Extended Abstracts of the 2010 International Conference on Solid State Devices and Materials, Tokyo, 2010, pp397-398

The Output Characteristics of a Soliton Cavity Laser Diode

M. C. Shih, W. C. Su, and C. S. Chen

Department of Electrical Engineering, National University of Kaohsiung
No.700, Kaohsiung University Rd, Nan-Tzu Dist. 811, Kaohsiung, Taiwan, R.O.C.
Phone: +886-7-5919237 Fax: +886-7-5919399 E-mail: mingshih@nuk.edu.tw

1. Introduction

Solitons are attracting much research interest in physics and engineering due to its potential applications in full optical controllability of optical signal processing. A spatial soliton refers to a beam of light propagates without change in its transverse profile due to a positive light-induced change in the index of refraction which balances normal diffraction in the light propagation medium. There had been reported about the spatial solitons excitation in photorefractive media by low optical power level [1-7]. Previously, we had presented the generation of spatial solitons on a substrate of MOCVD grown InGaAlP multiple quantum wells structure by the excitation of a circular ring resonator [8]. Here we present the output characteristics of a novel semiconductor laser diode with an intra cavity of soliton generated waveguide.

2. Device fabrication

The device structure is shown in figure 1. The circular ring resonator is the key element of the device in which spatial soliton can be generated on non-waveguide region. The Y-junction coupler section is used to couple out clockwise(CW) beam in the circular ring resonator, and part of the counter clockwise(CCW) beam to the spatial solitons waveguide section.

The device was fabricated on an MOCVD grown InGaAlP multiple quantum wells structure which is a photovoltaic–photorefractive media and had been shown to have spatial soliton generation under low excitation power level [8]. Circular ring resonators with radius of 100 μm, 250 μm, and 400 μm were fabricated. The Y-junction coupling branch is a ridge waveguide structure of 8 μm width and of 500 μm in length. UV laser assisted etching had been developed to achieve anisotropic etching of the uniform circular ridge waveguide structure without damage to the etched side wall [9]. A patterned 0.2 μm silicate based spin on glass (SOG) (ACCUGLASS 204) was used to provide electrical isolation and optical confinement of the ridge waveguide.

3. Characterizations and discussions

The fabricated devices were tested on a microscopic probe-station driven by a pulse mode current source (HP 8114A) at 10 kHz. As the increase of the emission in the ring resonator by higher current injection, the effective length of the soliton waveguide increases accordingly until lasing at the soliton cavity terminal is achieved.

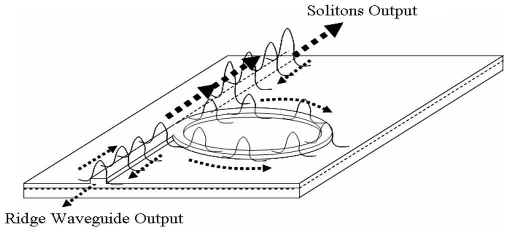

Fig.1. Sketch of the solitons cavity laser diode device.

We have found that the output characteristics at Y-junction waveguide terminal and solitons cavity terminal are quite different. Figure 2 shows the output power vs. injection currents (L-I) characteristics of the laser diode with a ring resonator diameter of 250 μm at Y-junction waveguide terminal and at soliton waveguide terminal. The threshold of the output power at the linear waveguide terminal is lower than the power output at soliton emission terminal. However, the quantum efficiency of the output at solitons cavity terminal is higher than at the Y-junction waveguide terminal.

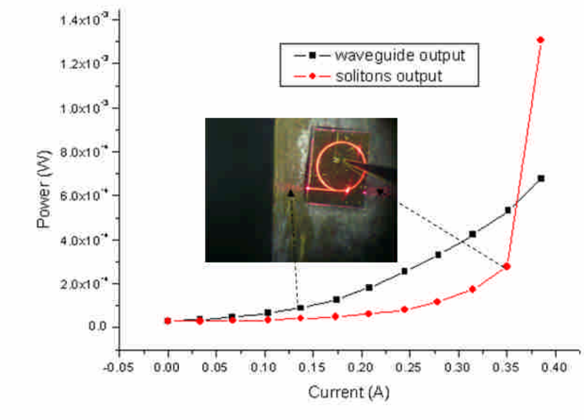

Fig.2. L-I characteristics at the linear waveguide terminal of the Y-junction and at the terminal of soliton emission of the soliton cavity laser diode with a ring resonator of 400 μm diameter.

It is interested to note that the output at the soliton terminal shows the combination of a single mode spectrum at 658 nm due to strong side modes suppressing from the circular ring resonator and a multi-modes spectrum which are contributed to the Fabry-Perrot cavity formed by the linear cavity of Y-junction coupling section plus the linear section of the spatial solitons cavity section. Figure 4 shows the results of the L-I measurements of the soliton cavity laser diodes with a ring cavity radius of 250 μm and a 500 μm long Y-junction coupling section while cleaving at the distance of 30 μm, 80 μm, and 150 μm on the non-waveguide region to form the output mirror of the soliton waveguide output terminal.

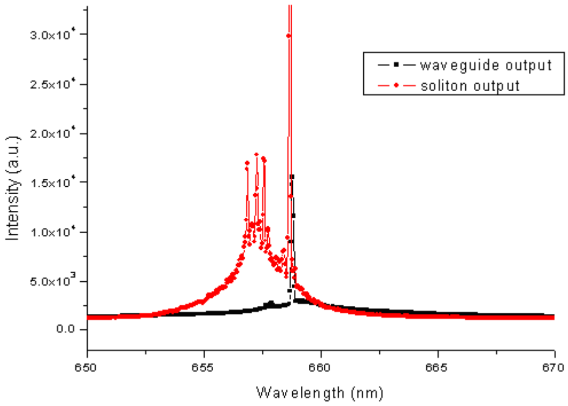

Fig.3. Spectrum characteristics of the soliton cavity laser diode with a ring resonator of 250 μm diameter at the Y-junction waveguide terminal and at the solitons waveguide terminal.

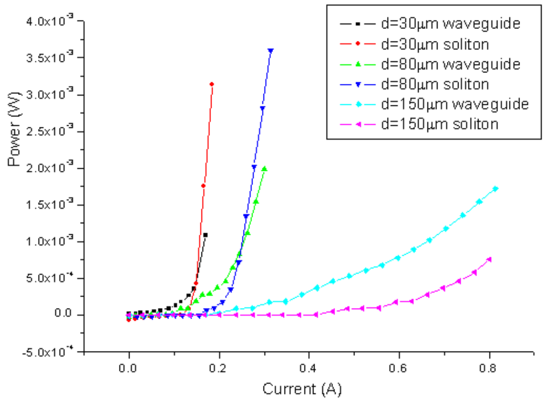

Fig.4. L-I characteristics of the emission at the soliton output terminal of the laser diode with a ring resonator radius of 250 μm and a 500 μm Y-junction coupling section with soliton cavity length of 30 μm, 80 μm, and 150 μm.

For the cases of short solitons cavity length, the threshold current density and external quantum efficiency at soliton output terminal are higher than at Y-junction waveguide output terminal. Figure 5 show the results of the calculated threshold current densities from L-I measured data in Fig. 4. The threshold current density monotonically increases with the length of the soliton cavity due to the increase of the loss of absorption along the soliton cavity. For soliton cavity as long as 150 μm, the deviation of the threshold current density between soliton output terminal and Y-junction waveguide terminal increase while the external quantum efficiency approaching the same value.

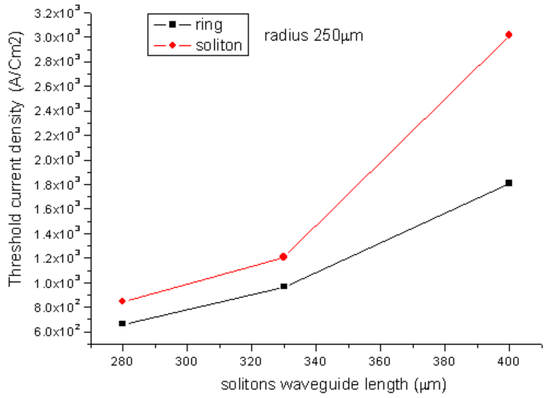

Fig.5. Dependence of the threshold current densities on the length of the solitons cavity at the Y-junction terminal and at the soliton waveguide terminal.of a sloliton cavity laser diode with a ring resonator with radius of 250 μm.

4. Conclusions

In conclusion, we have demonstrated the operation and output characteristics of a semiconductor laser diode structure with a soliton intra-cavity excited by a circular ring resonator. It shows interested output characteristics which are different from traditional linear laser stripe lasers that the threshold current densities of lasing at the soliton output terminal were higher than the output at normal waveguide terminal, and were approximately linearly increased with the length of the soliton cavity due to absorption of the gain medium while no current injection. Experiments and study of the soliton cavity laser mechanism are under going and detailed modeling of the output mechanism of the soliton cavity laser will be presented in the near future.

References

[1] A. Barthelemy, S. Maneuf, and C. Froehly, Opt. Commun. 55, (1985) 210.

[2] J. S. Aitchison, A. M. Weiner, Y. Silberberg, M. K. Oliver, J. L. Jackel, D. E. Leaird, E. M. Vogel, and P. W. E. Smith, Opt. Lett. 15, (1990) 471.

[3] W. Snyder, D. J. Mitchell, L. Poladian, and F. Ladouceur, Opt. Lett **16,** (1991) 21.

[4] M. Segev, B. Crosignani, A. Yariv, and B. Fischer: Phys. Rev. Lett. 68 (1990) 923.

[5] B. Crosignani, M. Segev, D. Engin, P. DiPorto, A. Yariv, and G. Salamo: J. Opt. Soc. Am. B 10 (1993) 466.

[6] J. M. Soto-Crespo, D. R. Heatler, E. M. Wright, and N. N. Akhmediev, Phys. Rev. A **44,** (1991) 636.

[7] G. Duree, J. L. Shultz, G. Salamo, M. Segev, A. Yariv, B. Crosignani, P. DiPorto, E. Sharp, and R. Neurgaonkar, Phys. Rev. Lett. **71,** 533 (1993); **74,** (1995) 1978.

[8] M. C. Shih, Shih Chang Wang, Chang En Ho, Wei Chun Su, Sheng Tsung Chen, Ho Ming Shei, Chih Wei Tien, and Sheng Min Wu, Japanese Journal of Applied Physics, 48 (2009) 04C114.