gen is deduced from the intensity and lifetime of the fluorescence in the exposed channel, with the help of calibration data acquired via the reference channel. Because the sensory chemical is placed directly in and throughout the cross section of the light path, approximately 99 percent of the light in the

waveguide is available for interaction with the chemical, in contradistinction to only about 1 percent of the light in an optical sensor that utilizes evanescent-wave coupling. Hence, a sensor of this type is significantly more sensitive.

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Ka-Band Autonomous Formation Flying Sensor

NASA's Jet Propulsion Laboratory, Pasadena, California

A Ka-band integrated range and bearing-angle formation sensor called the Autonomous Formation Flying (AFF) Sensor has been developed to enable deep-space formation flying of multiple spacecraft. The AFF Sensor concept is similar to that of the Global Positioning System (GPS), but the AFF Sensor would not use the GPS. The AFF Sensor would reside in radio transceivers and signal-processing subsystems aboard the formation-flying spacecraft. A version of the AFF Sensor has been developed for initial application to the two-spacecraft StarLight op-

tical-interferometry mission, and several design investigations have been performed. From the prototype development, it has been concluded that the AFF Sensor can be expected to measure distances and directions with standard deviations of 2 cm and 1 arc minute, respectively, for spacecraft separations ranging up to about 1 km. It has also been concluded that it is necessary to optimize performance of the overall mission through design trade-offs among the performance of the AFF Sensor, the field of view of the AFF Sensor, the designs of the space-

craft and the scientific instruments that they will carry, the spacecraft maneuvers required for formation flying, and the design of a formation-control system.

This work was done by Jeffrey Tien; George Purcell, Jr.; Jeffrey Srinivasan; Michael Ciminera; Meera Srinivasan; Thomas Meehan; Lawrence Young; MiMi Aung; Luis Amaro; Yong Chong; and Kevin Quirk of Caltech for **NASA's Jet Propulsion Laboratory** *and Dean Paschen of Ball Aerospace Technology Corporation. Further information is contained in a TSP (see page 1). NPO-30813.*

CMOS VLSI Active-Pixel Sensor for Tracking

Data could be acquired from as many as eight windows within a frame.

NASA's Jet Propulsion Laboratory, Pasadena, California

An architecture for a proposed active-pixel sensor (APS) and a design to implement the architecture in a complementary metal oxide semiconductor (CMOS) very-large-scale integrated (VLSI) circuit provide for some advanced features that are expected to be especially desirable for tracking point-like features of stars. The architecture would also make this APS suitable for robotic-vision and general pointing and tracking applications.

CMOS imagers in general are well suited for pointing and tracking because they can be configured for random access to selected pixels and to provide readout from windows of interest within their fields of view. However, until now, the architectures of CMOS imagers have not supported multiwindow operation or low-noise data collection. Moreover, smearing and motion artifacts in collected images have made prior CMOS imagers unsuitable for tracking applications.

The proposed CMOS imager (see figure) would include an array of 1,024 by 1,024 pixels containing high-performance photodiode-based APS circuitry. The pixel pitch would be 9 μm. The operations of the pixel circuits would be sequenced and otherwise controlled by an on-chip timing and control block, which would enable the collection of image data, during a single frame period, from either the full frame (that is, all 1,024 × 1,024 pixels) or from within as many as 8 different arbitrarily placed windows as large as 8 by 8 pixels each.

A typical prior CMOS APS operates in a row-at-a-time ("rolling-shutter") readout mode, which gives rise to exposure skew. In contrast, the proposed APS would operate in a sample-first/read-later mode, suppressing rolling-shutter effects. In this mode, the analog readout signals from the pixels corresponding to the windows of the interest (which windows, in the star-tracking application, would presumably contain guide stars)

would be sampled rapidly by routing them through a programmable diagonal switch array to an on-chip parallel analog memory array. The diagonal-switch and memory addresses would be generated by the on-chip controller.

The memory array would be large enough to hold differential signals acquired from all 8 windows during a frame period. Following the rapid sampling from all the windows, the contents of the memory array would be read out sequentially by use of a capacitive transimpedance amplifier (CTIA) at a maximum data rate of 10 MHz. This data rate is compatible with an update rate of almost 10 Hz, even in full-frame operation.

In the multiwindow readout mode, this APS could operate with ultralow noise. When an APS of prior design is operated in row-at-a-time readout, the main component of noise in each pixel is the reset noise at the sensing node. In the proposed APS, the reset levels for an