puter for monitoring surface defects. The first image is a wide-angle view to assist the user in locating defects. The second provides an enlarged view of a defect centered in the window of the first image. The focus is adjustable for each of the images. However, the enlarged view was designed to have a focal plane with a short depth. This allows the user to get a feel for the depth of different parts of the defect under inspection as the focus control is varied. A light source is also provided to illuminate the defect, precluding the need for separate lighting tools. The software provides many controls to adjust image quality, along with the ability to zoom digitally the images and to capture and store them for later processing.

Two LED light sources are included for improved illumination, allowing the user to work without an external light source. The optics enable the two cameras to be mounted in a compact manner and allow them to focus on the same image. Software provided from the camera manufacturer provides the users the capability to view the two images simultaneously to facilitate rapid defect detection. The user may use a digital zoom to enlarge smaller details, if needed. Full-resolution digital images and limited-

The **Surface Inspection Tool** (left), shown in use (right). The handle was added to accommodate smaller hands and reduce user fatigue.

resolution video can be captured and stored for later processing.

The surface inspection tool addresses many of the limitations of the existing refocus microscope. It is smaller and provides a live video output on a laptop computer that allows the user to locate defects more rapidly. The camera with the microscope objective has a depth of focus of approximately 0.00014 in. ($\approx$4 µm) and a user-varied focus. This allows the user to gain a better understanding of the depth and character of the defect under inspection. Likewise, lower-resolution video capture is also an avail-

able feature not present with the refocus microscope.

The surface inspection tool consists of components that are more expensive than the refocus microscope. However, the inclusion of the wide-angle camera allows for inspection of a larger area at a time, making it quicker to scan and locate defects in large surfaces. This time savings, combined with the added features, may make it interesting enough to potential users to justify the added initial cost.

Per-Pixel, Dual-Counter Scheme for Optical Communications

Per-pixel processing scheme for single-photon detectors would require 10 to 100 times less beacon transmit power.

NASA's Jet Propulsion Laboratory, Pasadena, California

Free space optical communications links from deep space are projected to fulfill future NASA communication requirements for 2020 and beyond. Accurate laser-beam pointing is required to achieve high data rates at low power levels. For the highest pointing accuracy, a laser beacon transmitted from near the Earth receiver location is acquired and tracked by the space transceiver to obtain accurate knowledge of the Earth receiver position in the pitch and yaw degrees of freedom. This pointing knowledge is generated by forming estimates of the beacon transmitter location by centroiding the position of a focused spot on a focal plane detector array in the space transceiver, perhaps a two-by-two pixel array (a quad detector), but often on a larger array to ease initial spatial acquisition. The accuracy of those estimates, and, therefore, the accuracy of the space transceiver point-

ing, is a function of the received optical signal power, accepted optical background power, and detector readout noise. The centroiding performance of a typical focal plane array can be 10 to 100 times poorer than the shot noise limit due to readout noise. A focal plane array of single-photon detectors can fully close this gap, and thereby require 10 to 100 times less beacon transmit power, but specialized per-pixel processing circuitry is required.

This innovation is a per-pixel processing scheme using a pair of three-state digital counters to implement acquisition and tracking of a dim laser beacon transmitted from Earth for pointing control of an interplanetary optical communications system using a focal plane array of single sensitive detectors. It shows how to implement dim beacon acquisition and tracking for an interplanetary optical transceiver with a method

that is suitable for both achieving theoretical performance, as well as supporting additional functions of high data rate forward links and precision spacecraft ranging.

Spatial acquisition and tracking on the uplink laser beacon from Earth can be achieved on the space transceiver focal plane array by connecting two counters to every array pixel. This scheme provides a low-complexity method to monitor all pixels in the detector array until a beacon signal is detected. Temporal acquisition of the uplink laser beacon square wave signal is performed using outputs from a pair of phase-offset counters. The counters alternate among three states denoted by "up," "down," and "idle." In the up state, a counter increments its value when its pixel registers a photon arrival. In the down state, the counter decrements its value when a photon arrival is

detected. The counter maintains its value in the idle state. For an outer modulation signal of 2 PPM + two inter-symbol guard time slots with slot widths T_{slot}, the counters cycle through the three states with period of $4T_{slot}$. The counters can be seen as approximations to a maximum-likelihood timing estimation with a modified pulse shape. Post-processing in software allows the outputs of the counters to be integrated in time.