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Output Characteristics of a Double Circular Ring Resonators Laser Diode Through Slioton Wave Guiding

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Abstract

We present the study of the output characteristics of an InGaAlP multiple-quantum-well double ring resonators laser diode through soliton wave guiding. It was found that the output can be coupled out through the formation of soliton wave guiding due to nonlinear change in the refractive index of the laser substrate. It shows that either one of the resonator modes (CW/CCW) in the circular resonator can be effectively coupled out through soliton wave guiding while the other mode is suppressed. Measurements of light-current (L-I) characteristics and spectral analysis are used to explore the output modes coupling due to the formation of soilton wave guiding.

1. Introduction

Semiconductor circular ring laser diode (SCRLD) has been attracted much attention for its single mode emission and output coupling characteristics that are potentially valuable in integration of light source and passive components for advanced optical signal processing. Recently, we have presented the exploration of spatial soliton formation in a SRCLD in which light beam propagation in the circular ring resonator can be switched by soliton wave guiding[1-5]. The properties of soliton wave guiding not only provide possibility of non-waveguide optical interconnection for advanced opto-electronic devices integration but also inspiring inventive functions of photonic devices. As reported that the circular resonator play an important role in generation of soliton wave due to modulation of the index of refraction of the laser substrate[6-10]. In principle, there are existing two resonator modes; the clockwise (CW) propagation mode and the counter clockwise (CCW) propagation mode in the circular ring resonator. However, the symmetry coupling of the output of the SRCLD can be perturbed due to the generation of soliton wave guiding[3]. Here we report the fabrication of a SCRLD with double circular ring resonators and its output characteristics.

2. Device Fabrication

The SCRLD is 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 double circular ring resonator with diameters (D) of 200 μm . To fabricate the SCRLD device, a SiO_2 thin film of 200 nm was deposited by chemical vapor deposition (CVD) as an etching resisted layer, then a pattern of the SCRL device with double ring resonators is generated by using photo-lithography followed by reactive ion etcher (RIE) to etch off the SiO_2 layer. Then an inductive collide plasma etching (ICP) is used to etch out the ridge waveguide structure of 20 μm in width (W) and 0.8 μm in depth (h). Then a patterned insulating layer of SiN_x on top of the ridge waveguide is form by lift-off process. An Au (200 nm)/Cr (10 nm) layer is deposited using e-beam-deposition then followed by rapid thermal annealing at 650 ^{0}C to achieve good electric ohmic contact property. The fabricated device is grinded to minimize the resistance and coated with a thick AuGe/Ni film for probing test. Finally, the fabricated device is mirror scribed by diamond scribing.

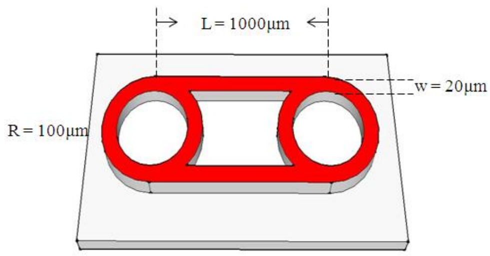

Figure 1, Dimension of the fabricated SCRLD with double circular ring resonators of 100 μm in radius and with a separation distant of 1000 μm .

3. Outputs Measurements and Discussions

The fabricated device was probe-tested on a microprobe station to measure the output characteristics and spectrum current-light (L-I). In principle, there are two resonant modes; the clockwise (CW) propagation mode and the counter clockwise (CCW) propagation mode existing in a circular ring cavity. Since that there is no output coupling structure; for example, the Y-junction coupler fabricated, it has no channel for output emission in lasing. However, we have measured emissions through spatial soliton waveguides formed by modulation of the index of refraction in the non-waveguide region excited by the emission from a circular ring resonator. In addition, it was carefully verified that the output modes from each circular ring resonator are asymmetric. The L-I measuring system is consisted with an HP 8114A pulse current source operating at 1 kHz, and the emission is measured by a Si-based photo detector (EOT 2020). A personal computer (PC) is used to control the measuring parameters and record the data of testing devices. Fig. 2 shows that there are two different output emission characteristics of the L-I curve; the output emission from C and D terminals which are laser emission with threshold currents at around 500 mA, and the output from A, and B terminals which are spontaneous emission.

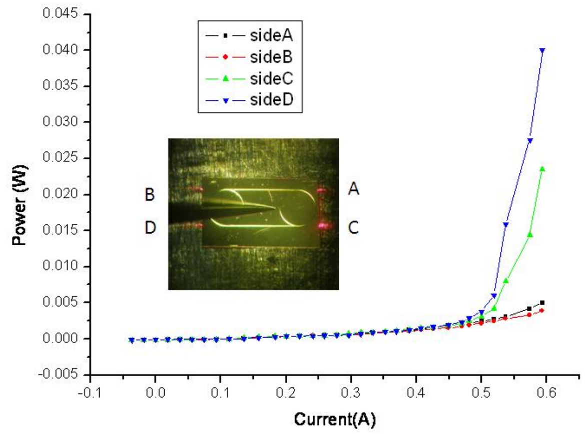

Figure 2, The L-I characteristics of the output from A,B,C, and D terminal through spatial soliton wave guiding channel of the double rings SCRLD of 200 μm in diameters.

A Jobin Yvon SPEX 500 spectrometer with 0.01 nm spectral resolution is used to reveal detailed features from each terminal. Fig. 3 shows the output spectral of the double ring resonator device operating at threshold current injection around 500 mA. It also shows asymmetric spectral emission characteristics, a strong single mode lasing spectrum at 658 nm from terminal C and D, but a broad background spontaneous emission from terminal A and B. As reported previously[6,7], a single mode emission is easily achieved due to the long optical amplification path in a circular ring resonator.

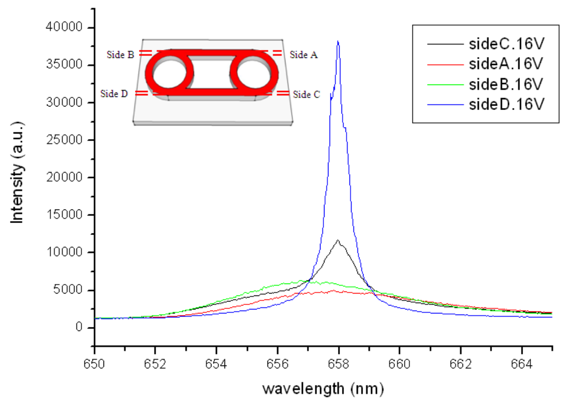

Fig. 3, Outputs spectrums measured at A,B,C, and D terminals of the double circular ring SCRLD operating at threshold current injection at around 500 mA.

In principle, there are existing CW and CCW propagation modes in a circular ring resonator. Therefore, the single mode output from terminal C corresponds to the counter clockwise (CCW) propagation emission in the circular ring resonator of the right hand side, and the single mode output from terminal D corresponds to the clockwise (CW) propagation emission in the circular ring resonator of the left hand side. Since the lasing mode (CW or CCW) is critical depend on the wave propagation parameters of the waveguide structure of the circular ring resonator, the asymmetric output of a broad spontaneous emission from terminal A and D which can be explained due to the structure perturbation during device processing.

4. Conclusions

We have demonstrated the possibility of laser output through spatial soliton wave guiding excited due to the nonlinear change in the refractive index modulation of the index of refraction of the laser substrate of a double circular ring SCRLD device. The L-I measurement and spectral analysis shows asymmetric characteristics of the output at each soliton wave guiding terminals, and either one of the CW or CCW mode can be coupled out efficiently through these soliton wave guiding terminals. However, the mechanism responsible for the correlation of the output modes between double circular ring resonators is still needed to explore. Investigation of the detailed modes coupling in this double circular ring SCRLD device is under going and more experimental results will be reported.

Acknowledgements

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