Local Leak Detection and Health Monitoring of Pressurized Tanks

Marshall Space Flight Center, Alabama

An optical gas-detection sensor safely monitors pressurized systems (such as cryogenic tanks) and distribution systems for leaks. This sensor system is a fiber-coupled, solid optical body interferometer that allows for the miniaturized sensing element of the device to be placed in the smallest of recesses, and measures a wide range of gas species and densities (leaks). The deflection of the fringe pattern is detected and recorded to yield the time-varying gas density in the gap. This technology can be used by manufacturers or storage facilities with toxic, hazardous, or explosive gases.

The approach is to monitor the change in the index of refraction associated with low-level gas leaks into a vacuum environment. The completion of this work will provide NASA with an enabling capability to detect gas system leaks in space, and to verify that pressurized systems are in a safe (i.e. non-leaking) condition during manned docking and transit operations.

By recording the output of the sensor, a time-history of the leak can be constructed to indicate its severity. Project risk is mitigated by having several interferometric geometries and detection techniques available, each potentially leveraging hardware and lessons learned to enhance detectability.

This work was done by Kurt Polzin and William Witherow of Marshall Space Flight Center; Valentin Korman formerly of Madison Research Corp; John Sinko of Kratos Defense; and Adam Hendrickson of the U.S. Army. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32584-1.

Dielectric Covered Planar Antennas at Submillimeter Wavelengths for Terahertz Imaging

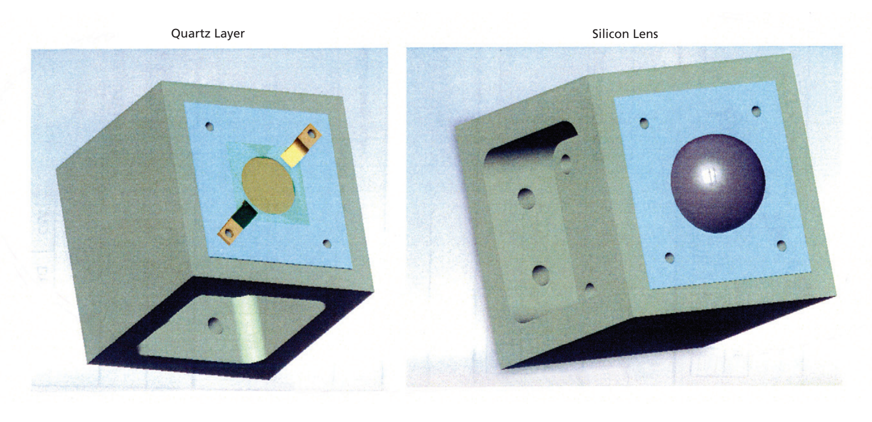
This technology has potential uses for terahertz radar imagers, radiometers, and spectrometers for earth-science observing instruments.

NASA's Jet Propulsion Laboratory, Pasadena, California

Most optical systems require antennas with directive patterns. This means that the physical area of the antenna will be large in terms of the wavelength. When non-cooled systems are used, the losses of microstrip or coplanar waveguide lines impede the use of standard patch or slot antennas for a large number of elements in a phased array format.

Traditionally, this problem has been solved by using silicon lenses. However, if an array of such highly directive antennas is to be used for imaging applications, the fabrication of many closely spaced lenses becomes a problem. Moreover, planar antennas are usually fed by microstrip or coplanar waveguides while the mixer or the detector elements (usually Schottky diodes) are coupled in a waveguide environment. The coupling between the antenna and the detector/mixer can be a fabrication challenge in an imaging array at submillimeter wavelengths.

Antennas excited by a waveguide (TE10) mode makes use of dielectric superlayers to increase the directivity. These antennas create a kind of Fabry-Perot cavity between the ground plane and the first layer of dielectric. In reality, the antenna operates as a leaky wave mode where a leaky wave pole propagates along the cavity while it radiates. Thanks to this pole, the directivity of a small antenna is considerably enhanced.



The **Waveguide Block** with the quartz layer (left) and the silicon lens (right).

The antenna consists of a waveguide feed, which can be coupled to a mixer or detector such as a Schottky diode via a standard probe design. The waveguide is loaded with a double-slot iris to perform an impedance match and to suppress undesired modes that can propagate on the cavity. On top of the slot there is an air cavity and on top, a small portion of a hemispherical lens. The fractional bandwidth of such antennas is around 10 percent, which is good enough for heterodyne imaging applications.

The new geometry makes use of a silicon lens instead of dielectric quarter wavelength substrates. This design presents several advantages when used in the submillimeter-wave and terahertz bands:

- Antenna fabrication compatible with lithographic techniques.
- Much simpler fabrication of the lens.
- A simple quarter-wavelength matching layer of the lens will be more efficient if a smaller portion of the lens is used.
- The directivity is given by the lens diameter instead of the leaky pole (the bandwidth will not depend anymore on the directivity but just on the initial cavity).

The feed is a standard waveguide, which

is compatible with proven Schottky diode mixer/detector technologies.

The development of such technology will benefit applications where submillimeter-wave heterodyne array designs are required. The main fields are national security, planetary exploration, and biomedicine. For national security, wideband submillimeter radars could be an effective tool for the standoff detection of hidden weapons or bombs concealed by clothing or packaging. In the field of planetary exploration, wideband submillimeter radars can be used as a spectrometer to detect trace concentrations of chemicals in atmospheres that are too cold to rely on thermal imaging techniques. In biomedicine, an imaging heterodyne system could be helpful in detecting skin diseases.

This work was done by Goutam Chattopadhyay, John J. Gill, Anders Skalare, Choonsup Lee, and Nuria Llombart, and Peter H. Siegel 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-46969, volume and number of this NASA Tech Briefs *issue, and the page number.*

Automated Cryocooler Monitor and Control System

Small-scale cryogenic cooler applications include medical imaging for MRI systems and infrared sensor cooling.

NASA's Jet Propulsion Laboratory, Pasadena, California

A system was designed to automate cryogenically cooled low-noise amplifier systems used in the NASA Deep Space Network. It automates the entire operation of the system including cool-down, warm-up, and performance monitoring. The system is based on a single-board computer with custom software and hardware to monitor and control the cryogenic operation of the system. The system provides local display and control, and can be operated remotely via a Web interface.

The system controller is based on a commercial single-board computer with onboard data acquisition capability. The commercial hardware includes a microprocessor, an LCD (liquid crystal display), seven LED (light emitting diode) displays, a seven-key keypad, an Ethernet interface, 40 digital I/O (input/output) ports, 11 A/D (analog to digital) inputs, four D/A (digital to analog) outputs, and an external relay board to control the high-current devices.

The temperature sensors used are commercial silicon diode devices that provide a non-linear voltage output proportional to temperature. The devices are excited with a 10-microamp bias current. The system is capable of monitoring and displaying three temperatures.

The vacuum sensors are commercial thermistor devices. The output of the sensors is a non-linear voltage proportional to vacuum pressure in the 1-Torr to 1-millitorr range. Two sensors are used. One measures the vacuum pressure in the cryocooler and the other the pressure at the input to the vacuum pump. The helium pressure sensor is a commercial device that provides a linear voltage output from 1 to 5 volts, corresponding to a gas pressure from 0 to 3.5 MPa (≈500 psig).

Control of the vacuum process is accomplished with a commercial electrically operated solenoid valve. A commercial motor starter is used to control the input power of the compressor. The warm-up heaters are commercial power resistors sized to provide the appropriate power for the thermal mass of the particular system, and typically provide 50 watts of heat.

There are four basic operating modes. "Cool" mode commands the system to cool to normal operating temperature. "Heat" mode is used to warm the device to a set temperature near room temperature. "Pump" mode is a maintenance function that allows the vacuum system to be operated alone to remove accumulated contaminants from the vacuum area. In "Off" mode, no power is applied to the system.

This work was done by Michael J. Britcliffe, Theodore R. Hanson, and Larry E. Fowler of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47246

Broadband Achromatic Phase Shifter for a Nulling Interferometer

A uniform broadband phase shift is achieved while minimizing intensity, polarization, and chromatic spread differences between interferometer beams.

Goddard Space Flight Center, Greenbelt, Maryland

Nulling interferometry is a technique for imaging exoplanets in which light from the parent star is suppressed using destructive interference. Light from the star is divided into two beams and a phase shift of π radians is introduced into one of the beams. When the beams are recombined, they destructively interfere to produce a deep null. For monochromatic light, this is implemented by introducing an optical path difference (OPD) between the two beams equal to $\lambda/2$, where λ is the wavelength of the light. For broadband light, however, a different phase shift will be introduced at each wavelength and the two beams will not effectively null when recombined.

Various techniques have been devised to introduce an achromatic phase shift — a phase shift that is uniform across a particular bandwidth. One popular technique is to use a series of dispersive elements to introduce a wavelength-de-