Physical Sciences

Image Quality Indicator for Infrared Inspections

John F. Kennedy Space Center, Florida

The quality of images generated during an infrared thermal inspection depends on many system variables, settings, and parameters to include the focal length setting of the IR camera lens. If any relevant parameter is incorrect or sub-optimal, the resulting IR images will usually exhibit inherent unsharpness and lack of resolution.

Traditional reference standards and image quality indicators (IQIs) are made of representative hardware samples and contain representative flaws of concern. These standards are used to verify that representative flaws can be detected with the current IR system settings. However, these traditional standards do not enable the operator to quantify the quality limitations of the resulting images, i.e. determine the inherent maximum image sensitivity and image resolution.

As a result, the operator does not have the ability to optimize the IR inspection system prior to data acquisition.

The innovative IQI described here eliminates this limitation and enables the operator to objectively quantify and optimize the relevant variables of the IR inspection system, resulting in enhanced image quality with consistency and repeatability in the inspection application.

The IR IQI consists of various copper foil features of known sizes that are printed on a dielectric non-conductive board. The significant difference in thermal conductivity between the two materials ensures that each appears with a distinct grayscale or brightness in the resulting IR image. Therefore, the IR image of the IQI exhibits high contrast between the copper features and the underlying dielectric board, which is required to detect the edges of the various copper features.

The copper features consist of individual elements of various shapes and sizes, or of element-pairs of known shapes and sizes and with known spacing between the elements creating the pair. For example, filled copper circles with various diameters can be used as individual elements to quantify the image sensitivity limit. Copper line-pairs of various sizes where the line width is equivalent to the spacing between the lines can be used as element-pairs to quantify the image resolution limit.

This work was done by Eric Burke of the United Space Alliance, Ground Operations Division, for Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13484

Micro-Slit Collimators for X-Ray/Gamma-Ray Imaging

Goddard Space Flight Center, Greenbelt, Maryland

A hybrid photochemical-machining process is coupled with precision stack lamination to allow for the fabrication of multiple ultra-high-resolution grids on a single array substrate. In addition, special fixturing and etching techniques have been developed that allow higher-resolution multi-grid collimators to be fabricated.

Building on past work of developing a manufacturing technique for fabricating multi-grid, high-resolution coating modulation collimators for arcsecond and sub-arcsecond x-ray and gamma-ray imaging, the current work reduces the grid pitch by almost a factor of two, down to 22 microns. Additionally, a process was developed for reducing thin, high-Z (tungsten or molybdenum) from the thinnest commercially available foil (25 microns thick) down to ≈10 microns thick using precisely controlled chemical etching.

This work was done by Michael Appleby, Iain Fraser, and Jill Klinger of Mikro Systems Inc. for Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15628-1

Scatterometer-Calibrated Stability Verification Method

This method can be used in microwave remote sensing, telecommunications, and in reconnaissance and homeland security applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

The requirement for scatterometer-combined transmit-receive gain variation knowledge is typically addressed by sampling a portion of the transmit signal, attenuating it with a known-stable attenuation, and coupling it into the receiver chain. This way, the gain variations of the transmit and receive chains are represented by this loop-back calibration signal, and can be subtracted from the received remote radar echo. Certain challenges are presented by this process, such as transmit and receive components that are outside of this loop-back path and are not included in this calibration, as well as the impracticality for measuring the transmit and receive chains' stability and post fabrication separately,

without the resulting measurement errors from the test set up exceeding the requirement for the flight instrument.

To cover the RF stability design challenge, the portions of the scatterometer that are not calibrated by the loop-back, (e.g., attenuators, switches, diplexers, couplers, and coaxial cables) are tightly thermally controlled, and have been characterized over temperature to contribute less than 0.05 dB of calibration error over worst-case thermal variation. To address the verification challenge, including the components that are not calibrated by the loop-back, a stable fiber optic delay line (FODL) was used to delay the transmitted pulse, and to route it into the receiver. In this way, the internal loop-back signal amplitude variations can be compared to the full transmit/receive external path, while the flight hardware is in the worst-case thermal environment.

The practical delay for implementing the FODL is 100 µs. The scatterometer pulse width is 1 ms so a test mode was incorporated early in the design phase to scale the 1 ms pulse at 100-Hz pulse repetition interval (PRI), by a factor of 18, to be a 55 µs pulse with 556 µs PRI. This scaling maintains the duty cycle, thus maintaining a representative thermal state for the RF components.

The FODL consists of an RF-modulated fiber-optic transmitter, 20 km SMF-28 standard single-mode fiber, and a photodetector. Thermoelectric cooling and insulating packaging are used to achieve high thermal stability of the FODL components. The chassis was insulated with 1-in. (≈2.5-cm) thermal isolation foam. Nylon rods support the Micarta plate, onto which are mounted four 5-km fiber spool boxes. A copper plate heat sink was mounted on top of the fiber boxes (with thermal grease layer)

and screwed onto the thermoelectric cooler plate. Another thermal isolation layer in the middle separates the fiber-optics chamber from the RF electronics components, which are also mounted on a copper plate that is screwed onto another thermoelectric cooler.

The scatterometer subsystem's overall stability was successfully verified to be calibratable to within 0.1 dB error in thermal vacuum (TVAC) testing with the fiber-optic delay line, while the scatterometer temperature was ramped from 10 to 30 °C, which is a much larger temperature range than the worst-case expected seasonal variations.

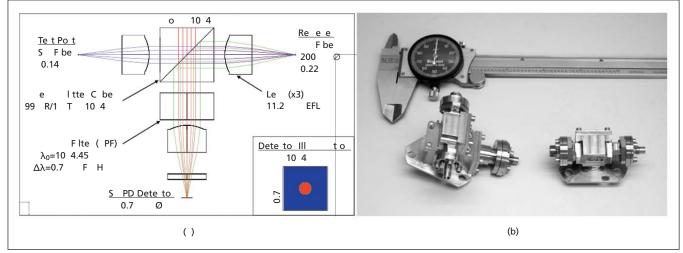# Test Port for Fiber-Optic-Coupled Laser Altimeter
Test port simplifies verification of focal setting and boresight alignment.

Goddard Space Flight Center, Greenbelt, Maryland

A test port designed as part of a fiber-optic-coupled laser altimeter receiver optical system allows for the back-illumination of the optical system for alignment verification, as well as illumination of the detector(s) for testing the receiver electronics and signal-processing algorithms. Measuring the optical alignment of a laser altimeter instrument is difficult after the instrument is fully assembled. The addition of a test port in the receiver aft-optics allows for the back-illumination of the receiver system such that its focal setting and boresight

alignment can be easily verified. For a multiple-detector receiver system, the addition of the aft-optics test port offers the added advantage of being able to simultaneously test all the detectors with different signals that simulate the expected operational conditions.

On a laser altimeter instrument (see figure), the aft-optics couple the light from the receiver telescope to the receiver detector(s). Incorporating a beam splitter in the aft-optics design allows for the addition of a test port to back-illuminate the receiver telescope

and/or detectors. The aft-optics layout resembles a "T" with the detector on one leg, the receiver telescope input port on the second leg, and the test port on the third leg. The use of a custom beam splitter with 99-percent reflection, 1-percent transmission, and a mirrored roof can send the test port light to the receiver telescope leg as well as the detector leg, without unduly sacrificing the signal from the receiver telescope to the detector.

The ability to test the receiver system alignment, as well as multiple detectors

Lunar Orbiter Laser Altimeter (LOLA) Aft-Optics: (a) Optical Layout, (b) Assemblies.