Band-structure and gain-cavity tuning of 2.4- μm GaSb buried tunnel junction VCSELs

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One promising approach to cover the spectral range between 2 and 3 μm , where several pollutant gases such as CO, CO₂, CH₄ and NH₃ have strong absorption lines, is the development of GaSb-based inter-band lasers. Low-cost, continuous-wave GaSb-based vertical cavity surface emitting lasers (VCSELs) operating at $\sim 2.4 \mu\text{m}$ up to 50°C have been demonstrated recently [1]. In this work we have used high pressure techniques to investigate ways to improve their performance and extend their working temperature range. Since the band-gap and energy of the gain peak (E_p) increase with pressure at 0.126 meV/MPa [2] at constant temperature, when applied to edge emitting lasers (EEL) we can use pressure to determine the radiative and non-radiative recombination processes occurring [3]. In VCSELs, the pressure also tunes E_p relative to the cavity mode energy E_{cm} , which has a much weaker pressure dependence. Figure 1 shows the pressure dependence of the threshold current, I_{th} , of the VCSEL at three different temperatures (-10°C, 20°C and 30°C) and of a reference EEL with the same active region (I_{th} in this case normalised to its value at atmospheric pressure). The decrease in I_{th} with increasing pressure in the EEL indicates that Auger recombination is dominant at room temperature in this materials system and explains the temperature sensitivity of these EELs [3]. In the VCSEL the pressure dependence of I_{th} is much more complicated. At -10°C, pressure moves E_p above E_{cm} and the detuning effect dominates I_{th} , which therefore increases. At the higher temperatures the decreasing Auger recombination initially dominates. Detailed analysis will be given, but one can immediately note that at $\sim 130 \text{ MPa}$ I_{th} is lower at 20°C and is almost stable with temperature. Therefore we predict that either increasing the band gap or increasing the operating wavelength will allow an improved temperature performance of these GaSb-based VCSELs.

Fig. 1 Pressure dependence of I_{th} of the GaSb-based VCSEL at three different temperatures: -10°C, 20°C and 30°C as well as pressure dependence of normalised threshold current of edge emitting laser with the same active region at 20°C.

References

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