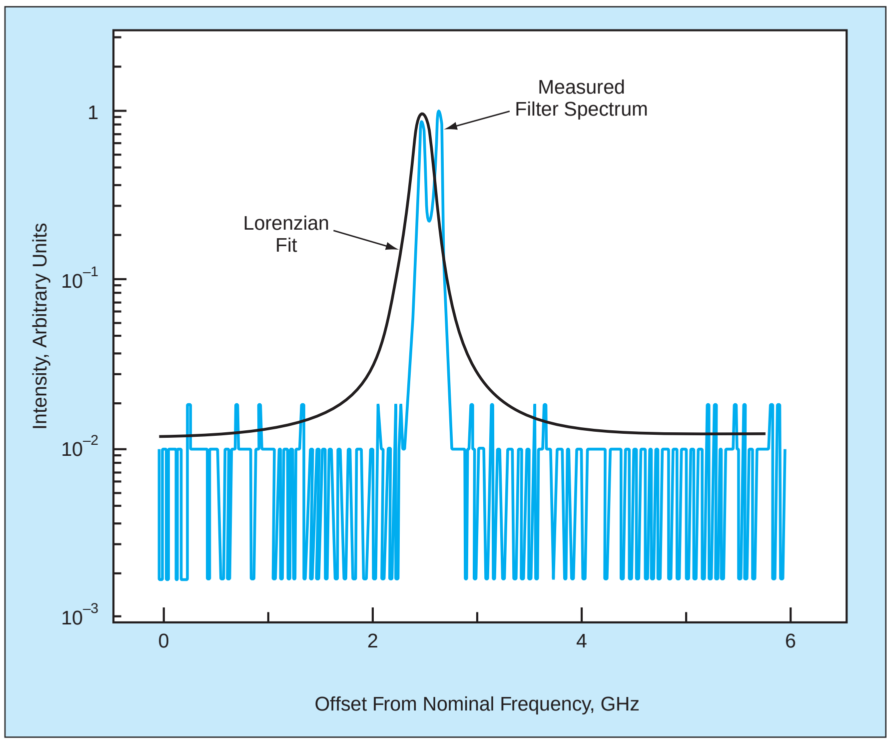
This work was done by Victor John Chambers, Raymond G. Ohl, and Ronald G. Mink of Goddard Space Flight Center and Steven Arnold of Diffraction International Ltd. Further information is contained in a TSP (see page 1). GSC-14789-1

Series-Coupled Pairs of Silica Microresonators

Pass bands are narrower and flatter than those of single microresonators.

NASA's Jet Propulsion Laboratory, Pasadena, California

Series-coupled pairs of whispering-gallery-mode optical microresonators have been demonstrated as prototypes of stable, narrow-band-pass photonic filters. Characteristics that are generally considered desirable in a photonic or other narrow-band-pass filter include response as nearly flat as possible across the pass band, sharp roll-off, and high rejection of signals outside the pass band. A single microresonator exhibits a Lorentzian filter function: its peak response cannot be made flatter and its roll-off cannot be made sharper. However, as a matter of basic principle applicable to resonators in general, it is possible to (1) use multiple resonators, operating in series or parallel, to obtain a roll-off sharper, and out-of-band rejection greater, relative to those of a Lorentzian filter function and (2) to make the peak response (the response within the pass band) flatter by tuning the resonators to slightly different resonance frequencies that span the pass band.



This **Second-Order Filter Spectral Response** was determined in measurements on a band-pass filter comprising a germania-doped silica microtorus series-coupled to a silica microsphere. A Lorentzian fit to the corresponding spectral response of a single microresonator is also shown for comparison.

The first of the two microresonators in each series-coupled pair was a microtorus made of germania-doped silica (containing about 19 mole percent germania), which is a material used for the cores of some optical fibers. The reasons for choosing this material is that exposing it to ultraviolet light causes it to undergo a chemical change that changes its index of refraction and thereby changes the resonance frequency. Hence, this material affords the means to effect the desired slight relative detuning of the two resonators. The second microresonator in each pair was a microsphere of pure silica. The advantage of making one of the resonators a torus instead of a sphere is that its spectrum of whispering-gallery-mode resonances is sparser, as needed to obtain a frequency separation of at least 100 GHz between resonances of the filter as a whole.

The two microresonators in each pair were mounted in proximity to each other so that the two were optically coupled. Half of the amplified light from a laser diode at a nominal wavelength of 1.55 μm was coupled into the first microresonator by means of an angle-polished optical fiber. The other half of the amplified laser light was passed through a Fabry-Perot cavity having a free spectral range of 20 GHz; this cavity served as both a reference to correct for laser frequency drift and a scale for measuring the difference between resonance frequencies. By use of a second angle-polished optical fiber, light was coupled out of the second microresonator to a photodiode.

An argon-ion laser operating at a wavelength of 351 nm (the wavelength