New quantum cascade lasers emit more light than heat

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Northwestern University researchers have developed compact, mid-infrared laser diodes that generate more light than heat - a breakthroughs in quantum cascade laser efficiency.

The results are an important step toward use of quantum cascade lasers in a variety of applications, including remote sensing of hazardous chemicals.

The research, led by Manijeh Razeghi, the Walter P. Murphy Professor of Electrical Engineering and Computer Science at the McCormick School of Engineering and Applied Science, was published online in the journal Nature Photonics on Jan. 10.

After years of research and industrial development, modern laser diodes in the near-infrared (approximately 1 micron) wavelength range are now extremely efficient. However the mid-infrared (greater than 3 microns) is much more difficult to access and has required the development of new device architectures.

The quantum cascade laser (QCL) is a diode laser that is designed on the quantum mechanical level to produce light at the desired wavelength with high efficiency. Unlike traditional diode lasers, the device is unipolar, requiring only electrons to operate. A significant effort has been spent trying to understand and optimize the electron transport, which would allow researchers to improve the laser quality and efficiency.

Despite the special nature of these devices, laser wafer production is done using standard compound semiconductor growth equipment. By optimizing the material quality in these standard tools, researchers at the Center for Quantum Devices (CQD) at Northwestern, led by Razeghi, have made significant breakthroughs in QCL performance.

Previous reports regarding QCLs with high efficiency have been limited to efficiency values of less than 40 percent, even when cooled to cryogenic temperatures.

After removing design elements unnecessary for low-temperature operation, researchers at CQD have now demonstrated individual lasers emitting at wavelengths of 4.85 microns with efficiencies of 53 percent when cooled to 40 Kelvin.

"This breakthrough is significant because, for the very first time, we are able to create diodes that produce more light than heat," says Razeghi. "Passing the 50 percent mark in efficiency is a major milestone, and we continue to work to optimize the efficiency of these unique devices."

Though efficiency is currently the primary goal, the large demonstrated efficiencies also can be exploited to enable power scaling of the QCL emitters. Recent efforts in broad area QCL development have allowed demonstration of individual pulsed lasers with record output powers up to 120 watts, which is up from 34 W only a year ago.

Provided by Northwestern University