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Monolithic Integration of High-Power Buried Stripe (GaAl)As Laser with High Frequency Modulator MESFET Circuit

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A new high-power (GaAl)As laser monolithically integrated with a high-frequency modulator for noise suppression is reported. The laser is of buried stripe structure featured by a twin-ridge substrate and the modulator is made up of a 5-stage ring MESFET oscillator with an output buffer MESFET. The maximum output power as high as 30 mW and the read-RIN value as low as -140 dB/Hz have been attained.

§1. Introduction

Many efforts have been devoted to the implementation of optoelectronic integrated circuits (OEIC) for applications to optical communication and data processing systems. The laser diodes so far used in the (GaAl)As OEICs[1)2)] with GaAs MESFET circuits have been limited to those with low-power structures. It is because the high-power laser structure requires strict control of each layer thickness in multi-steps epitaxial growth.

In this paper, is described the first application of the high-power buried stripe (GaAl)As laser to OEICs with GaAs MESFET circuits. The elevation of the output power is achieved by successful use of the buried twin-ridge substrate (BTRS) structure on the semi-insulating substrate. The BTRS structure is known[3)] to be well suited for controlling the thickness of each layer thus allowing the formation of the extremely thin active layer for high power outputs.

The high power OEIC has been implemented incorporating a noise suppression high frequency modulator MESFET circuit. The new OEIC is designed to have an output power of 30 mW and a read-RIN(relative intensity noise) of -140 dB/Hz in an attempt to applying to optical read/write disc systems.

§2. Design

Figure 1 shows a schematic cross section of the OEIC. The BTRS structure laser is formed on the partially etched-down surface of the semi-

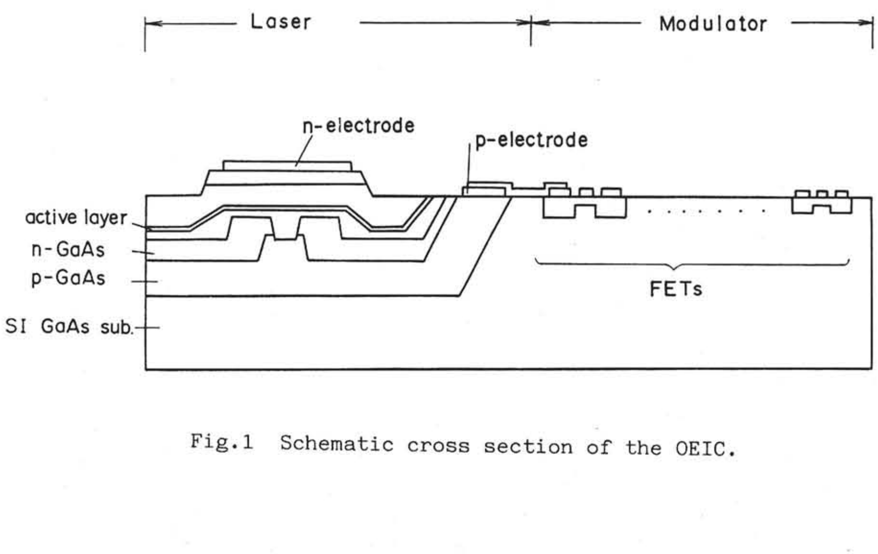

Fig.1 Schematic cross section of the OEIC.

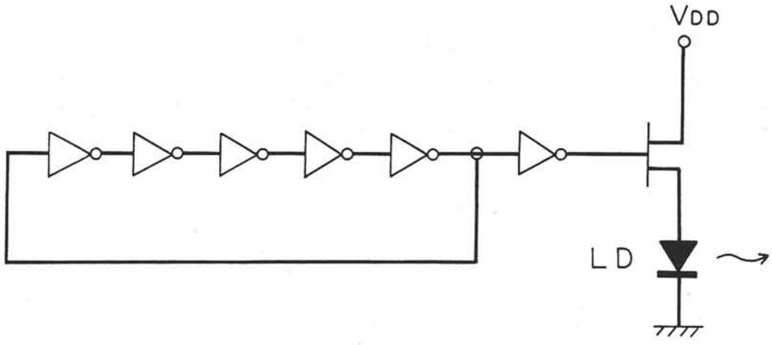

Fig.2 (a) Circuit block diagram of the present OEIC.

insulating GaAs substrate in order to allow use of the conventional planar process in fabricating MESFET circuits. The p-electrode of the laser is formed on the exposed surface of the chip for making possible the interconnection between the laser and the MESFET circuits. The injection current from the p-electrode is well-confined to a lasing region owing to the presence of the buried stripe composed of the n-GaAs blocking layer so that the low operating current can be obtained.

Figure 2(a) shows a circuit block diagram of the present OEIC. The noise suppression high-frequency modulator is made up of a 5-stage ring oscillator with an output buffer FET. A unit inverter comprised in the ring oscillator is constructed with the Buffered FET Logic (BFL) circuit as shown in Fig. 2(b). The modulator was designed to provide a 15 dBm/800 MHz oscillation power.

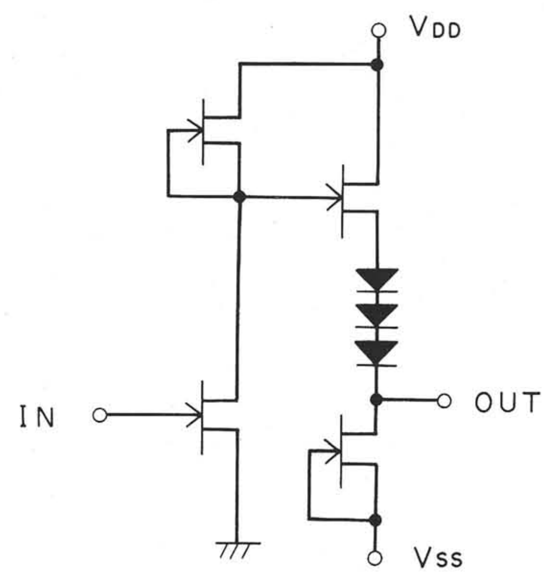

Fig.2 (b) Circuit configuration of BFL.

§3. Fabrication

Steps for fabricating the present OEIC are as follows. Three steps selective LPE growth were used for fabricating the laser. In the first growth, the p-GaAs current injection layer was grown on the partially etched-down surface of the semi-insulating GaAs with 7 μm depth. Prior to second LPE growth, a rectangular mesa with 2 μm height and 12 μm width was formed along a direction of $\langle 01\bar{1} \rangle$ of the p-GaAs layer. An n-GaAs blocking layer was grown on the substrate for the second LPE growth. The thickness of the blocking layer was designed to be 0.8-1.0 μm on the mesa. Two rectangular ridges with 1.5 μm height, 20 μm width and 5 μm spacing were formed in parallel to the mesa. The channel between two ridges is located just above the mesa and reaches to the p-GaAs current injection layer. Remaining four layers including an active layer of 0.06 μm thickness were grown for the third LPE growth. An n-electrode was formed on the grown surface and a p-electrode was formed on the exposed surface of p-GaAs layer. Cavity facets of the laser were made by successful use of the etched-cavity technique reported by present authors.[4] The laser cavity length is 280 μm.

The MESFET circuit was built up on the remaining surface by using the conventional full ion-implantation process. The n^+ regions for the source, drain and Shottky diodes were formed by heavy implantation of Si ion with a dose of 5 x 10^{13} cm^{-2} and an acceleration voltage of 140 keV. The channel region was formed by light implantation of Si ion of which a dose and an acceleration voltage are 5 x 10^{12}cm^{-2} and 60 keV, respectively. The implanted wafers were annealed at 800°C in an N_2 ambient gas. AuGe/Ni/Au triple layer metals were used for ohmic contacts of the FETs, the Shottky diodes and the n-electrode of the laser. AuZn was used for ohmic contact of the p-electrode of the laser. The Ti/Pt/Au triple layer gates of 1 μm length were formed by using the conventional lift-off technique. The plasma-deposited SiN film was grown on the wafer to provide an insulator for the first-level metal. The second-level metal used was a doubly EB-deposited Ti/Al. The passivation is performed with the plasma-deposited SiN film.

A photomicrograph of the chip is shown in Fig.3. The fabricated chip measures 0.35mm x 1.20mm.

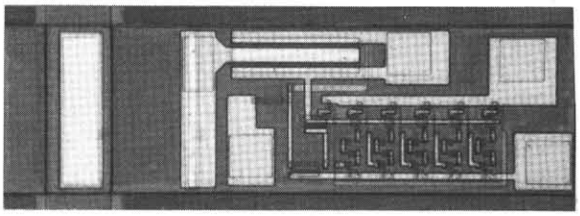

Fig.3 Chip pattern of the OEIC.

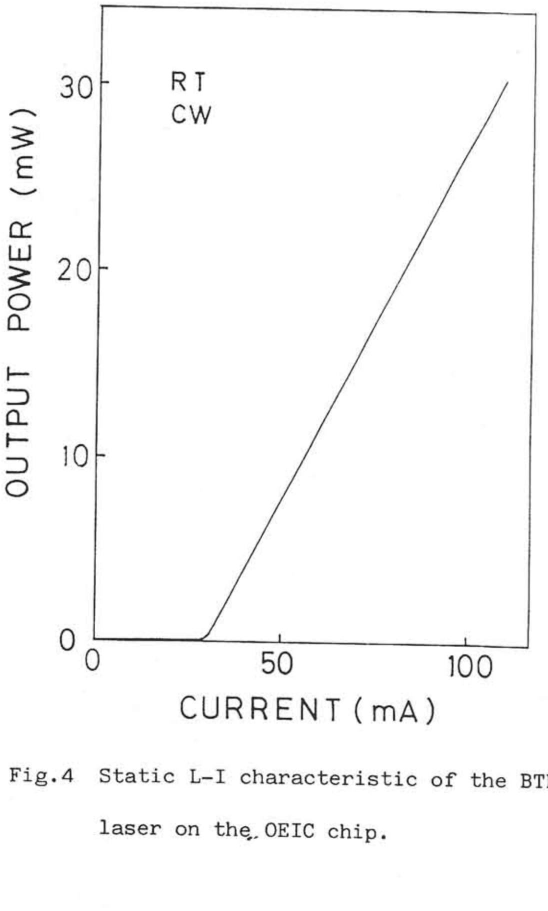

Fig.4 Static L-I characteristic of the BTRS laser on the OEIC chip.

§4. Characteristics

Figure 4 shows a static output versus current characteristic of the BTRS laser on the experimentally fabricated OEIC chip. The threshold current, the external quantum efficiency and the maximum output power are 30 mA, 27%/facet and 30 mW/facet, respectively. The lasing characteristics are similar to those of the conventional BTRS laser fabricated on a p^+-type GaAs substrate. Figure 5 shows an output wave form of the modulator circuit on the OEIC chip. The observed oscillation frequency is 800 MHz which agrees well with the designed value. Figure 6 shows a dynamic performance of the present OEIC, where the RIN values at a frequency of 5 MHz are plotted as a function of the optical feedback ratio. The output oscillation power of the modulator circuit is 15 dBm. It is clear in this figure that the RIN value is suppressed by more than 15 dB/Hz by operating the modulator circuit on the chip.

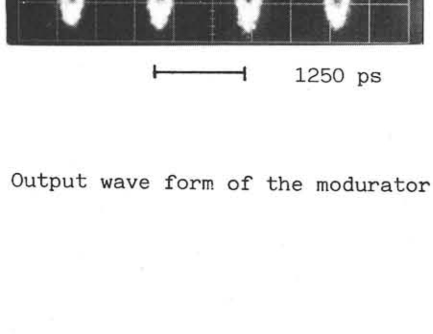

Fig.5 Output wave form of the modurator circuit.

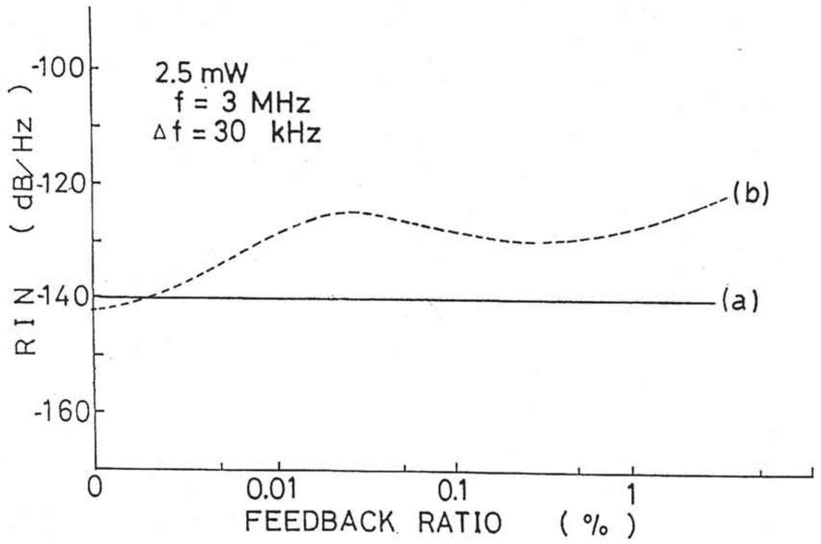

Fig.6 RIN values as a function of the optical feedback ratio.
(a) with HF moduration (b) without moduration

§5. Conclusion

We have successfully fabricated a new monolithic OEIC composed of a high-power buried stripe (GaAl)As laser and a MESFET circuit on a GaAs single chip. It has been shown that the OEIC exhibits an output power of 30 mW and a read-RIN of -140 dB/Hz by monolithically combining the BTRS structure laser and the noise suppression high frequency modulator MESFET circuit.

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