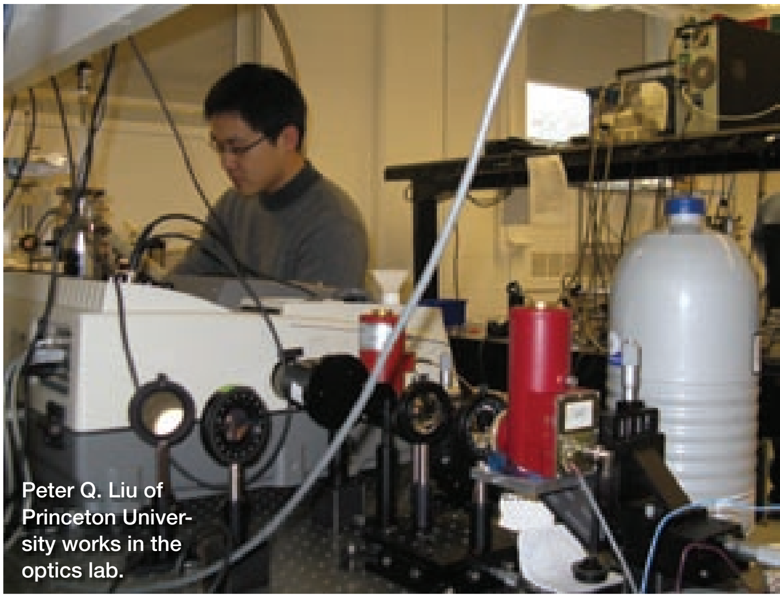
Andrew Campbell, Northwestern University

OSA Fellow Manijeh Razeghi in her Northwestern University lab.

Claire Gmachl research group, Princeton University



Peter Q. Liu of Princeton University works in the optics lab.

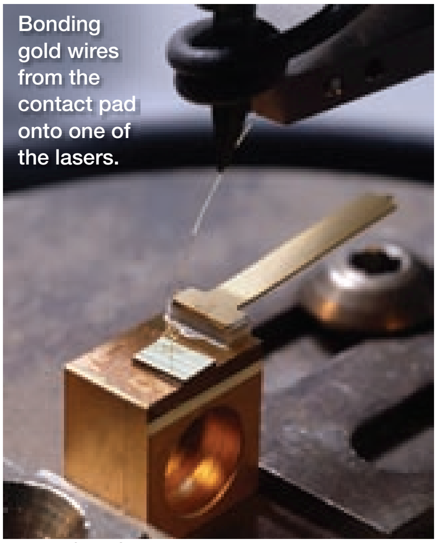
Quantum Cascade Lasers Gain Efficiency

Quantum cascade lasers (QCLs) have much potential in the mid-infrared spectral region, but their low energy efficiency has limited their application prospects. Two separate U.S. research teams have fabricated QCLs that significantly boost "wall plug efficiency," or the ratio of the power the laser emits to the power that the device consumes.

At Northwestern University, OSA Fellow Manijeh Razeghi and her colleagues made a 4.85-μm-wavelength pulsed QCL with a wall plug efficiency of 53 percent at an operating temperature of 40 K (Nature Photon. **4**, 99). The authors wrote in their abstract, "In other words, we demonstrate a quantum cascade laser that produces more light than heat."

The second group of researchers from Princeton University, Johns Hopkins University and AdTech Optics Inc. built a series of pulsed QCLs that attained 40 to 50 percent wall plug efficiency at temperatures of 160 K or lower (Nature Photon. **4**, 95). Their QCLs had emissions in the 4.5- to 4.7-μm spectral region.

The Northwestern team sought to demonstrate the highest possible wall plug efficiency in pulsed-mode operation. The researchers designed their QCLs with a single-well injector, specifically made for low temperatures, that creates a thermal forward filling effect. They also managed to reduce the voltage defect at turn-on and turn-off stages of operation, which led directly to a lower operating voltage—another factor in boosting efficiency.



Bonding gold wires from the contact pad onto one of the lasers.

Claire Gmachl research group, Princeton University

The Princeton-Hopkins QCL consists of InGaAs and AlInAs layers on an InP substrate. The lasers are tiny: roughly 3 mm long, 15 μm wide and less than 10 μm high, said Peter Q. Liu, a Princeton graduate student and lead author of the second paper. These QCLs demonstrate significantly increased coupling between the injector ground level and the active laser region by removing the barrier between the injector and the active region. The Northwestern design incorporates the traditional injection barrier.

Since the Princeton-Hopkins QCLs operate close to the 4.55-μm absorption peak of carbon monoxide, these lasers might someday be useful in CO detectors, Liu said.

Even at 300 K, the Princeton-Hopkins QCLs showed wall plug efficiency of roughly 15 percent, which is still among the best recorded values, Liu said. By contrast, the Northwestern QCLs measured only about 5 percent efficient at room temperature.

The need for cryogenic operating temperatures would make QCL-based devices much more expensive than instruments that run in shirtsleeve environments. "People are not interested in low-temperature applications," Liu said. The Princeton-Hopkins team would like to tweak their devices to demonstrate the same kind of wall plug efficiency during continuous wave operation.

—Patricia Daukantas