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Temperature- and Current-dependent Repetition Frequency of a 2 µm InGaSb/AlGaAsSb Mode-locked Quantum Well Laser

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Abstract: Mode locking is achieved in a 2 µm monolithic GaSb-based laser. The repetition frequency of the laser, as a function of temperature and injection current, is investigated. The reasons for the frequency tuning are discussed.
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 quantum well lasers [3,4]. However, mode locking characteristics of the lasers at high temperatures remain unexplored. Specifically, the effects of working temperature (T) and injection current into the gain section (I_g) on the repetition frequency 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 at 20 and 40 ^{o}C. Its repetition frequency, as a function of temperature and injection current, is investigated for the first time. The mechanisms behind the frequency tuning are analyzed.

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 $In_{0.2}Ga_{0.8}Sb$ single QW (SQW) with lattice-matched 270 nm-thick $Al_{0.25}GaAsSb$ 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}).

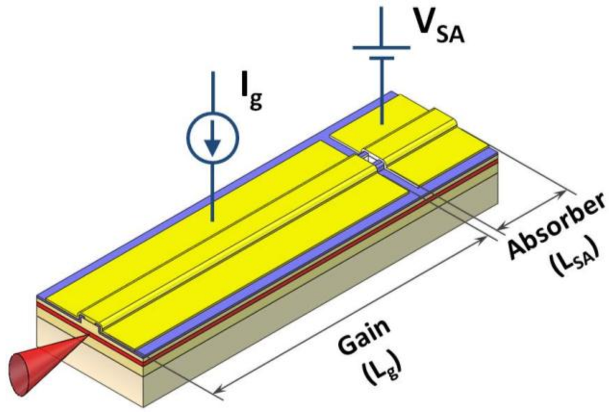

Fig. 1. Schematic diagram of the two-section passively mode-locked laser.

Stable mode locking was achieved under a wide range of bias conditions at 20 and 40 ^{o}C. Figure 2(a) shows the RF spectra at these two temperatures when the laser was biased at I_g=150 mA and V_{SA}=-1.2 V. The repetition frequency at 40 ^{o}C is obviously higher than that at 20 ^{o}C. At the same time, the optical spectrum at 40 ^{o}C exhibits a peak at obviously longer wavelengths as shown in Fig. 2(b) (the bias condition is the same as that of Fig. 2(a)).

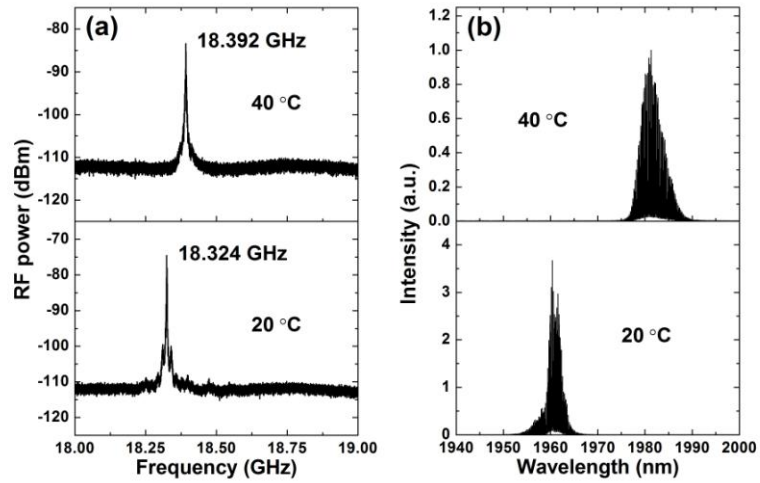

Fig. 2. (a) Electrical spectra and (b) optical spectra of the laser at 20 and 40 ^{o}C when it is biased at I_g=150 mA and V_{SA}=-1.2 V.

Figure 3 shows the repetition frequency of the laser as a function of I_g at 20 and 40 ^{o}C. The bias condition at these two temperatures is the same, i.e. I_g was varied from 120 to 150 mA while V_{SA} was fixed at -1.2 V. At each temperature, the frequency decreases consistently and linearly at the rates of 1.94 and 0.78 MHz/mA for 20 and 40 ^{o}C respectively. This decrease is due to several reasons, all of which are originated from current induced temperature increase: increased laser cavity length due to thermal expansion; increased refractive index (n) due to carrier escape (free-carrier plasma effect) and band gap shrinkage. On the other hand, the frequencies at 40 ^{o}C are higher throughout the current range. It is due to the decrease in n of the laser waveguide caused by wavelength redshift at higher temperatures as shown in Fig. 2(b), and this effect overwhelms the above two opposite effects.

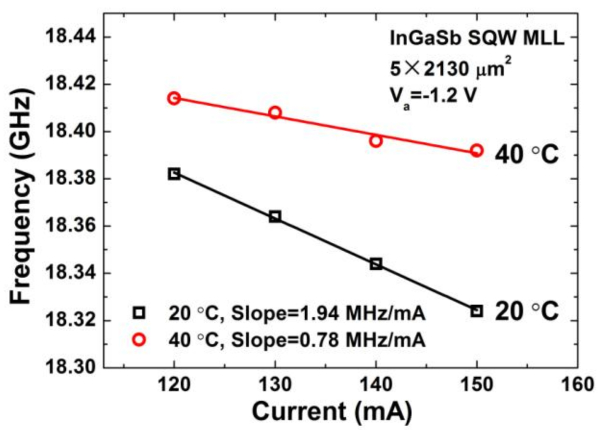

Fig. 3. Repetition frequency of the laser as a function of I_g when V_{SA} is fixed at -1.2 V at 20 and 40 ^{o}C.

3. Conclusion

Stable mode locking is achieved in a two-section InGaSb/AlGaAsSb SQW MLL emitting at 2 μm at 20 and 40 ^{o}C. The repetition frequency decreases linearly with I_g at fixed V_{SA} at both temperatures, and it increases when temperature is raised from 20 to 40 ^{o}C.

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