High quantum-efficiency GaInAs/Al(Ga)AsSb quantum cascade lasers for the 3-5 μm wavelength range

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In the past few years, there has been significant progress on quantum cascade (QC) lasers based on the GaInAs/AlAsSb materials combination lattice-matched to InP, which offers a conduction band offset at the Γ-conduction band minimum of as high as ~ 1.6 eV. We also demonstrated the use of quaternary AlGaAsSb barrier layers in order to reduce the barrier height for the purpose of enhancing the electronic tunneling probability, while simultaneously maintaining sufficient carrier confinement for the active region,

In this contribution, we report on recent progress on GaInAs/AlAsSb-based as well as on GaInAs/AlGaAsSb-based QC lasers. First we discuss the possible limitations for realizing short-wavelength GaInAs/AlAsSb QC lasers, demonstrating room-temperature (T_{max} = 310 K) short-wavelength (λ ~ 3.7-3.9 μm) GaInAs/AlAsSb QC lasers based on triple-well vertical-transition active regions. The characteristic temperature of the laser is 170 K in the temperature range between 220 K and 310 K.

By using quaternary AlGaAsSb as barrier material along with other modifications of the active region design, high peak-power operation of GaInAs/AlGaAsSb QC lasers emitting at λ~3.6-3.8 μm has been achieved. With as-cleaved facets, these lasers (18 μm × 2.7 mm) emit a maximum peak power of 8.2 W per facet at 77 K. When applying a high-reflection coating to the back facet, a maximum peak power emitted from the front facet of 10.5 W at 77 K has been obtained for an 18 μm × 2.0 mm device. The lasers operate in pulsed mode up to 340 K, and their emission wavelength shifts from 3.65 μm at 77 K to 3.79 μm at 300 K. The external differential quantum efficiency at 77 K is 15.84 for a laser with 30 periods active region, and the maximum wall-plug efficiency is 23.2% at 77 K. At 220 K, the external differential quantum efficiency of the laser is 6.02, and the maximum wall-plug efficiency is 6.0%.

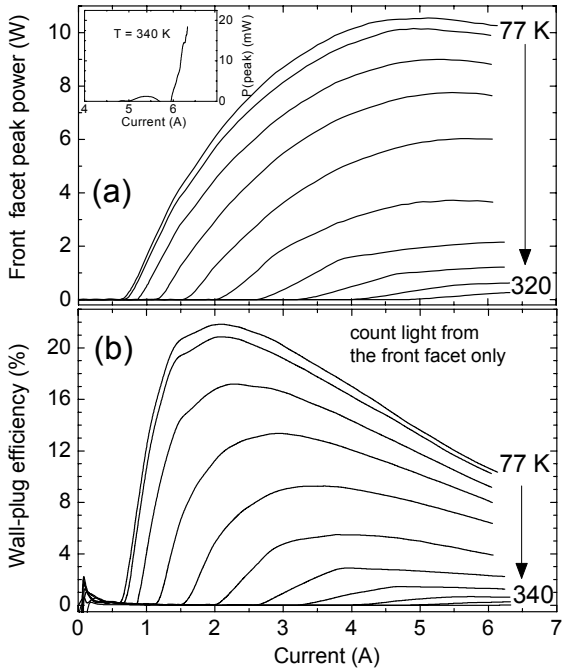

Fig. 1. (a) Light output from the front facet versus injection current dependences for a high-power GaInAs/AlGaAsSb QC laser with a ridge size of 18 μm × 2.0 mm recorded at various heat-sink temperatures. The back facet of the device is high reflectively coated and the front facet is as cleaved. Inset: L-I curve of the device at 340 K. (b) Front-facet wall-plug efficiencies at various temperatures as a function of injection current.

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