Chapter 5

Conclusion

We fabricated 850 nm proton-implanted VCSELs, and the fabrication process was performed with four photolithographic procedures. First, we deposited SiO_2 on the wafer for device passivation. Second, the contact metal is evaporated on the top and bottom of wafer surface. The third lithographic process was the ion implantation to form the transverse extent of the optical cavity. The final step was performed to evaporate the bonding pad metal. A variety of active region sizes for our VCSEL devices were fabricated on the sample with photoresist implant mask nominal diameters of 10, 12, 15, and 20 μm.

In first part, the room temperature CW L-I-V characteristics of the devices were measured, and the dependence of VCSEL performance on device size was discussed. We found that the series resistance increases as device size is reduced. The series resistance is primarily due to the vertical resistance of p-type DBRs. The lateral resistances caused by ion implantation also contribute to the series resistance. In addition, we observed that the threshold current density increases with the decrease in active region size. This is partly due to effects that require additional currents which scale with the device circumference, such as nonradiative recombination that occurs at the periphery of the implant. The threshold current is approximately proportional to the active region area. On the other hand, the current range and maximum output power are reduced with device size. Several effects are responsible for the reduction, such as thermal resistance, cavity loss, and threshold current density increase as device size is reduced.

In second part, the influence of SHB and self-focusing effect due to thermal lensing on the transverse modes was discussed. The transverse mode formation in relation to the kink in the L-I curve for implanted VCSEL was investigated. Then, the emission spectra in the vicinity of the kink in L-I curve were shown. We could see the variation of transverse mode in the vicinity of the kink in L-I curve. Hence, we could further understand the effect of SHB and self-focusing on transverse mode of VCSEL device.

In final part, the influence of temperature on VCSEL device was discussed. We observed a thermal roll-over in the CW L-I characteristics. This phenomenon is due to the thermal leakage of carriers and the gain spectrum peak as well as the FP resonance mode red shift with increasing temperature. Therefore, the output power decreases with increasing the injection current. In addition, to understand the influence of temperature on VCSEL device, we calculate the temperature of active region with various biased current. Using the measured FP mode wavelengths as a thermometer, we have shown that the temperature of active region rises from 25℃ to 51.6℃ when it reaches threshold at 6.7 mA, and increases by as much as 99℃ above that of the heat-sink to 124℃ when it reaches thermal roll-over at 13.7 mA. The electrical power dissipated at this current is 78.92 mW, and the thermal impedance is 1254.4 K/W. On the other hand, the influence of heat-sink temperature on threshold current, output power, and slope efficiency was also discussed. We observed the threshold current, which is dependent on the selection of gain offset wavelength, increases with the increase of temperature. However, the operating current range and maximum output power both reduce as heat-sink temperature is increased. The slope efficiency decreases with the increase of temperature. This is attributed to the reduction of the overlap between the gain peak and the FP resonance mode as temperature increases.