LETTER

Room Temperature CW Operation of GaAs Vertical Cavity Surface Emitting Laser

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SUMMARY This is the first report on room temperature CW operation of GaAlAs/GaAs vertical Fabry-Perot cavity surface emitting lasers. A vertical microcavity was formed with a diameter of 7 μm and cavity length of 5.5 μm by a two-step MOCVD growth and fully monolithic technology. The threshold current was 32 mA under CW condition at 22.5°C. Stable single transverse and longitudinal mode operation was obtained.

Recently, much interest has been paid for surface emitting semiconductor lasers[(1)] for the purpose of high power application, parallel processing, and so on. Especially, a vertical cavity surface emitting (SE) is attractive for various applications in future opto-electronics fields. We have paid much efforts for realizing a vertical cavity surface emitting lasers and demonstrated a low threshold operation of a micro-cavity SE lasers[(1)-(3)]. However, a low thermal dissipation has prevented room temperature CW operation of SE laser devices. Recently, Ogura et al. reported CW vertical emission from a semiconductor multilayer structure[(4)], but the spectral width was very wide (greater than 30 Å) and a spontaneous emission was not saturated even above the threshold.

In this letter, we would like to report the first successful room terperature CW operation of a vertical Fabry-Perot cavity surface emitting laser. We fabricated the micro-cavity GaAlAs/GaAs surface emitting laser and CW operation was achieved up to 22.5°C. We observed a resolution-limited spectral width and saturated spontaneous emission above the threshold. These indicate clear CW lasing operation of fabricated devices.

Figure 1 shows a schematic view of an MOCVD grown SE laser. This laser was fabricated by a two-step MOCVD growth and fully monolithic technology. First, a GaAlAs/GaAs DH wafer with a active layer thickness of 2.5 μm was grown by an atmospheric pressure MOCVD. After that, a circular mesa with a diameter of 7 μm was chemically etched almost reaching the achive layer. The current blocking layers (0.7 μm thick n-GaAs and 0.3 μm thick p-GaAs) were regrown to form a current confining structure as reported previously[(5)].

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The short cavity structure with a cavity length of 5.5 μm was formed by chemically removing the GaAs substrate.

In order to reduce the threshold current of a vertical cavity SE laser, a high reflectivity of laser reflectors is very important. Previously, a AuZn/SiO_2 mirror has been used for a bonding side. In order to increase the reflectivity of the bonding side, a Au/SiO_2/TiO_2/SiO_2 mirror was introduced. Then, a AuZn/Au ring electrode with outer/inner diameter of 40/5 μm was adopted. Finally, a 5 pair SiO_2/TiO_2 dielectric multilayer reflector was formed on the output side by electron beam evaporation. The reflectivity of the 5 pair dielectric multilayer was 95% at a wavelength of 0.89 μm.

The fabricated devices were initially tested under room temperature pulsed condition with a pulse width of 300 nsec and a repetition rate of 2 kHz. The threshold current ranged from 28 mA to 40 mA. The output power exceeded 10 mW and the differential quantum efficiency was typically 9.8%. The injected current spreads in a circle of 10 μm in diameter in the active layer, since the active layer was not buried by current blocking layers. Thus, the threshold current density was estimated to be 36 kA/cm^2, which could be reduced by optimizing and active layer thickness and increasing the mirror reflectivity.

Although the threshold was quite low (6 mA) in the previous experiment[(3)], room temperature CW operation

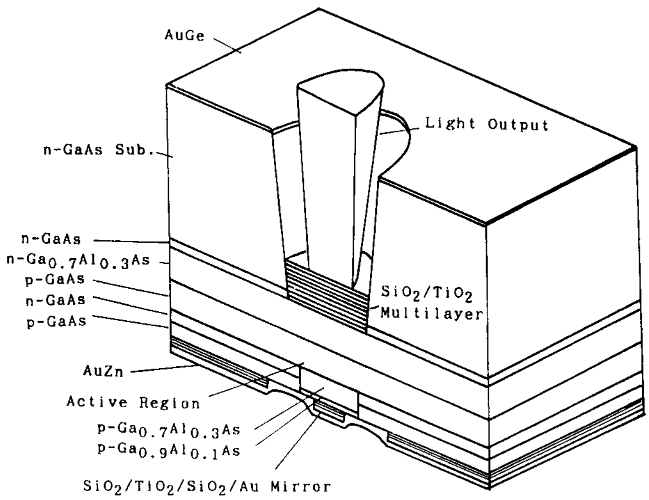

Fig. 1 Schematic structure of an MOCVD grown GaAlAs/GaAs vertical cavity surface emitting laser.

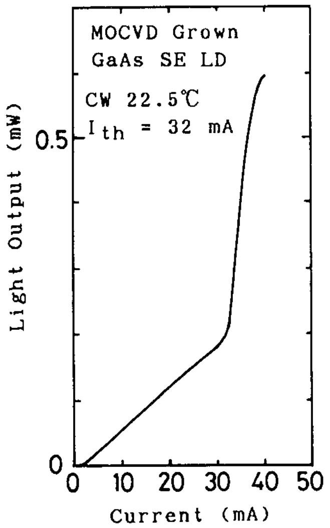

Fig. 2 Current/light output characteristic under room temperature CW condition. (I_{th}=29 mA : pulsed)

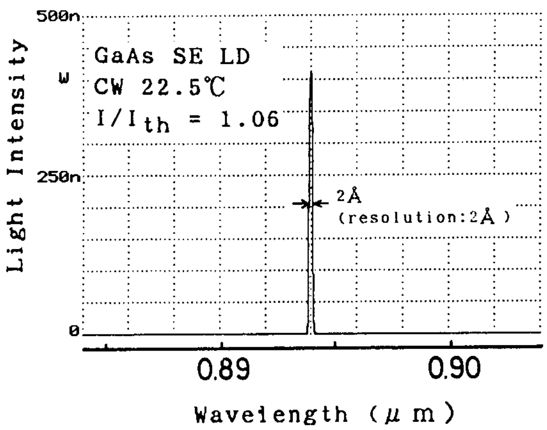

Fig. 3 Lasing spectrum under CW condition. (The spectral resolution of the used spectrometer is 2 Å).

was not obtained due to a thermal problem. It is because that the electrical resistance was rather high (~500 Ω) and the device was not bonded on a heatsink for thermal dissipation. The electrical resistance of the present device was reduced down to 30 Ω. The device was bonded junction down on a copper heatsink using a Ga metal for thermal removal.

Figure 2 shows a current/light output characteristic under CW condition at room temperature (22.5 °C). The threshold current was 32 mA. The differential quantum effichency was 9.3 % at 20 °C. This may be improved by optimizing the reflectivity of the bonding side mirror. The output power was saturated around 0.6 mW due to a temperature rise of the device as shown in Fig. 2.

Figure 3 shows lasing spectra under room temperature CW condition. Stable single mode operation was observed without any sub-transverse modes and other longitudinal modes. The spectral width above the threshold was 2 Å, which is limited by the resolution of the used spectrometer. The spectral width as narrow as the resolution limit indicates that the clear lasing operation was obtained. We found that the spectral width was wide, i. e., a few Å in full width below the threshold, which is in good agreement with a theoretical expectation. In addition, we found that the spontaneous emission was saturated above the threshold. The detailed measurements on the spectra near the threshold will be presented in the near future.

In conclusion, we believe that this is the first report on clear room temperature CW operation of a vertical Fabry-Perot cavity GaAlAs/GaAs surface emitting laser. The threshold current was 32 mA at the temperature of 22.5 °C. The obtained results together with the potentiality of the SE laser such as 2-D array, dynamic single mode operation and a circular sharp beam, would encourage further development of vertical cavity surface emitting lasers.

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References

(1) H. Soda, K. Iga, C. Kitahara and Y. Suematsu: "GaInAsP/InP surface emitting injection lasers", Jpn. J. Appl. Phys., **18**, pp. 59-60 (1979).
(2) K. Iga, S. Ishikawa, S. Ohkouchi and T. Nishimura: "Room temperature pulsed oscillation of GaAlAs/GaAs surface emitting junction laser", IEEE J. Quantum Electron., **QE-21**, pp. 663-668 (1985).
(3) K. Iga, S. Kinoshita and F. Koyama, "Microcavity GaAlAs/GaAs surface emitting laser with I_{th}=6 mA", Electron. Lett., **23**, pp. 134-136 (1987).
(4) M. Ogura, W. Hsin, M. Chiang, S. Wang and J. R. Whinnery: "Surface emitting laser diode with vertical GaAs/GaAlAs quater-wavelength multilayers and lateral buried heterostructure", Appl. Phys. Lett., **51**, pp. 1655-1656 (1987).
(5) F. Koyama, K. Tomomatsu and K. Iga: "GaAs surface emitting lasers with circular buried heterostructure grown by metalorganic chemical vapor deposition and two-dimensional laser array", Appl. Phys. Lett., **52**, pp. 528-529 (1988).