고출력 응용을 위한 1.3 μm InAs/GaAs 양자점 레이저 다이오드의 특성 연구

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Characteristics of 1.3 μm InAs/GaAs Quantum Dot Laser Diode for High-Power Applications

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Abstract : Characteristics of InAs/GaAs quantum dot (QD) ridge laser diodes (LDs) are investigated for high-power 1.3 μm applications. For QD ridge LDs with a 5-μm-wide stripe and a 1-mm-long cavity, the emission wavelength of 1284.1 nm, the single-uncoated-facet CW output power as high as 90 mW, the external efficiency of 0.31 W/A and the threshold current density of 800 mA/cm^2 are obtained. The linewidth enhancement factor (α-factor) is successfully measured to be between 0.4 and 0.6, which are about four times as small values with respect to conventional quantum well structure. It is possible that this result significantly reduce the filamentation of far-field profiles resulting in better beam quality for high power operation.

Key Words : InAs/GaAs, Linewidth enhancement factor, LD (Laser Diode), QD (Quantum Dot)

1. Introduction

High-power semiconductor laser diodes (LDs) have potential applications such as pumping sources for fiber optical communications, diode pumped solid-state lasers and material processing. On the other hand, LDs having quantum dot (QD) structure instead of quantum well as an active region have numerous advantages of device performance regarding very low threshold current and high characteristic temperature [1,2]. Especially, the linewidth enhancement factor (α-factor) which significantly affects the filamentation of far-field profiles can be reduced by using QD structures resulting in better beam quality. In these reasons, LDs having QD structure as an active region are one of the key solutions for higher-power and better beam quality.

In this work, InAs/GaAs QD ridge LDs grown by molecular beam epitaxy (MBE) are fabricated and characterized for high-power 1.3 μm application.

2. Experiment

InAs/GaAs QD LDs were grown on n+ GaAs substrates by using MBE system and purchased from Nanosemiconductor company (NSC). Fig. 1 shows schematic drawings of the InAs/GaAs QD LD. The laser structure consisted of a 500-nm-thick GaAs buffer layer, a 1.5-μm-thick n-$Al_{0.35}Ga_{0.65}As$ lower cladding layer, a 1.5-μm-thick p-$Al_{0.35}Ga_{0.65}As$ upper cladding layer, and a 400-nm-thick GaAs p+ contact layer grown from the bottom. Between the cladding layers was a graded index waveguide which consisted of 36 pairs of short period lower and upper superlattice of a 2-nm-thick $Al_{0.3}Ga_{0.7}As$ and a 2-nm-thick GaAs layer. The active region consisted of five alternately stacked a 0.8-nm-thick InAs QD layer and a 5-nm-thick $In_{0.2}Ga_{0.8}As$ layer with each stack separated by a 38-nm-thick GaAs strain barrier layer, respectively. InAs/GaAs QD LDs were fabricated using standard semiconductor process.

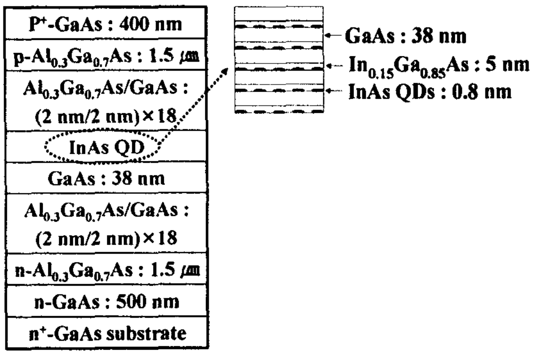

Fig. 1. Schematic drawings of InAs/GaAs QD LD in the vertical direction

3. Results and Discussion

Figure 2 shows the light-output power versus current (L-I) characteristics measured from uncoated InAs/GaAs QD LDs with a 5-μm-wide stripe and a 1-mm-long cavity in the CW mode at room temperature. The lasing wavelength of ridge LDs was measured to be 1284.1 nm at a current of 50 mA, as shown in the inset of Fig. 2. The light-output power was measured using a calibrated Newport thermopile detector (model: 818T-30/CM). The light-output power of the ridge LDs was measured to be 90 mW at a current of 360 mA. The threshold current of 40 mA, the corresponding threshold current density of 800 mA/cm^2 and the external efficiency of 0.31 W/A of the present QD ridge LDs were recorded at this moment.

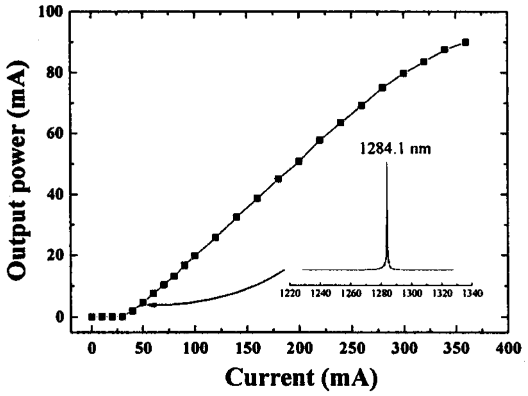

Fig. 2. L-I characteristics and typical lasing spectrum measured from uncoated ridge LDs with a 5-μm-wide stripe and a 1-mm-long cavity in the CW mode at room temperature.

The result of the calculated α-factor at different wavelength is shown in Fig. 3. The calculated α-factor is distributed between 0.4 and 0.6, which are about four times as small values with compared to quantum well (QW) structure of our previous work [3]. It is attributed to usage of QD instead of QW as an active region This result is thought to be expected to decrease the full width at half maximum (FWHM) of the far-field of LDs resulting in good beam quality at a high-power operation.

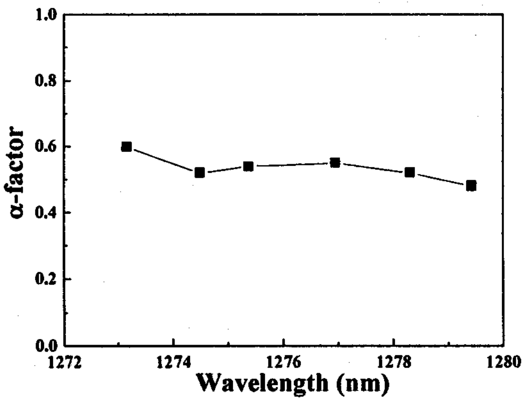

그림 3. The calculated α-factor at different wavelength for InAs/GaAs QD ridge LD with a 5-μm-wide stripe and a 1-mm-long cavity.

4. Conclusion

For high-power 1.3 mm applications we have experimentally investigated characteristics of InAs/GaAs QD ridge LDs grown by molecular beam epitaxy. For the ridge LDs with a 5-μm-wide stripe and a 1-mm-long cavity, the lasing wavelength of 1284.1 nm, the single-uncoated-facet CW output power as high as 90 mW, the threshold current of 40 mA, the corresponding threshold current density of 800 mA/cm^2 and the external efficiency of 0.31 W/A of the present QD ridge LDs were obtained. And also α-factor was measured to be between 0.4 and 0.6, which were about four times as small values with respect to the quantum well structure. It is possible that this result significantly reduce the filamentation of far-field profiles resulting in better beam quality.

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