Single-mode CW Monolithic GaSb-VCSEL operating up 70°C

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BIOGRAPHY

Dorian Sanchez received the B.Sc. degree in EEA in 2007, and the M.Sc. degree in Electronic devices from University of Science, Montpellier, France, in 2009. He is currently working toward the Ph.D. degree at the University of Science, Montpellier, France. His current research interests include GaSb-based vertical-cavity surface-emitting lasers (VCSELs) for Mid-Infrared applications.

TECHNICAL ABSTRACT

Vertical Cavity Surface Emitting Lasers (VCSELs) present several interesting characteristics such as longitudinal single-mode operation, circular output beam and low power consumption. These properties combined with a large continuous tunability make VCSELs good candidates for gas sensing via Tunable Diode Lasers Absorption Spectroscopy (TDLAS). The wavelength range above 2 µm is rich of interest due to the presence of atmospheric windows and strong absorption lines of several pollutants such as NH3, CH4, CO2, ... GaSb-based materials allow covering this wavelength range by exploiting efficient GaInAsSb/AlGaAsSb type I quantum wells (QWs) system.

Up to now, GaSb-based VCSEL operating in CW are based either on buried tunnel junction (BTJ) or a monolithic etched mesa. The first technology allowed demonstrating single mode operation up to 70 °C at 2.3 µm [1] and up to 50°C at 2.6 µm [2]. However device processing is complex and relies on an epitaxial re-growth step. The second technology is simpler but lacks an efficient electro-optical confinement which limits CW operation to temperatures below 20°C and precludes single mode emission [3].

In this paper, we report the first single-mode monolithic GaSb-based VCSELs based on a lateral etching of the InAs/GaSb tunnel junction to provide efficient electro-optical confinement. The structure is grown in one run by solid source molecular beam epitaxy (MBE) on n-doped GaSb substrate. It consists of 2 N-type lattice matched AlAsSb/GaSb distributed Bragg reflectors (DBRs), a MQWs active region for emission at 2.3 µm, and an InAs/GaSb TJ positioned above the QWs at a standing wave null position in order to reduce absorption losses.

Device processing involved first a wet etching of the top DBR down to the InAs TJ. Then, InAs is selectively etched with a solution of citric acid and hydrogen peroxide to form the thin air gap aperture. Figure 1.a shows a scanning electron microscopy (SEM) image of the structure after selective lateral etching. Figure 1.b illustrates the device structure after the whole process. We focus on a device with 35 µm pillar diameter, a top aperture of 25 µm and 6 µm TJ aperture diameter.

Figure 2 presents the light-current-voltage (L-I-V) characteristics in CW mode at various temperatures. CW operation was obtained up to a temperature of 70°C. The threshold reaches a minimum value around 1.9 mA at 30°C, which is the temperature where the QWs emission and the microcavity resonance match perfectly. The I-V characteristics at 20°C exhibits a turn on voltage around 3 V. This high voltage can be attributed to the small aperture of the TJ combined with the total thickness of the structure (~16 µm). The inset in figure 2 shows the emission spectra taken at 20 °C under various driving currents. The laser exhibits single-longitudinal mode emission with a Side Mode Suppression Ratio (SMSR) around 25 dB in the whole range of driving current. From these measurements an electro-thermal continuous tunability of 14 nm has been measured. This large continuous wavelength tuning with a single mode emission demonstrates that this device is well suited to scan several gas absorption lines as requested for TDLAS applications.
Figure 1. a) Cross-sectional SEM picture of a selectively etched InAs/GaSb TJ of a monolithic GaSb-VCSEL. b) Schematic diagram of the processed structure.

Figure 2. L-I-V characteristics in CW for a 2.3 µm GaSb monolithic VCSEL with a 6 µm TJ aperture diameter.

References:


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