High-power $\lambda = 8 \mu$m quantum-cascade lasers at room temperature

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Abstract The paper presents the results of characterization of the high-power quantum cascade lasers for $8 \mu$m spectral range. Lasers demonstrate stable generation at room temperature with the maximum output peak power of $\sim 0.9$ W per facet.

1. Introduction

The concept of quantum cascade lasers (QCLs) emitting via intraband transitions was proposed as early as the 70s of the last century [1], and was practically implemented only in 1994 [2]. They are currently the most compact and efficient sources of laser radiation in the mid-infrared range. QCL is widely in demand in many fields of science and technology, especially in gas analysis [3-5] and biomedicine [6]. The presence of intense absorption lines of many gases and organic substances, including explosives [7], causes an active interest in the development of QCLs that generate radiation in the spectral range near $8 \mu$m [8-11].

2. Experiment

The QCL heterostructures were fabricated by molecular beam epitaxy (MBE) on InP substrates at the Riber 49 facility at Connector Optics LLC. The QCL active region was calculated for laser generation near $8 \mu$m. A detailed description of the QCL heterostructure is presented in [13]. The population inversion in the cascade is provided by two-phonon depletion of the lower level of the laser transition [14]. It should be noted that the necessary rate of depletion of the lower level will be maintained only under the condition that the energy gap between the quantum levels of the neighbouring quantum wells is close to the phonon LO energy of $\sim 34$ meV [15] for the structure used.

The heterostructure was post-growth processed to produce stripes that form the side wall of the laser waveguide and limit the pumping region. Stripes with a width of $20 \mu$m were formed by etching of shallow (down to the active region) trench [16]. After the formation of stripes, upper and lower contacts, the structure was cleaved into separate chips. Experimental samples of QCL were then mouted to the primary heat sinks. The length of the studied QCLs was $\sim 4.5$ mm.
3. Results and Discussion

The QCL properties were studied at pulsed current pumping with a pulse duration of ~ 75 ns at a repetition rate of 48 kHz. The heat sink temperature has been stabilized. Spectral measurements show multimode generation near 8 μm. Spectral measurements were carried out using an MDR-23 monochromator with a Vigo Systems PVI-4TE-10.6 photodetector. The measurement technique is described in more detail in [17]. A typical generation spectrum is shown in Figure 1.

![Figure 1](image1.png)

**Figure 1** Typical QCL generation spectrum at room temperature.

![Figure 2](image2.png)

**Figure 2** Typical QCL light-current curve at room temperature without correction for the transmittance of the focusing optics.
Light-current characteristics were measured using a calibrated Thorlabs PM100 power meter with a S401C thermoelectric detector head. All experimental samples demonstrate lasing at room temperature. The threshold current densities of the studied QCLs were 4.5 kA/cm². A typical light-current characteristic of the studied QCLs is shown in Fig. 2. Rollover of light-current characteristic was observed after 16 A. The maximum peak power per facet was more above 0.9 W without taking into account losses on focusing optics, the transmittance of which was below 0.85. The obtained value of the maximum output peak power (~1 W) is higher than previously reported for unstrained 8 μm QCL structures (0.75 W [18]) and very comparable to the strained QCL structures (1.5 W [8]).

4. Conclusion
The paper presents studies of the long-wave infrared QCLs. High-power laser generation at room temperature was demonstrated. Roll-over of the light-current characteristic was observed at a current amplitude corresponding to over 4-fold threshold value. The maximum output peak power from two facets exceeds 2 W.

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