Invited Paper

Novel Large Coupled Optical Cavity Semiconductor Lasers and Multi-active Region Light Emitting Diodes with High Performances

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ABSTRACT

Novel multi-active region semiconductor lasers with large coupled optical cavity and high quantum efficiency, and new mechanism tunneling-regenerated multi-active region light emitting diodes with high quantum efficiency and high brightness have been proposed and fabricated. The external and differential quantum efficiency are 2.9 and 3.0W/A, and the output light power as high as ~5W when the injecting current equals 2A for the four active region 980nm strained InGaAs/GaAs QW lasers. The fundamental mode light output with perpendicular angle≤17° for this type of large coupled optical cavity laser has been achieved. The on-axis luminous intensity of the new mechanism 620nm AlGaInP/AlInP LEDs with two active regions is more than 5 cd. It was theoretically and experimentally resulted in that the electro-luminescence efficiency and the on-axis luminous intensity are linearly increasing approximately with the number of the active regions.

Keywords semiconductor laser, LED, multi-active region, high efficiency

1. INTRODUCTION

High power semiconductor laser (LDs) and high brightness light emitting diodes (LEDs) have been extensively paid attention[1,2] due to their very wide and important applications. The main obstacles of further increasing the output light power of conventional LDs are the catastrophic mirror damage at high light power density, electro-thermal destroy under high drive current and worse light beam quality[3, 4, 5] The brightness of the traditional LEDs is limited by two facts: over-heating damage due to high power in the small active region, and the low efficiency[6, 7].

In this paper, novel LDs with large coupled optical cavity and high quantum efficiency, and a new mechanism tunneling regenerated multi-active region LEDs with high quantum efficiency and high brightness have been proposed and fabricated. In these new types of LDs and LEDs, the main shortcomings and problems of the conventional LDs and LEDs mentioned above can be overcame and resolved, the excellent device properties including very high external and differential quantum efficiency, high output light power and high brightness under low injecting current, and outstanding light beam quality have been obtained.

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In *Optical Interconnects for Telecommunication and Data Communications*, Xiaomin Ren, Suning Tang, Editors, Proceedings of SPIE Vol. 4225 (2000) • 0277-786X/00/$15.00

2. THE PHYSICAL PRINCIPLES OF THE NOVEL DEVICES

The basic structure of the novel semiconductor lasers or LEDs is cascading some usual active regions by several tunnel junctions. In these structures, after an electron-hole pair is radiation recombined in the previous active region, the electron fallen into the p-side valance band can tunneling into the n-side conduction band and participate in radiation recombination again in next active region. Thus the quantum efficiency of the device can be increased dramatically, even larger than 1 and ideally proportional to the numbers of the active regions stacked by the tunnel junctions. So, we can obtain high light output at a relative low injection current. And more, the carefully designed coupled multi-active regions of a novel laser can form a whole large optical cavity, which results in a lower light power density intensity at the output facet and a narrower vertical beam divergence.

3. THE LAYER STRUCTURE GROWTH AND THE DEVICE FABRICATION

Both InGaAs/GaAs QW LD and AlGaInP LED epitaxial layer structure were grown by low-pressure MOCVD on n-GaAs substrate. The (100) GaAs substrate was oriented at 2° off the <110> direction for LDs while 15° for LEDs. TMGa, TMAl, TMIn were used as grouped V element precursors. SiH_4 diluted in hydrogen and liquid CCl_4 were used as donor and acceptor dopants respectively for reversed GaAs tunnel junction which sandwiched between the two active regions. Ti/Pt/Au and Au/Ge/Ni were used as p-type and n-type contact materials respectively.

4. CHARATERISTICS OF THE NOVEL DEVICES

4.1 The performances of the novel InGaAs/GaAs laser diodes

The P-I and V-I curves of a novel laser diode with three active regions and 100μm width stripes are shown in Fig.1. There is no kink in the P-I curves, which indicates that the three active layers are stimulated simultaneously. The external slope efficiency is up to 2.9W/A, which corresponding to an external quantum efficiency 2.32. The output power of the front facet can reach 2.5W at injection current 2.0A for the uncoated device.

The influence of the active region number is shown in Fig.2. It can be seen that the output power and the efficiency is increase with the number of the active region. When the number of the active regions

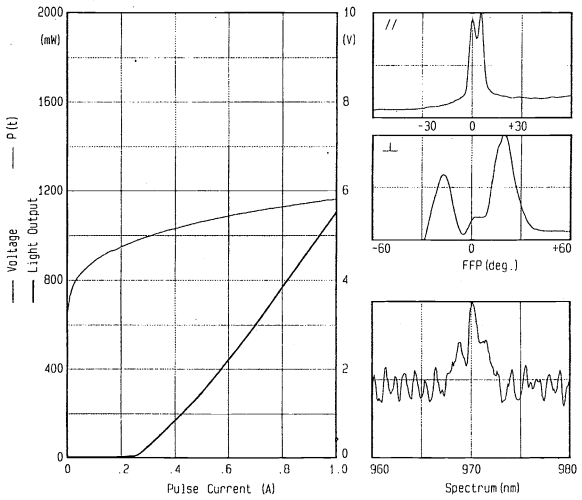

Fig.1 The typical characteristics of the novel lasers

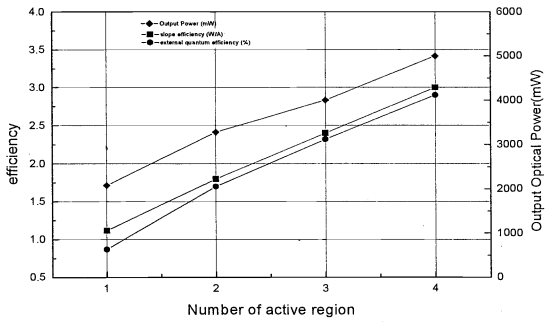

Fig.2 The influence of the active region on the novel laser power and efficiency

reaches to four, the output power, the external quantum efficiency and the slope efficiency can reach to 5W, 2.9 and 3W/A respectively.

The novel laser diode with narrow vertical beam divergence was also made. Fig.3 shows the typical characteristics of the devices. It can be seen that the vertical beam divergence is just 17°.

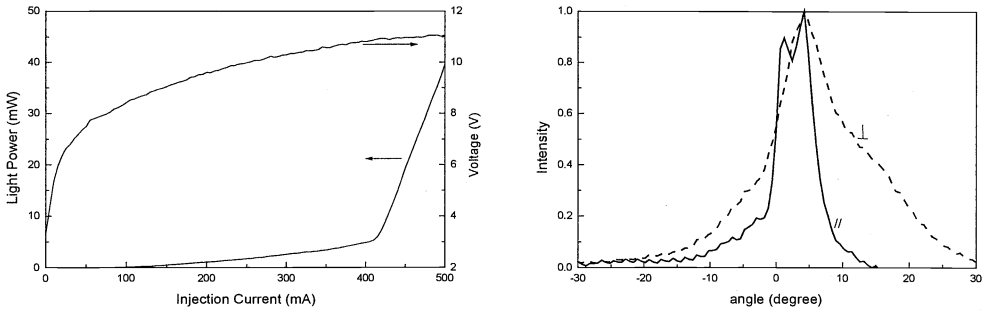

Fig.3 The typical characteristics of the novel laser diode with narrow beam devergence

4.2 The performances of the novel AlGaInP/GaAs LEDs

Fig.4 illuminates that the on-axis luminous intensity is about 15mcd for the traditional LEDs and is about 35mcd for the new-type LEDs at I=20mA. The on-axis luminous intensity of new-type LEDs is about twice as much as that of traditional LEDs. The fit line through these experimental data is done by computer, which indicates that the on-axis luminous intensity of new-type LEDs will increase linearly with the

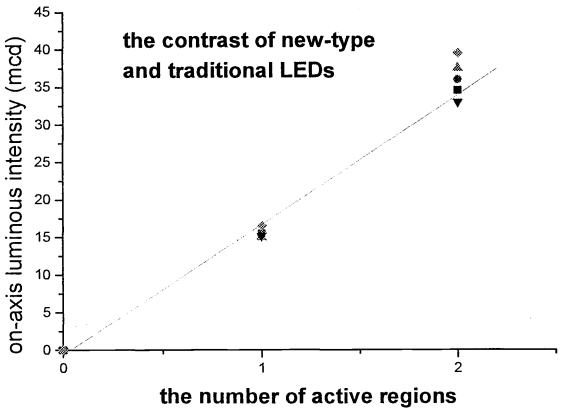

Fig.4 The contrast of brightness of new type LEDs and traditional LEDs

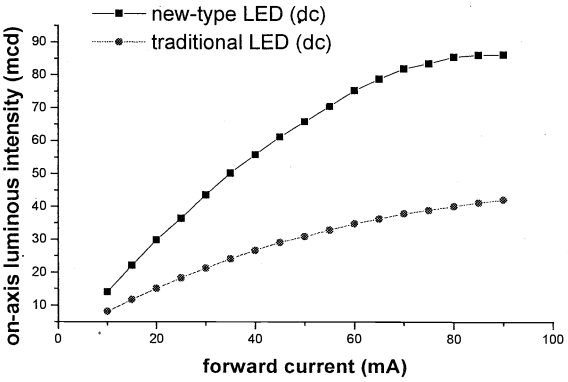

Fig.5 The on-axis luminous intensity of the new type LED and the traditional one vs. DC forward current

number of active region approximately. We can see from Fig.5 that both the DC resistance and the middle tunnel junction resistance do not influence the heat characteristic of the new-type LEDs compared with traditional LEDs. With the current increase, the on-axis luminous intensity of the new-type LEDs increases more quickly than that of the traditional LEDs.

Fig.6 shows that of all these 189 encapsulated new-type LEDs, the on-axis luminous intensity of 169 and 112 LEDs exceeds 2cd and 3cd which occupied 90% and 60% of whole device number respectively, and the maximum intensity is more than 5cd under 20mA DC current. These new-type LEDs without current spreading layer and DBR show immense potential and advantage over the traditional LEDs.

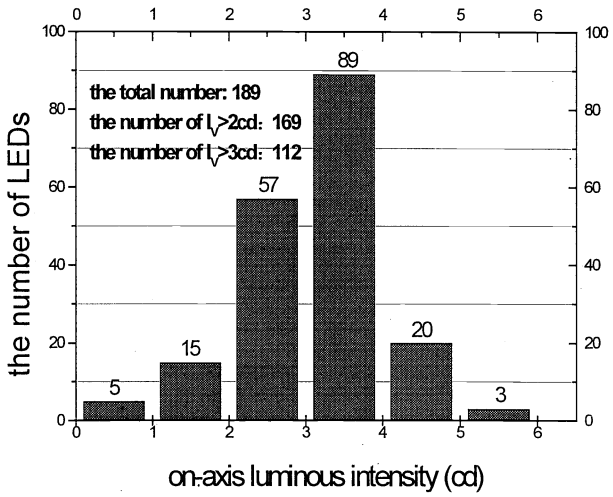

Fig.6 The statistics of the on-axis luminous intensity of encapsulated LEDs

5. CONCLUSION

Novel multi-active region lasers diodes and LEDs with high quantum efficiency and high brightness have been proposed and fabricated. The external and differential quantum efficiency are 2.9 and 3.0W/A, and the output light power as high as ~5W at the injecting current 2A for the four active region 980nm strained InGaAs/GaAs QW lasers. The fundamental mode light output with perpendicular angle≤17° for this new type laser has been achieved.

The on-axis luminous intensity of the new mechanism 620nm AlGaInP/AlInP LEDs with two active regions is more than 5 cd. The electro-luminescence efficiency and the on-axis luminous intensity are linearly increasing approximately with the number of the active regions.

6. REFERENCES

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