Ultra-low-threshold GaSb-based Laser Diodes at 2.65 µm

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Abstract: We present the design and results of a continuous wave room temperature operating GaSb-based edge emitter at 2.65 µm with threshold current densities as low as 50 A/cm² (L →∞).

OCIS codes: (300.6360) Spectroscopy, laser; (140.5960) Semiconductor lasers

1. Introduction

GaSb-based lasers are ideal light sources for tunable diode laser absorption spectroscopy (TDLAS) [1], as they can access the mid-infrared wavelength range (2 – 4 µm), where a lot of industrially important gases show strong absorption lines [2]. Recently, electrically pumped VCSELs emitting at 2.3µm could be realized [3, 4] and open the technology for low cost applications. The challenge gets harder with the rising wavelength as absorption losses and Auger recombination increase. While edge emitters were realized up to emission wavelengths of 3.36 µm [5], the performance stays poor. At 2.7 µm, the best recorded values for the threshold current density are 350 A/cm² [6]. We introduce an improved waveguide design and MBE growth at low temperatures yielding ultra-low threshold current densities of 50 A/cm² (L →∞) in cw operation at room temperature.

2. Design and Growth

The epitaxial structure of the edge emitters is grown on an *n*-type GaSb substrate with a Varian Gen-II-MBE system equipped with solid sources and valved cracker cells for Arsenic and Antimony. On both sides, the cladding consists of a 2 µm thick layer of $Al_{0.50}Ga_{0.50}As_{0.04}Sb_{0.96}$ with a Te doping of $2\cdot10^{18}$ cm^{-3} and Si doping of $5\cdot10^{17}$ cm^{-3} on the *n*- and *p*-side, respectively. The nominally undoped waveguide consists of 400 nm thick $Al_{0.10}Ga_{0.90}As_{0.01}Sb_{0.99}$ on both sides. The active region comprises one 15 nm $Ga_{0.57}In_{0.43}As_{0.14}Sb_{0.86}$ quantum well (QW) between 8 nm thick GaSb barrier layers. The QWs are 1.7% compressively strained. A band structure of the device, calculated with nextnano ++ [7] with material parameters taken from [8], is shown in fig. 1. The relatively low Al content in the cladding and waveguide layers was chosen to keep the growth temperature as low as possible since materials with higher Al contents can only be grown in good quality at elevated temperatures (> 500°C). In our structure the layers following the active region were grown at 430°C and thus the blueshift of the active region due to annealing [9] could be minimized.

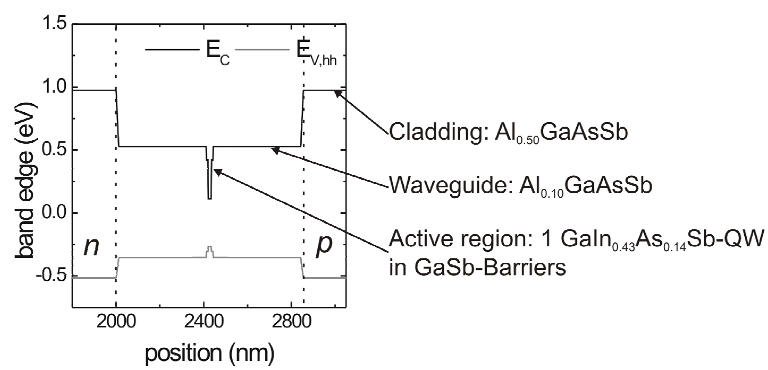

Fig. 1. Schematic energy-band diagram of the 2.7 µm edge emitting laser

3. Results

After epitaxy, ridge waveguide edge emitters with stripe widths ranging from 15 to 200 µm were processed, cleaved and mounted epi-side up. No facet coating was applied. The measurements were made on a temperature controlled heat sink. The devices show multimode cw laser emission at 2.65 µm at temperatures up to 55°C. Fig 2 a) shows the measured threshold current densities including a measured lateral carrier broadening of 3.1 µm on each

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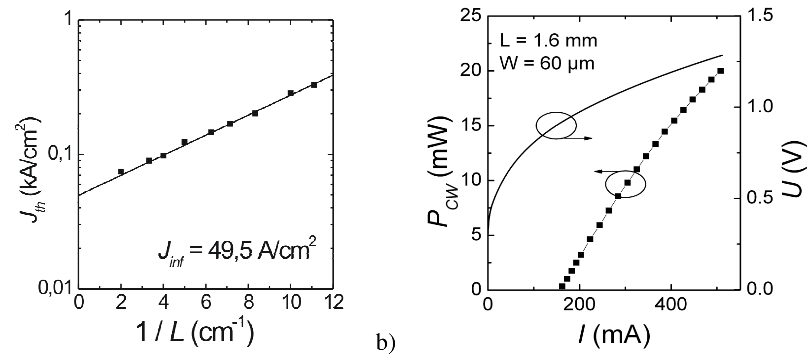
side due to current spreading and diffusion. The lowest measured value was about 74 A/cm² for a 5.0 mm long device. These are the lowest values reached so far for lasers at this wavelength and can be compared even with the well known GaAs and InP material systems at much shorter wavelengths. The device shows a low internal loss of about 3 cm^{-1} and a T_0 of 62 K. The good temperature behavior indicates that carrier leakage out of the QW is not a major loss component. The optical output power over current and voltage over current characteristics of a 1.6 mm long and 60 µm wide device are shown in fig 2 b). The maximum measured cw output power is 20 mW for both facets, limited by the current source. The superior device performance derives from the improved design and excellent material quality of the low temperature MBE growth.



a) b)

Fig. 2. a) Threshold current densities over the inverse length. b) Power over current and voltage over current characteristics of the 2.65 µm laser.

4. Conclusion

2.65 µm GaSb-based edge emitters with an improved growth and waveguide design are presented. They show excellent low threshold current densities and demonstrate the performance of this material system for mid infrared devices.

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