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Superluminescent Emission of a Novel Semiconductor Diode with Double Ring Cavities and a Y-junction Coupler

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1. Introduction

Semiconductor laser diodes with the circular ring cavity had been shown attractive properties of its output characteristics[1-4]. A circular ring cavity can achieve optical resonant without mirrors, and various coupling structures or mechanisms can be applied in system integration with other passive components monolithically for the single chip opto-electronic integrated circuit (OEIC) device. Light source of superluminescent diode (SLD) is attractive by its unique property of laser-diode-like output power and brightness with broad LED-like optical spectrum in applications of laser gyroscope and high spatial resolution tomography. As previous reported that spatial solitons wave guiding can be excited by the nonlinear change in the refractive index of the MQW structure due to the photovoltaic screen charge field and electro-optic effect.[5-6]. It suggests that the soliton waveguide can provide an optical confinement of low feedback. Here we demonstrate superluminescent emission in a novel semiconductor diode structure with a soilton waveguide generated by two circular ring cavities.

2. Device processing

The ridge waveguide structure of the diode was etched out by inductive colliding plasma (ICP) on an MOCVD grown InGaAlP multiple quantum wells (MQW) substrate as shown in Fig.1. Figure 2 shows the dimension of the diode of two circular ring cavities at right intersection one of R1=300 μm in diameter and another of R2=100 μm in diameter, and a Y-junction output coupling section of D1=600 μm in length.

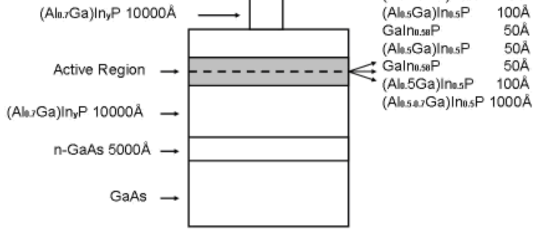

Fig. 1, Material structure of the fabricated MOCVD grown waveguide.

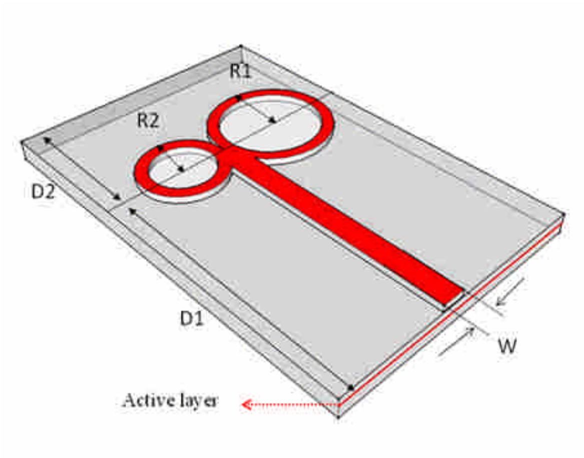

Fig. 2, Dimension of the fabricated diode with two right intersected circular ring cavities (R1=300 μm, R2=100 μm), and a Y-junction output coupling section(D1=600 μm), and the width of the ridge waveguide is W=20 μm.

For the process of the device, first a layer of SiO_2 was deposited by Plasma Enhanced chemical vapor deposition (PECVD), the device pattern was then developed by lithography followed by reactive ion etching (RIE) solution. The etching for defining the circular ridge-waveguide is crucial to the optical property of the waveguide due to the uniformity of the etched side-walls. Inductive coupling plasma (ICP) etching was used to achieve anisotropic of the circular ridge waveguide. Uniform ridge waveguide of the circular ring resonator and the Y-junction coupling section was achieved. The depth of the waveguide was around 800 nm to 900 nm where above the active layer of the multiple quantum wells. The etching resisted pattern of SiO_2 was removed by BOE wet etching.

A passivation layer of SiNx was deposited by PECVD, then electric contact pattern was aligned and developed by lithography followed by lift off to open the window for current injection.

The thickness of the substrate was grinded down to 150 μm to reduce resistance in current injection, and an N-type metallization layer of Cr/Au and a P-type metallization layer were deposited separately by e-beam evaporation then followed by rapid thermal annealing at 450 C for 1 minute to form good electric contact.

3. Characterizations

The fabricated device was cleaved by diamond scribing and probe-tested on a micro-probing stage at room temperature by a pulse current source at 2 kHz as shown in Fig.3. We had studied output emission at both terminals of the device, one from the Y-junction coupling terminal, and another one from the soliton guiding terminal[6]. Spectrum of each output terminal was measured by a spectrum analyzing system (Jobin Yvon SPEX 500) with 0.01 nm resolution. Fig. 4 shows superluminescent emission characteristics at injection current around 280 mA to 370 mA. The band width (FWHM) of the superluminscent emission is about 3 nm with a center wavelength at 657 nm operated at 370 mA. At injection current above the threshold at 390 mA, lasing modes start dominating. It also showed a lasing peak at 657.2 nm.

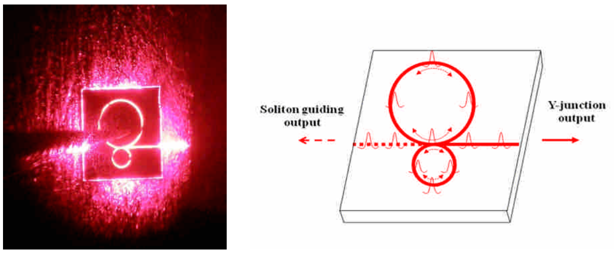

Fig. 3, The probe testing device by current injection(left), and schematic of the emission of the soliton.

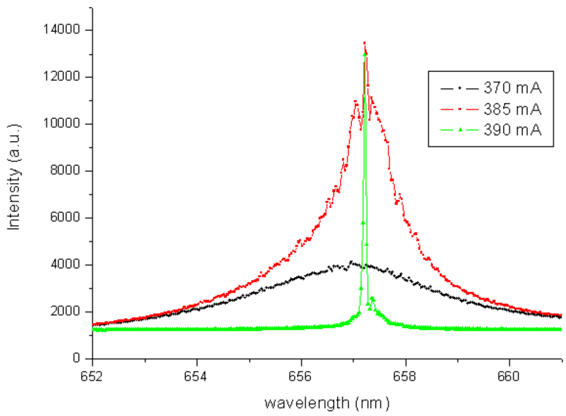

Figure 4, Emission spectrums at the soliton guiding terminal under various current injection at superluminescent emission mode and lasing mode.

Fig. 5 shows the light-current (L-I) characteristics of the device at both terminals of the Y-junction waveguide terminal and the soliton guiding. It shows that output emission power at both terminals increasing monotonically with injection current and super-luminescent emission can be achieved with injection current range from 280 mA to 370 mA. At injection current above the threshold current at 390 mA, feedback from the soliton guided terminal increasing until resonant is reached, and lasing dominated.

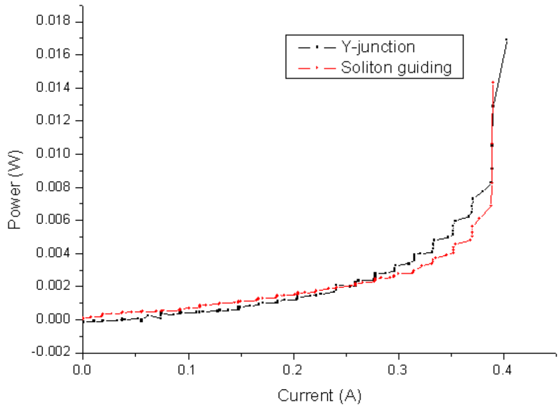

Figure 5, The L-I characteristics at Y-junction and at soliton guiding terminal.

4. Conclusions

We have demonstrated the generation of super-luminescent emission in a novel InGaAlP multiple MQW diode structure with double ring cavities and a Y-junction output coupler. The spatial solitons wave guide cavity excited by emission from the ring cavity due to nonlinear change in the refractive index of the MQW structure provides an optical cavity with low feedback. In addition, the double rings cavities provide high gain of emission and controlling the feedback from the soliton guided cavity to reversibly achieve super-luminescent mode or lasing mode output operation on the same device.

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