Quantum Cascade Electroluminescence from a ZnCdSe/ZnCdMgSe on InP Structure

K.J. Franz[1*], W.O. Charles[2], A. Shen[2], A.J. Hoffman[1], M.C. Tamargo[3], and C. Gmachl[1]

[1]*Department of Electrical Engineering, Princeton University, Princeton, New Jersey*
[2]*Department of Electrical Engineering, The City College of New York, New York, New York*
[3]*Department of Chemistry, The City College of New York, New York, New York*

Quantum cascade lasers have matured to be useful and capable light sources through more than a decade of research. Using telecom diode laser materials systems as a foundation, development has been rapid and highly successful for InGaAs/AlInAs and GaAs/AlGaAs structures. Recently, the push to shorter operating wavelengths has incorporated Sb into the materials mix, with record short-wavelength lasing at 2.75 µm [1]. As the QC device concept is not limited only to these III-V materials systems, development of new materials systems may yield performance improvements and broader capabilities. For example, ongoing work has shown intersubband absorption in GaN/AlGaN multiple quantum wells and intersubband electroluminescence from Si/SiGe heterostructures. Here, we present a II-VI quantum cascade structure made from ZnCdSe well layers and ZnCdMgSe barrier layers that shows room temperature TM-polarized intersubband electroluminescence (EL) [2].

The well and barrier layers used in our design—respectively $Zn_{0.43}Cd_{0.57}Se$ and $Zn_{0.20}Cd_{0.19}Mg_{0.61}Se$—have lattice constants equal to that of InP and a conduction band offset of 780 meV. Our structure, shown in Fig. 1(a), is a typical QC design, which includes two active region wells to create a 284 meV (4.37 µm) optical transition. Each 122 Å active region is connected by a 412 Å injector region. Ten periods of the active region-injector sequence were grown by molecular beam epitaxy and then fabricated into semi-circular EL mesa structures.

We observed EL centered near 4.8 µm. Emission polarization characteristics were examined to confirm intersubband light generation; intersubband optical transitions in quantum wells are TM polarized. While a small amount of TE light is observed, which we attribute to scattering from within the rounded mesa, the EL is predominantly TM polarized, as seen in Fig. 1(b). Fig 2(a) illustrates how, at low temperatures near 78 K, only a primary emission peak is observed near 4.8 µm. The 4.8 µm emission peak grows with increasing pumping current. We also observed the temperature-induced growth of a secondary, lower energy emission, as seen in Fig. 2(b). This broad emission is more intense for both higher currents and higher temperatures. While the origin of this low energy emission is still under investigation, the 4.8 µm intersubband emission is dominant and persists through room temperature.

Thus, we show a II-VI materials system capable of room temperature QC light generation at 4.8 µm. Shorter wavelength emission energies are possible with further materials and QC design development, both of which are currently underway.

This work is supported in part by MIRTHE (NSF-ERC # EEC-0540832), NASA URC COSI grant # NCC-1-03009, and Department of Defense grant # W911NF-04-01-0023. K.J.F. gratefully acknowledges the support of the National Science Foundation Graduate Research Fellowship Program.

[1] J. Devenson et al., *Appl. Phys. Lett.* **91** 251102 (2007).
[2] K.J. Franz et al., *Appl. Phys. Lett.*, **92** 121105 (2008).

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[*] Corresponding author email: kfranz@princeton.edu

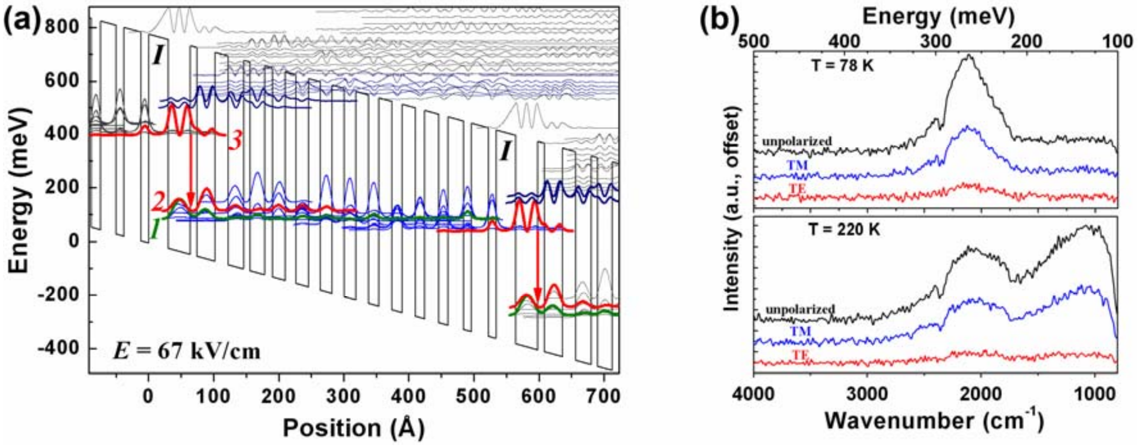

Fig. 1. (a) Conduction band energy diagram, shown under an applied field *E* = 67 kV/cm. Optical transitions of 284 meV are indicated by arrows. A single stage of the QC layer sequence is (in angstroms starting from the injection barrier ***I***) **30**/34/**10**/28/**20**/24/**10**/22/**12**/20/**16**/20/**18**/18/**18**/18/**20**/16/**20**/**20**/14/**22**/14/**24**/12/**26**/12, where ZnCdMgSe barriers are in bold and ZnCdSe wells are in normal font. Underlined layers represent ZnCdSe that is Cl-doped (2×10^{17} cm^{-3}) and ZnCdMgSe doped with the same $ZnCl_2$ flux as the ZnCdSe layers. (b) Polarization-dependent emission spectra for a device driven with 3.6 A and 3% duty cycle at 78 K and 220 K. The emission is predominantly TM polarized.

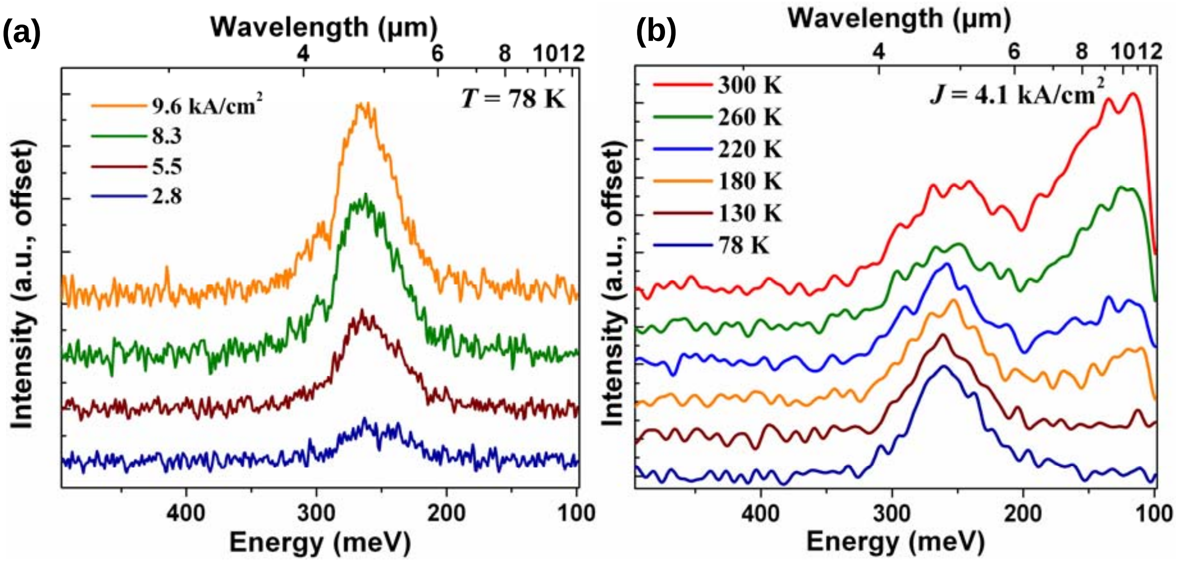

Fig. 2. (a) Electroluminescence (EL) spectra for variations in current densities at T = 78 K. Peak emission is centered near 4.8 µm. (b) EL spectra at *J* = 4.1 kA/cm^2 for temperatures from 78 to 300 K. Additional longer-wavelength light is seen with increasing temperature.