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Characteristic Temperature of a 2 μm InGaSb/AlGaAsSb Mode-locked Quantum Well Laser

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Abstract: Mode locking is achieved in a 2 μm GaSb-based laser up to 60 °C. The laser has a T_0 of ~82 K at room temperature, and the absorber bias voltage has little effect on T_0 . © 2018 The Author(s)
OCIS codes: (140.5960) Semiconductor lasers; (140.4050) Mode-locked lasers

1. Introduction

Ultrafast light sources operating in the 2 μm range are promising for many applications such as molecular spectroscopy, high resolution gas sensing, advanced telecommunications, and eye-safe light detection and ranging (LIDAR) [1,2]. Recently, passive mode locking has been demonstrated in 2 μm monolithic GaSb-based diode lasers [3,4]. However, high temperature performance of the lasers remains unexplored. Specifically, the characteristic temperature T_0 of a 2 μm mode-locked diode laser as well as the effects of the absorber bias voltage on T_0 have not been reported. These issues are important when the mode-locked lasers (MLLs) are used as light sources at high temperatures.

In this work, stable mode locking is demonstrated in a two-section InGaSb/AlGaAsSb quantum well laser emitting at 2 μm . Its characteristic temperature T_0 is investigated at different absorber bias voltages for the first time.

2. Experiment, Results and Discussion

The laser structure was grown on an (100) n-GaSb substrate by molecular beam epitaxy (MBE). It comprises a 10 nm-thick $\text{In}_{0.2}\text{Ga}_{0.8}\text{Sb}$ single QW (SQW) with lattice-matched 270 nm-thick $\text{Al}_{0.25}\text{GaAsSb}$ barriers on both sides. The detailed laser structure and the two-section laser fabrication process can be found in our previous work [4]. The schematic diagram of the two-section MLL is shown in Fig. 1. For the tested laser in this study, the ridge width is ~5 μm , which provides single lateral mode operation. The lengths of the gain section (L_g) and the absorber section (L_{SA}) are 1.89 mm and 0.23 mm, respectively. When working in the mode locking regime, the gain section is forward biased (I_g) while the absorber section need to be reverse biased (V_{SA}).

Fig. 1. Schematic diagram of the two-section passively mode-locked laser.

Stable mode locking was achieved under a wide range of bias conditions up to 60 °C. Figure 2 shows the RF spectrum, pulse train, and optical spectrum of the laser at $I_g=130$ mA and $V_{SA}=-1.7$ V. Figure 2(a) shows a strong RF peak with more than 40 dB signal to noise ratio at ~18.37 GHz, corresponding to the photon round-trip time in the 2.13 mm-long laser cavity. The RF spectrum at 60 °C is also shown in the inset. The time interval between two pulses is ~54.43 ps as shown in Fig. 2(b), corresponding well to the fundamental repetition rate at ~18.37 GHz. The optical spectrum shown in Fig. 2(c) gives a full width at half maximum (FWHM) of ~3 nm.

The temperature dependence of the threshold current density (J_{th}) is shown in Fig. 3. The absorber was biased at three different voltages: a small positive voltage (+0.5 V), a moderate negative voltage (-1 V), and a large negative voltage (-3 V). The threshold current density increases with increasing negative V_{SA} . From the slopes of these lines, there is no obvious difference in the characteristic temperature T_0 throughout the V_{SA} range. T_0 is determined to be about 82 K in the temperature range of 20 to 40 °C, and decreases to about 47 K in 40 to 70 °C range. According to

Fig. 3. (a) Electrical spectrum, (b) pulse train, and (c) optical spectrum of the laser when it is biased at $I_g=130$ mA, $V_{SA}=-1.7$ V.

these results, at a certain temperature, higher current is needed to compensate the additional loss caused by the stronger SA absorption. This additional loss has nothing to do with the laser's band structure and crystal quality which dominate the temperature-dependent thermionic carrier emission, and thus T_0 in the current density range.

Fig. 3. Temperature dependence of the threshold current density when V_{SA} is varied from +0.5 to -3 V.

3. Conclusion

Stable mode locking is achieved in a two-section InGaSb/AlGaAsSb SQW MLL emitting at 2 μm up to 60 $^{\circ}\text{C}$. The laser has a T_0 of ~ 82 K at room temperature, and the bias voltage applied to the saturable absorber has no obvious effect on it.

4. References

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