Room Temperature Operation of Distributed Feedback GaAs/AlGaAs Quantum-Cascade Lasers

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Quantum cascade lasers (QCL) are mid infrared light sources. So far, QCLs have been demonstrated only in two material systems, InGaAs/InAlAs on InP and AlGaAs/GaAs grown on GaAs, though spontaneous emission from quantum cascade structures has been achieved in some other materials. Recently, room temperature operation of GaAs/AlGaAs based QCL has been demonstrated, which before was a privilege for QCL grown on InP. This is an important step for commercial applications. However, single mode lasers are favored for gas sensing via infrared spectroscopy (single- or multiple pass absorption).

We achieved pulsed room temperature operation of first order distributed feedback (DFB) quantum cascade lasers in the GaAs/AlGaAs material system. Two different designs were used for the active material. Sample A is a design where the active cell is formed by three coupled quantum wells and sample B is a chirped superlattice. For both samples, an Al content of 45% was chosen. The emission wavelength of the sample A is around 9.5 µm and around sample B emits at an wavelength of 12.5 µm. The larger band discontinuity of the $Al_{0.45}Ga_{0.55}As$ barriers compared to the previously used $Al_{0.33}Ga_{0.67}As$ has been shown to be singularly responsible for the higher operating temperature of these devices.

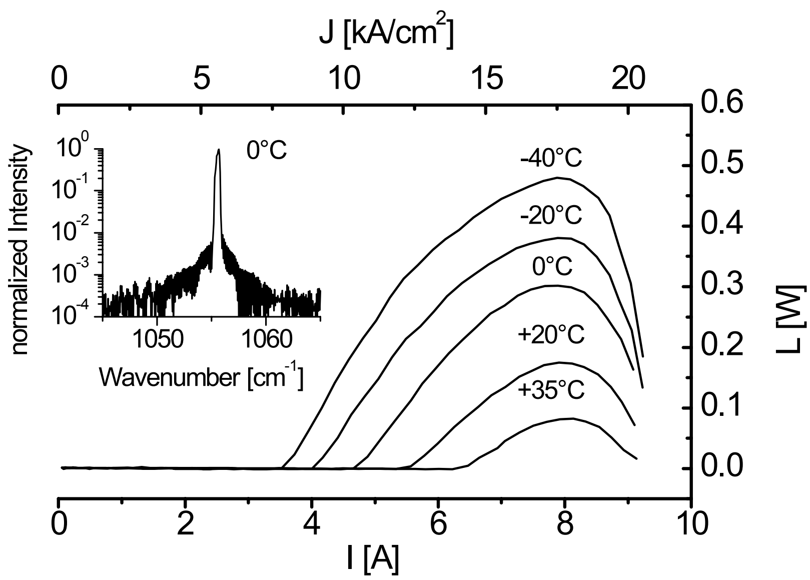

Fig. 1: Light output power versus current of an L = 1.5 mm long and w = 30 µm wide DFB laser in pulsed operation for several heat sink temperatures (Peltier cooler) between –40 °C and +35 °C. The inset shows the emission spectrum at 0 °C.

We fabricated first-order distributed feedback lasers with a metallized surface relief grating. The calculated coupling coefficients are κ = (-19.6 - i0.3) cm^{-1} for sample A (grating period Λ = 1.48 µm, grating depth 850 nm) and κ = (65 + i5.8) cm^{-1} for sample B (grating period Λ = 2.00 µm, grating depth 1200 nm). The large coupling coefficient allows the realization of short devices with reasonable low threshold current densities. The advantages of shorter devices are the reduced currents and lower heat dissipation.

Both types of lasers show room temperature operation in pulsed mode. The highest working temperature of sample A was measured to be 335 K for a 2 mm long device. Figure 1 shows the light output power versus current for several heat sink temperatures for a three well design laser mounted on a Peltier cooler. The 1.5 mm long and 30 µm wide DFB laser is operated in pulsed mode with 50 ns pulses at 10 kHz. The maximum peak power of the single mode emission is 0.5 W at –40°C, and still 80 mW at +35°C. The slope efficiency is 172 mW/A (-40°C), and 64 mW/A (+35°C).

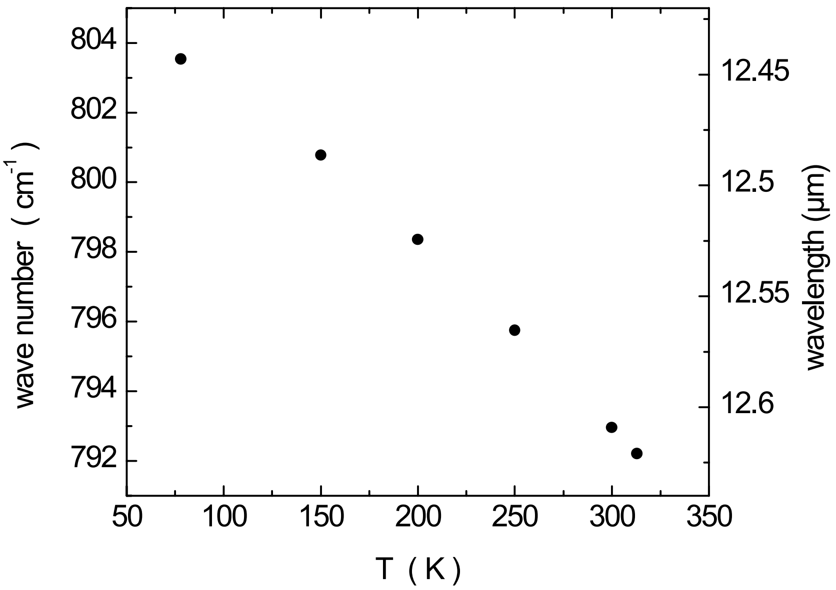

Fig. 2: Emission wavelength as a function of the heat sink temperature. The laser is operated in pulsed mode with 100 ns long pulses at 5 kHz repetition rate.

The emission wavelength of DFB lasers is continuously tunable with the temperature. Figure 2 shows the emission wavelength of sample B as a function of the heat sink temperature.