of holes to the conduction band and buildup of charge at the Bn (i.e., at the barrier and n-contact) interface.

The lower part of the figure depicts the energy-band structure for one of the proposed modified device structures. In this case, the plain n-type contact layer would be replaced with a graded III–V alloy layer with proper doping gradient from undoped to doped n contact. The valence band potential dip can be eliminated under proper bis condition. In a different modification, not shown in the figure, the plain photon-absorption layer could be replaced with a chirped strain-layer superlattice. In either modification, the graded or chirped structure would provide an energy ramp that would serve as a smooth path for transport of minority charge carriers. The valence-band hole trap and the associated undesired effects would be eliminated.

This work was done by Sarath D. Gunapala, David Z. Ting, Cory J. Hill, and Sumith V. Bandara of Caltech for NASA's Jet Propulsion Laboratory.

# Atomic References for Measuring Small Accelerations
These systems may be used in military and geological applications.
NASA's Jet Propulsion Laboratory, Pasadena, California

Accelerometer systems that would combine the best features of both conventional (e.g., mechanical) accelerometers and atom interferometer accelerometers (AIAs) have been proposed. These systems are intended mainly for use in scientific research aboard spacecraft but may also be useful on Earth in special military, geological, and civil-engineering applications.

Conventional accelerometers can be sensitive, can have high dynamic range, and can have high frequency response, but they lack accuracy and long-term stability. AIAs have low frequency response, but they offer high sensitivity, and high accuracy for measuring small accelerations. In a system according to the proposal, a conventional accelerometer would be used to perform short-term measurements of higher-frequency components of acceleration, while an AIA would be used to provide consistent calibration of, and correction of errors in, the measurements of the conventional accelerometer in the lower-frequency range over the long term.

A brief description of an AIA is prerequisite to a meaningful description of a system according to the proposal. An AIA includes a retroreflector next to one end of a cell that contains a cold cloud of atoms in an ultrahigh vacuum. The atoms in the cloud are in free fall. The retroreflector is mounted on the object, the acceleration of which is to be measured. Raman laser beams are directed through the cell from the end opposite the retroreflector, then pass back through the cell after striking the retroreflector. The Raman laser beams together with the cold atoms measure
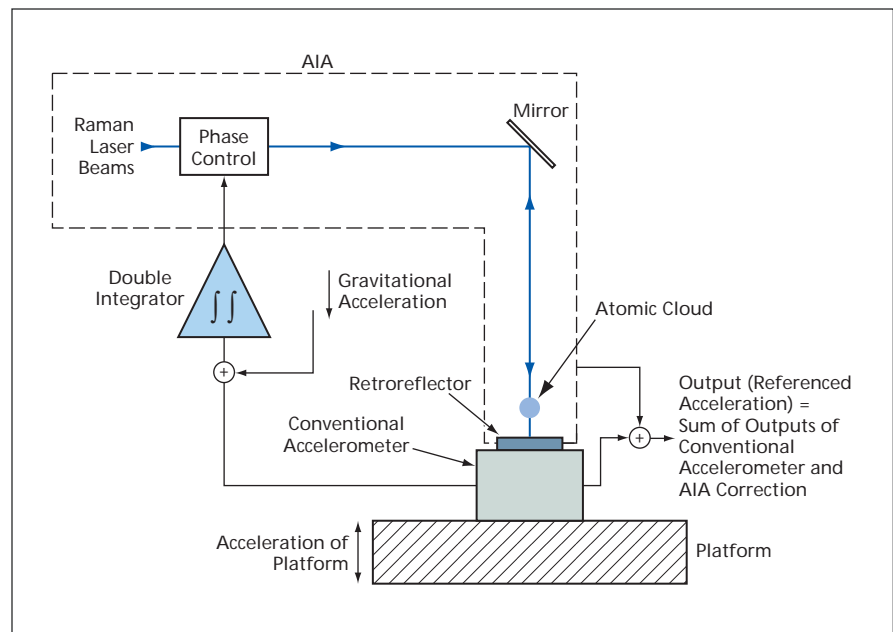
An **Atom-Interferometer Accelerometer** (AIA) and a conventional accelerometer would be connected in a feedback loop, such that the net acceleration measurement would be that of the conventional accelerometer plus a correction term provided by the AIA.

the relative acceleration, through the readout of the AIA, between the cold atoms and the retroreflector.

A system according to the proposal could be realized in several alternative implementations. In the simplest implementation (see figure), the conventional accelerometer and the retroreflector of the AIA would be mounted on a platform, the acceleration of which was to be measured. The phase of the Raman laser beams is frequency-chirped to remove the known gravity acceleration. From the output of the conventional accelerometer, the equivalent phase shift of the AIA is converted through the electronic double integrator. This phase is electronically fed forward to a Raman laser phase shifter such that it cancels out the phase shift in the AIA due to the acceleration read by the conventional accelerometer. The remaining part of the AIA phase shift would be used to compute a residual acceleration that would be applied as a correction to the acceleration measurement of the conventional accelerometer.

This work was done by Lute Maleki and Nan Yu of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).
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