Highly Temperature-Stable, Long Wavelength Short-Injector Quantum Cascade Laser

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A short-injector quantum cascade laser is presented emitting at 8 µm with a slope efficiency of 1.4 W/A and a characteristic temperature value of 260 K for pulsed operation above 240 K. The high slope efficiency is attributed to the short injector sections and the high temperature stability is attributed to the inclusion of AlAs barriers in the active region of the device.

Recently, the injectorless concept of the quantum cascade laser (QCL) active region has shown improved performance compared to the injector-based active region [1, 2]. However, the removal of the injector sections requires higher electrical fields to match the energy levels of subsequent stages. This appears to be a limiting factor for making short wavelength QCLs. As a tradeoff, the injector section can be made shorter, instead of being removed. This is the so-called short-injector QCL [3].

Our device is based on the strain-balanced $Al_{0.635}In_{0.365}As$ / $Ga_{0.4}In_{0.6}As$ material system grown on InP by solid-source MBE. Pure AlAs layers were added in the barriers for improved temperature performance. The transition energy was designed to be 151 meV at an applied field of 72 kV/cm. The schematic conduction band profile is shown in Fig. 1. The layer sequence, starting from the injection barrier (right hand side) is as follows: **0.6**/*0.45*/**1.2**/1.4/**1.3**/2.7/**1.05**/5.6/**1.1**/4.9/**1.3**/4.5/**1.4**/3.5/**1.6**/3.4. Here, **$Al_{0.635}In_{0.365}As$ barriers are shown in bold,** *AlAs barriers in italic* and $Ga_{0.4}In_{0.6}As$ wells in standard font. The underlined layers are doped to $2\times10^{17}cm^{-3}$ with Si. The QCL structure has 64 periods of the active stage as described previously. The samples were processed as conventional ridge-waveguide lasers, then cleaved into laser bars of different length and mounted on a copper heatsink for characterisation. The characterisation of the devices was done in a temperature range from 77 K to 360 K. The pulsed threshold current density was measured to be 1.2 kA/cm^2 at 300 K for a 4 mm long and 26 µm wide device. The characteristic temperature was found to be 135 K below heatsink temperatures of 240 K, and 260 K for higher temperatures (Fig. 2). The peak output power under pulsed operation was found to be 726 mW per facet at 299 K with a slope efficiency of 1.4 W/A for an uncoated device (Fig. 3). At room temperature (RT) the device had an emission wavelength of 8 µm (Fig. 3 inset). Waveguide losses at RT were extracted to be 15.6 cm^{-1} and the threshold modal gain - 15.14 cm/kA.

In conclusion, we present a high performance short-injector quantum cascade laser emitting at 8µm. High slope efficiency and characteristic temperature values are promising for continuous wave operation.

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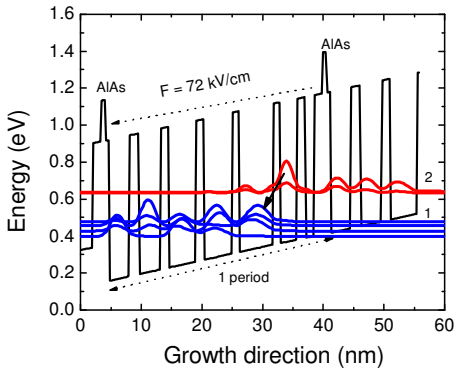

Fig. 1: Conduction band profile of one active region period under an applied bias field of 72 kV/cm.

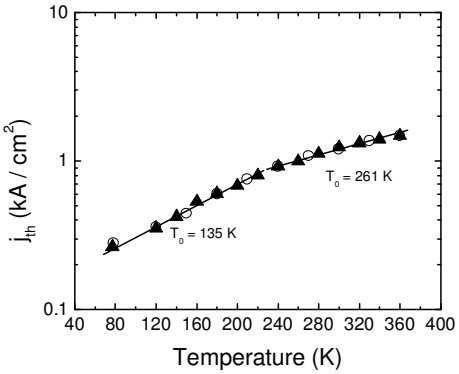

Fig. 2: Threshold current density vs. heatsink temperature for two 4 mm long and 26 µm wide devices.

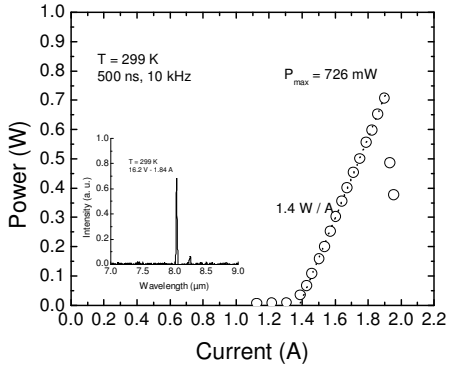

Fig. 3: Optical output power vs. current for a 4 mm long, 26 µm wide device at 299 K. The inset shows a room temperature emission spectrum.