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The Fabrication of a multiple Outputs Semiconductor Ring Laser Diode and its Output Characteristics

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1. Introduction

A semiconductor laser diode with a circular ring waveguide cavity had been shown attractive properties of output[1-6]. Since circular laser diode does not need cleaved facets for mirrors, it can be more flexible to achieve system integration with other passive components monolithically to accomplish the goal of opto-electronic integrated circuits on a chip. In addition, a ring laser diode can achieve high side modes suppression due to its long traveling length around the ring cavity. It is suggested that multiple outputs can be achieve in this circular ring laser diode for the multiple channels of light sources in optical fiber communication. In this paper, we will present the fabrication of a semiconductor ring laser diode with two ridge-waveguide Y-junction output couplers ant its output characteristics.

2. Device processing

The lasers were fabricated with an MOCVD grown InGaAlP multiple quantum wells laser structure as shown in figure 1. Figure 2 shows the dimension of the ring laser diode with a circular ring cavity of 100 μm and two Y-junction output couplers of 500 μm in length.

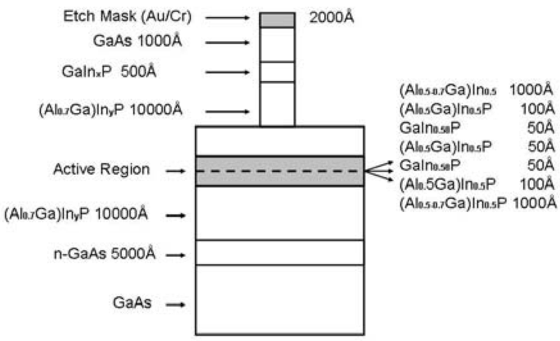

Figure 1, Detailed structure of the MOCVD grown InGaAlP circular ring laser device.

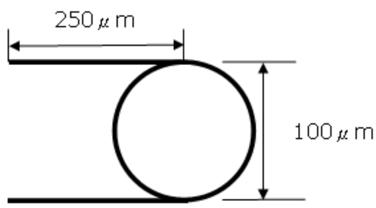

Figure 2, Dimension of the fabricated circular ring resonator laser diode with two Y-junction output coupling section, the diameter of the circular ring resonator is one is 100 μm and the output coupling section is 250, the width of the ridge waveguide is 10 μm .

For the process of the ring laser diode, a device pattern of was developed by using a negative photoresist (AZ-nLOF2020) lithography followed by deposition of a Cr/Au layer by e-beam evaporation for the purpose of etching resisted.

The etching process for defining the circular ridge-waveguide structure is crucial to the optical property of the device due to the uniformity of the etched side-walls. Reactive ion etching has been shown to give highly anisotropic etched sidewalls; however, etch damage incurred in this etching has been conjectured to lead to increased optical loss on the etched surface. we have developed a Excimer laser assisted cryoetching technique to achieve anisotropic of the circular ridge waveguide without damage to the etched side wall and maintain optical properties of the ridge waveguide circular ring resonator.[9,10] Uniformly etched ridge waveguide circular ring resonator and the Y-junction coupling section of precisely controlled depth of 900 nm were achieved by this excimer laser etching process operating at 140 K, 10 mTorr of chlorine, and 150 mJ/cm^2 of 193nm ArF excimer laser operated at 10Hz repetition rate. A etching depth of 800 nm was achieved by A 0.2 μm spin on glass (SOG) (ACCUGLASS 314) dielectric layer for passivation was then spin coated and followed by a curing procedure (soft bake at 150 ^{o}C for 5 min, then hard bake at 300 ^{o}C for 60 min) process. The device was grinded down to 150 μm to reduce the resistivity of the substrate. A P-type metallization was formed by rapid thermal annealing of an Au/Ge thin film deposited by e-beam evaporation. A thick Au metal layer of 400 nm was then deposited uniformly by e-beam evaporation on top of the laser device for electrode.

3. Characterizations

The fabricated laser diode device was cut by diamond scribing and probe-tested at room temperature under pulse current injection of 2 kHz as shown in figure 3. We had characterized two outputs of the ring laser diode, one for the clockwise output coupling and another for the counter clockwise output coupling. Spectrum of each output terminals were measured by a spectrum analyzing system (Jobin Yvon SPEX 500) with 0.01 nm resolution. Figure 4 shows spectrum characteristics for two output terminal both of which are multimode with a peak wavelength at 651.54 nm and another one at 651.40 nm. Figure 5 shows the light-injection current (L-I) characteristics of each output terminal and shows similar L-I output characteristics for both output terminals.

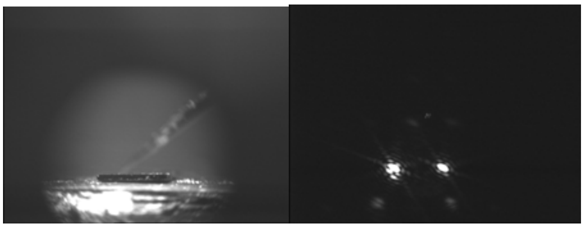

Figure 3, The probe tested device without current injection(left), and the emission of the laser device from two Y-junction coupling section under current injection.

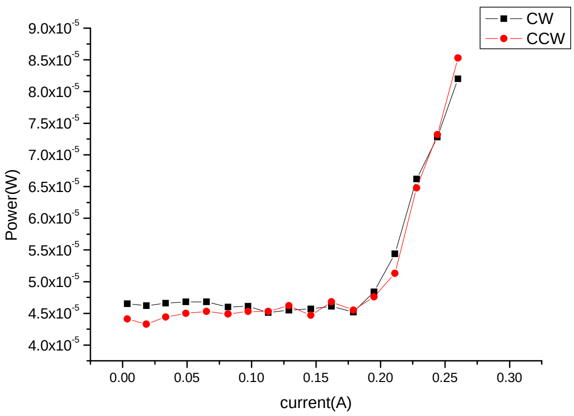

Figure 5, The L-I measurement of the double circular ring laser at constant current injection mode.

We had also observed the far field pattern of the laser diode, and found that no interference pattern in the overlap region that revealed no coherence between these two outputs light.

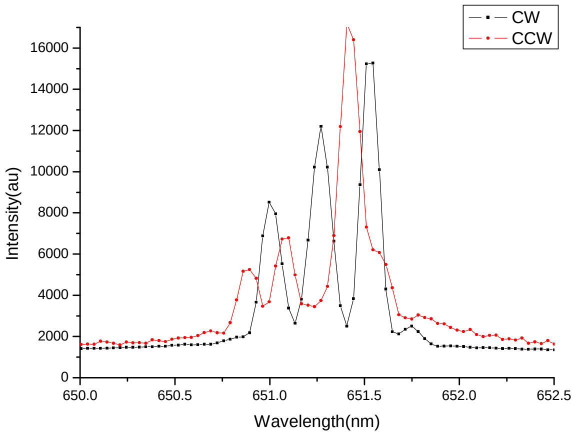

Figure 4, Two outputs spectrums with wavelength shifting of the ring laser diode operated at 200 mA.

4. Conclusions

We have demonstrated the fabrication of a circular ring laser with two Y-junction output coupling section and its output characteristics. Both CW and CCW coupling output has almost the same L-I characteristics, but there is a wavelength shift between these two output modes. It is interested to find that no coherent relation between CW and CCW output emission. Detailed exploration of the output efficiency and wavelength selection in term of diameter of the circular ring cavity will be present in the near future.

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