Extended Abstracts of the 19th Conference on Solid State Devices and Materials, Tokyo, 1987, pp. 99-102

Low Noise and Low Astigmatic Properties of GaAlAs Laser Diodes with ZnSe Layer Grown by Adduct-Source MOCVD

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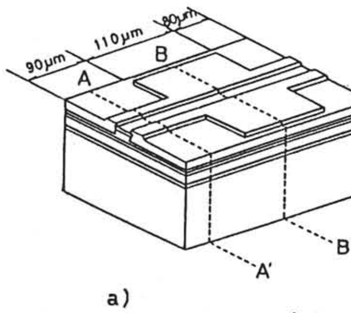
A Novel GaAlAs laser diode with low noise and low astigmatism has been developed by a technique of MOCVD. This laser diode includes both a real refractive index-guided structure near the facet and a gain-guided structure in the middle region of the cavity with a ZnSe layer. The fundamental transverse mode and multi-longitudinal mode oscillation are obtained with a threshold current of 42mA and a quantum efficiency of 66%. The relative intensity noise induced by optical feedback is less than 3×10^{-14} (Hz^{-1}) at an output power of 5mW and the astigmatic distance is proved to be below 5µm up to 20mW.

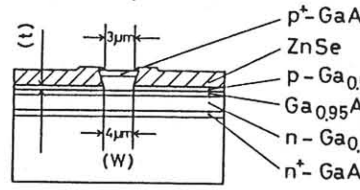
1. Introduction

For the application to optical memory systems such as write-once or erasable memories, a laser diode is strictly required to combine high output power, low noise induced by optical feedback, low astigmatism and stable single near- and far-field patterns. Especially, the noise induced by optical feedback is an important factor for the practical use of optical pick-up systems.

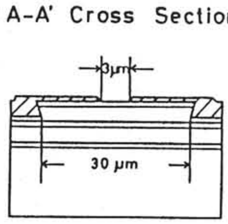
Low noise characteristics have been realized by the self-pulsation structure[1] or driving by the high frequency (HF) current superposition method.[2)3)] The former, however, lacks the sufficient low astigmatism because the lateral mode propagation contains a gain-guided profile. And the latter needs an HF circuit which is disadvantageous for making a pick-up system compact.

On the other hand, a ZnSe epitaxial layer with high quality and uniformity has been realized by adduct-source MOCVD at low temperature.[4] This ZnSe layer is very useful for real index-guided structure and cavity shape modulation, since it has high resistivity enough to completely block a leakage current[5] and a smaller refractive index than that of GaAlAs for effective optical confinement. In this paper, we report low noise and low astigmatic characteristics of newly developed





b) A-A' Cross Section



c) B-B' Cross Section

Fig.1 Schematic drawing of index- and gain-guided laser diode

GaAlAs laser diode with ZnSe layer. This laser has a real index-guided structure near the facet and a gain-guided structure in the middle region of the cavity, as shown in a schematic cross section of Fig.1 (b) and (c). Stable single near- and far-field patterns are achieved up to an output power as high as 20mW, and the astigmatic distance can be reduced to less than 5μm. The relative intensity noise (RIN) induced by optical feedback is proved to be less than 3×10^{-14} (Hz^{-1}) since the multiple longitudinal mode oscillation is obtained.

2. Device Fabrication

Fig.1 shows a laser structure and a dimension at the index- and gain-guided region. This structure is advantageous because it does not cause a coupling loss due to a difference of the active layer thickness or an active layer bending between the index- and gain-guided region.[6)]

A two step MOCVD technique was used for the fabrication of laser. The first step was the growth of a conventional double heterostructure by low-pressure MOCVD.

Trimethylgallium (TMG), trimethylalminum (TMA) and arsine (AsH_3) were used as source materials and cyclopentadienylmagnesium (Cp_2Mg) and hydrogenselenide (H_2Se) were used as p-type and n-type dopants, respectively.

Table 1 Growth conditions for double heterostructure

	GaAs	GaAlAs
Substrate Size (mm)	20x36	20x36
Growth Temperature (°C)	765	765
Growth Pressure (torr)	150	150
Flow Rate		
TMG (mol / min)	1.3×10^{-5}	1.3×10^{-5}
TMA (mol / min)	—	2.5×10^{-6}
Cp2Mg (mol / min)	5.9×10^{-8}	4.7×10^{-8}
H2Se 100ppm (sccm)	50	20
AsH3 10 % (sccm)	300	300
Total Flow Rate (sccm)	3500	3500
Growth Rate (Å / min)	360	500

Typical growth conditions are listed in Table 1.

A five-layer structure was grown successively on a (100) oriented Si-doped n-GaAs substrate; (1) a Se-doped n-GaAs buffer layer (2×10^{18} cm^{-3}, 0.5μm), (2) a Se-doped n-$Al_{0.41}Ga_{0.59}As$ cladding layer (5×10^{17} cm^{-3}, 1.5μm), (3) an undoped $Al_{0.05}Ga_{0.95}As$ active layer (0.1μm) (4) a Mg-doped p-$Al_{0.41}Ga_{0.59}As$ cladding layer (3×10^{18} cm^{-3}, 1.5μm), (5) a Mg-doped p-GaAs contact layer (5×10^{18} cm^{-3}, 0.5μm).

Fig.2 shows a fabrication process of the laser diode after the first growth. As shown in Fig.2 (b), a ridge stripe with a width of 5μm and 30μm was defined by chemical etching (H_2SO_4:H_2O_2:H_2O, 1:8:8, 20°C) into the p-cladding layer to 0.4μm ((t) in Fig.1 (b)) of the active layer.

In the second step, a ZnSe layer was grown on the etched wafer by MOCVD at 325°C using an adduct of dimethylzinc-dimethylselenium (DMZn-DMSe) and H_2Se as source materials.

The ZnSe layer was etched by chemical etching (HNO_3:HCl:H_2O, 1:3:1, 20°C) with a

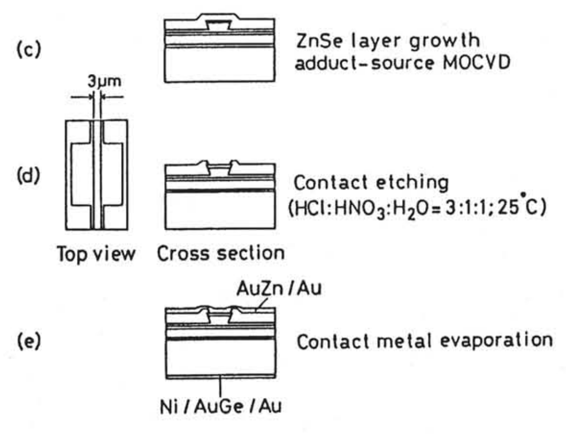


Fig.2 Fabrication process of index- and gain-guided laser diode

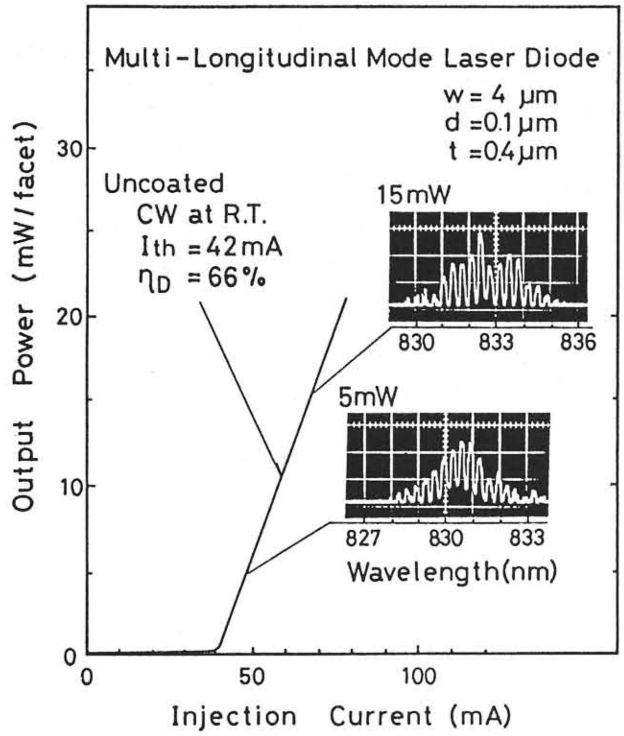


Fig. 3 Light output power vs. current characteristics and lasing spectra at different power levels

stripe width of 3μm into the p-GaAs contact layer using a SiO_2 mask as shown in Fig.2 (d). After cleaving, the laser chip without facet coating was mounted on a Si heat-sink in the p-side down configuration.

3. Device Characteristics

Fig.3 shows the typical light output power vs. current (I-L) characteristics and the lasing spectra at 25°C under continuous wave (CW) operation.

The threshold current is 42mA and the external differential quantum efficiency is 66%. Also, no kinks are observed in the I-L characteristics to an output power of 20mW.

Multi-longitudinal mode oscillation is obtained over a large power region from 2mW to more than 20mW. However, an entirely index-guided laser with a same dimention of (W) and (t) in Fig.1 (b) exhibits single longitudinal mode oscillation at more than 2mW. So this multi-mode operation is caused by the built-in gain-guided region.

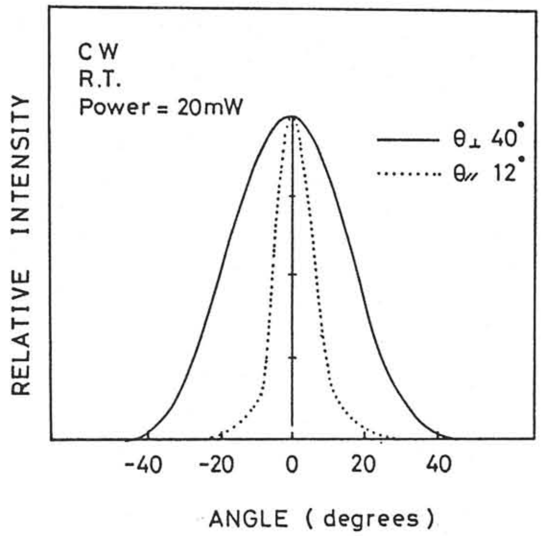


Fig.4 Far-field patterns in parallel ($\theta_{//}$) and perpendicular ($\theta_{\perp}$) to the junction plane at an output power of 20mW

On the other hand, the fundamental transverse mode oscillation is obtained up to 20mW as shown in Fig.4. The full angle at half-maximum in perpendicular ($\theta_{\perp}$) and parallel ($\theta_{//}$) to the junction plane are typically 40° and 12°, respectively.

A real effective refractive index step (Δn_{eff}) in the lateral direction is 2.2×10^{-3} so that only fundamental mode propagation is permitted when the stripe width (W) at the bottom of ZnSe layer is less than 4μm. This stable transverse mode operation is considered to be the result of lateral mode filtering due to the index guiding near the facet.[7)]

And the astigmatic distance (ΔZ) was measured by observing the full width at half power of the near-field patterns.

Fig.5 shows a relationship between the ΔZ and the output power. The ΔZ is reduced to less than 5μm up to 20mW. This low astigmatism indicates that the ZnSe layer near the facet plays an effective role of wave guiding without an absorption at the side of ridge stripe.

Fig.6 shows the RIN as a function of the optical feedback ratio at an output power of

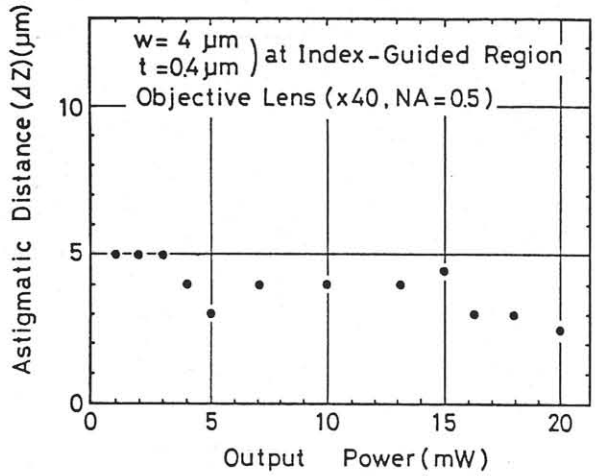


Fig.5 Astigmatic distance (ΔZ) vs. output power characteristics under CW operation

5mW. The solid line in Fig.6 represents RIN vs. optical feedback ratio for the multi-mode laser in this work and the broken line is for a conventional index-guided laser which is operated in a single longitudinal mode oscillation. As shown clearly in Fig.6, an excellent reduction of the noise level is realized by the multi-mode laser. The RIN is proved to be less than $3x10^{-14}$ (Hz^{-1}) up to a feedback ratio of 10%.

4. Conclusion

A novel built-in waveguide GaAlAs laser diode using adduct-source MOCVD grown ZnSe layer has been developed. Multi-longitudinal mode operation has been obtained to 20mW with a threshold current of 42mA under CW. Astigmatic distance is less than 5µm and relative intensity noise induced by the optical feedback is proved to be below $3x10^{-14}$ (Hz^{-1}), which are enough values to utilize this laser for various optical memory systems.

Acknowledgement

The authors would like to thank T. Asaka, M. Yonekubo, N. Kenmochi and T. Takeda for their useful discussions and measurements. Thanks also to C. Natori for her support during this work.

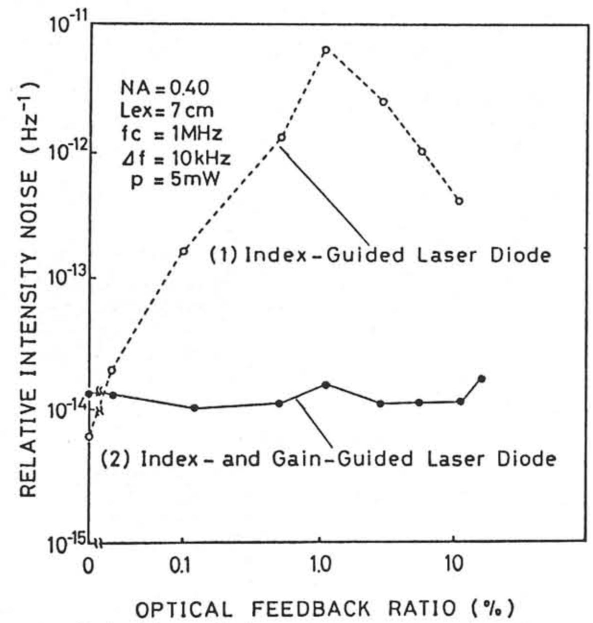


Fig.6 Relative intensity noise (RIN) as a function of optical feedback ratio at an output power of 5mW.
(1) Conventional index-guided laser (broken line)
(2) Index- and gain-guided laser in this work (solid line)

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