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Fabrication of an Integrated DFB Laser/Amplifier with Reactive-Ion-Etched Tilted Facets for Reduction of Optical Crosstalk

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We describe fabrication and characteristics of a DFB laser monolithically integrated with an optical traveling-wave amplifier prepared using OMVPE/LPE hybrid growth. A unique feature is its 7°-tilted end facets formed by RIE for reduction of optical crosstalk. Owing to low reflectivity of the facets the elemental devices have operated with little interference.

1. Introduction

Integration of photonic devices is expected to bring enhanced capabilities and complicated functions beyond existing discrete devices.[1-3] However, the optical crosstalk between component devices is a major problem.

In this paper we describe a novel scheme for handling this problem and its application to a monolithically integrated photonic device consisting of a distributed feedback (DFB) laser and an optical traveling-wave amplifier (TWA).

2. Device Structure

The structure of the integrated device is depicted in Fig.1. Its distinctive feature is the 7°-tilted end facets formed by reactive ion etching (RIE). If the light reflected at the output facet of the amplifier is reinjected into the laser, it changes the lasing characteristics according to the gain of the amplifier.[4] This may cause a serious crosstalk between these elemental devices. Hence, the facet reflection ought to be eliminated.

Anti-reflection (AR) coating is one way of carrying out this purpose, but it requires very strict control of both refractive index and thickness of the AR film if less than 1% reflectivity is needed. Making the incident direction off the normal is another simpler way for reducing the facet reflection below 1%.[5] 7°-tilted laser stripes have been used particularly for the reflection suppression in TWA's.[6]

The way we employed here, namely 7°-tilted etched facets, is the alternative to that, but has a merit that they do not require cleaving and the facets can be made in almost any direction independent of crystallographic orientations. This approach therefore seems more suitable for integration.

3. Fabrication

The first growth step up to the p-GaAlAs waveguiding layer was done by organometallic vapor phase epitaxy (OMVPE). The second-order diffraction grating (260nm pitch) in the DFB laser section was next engraved utilizing RIE.[7] The upper cladding and the contact layers were grown by liquid phase epitaxy (LPE) on the waveguiding layer.

After constructing 4μm-wide ridge waveguide structure, we etched the epitaxial wafer down to the upper cladding layer with RIE to form a 10μm-wide groove between the laser and the amplifier for electri-

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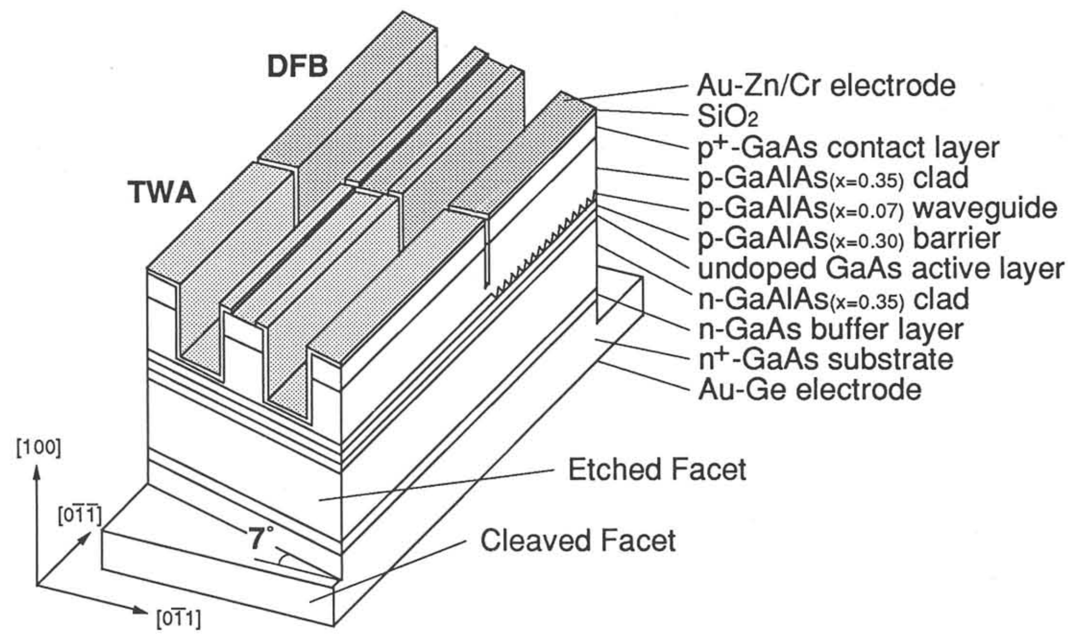

Fig.1 Schematic drawing of the DFB laser integrated with an optical traveling-wave amplifier.

cal isolation. Resistance between them was measured as 760Ω. Finally, the 7°-tilted end facets were built also by making use of the anisotropic and non-preferential nature of RIE.

Figure 2 is a photograph showing the top view of the integrated device thus fabricated. Length of the DFB laser and the amplifier is 300μm each. For the purpose of measurement, the wafer was cleaved into unit devices.

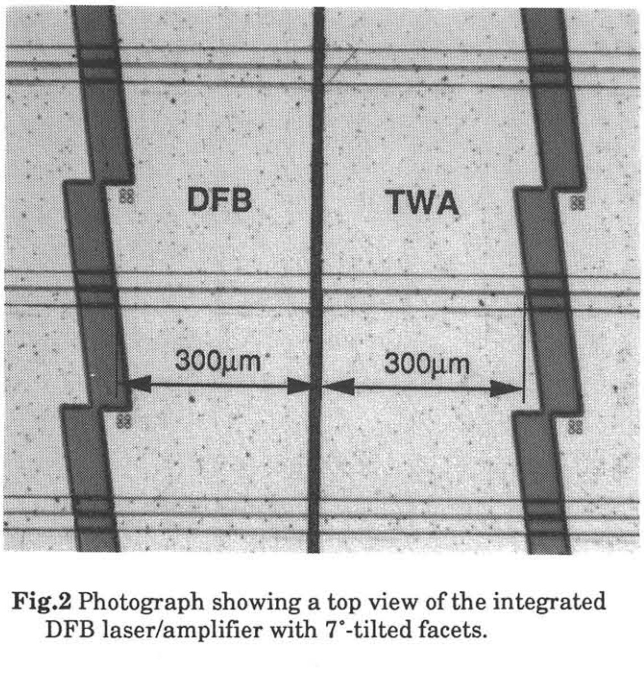

Fig.2 Photograph showing a top view of the integrated DFB laser/amplifier with 7°-tilted facets.

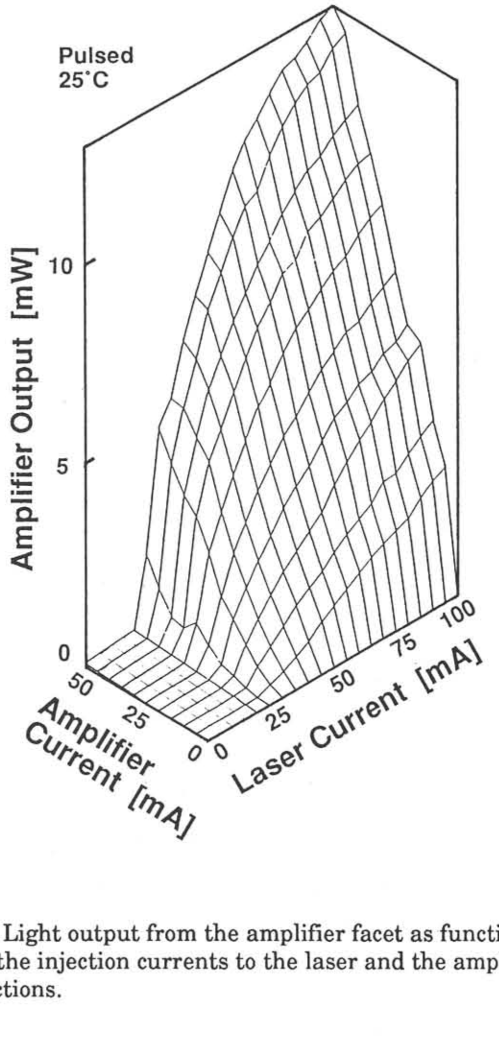

Fig.3 Light output from the amplifier facet as functions of the injection currents to the laser and the amplifier sections.

4. Characteristics

Light output from the amplifier facet was measured as functions of pulsed injection currents to the amplifier and the DFB laser, and plotted in Fig.3. The laser threshold is around 20mA. More than 10mW power is obtainable yet the linearity to the currents are gradually lost at the high power region because of the gain saturation in the amplifier.

Figure 3 can be re-written in terms of the amplifier optical gain as shown in Fig.4. The gain increases monotonously with increasing amplifier current. This is one of the indications suggesting very low reflectivity of the etched tilted facet.[4)] The maximum gain available here is around 13dB. This value can be enlarged if we detune the DFB lasing wavelength to the shorter side, or make the amplifier length longer.

One great advantage of this integrated device is that the laser can always be operated at a fixed appropriate injection level since the output power is adjustable through the amplifier. In our case the laser current was kept at 35mA (1mW power from the laser facet) in order to prevent the longitudinal spatial hole burning from exciting a satellite mode. The output power from the amplifier facet was able to be varied

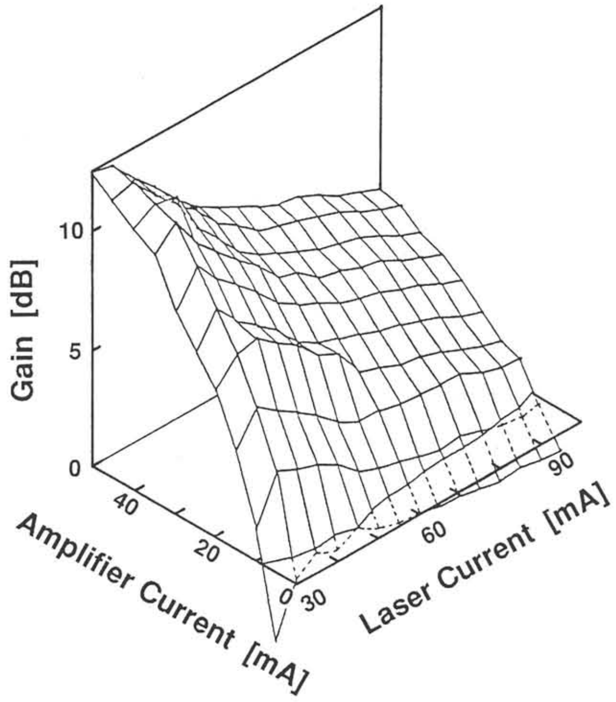

Fig. 4 Amplifier gain as functions of the injection currents to the laser and the amplifier sections.

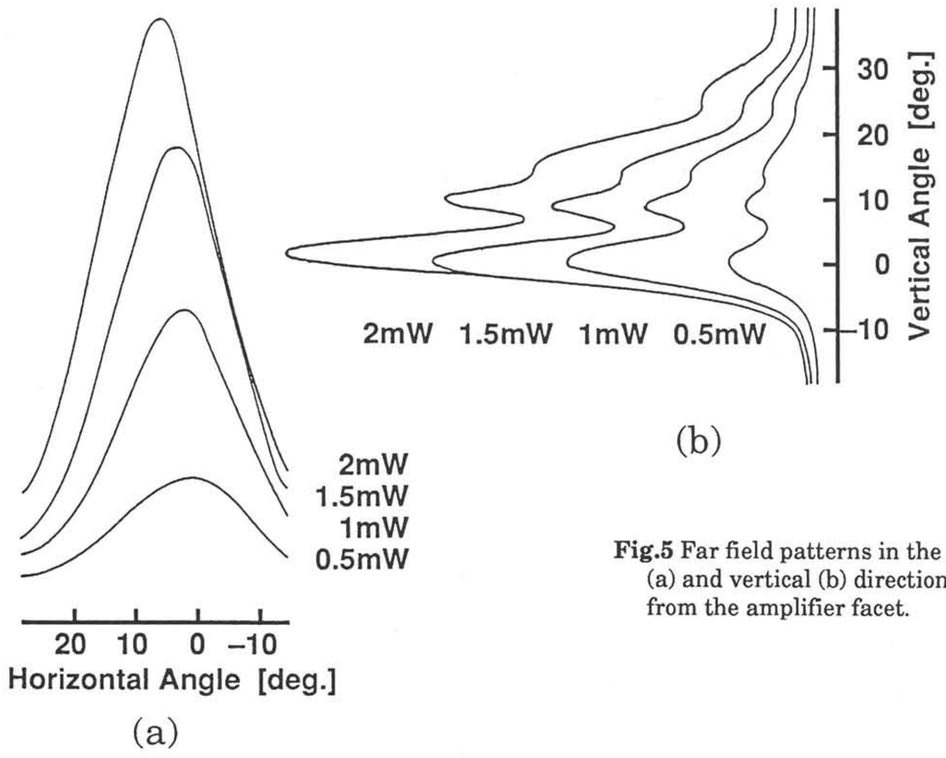

Fig.5 Far field patterns in the horizontal (a) and vertical (b) directions observed from the amplifier facet.

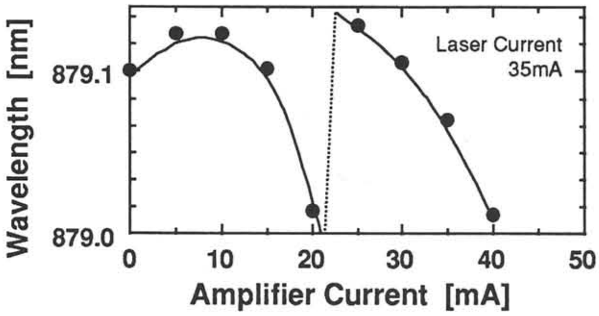

Fig.3 Lasing wavelength shift caused by the current injection to the amplifier.

from 0 to 10mW by changing the amplifier current from 0 to 50mA.

Horizontal and vertical far field patterns are shown in Figs.5(a) and (b). The patterns are almost symmetric in the horizontal direction, whereas those in the vertical direction are asymmetric and wavy. This is due to the projection of the substrate shown in Fig.1. It reflects a part of the emitted light upward to produce the interference-like far field pattern. This effect can be avoided if we take off the projection by further etching or if we take out the optical power using waveguides or fibers.

Next we estimated crosstalk property. Illustrated in Fig.6 is the lasing wavelength shift caused by current injection to the amplifier portion. The oscillation wavelength changes within a 0.12nm range, and a discontinuous transition occurs around 22mA. This crosstalk could be attributed to a combined effect of thermal, electrical, and optical interferences between the elemental devices. Among them the optical crosstalk component is expected to be reduced further by applying crude AR coatings on the tilted facets to eliminate the residual reflectivity.

5. Summary

We have fabricated an integrated DFB laser/amplifier with reactive-ion-etched tilted facets for the first time. Owing to the low reflectivity of the tilted etched facets, the two component devices operated almost independently. The lasing wavelength shift due to interaction was limited within 0.12nm. This approach of crosstalk suppression seems to fit in with monolithic integration of optical devices.

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