Figure 1. **Tm,Ho:YLF MO/LO Offset Locking System** incorporates the described improvements.

SA Settings:
RBW = 1 KHz
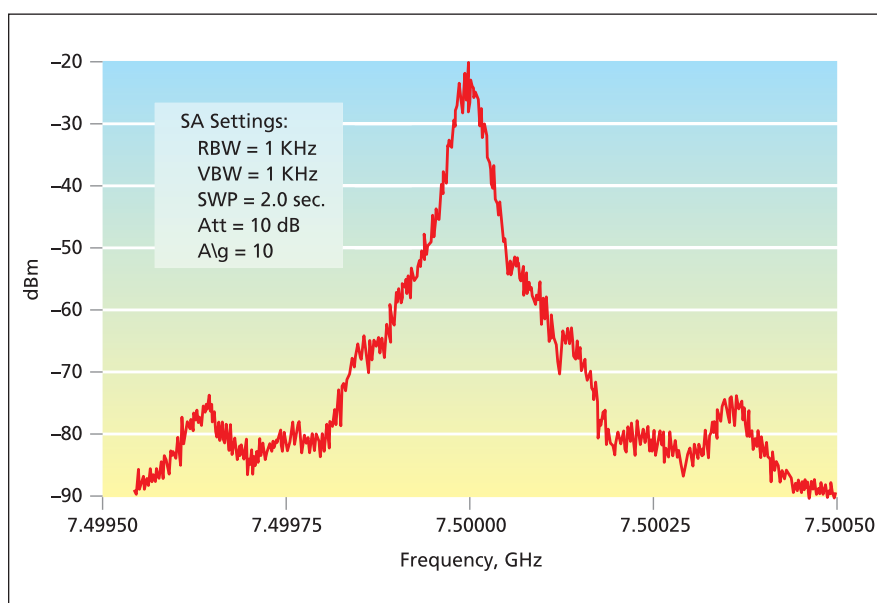VBW = 1 KHz
SWP = 2.0 sec.
Att = 10 dB
A\g = 10

Figure 2. **Heterodyne Beat Note Stability** is depicted when Tm,Ho:YLF MO and LO lasers are actively offset-locked 7.5 GHz apart. Locking stability is ≈30 kHz over many seconds. [SA = signal analyzer; RBW = resolution bandwidth; VBW = video bandwidth; SWP = duration of frequency sweep; Att = attenuation; A\g = antenna gain.]

Recent work on MO/LO offset locking has focused on increasing the offset locking range, improving the graded-InGaAs photoreceiver performance, and advancing the maturity of the offset locking electronics. Figure 1 provides a schematic diagram of the offset-locking system. Improvements to the design of the tunable MO laser resonator resulted in continuous, fast, SLM piezo-tuning range of 25 GHz—more than double the range of the initial prototype. Major progress was also made in the performance of very wideband, 2-μm-sensitive heterodyne photoreceivers. The fiber-coupled, hybridized-preamplifier photoreceivers developed most recently exhibited heterodyne detection bandwidth of 4 GHz to the 3 dB point, and adequate bandwidth to demonstrate robust offset-locking to 10 GHz. This advanced component is now offered as a standard product. Remarkably, these very small (30-μm active area diameter), thin, fast PIN (positive/intrinsic/negative) devices exhibit ≈70 percent quantum efficiency to 4 GHz, adequate for direct use as a heterodyne receiver in many applications. With some degradation in locking robustness, MO/LO offsets of as much as 13.2 GHz were obtained. Settling times were typically 15 ms for 1 GHz steps, and locking stability was measured at 30 kHz over 20-s intervals. The system incorporated a LabVIEW-based GUI and robust auto-locking servo, greatly enhancing its usefulness in offset locking experiments and use as a wideband photoreceiver calibration instrument. Figure 2 shows a typical locking stability result.

very high target velocities with respect to a static or moving lidar platform.

Efforts to date have focused on development of Tm,Ho:YLF lasers operating near 2.05 μm, which have much potential for both efficient space-based wind lidar systems and CO_2 DIAL measurements. The locking techniques are readily applicable to any number of other wavelengths and laser formats.

# Optical Profilometers Using Adaptive Signal Processing

Sizes would be reduced, leading to development of hand-held profilometers.

John F. Kennedy Space Center, Florida

A method of adaptive signal processing has been proposed as the basis of a new generation of interferometric optical profilometers for measuring surfaces. Many current optical surface-measuring profilometers utilize white-light-interferometry and, because of optical and mechanical components essential to their operation, are comparable in size to desktop computers. In contrast, the proposed profilometers would be portable, hand-held units. Sizes could be thus reduced because the adaptive-signal-processing method would make it possible to substitute lower-power coherent light sources (e.g., laser diodes)
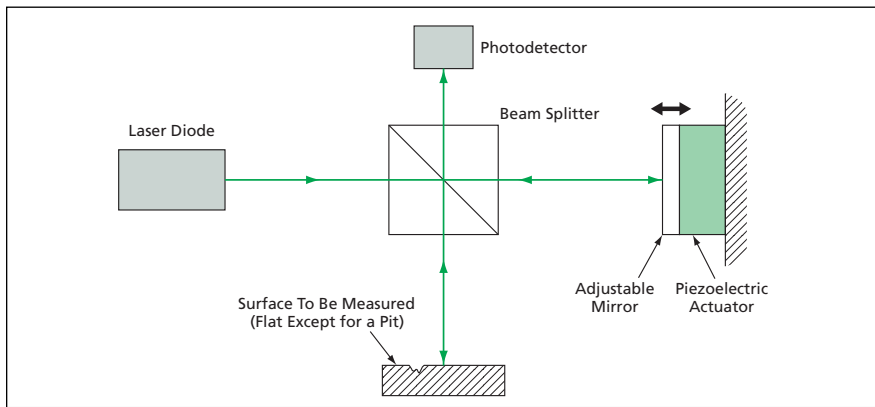
A **Simple Michelson Interferometer** could constitute the optical subsystem of a profilometer, provided that the adjustable mirror were scanned and the output of the photodetector processed as described in the text.

for white light sources and would eliminate the need for most of the optical components of current white-light profilometers. Furthermore, whereas the height scanning ranges of current surface-measuring profilometers are of the order of millimeters, the adaptive-signal-processing method would make it possible to attain scanning ranges of the order of decimeters in the proposed profilometers.

The figure depicts the optical layout of a simple Michelson interferometer configured for use as a profilometer, according to the proposal, for measuring the deviation from flatness of a nominally flat surface that contains a pit. The pit can be characterized as comprising multiple facets at different depth, each producing a coherence function having signal intensity proportional to its size. As a result, the output of the photodetector in this interferometer would include a multitude of overlapping coherence functions that cannot be easily discriminated.

A complete overlapping-coherence-function profile of the surface area within the interrogating light beam would be collected by recording and processing the photodetector output as a function of height while scanning the adjustable mirror through the interrogation depth. The adjustable mirror could be mounted on a piezoelectric actuator for rapid scanning in height. Optionally, a digitally controlled micromirror device could also be used to scan the light beam laterally (horizontally in the figure) across the surface. Modern digital signal-processing hardware would be used to rapidly acquire and process the photodetector output and the overlapping coherence signals contained therein according to the adaptive method described below.

In this method, a Fourier transform of a synthetic intensity-versus-depth signal generated from a mathematical model of the surface to be measured would be subtracted from the Fourier transform of the intensity-versus-depth signal obtained by the interferometer scan of the surface to be measured. The result of the subtraction would be an error signal. The coefficients of the model, representing the sizes and depths of facets in the pit, would be adjusted to minimize the error signal. To obtain the coherence function needed for the model, it would be necessary to perform a calibration measurement, prior to operation, in which a reference mirror known to be optically smooth and flat would be substituted for the surface to be measured.

This work was done by Gregory A. Hall, Robert Youngquist, and Wasfy Mikhael of **Kennedy Space Center**. *Further information is contained in a TSP (see page 1).* KSC-12647

Improved Photon-Emission-Microscope System

An advanced photon-emission microscope is combined with the latest image-processing software.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved photon-emission-microscope (PEM) instrumentation system has been developed for use in diagnosing failure conditions in semiconductor devices, including complex integrated circuits. This system is designed primarily to image areas that emit photons, at wavelengths from 400 to 1,100 nm, associated with device failures caused by leakage of electric current through SiO_2 and other dielectric materials used in multilayer semiconductor structures. In addition, the system is sensitive enough to image areas that emit photons during normal operation. This system supplants a prior PEM system based on a photon-intensified, gated, charge-coupled-device (CCD) camera.

This system includes an optical microscope fitted with a low-light-level imaging subsystem based on a state-of-the-art high-resolution ($1,024 \times 1,024$ pixel), cooled, back-illumination CCD camera in a light-proof enclosure. Another major subsystem is a computer running the latest in Windows-based image-processing software, which can facilitate generation of test reports and research papers by putting out image files in popular formats, including tagged image file (TIF), bit map (BMP), and Joint Photographic Experts Group (JPG) formats.

A device under test (DUT) is placed on a translation stage under the microscope. This stage enables movement of the DUT along both axes perpendicular to the optical axis, as well as along the optical axis for focusing. Any of several microscope objective lenses affording different magnifications (5×, 20×, 50×, and 100× with extra long working distance) can be selected. The exposure time is programmable between 5 milliseconds and 2 hours. Provisions for setups of external equipment, including the power supply for the DUT and digital multimeters, can be incorporated into custom software.

In operation, the system integrates the photons emitted from the DUT, and the resulting bright spots (showing the locations of substantial emission of photons) are displayed superimposed on an image of the DUT that was acquired previously under visible light. Failure-analysis engineers can use the information in this display to locate failure sites on the DUT.

This work was done by Duc Vu of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1). NPO-42121*