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The Optical Characteristics of Mesa-stripe-geometry Double-heterostructure Injection Lasers

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In this paper, we describe the fabrication and optical characteristics of versions of the mesa-stripe-geometry double-heterostructure lasers. The original mesa-stripe-geometry lasers were made by etching the epitaxial layers up to the first epitaxial layer (n-GaAlAs), leaving the stripe region whose width is ranging from 6 to 40 μm.[1] In lasers of this geometry, the stripe width can be narrowed without appreciable increase of the threshold current density. As a result of the low threshold current density and the small area, a considerable reduction of the total threshold current has been realized. The minimum threshold current so far obtained is 31 mA in pulsed operation in a diode of 6 X 97 μm^2, and is 75 mA in dc in a diode of 19 X 180 μm^2 area of which pulsed threshold current is 50 mA. The lowest threshold current density is 900 A/cm^2 in a diode of 19 X 608 μm^2 area.

In mesa-stripe-geometry lasers there exists a large difference of refractive indices parallel to the junction plane between the active and the inactive region, so that the transversal higher-order modes are often excited. One way to achieve a single fundamental transverse-mode operation is to utilize a mode-dependent loss at the side walls which will suppress higher modes.[2] In fact, tendency of the higher-mode suppression was sometimes observed in diodes with higher thresholds. The other way is to decrease the difference of refractive indices between the active and the inactive region. If we can stop mesa-stching just above the active region, the transversal difference of refractive indices can be made much smaller than that of the above-mentioned lasers (high-mesa-type) with little spreading of current. We may expect to get lasers which have better optical characteristics in this way.

We have fabricated the mesa-stripe-geometry lasers of this type (low-mesa-type) by adopting HF as a selective etchant of GaAlAs. After etching the top epitaxial layer (p-GaAs) and a part of the third layer (p-GaAlAs) using the sulfuric acid system as a etchant, the remaining part of the third layer was removed by HF. Because HF does not affect GaAs, the etching automatically ceases just at the interface of p-GaAlAs and the active region. The fabrication procedures after this etching process is the same as described before, concerning HMS (high-mesa-type) lasers.[1] As the stripe width becomes narrower, there is a small increase of the threshold current density in mesa-stripe-geometry lasers. In HMS lasers the threshold current density of the laser with the 20 μm and 10 μm stripe width is 1.1–1.5 times and 1.5–2 times that of the broad contact laser respectively. In LMS (low-mesa-type) lasers the threshold current density of the laser with the 15 μm stripe width is 1.5–2 times that of the broad contact lasers. This means a slight increase of the threshold compared with the HMS lasers with the same stripe widths. As a mechanism of the increase of the threshold current density when the stripe width is narrowed, we can consider the diffraction and the scattering loss at the side boundaries of mesa-stripe region. The scattering loss will dominate in HMS lasers. In LMS lasers leaky electromagnetic waves are absorbed in the unpumped region, and this is considered to be the cause of the rise of the threshold current density which is, according to the above experimental result, a little larger than that of HMS lasers due to scattering loss.

In LMS lasers, we have observed the nearly single mode operation. The operating current is 340 mA and this is 1.7 times the threshold current density. The output power is at least 15 mW. In another laser the nearly single mode operation has been observed at the current level twice the threshold current density.

The laser light shows the TE polarization in most diodes. The highest value of the polarization ratio $E_{\parallel}^2/E_{\perp}^2$ is 47. As the current increases, this ratio decreases in most diodes. However, it was observed that the polarization ratio of the diode which shows nearly single mode operation does not vary even if the current is increased up to 2.5 times the threshold current.

A high-power single-mode lasing was also observed in a diode of the following geometry. If we etch the broad contact lasers by HF, n- and p-GaAlAs layers are etched but GaAs layers remains as it was. As a result, the current flowing area becomes smaller than the GaAs area, and the regions neighbouring the cleaved ends were unpumped acting as a saturable absorber of the oscillating cavity. When the GaAlAs layers were etched at 30°C for 15 minutes, the threshold current decreases from the initial value, 400 mA, to 200 mA because the current flowing area shrinks. At the 720 mA current, that is, 3.6 times the threshold current this diode also shows nearly single mode operation whose peak output power is as high as 150 mW.

REFERENCES:

1) T. Tsukada et al., Appl. Phys. Letters (to be published).

2) Y. Suematsu et al., 1972 IEEE Semiconductor Laser Conference (Boston).