

behaviors. Biological entities consist mostly of diamagnetic molecules (e.g., water molecules) and thus can be levitated by use of sufficiently strong magnetic fields having sufficiently strong vertical gradients.

The heart of the present maglev apparatus is a vertically oriented superconducting solenoid electromagnet (see figure) that generates a static magnetic field of about 16 T with a vertical gradient sufficient for levitation of water in normal Earth gravity. The electromagnet is enclosed in a Dewar flask having a

volume of 100 L that contains liquid helium to maintain superconductivity. The Dewar flask features a 66-mm-diameter warm bore, lying within the bore of the magnet, wherein experiments can be performed at room temperature. The warm bore is accessible from its top and bottom ends. The superconducting electromagnet is run in the persistent mode, in which the supercurrent and the magnetic field can be maintained for weeks with little decay, making this apparatus extremely cost and energy efficient to operate. In addition to water,

this apparatus can levitate several common fluids: liquid hydrogen, liquid oxygen, methane, ammonia, sodium, and lithium, all of which are useful, variously, as rocket fuels or as working fluids for heat transfer devices. A drop of water 45 mm in diameter and a small laboratory mouse have been levitated in this apparatus.

*This work was done by Yuanming Liu, Donald M. Strayer, and Ulf E. Israelsson of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).NPO-45886*

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## Hybrid AlGaIn-SiC Avalanche Photodiode for Deep-UV Photon Detection

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The proposed device is capable of counting ultraviolet (UV) photons, is compatible for inclusion into space instruments, and has applications as deep-UV detectors for calibration systems, curing systems, and crack detection. The device is based on a Separate Absorption and Charge Multiplication (SACM) structure. It is based on aluminum gallium nitride (AlGaIn) absorber on a silicon carbide APD (avalanche photodiode). The AlGaIn layer absorbs incident

UV photons and injects photogenerated carriers into an underlying SiC APD that is operated in Geiger mode and provides current multiplication via avalanche breakdown.

The solid-state detector is capable of sensing 100-to-365-nanometer wavelength radiation at a flux level as low as 6 photons/pixel/s. Advantages include, visible-light blindness, operation in harsh environments (e.g., high temperatures), deep-UV detection response,

high gain, and Geiger mode operation at low voltage. Furthermore, the device can also be designed in array formats, e.g., linear arrays or 2D arrays (micropixels inside a superpixel).

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## High-Speed Operation of Interband Cascade Lasers

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Optical sources operating in the atmospheric window of 3–5  $\mu\text{m}$  are of particular interest for the development of free-space optical communication link. It is more advantageous to operate the free-space optical communication link in 3–5- $\mu\text{m}$  atmospheric transmission window than at the telecom wavelength of 1.5  $\mu\text{m}$  due to lower optical scattering, scintillation, and background radiation. However, the realization of optical communications at the longer wavelength has encountered significant difficulties due to lack of adequate optical sources and detectors operating in the desirable wavelength regions.

Interband Cascade (IC) lasers are novel semiconductor lasers that have a great potential for the realization of high-power, room-temperature optical sources in the 3–5- $\mu\text{m}$  wavelength region, yet no experimental work, until this one, was done on high-speed direct modulation of IC lasers. Here, high-speed interband cascade laser, operating at wavelength 3.0  $\mu\text{m}$ , has been developed and the first direct measurement of the laser modulation bandwidth has been performed using a unique, high-speed quantum well infrared photodetector (QWIP). The developed laser has modulation bandwidth exceeding 3

GHz. This constitutes a significant increase of the IC laser modulation bandwidth over currently existing devices. This result has demonstrated suitability of IC lasers as a mid-IR light source for multi-GHz free-space optical communications links.

*This work was done by Alexander Soibel, Cory J. Hill, Sam A. Keo, Malcom W. Wright, and William H. Farr of Caltech; Rui Q. Yang of the University of Oklahoma; and H.C. Liu of the Institute for Microstructural Science for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46738*