necessary for nulling. The advantage over prior art is that an entire subsystem, the field-flipping optics, can be eliminated.

For ultimate simplicity in the flight instrument, one might fabricate coatings to very high tolerances and dispense with the adaptive nullers altogether, with all their moving parts, along with the field flipper subsystem. A single adaptive nuller upstream of the beam combiner may be required to correct beam train errors (systematic noise), but in some circumstances phase chopping reduces these errors substantially, and there may be ways to further reduce the chop residuals. Though such coatings are beyond the current state of the art, the mechanical simplicity and robustness of a flight system without field flipper or adaptive nullers would perhaps justify considerable effort on coating fabrication.

This work was done by Eric E. Bloemhof of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47027

Portable Dew Point Mass Spectrometry System for Real-Time Gas and Moisture Analysis

This system has applications in semiconductor fabrication, industrial gas production, and natural gas refineries.

John F. Kennedy Space Center, Florida

A portable instrument incorporates both mass spectrometry and dew point measurement to provide real-time, quantitative gas measurements of helium, nitrogen, oxygen, argon, and carbon dioxide, along with real-time, quantitative moisture analysis.

The Portable Dew Point Mass Spectrometry (PDP-MS) system comprises a single quadrupole mass spectrometer and a high vacuum system consisting of a turbopump and a diaphragm-backing pump. A capacitive membrane dew point sensor was placed upstream of the MS, but still within the pressure-flow control pneumatic region. Pressure-flow control was achieved with an upstream precision metering valve, a capacitance diaphragm gauge, and a downstream mass flow controller. User configurable LabVIEW software was developed to provide real-time concentration data for the MS, dew point monitor, and sample delivery system pressure control, pressure and flow monitoring, and recording. The system has been designed to include *in situ*, NIST-traceable calibration.

Certain sample tubing retains sufficient water that even if the sample is dry, the sample tube will desorb water to an amount resulting in moisture concentration errors up to 500 ppm for as long as 10 minutes. It was determined that Bev-A-Line IV was the best sample line to use. As a result of this issue, it is prudent to add a high-level humidity sensor to PDP-MS so such events can be prevented in the future.

This work was done by C. Arkin, Stacey Gillespie, and Christopher Ratzel of ASRC Aerospace Corporation and Mary Whitten of the University of Central Florida for Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13316

Maximum Likelihood Time-of-Arrival Estimation of Optical Pulses via Photon-Counting Photodetectors

NASA's Jet Propulsion Laboratory, Pasadena, California

Many optical imaging, ranging, and communications systems rely on the estimation of the arrival time of an optical pulse. Recently, such systems have been increasingly employing photon-counting photodetector technology, which changes the statistics of the observed photocurrent. This requires time-of-arrival estimators to be developed and their performances characterized.

The statistics of the output of an ideal photodetector, which are well modeled as a Poisson point process, were considered. An analytical model was developed for the mean-square error of the maximum likelihood (ML) estimator, demonstrating two phenomena that cause deviations from the minimum achievable error at low signal power. An approximation was derived to the threshold at which the ML estimator essentially fails to provide better than a random guess of the pulse arrival time. Comparing the analytic model performance predictions to those obtained via simulations, it was verified that the model accurately predicts the ML performance over all regimes considered.

There is little prior art that attempts to understand the fundamental limitations to time-of-arrival estimation from Poisson statistics. This work establishes both a simple mathematical description of the error behavior, and the associated physical processes that yield this behavior. Previous work on mean-square error characterization for ML estimators has predominantly focused on additive Gaussian noise. This work demonstrates that the discrete nature of the Poisson noise process leads to a distinctly different error behavior.

This work was done by Baris I. Erkmen and Bruce E. Moision of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46857

Handheld White Light Interferometer for Measuring Defect Depth in Windows

The device replaces a refocus microscope for quantification of defects such as scratches and impacts.

John F. Kennedy Space Center, Florida

Accurate quantification of defects (scratches and impacts) is vital to the certification of flight hardware and other critical components. The amount of damage to a particular component contributes to the performance, reliability, and safety of a system, which ultimately affects the success or failure of a mission or test. The launch-commit criteria on a Space Shuttle Orbiter window are governed by the depth of the defects that are identified by a visual inspection. This measurement of a defect is not easy to obtain given the environment, size of the defect, and location of the window(s). The determination of depth has typically been performed by taking a mold impression and measuring the impression with an optical profiling instrument. Another method of obtaining an estimate of the depth is by using a refocus microscope. To use a refocus microscope, the surface of the glass and bottom of the defect are, in turn, brought into focus by the operator. The amount of movement between the two points corresponds to the depth of the defect. The refocus microscope requires a skilled operator and has been proven to be unreliable when used on Orbiter windows. White light interferometry was chosen as a candidate to replace the refocus microscope.

The White Light Interferometer (WLI) was developed to replace the refocus microscope as the instrument used for measuring the depth of defects in Orbiter windows. The WLI consists of a broadband illumination source, interferometer, detector, motion control, displacement sensor, mechanical housing, and support electronics. The illumination source for the WLI is typically a visible light emitting diode (LED) or a near-infrared superluminescent diode (SLD) with power levels of less than a milliwatt. The interferometer is a Michelson configuration consisting of a 1-in. (2.5-cm) cube beam splitter, a 0.5-in. (1.3-cm) optical window as a movable leg (used to closely match the return intensity of the fixed leg from the window), and a mirrored prism to fold the optics into the mechanical housing. The detector may be one of many C-mount CCD (charge-coupled device) cameras. Motion is provided by a commercial nanostepping motor with a serial interface. The displacement sensor is a custom device specifically designed for this application. The mechanical housing and support electronics were designed to integrate the various components into an instrument that could be physically handled by a technician and easily transported.

The WLI is placed over a defect using the video image from the camera. The electronic control is used to reposition the movable mirror. Interference fringes at the surface of the glass are imaged onto the camera (surface position), the mirror is then moved, and interference fringes are formed at various defect site(s). The position of each defect site can be read from the controller's LCD (liquid crystal display). The difference in these positions from the surface determines the depth of the defect(s).

The device contains an interferometer, and alignment of the optics is critical to the operation of the instrument. Maintenance would consist of the proper alignment of the optics and calibration of the position. The measurement resolution for the instrument was expected to be better than 0.0001 in. (2.5 μm.); the unit has exhibited a resolution on the order of 2 μin. (0.05 μm). This capability is more than adequate for this application, but could be extended with different optics.

While in operation, the WLI displays a continually updated depth measurement on the integrated LCD. The LCD shows displacement information in microns and inches, provides scan speed and direction, mode information, and prompts the operator. Both manual and automatic scans are supported by the electronics; the information is also available from a serial data port. The WLI's use of a video camera allows several people to observe and comment on the defect; consulting/collaboration while using the refocus microscope was not possible.

This work was done by Robert Youngquist, Stephen Simmons, and Robert Cox of Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13417