ANDREWS

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Lenggries, Germany

Abstract Book

III-Vs (Chair: Lutz Geelhaar)

Monday, 18.02.2019, 08:45 – 10:15

08:45	Charles Cornet (invited)	A universal mechanism to describe III-V epitaxy on Si
09:15	Marta Rio Calvo	GaSb growth on Si (001) using a GaAs nucleation layer
09:30	Fabrice Oehler	Epitaxy of GaAs on Ge 111: twinning and polarity
09:45	Aaron Maxwell Andrews	Barrier height selection for high temperature THz quantum cascade lasers
10:00	Esperanza Luna	Transmission electron microscopy of GaAs/(Al,Ga)As terahertz quantum-cascade lasers with ultra-thin barriers: the impact of the intrinsic interface width

Barrier height selection for high temperature THz quantum cascade lasers

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The terahertz (THz) gap is due to a lack of high-power coherent sources operating near room-temperature. The THz region of the electromagnetic spectrum (0.1-10 THz) is of great importance to spectroscopy, free-space communication, medical, industrial safety, and security applications. Quantum cascade lasers (QCLs) are solid-state unipolar devices that use bandgap engineering to design the lasing levels and injector/extractor regions [1]. THz QCLs have their optical transition energy below the Reststrahlen band (<21 meV, <5 THz, >60 µm). In order for QCLs to achieve wide adoption for spectroscopy, THz QCLs need to operate >230 K, where they can be thermoelectrically (TEC) cooled. The current pulsed T_{max} record is 199 K at 3.22 THz, 1.28 $k_B T_{max}/\hbar\omega$, is reported for a 3-well LO-phonon depletion scheme design lasing at [2], well below the minimum needed for TEC.

Several different III-V material systems have been utilized for THz QCLs: AlGaAs/GaAs, InGaAs/InAlAs, InGaAs/GaAsSb, and InAs/AlAsSb, each with a different conduction band offset (CBO) and effective mass m_e^* for the well and barriers [3,4]. Despite having the lowest intersubband gain, AlGaAs/GaAs active regions demonstrate the highest T_{max}.

In order to gain a better understanding of the LO-phonon transition influence in high temperature operation, the tuning and detuning of the active region with the LO-phonon was studied. In the versatile $Al_xGa_{1-x}As$/GaAs material system, the Γ barrier height is selectable with the Al mole fraction using (x=0-0.45) from 0-360 meV, while remaining approximately lattice-matched. This makes it an excellent toolbox for characterizing the effect of the conduction band offset (CBO) and the efficiency of the active region design.

Initially, the nominal structure from the record design [2] was regrown with various Al fractions (x=0.12-0.24). The highest T_{max} of 186 K at 2.7 THz, a new LO-phonon design $k_B T_{max}/\hbar\omega$ record of 1.36, was observed for $Al_{0.21}Ga_{0.79}As$ barriers. The structure was unstable at the lasing bias due to a detuning of the injector levels, extractor levels, and the LO-phonon resonance. For truly comparable structures, changing the Al mole fraction from the typical $Al_{0.15}Ga_{0.85}As$ requires modifying the layer thicknesses to maintain the same wave functions, optical transition energies, and the LO-phonon resonance. Detuning the LO-phonon resonance results in unstable lasing with a reduced dynamic range. Optimizing the resonance results in a 20 K increase in T_{max}, reaching a reproducible 196 K at 3.8 THz, and stable operation over a broad range of temperatures.

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