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Modes Selection in a Semiconductor Circular Ring Laser Diode by Perturbation at the Active Soliton Cavity

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Abstract

We report the study of modes selection in a semiconductor laser diode by perturbation at the active soliton wave guiding cavity. It was found that one of the resonator modes in the circular ring cavity can be effectively eliminated by perturbing at the soliton wave guiding using an excimer laser direct writing. Measurements of light-current (L-I) characteristics and spectral analysis were used to explore the mechanism of output modes interaction in response to the variation of optical property along each part of the ring resonator.

1. Introduction

It is a trend of photonics researches to provide a solution of integrating active components of light source with passive components such as waveguides and detectors to meet the requirements for high bit rate signal communication and data processing on a chip. Semiconductor circular ring laser diode (SCRLD) had been attracted researches for its novel device structure that not only providing possibility of opto-electronic devices integration but also inspiring exotic functions of photonics. We have devoted to the study of SCRLD through a long learning process for decade, and experimental results about the SCRL output characteristics had been reported [1-2]. In principle, there are two modes; the clockwise (CW) propagation mode and the counter clockwise (CCW) propagation mode existed in the circular ring resonator, and these two modes are dynamically competing with each other [3]. In addition, the circular ring resonator plays an important role to the excitation of the soliton due to nonlinear change in the refractive index of the laser substrate [4-6]. The soliton wave guiding can perturb the light coupling ration at the Y-junction coupler. Here we report the experimental results of the output modes characteristics of a SCRLD with two symmetric Y-junction couplers by intentionally perturbing the soliton wave guiding section using an excimer laser direction writing system.

2. SCRLD Device Fabrication

The SCRLD was fabricated on a metal organic chemical vapor deposition (MOCVD)-grown InGaAlP multiple-quantum-well structure as previously reported. Fig. 1 shows the schematic of the fabricated SCRLD device, which is consisted with a ridge waveguide circular ring resonator with diameters (D) of 100 μm, 200 μm, and 300 μm and two Y-junction output coupling section. At the beginning of the device process, a SiO_2 thin film of 200 nm was deposited by chemical vapor deposition (CVD) as an etching resisted layer, then pattern of the SCRL device was generated by photo-lithography followed by reactive ion etcher (RIE) to etch off the SiO_2 layer. After the formation of the SCRLD pattern of the SiO_2 layer, an inductive collide plasma etching (ICP) was used to etch out the ridge waveguide structure of width (D) 8 μm and with depth (h) of 0.9 μm. Then a film of SiN_x passivation pattern was formed by lift-off process. An Au (200 nm)/Cr (10 nm) layer was deposited by e-beam-deposition followed by annealing at 650 ^{0}C for ohmic contact formation. The substrate was grinded to minimize the resistance and coated with an AuGe/Ni film for metal contact. The fabricated devices were mirror scribed by a diamond scriber.

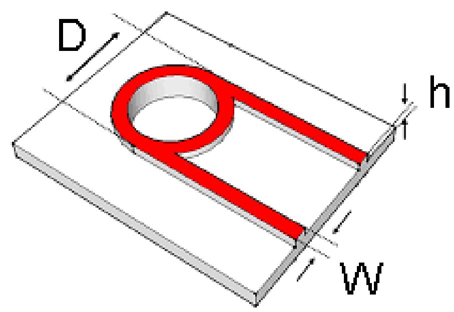

Figure 1, Dimension of the fabricated SCRLD with a circular ring resonator and two Y-junction output couplers.

3. Outputs Characteristics

The fabricated device was probe-tested on a microprobe station to measure the current-light (L-I) output characteristics and spectrum. As expected that there are two modes; the CW propagation mode and the CCW propagation mode generated in the circular ring resonator which respectively coupled out through each of the two Y-junction couplers. In addition, the reflection from each Y-junction coupling sections can excited soliton wave on non-waveguide region due to nonlinear change in the refractive index of the laser substrate. The ridge waveguide circular ring, the Y-junction coupling section,and the non-wave soliton wave guiding formed a complex resonator which their optical parameters response to current injection separately. Fig. 2 shows the L-I characteristics of the output modes from Y-junction coupler terminals and from soliton wave guiding terminals of a fabricated SCRLD with a ring resonator diameter of

200 μm. It shows that the lasing threshold in the L-I curve from the Y-junction coupling terminals and from the soliton wave guiding terminals both are close to the same.

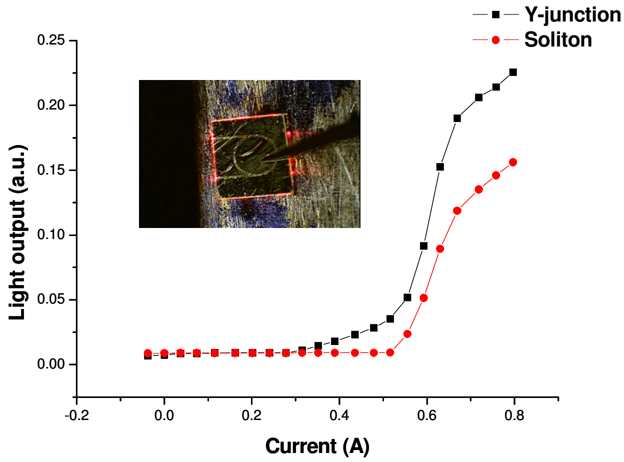

Figure 2, The L-I characteristics of the emission from the Y-junction coupling terminal and from the soliton wave guiding terminals of a fabricated SCLD with diameters of 200 μm.

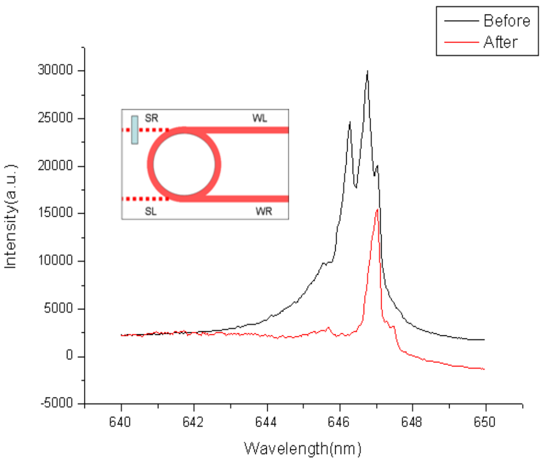

Fig. 3, Outputs spectrums measured at Y-junction waveguide terminals (marked as WL, and WR) before and after perturbed by the excimer laser direct writing.

In order to study the effect of the soliton wave guiding to the output modes of the SCRLD, a small region on the soliton wave guiding (SR) was intentionally perturbed by an excimer laser direct writing with a power around 1 mJ which degrade only limited to the wave guiding layer and would not deteriorate the electrical property of the diode structure. Fig. 3 and Fig, 4 show the outputs spectrums of a fabricated SCRLD with diameters of 200 μm measured at Y-junction wave guiding terminals (marked as WL, and WR) and soliton wave guiding terminals (marked as SL, and SR) before and after perturbed by the excimer laser direct writing. Before perturbing, there are two peaks of wavelength separation within 1 nm in the output spectrum from the Y-junction coupling terminals (WR, WL) and from the soliton wave guiding terminals as well which correspond to the CW mode and CCW mode in the circular ring resonator. However, one of the lasing modes, CW mode in this case was eliminated while the soliton wave guiding being perturbed.

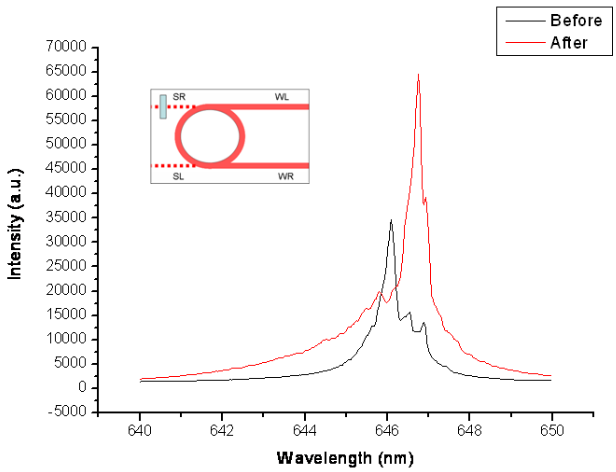

Fig. 4, Outputs spectrums measured at soliton wave guiding terminals (marked as SL, and SR) before and after perturbed by the excimer laser direct writing.

4. Conclusions

It shows that the soliton wave guiding play an important role not only to the threshold of the lasing mode but to the modes switching of CW and CCW modes in the circular ring resonator. Either one of the CW mode or CCW mode in the circular ring resonator is possible to be selectively switched up just by perturbing the other soliton wave guiding related to the other ring laser mode. Investigation of the detailed modes switching mechanism in the SCRLD is under going and some more experimental results will be explored to demonstrate new functions of this novel device.

Acknowledgements

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References

[1] J. P. Hohimer, G. A. Vawter, and D. C. Craft, 1993 American Institute of Physics, Appl. Phys. Lett. 62(11), 15 March 1993.

[2] M. C. Shih, M. H. Hu, M.B. Freiler, M. Levy, R. Scarmozzino, R. M. Osgood, Jr., I. W. Tao, and W. I. Wang, American Institute of Physics, Appl. Phys. Lett 66(20), 15 May 1995.

[3]M. C. Shih, C. S. Chen, Jpn. J. Appl. Phys. 50, 04DG17-1(2011).

[4] C. R. Doerr, C. H. Joyner, L. W. Stulz, and J. Gripp, IEEE Photon. Tech. Lett. 10, 1374 (1998).

[5] M. Sorel and P. J. R. Laybourn**,** OPTICS LETTERS / Vol. 27, No. 22 / November 15, 2002.

[6]M. C. Shih, C. L. Yen, Jpn. J. Appl. Phys. 53, 04EG06-1(2014).