SAND2010-4269P

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Embargoed for release 27 June 2010 at 1800 London time / 1300 US Eastern time

First successful monolithic integration of THz quantum cascade laser and diode mixer seen in solid-state terahertz transceiver

A solid-state system for putting to use the "neglected middle child" terahertz (THz) region that lies between the microwave and infrared parts of the electromagnetic spectrum has been developed at Sandia National Laboratories. Described in the current (June 27 2010) issue of *Nature Photonics*, it represents the first successful monolithic integration of a THz quantum cascade laser and diode mixer to form a simple but generically useful terahertz photonic integrated circuit—a microelectronic terahertz transceiver (transmitter/receiver).

It has been apparent since the demonstration of semiconductor THz quantum cascade lasers (QCLs) in 2002 that these devices could offer unprecedented advantages in technologies used for security, communications, radar, chemical spectroscopy, radioastronomy, and medical diagnostics. Until now, however, sensitive coherent transceiver systems were assembled from a collection of discrete and often very large components. Similar to moving from discrete transistor to integrated chips in the microwave world and moving from optical breadboards to photonic integrated circuits in the visible/infrared world, this work represent the first steps toward reduction in size and enhanced functionality in the THz frequency spectrum.

With investment from Sandia's Laboratory-Directed Research and Development (LDRD) program, the lab focused on the integration of THz QCLs with sensitive, high-speed THz Schottky diode detectors, resulting in a compact, reliable solid-state platform. The transceiver embeds a small Schottky diode into the ridge waveguide cavity of a QCL, so that local-oscillator power is directly supplied to the cathode of the diode from the QCL internal fields, with no optical coupling path.

A collection of applications are being explored at Sandia and elsewhere. Terahertz radiation can "see through" some materials, depending on the frequency. At a relatively high frequency (the Sandia team is working at 3 THz), it could potentially be used in dental or skin cancer imaging to distinguish different tissue types, or permit improved nondestructive testing during production monitoring. Other frequencies could be used to penetrate some semiconductors and clothing, and possibly identify chemical/biological weapons and narcotics.

Other potential applications include atmospheric monitoring, short range communication links, short range coherent imaging, or high specificity identification of preconcentrated, low-pressure, vapor-phase explosives.

The Sandia semiconductor THz development team, headed by Michael C. Wanke, also included Erik W. Young, Christopher D. Nordquist, Michael J. Cich, Charles T. Fuller, John L. Reno, Mark Lee – all of Sandia Labs -- and Albert D. Grine of LMATA Government Services, Albuquerque. Young recently joined Philips Lumileds, San Jose, California.

The paper is available online following the embargo (abstracts are available to everyone, full text only to subscribers) by employing the following URL: http://dx.doi.org/10.1038/NPHOTON.2010.137

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