High power CW output from low confinement asymmetric structure diode laser


High power continuous wave output from diode lasers using low loss, low confinement, asymmetric structures is demonstrated. An asymmetric structure with an optical trap layer was grown by metal organic vapour phase epitaxy. Gain guided 50μm wide stripe 1.3nm long diode lasers were studied. 1.8W of continuous wave optical power per uncoated facet was obtained at an injection current of 4.7A (36mW/μm). The threshold current density is 270-400A/cm².

Introduction: High optical power from diode lasers can be obtained using structures designed to realise a low confinement factor in the active region [1-3]. About three times smaller than in usual GRIN symmetric structures. An asymmetric design meets this requirement more easily and avoids the limitations related to the thickness of the confinement layers. This Letter reports results obtained using diode lasers having a low confinement InGaAs/AlGaAs double quantum well (DQW) asymmetric structure with an optical trap layer, grown by metal organic vapour phase epitaxy.

Structure: As the DQW asymmetric InGaAs/AlGaAs structure with optical trap layer was designed for high power continuous wave (CW) operation, the confinement factor is low (Γ = 7.7 × 10⁻⁴) for each of the two 6nm quantum wells. The corresponding spot size is d = 0.78μm. The quantum wells are bordered by graded layers with a composition index varying from 0.20 to 0.60. The waveguide and the optical trap layer are separated by a 0.1μm thick layer with Al content x = 0.60. To lower the confinement factor of the structure by shifting the maximum of the optical field away from the active region, we use a 0.22μm thick Al₀.₅Ga₀.₅As ‘optical trap’ layer on the n-side, as shown in Fig. 1.

The limitation of the optical field extension in the p-side of the structure leads to minimised series resistance and free-carrier losses, which are essential for low confinement laser diodes. A low absorption coefficient, ~1cm⁻¹, is an important requirement for low confinement laser diode structures [1-3]. It was obtained using low doped layers.

Experimental results: Gain-guided, 1.3nm long diode lasers were studied. The 50μm wide stripe was defined by shallow 0.2μm wet etching. Uncoated devices were mounted p-down on Cu and diamond heatsinks using In as a solder. The wavelength of the emitted radiation is λ = 970nm at 20°C for a driving current of 4A.

The CW measurement results for the most important parameters (output optical power, voltage and power conversion efficiency) against direct driving current are presented in Fig. 2. The threshold current density for CW operation is 270-400A/cm². The internal efficiency is ~90% and the value of the internal absorption coefficient is very low, ~1cm⁻¹ as deduced from the differential efficiency dependence on device length. The value of the external differential efficiency is 70%. The series resistance is ~2.0 × 10³ Ω cm⁻¹, which is comparable to values reported for the usual GaAs/AlGaAs QW GRIN symmetric structures. The transversal emitted laser beam far field distribution is 25°, FWHM.

Fig. 1 Refractive index profile and optical field distribution for low loss, low confinement, asymmetric laser diode structure with ‘optical trap layer’

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Fig. 2 Total (both facets) optical output power, voltage and power conversion efficiency against direct driving current for 50μm wide stripe, 2mm long, laser diodes with asymmetric structure with ‘optical trap layer’

Device mounted p-down on diamond heat-sink
(i) power conversion efficiency
(ii) voltage
(iii) output power

The maximum output power per stripe width before catastrophic optical damage (COD) for uncoated devices is as high as 36mW/μm, which is 2.5 times higher than those reported for uncoated conventional structures [4]. Even better results should be obtained from mirror coated devices.

The T, parameter, which describes the temperature sensitivity of the threshold current, is 175K.

Conclusion: The results presented here clearly demonstrate the possibility of obtaining high power output from diode lasers using low loss, low confinement, asymmetric structures as predicted in [1-3]. This Letter describes also a new semiconductor InGaAs/AlGaAs DQW laser structure for high power CW operation, which uses a separate ‘optical trap’ layer on the n-side of the active region to meet the requirement for low confinement factor, down to 7.7 × 10⁻⁴ per QU. The structure shows very low values for light output power.

References
for the absorption coefficient, i.e. $\alpha = 1 \text{ cm}^{-1}$, and a high COD output power level, i.e. 36mW/$\mu$m for uncoated devices, which represents an improvement by a factor of 2.5 times when compared with conventional structures. The threshold current density is $\sim 270-400 \text{ A/cm}^2$ for 1-3mm long laser diodes.

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REFERENCES


4. HERLEIN, J., SCHIECHLEN, E., JAGER, R., AND UNGER, P.: '63% wall plug efficiency InGaAs/AlGaAs broad-area laser diodes and arrays'. CLEO/Europe '98, Proceedings, p. 267


Fig. 1 shows our proposed configuration for the integrated external cavity laser. The groove in the silica waveguide is filled with silicone [5]. The TO coefficient of silicone is opposite to that of the LD. This matches the coefficient of the longitudinal mode to that of the silica waveguide when the silicone length is optimised. The mode hopping temperature interval is

$$T = \frac{e}{2(n_{LD}L_{LD} + n_{P}L_{P} + n_{S}L_{S})} \left| m - m_{S} \right|$$

The TO coefficient of the longitudinal mode in the integrated external cavity laser is

$$m = \frac{m_{LD}n_{LD}L_{LD} + m_{P}n_{P}L_{P} + m_{S}n_{S}L_{S}}{n_{LD}L_{LD} + n_{P}L_{P} + n_{S}L_{S}}$$

Here, $m_{LD}$, $m_{P}$, and $m_{S}$ are the TO coefficients of the Bragg wave-length of the grating in the silica waveguide, SS-LD and silicone, respectively, and $n_{LD}$, $n_{P}$, and $n_{S}$ are their respective refractive indices. The length of the silica waveguide, SS-LD and the silicone-filled groove are $L_{LD}$, $L_{S}$, and $L_{P}$, respectively. We can estimate the required silicone groove length using these equations.

Fig. 2 Optical power against current at 25°C

![Fig. 2 Optical power against current at 25°C](image)

Fig. 2 shows the output power against current. The threshold current is 15mA and the optical power is 1mW at an injection current of 60mA. There is no mode hopping with changes in current. Fig. 3 shows the dependence of the oscillation wavelength on temperature. The conventional integrated external cavity laser shows mode hopping every 6.5°C but in our proposed configuration, this is caused by the difference between the TO coefficients of the longitudinal mode and the Bragg wavelength. To eliminate mode hopping, the TO coefficient of the longitudinal mode must coincide with that of the Bragg wavelength.