P2-6

Ti:Er:LiNbO3 Laser with Ridge Structure Pumped at 980 and 1477 nm

Ju-Feng Liu, Yih-Bin Lin, Way-Seen Wang*, *Member, IEEE*

Department of Electrical Engineering andGraduate Institute of Electro-optical Engineering

National Taiwan University N0.1Sec.4 Rossevelt Road,Taipei 10617, Taiwan, ROC

8862-2-2-2363-5251~423 Fax: +886-2-2362-1950 Email: wswang@cc.ee.ntu.edu.tw

Abstract

The effective pump area and coupling efficiency as functions of ridge structure in coaxially pumped Ti-diffused $Er:LiNbO_3$ waveguide lasers pumped at wavelengths 980 and 1477 nm are theoretically studied.

1. Introduction

Ridge structure has been successfully used to lower the threshold pump power of coaxially-pumped Ti-diffused Er-doped lithium niobate ($Ti:Er:LiNbO_3$) lasers pumped at wavelength 1477 nm [1]. However, another important optical pumping source wavelength 980 nm in $Ti:Er:LiNbO_3$ lasers with ridge structure has not been discussed yet. In order to evaluate the effect of the pumping wavelength, we theoretically study the effective pump area and coupling efficiency as functions of ridge structure in a coaxially pumped Ti-diffused $Er:LiNbO_3$ waveguide laser at pumping wavelengths 980 and 1477 nm. The results show the effective pump area at 980 nm is also reduced by the ridge structure, and is always smaller than at 1477 nm under the same conditions. Whereas, the scaling of reduction of the pump effective area at 980 nm is smaller than that at 1477 nm by comparing a typical waveguide. Moreover, the coupling efficiency at 980 nm as well as 1477 nm is found not significantly changed by the ridge structure.

2. Numerical results and Discussions

In this simulation, a c-cut $LiNbO_3$ substrate is used for its higher erbium diffusivity. The erbium concentration profile is assumed to be a Guassian profile with a surface concentration of 1.35×10^{20} cm^{-3} and a $1/e$-depth of 6 μm [2]. The laser cavity configuration is assumed as that reported by Brinkmann *et al.* [3]. The TM mode is taken to provide the strongest electro-optical effect. The

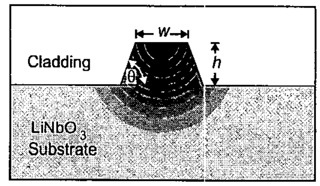

Fig. 1 Typical Ti-diffused lithium niobate ridge waveguide of ridge width w and height h.

initial Ti strip is diffused at a rate of 12 nm/h and at a temperature of 1050 °C, and the initial Ti strip width W is 7 μm. A ridge structure of width w and height h is incorporated with the waveguide laser and the refractive index profile is shown in Fig. 1, where contours represent the refractive index distribution of waveguide in a $LiNbO_3$ substrate and the sidewall tilt θ is assumed to be 70° [4]. The refractive-index profile of a Ti-diffused channel waveguide is chosen as that expressed by Zhang *et al.* [5] and all the cladding indices are assumed to be unity. The wavelength of the signal beam is 1530 nm and the wavelengths of pump beam are 980 and 1477nm. The effective pump area and the coupling efficiency η_c are defined as [5]

$$A_{eff} = \left[l \int_{cavity} s_0(x,y,z) r_0(x,y,z)\,dxdydz\right]^{-1} \quad (1)$$

$$\eta_c = \frac{\left[\int_{cavity} s_0(x,y,z) r_0(x,y,z)\,dxdydz\right]^2}{\int_{cavity} s_0^2(x,y,z) r_0(x,y,z)\,dxdydz} \quad (2)$$

Where s_0 is the normalized single mode intensity distribution and r_0 is the normalized pump mode rate intensity distribution. Following the process we proposed in [1], the calculations are done with the initial Ti strip thickness τ of 150 nm for a lower threshold pump power and a τ of 100 nm, a typical process, for comparsion. Fig.2 shows the

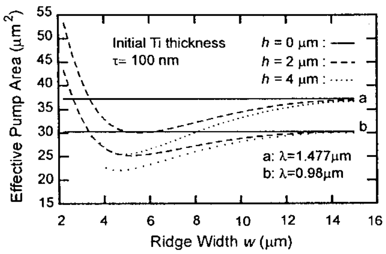

Fig. 2 Comparison of effective pump area versus ridge width with ridge height and pumping wavelength as parameters where τ = 100 nm.

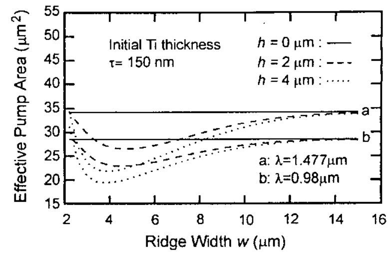

Fig. 3 Comparison of effective pump area versus ridge width with ridge height and pumping wavelength as parameters where τ = 150 nm.

variations of the effective pump area versus the ridge width with τ = 100 nm and h = 0, 2, and 4μm. Where the effective pump areas of typical channel waveguides (h=0) are used as references. It is observed that the effective pump areas at 980 nm are advantageously reduced by the ridge structure as done at 1477 nm, and always smaller than those at 1477 nm. A larger ridge height makes more improvement. At both pumping wavelengths, the optimal ridge widths are almost same within the range of 4-6μm. That means the optimal ridge size is almost independent of the pumping wavelength. Fig.3 shows the variations of the effective pump area versus the ridge width with τ = 150 nm and h = 0, 2, and 4μm. The results are similar to those shown in Fig. 2, however, the effective pump areas are more reduced for a thicker Ti strip and the optimal ridge width is smaller as the Ti strip is thicker. The scaling of reduction of the effective pump area at 980 nm is calculated to be about 30%, by comparing a typical waveguide with τ = 100 nm to a ridge waveguide with τ = 150 nm, w = 4 μm, and h = 4 μm. However, it is smaller than 40% at 1477 nm. The variations of the coupling efficiencies versus the ridge width for h = 0, 2, and 4μm and τ = 150 nm at both wavelengths are depicted in Fig.4. Here, the coupling efficiencies of a typical channel waveguide (h=0) are also used as references. It is observed that the coupling efficiencies at 1477 nm are also improved by the ridge structure, whereas those at 980 nm are decreased as the ridge is smaller. Nevertheless, the changes on coupling efficiencies are not as evident as those on the effective pump areas.

3. Conclusion

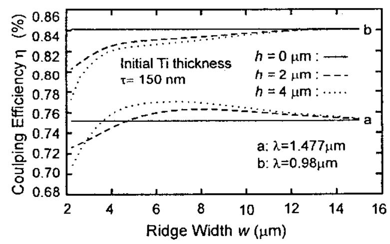

Fig. 4 Comparison of coupling efficiency versus ridge width with ridge height and pumping wavelength as parameters.

In this paper, numerical results show that the ridge structure can be used to lower the effective pump area of a waveguide laser at 980 nm as well as 1477 nm. And for diffused waveguides, the optimal ridge width at 980 nm are almost same as that at 1477 nm and within the range of 4-6μm. However, the scaling of reduction of the pump effective area at 980 nm is smaller than at 1477 nm.

References

[1]J. F. Liu, Y. H. Wang, S. J. Chang, and W. S. Wang, *IEEE Photon. Technol. lett.*, vol. 12, no.9, pp. 1204-1206, 2000.

[2]I. Baumann, R. Brinkmann, M Dinand, W. Sohler, and S. Westenhöfer, *IEEE J. Quantum Electron.*, vol. 32, no. 9, pp.1695-1706, 1996.

[3]R. Brinkmann, W. Sohler, and H. Suche, *Electron. Lett.*, vol. 27, no. 5, pp.415-417, 1991.

[4] K. Noguchi, O. Mitomi, H. Miyazawa, and S. Seki, *IEEE J. Lightwave Technol.*, vol. 13, no. 6, pp. 1164-1168, 1995.

[5] D. Zhang, C. Chen, J. Li, G. Ding, X. Chen, and Y. Cui, *IEEE J. Quantum Electron.*, vol. 32, no.10, pp. 1833-1838, 1996.