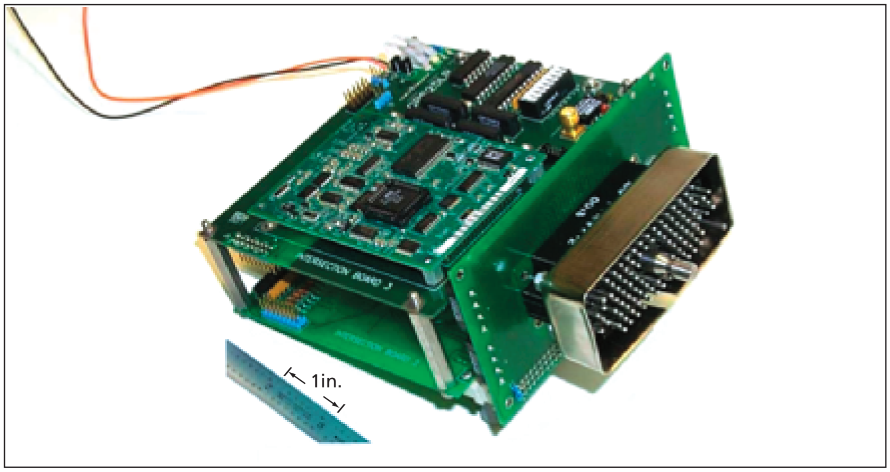
Intersection Monitor for Traffic-Light-Preemption System

This unit provides real-time phase data essential for effective preemption.

NASA's Jet Propulsion Laboratory, Pasadena, California



The **Intersection Monitor**, shown here with its covers off, provides real-time data on the phases of traffic lights at an intersection, without interfering with the traffic-light control circuitry.

The figure shows an intersection monitor that is a key subsystem of an emergency traffic-light-preemption system that could be any of the systems described in the three immediately preceding articles and in "Systems Would Preempt Traffic Lights for Emergency Vehicles" (NPO-30573), *NASA Tech Briefs*, Vol. 28, No. 10 (October 2004), page 36. This unit is so named because it is installed at an intersection, where it monitors the phases (in the sense of timing) of the traffic lights. The mode of operation of this monitor is independent of the type of traffic-light-controller hardware or software in use at the intersection. Moreover, the design of the monitor is such that (1) the monitor does not, by itself, affect the operation of the traffic-light controller and (2) in the event of a failure of the monitor, the traffic-light controller continues to function normally (albeit without preemption).

The monitor is installed in series with the traffic-light controller at an intersection. The control signals of interest are monitored by use of high-impedance taps on affected control lines. These taps are fully isolated and further protected by high-voltage diodes that prevent any voltages or short circuits that arise within the monitor from affecting the controller. The signals from the taps are processed digitally and cleaned up by use of high-speed logic gates, and the resulting data are passed on to other parts of the traffic-light-preemption intersection subsystem. The data are compared continuously with data from vehicles and used to calculate timing for reliable preemption of the traffic lights. The pedestrian crossing at the intersection is also monitored, and pedestrians are warned not to cross during preemption.

This work was done by Aaron Bachelder and Conrad Foster of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-30612, volume and number of this NASA Tech Briefs *issue, and the page number.*

Full-Duplex Digital Communication on a Single Laser Beam

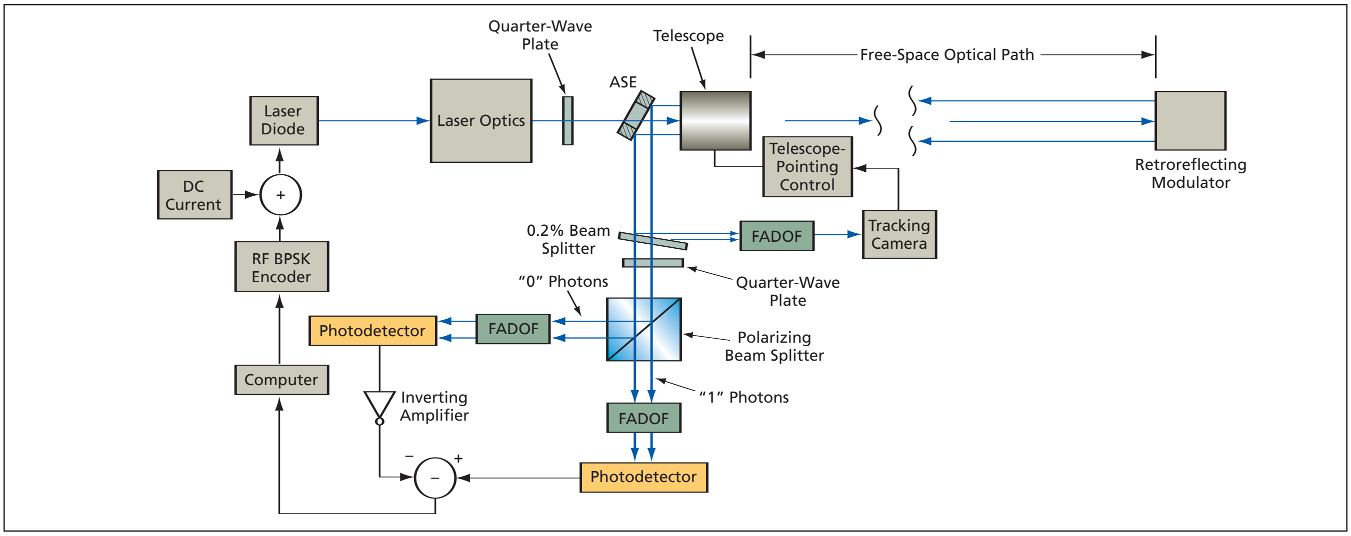
The laser beam would be transmitted with one modulation and retroreflected with another modulation.

Goddard Space Flight Center, Greenbelt, Maryland

A proposed free-space optical communication system would operate in a full-duplex mode, using a single constant-power laser beam for transmission and reception of binary signals at both ends of the free-space optical path. The system was conceived for two-way data communication between a ground station and a spacecraft in a low orbit around the Earth. It has been estimated that in this application, a data rate of 10 kb/s could be achieved at a ground-station-to-spacecraft distance of 320 km, using a laser power of only 100 mW. The basic system concept is also applicable to terrestrial free-space optical communications.

The system (see figure) would include a diode laser at one end of the link (originally, the ground station) and a liquid-crystal-based retroreflecting modulator at the other end of the link (originally, the spacecraft). At the laser end, the beam to be transmitted would be made to pass through a quarter-wave plate, which would convert its linear polarization to right circular polarization. For transmission of data from the laser end to the retroreflector end, the laser beam would be modulated with subcarrier phase-shift keying (SC-PSK). The transmitted beam would then pass through an aperture-sharing element (ASE) — basically, a mirror with a hole in it, used to separate the paths of the transmitted and received light beams. The transmitted beam would continue outward through a telescope (which, in the original application, would be equipped with a spacecraft-tracking system) that would launch the transmitted beam along the free-space optical path to the retroreflector end.

At the retroreflector end, a portion of the received laser beam would be sent to a demodulator for detection of the SC-PSK signal. For transmitting data to the laser end, the retroreflected portion of the received laser beam would be modulated with circular-polarization keying (CPK), in which left circular polarization signifies a binary level ("1" in this case) and right circu-



The **Laser at One End** of the free-space optical path would provide all of the beam power needed for transmission of data signals in both directions along the path.

lar polarization signifies the other binary level ("0" in this case). Hence, to transmit "0," the retroreflecting modulator would leave the right circular polarization of the retroreflected beam unchanged; to transmit "1," the retroreflecting modulator would flip the polarization of the reflected beam to left circular. Full-duplex operation would be possible because the CPK and the SC-PSK would be transparent to each other.

At the laser end, the reflected, CPK-modulated beam would return through the telescope and would then be reflected by the ASE into a receiver subsystem. A beam splitter would divert 0.2 percent of the beam power to a camera in the tracking system. The remainder of the beam would pass through the beam splitter to a quarter-wave plate, which would convert the circular polarization to two orthogonal linear polarizations. A polarizing beam splitter would then split the light in these two polarizations so that photons corresponding to "0" would go to one photodetector and photons corresponding to "1" would go to another photodetector.

It should be emphasized that this arrangement would yield a nonzero photodetector output of nominally the same magnitude for either "0" or "1." This is fundamentally different from on-off keying (OOK), in which "0" or "1" is represented by the absence or presence, respectively, of a signal. Taking advantage of this, prior to final digitization of the return signal at "0" or "1," the output of the "0" photodetector could be inverted, then subtracted from the output of the "1" photodetector to obtain twice the signal-to-noise ratio achievable in OOK.

The receiver subsystem would include Faraday-anomalous-dispersion optical filters (FADOFs), which would reject background light to such a high degree that the system could operate over a long path during daytime. The FADOFs would essentially prevent skylight from reaching the photodetectors while allowing about 80 percent of the signal photons to pass through. Without the FADOFs, it would be necessary to increase the laser power by a factor of 10 for daytime operation.

This work was done by D. A. Hazzard, J. A. MacCannell, G. Lee, E. R. Selves, D. Moore, J. A. Payne, C. D. Garrett, N. Dahlstrom, and T. M. Shay of New Mexico State University for **Goddard Space Flight Center**. *Further information is contained in a TSP (see page 1).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to GSC-14759-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Stabilizing Microwave Frequency of a Photonic Oscillator

Microwave frequency is stabilized by stabilizing optical frequency to an atomic transition.

NASA's Jet Propulsion Laboratory, Pasadena, California

A scheme for stabilizing the frequency of a microwave signal is proposed that exploits the operational characteristics of a coupled optoelectronic oscillator (COEO) and related optoelectronic equipment. An essential element in the scheme is a fiber mode-locked laser (MLL), the optical frequency of which is locked to an atomic transition. In this scheme, the optical frequency stability of the mode-locked laser is transferred to that of the microwave in the same device. Relative to prior schemes for using wideband optical frequency comb to stabilize microwave signals, this scheme is simpler and lends itself more readily to implementation in relatively compact, rugged equipment. The anticipated development of small, low-power, lightweight, highly stable microwave oscillators based on this scheme would afford great benefits in communication, navigation, metrology, and fundamental sciences.

COEOs of various designs, at various stages of development, in some cases called by different names, have been described in a number of prior *NASA Tech Briefs* articles. A COEO is an optoelectronic apparatus that generates both short (picosecond) optical pulses and a steady microwave signal having an ultra-high degree of spectral purity. The term "coupled optoelectronic" in the full name of such an apparatus signifies that