Red Laser Diode with 2.1-W CW Operation for Projectors

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In the pursuit of improved brightness, efficiency, and lifetime of projectors, it is desirable to use semiconductor lasers, i.e. laser diodes (LDs), for the light source. Following a conventional 2.5-W pulse-operated red LD, Mitsubishi Electric Corporation started mass production of a red LD that supports continuous wave (CW) operation at the world's highest [1] 2.1-W output by improving the device structure.

1. Introduction

Currently, high-pressure mercury lamps are widely used as the light source for projectors. Such lamps have several disadvantages including a relatively short lifetime of about 3,000 to 6,000 hours, large power consumption, and the environmental load of mercury. Accordingly, mercury lamps used as light sources are being replaced with LDs, which have such advantages as higher efficiency, higher color reproducibility, longer life, and lower environmental load. In September 2015, we started mass production of a red LD light source (ML562G84) capable of 2.5-W pulse operation. Since then, the red LD has gradually penetrated the market as a substitute for mercury lamps.

Projectors can be classified into two types: one that uses a single digital mirror device, and one that uses three digital mirror devices. Pulse light sources are used for the former, while CW light sources are used for the latter. We have developed and placed on the market a new red semiconductor LD that supports CW operation and 2.1-W output. This article describes the design, device characteristics, and lifetime test results of the high-output red LD.

2. Device Structure and Device Design

Figure 1 shows a schematic view of the basic structure of the red LD placed on the market. Using AlGaInP-based material, a broad stripe (BS) LD structure is adopted, which makes it relatively easy to increase the output.

The main reason for the reduced optical output of a red LD at high temperatures is that electrons with thermal energy pass through the band barrier in the p-cladding layer and no longer contribute to the light emission (electron overflow). To prevent this, the new product has a highly doped p-cladding layer. Furthermore, an increase in the amount of light confined in the active layer can suppress the electron overflow by reducing the carrier density required for oscillation.

As a measure for the catastrophic optical damage (COD) deterioration caused by optical absorption in the vicinity of the edges, the emission edge is provided with a window-mirror structure that involves disordering the quantum well structure through our own technique of Zn diffusion. In addition, the front edge is given a low-reflection coating, while the rear edge is given a high-reflection coating.

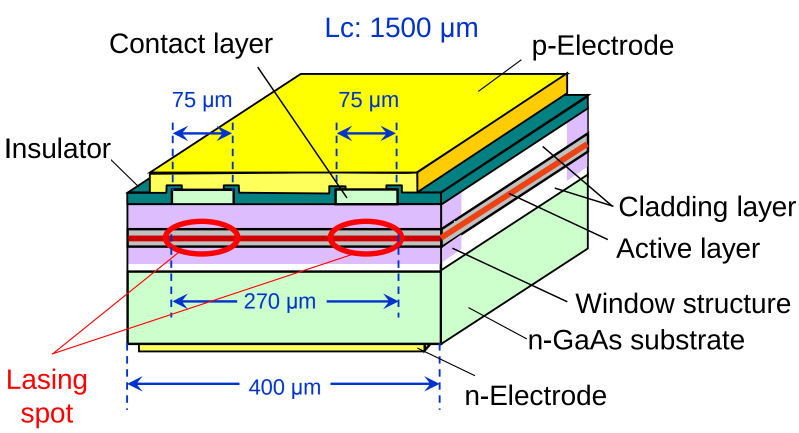

Fig. 1 Device structure of the red LD

[1] As of October 16, 2017 (our own research)

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Furthermore, by dividing the light-emitting region into two parts that are 75 μm in width, the heat generation density has been reduced, thereby suppressing the increase in temperature of the active layer. The length of the LD resonator has been determined to be 1,500 μm.

To facilitate efficient heat radiation from the active layer, the device has been assembled using a junction-down method, which involves die bonding the active layer side to the submount, which is then mounted on a TO-CAN package (Fig. 2) which is 9.0 mm in diameter.

The barrier to a power output increase for red LDs is mainly the COD at the front edge. This is a phenomenon in which the edge melts due to optical absorption in the vicinity, resulting in device failure. The average lifetime in such a failure mode, called the mean time to failure (MTTF), tends to be shorter as the optical density at the front edge becomes larger. For this reason, an extremely effective method for ensuring high reliability is to increase the full width of the light-emitting region to reduce the light density.

However, the light-emitting region is also a heat-generating region; an increase in the full stripe width causes the heating value to increase, resulting in reduced optical output at a high temperature or at high output power. Given this, we have selected for the new product a structure with two light-emitting points that are 75 μm in width, as such a structure can achieve a balance between an MTTF of at least 20,000 hours and favorable high temperature properties.

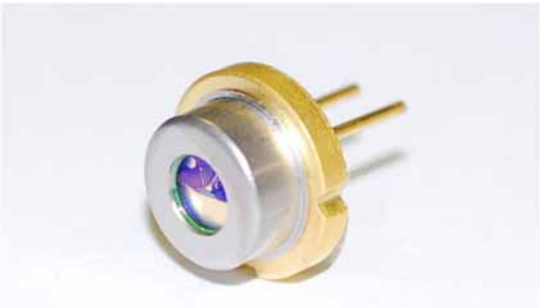

Fig. 2 Appearance of the ϕ9.0 mm TO-CAN

3. Device Characteristics and Reliability Evaluation Results

Figure 3 shows a typical graph of the relationship between the optical output and current characteristics of the new red LD. The red LD was operated in CW mode at the temperatures shown in the figure which are the case temperature measured at the package bottom. The operating current of the product at 25°C and 45°C for the output power of 2.1 W was 2.25 A and 2.95 A, respectively; and the operating voltage was 2.27 V and 2.34 V, respectively. The slope efficiency at 25°C was 1.20 W/A.

Figure 4 shows a graph of the far-field pattern (FFP) in the horizontal direction (FFP//) and vertical direction (FFP⊥) when the product was CW-operated at 25°C for 2.1-W power output. When the optical output was 1/e2 of the peak value, the full width in FFP// and FFP⊥ was 8.9° and 62.1°, respectively. When the product was CW-operated at 25°C for 2.5-W power output, the wavelength spectrum had a peak waveform of 638.5 nm and a full width at half maximum of approx. 0.9 nm.

When the product was operated at 3.55-W power output in CW mode at the case temperature of 20°C with constant current, the MTTF was 3,990 hours. All deteriorated parts detected were those involving COD. The results from another verification test revealed that the deterioration acceleration involving COD during the 3.55-W operation was 5.90 times that during the 2.1-W power output operation. Therefore, the MTTF during 2.1-W CW operation was equivalent to 3,990 × 5.9 = 23,500 hours.

Figure 5 shows a graph of the lifetime test results by performing CW operation of the product for 2.1-W power

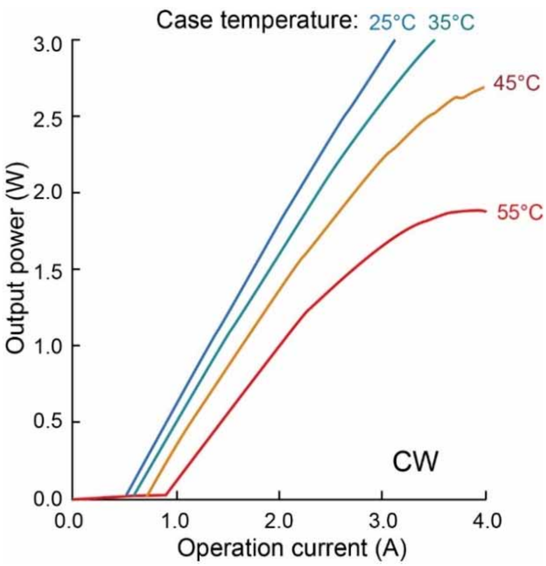

Fig. 3 Output power – Current characteristics

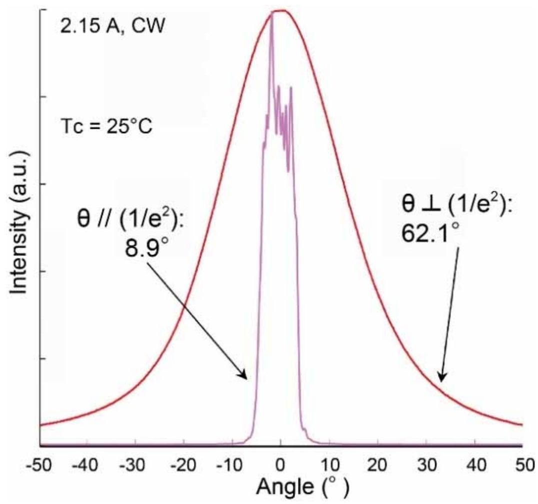

Fig. 4 FFP pattern

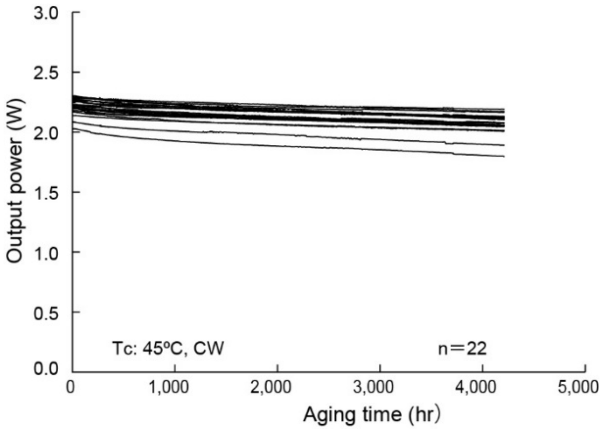

Fig. 5 Aging test results

output with constant current at the case temperature of 45°C. After 4,200 hours, the operation was stable. Under the condition of 50% reduced optical output defined as a failure, the MTTF was derived from the amount of optical output reduction in the test. As a result, the MTTF was 42,700 hours. These results show that the LD has high reliability.

The CW operation output power of 2.1 W is the world's highest output operation of a TO-CAN packaged 639-nm-band red LD.[1]

4. Conclusion

We have placed on the market a 2.1-W output red LD that supports CW operation for projectors that require a CW light source. By optimizing the full width of the light-emitting region while using the ϕ9.0-mm TO-CAN package for existing pulse technology products, a balance was achieved between the suppression of deterioration involved in COD and favorable temperature characteristics. As a result, stability was confirmed during CW operation for 2.1-W output power for at least 23,500 hours at 45°C.

We believe that together with the pulse-operated products released previously, the new product will further improve the functionality of projectors.