Effect of Flat Region between Mesa and Gratings in Ridge-Type Semiconductor Lasers with Transversal Diffraction Gratings

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***Abstract*—This paper reports on effect of flat region between a mesa and gratings on single transverse mode operation of a ridge-type semiconductor laser with transversal diffraction gratings. It is found that the grating regions far from the mesa play key roles in single transverse mode operation.**

Keywords—semiconductor laser, ridge, grating, transverse

I. INTRODUCTION

As pumping sources of erbium doped optical fiber amplifiers (EDFAs) in long-haul optical fiber communication systems, high power 980-nm semiconductor lasers, in which AlGaAs layers are used as cladding layers and guiding layers, have been utilized [1]. To avoid oxidization of AlGaAs layers during etching process, 980-nm semiconductor lasers have ridge structures for confining horizontal transverse modes. To obtain high light output, the mesa width should be larger than 2 □m, leading to oscillation of not only the fundamental horizontal transverse mode but also higher-order horizontal transverse modes. Oscillation of the higher-order horizontal transverse modes causes kinks in their light-output versus current (L-I) curves [2]. Above the kink level light coupling efficiency between 980-nm semiconductor lasers and erbium doped optical fibers (EDFs) becomes lower.

To achieve high light coupling efficiency between 980-nm semiconductor lasers and EDFs, high kink level or kink-free operation is needed for 980-nm semiconductor lasers. To satisfy this requirement in 980-nm ridge-type semiconductor lasers, lossy met-al layers [3], highly resistive regions in both sides of ridge stripe [4], incorporation of a graded V-shape layer [5], optical antiguiding layers [6], [7], separate confinement of carriers and horizontal transverse mode [8], horizontal coupling of horizontal trans-verse modes by a groove in the mesa [9], and transversal diffraction gratings [10], [11] have been demonstrated.

In this paper, ridge-type semiconductor lasers with transversal diffraction gratings are simulated, and it is found that the diffraction gratings far from the mesa play key roles in kink-free operation for the mesa with 8 μm wide.

II. STRUCTURE

Figure 1 shows a schematic cross-sectional view of the facet of the 980-nm ridge-type semiconductor laser with transversal diffraction gratings. There are flat regions between the mesa and the diffraction gratings. The mesa width W is 8 μm, the grating pitch Λ is 428.7 nm, the grating depth d is 400 nm (the coupling constant κ of 69.8 cm-1), and the de-vice width is 120 μm. Both the flat regions and the diffraction gratings are formed symmetrically with respect to the central axis of the mesa. The height of the mesa is 1.55 μm. The cavity length is 1200 μm. Power reflectivity of the front facet and that of the rear facet are 2 and 90%, respectively. Layer parameters are the same as those described in Refs. 6-11.

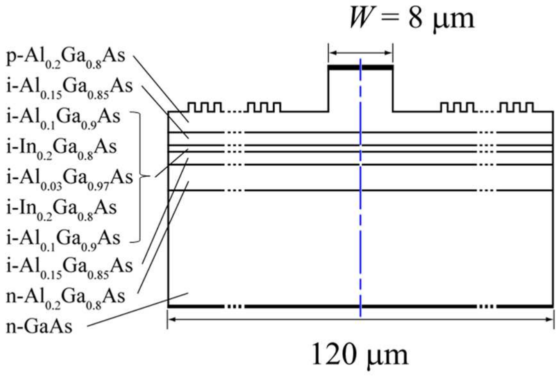


Fig. 1 Schematic cross-sectional view of the facet of the 980-nm ridge-type semiconductor laser with transversal diffraction gratings.

Figure 2 shows the expanded view of the right-hand side of Fig.1 where N is the number of periods of the gratings; N_{flat} is the number of periods of the re-moved gratings. In preliminary simulations with $N_{\mathrm{flat}} = 0$, $N \leq 58$ leads to kink in *L-I* curves; $N \geq 59$ results in kink-free operation. To examine the effect of the flat regions, we remove gratings near the me-sa by maintaining $N_{\mathrm{flat}} + N = 59$, which is the critical value of the kink free operation without removing the gratings.

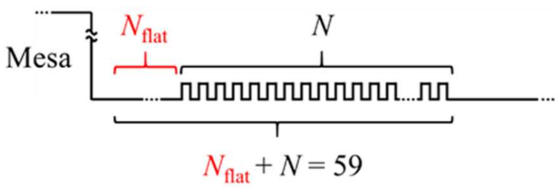


Fig. 2 Expanded View of the right-hand side of Fig.1.

III. SIMULATED RESULTS AND DISCUSSIONS

Figure 3 shows L-I curves when $N_{\mathrm{flat}} + N = 59$ and d=400 nm. The parameter is the number of periods of the removed gratings N_{flat}. When $N_{\mathrm{flat}} \leq 41$ kink-free operation is obtained when $N_{\mathrm{flat}} \geq 42$ kinks appear in *L-I* curves.

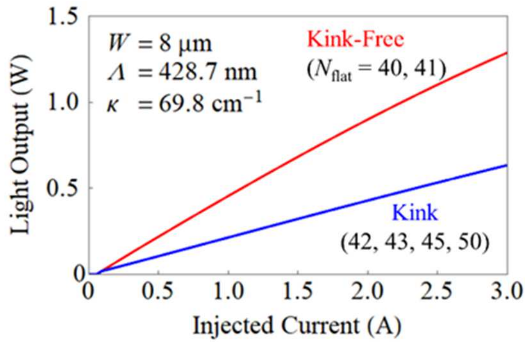
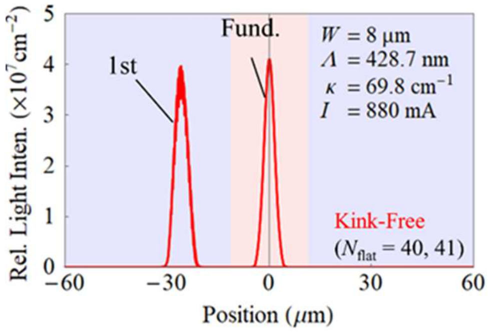
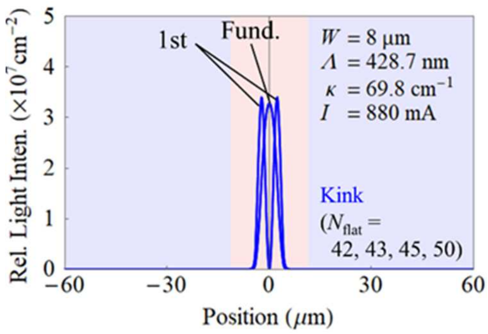


Fig.3 Light output versus injected current when $N_{flat}+N=59$ and $d=400$ nm. The parameter is the number of periods of the removed gratings N_{flat}.

Figure 4 shows near field patterns for (a) kink-free operation and (b) kink in L-I curves. The red regions are gain regions; the blue regions are loss regions. When only the fundamental mode exists in the gain region and the first-order mode exists in the loss region as shown in Fig.4 (a), kink-free operation is obtained. The full width at half maximum (FWHM) of the fundamental mode is 3.6 µm. The coupling loss between the semiconductor laser and an EDF is 5.2 dB. When both the fundamental mode and the first-order mode exist in the gain region as shown in Fig.4 (b), kinks appear in L-I curves. The FWHM of the fundamental mode is 4.8 µm.



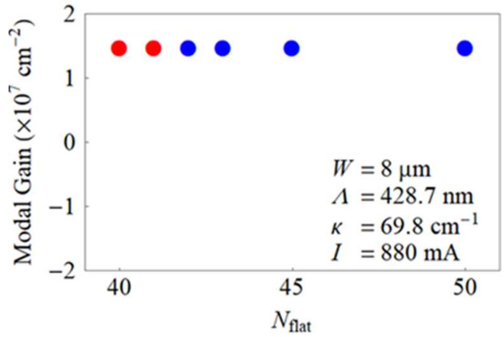
(a)



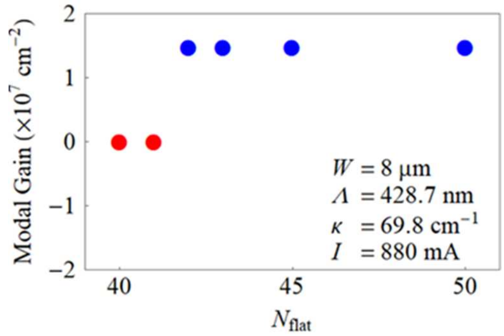
(b)

Fig.4 Near field patterns for (a) kink-free operation and (b) kink in L-I curves. The parameter is the number of periods of the removed gratings N_{flat}.

Figure 5 shows modal gains as a function of the number of periods of the removed gratings N_{flat} for (a) the fundamental mode and (b) the first-order mode. Here, the square of the laser electric field which was integrated over the area is normalized. The modal gain for the fundamental mode is almost independent of N_{flat}; the modal gain for the first-order mode is much lower than that for the oscillating mode when $N_{flat} \leq 41$, resulting in kink-free operation.



(a)



(b)

Fig.5 Modal gains as a function of the number of periods of the removed gratings N_{flat} for (a) the fundamental mode and (b) the first-order mode.

IV. Conclusions

It is found that the grating regions far from the mesa play key roles in single transverse mode operation. In other words, we do not have to fabricate the gratings in the vicinity of the mesa in order to achieve single transverse mode operation.

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