ward prediction system would be relatively invulnerable to noise, would not be subject to significant range limitations, and would function well in large cities — even in such places as underneath bridges and in tunnels, where GPS-based systems do not work.

One proposed system has been characterized as "car-active" because each participating emergency vehicle would be equipped with a computer and a radio transceiver that would communicate with stationary transceivers at the traffic loops (see figure). Whenever a vehicle was detected passing over a traffic loop, the loop transceiver, possibly using the loop as an antenna, would transmit a signal identifying the location of the loop and the direction of travel. (Traffic-loop equipment that performs this function is already commercially available.) If the vehicle passing over the loop were a participating vehicle, its transceiver would receive the position signal. The computer in the vehicle would use the signal and the time of its receipt as a time-and-position fix in a continuous "dead reckoning" estimation of the current position of the vehicle as function of speed and compass heading. At time intervals of 1 second, the transceiver would broadcast the updated estimate of position to loop receivers at neighboring intersections. The stationary portion of the system would determine, on the basis of the updates, whether the vehicle was likely to pass through a given intersection within a suitable amount of time (typically of the order of 1 minute), in which case the system would preempt the switching of traffic lights at the intersection.

The other proposed system has been characterized as "car-passive" because a passive radio transponder would be installed on the underside of a participating vehicle. When passing over a traffic loop, the transponder would be energized by a signal, at a frequency of 450 MHz, radiated via the loop. When so energized, the transponder would transmit a vehicle identification number signal at a carrier frequency of 900 MHz. Unlike in the car-active system, there would be no continuous estimation of vehicle position. Instead, traffic lights would be preempted on the basis of simple proximity detection. For this purpose, upon detection of a participating vehicle at a loop at a given intersection, the detection would be signaled to neighboring intersections. Traffic lights at the next intersection or next few intersections through which the vehicle could be expected to pass could then be preempted until the vehicle passed through or until a specified time elapsed.

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).*

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Refer to NPO-30573, volume and number of this NASA Tech Briefs *issue, and the page number.*

Optical Position Encoders for High or Low Temperatures

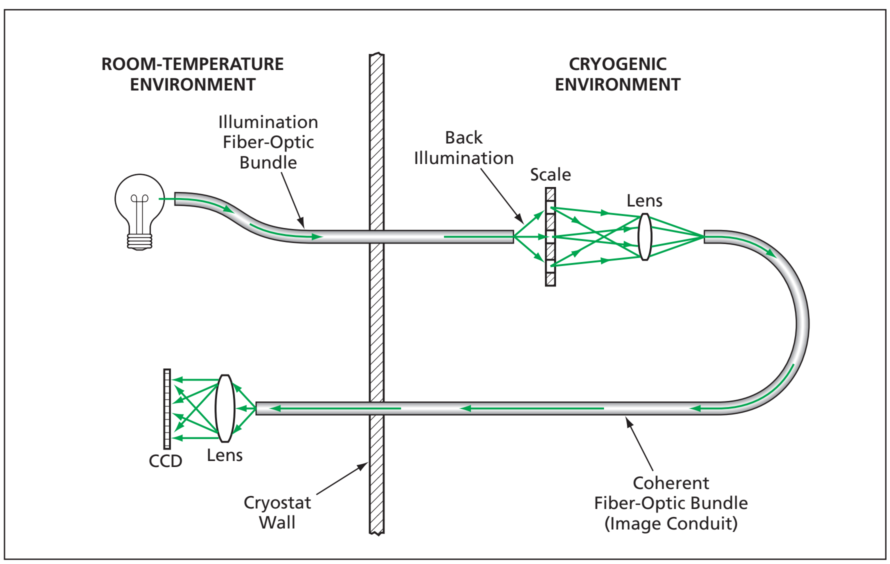
CCD cameras monitor backlit scales via coherent fiber-optic bundles.

Goddard Space Flight Center, Greenbelt, Maryland

Optoelectronic pattern-recognition systems (optical encoders) for measuring positions of objects of interest at temperatures well below or well above room temperature are undergoing development. At present, the development effort is concentrated on absolute linear, rotary, and Cartesian encoders and Cartesian autocollimators for scientific instruments that operate in cryostats.

Like some prior pattern-recognition optical encoders, a system of the present type includes a backlit scale attached to the object of interest, a charge-coupled-device (CCD) camera, a lens to project a possibly magnified image of the scale onto the CCD, circuitry to digitize the image detected by CCD, and a computer to process the image data to determine positions of the optically projected scale marks in the reference frame embodied in the array of pixels of the CCD. Unlike in prior systems, neither the light source for illuminating the scale nor the CCD is located in the cold or hot environment that contains the object of interest and the attached scale. This arrangement makes it possible for the CCD to read the scale even though the CCD could not function properly if it were located in that environment. In the case of a cryogenic environment, this arrangement is particularly advantageous because it minimizes spurious heating by the light source and eliminates spurious heating that would otherwise be caused by dissipation of power in the CCD circuitry.

A cryogenic implementation of a linear or rotary encoder of this type is con-



Fiber-Optic Bundles are used to feed light to and from a position-encoding scale in a cryostat.

ceptually straightforward (see figure). By use of a conventional illumination-type fiber-optic bundle, visible light from a source outside a cryostat is fed into the cryostat to back-illuminate the scale. In a typical case, an image of the scale can be acquired and fed to the CCD optics by use of a lens-tipped coherent fiber-optic bundle similar to a fiber-optic borescope or endoscope. A low-thermal-conductivity hermetic feedthrough is installed at the point where the fiber-optic bundle passes through the cryostat wall. Alternately, an image of the scale can be projected out through a small window in the cryostat wall. Either way, the encoding function involves very little energy dissipation inside the cryostat.

This work was done by Douglas B. Leviton of **Goddard Space Flight Center**. *Further information is contained in a TSP (see page 1).*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center, (301) 286-7351. Refer to GSC-14766-1.

Inter-Valence-Subband/Conduction-Band-Transport IR Detectors

These devices would be capable of operation at normal incidence.

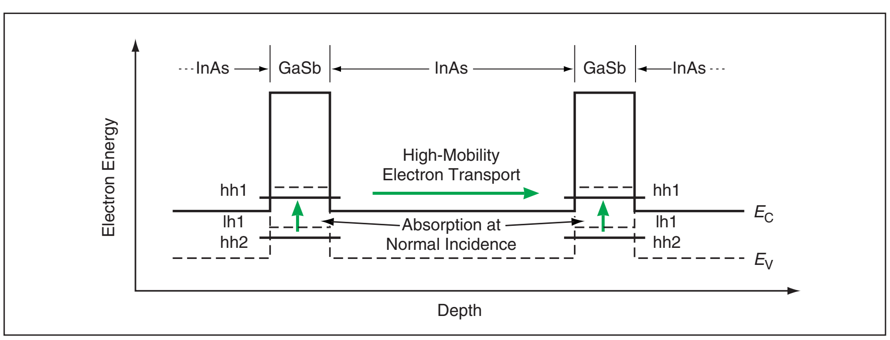
NASA's Jet Propulsion Laboratory, Pasadena, California

Infrared (IR) detectors characterized by a combination of (1) high-quantum-efficiency photoexcitation of inter-valence-subband transitions of charge carriers and (2) high-mobility conduction-band transport of the thus-excited charge carriers have been proposed in an effort to develop focal-plane arrays of such devices for infrared imaging. Like many prior quantum-well infrared photodetectors (QWIPs), the proposed devices would be made from semiconductor heterostructures. In order to obtain the combination of characteristics mentioned above, the proposed devices would be designed and fabricated in novel InAs/GaSb superlattice configurations that would exploit a phenomenon known in the semiconductor art as type-II broken-gap band offset.

Previously tested GaInSb/InAs type-II strained-layer-superlattice devices have shown the potential to offer optical properties comparable to, degrees of uniformity greater than, and tunneling currents and Auger recombination less than, those of HgCdTe IR photodetectors. Moreover, the GaInSb/InAs type-II strained-layer devices have been shown to be capable of operation at normal incidence. The operation of the GaInSb/InAs type-II strained-layer devices involves transitions from valence subbands in GaInSb to conduction subbands in InAs. The spatial separation of wave functions involved in the transition results in reduced oscillator strengths. Therefore, to obtain adequate quantum efficiency, it is necessary to grow thick, high-quality superlattices — a task that is challenging because GaInSb and InAs are lattice-mismatched. The development of the proposed devices would implement an alternative approach to exploitation of some of the same basic principles as those of the GaInSb/InAs type-II strained-layer devices.

It is useful to compare the proposed GaSb/InAs QWIPs with prior GaAs/AlGaAs QWIPs, which utilize n doping. Because quantum-mechanical selection rules in n-doped QWIPs forbid inter-conduction-subband transitions induced by normally incident light, optical coupling gratings are needed to achieve acceptable quantum efficiencies in such QWIPs. On the other hand, inter-valence-subband transitions in p-doped QWIPs can absorb normally incident photons with high quantum efficiency, so that optical coupling gratings are not needed.

An InAs/GaSb multi-quantum well structure according to the proposal would comprise p-doped GaSb quantum wells embedded in InAs barriers (see figure). The inter-valence-subband transitions in the GaSb wells would absorb normally incident photons with high quantum efficiency. Although the InAs layers would be barriers to ground-state electrons, a device of this type would take advantage of the high electron mobility in the InAs conduction band for transporting excited electrons between the GaSb quantum wells. This would be made possible by the type-II broken-gap band offset between InAs and GaSb: The edge of the valence band of GaSb is approximately 0.15 eV higher than the conduction-band edge of InAs. Therefore, electrons in the p-doped GaSb quantum wells that were photoexcited to the uppermost subband (denoted the heavy-hole 1 or hh1 subband) could easily escape into the conduction band in InAs layers.



This **Energy-Band Diagram of a GaSb/InAs QWIP** depicts the energy levels involved in the exploitation of (1) inter-valence-subband transitions in GaSb for detection and (2) transport in the InAs conduction band. The relevant energy bands and the energies at their edges are denoted as follows: EC for conduction band; EV for valence band; hh1 and hh2 for heavy-hole bands 1 and 2, respectively; and lh1 for light-hole band 1.

This work was done by David Ting, Sarath Gunapala, and Sumith Bandara of Caltech for **NASA's Jet Propulsion** *Laboratory. Further information is con*tained in a TSP (see page 1).

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