Simulation of a Ridge-Type Semiconductor Laser with Transversal Diffraction Gratings

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***Abstract*- This paper reports on improvement of stability of the fundamental horizontal transverse mode in a ridge-type semiconductor laser by incorporating transversal diffraction gratings. Kinks do not appear in current versus light-output curves by appropriately designing the number of the grating periods when the mesa width is 5 μm.**

I. INTRODUCTION

Due to COVID-19 people are obliged to work from home and join online meetings. As a result, capacity of telecommunications has been running short. To overcome this problem, capacity and E/O conversion efficiency of trunk lines of telecommunications has to be improved.

As trunk lines, long-span optical fibers with erbium doped optical fiber amplifiers (EDFAs) have been used. To pump EDFAs, we have utilized high power 980-nm semiconductor lasers [1]. In general, they have ridge structures to confine horizontal transverse modes because their cladding and guiding layers are AlGaAs layers, which are oxidized easily during etching process. The oxidized AlGaAs layers degrade electrical and optical characteristics highly. To avoid these problems, ridge structures are adopted.

In the ridge structures, higher-order horizontal transverse modes as well as the fundamental horizontal transverse mode are confined. Therefore, with an increase in injected current, higher-order horizontal transverse modes lase; kinks appear in their current versus light-output (*I-L*) curves [2]. Below the kink level — the light output where a kink appears — only the fundamental horizontal transverse mode oscillates; above the kink level a higher order horizontal transverse mode oscillates. The higher-order horizontal transverse modes have much lower light coupling efficiency to the single mode fiber than the fundamental horizontal transverse mode, which leads to low E/O conversion efficiency.

To achieve high light coupling efficiency to the single mode fiber, high kink level or kink-free operation is needed. To increase the kink level in ridge-type structures, lossy metal 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], and horizontal coupling of horizontal transverse modes by a groove in the mesa [9] have been studied.

In this paper, a ridge-type semiconductor laser with transversal diffraction gratings is proposed to obtain kink-free operation. From simulations, it is found that kink-free operation is obtained by appropriately designing the number of the grating periods.

II. OPERATING PRINCIPLE AND STRUCTURE

Figure 1 shows a schematic cross-sectional view of the facet of the proposed ridge structure with transversal diffraction gratings. By utilizing the difference between the spatial distribution of the fundamental horizontal transverse mode and those of higher order horizontal transverse modes generated by the diffraction gratings, only the fundamental horizontal transverse mode is confined in the gain region; the higher order horizontal transverse mode is located in the loss region. In Fig.1, W is the mesa width, S is the space between the mesa and the diffraction gratings, Λ is the grating pitch, and d is the grating depth. The height of the mesa is 1.55 μm and width of the base is 60 μm. The cavity length is 1200 μm. Power reflectivities of the front and rear facets are 2 and 90%, respectively.

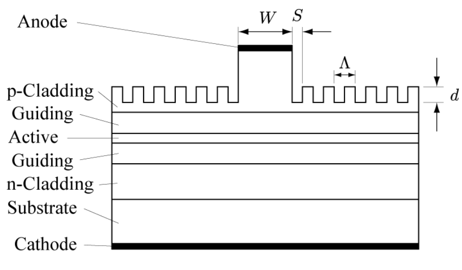

Fig. 1 Schematic cross-sectional view of the facet of the proposed ridge structure with transversal diffraction gratings.

Layer parameters are the same as those described in Refs. 6-9. Lasing characteristics are simulated by using a device simulation software ATLAS (Silvaco) in which Poisson's equations and Helmholtz equation are solved with a finite element method.

III. SIMULATED RESULTS AND DISCUSSIONS

Figure 2 shows injected current versus light output (*I-L*) curves when *W*=5.0 μm, *S*=426 nm, Λ=428.7 nm, and *d*=400 nm. The parameter is the number of the grating periods *N* at one side of the mesa. When *N*=20, a kink appears in *I-L* curve with oscillation of the first-order horizontal transverse mode. When *N*≥25, kinks do not exist in *I-L* curves and only the fundamental horizontal transverse mode oscillates up to the injected current of 3 A.

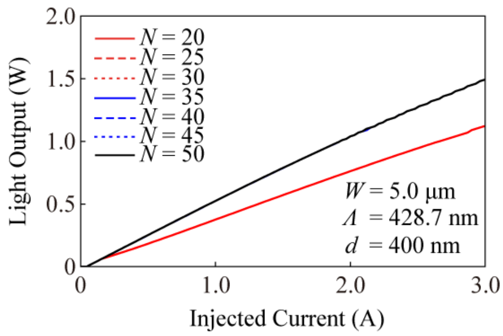

Fig.2 Injected current versus light output curves when *W*=5.0 μm, *S*=426 nm, Λ=428.7 nm, and *d*=400 nm. The parameter is the number of the grating periods *N*.

Figure 3 shows the threshold current I_{th} for the fundamental horizontal transverse mode as a function of the grating periods *N*. The threshold current has the lowest value at *N*=40 where overlapping of the optical field and the optical gain is the largest.

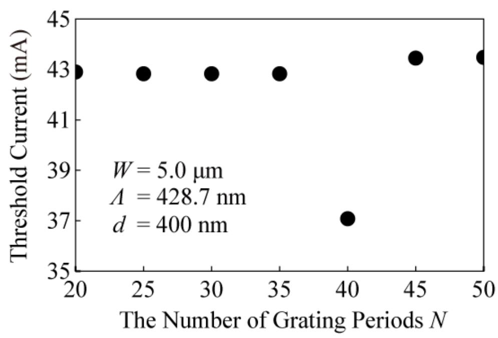

Fig.3 Threshold current I_{th} for the fundamental horizontal transverse mode as a function of the number of the grating periods *N* at one side of the mesa.

Figure 4 shows the near field patterns (NFPs) for the fundamental horizontal transverse mode when the injected current *I* is 1 A where kink appears when *N*=20; kink does not exist when *N*≥ 25. The NFPs almost overlapped with FWHM=3.0 μm, irrespective of existence or non-existence of kink.

Figure 5 shows the NFPs for the first-order horizontal transverse mode when *I* =1 A. When *N*=20 the NFP for the first-order horizontal transverse mode exists in the gain region; when *N*= 25 the NFP exists in the loss region, leading to kink-free.

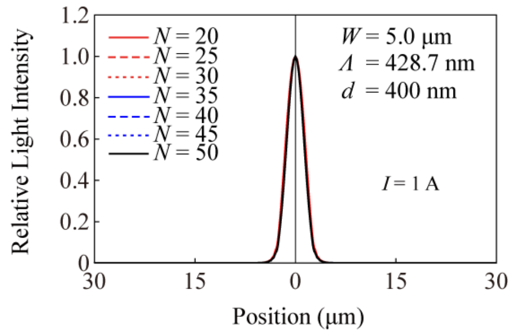

Fig.4 Near field patterns for the fundamental horizontal transverse mode.

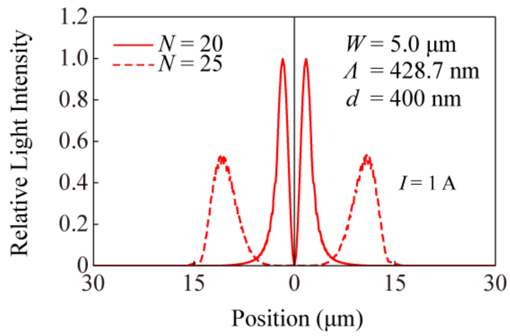

Fig.5 Near field patterns for the first-order horizontal transverse mode.

IV. CONCLUSIONS

To improve kink levels, a ridge-type semiconductor lasers with transversal diffraction gratings was proposed and simulated. It is found that kinks do not appear by designing the number of the grating periods appropriately when the mesa width is 5 μm.

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