InGaAs/GaAsSb Material System for Quantum Cascade Lasers

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BIOGRAPHY

Aaron Maxwell Andrews is a University Assistant at the Vienna University of Technology, Austria. He received his B.S. degree from the University of California, Los Angeles, and his Ph.D. from the University of California Santa Barbara. He was a post-doctoral researcher and a Marie-Curie researcher at the Vienna University of Technology.

Dr. Andrews' research interests include the growth by molecular beam epitaxy, characterization, and fabrication of optoelectronic nanostructures and devices. He has been active in the development of intersubband devices in the mid-infrared and terahertz spectral regions.

TECHNICAL ABSTRACT

Quantum cascade lasers (QCLs) utilize intersubband (ISB) transitions to produce coherent light in the mid-infrared (MIR) and terahertz (THz) spectral regions, 3-300 µm. Each cascade cell is a sequence of quantum wells and barriers, engineering an upper and lower laser level, where electrons can relax in a radiative transition. The unipolar nature of the QCL allows great creativity and flexibility in the active region and waveguide design. The material system is a key component when fabricating ISB devices. InGaAs/InAlAs lattice-matched to InP and strain-compensated has achieved room-temperature, continuous-wave, watt-level power, and broad gain in the MIR [1,2,3]. The AlGaAs/GaAs material system has an adjustable conduction band offset from 0-450 meV, making it suitable for quantum well infrared photodetectors (QWIPs) and THz QCLs [4,5,6].

The InGaAs/GaAsSb material system, lattice-matched to InP, is an excellent candidate to replace the commonly used GaAs/AlGaAs material system for both MIR and THz lasers and detectors. This material system has the potential to improve ISB devices by reducing the electron effective mass in the wells [7] and through the elimination of aluminum from the barriers, reducing the electron effective mass in the barriers as well, and the elimination of Al-oxide from the exposed surfaces, therefore simplifying subsequent post processing and/or regrowth. The low effective mass for electrons leads to a spreading of the electron wave function, allowing for a thicker barrier, and a higher optical matrix element and thus improved laser gain. The InP substrate is ideal for dielectric waveguiding in the MIR and for substrate lift off in THz double-metal waveguides. A MIR QWIP and QCLs have been realized in the InGaAs/GaAsSb material system [8]. THz QCLs based on LO-phonon depletion have been produced and characterized [9], shown in Figure 1.

We present recent progress in the design, growth, and fabrication of MIR and THz QCLs from the InGaAs/GaAsSb material system, including some features of these intersubband devices.

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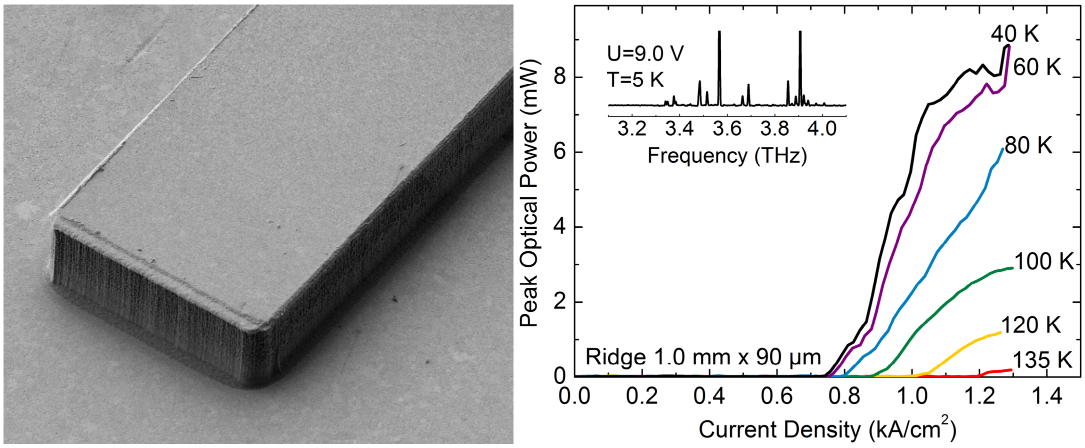

Figure 1. Scanning electron microscopy image of a double-metal InGaAs/GaAsSb THz QCL ridge and the laser output temperature dependence. The laser spectrum at 5 K is shown in the inset.

Keywords: quantum cascade laser, mid-infrared, terahertz, molecular beam epitaxy, intersubband transition

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