High power, continuous wave, room temperature operation of $\lambda \sim 3.39$ μm and $\lambda \sim 3.56$ μm AlInAs/GaInAs/InP-based quantum cascade lasers

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BIOGRAPHY

Neelanjan Bandyopadhyay is currently a PhD student in the Center for Quantum Devices, Department of Electrical Engineering and Computer Science, Northwestern University, Evanston, USA. He is working on the development of high power mid-infrared AlInAs/GaInAs/InP based quantum cascade lasers operating in continuous wave at room temperature. In particular, he has designed, grown, and demonstrated short wavelength quantum cascade lasers operating between 3 and 4 μm.

TECHNICAL ABSTRACT

High power, continuous wave (CW), room temperature (RT) operation of quantum cascade lasers(QCLs) in the lower part (3-4μm) of the mid-infrared atmospheric window (3-5μm) is needed for environmental monitoring, trace gas detection, exhaust control and countermeasures. Though more than 5W CW RT operation is demonstrated at a longer wavelength of 4.9μm [1], high power CW RT QCLs around and below 3.5μm operation remain a difficult goal.

The primary challenge for short wavelength InP-based QCLs is material growth of highly strain balanced AlInAs/GaInAs superlattices, as lattice matched material is not suitable for achieving short wavelength emission. To achieve a large conduction band offset, $In_{0.80}Ga_{0.20}As/In_{0.18}Al_{0.82}As$ strain balanced superlattices were grown in a gas source molecular beam epitaxy reactor. The high Aluminum content in the $In_{0.18}Al_{0.82}As$ layers provides sufficient electron confinement and the high Indium content in the $In_{0.80}Ga_{0.20}As$ layers increases the separation of Γ and L-valley electrons, both of which preserve material gain at short wavelengths. The full width of half maximum of the electroluminescence spectra of the λ~3.56 μm laser structure at RT in pulsed operation was 47.4meV, which shows good material quality and interface quality, despite the very high strain used in the core region.

The wafers were processed into double channel ridge structures of width W = 8.6 μm and 10.5 μm for λ~3.39 μm and λ~3.56 μm QCLs, respectively, with processing details given in Ref. 2. Lasers with a cavity length of 5 mm, with high reflection coated rear facets, were bonded epilayer down with indium solder on diamond submounts, and tested. Characteristic temperatures T_0 (T_1) for threshold current density (slope efficiency) are calculated to be 165.6K (115.9K) and 151.5K (190.8 K) for pulsed operation of λ~3.39 μm and λ~3.56 μm QCLs, respectively. The maximum pulsed powers are more than 1.1 W and 1.66 W at 15^{o} C, respectively.

The CW results are shown in Fig. 1 (a) and (b) 576 for λ~3.39 μm and λ~3.56 μm QCL, respectively [3]. The CW threshold current densities at 15 ^{o}C are 1.2 and 1.35 kA/cm^2, with CW optical powers of 504 mW and 576 for λ~3.39 μm and λ~3.56 μm QCL, respectively. The 3.39μm laser represents the shortest wavelength CW RT QCL in any material system at a wavelength lesser than 3.55μm. The RT CW output power for the λ~3.56 μm QCL is an order of magnitude more than the previous best report (Ref. 4).

These results show that the AlInAs/GaInAs/InP material system, which is the basis of all high power QCLs at longer wavelengths, still has significant development potential at shorter wavelengths (3-4 μm). It is to be noted that the results given above were achieved without buried ridge processing, which, if done, is expected to produce even more CW power and increase the maximum operating temperature.

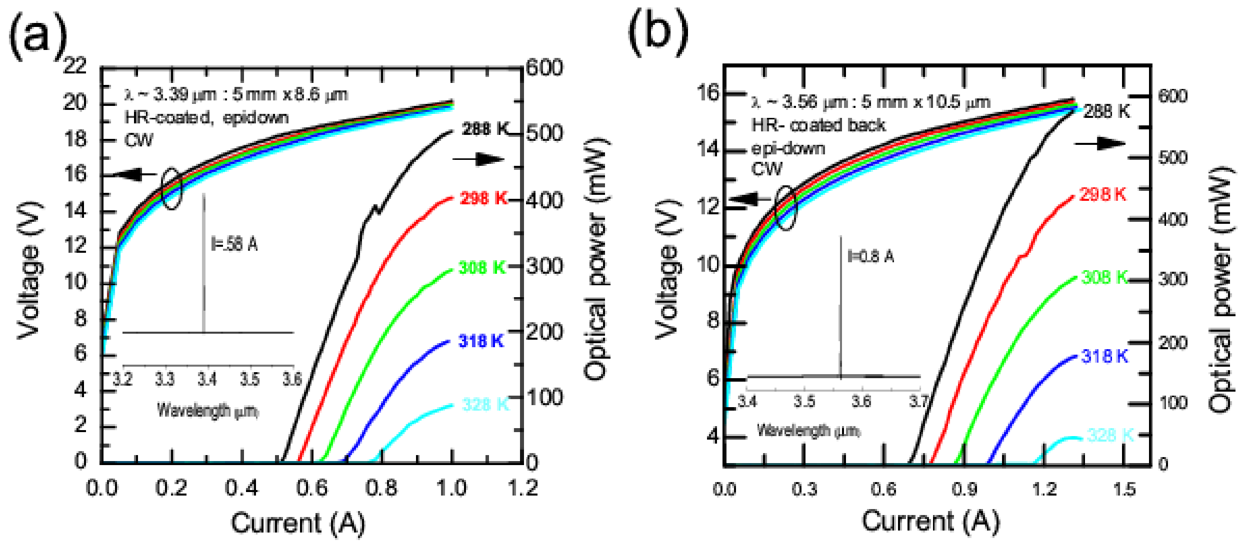

FIG. 1. Continuous-wave optical output power and voltage as a function of injection current at temperatures between 288 K and 328 K for the a) λ~3.39 QCL and b) λ~3.56 QCL. The insets in both figures show the CW emission spectra for the lasers at 0.58 A and 0.8 A, respectively.

References

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Keywords: quantum cascade laser, short wavelength, room temperature, continuous wave, high power