rored, or otherwise corrupted during the extensive FS and GS processing. This would normally be done by projecting an image on the focal plane array (FPA), collecting the data in a flight-like way, and making a comparison between the original data and the data reconstructed by the science data system.

Projecting a focused image onto the FPA through the telescope would normally involve using a collimator suspended over the telescope opening. There were several problems with this approach: the collimation equipment is elaborate and expensive; as conceived, it could only illuminate a limited section of the FPA (≈25 percent) during a given test; the telescope cover would have to be deployed during testing to allow the image to be projected into the telescope; the equipment was bulky and difficult to situate in temperature-controlled environments; and given all the above, test setup, execution, and repeatability were significant concerns. Instead of using this complicated approach of projecting an optical image on the FPA, the Kepler project developed a method using known defect features in the CCDs to verify proper collection and reassembly of the pixels, thereby avoiding the costs and risks of the optical projection approach.

The CCDs composing the Kepler FPA, as all CCDs, had minor defects. At ambient temperature, some pixels look far brighter than they should. These "hot" pixels have a higher rate of charge leakage than the others due to manufacturing variations. They are usually stable over time, and appear at temperatures above 5 °C. The hot pixels on the Kepler FPA were mapped before photometer assembly during module testing. Selected hot pixels were used as target "stars" for the purposes of EEIS testing. "Dead" pixels are permanently off, producing a permanently black pixel. These can also be used if there is some illumination of the FPA.

During EEIS testing, Dark Current Full Frame Images (FFIs) taken at room temperature were used to create the hot pixel maps for all 84 Kepler photometer CCD channels. Data from two separate nights were used to create two hot pixel maps per channel, which were cross-correlated to remove cosmic ray events which appear to be hot pixels. These hot pixel maps obtained during EEIS testing were compared to the maps made during module testing to verify that the end-to-end data flow was correct.

This work was done by Shaun P. Standley and Thomas N. Gautier of Caltech; Douglas A. Caldwell of SETI Institute; and Maura Rabbette of Ames Research Center for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46868

Transverse Pupil Shifts for Adaptive Optics Non-Common Path Calibration

NASA's Jet Propulsion Laboratory, Pasadena, California

A simple new way of obtaining absolute wavefront measurements with a laboratory Fizeau interferometer was recently devised. In that case, the observed wavefront map is the difference of two cavity surfaces, those of the mirror under test and of an unknown reference surface on the Fizeau's transmission flat. The absolute surface of each can be determined by applying standard wavefront reconstruction techniques to two grids of absolute surface height differences of the mirror under test, obtained from pairs of measurements made with slight transverse shifts in X and Y.

Adaptive optics systems typically provide an actuated periscope between wavefront sensor (WFS) and common-mode optics, used for lateral registration of deformable mirror (DM) to WFS. This periscope permits independent adjustment of either pupil or focal spot incident on the WFS. It would be used to give the required lateral pupil motion between common and non-common segments, analogous to the lateral shifts of the two phase contributions in the lab Fizeau.

The technique is based on a completely new approach to calibration of phase. It offers unusual flexibility with regard to the transverse spatial frequency scales probed, and will give results quite quickly, making use of no auxiliary equipment other than that built into the adaptive optics system. The new technique may be applied to provide novel calibration information about other optical systems in which the beam may be shifted transversely in a controlled way.

This work was done by Eric E. Bloemhof of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48060

Qualification of Fiber Optic Cables for Martian Extreme Temperature Environments

NASA's Jet Propulsion Laboratory, Pasadena, California

Means have been developed for enabling fiber optic cables of the Laser Induced Breakdown Spectrometer instrument to survive ground operations plus the nominal 670 Martian conditions that include Martian summer and winter seasons. The purpose of this development was to validate the use of the rover external fiber optic cabling of ChemCam for space applications under the extreme thermal environments to be encountered during the Mars Science Laboratory (MSL) mission.

Flight-representative fiber optic cables were subjected to extreme temperature thermal cycling of the same diurnal depth (or ΔT) as expected in flight, but for three times the expected number of in-flight thermal cycles. The survivability of fiber optic cables was tested for 600 cumulative thermal cycles from –130 to +15 °C to cover the winter season, and another 1,410 cumulative cycles from –105 to +40 °C to cover the summer season. This test satisfies the required 3 times the design margin that is a total of 2,010 thermal cycles (670 × 3). This development test included functional optical transmission tests during the course of the test. Transmission of the fiber optic cables was performed prior to and after 1,288 thermal cycles and 2,010 thermal cycles. No significant changes in transmission were observed on either of the two representative fiber cables subject through the 3X MSL mission life that is 2,010 thermal cycles.

This work was done by Rajeshuni Ramesham, Christian A. Lindensmith, William T. Roberts, and Richard A. Rainen of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-48055

Solid-State Spectral Light Source System

Goddard Space Flight Center, Greenbelt, Maryland

A solid-state light source combines an array of light-emitting diodes (LEDs) with advanced electronic control and stabilization over both the spectrum and overall level of the light output. The use of LEDs provides efficient operation over a wide range of wavelengths and power levels, while electronic control permits extremely stable output and dynamic control over the output.

In this innovation, LEDs are used instead of incandescent bulbs. Optical feedback and digital control are used to monitor and regulate the output of each LED. Because individual LEDs generate light within narrower ranges of wavelengths than incandescent bulbs, multiple LEDs are combined to provide a broad, continuous spectrum, or to produce light within discrete wavebands that are suitable for specific radiometric sensors.

This work was done by Robert Maffione and David Dana of Hydro-Optics, Biology & Instrumentation Laboratories, Inc. for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15851-1

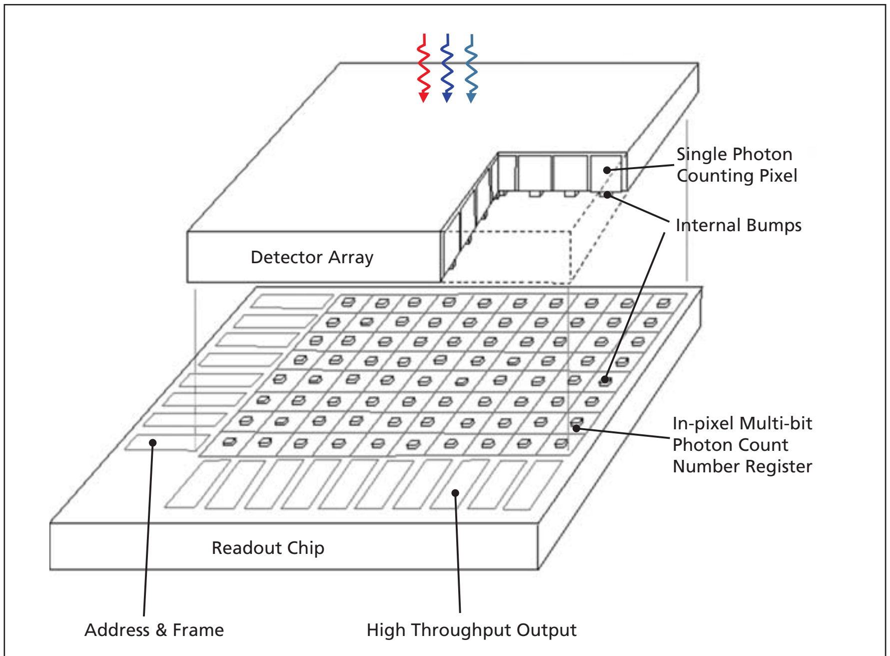
Multiple-Event, Single-Photon Counting Imaging Sensor

This sensor has applications in high-energy physics and medical and biological imaging systems.

NASA's Jet Propulsion Laboratory, Pasadena, California

The single-photon counting imaging sensor is typically an array of silicon Geiger-mode avalanche photodiodes that are monolithically integrated with CMOS (complementary metal oxide semiconductor) readout, signal processing, and addressing circuits located in each pixel and the peripheral area of the chip. The major problem is its "single-event" method for photon count number registration. A single-event single-photon counting imaging array only allows registration of up to one photon count in each of its pixels during a frame time, i.e., the interval between two successive pixel reset operations. Since the frame time can't be too short, this will lead to very low dynamic range and make the sensor merely useful for very low flux environments. The second problem of the prior technique is a limited fill factor resulting from consumption of chip area by the monolithically integrated CMOS readout in pixels. The resulting low photon collection efficiency will substantially ruin any benefit gained from the very sensitive single-photon counting detection.

The single-photon counting imaging sensor developed in this work has a novel "multiple-event" architecture, which allows each of its pixels to register as more than one million (or more) photon-counting events during a frame time. Because of a consequently boosted dynamic range, the imaging array of the invention is capable of performing single-photon counting under ultra-low light through high-flux environments. On the other hand, since the multiple-event architecture is implemented in a hybrid structure, back-illumination and



Structure of a multiple-event **Single-Photon Counting Imaging Sensor** implemented using flip-chip bump bonding technique.