



## Physical Sciences

### Laser Ablation Electrodynamic Ion Funnel for *In Situ* Mass Spectrometry on Mars

NASA's Jet Propulsion Laboratory, Pasadena, California

A front-end instrument, the laser ablation ion funnel, was developed, which would ionize rock and soil samples in the ambient Martian atmosphere, and efficiently transport the product ions into a mass spectrometer for *in situ* analysis.

Laser ablation creates elemental ions from a solid with a high-power pulse within ambient Mars atmospheric conditions. Ions are captured and focused with an ion funnel into a mass spectrometer for analysis. The electrodynamic ion fun-

nel consists of a series of axially concentric ring-shaped electrodes whose inside diameters (IDs) decrease over the length of the funnel. DC potentials are applied to each electrode, producing a smooth potential slope along the axial direction. Two radio-frequency (RF) AC potentials, equal in amplitude and 180° out of phase, are applied alternately to the ring electrodes. This creates an effective potential barrier along the inner surface of the electrode stack. Ions entering the

funnel drift axially under the influence of the DC potential while being restricted radially by the effective potential barrier created by the applied RF. The net result is to effectively focus the ions as they traverse the length of the funnel.

*This work was done by Paul V. Johnson and Robert P. Hodyss of Caltech, and Keqi Tang and Richard D. Smith of PNNL for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-47638*

### High-Altitude MMIC Sounding Radiometer for the Global Hawk Unmanned Aerial Vehicle

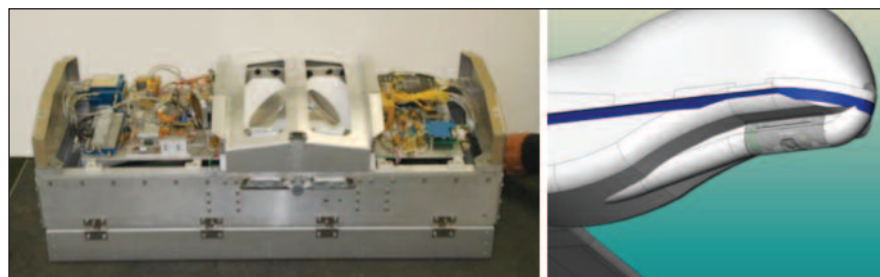
**This instrument can be used for improved weather forecasting and environmental monitoring.**

NASA's Jet Propulsion Laboratory, Pasadena, California

Microwave imaging radiometers operating in the 50–183 GHz range for retrieving atmospheric temperature and water vapor profiles from airborne platforms have been limited in the spatial scales of atmospheric structures that are resolved not because of antenna aperture size, but because of high receiver noise masking the small variations that occur on small spatial scales. Atmospheric variability on short spatial and temporal scales (second/km scale) is completely unresolved by existing microwave profilers.

The solution was to integrate JPL-designed, high-frequency, low-noise-amplifier (LNA) technology into the High-Altitude MMIC Sounding Radiometer (HAMSR), which is an airborne microwave sounding radiometer, to lower the system noise by an order of magnitude to enable the instrument to resolve atmospheric variability on small spatial and temporal scales.

HAMSR has eight sounding channels near the 60-GHz oxygen line complex, ten channels near the 118.75-GHz oxygen line, and seven channels near the 183.31-GHz water vapor line. The HAMSR receiver system consists of three heterodyne spectrometers cover-



The HAMSR Instrument (left) is deployed in a forward bay under the nose of the Global Hawk aircraft (right).

ing the three bands. The antenna system consists of two back-to-back reflectors that rotate together at a programmable scan rate via a stepper motor. A single full rotation includes the swath below the aircraft followed by observations of ambient (roughly 0 °C in flight) and heated (70 °C) blackbody calibration targets located at the top of the rotation.

A field-programmable gate array (FPGA) is used to read the digitized radiometer counts and receive the reflector position from the scan motor encoder, which are then sent to a microprocessor and packed into data files. The microprocessor additionally

reads telemetry data from 40 onboard housekeeping channels (containing instrument temperatures), and receives packets from an onboard navigation unit, which provides GPS time and position as well as independent attitude information (e.g., heading, roll, pitch, and yaw). The raw data files are accessed through an Ethernet port. The HAMSR data rate is relatively low at 75 kbps, allowing for real-time access over the Global Hawk high-data-rate downlink. Once on the ground, the raw data are unpacked and processed through two levels of processing. The Level 1 product contains geo-located, time-stamped, calibrated brightness tempera-

tures for the Earth scan. These data are then input to a 1D variational retrieval algorithm to produce temperature, water vapor, and cloud liquid water profiles, as well as several derived products such as potential temperature and relative humidity.

The addition of a state-of-the-art LNA to the 183-GHz receiver front-end and the upgrade of the 118-GHz LNA provide excellent low-noise performance, which is critical for microwave sounding retrievals. The data system is upgraded to provide in-flight data access through the Global Hawk data link, making it

possible to relay data to the ground in real time. This is particularly relevant for hurricane observations where HAMSr can provide real-time information on tropical storm structure, intensity, and evolution.

This instrument is the first to demonstrate the value of the technology through atmospheric water vapor measurements. The receiver noise was reduced by an order of magnitude compared to the previous receiver. A ground-based measurement campaign demonstrated unprecedented measurements of small-scale water vapor vari-

ability, resolving atmospheric fluctuations on meter and second space and time scales. Subsequent airborne measurements on the Global Hawk UAV showed similar results over a 40-km swath. This is a critical step in space-qualifying these receivers.

*This work was done by Shannon T. Brown, Boon H. Lim, Alan B. Tanner, Jordan M. Tanabe, Pekka P. Kangaslahti, Todd C. Gaier, Mary M. Soria, Bjorn H. Lambriksen, Richard F. Denning, and Robert A. Stachnik of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-48100*

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## PRTs and Their Bonding for Long-Duration, Extreme-Temperature Environments

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Research was conducted on the qualification of Honeywell platinum resistance thermometer (PRT) bonding for use in the Mars Science Laboratory (MSL). This is the first time these sensors will be used for Mars-related projects. Different types of PRTs were employed for the Mars Exploration Rover (MER) project, and several reliability issues were experienced, even for a short-duration mission like MER compared to MSL. Therefore, the development of a qualification process for the Honeywell PRT bonding was needed for the MSL project. Reliability of the PRT sensors,

and their bonding processes, is a key element to understand the health of the hardware during all stages of the project, and particularly during surface operations on Mars. Three extreme temperature summer season cycles and three winter season cycles (total: 1983 thermal cycles) were completed, and no Honeywell PRT failures associated with the bonding process were found.

Seventy-eight PRTs were bonded onto six different substrate materials using four different adhesives during the thermal cycling, which included a planetary protection cycle to +125 °C

for two hours, three protoflight/qualification cycles (–135 to 70 °C), 1,384 summer cycles (–105 to 40 °C), and 599 winter cycles (–130 to 15 °C). There were no observed changes in PRT resistances, bonding characteristics, or damage identified from the package evaluation as a result of the qualification tests.

*This work was done by Rajeshuni Ramesham, Gordon C. Cucullu III, and Rebecca L. Mikhaylov of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-47649*

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## Mid- and Long-IR Broadband Quantum Well Photodetector

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A single-stack broadband quantum well infrared photodetector (QWIP) has been developed that consists of stacked layers of GaAs/AlGaAs quantum wells with absorption peaks centered at various wavelengths spanning across the 9- to 11- $\mu\text{m}$  spectral regions. The correct design of broadband QWIPs was a critical step in this task because the earlier implementation of broadband QWIPs suffered from a tuning of spectral response curve with an applied bias. Here, a new QWIP design has been developed to overcome the spectral tuning with voltage that results from non-uniformity and bias variation of the electrical field

across the detector stacks with different absorption wavelengths.

In this design, a special effort has been made to avoid non-uniformity and bias tuning by changing the doping levels in detector stacks to compensate for variation of dark current generation rate across the stacks with different absorption wavelengths. Single-pixel photodetectors were grown, fabricated, and tested using this new design.

The measured dark current is comparable with the dark measured current for single-color QWIP detectors with similar cutoff wavelength, thus indicating high material quality as well as absence of per-

formance degradation resulting from broadband design. The measured spectra clearly demonstrate that the developed detectors cover the desired spectral range of 8 to 12  $\mu\text{m}$ . Moreover, the shape of the spectral curves does not change with applied biases, thus overcoming the problem plaguing previous designs of broadband QWIPs.

*This work was done by Alexander Soibel, David Z. Ting, Arezou Khoshakhlagh, and Sarath D. Gunapala of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48398*