High Power 1064nm Laser Diode Array and Measuring Chip Temperature Based on Emitting Spectra

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ABSTRACT

High power laser diode array with an emission wavelength of 1064nm is presented. The epitaxial structure is an InGaAs/GaAsP strained-compensated single-quantum well structure. The modules CW output power can reach to 56.5W at current of 80A. Because the heat capacity of st rather shorter pulse duration and lower duty cycle, the average driving power in the laser chip is quite low, so the heating effect cemiconductor laser is very small, using pulse injection can reduce temperature rising significantly. Aould be neglected. The definite relation between lasing wavelength and chip temperature is developed. The temperature drift coefficient is 0. 45nm/ K

Keywords: high power, 1.06μm, chip temperature, pulse injection, thermal resistance, low duty cycle

1. INTRODUCTION

The development of new solid-state pumping medium requires the increasing of common spectral range to higher values of wavelength up to 1064nm. The other important reason of interest in this wavelength is to use laser diodes instead of solid state lasers, such as Nd:YAG lasers, with laser diode has much merit in terms of size efficiency, simplicity of configuration, and cost in some applications. InGaAs strained-quantum-well laser diodes with emission wavelength of 980nm have been conventionally used for pumping erbium-doped fiber amplifiers. To extend their lasing wavelength beyond 1000nm, the indium content of the InGaAs strained quantum-well (QW) layer has to he increased. However, this result in higher strain in the QW layer and consequently prevents the realization of high-performance LDs. There are two approaches to overcoming this difficulty. One is to grow the InGaAs well layer at low temperature. Indium incorporation into the InGaAs well layers enhanced and critical layer thickness is increased in this approach. The other is to use a strain-compensated layer structure. Compressive stress of the InGaAs layer is compensated by the tensile stress of the barrier layer of GaAsP. Through strained-compensated design of quantum well, the emission wavelength of laser diode is extended to around 1064nm[1,2,3]. In this paper, we present a high power 1064nm diode array module and the temperature characteristics are investigated.

1.1 Material and device design

The wafers are grown by Metal Organic Chemical Vapor Deposition (MOCVD). The epitaxial structure consists of an InGaAs/GaAsP strained-compensated single-quantum well (QW) surrounded by undoped InGaAsP waveguide layers and InGaAsP claddings. A schematic diagram of the epitaxial structure is shown in Fig.2.

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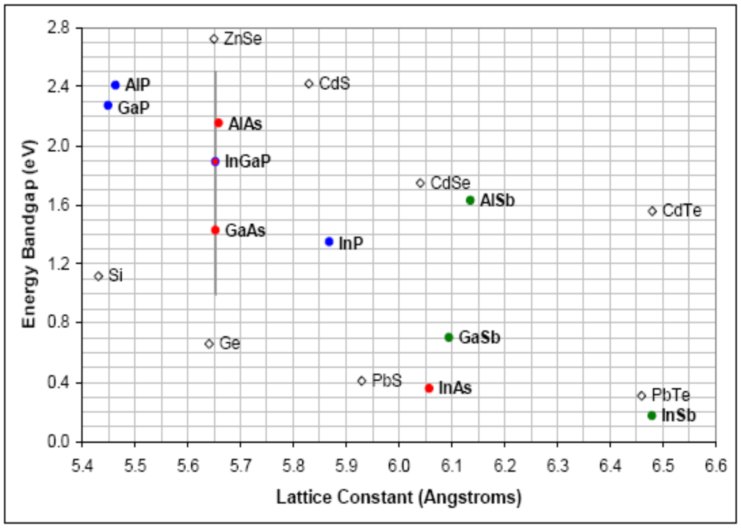

Fig. 1. Energy band-gap versus lattice constant for common semiconductors

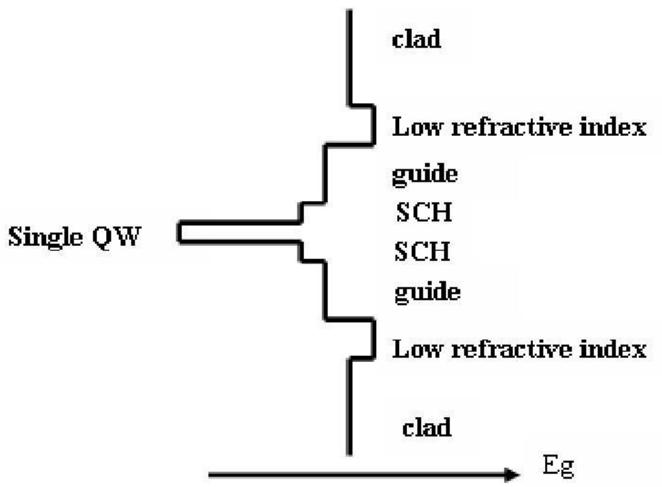

Fig. 2. Schematic energy band diagram of the epitaxial layers near the active region

Figure 2 illustrates the laser bar geometry. The bar dimensions are 150μm (total thickness)×1.2m (cavity length)×10mm (total lateral width), with a 30% fill factor (i.e. 19 broad-area emitters, each 150-μm wide, spaced on 500-μm centers). The isolation region between emitters formed by photolithography and wet etching was used as confining optical oscillation. The wafer was cut into bar stripe with cavity length of 1200μm after p-and n-side was evaporated TiPtAu and AuGeNi respectively. The front and back facets are coated with AR and HR coatings respectively. The bar is bonded p-side down on the edge of Cu heat sink with In solders at 160ºC. The thickness of the solder is 5μm. 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.

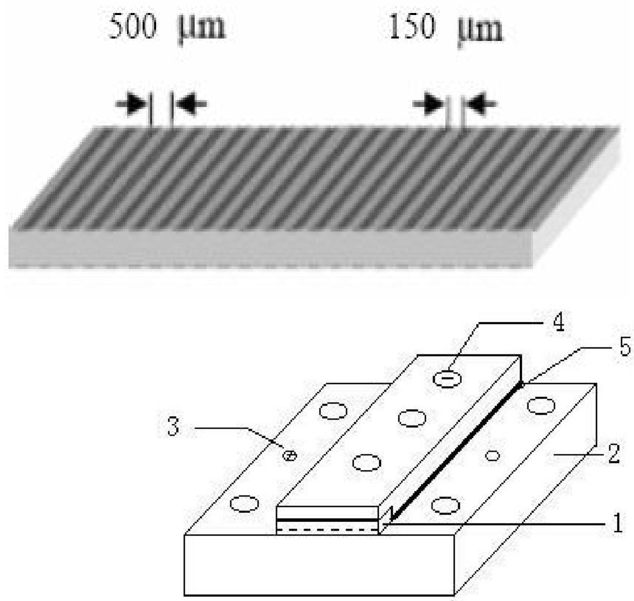

Fig.3 Schematic diagram of 30% fill-factor bar and conductively cooled heat sink

As connect the bottom of the laser module to a water cooler by using thermal conduct silicone, the water cooler is a simple macro channel heat sink made of Cu with the hydraulic diameter of the channel is 4mm. Presented measurements are performed under CW conditions with a coolant water temperature set to 20ºC and a flux of 4.5l/min .The current was increased in steps of 0.5A. Figure 5 illustrates the typical power vs. current (P-I) characteristics, voltage vs. current (U-I) characteristics. The threshold current is about 10A. The output power reaches its maximum of 56.5W at 80A with an electro-optical conversion efficiency of 26.1% nd a slope efficiency of 0.6W/A.

The measured spectrum distribution of the module at 56.5W output is given in fig4.

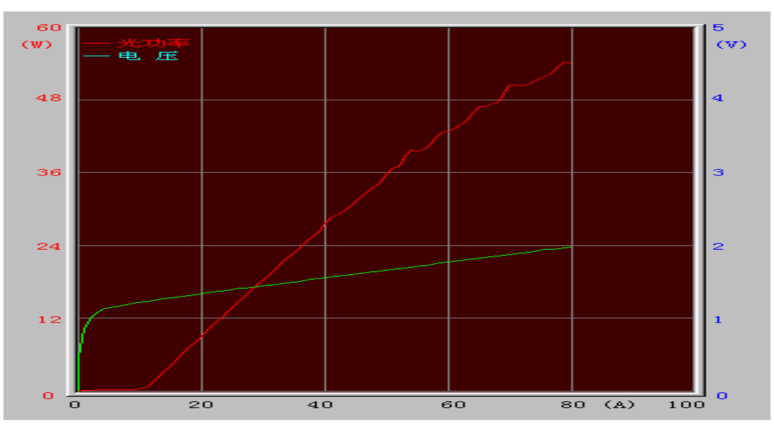

Fig.4 P-I and U-I curve

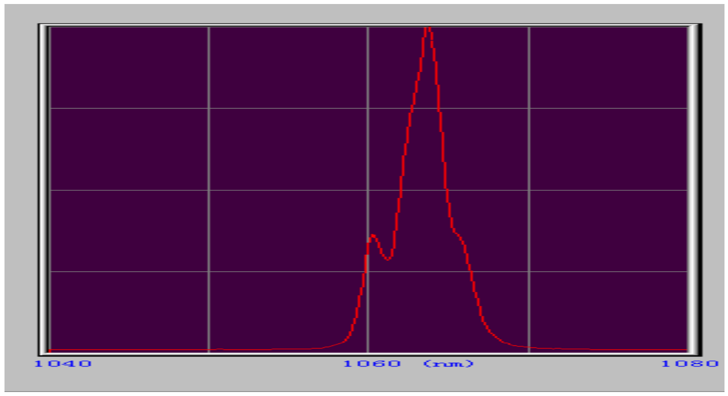

Fig.5 spectrum distribution of the module at CW

1.2 Measurement principle

The thermal characterization of laser diodes, the chip temperature Tc under certain current is a key parameter. At most condition, Tc is not a parameter to be measured directly. Fortunately, some other parameters such as threshold current, junction voltage drop and lasing wavelength, have a fixed relationship with Tc. However, under the pulse driving conditions especially at rather short pulse duration, current and voltage could not be measured precisely under most experiment conditions. So radiation-wavelength seems to be an appropriate parameter for determining Tc. In this work, the radiation-wavelength under driving pulse is measured for determining the thermal resistance of the laser chip. At rather shorter pulse duration and lower duty cycle, the average driving power in the laser chip is quite low, so the heating effect could be neglected. In this case, the chip temperature Tc is the same as the heat sink temperature Ts, and the measured relationship determine Tc in different driving conditions. the definite relation between lasing wavelength and chip temperature is developed, and the temperature drift coefficient is 0.45nm/K. The change of environment temperature versus lasing wavelength under pulse injection is discussed. Spectrum distribution of the module is measured under the condition of 100μs pulse duration and 20Hz repetition at 50 A.

$$\triangledown\lambda = k\triangledown T_c$$

Fig. 6 shows the lasing spectra of an InGaAs/ GaAs SQW laser chip under same driving pulse widths of 100μs at heat sink temperature Ts from 24℃ to 30℃, the changing step of the heat sink temperature was chosen to be 2℃. The driving pulse frequency was 20Hz. During the measurements , the driving current for the laser chip is fixed at 50A. At rather short pulse duration of 100μs at 20Hz (i. e.0.2% duty cycle) A temperature coefficient of about 0.45nm/ K could be estimated in the temperature range from 24℃to 30℃. For the measurement, the fiber etector of ANDO-6317B spectrometer (fiber core diameter is 200μm) is placed into the integrating sphere to collect the light signal. The peak lasing wavelength is 1052.6nm with a FWHM of 4.4nm, which results in the much wider FWHM than ordinary diode laser module with a wavelength of 808nm or 980nm. This probably because of the increasing of the In content in the InGaAs epitaxial layer in order to shift he lasing peak to the longer wavelength in the process of epitaxy growing.

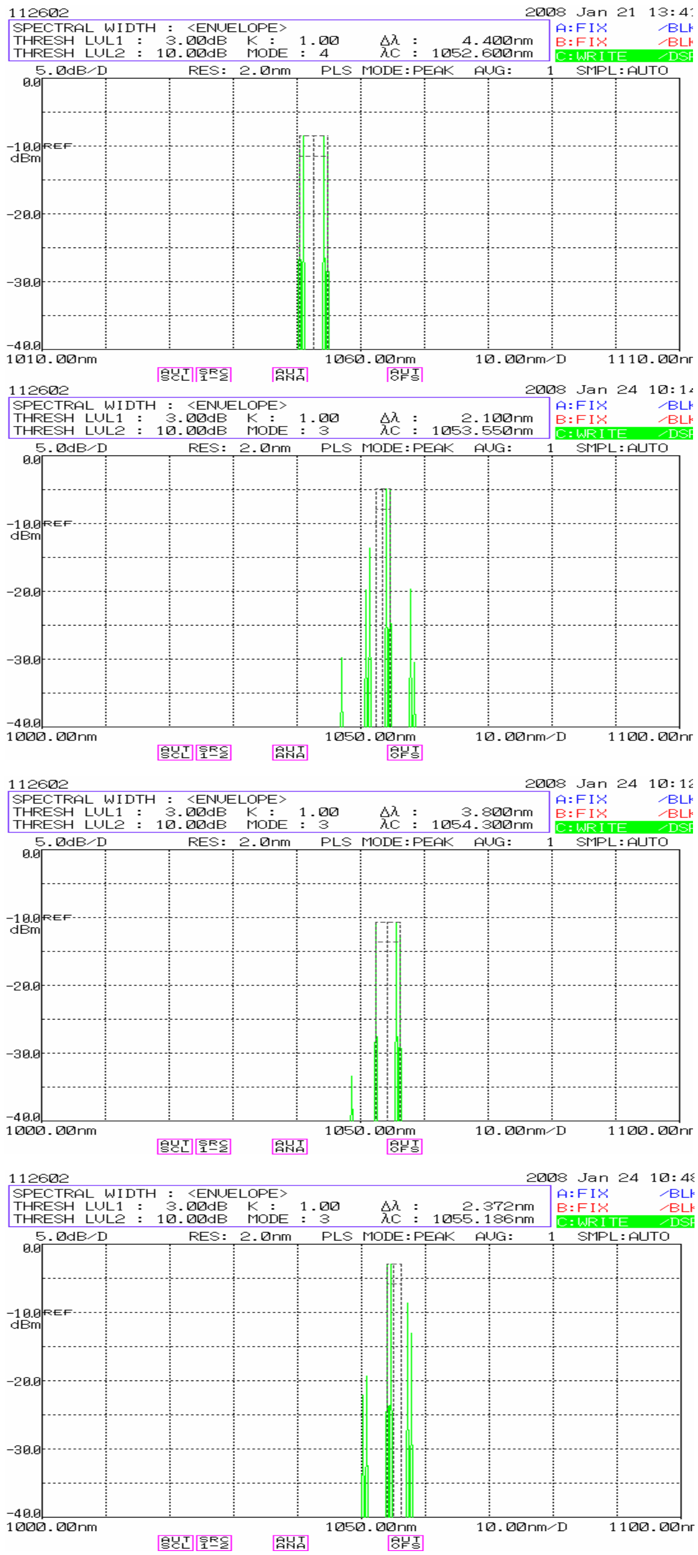

Fig. 6 spectra under same driving pulse widths of 100μs at heat sink temperature Ts from 24℃ to 30℃,

Wavelength(nm)	1052.600	1053.550	1054.3	1055.186
Temp(^{0}C)	24	26	28	30
Pulse duration(μs)	100	100	100	100
Pulse repetition(HZ)	20	20	20	20

Table 1

$$P_{th}= k(UI_{op}-P)$$

$$R_{th}= \triangledown\lambda/k\triangledown P_{th}$$

1.3 Conclusions

The module's CW output power can reach to 56.5 W at a current of 80A when the temperature of cooling water is 20◦ C central wavelength is 1063.8nm. An accurate method for measuring the chip temperature of semiconductor lasers is presented. Because the heat capacity of semiconductor laser is very small, using pulse injection can reduce temperature rising significantly. The definite relation between lasing wavelength and chip temperature is developed, and the drift t coefficient is 0. 45nm/ K. Those results are quite important to the further optimization of the design, processing as well as packaging of the lasers.

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