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High-Power Pure Blue InGaN Laser Diodes

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SUMMARY We fabricated high-power pure blue laser diodes (LDs) by using GaN-based material for full-color laser display. The operating output power, voltage and wall-plug efficiency of the LDs at forward current of 1.0 A were 1.17 W, 4.81 V and 24.3%, respectively. The estimated lifetime of the LDs was over 30,000 hours under continuous-wave operation.

key words: InGaN, GaN, high-power laser, blue LD

1. Introduction

In late years, laser light has drawn attention as light source for full color display. Using the lasers with three primary colors leads to the wider color coordination compared with the conventional display one. The red and green laser light sources have been developed by AlInGaP material and second harmonic generation (SHG) laser, respectively. For the blue laser light source, we have reported the blue LDs at 445 nm with output power at 500 mW [1]. However, upsizing the recent display requires the higher output power in lasers light source. For this objective, we succeeded in developing the high-power (1 W) and high-efficiency pure blue laser diodes (LDs). We reported the corresponding characteristic of the high power pure blue LD in this work.

2. Experiment

The schematic picture of the high-power blue LDs is shown in Fig. 1. The LD was grown on c-plane freestanding GaN substrates [2] by the metal organic chemical vapor deposition (MOCVD). The LD structure was based on separate confinement heterostructure multiple quantum well (SCH-MQW) with ridge-waveguide [1]. The cavity facet was formed by cleavage an m-plane facet.

We employed a new package in order to lower the thermal resistance for the realization of higher output power. The diameter of a new package was $\phi 9$ mm. The laser chip was mounted in a p-side up configuration. The thermal resistance of the new package is shown in Fig. 2. The thermal resistance at 1.0 A forward current under continuous-wave (cw) operation at 25°C was 10°C/W.

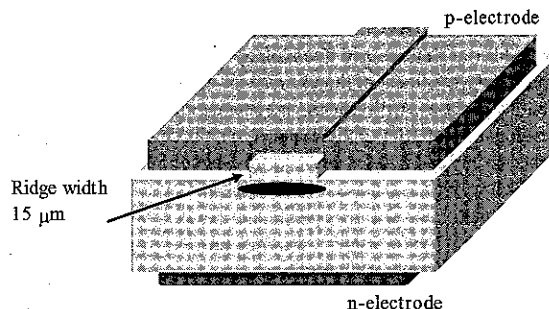


Fig. 1 Schematic picture of high-power blue LD chip.

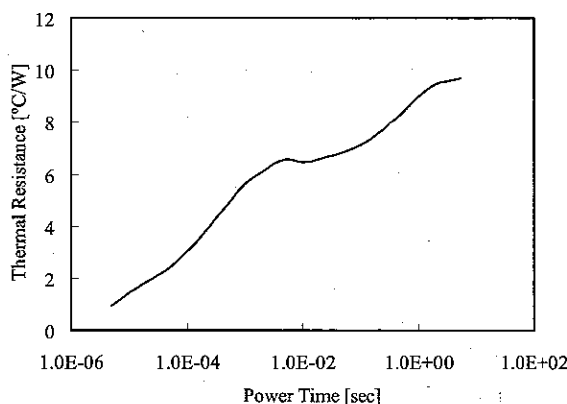


Fig. 2 Thermal resistance of high-power blue LD with $\phi 9$ mm package.

3. Characteristics of Blue LDs

The typical current-voltage (I-V) and current-output power (I-L) characteristics of the high power blue LDs under cw operation at 25°C are shown in Fig. 3. The threshold current was 184 mA, and the operating output power, voltage and wall-plug efficiency at forward current of 1.0 A were 1.17 W, 4.81 V and 24.3%, respectively. Wall-plug efficiency reaches up to 24% at 1.2 A forward current.

Figure 4 shows the typical far field patter (FFP) at 1.0 A forward current under cw operation at 25°C. Beam divergence angle in fast, and slow axis at the intensity of $1/e^2$ indicated 38.2° and 11.7°, respectively. FFP in fast axis is nearly Gaussian distribution. On the other hand, we observed the mixed shape with multi peaks at FFP in a slow axis due to the transverse mode being multi mode.

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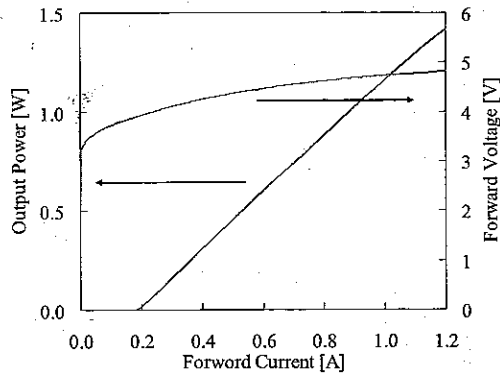


Fig. 3 Typical L-I and V-I characteristics of blue LDs under cw operation at 25°C.

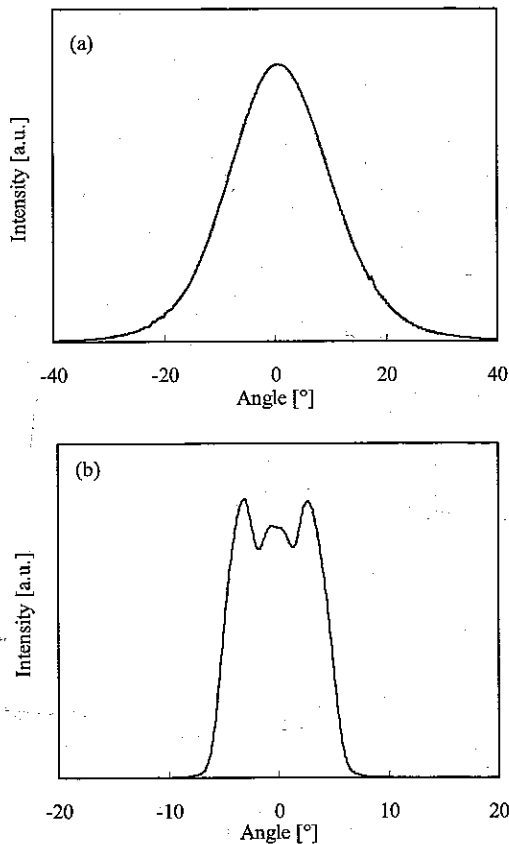


Fig. 4 Typical far field pattern in (a) fast axis and (b) slow axis of high-power blue LDs at current of 1.0 A under cw operation at 25°C.

The typical near field pattern (NFP) at forward current of 1.0 A under cw operation at 25°C is shown in Fig. 5. The emitting size in slow axis was $16 \mu\text{m} \times 1 \mu\text{m}$ which is almost the same ridge-width.

The typical emission spectrum at 1.0 A forward current under cw operation at 25°C is shown in Fig. 6. The multi-mode emission was observed at around 445 nm.

The L-I characteristics in the pulsed condition (duty 1%, Cycle 200 μsec) at 25°C is shown in Fig. 7. The output power in the pulsed condition of the LDs was over 3 W and

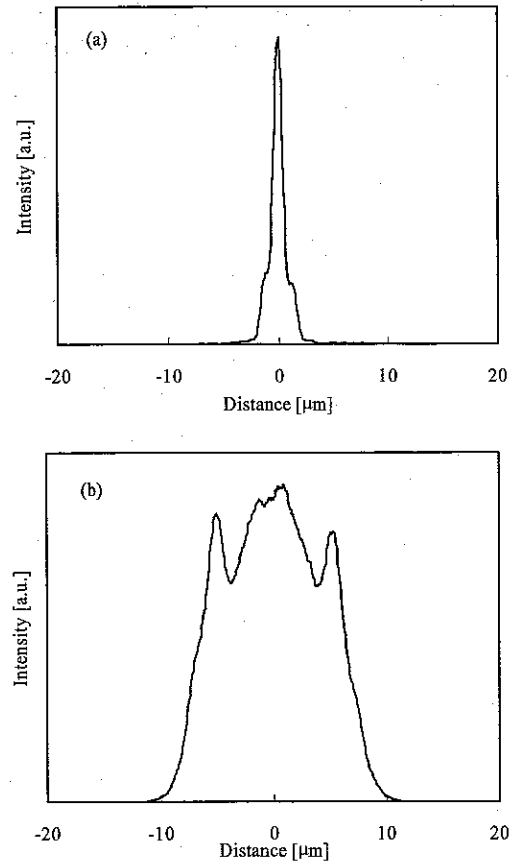


Fig. 5 Typical near field pattern in (a) fast axis and (b) slow axis of high-power blue LDs at current of 1.0 A under cw operation at 25°C.

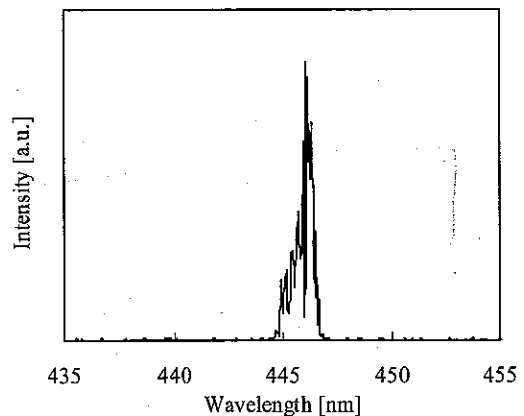


Fig. 6 Typical emission spectrum of high-power blue LDs at forward current of 1.0 A under cw operation at 25°C.

the catastrophic optical damage (COD) was unconfirmed at the facet of the cavity. The optical power density at the output power of 3.0 W was about $19 \text{ MW}/\text{cm}^2$.

The temperature dependences of L-I characteristics, FFP and dominant wavelength are shown in Figs. 8(a), (b) and (c), respectively. From Fig. 8(a), the threshold current increased with increasing the temperature, and characteristic temperature (T_0) was 105 K. However, the deterioration of

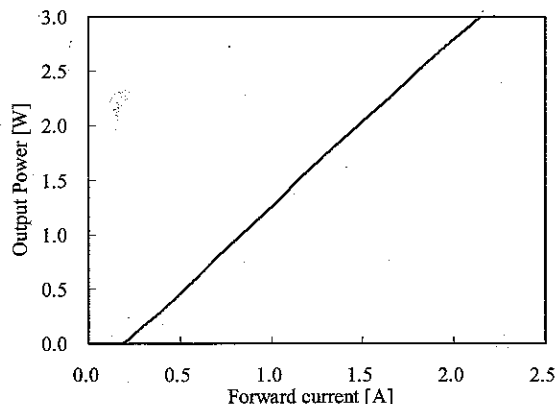


Fig. 7 Typical L-I of high-power blue LEDs under pulsed operation at 25°C.

the slope efficiency was unobservable by increasing a temperature. The FFP width in both slow and fast axis was unchanged by varying the shown in Fig. (b). The red shift of emission wavelength was 0.06 nm./°C in Fig. (c).

A lifetime test of high-power blue LEDs was carried out at a temperature of 25°C under 1.0 A automatic current control (ACC) condition. The result of the lifetime tests is shown in Fig. 9. The lifetime was defined as the expected time when the output power of the LEDs reached 50 percent from the initial output power. The lifetime was estimated to be over 30,000 hours at 1000 hours operation. As a result, we confirmed the long-term reliability of the high-power blue LEDs.

4. Conclusion

We succeeded in fabricating high-power blue LEDs with an optical output power of 1 W by using GaN-based material. The operating output power, voltage and wall-plug efficiency of the LEDs at forward current of 1.0 A were 1.17 W, 4.81 V and 24.3%, respectively. The output power in the pulsed condition of the LEDs was over 3 W. The estimated lifetime of the LEDs was over 30,000 hours under cw operation.

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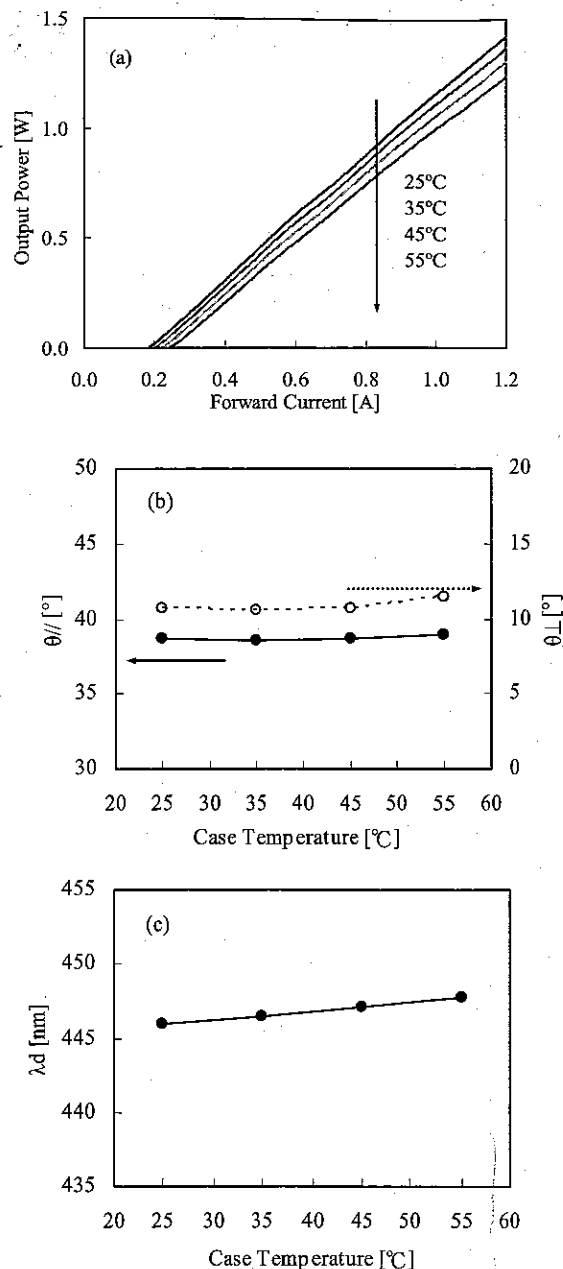


Fig. 8 Temperature dependences of (a) L-I characteristics, (b) FFP-width of intensity of 1/e2 and (c) dominant wavelength of high-power blue LEDs at forward current of 1.0 A under cw operation at 25°C.

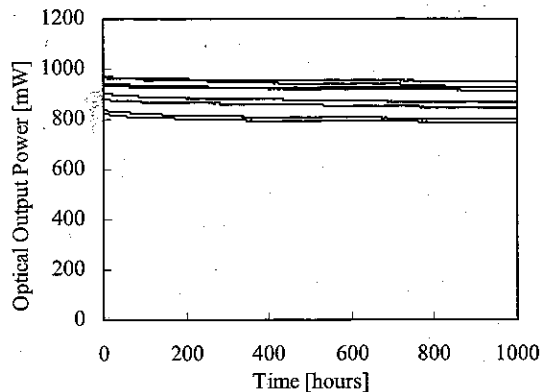
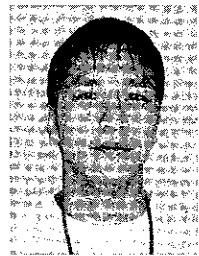


Fig. 9 Result of lifetime test under ACC with forward current of 1.0 A under cw operation at 25°C.



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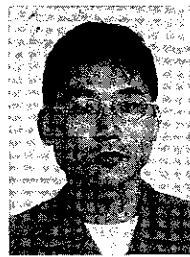
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