The Analysis on 808 nm Semiconductor Laser Facet Temperature Characteristics

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Abstract. The facet temperature characteristic of 808 nm semiconductor laser was researched. Catastrophic optical mirror damage (COMD) is one of major factor, which drastically limits optical power and lifetime of semiconductor laser. The heat source of semiconductor laser facet and the facet temperature field distribution were analyzed. The model of facet temperature distribution was established. The facet temperature characteristic of 808 nm semiconductor lasers for the ZnSe passivation coating of facet and uncoated the ZnSe passivation coating was analyzed. It is found that the temperature of device with the coated ZnSe passivation coating is lower than uncoated ZnSe passivation coating by 5.3C. It can effectively reduce the semiconductor laser facet temperature and improve the COMD threshold of 808 nm semiconductor laser with ZnSe passivation coating.

Introduction

808 nm high power semiconductor lasers are widely used in pumping solid state laser[1-2], laser medical[3-4], material processing and military applications[5]. With the increase on output power and brightness of solid state laser, we need more performance pumping source[6]. Semiconductor laser devices are subject to optical power, drive current and thermal effect while working. The facet of semiconductor laser devices can be easily oxidized and oxidized facet will dramatically degenerate device, even result in catastrophic optical mirror damage (COMD) [7] and make device failure.

In order to improve the COMD threshold of semiconductor laser facet, the most common method is to coat passivation film which can also protect facet and make semiconductor laser work at high power. We selected ZnSe as facet passivation film to reduce the facet temperature. The energy gap width of ZnSe material is 2.75eV, which is much larger than GaAs material. This can effectively prevent electrons and holes diffusing and recombining at the facet, reduce optical absorption and facet heat. The resault is ZnSe passivation film can effectively inhibit the semiconductor laser facet being oxidized, improve COMD threshold and output power.

Physical Model

There were two parts of heat generated by semiconductor laser, the heat source from active region and the heat source from non-active region[8-9].

(1)The heat source from active region(Q_{act}): Under working condition, the active region generated lots of carriers and photons. The result of the carriers and photons was nonradiative recombination, radiant absorption and absorption of the spontaneous radiation, and then generating a large amount of heat.

(2)The heat source from non-active region(Q_F): the facet heat source was the joule heat.

The total temperature distribution of facet:

$$Q = Q_{act} + Q_J \tag{1}$$

However, when semiconductor lasers was under high continuous current condition or high intensity pulsed current condition, facet heat will gradually ascend, which leads to light absorption of facet, and generates more heat. The heat made quantum well bandgap become narrow, resulting in more light absorption and generating more heat. As to analyse temperature distribution of facet, facet optical loss heat source（Q_{opt}）[10] is a need parameter when the divices work at high continuous current condition or high intensity pulsed current condition. Q_{opt} is that the heat generated by light absorption of facet under high temperature condition.

Therefore, the facet heat source of divice under high continuous current condition or high intensity pulsed current condition:

$$Q_F = Q_{opt} + Q_J \tag{2}$$

The total temperature distribution of facet:

$$Q = Q_{act} + Q_F \tag{3}$$

$$Q_{act} \cong \frac{E_{ph}}{d_w} J(1-\eta_i) \tag{4}$$

$$Q_{opt} \cong \alpha_i \frac{\Gamma}{wd_w} \frac{P_{out}}{1-R_F}[e^{-\alpha_m z} + R_F e^{\alpha_m z}] \tag{5}$$

$$Q_J = J\rho_i \tag{6}$$

Thereinto J is current density, E_{ph} is photon energy, η_i is internal quantum efficiency of stimulated emission, d_w is quantum well thickness, α_i is optical loss, Γ is pattern restriction factor, w is laser strip width, P_{out} is output light power, R_F is front mirror reflectivity, α_m is total facet loss, z is axial distance to facet, ρ_i is resistivity of each layer.

Analysis and Simulation

808nm laser diode is based on AlGaAs/GaAs material system with the structure of graded-refractive index separate confinement heterostructure single quantum well (GRIN-SCH-SQW). The epitaxial wafer structure consisted of a GaAs:Si buffer layer, a 1.5μm$Al_{0.7}Ga_{0.3}As$ ($1\times10^{18}cm^{-3}$ Si doped) cladding layer, a 0.15μm undoped $Al_xGa_{1-x}As$ waveguide layer with an Al composition varying linearly from 0.7 to 0.25, a 8 nm of undoped GaAs active layer, a 0.15μm undoped $Al_xGa_{1-x}As$ waveguide layer with an Al composition varying linearly from 0.25 to 0.7, a 1.5μm $Al_{0.7}Ga_{0.3}As$ ($2\times10^{18}cm^{-3}$Zn doped) cladding layer, a 0.15μm high-doped P^+-GaAs ($2\times10^{19}cm^{-3}$ Zn doped) contact layer. The structure of 808nm semiconductor laser wafer is shown in Figure 1.

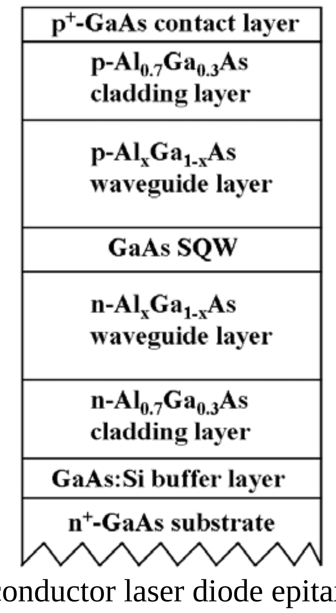

Fig.1 808nm semiconductor laser diode epitaxial wafer structure

Simulating the facet temperature characteristics of 808 nm semiconductor laser facet by the finite element software ANSYS. The facet temperature characteristic of 808 nm semiconductor lasers for the ZnSe passivation coating of facet and uncoated the ZnSe passivation coating was analyzed, which are shown in Fig. 2 and Fig. 3.

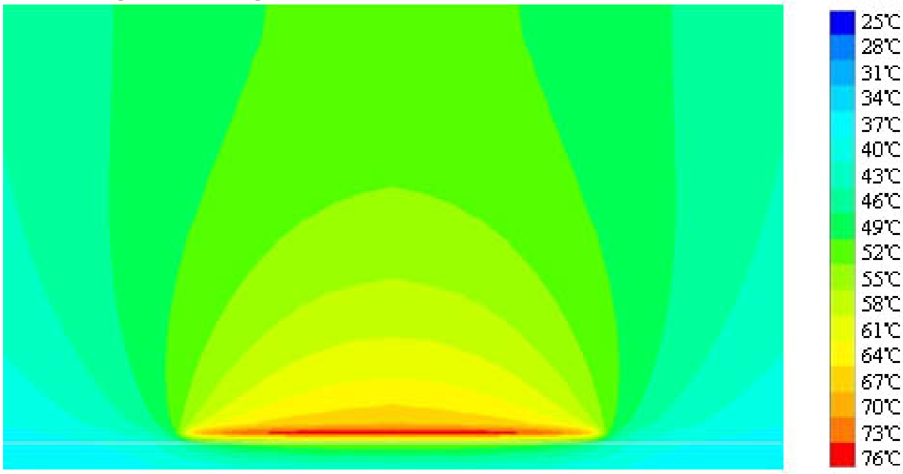

Fig.2 The temperature distribution of front facet with uncoated ZnSe passivation coating for 808 nm semiconductor laser

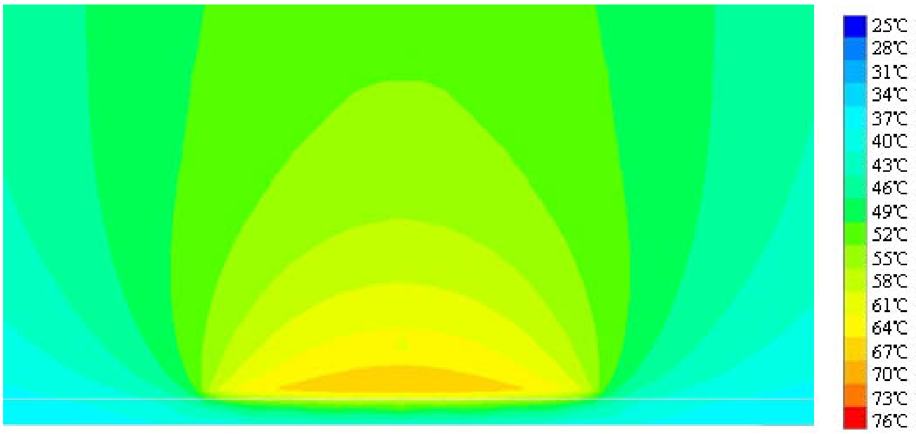

Fig. 3 The temperature distribution of front facet with coated ZnSe passivation coating for 808nm semiconductor laser

From Fig. 2, we found that the maximum temperature of 808 nm semiconductor lasers for the ZnSe passivation coating of facet is 75.8 C. And the maximum temperature of 808 nm semiconductor lasers for uncoated the ZnSe passivation coating of facet is 70.5 C which is shown in Fig. 3. It is found that the temperature of device with the coated ZnSe passivation coating is lower than uncoated ZnSe passivation coating by 5.3C. Especially under high current condition, the facet temperature went up continually. The facet with higher temperature can result in more light absorption, COMD and even device failure. Obviously, the device with ZnSe passivation coating has great facet temperature characteristics, can effectively improve the COMD threshold of semiconductor laser facet.

Conclusion

In this paper, the facet temperature characteristic of 808 nm semiconductor laser was researched. By analyzed the facet temperature characteristic of 808 nm semiconductor lasers for the ZnSe passivation coating of facet and uncoated the ZnSe passivation coating, we found that the maximum temperature for the ZnSe passivation coating of facet is 75.8 C, and the maximum temperature for uncoated the ZnSe passivation coating of facet is 70.5 C. It is found that the temperature of device with the coated ZnSe passivation coating is lower than uncoated ZnSe passivation coating by 5.3C. ZnSe as passivation coating, provides a barrier between the facet and transmission film, which also can reduce facet light absorption and facet temperature, and improve the COMD threshold of 808 nm semiconductor laser.

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