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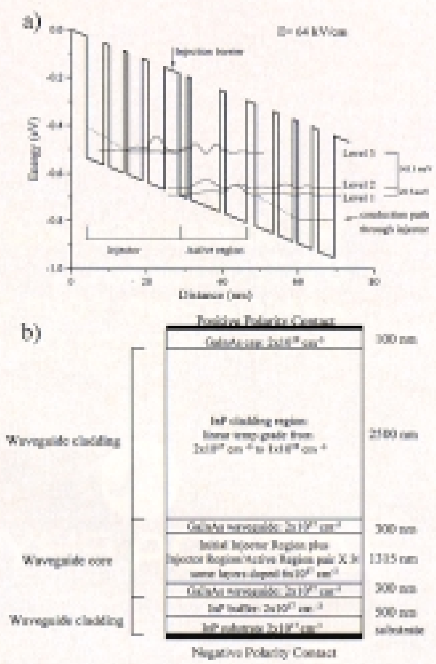
Stories by Susan M. Reiss

s c a t t e r i n g s

Northwestern Team Produces Quantum Cascade Laser

Using a one-step growth process, Northwestern University researchers have produced room temperature 8.5 μm quantum cascade lasers (QCL). The lasers produce 1 μsec pulses at a repetition rate of 200 Hz. Peak output power reaches more than 700 mW at 79 K and 25 mW at 300 K for a 1.5 mm cavity, with a T_0 of 188 K. The work was presented in an invited talk at the Electrochemical Society Meeting in Paris, held Aug. 31–Sept. 5, 1997, and will be published in *Applied Physics Letters*.[1]

Those involved in semiconductor laser research note that the Northwestern QCL is important since it is the first demonstration of a QCL from a group other than the Bell Labs team who first described the work in the Sept. 22, 1994 *Science* article. "These results prove that QCLs are not a singularity or a fortuitous combination of events, but can be reproduced elsewhere, using different growth techniques," commented a reviewer for *Applied Physics Letters*.



a) Conduction band schematic of a quantum cascade active region surrounded by two injector regions at an electric field of 64 kV/cm. Solid curves represent squared moduli of wavefunctions involved in the lasing transition. Dashed curves indicate conduction path of electrons through the injector regions. b) Cross section of laser structure grown by gas source MBE.

The theory

QCLs are based on electron relaxation inside a quantum well active region. Electrons are injected at a high electric field into a high energy subband that serves as an upper lasing level. At the same time, careful design of the active region ensures rapid depletion of carriers from the lower lasing level via optical phonon scattering.

Through the combination of injection, relaxation, and collection mechanisms, a population inversion is achieved in the active region between the upper and lower lasing levels. By stacking many active/injector regions, the same electron can be available to emit many photons. The current laser design uses a triple quantum well active region that allows three bound subbands. Lasing occurs between the second and third subbands, with fast electron collection from the first level into the next injector region via resonant tunneling.

Reproducing QCLs

"By using gas source MBE [molecular beam epitaxy] or MOCVD and one-step growth, we are able to create a simple structure without interface grading and fewer layers," says Manijeh Razeghi, director of Northwestern's Center for Quantum Devices. "This makes the device more reliable, cheaper, and easier for industrial manufacturing."

The GaInAs/AlInAs active/injector regions are grown lattice-matched to an n-type InP substrate by gas source MBE at a temperature of 530°C. The waveguide core consists of 30 active/injector pairs surrounded on both sides with n-type GaInAs. To increase the laser's thermal conductivity, a 2.5 μm InP cladding region was grown directly on the core.

Although the Northwestern QCL currently operates in pulsed mode, Razeghi and her team are investigating continuous mode operation. Applications include communications, spectroscopy, pollution monitoring, and remote sensing. "If we find good partners, it could be less than a year before these devices are available commercially," Razeghi concludes. The Defense Advanced Research Projects Agency (DARPA) is funding the QCL research.

Reference

1. S. Slivken et al., "Room temperature gas-source molecular beam epitaxy grown 8.5 μm quantum cascade lasers," Appl. Phys. Lett. to be published Nov. 3, 1997. ◆