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Modes Switching in a Semiconductor Circular Ring Laser Diode due to the Generation of Solitons Wave Guiding

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Abstract

We demonstrated output switching of the semiconductor circular ring laser diode (SCRLD) between two Y-junction couplers. The generation of solitons guiding wave can affect coupling between ring resonator and the Y-junction coupler. Measurements of Light-current (L-I) and spectral analysis are used to explore the mechanism of output modes switching in the SCRLD device.

1. Introduction

Semiconductor circular ring laser diodes (SCRLD) had been attracted researches for its novel functions in providing device integration and creation new functional properties of photonics [1-4]. In principle, there are two propagation modes in the ring resonator; one is the clock wise (CW) propagation direction, the other is the counter clock wise (CCW) propagation direction, and these two modes are dynamically competing each other [5]. There were reports of different output characteristics with respect to various coupling structures [6]. We have reported previously that the existence of solitons wave guiding in a circular ring laser diode with a Y-junction output coupler due to nonlinear change in the refractive index of the laser substrate.

Here we present the phenomena of output modes switching in a SCRLD with two Y-junction couplers and the study of the effect of solitons wave guiding to its output characteristics.

2. 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 a schematic of the fabricated device, which is consisted with a ridge waveguide circular ring resonator with diameters of 100 μm, 200 μm, and 300 μm and two Y-junction output coupling section. The width of the ridge waveguide was 8. At the beginning of the device process, a SiO_2 thin film of 200 nm as an etching resisted layer was deposited by chemical vapor deposition (CVD), then pattern of the SCRL device was formed by photo-lithography followed by reactive ion etching (RIE) off the SiO_2 layer. Follow the etching of the SiO_2 layer, an inductive collide plasma etching (ICP) was used to etch out the structure of the ridge waveguide. Two etched depth of 0.9 μm and 1.1 μm of the ridge waveguide were prepared to study the effect of the optical confinement of the ridge waveguide to the output characteristics of the SCRLD. A lift-off process was used to pattern the passivation of the SCRLD using a CVD grown SiN_x film. 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 a thick AuGe/Ni film for p-type metal. The fabricated devices were mirror scribed by a diamond scriber.

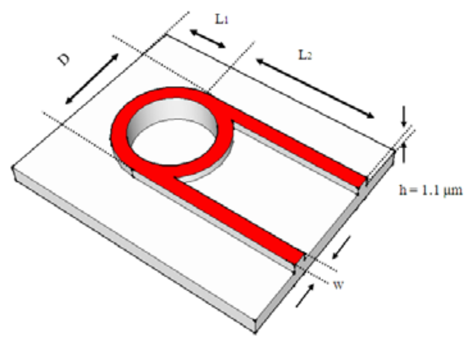

Figure 1, Dimension of the fabricated SCRLD with a circular ring resonator and two Y-junction output couplers.

3. Results and Discussions

The fabricated device was probe-tested on a microprobe station to measure the current-light (L-I) output characteristics and spectrum. An HP 8114A pulse current source operating at 1 kHz was used for current injection on the fabricated SCRLD, and a Si-based photo-detector (EOT 2020) combined with aligned optical collimator and objective lens were used to measure the output power of the test device. A Tektronix TDS 2024 oscilloscope was used to monitor the instance of the injection current and output intensity of the device, which was recorded by a PC with GPIB interface. The spectral measurement system was similar to the L-I characterization system, but the Si photo-detector was replaced by a Jobin Yvon SPEX 500 spectrometer with 0.01 nm spectral resolution.

Fig. 2 shows the L-I characteristics at four output terminals; two Y-junction coupler terminals as referred to CW and CCW coupling of the circular ring resonator modes, and two solitons wave guiding terminals as referred to CCW and CW coupling of the ring resonator modes of the fabricated SCRLD with a ring resonator diameter of 200 μm, and the ridge waveguide of 10 μm in width and 0.9 μm of depth. It shows that laser outputs are drawn to one Y-junction coupling terminal and one solitons wave coupling terminal; ring CW and solitons CCW respectively in the figure. In another word, one of the ring resonator modes; CW mode in this device can be dominantly coupled out through the Y-junction couplers for CW mode in circular ring resonator. Fig. 4 shows spectrum characteristics respect to these four output terminals. It shows strong single mode spectrum at 656.19 nm of the ring resonator at Y-junction of CW mode coupling terminal, and at solitons wave guiding terminal of CCW mode. However, output spectrum at the other two terminals show similar spectrum of a weak peak of same lasing mode of the ring resonator combined with a broad spontaneous emission background. There were experiments of the same SCRLD structure except the depth of the ridge waveguide was deeper as 1.1 μm , which believed to have better optical confinement. But there was no solitons wave guiding excited, and the output of the ring resonator was equally distributed only at two Y-junction coupler terminals.

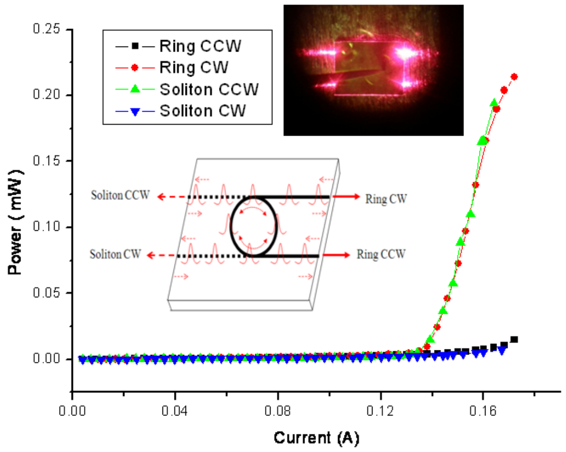

Figure 2, The L-I characteristics of the SCRLD at four output terminals of the SCRLD with a ring resonator diameter of 200 μm , and the ridge waveguide of 10 μm in width and 0.9 μm of depth.

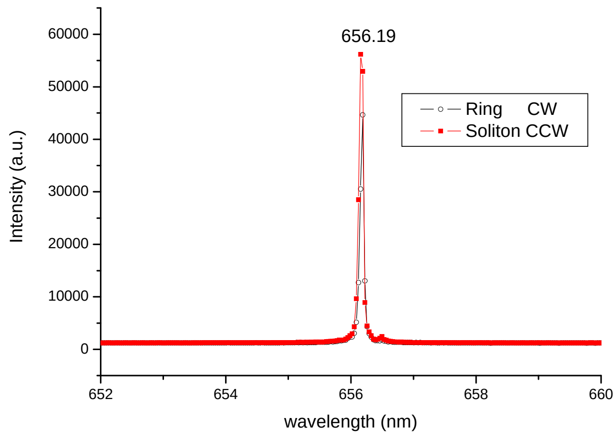

Fig. 3, Outputs spectrums with wavelength shifting of the ring laser diode operated at 200 mA.

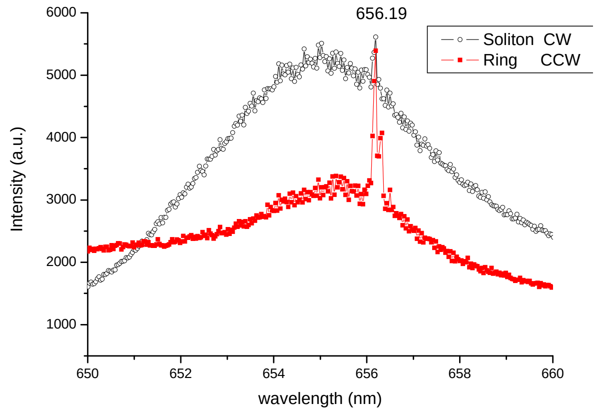

Fig. 4, Two outputs spectrums with wavelength shifting of the ring laser diode operated at 200 mA.

4. Conclusions

We have demonstrated switching of the output mode between two Y-junction coupler of the SCRLD due to the generation of solitons wave guiding. We also found that not only CW mode, but CCW mode was possible to become dominated output mode for some few SCRLD devices using different process parameters. It is worth to conduct further investigation of the detailed coupling mechanism between the solitons wave guide and the circular ring resonator to achieve a systemic control of the output mode of SCRLD to fulfill new function of this novel device.

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