ing pressure, so that the ionizer always operates on the non-breakdown side of the applicable Paschen curve (a standard plot of breakdown potential on the ordinate and pressure electrode separation on the abscissa).

The field ionizer in this instrument is fabricated by micromachining a submicron-thick membrane out of an electrically nonconductive substrate, coating the membrane on both sides to form electrodes, then micromachining small holes through the electrodes and membrane. Because of the submicron electrode separation, even a potential of only 1 V applied between the electrodes gives rise to an electric field with a strength of in excess of a megavolt per meter — strong enough to ionize any gas molecules passing through the holes.

An accelerator grid and an electrostatic deflector focus the ions from the field ionizer into the rotating-field cell of the RFMS. The potentials applied to the electrodes of the cell to generate the rotating electric field typically range from 1 to 13 V. The ions travel in well-defined helices within this cell, after which they are collected in a Faraday cup. The mass of most of the molecules reaching the Faraday cup decreases with increasing frequency of rotation of the electric field in the cell. Therefore, the frequency of rotation of the electric field is made to vary in order to scan through a desired range of ion masses: For example, lightweight gas molecules are scanned at frequencies in the megahertz range, while DNA and other large organic molecules are scanned at kilohertz frequencies.

The current of accelerated ions is attenuated by collisions between these ions and the much slower (thermal) background gas molecules. In a typical case of operation at 5 Torr, an initial ion-beam current of about 10 nA would be attenuated to about 40 pA. However, the instrument could still afford adequate sensitivity because the electric current of ions collected by the Faraday cup is read by use of an electrometer that can resolve a current of the order of a femtoampere. In certain cases of low vacuum ($10^{-5}$ Torr), a channel electron multiplier (CEM) plate could also be utilized in a single ion detection mode.

*This work was done by Frank Hartley and Steven Smith 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:*

*Innovative Technology Assets Management*
*JPL*
*Mail Stop 202-233*
*4800 Oak Grove Drive*
*Pasadena, CA 91109-8099*
*(818) 354-2240*
*E-mail: iaoffice@jpl.nasa.gov*

*Refer to NPO-30245, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# Modifying Operating Cycles To Increase Stability in a LITS

## Microwave-interrogation time can be increased while maintaining optimum lamp duty cycle.

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

The short-term instability in the frequency of a linear-ion-trap frequency standard (LITS) can be reduced by modifying two cycles involved in its operation: (1) the bimodal (bright/dim) cycle of a plasma discharge lamp used for state preparation and detection and (2) a microwave-interrogation cycle. The purpose and effect of the modifications is to enable an increase in the microwave-interrogation cycle time, motivated by the general principle that the short-term uncertainty or instability decreases with increasing microwave-interrogation time. Stated from a slightly different perspective, the effect of modifications is to enable the averaged LITS readings to settle to their long-term stability over a shorter total observation time.

The basic principles of a LITS were discussed in several *NASA Tech Briefs* articles. Here are recapitulated only those items of background information necessary to place the present modifications in context. A LITS includes a microwave local oscillator, the frequency of which is stabilized by comparison with the frequency of a ground-state hyperfine transition of $^{199}Hg^{+}$ ions. In a LITS of the type to which the modifications apply, the comparison involves a combination of optical and microwave excitation and interrogation of the ions in two collinear ion traps: a quadrupole trap wherein the optical excitation used for state preparation and detection takes place, and a multipole (e.g., 12-pole) trap wherein the microwave interrogation of the "clock" transition takes place. The ions are initially loaded into the quadrupole trap and are thereafter shuttled between the two traps. This concludes the background information.

One source of systematic frequency error is an AC Stark shift caused by light present during microwave interrogation. To minimize this source of error, most stray light is suppressed by design, and heretofore, the microwave-interrogation time has been limited to the dim portion of the bimodal lamp cycle. It has now been learned that it is not necessary to limit the microwave interrogation to the dim portion of the lamp cycle because the separation of the two collinear ion traps is such that very little light from the lamp reaches the multipole trap wherein the microwave interrogation takes place. Indeed, the lamp-light-attenuation factor associated with the separation of the collinear ion traps is greater than the ratio between the bright and dim lamp intensities. The abandonment of this limitation creates an option to operate the lamp at an optimum duty cycle and to perform the microwave interrogation for a longer time, as described next.

The equilibrium temperature of the lamp depends on the ambient temperature and the lamp duty cycle. For each lamp, it is possible to empirically determine an equilibrium temperature (and, hence, a duty cycle) that is optimum in the sense that it maximizes the signal-to-noise ratio (SNR) during microwave interrogation. Hence, one of the modifications is to set the bimodal lamp operating cycle to the optimum duty cycle. The other modification is to increase the microwave-interrogation time to a desired integer multiple of the lamp cycle time. (The multiple must have an integer value because it is still necessary to synchronize the optical and microwave operating cycles.) The size of the integer multiple is subject to an overall limit determined by the quantum-coherence time of the $^{199}Hg^+$ ions and the characteristic stability time of the microwave source.

The following results have been reported from experiments performed on a LITS to demonstrate these modifications: The best short-term fractional frequency instability achieved with a typical microwave-interrogation time of 6 s in the unmodified bimodal lamp cycle was between 7 and $10 \times 10^{-14}\tau^{-1/2}$, where $\tau$ is the averaging (observation) time in seconds. The use of the modified lamp mode and a microwave-interrogation time of 30 s resulted in a short-term fractional instability of 5 and $10 \times 10^{-14}\tau^{-1/2}$. To put these numbers in perspective, it was calculated that the time for the LITS to settle to a fractional frequency instability of $10^{-16}$ would be about 8.4 days without the modifications or 2.9 days with the modifications.

*This work was done by Eric Burt and Robert Tjoelker of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-44271*

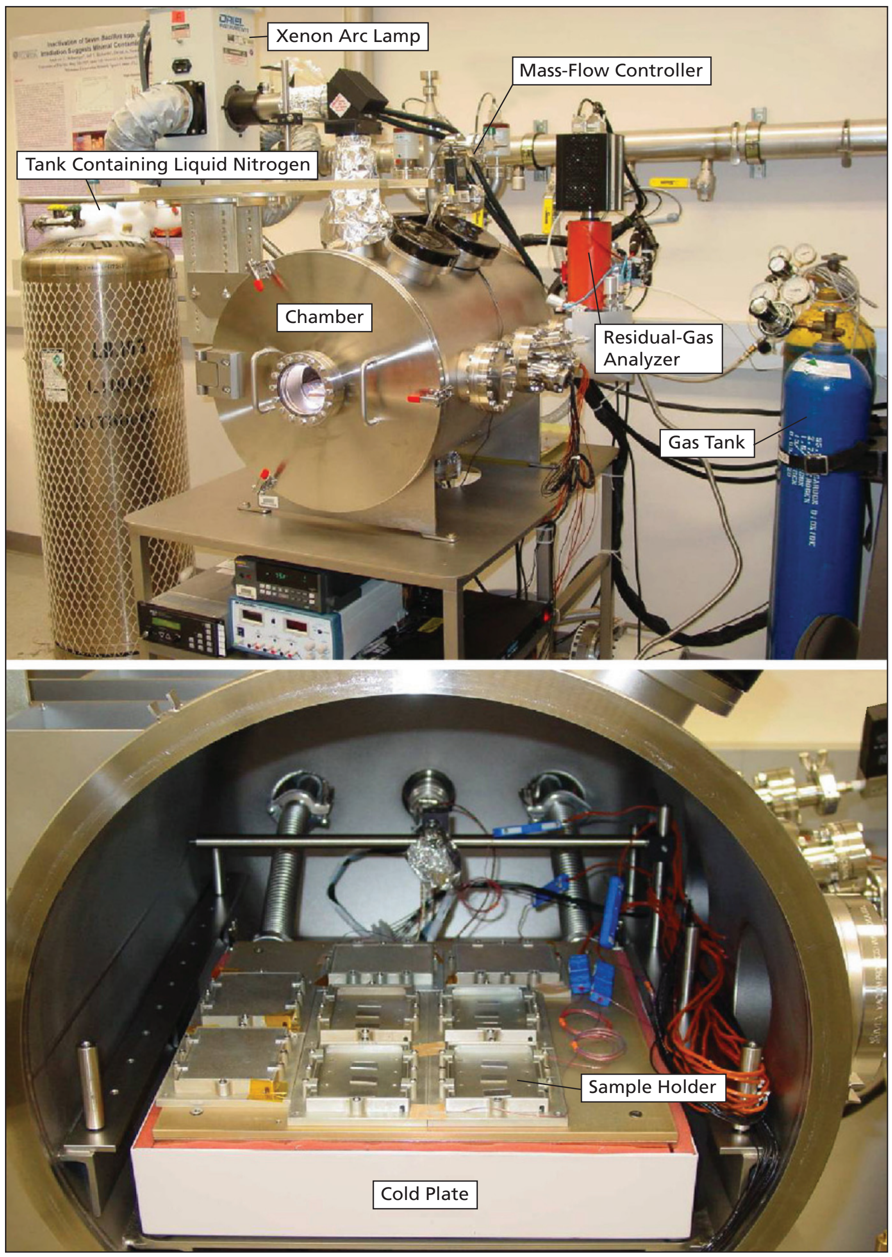
# Chamber for Simulating Martian and Terrestrial Environments

## Temperature, pressure, and simulated solar radiation can be controlled over wide ranges.

*John F. Kennedy Space Center, Florida*

An apparatus for simulating the environment at the surface of Mars has been developed. Within the apparatus, the pressure, gas composition, and temperature of the atmosphere; the incident solar visible and ultraviolet (UV) light; and the attenuation of the light by dust in the atmosphere can be simulated accurately for any latitude, season, or obliquity cycle over the entire geological history of Mars. The apparatus also incorporates instrumentation for monitoring chemical reactions in the simulated atmosphere. The apparatus can be used for experiments in astrobiology, geochemistry, aerobiology, and aerochemistry related to envisioned robotic and human exploration of Mars. Moreover, the apparatus can be easily adapted to enable similar experimentation under environmental conditions of (1) the surfaces of moons, asteroids, and comets, and (2) the upper atmospheres of planets other than Mars: in particular, it can be made to simulate conditions anywhere in the terrestrial atmosphere at altitudes up to about 100 km.

The apparatus (see figure) includes a cylindrical stainless-steel chamber, wherein the simulated atmospheric pressure is maintained between set points by means of a vacuum pump and a throttle valve controlled by an electronic pressure controller. The pressure can be set at any level from ambient down to 0.1 mb (100 Pa). A commercially available Martian-atmosphere-simulating mixture of gases (95.54% $CO_2$ + 2.7% $N_2$ + 1.6% Ar + 0.13% $O_2$ + 0.03% $H_2O$) is delivered from a tank to the chamber through a mass-flow controller. The primary temperature-control system is a commercially available unit that includes a cold plate in the chamber and that utilizes liquid nitrogen to reach the




This **Laboratory Apparatus** reproduces, inside the chamber, environmental conditions like those on the Martian surface or in the upper terrestrial atmosphere.