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# Mode Properties of MOCVD Grown High Power GaAlAs Lasers

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The mode properties of m-ECO and ECO lasers have been compared up to high output power levels. Although both lasers could emit 50 mW in the fundamental transverse mode, focusing properties are influenced by the guiding mechanism, and a near-diffraction-limit spot size was obtained for the m-ECO laser.

Furthermore, the transverse mode instability associated with spatial hole burning was suppressed in the range of less than 2 μm stripe width and more than $6\times10^{-3}$ effective index step, for the m-ECO laser.

## 1. Introduction

Metalorganic chemical vapor deposition (MOCVD) is attracting increasing attention as a powerful technique for large scaled laser diode production, since it is potentially suited for uniform thin film growth on large substrates with high throughput.[1-3]

Recently, high power GaAlAs lasers are coming to be used as optical disk memory read/write light sources. In such applications, stability of the fundamental transverse mode and excellent focusing are required both at low power in reading and at high power in writing.

The ECO (Embedded Confining layer in Optical guide) laser[4] and the modified ECO (m-ECO) laser,[5] which are both grown by MOCVD, both have built-in waveguiding structures with flat active layers. However, the mode guiding mechanism is different : namely, the m-ECO laser has a refractive index guide and the ECO laser has a built-in loss guide. Both lasers are favorable for high power operation, since the optical fields spread sufficiently into the cladding layers, as in large optical cavity structures.[6]

In this paper, we have compared the mode properties of the m-ECO and the ECO lasers from low power through high power levels, with attention to the difference in guiding mechanism.

## 2. Device Structures

Figure 1 shows schematic diagrams of the m-ECO and the ECO laser structures. Both lasers require two-step MOCVD growth. The GaAlAs layers were grown in an rf-heated vertical MOCVD reactor under atmospheric pressure. Source materials were trimethylgallium (TMG), trimethylaluminum (TMA) and arsine ($AsH_3$), with diethylzinc (DEZ) and hydrogenselenide ($H_2Se$) as p-type and n-type dopants, respectively. The growth temperature was 750°C.

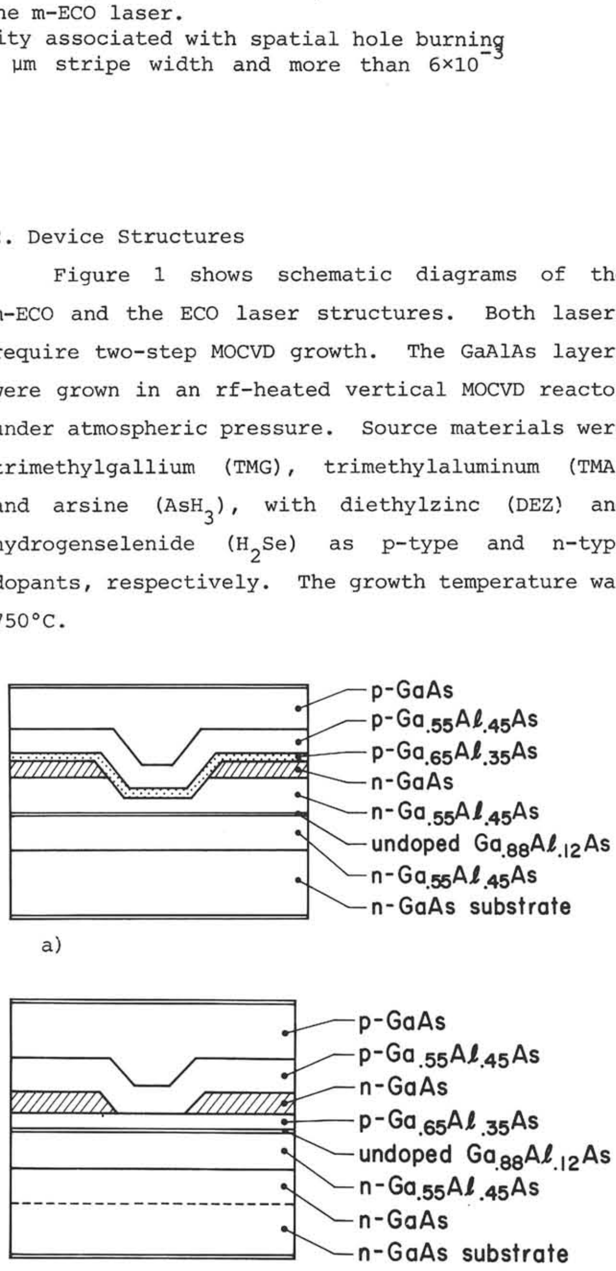



Fig.1 Schematic diagrams of a) the m-ECO and b) the ECO laser structures.

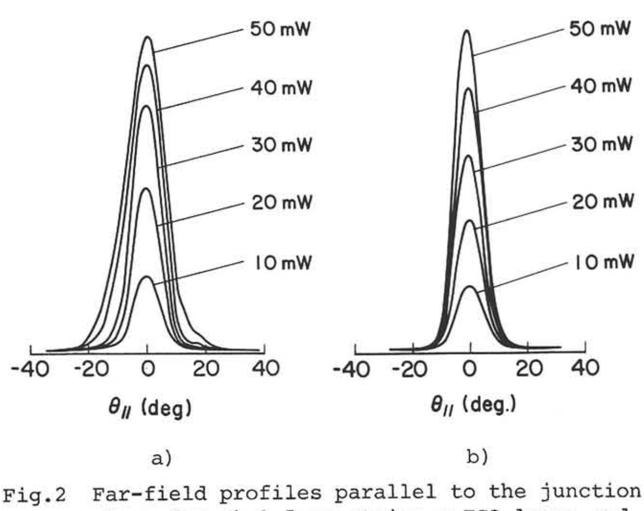
In the ECO structure, the n-GaAs confining layer, embedded between the p-GaAlAs optical guide layer and p-GaAlAs cladding layer, provides lateral transverse mode guiding due to differential loss, as well as current blocking outside the channel.

In the m-ECO structure, the n-GaAs current blocking layer no longer plays an essential role in stabilizing the transverse mode. A thin GaAlAs (x=0.35) layer, whose refractive index is larger than the GaAlAs (x=0.45) cladding layer, is introduced near the active layer inside the stripe channel, and this provides an effective index step sufficient for transverse mode guiding.

To realize higher output power operation, anti-reflection coatings consisting of $Al_2O_3$ layers were applied to the output facets of both lasers.

## 3. Mode Properties

Figure 2 shows far-field profiles parallel to the junction plane for an m-ECO and an ECO laser. In these types of laser the stripe width W is an important parameter. Gaussian-like profiles are obtained up to 50 mW for a comparatively narrow stripe (W=1.5μm) in the case of an m-ECO laser, and for a wide stripe (W=3.5μm) in the case of an ECO laser. This difference arises from the resistance of the waveguide to spatial hole burning and insensitivity to the gain profiles due to injected current distribution.[7]

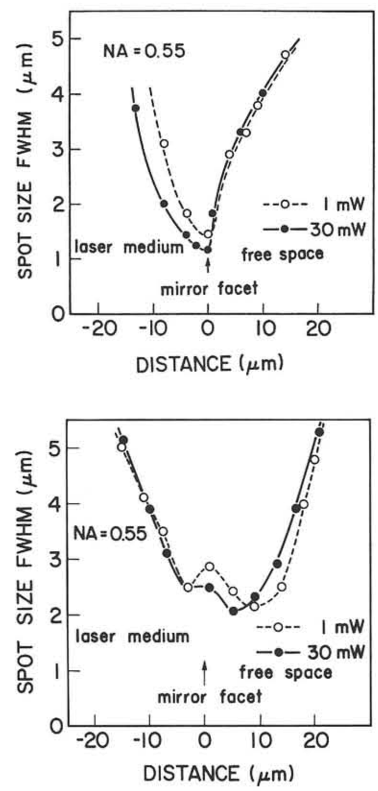



a) b)

Fig.2 Far-field profiles parallel to the junction plane for a) 1.5 μm stripe m-ECO laser and b) 3.5 μm stripe ECO laser.

Figure 3 shows the half beamwidth, measured parallel to the junction plane, as a function of lens position for a NA = 0.55 objective lens. Open and closed circles represent the values at 1 mW and at 30 mW respectively. As shown Fig.3-b), two points of minimum beamwidth are observed for the ECO laser. This indicates that the wavefront of the ECO laser is composed of a flat portion, which implies a small astigmatism, and a curved portion, which implies a large astigmatism.[7] Moreover, these minimum points shift with increasing output power. On the other hand, the astigmatism of the m-ECO laser is less than 2 μm and does not change with output power (Fig.3-a)), which is characteristic of an index-guide laser.

Figure 4 shows the power dependence of the normalized spot size $W/W_o$. W is the minimum spot size and $W_o$ is the Gaussian spot size corresponding to the observed beam divergence. $W/W_o$ represents the magnitude of the deviation from the diffraction limited spot size. Above 10 mW, $W/W_o$ for the ECO laser is almost unity, while $W/W_o$ for the ECO laser is larger than unity by 5%, a quantitative measure of the wavefront distortion.




a)

b)

Fig.3 Position dependence of focused spot size (NA=0.55 objective lens) for a) an m-ECO laser (1.5 μm stripe), and b) an ECO laser (3.5 μm stripe).

The difference between the m-ECO and ECO laser spot sizes become more distinct at a lower power level (Fig.4). This is attributable to their spontaneous emission characteristics. The comparatively large loss, measured at typically 60 $cm^{-1}$, and the wavefront distortion result in an increase in the spontaneous emission of the ECO laser. The internal loss of the m-ECO laser was 20 - 30 $cm^{-1}$,[5] and the wavefront was almost flat as described above.

As mentiond above, although both the m-ECO and the ECO lasers could emit CW 50 mW in the fundamental transverse mode, more suitable focusing properties were obtained with the m-ECO laser, particularly at a lower power level.

At a higher power level, in contrast, it is known that lateral transverse mode instability, associated with spatial hole burning,[8] arises more easily for an index guiding structure than for loss guiding, if the index guide is not so strong or the stripe width is comparatively wide.

Figure 5 shows the transverse mode behaviors of the m-ECO lasers up to 30 mW as functions of the effective refractive index step $\Delta n_{eff}$ and stripe width W. For the m-ECO structure, the effective index step is easily controlled by the guiding layer - active layer spacing h. The solid curve represents the calculated cut-off condition of the first order mode. Closed circles represent measured higher order mode oscillation. For fundamental mode oscillation conditions, transverse mode instability at high power levels is

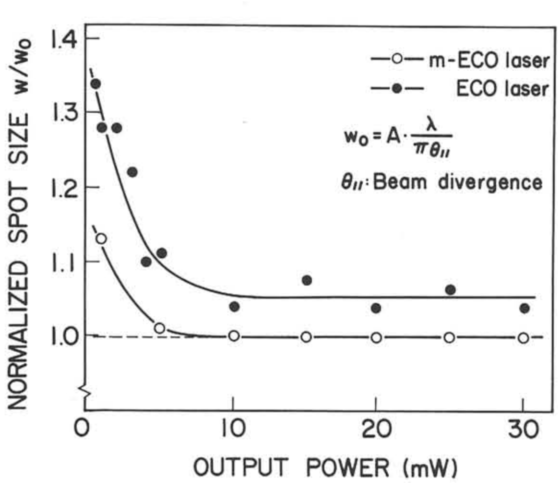



Fig.4 Output power dependence of normalized spot size for the same lasers as Fig.3.

observed for effective index steps of less than $6\times10^{-3}$. In particular, for effective index steps of less than $1\times10^{-4}$, gain guide-like mode behavior (large astigmatism, kinking and transverse mode instability with power) are observed independent of the stripe width. Hole-burning-free characteristics and diffraction-limit spot size are achieved with a stripe width of less than 2 μm and an effective index step of greater than $6\times10^{-3}$. The m-ECO structure is capable of realizing such large effective index steps in spite of its having a flat active layer.[5]

These properties and structure of the m-ECO laser are advantageous for obtaining tansverse mode stability at high power levels as well as at low power.

Figure 6 shows aging test results for the m-ECO laser. In addition to the above mentioned focusing properties, stable operation for over 4000 hours was obtained at 50°C with a constant output power of 30 mw/facet.

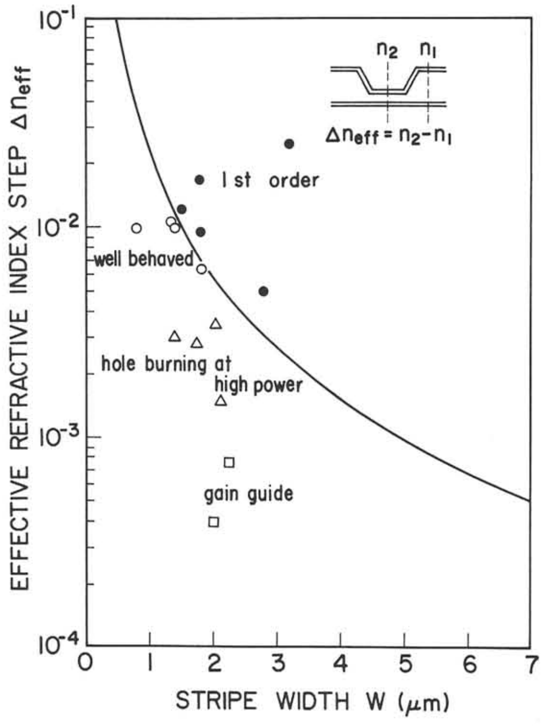



Fig.5 Transverse mode behavior of the m-ECO laser up to 30 mW as a function of the effective index step and stripe width.

## 4. Conclusion

The mode properties of m-ECO and ECO lasers have been compared up to high power levels. Although both lasers could emit CW 50 mW in the fundamental transverse mode, focusing properties are influenced by the guiding mechanism, and a near-diffraction-limit spot size was obtained of the m-ECO laser. Furthermore, the transverse mode instability associated with spatial hole burning was suppressed in the range of less than 2 μm stripe width and more than $6\times10^{-3}$ effective index steps, for the m-ECO laser.

Considering these focusing properties and the fact that more than 4000 hours of operation were achieved under 50°C/30mW conditions, it can be concluded that the m-ECO laser is a suitable structure as an MOCVD grown high power laser.

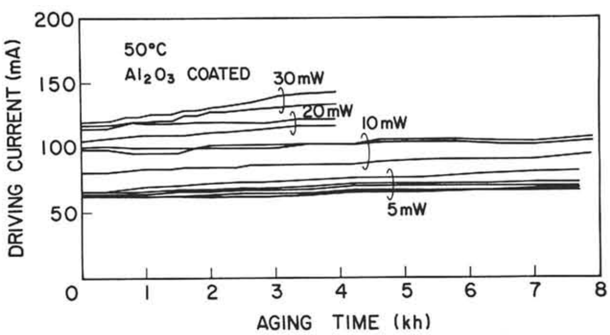



Fig.6 Aging test results for the m-ECO laser.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