



In a **Holographic Vortex Coronagraph**, a telescope would focus light onto a blazed first-order vortex grating. A beam block would absorb residual undiffracted light. Lens A would collimate the first-order-diffracted light, forming an exit pupil wherein a Lyot stop would be placed. Lens B would re-image the light transmitted through the Lyot stop to the final focal plane.

an optical surface. As shown in the figure, the interference pattern has a forked appearance.

Light incident perpendicular to the grating is diffracted into discrete orders at angles given by $\theta_n = \sin^{-1}(n\lambda/d)$, where n is the diffraction order, λ is the wavelength of the diffracted light, and d is the lateral distance between adjacent grooves in the grating. In addition, the

grating could be blazed to concentrate the diffracted light primarily into one order. If the grating is blazed to concentrate the light into the first ($n = 1$) order, then almost all of the light from a star or any other on-axis source will be transformed into a beam having a helical wavefront. Total destructive interference occurs along the axis of the helix over a broad wavelength band, attenuat-

ing the light from the star or other on-axis source.

The holographic vortex grating in the HVC is placed at the focus of the telescope and is designed and fabricated so as to almost completely suppress light from an on-axis star without significantly affecting images of planets or other light scatterers near the star. The starlight removed from the exit pupil appears outside exit pupil, whereas the light from scatterers near the star appears within the exit pupil. A Lyot stop — an aperture stop to block the starlight while passing the light from nearby scatterers — is placed in the exit pupil.

On the basis of previous research, it is anticipated that in comparison with a conventional coronagraph, the HVC would be less sensitive to aberrations, would yield higher throughput of light from scatterers near stars, and would offer greater planet/star contrast. On the basis of previous achievements in the fabrication of gratings similar to holographic vortex gratings, it appears that the grating for the HVC could readily be fabricated to satisfy initial requirements for imaging of extrasolar planets.

This work was done by David Palacios of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-45047

Optical Structural Health Monitoring Device

This device detects microscopic cracks and surface structural changes in components.

Dryden Flight Research Center, Edwards, California

This non-destructive, optical fatigue detection and monitoring system relies on a small and unobtrusive light-scattering sensor that is installed on a component at the beginning of its life in order to periodically scan the component *in situ*. The method involves using a laser beam to scan the surface of the monitored component. The device scans a laser spot over a metal surface to which it is attached. As the laser beam scans the surface, disruptions in the surface cause increases in scattered light intensity. As the disruptions in the surface grow, they will cause the light to scatter more. Over time, the scattering intensities over the scanned line can be compared to detect changes in the metal surface to find cracks, crack precursors, or corrosion. This periodic monitoring of the surface

can be used to indicate the degree of fatigue damage on a component and allow one to predict the remaining life and/or incipient mechanical failure of the monitored component.

This wireless, compact device can operate for long periods under its own battery power and could one day use harvested power. The prototype device uses the popular open-source TinyOS operating system on an off-the-shelf Mica2 sensor mote, which allows wireless command and control through dynamically reconfigurable multi-node sensor networks. The small size and long life of this device could make it possible for the nodes to be installed and left in place over the course of years, and with wireless communication, data can be extracted from the

nodes by operators without physical access to the devices.

While a prototype has been demonstrated at the time of this reporting, further work is required in the system's development to take this technology into the field, especially to improve its power management and ruggedness. It should be possible to reduce the size and sensitivity as well. Establishment of better prognostic methods based on these data is also needed. The increase of surface roughness with fatigue is closely connected to the microstructure of the metal, and ongoing research is seeking to connect this observed evidence of the fatigue state with microstructural theories of fatigue evolution to allow more accurate prognosis of remaining component life. Plans are also being discussed

for flight testing, perhaps on NASA's SOFIA platform.

This work was done by Benjamin D. Buckner and Vladimir Markov of MetroLaser, Inc. and James C. Earthman of the University of California for Dryden Flight Research Center.

Title to this invention, covered by U.S. Patent No. 7,221,445, has been waived under the provisions of the National Aeronautics and Space Act (42 U.S.C. 2457 (f)). Inquiries concerning licenses for its commercial development should be ad-

dressed to MetroLaser Inc. 8 Chrysler, Irvine CA 92618 Refer to DRC-007-065, volume and number of this NASA Tech Briefs issue, and the page number. Refer to DRC-007-065.

Fuel-Cell Power Source Based on Onboard Rocket Propellants

This high-energy density power source is an alternative to radioisotopes or primary batteries.

NASA's Jet Propulsion Laboratory, Pasadena, California

The use of onboard rocket propellants (dense liquids at room temperature) in place of conventional cryogenic fuel-cell reactants (hydrogen and oxygen) eliminates the mass penalties associated with cryocooling and boil-off. The high energy content and density of the rocket propellants will also require no additional chemical processing.

For a 30-day mission on the Moon that requires a continuous 100 watts of power, the reactant mass and volume would be reduced by 15 and 50 percent, respectively, even without accounting for boil-off losses. The savings increase further with increasing transit times. A high-temperature, solid oxide, electrolyte-based

fuel-cell configuration, that can rapidly combine rocket propellants — both monopropellant system with hydrazine and bi-propellant systems such as monomethyl hydrazine/ unsymmetrical dimethyl hydrazine (MMH/UDMH) and nitrogen tetroxide (NTO) to produce electrical energy — overcomes the severe drawbacks of earlier attempts in 1963–1967 of using fuel reforming and aqueous media. The electrical energy available from such a fuel cell operating at 60-percent efficiency is estimated to be 1,500 Wh/kg of reactants. The proposed use of zirconia-based oxide electrolyte at 800–1,000 °C will permit continuous operation, very high power densities, and

substantially increased efficiency of conversion over any of the earlier attempts. The solid oxide fuel cell is also tolerant to a wide range of environmental temperatures. Such a system is built for easy refueling for exploration missions and for the ability to turn on after several years of transit. Specific examples of future missions are *in-situ* landers on Europa and Titan that will face extreme radiation and temperature environments, flyby missions to Saturn, and landed missions on the Moon with 14 day/night cycles.

This work was done by Gani Ganapathi and Sri Narayan of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-44977

Polar Lunar Regions: Exploiting Natural and Augmented Thermal Environments

High vacuum cryogenic environments can be augmented with lightweight thermal shielding.

Stennis Space Center, Mississippi

In the polar regions of the Moon, some areas within craters are permanently shadowed from solar illumination and can drop to temperatures of 100 K or lower. These sites may serve as cold traps, capturing ice and other volatile compounds, possibly for eons. Interestingly, ice stored in these locations could potentially alter how lunar exploration is conducted. Within craters inside craters (double-shaded craters) that are shaded from thermal re-radiation and from solar illuminated regions, even colder regions should exist and, in many cases, temperatures in these regions never exceed 50 K. Working in these harsh environments with existing conventional systems, exploration or mining activities could be quite daunting and challenging. However, if the unique characteristics of these environments

were exploited, the power, weight, and total mass that is required to be carried from the Earth to the Moon for lunar exploration and research would be substantially reduced.

In theory, by minimizing the heat transfer between an object and the lunar surface, temperatures near absolute zero can be produced. In a single or double-shaded crater, if the object was isolated from the variety of thermal sources and was allowed to radiatively cool to space, the achievable temperature would be limited by the 3 K cosmic background and the anomalous solar wind that can strike the object being cooled. Our analysis shows that under many circumstances, with some simple thermal radiation shielding, it is possible to establish environments with temperatures of several de-

grees Kelvin. Electrostatic or other approaches for shielding from the solar wind and other high energy particles would enable the object to come into close thermal equilibrium with thermal cosmic background radiation. To minimize the heat transfer (conduction and radiation) between the ground and an object on the Moon (where the gravity is relatively small), a simple method to isolate even a relatively large object would be to use a low thermal insulating suspension structure that would hold both the thermal shield and the object above the thermal shield. The figure depicts a lunar polar region revealing a permanently shaded crater and a double-shaded crater. Within the double-shaded crater, a suspended thermal shield reflecting 50 K gray body radiation back towards the lunar