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High-power (>1 W) room-temperature quantum-cascade lasers for the long-wavelength IR region

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Abstract. **Ridge quantum-cascade lasers emitting at a wavelength near 8 μm are fabricated and studied. Lasing at room temperature with a maximum output peak power exceeding 1 W from one facet is demonstrated.**

Keywords: *quantum-cascade laser, heterostructure, high power.*

1. Introduction

Quantum-cascade lasers (QCLs), the idea of which was proposed in the 70s of the last century [1], are today the most compact and efficient sources of laser radiation in the mid- and long-wavelength IR region. At present, these lasers are widely used in many fields of science and engineering, especially in gas analysis [2–4] and biomedicine [5]. Active interest in the development of QCLs emitting in the long-wavelength IR region (8–14 μm) [6–10] is related to fact that the intense absorption lines of many gases and organic materials, including explosives, lie in this region [11].

2. Experimental samples

The epitaxial heterostructures of QCLs were grown by molecular-beam epitaxy (MBE) on InP substrates. The epitaxial growth was performed at the Connector Optics LLC in a Riber 49 production system. The active region of the QCLs is calculated for lasing at a wavelength near 8 μm and consists of 50 identical quantum cascades, i.e., alternating $In_{0.53}Ga_{0.47}As/Al_{0.48}In_{0.52}As$ heteropairs isoperiodic with the InP substrate. The heterostructure of the studied QCLs is described in detail in [12]. The population inversion in the cascade is formed by two-phonon escape of the lower laser transition level [13]. It should be noted that the necessary rate of the lower level escape is maintained only under the condition that the energy difference between the quantum levels of the neighbouring quantum wells is close to the LO phonon energy, which is ~34 meV [14] for the used structure.

The grown heterostructures were subjected to post-growth treatment to fabricate ridges which formed the sidewall of the laser waveguide and constrained the current flow region. The ridges were formed by etching shallow (to the active region) trenches [15]. After formation of the ridges and the upper and lower contacts, the heterostructure was cleaved into individual chips, which were then soldered on primary heat sinks. We fabricated ridges of two types, i.e., with widths of 20 and 50 μm. The length of the studied laser chips was ~4.5 mm.

3. Experimental

The characteristics of the QCLs were studied under pumping by 75-ns current pulses with a repetition rate of 48 kHz. The heat sink temperature was stable. Spectral measurements revealed multimode lasing near 8 μm. The spectra were measured using an MDR-23 monochromator with a Vigo Systems PVI-4TE-10.6 photodetector. The measurement technique is described in more detail in [16]. A typical laser spectrum is shown in Fig. 1a.

The light–current characteristics were measured using a calibrated Thorlabs PM100 power meter with an S401C thermoelectric head. All experimental samples demonstrated lasing at room temperature. The threshold current densities of the studied QCLs were 3.5 and 4.5 kA cm^{-2} at ridge widths of 50 and 20 μm, respectively. The higher threshold current densities for the samples with the narrower ridge are obviously explained by relatively higher losses at the side edges of the ridge. A typical light–current characteristic of the QCLs with a ridge width of 50 μm is presented in Fig. 1b. The maximum optical output peak power from one facet exceeded 1 W without taking into account the losses on the focusing optics, whose transmittance was no higher than 0.85. The obtained value of the maximum output peak power (~1.2 W) is comparable with the results published in the literature (the maximum optical output peak power was 0.75 W for a 8-μm QCL with a mechanically unstrained heteropair [17] and 1.5 W in the case of a strained heteropair [6]).

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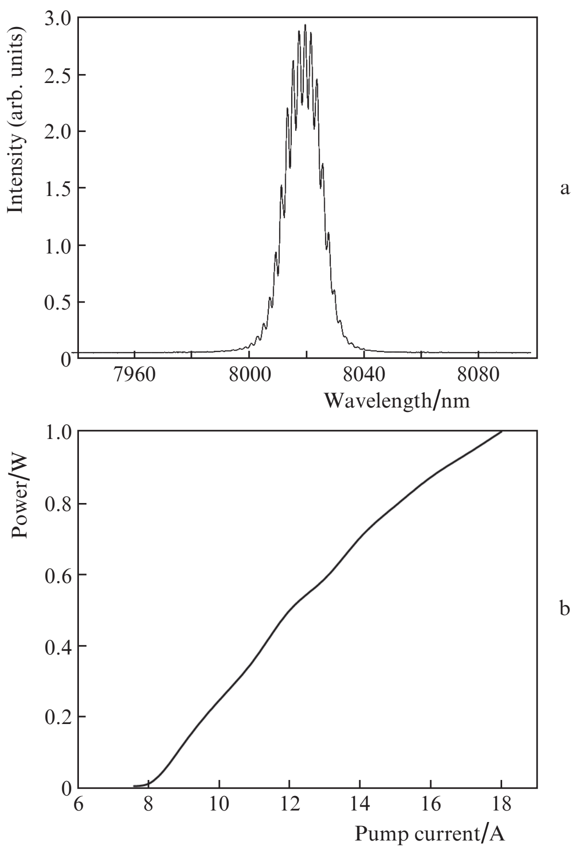

Figure 1. (a) Typical spectrum and (b) light–current characteristic of a QCL with a ridge width of 50 μm at room temperature.

Thus, in this work we presented the results of investigation of QCLs for the long-wavelength IR region. Room-temperature lasing with a maximum output peak power exceeding 1 W from one facet has been demonstrated.

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