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Semiconductor Ring Lasers Fabricated with UV Laser-assisted Cryo-etching

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Semiconductor circular ring lasers have attracted quite much attention because of the higher side-mode suppression ratio and the versatility of integration with other components. In order to reduce the scattering loss in the curved waveguide of such a ring laser, the etched wall of the waveguide ridge must be highly vertical and smooth. In the past, RIE dry etching was the major technique used for this etching process [1]. In this paper, we present the results of our GaAs/AlGaAs quantum well circular ring lasers which were etched with the UV laser-assisted cryo-etching technique.

In the cryo-etching technique [2], we first placed the sample inside a chamber of about 130 K, which was filled with Cl_2. The Cl_2 molecules would be physisorbed on the sample surface. Then, the UV photons from 193 nm excimer laser would dissociate physisorbed Cl_2 and desorb Chlorine compounds (e.g., $GaCl_3$). In such a process, the sample can be etched. Because of the directional illumination of excimer laser, it is expected that the etched wall is vertical and smooth. In etching our laser epitaxial structure, the Cl_2 pressure was 1m Torr and the 193 nm laser energy density was 13 mJ/cm^2 (5 Hz pulse repetition rate and 15 nsec pulse width). With laser illumination for 10 minutes, we could achieve etching depth around 1 μm, by which the curved ridge-loading or ridge waveguide was formed.

The ring cavity structure is in a σ-configuration as shown in Fig. 1. The epitaxial structure includes a 5-period GaAs/AlGaAs quantum well layer and an about 1.5 μm upper cladding layer. The ridge-loading or ridge waveguide has the ridge width 6 μm and ring radius varied from 100 to 300 μm. The orientation of the output arm was also varied from 0 to 15° with respect to the crystal cleaved facet. Figure 2 shows the L - I curve of a typical laser with the radius 300 μm and 15° tilt angle. The cryo-etching depth was 2 μm meaning that a ridge waveguide was formed. It can be seen that the threshold current is about 120 mA, corresponding to a threshold current density 839 A/cm^2. In the range of the injection current between 130 and 160 mA, the laser efficiency was estimated to be 8.32 %, which is much higher than those of the similar ring lasers processed with the same cryo-etching technique (less than 2 %) [3] and those etched with RIE (less than 4 %) [1]. Figure 3 shows a typical spectrum just below the threshold condition. We can see the clear Fabry-Perot pattern which shows the free spectral range a little bit larger than 1 nm. This value is about ten times that of the ring cavity itself. We suppose that the coupled-cavity effect between the ring and the output arm may be responsible for this difference. Finally,

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Fig. 4 shows a typical spectrum above threshold. During the measurements, we could observe mode-hopping. We are currently conducting theoretical studies for explaining these phenomena.

References:

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3. M. C. Shih, M. H. Hu, M. B. Freiler, M. Levy, R. Scarmozzino, R. M. Osgood, Jr., I. W. Tao and W. I. Wang, Appl. Phys. Lett. **66**, 2608, 1995.

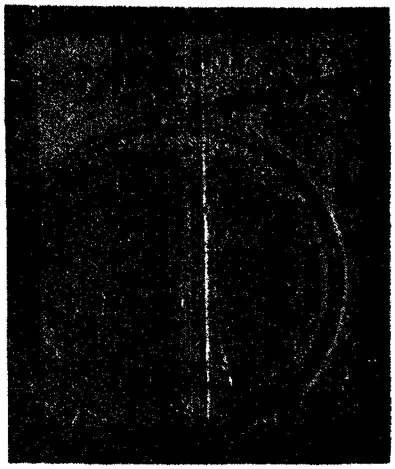

Fig. 1 Top view of a ring laser

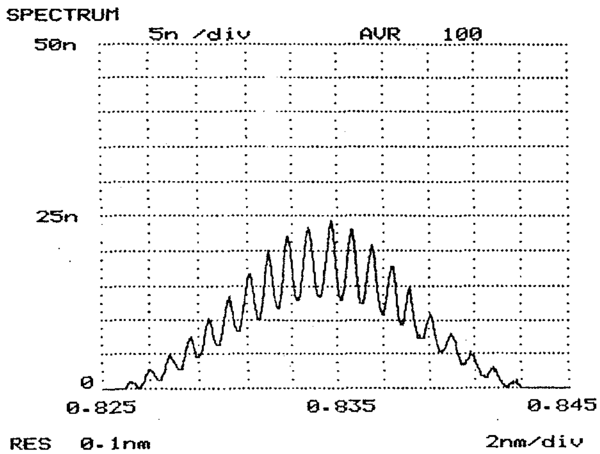

Fig. 3 A typical spectrum below threshold.

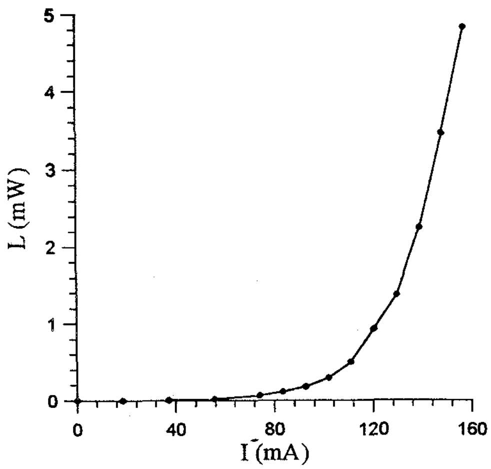

Fig. 2 L - I curve of a typical ring laser.

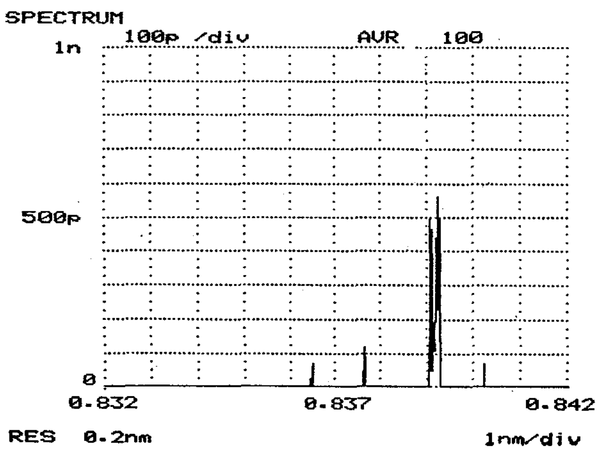

Fig. 4 A typical spectrum above threshold.