# 1050-nm high power diode array module


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High power diode array module has been fabricated. The epitaxial structure is an InGaAs/GaAsP strain compensated single quantum well. The laser bars are made with a filling factor of 84.6%. The module's quasi-continuous wave (100 $\mu$s, 1000 Hz) peak power can reach to 88.6 W at a current of 100 A. The central wavelength is 1050 nm and the full width at half maximum is 4.2 nm.



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The near infrared semiconductor laser has wide applications in short-distance range finding, short-distance collimating system and compact structure military system due to its small volume, high conversion efficiency, compact structure and low price. It can replace Nd:YLF as pumping source of Tm-doped fiber amplifier[1,2] and greatly improved its modularization level. The key is to obtain high quality and high power 1050-nm semiconductor laser. High power 1050-nm wavelength range laser has not been reported up to now at home. In the paper, we adopted InGaAs/InGaAsP strain quantum well combined with oxygen-free Cu heat sink to fabricate high power quasi-continuous wave (QCW) 1050-nm semiconductor laser bar modules.

The material composite, width of quantum well and strain determine the emission wavelength. In order to extend the emission wavelength to 1000 nm, indium composite should be increased. The strain in quantum well is induced when Indium is increased, which is negative for device operation. Commonly, there are two methods to resolve the problem, one is low temperature grow technology and the other is adding strain compensation layer. In this paper, we adopt a GaAsP strain compensation layer in InGaAs/InGaAsP quantum well layer to fabricate laser module. InGaAs/GaAsP strain compensated single quantum well structure with an emission wavelength of 1050 nm was grown. The structure of laser module was composed of p-InGaP cladding layer, upper and underside InGaAsP waveguide layer, GaAsP strain compensation layer and InGaAs quantum well layer.

Figure 1 is InGaAs/InGaAsP single quantum well confinement laser schematic structure. The upper and lower confined layers are 1000 nm p-$In_{0.49}Ga_{0.51}P$ and n-$In_{0.45}Ga_{0.55}As_{0.05}P_{0.95}$ respectively.

The front anti-reflection (AR) coating and the back high-reflection (HR) coating were designed according to InGaAs/InGaAsP epitaxial wafer structure. The front AR coating was grown by radio frequency magnetron scattering and the back HR coating was fabricated by ion-beam assisting electron gun evaporating. In experiment, the GaAs substrate wafer and K9 glass were used as measurement slices to monitor reflectivity of the front and the back cavity surface. Considering the catastrophic optical damage of the cavity facet coatings, the optimization of thickness and electrical field should be considered in designing the front and the back cavity facet coatings. Optimized structure and conglutination between optical film and cavity facet were designed. The front and the back cavity facet coatings are sub/1.18$Al_2O_3$/air and sub/$Al_2O_3$ 0.45$TiO_2$ 1.55$SiO_2$ ($TiO_2$ $SiO_2$)^3 $TiO_2$/air, respectively. The first layer $Al_2O_3$ can improve the conglutination and the use of $TiO_2$ can reduce the amount of growing layer. The layer of the back cavity facet is not regular 1/4 wavelength, which can reduce the strength of electrical field of the $TiO_2$ layer and therefore reduce the obsorption of the layer stack.

Figure 2 shows the experimental and theoretical curves of AR-coating of the front cavity facet (measurement slices are GaAs substrate). The facet reflectivity reached 5.12% through theoretical calculation (InGaAs substrate). Figure 3 shows experimental and theoretical curves of HR-coating of the back cavity facet (measurement slices are K9 glass). The facet reflectivity reached 96.7% through theoretical calculation (InGaAs substrate). The theoretical and experimental results fit well, and the reflectivity of optical coating fits the design result.

We adopted laser bars as laser module. Every bar was composed of several tens or several hundreds of emitting cells. The structure of laser bar should be optimized because the filling factor and isolation will affect operation performance. The laser bar with a stripe width of 110 $\mu$m (period of 130 $\mu$m) and a filling factor of 84.6% was fabricated. The isolation region between emitting cells formed by photolithography and wet etching was used as confining optical oscillation. The wafer was cut into bar stripe with cavity length of 1200 $\mu$m after p- and n-side was evaporated TiPtAu and AuGeNi respectively. The front and back facets are coated with AR

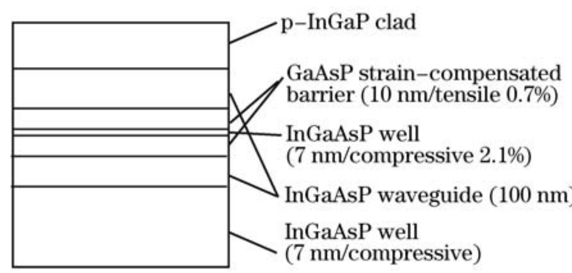


Fig. 1. Schematic structure of InGaAs/InGaAsP single quantum well laser.

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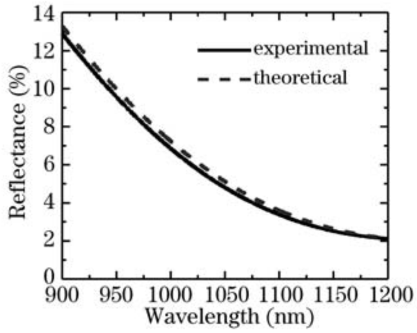

Fig. 2. Experimental and theoretical curves of AR coating.

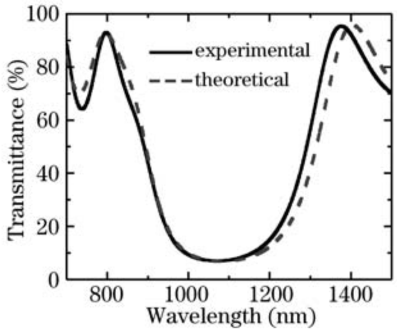

Fig. 3. Experimental and theoretical curves of HR coating.

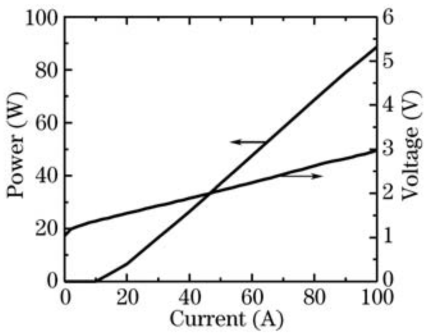

Fig. 4. Power-current and voltage-current curve of the module.

and HR coatings respectively. The p-side of bar stripe was soldered to heat-sink through Indium solder. The n-side and the upper electrode were connected with Cu foil. The p-side and n-side electrodes were isolated through isolation film. The laser module was cooled by refrigerating system.

Figure 4 is the measurement results about output power, electrical voltage and electrical current. The measurement conditions are follows: pulse width of 100 $\mu$s, frequency of 1000 Hz. The maximal output electrical current of power supply is 100 A. From Fig. 4, it can be seen that the threshold current of laser bar is 10 A. The peak output power is 88.6 W and slope efficiency is 0.98 W/A under electrical current of 100 A and electrical voltage of 2.97 V. Based on these operation condition, the laser bar still keeps good linearity. Figure 5 is the electro-optical conversion efficiency of laser module. The conversion efficiency is 36% when electrical current is 50 A. The front section of the Fig. 5 is not slippery under

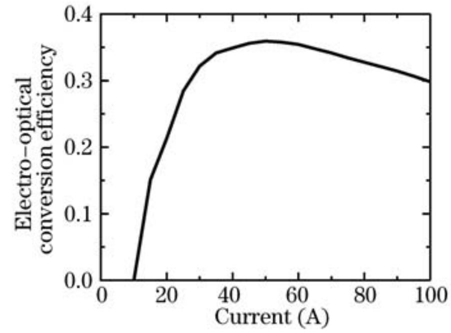

Fig. 5. Pump efficiency of the module.

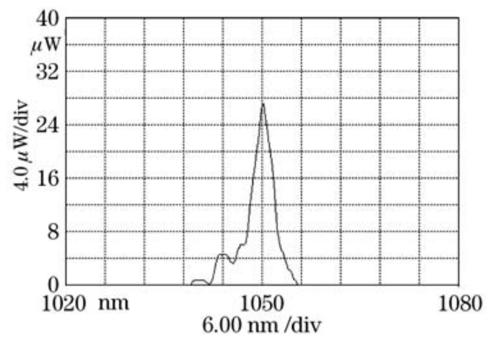

Fig. 6. Spectrum distribution of the module.

condition of small electrical current, which results from few measurement points due to larger error of power meter when average power of laser module is low. Figure 6 is the optical spectrum of laser module with 200 $\mu$m fiber detector and integraph under condition of 100 A. The central wavelength is 1050 nm and full-width at half-maximum (FWHM) is 4.2 nm.

The module was tested under direct current and 20 °C. The threshold current is 10 A and the central wavelength is 1050.0 nm with FWHM of 4.2 nm. The module's QCW output power reaches to 88.6 W at a current of 100 A.

In conclusion, a 1050-nm wavelength region laser module is designed, fabricated and assembled, and QCW output power of 88.6 W is obtained.

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