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Ultra High Speed GaInAsP/InP Self Aligned Constricted Mesa DFB Lasers Grown Entirely by MOCVD

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We have developed ultra high speed 1.5μm wavelength Self Aligned Constricted Mesa (SA-CM) distributed feedback lasers grown entirely by low pressure metalorganic chemical vapour deposition. A new self-aligning process was applied to these lasers. For high frequency response, the stray InP junction capacitance of the lasers was reduced to 1.6pF for 250μm cavity length. A record bandwidth of 13GHz in the 1.5μm wavelength lasers was achieved and 5Gbps NRZ operation was demonstrated.

Introduction

1.5μm wavelength DFB lasers with a modulation range over 10GHz are required for long haul multigigabit optical fiber communication systems. High performance GaInAsP/InP semiconductor lasers with high frequency response have been intensively studied[1)-8)]. Operation at above 10GHz was demonstrated using low capacitance 1.3μm wavelength constricted mesa lasers[1)-3)]. For optical fiber communication systems, however, single mode lasing, 1.5μm wavelength lasing and homogeneous characteristics are also important. Liquid phase epitaxial growth and time dependent processing techniques, such as side etching of the active layer and vapour phase or mass transport regrowth, should be replaced by other fabrication techniques to obtain controlled device dimensions.

We have developed ultra high speed 1.5μm wavelength Self Aligned Constricted Mesa (SA-CM) distributed feedback lasers grown entirely by low pressure metalorganic chemical vapour deposition (MOCVD). A new self-aligning process was applied to constricted mesa lasers. The controllability of the process was dramatically improved[8)]. A 3dB bandwidth of 13GHz was achieved, which is the widest value ever reported for 1.5μm wavelength DFB lasers.

Self Aligned Constricted Mesa Structure

For high frequency response, both electrical and optical confinement in a micro-active region is indispensable. Furthermore, the parasitic capacitance must be reduced to less than a few picofarads. The constricted mesa type laser structure[1)-3),7)] is considered to be one of the best designed structures for achieving the ultimate frequency response. We have developed a new self-aligning process and applied it to 1.5μm wavelength constricted mesa DFB lasers. A cross-sectional view of a SA-CM DFB laser is shown in Fig. 1. The active region width and thickness were 1.5μm and 0.1μm, respectively. The active region was buried by p-type InP (2μm width each).

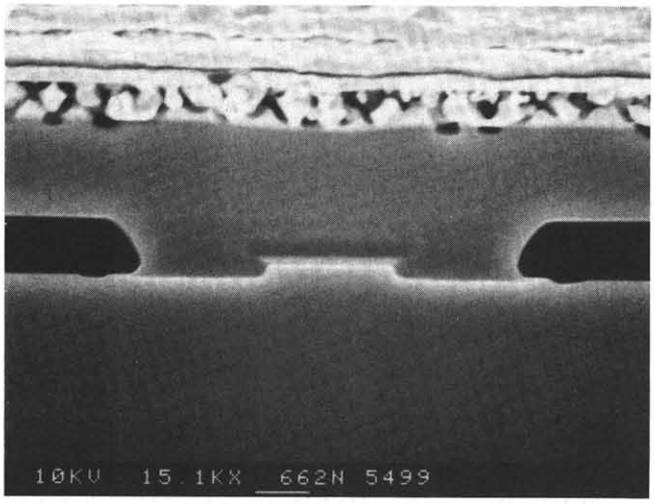

Fig. 1 A cross-sectional view of Self-Aligned Constricted Mesa (SA-CM) DFB laser

The controllability of the widths of the lateral confining InP regions was dramatically improved by the self-aligning process.

Self-Aligning Process

Figure 2 shows the fabrication procedure for SA-CM DFB lasers. All epitaxial growth was carried out by low pressure MOCVD. The layers were grown on a n-type (100) InP substrate using TMIn, TMGa, PH_3 and AsH_3 in a vertical quartz reactor. First, the 0.1μm thick GaInAsP active layer and a GaInAsP waveguide layer were grown on the n-type InP buffer layer. The first order gratings were fabricated on the waveguide layer using a holographic interferometer system. The GaInAsP active layer and the corrugated waveguide layer were patterned to define the burying regions (Fig. 2a). The active layer width and burying regions widths could be accurately set to designed values of 1.5μm and 2.0μm, respectively. Next, a p-type InP cladding layer and a p-type GaInAsP contact layer were successively over-grown on the structured wafer. Then a mesa was formed (Fig. 2b). Finally, selective undercut

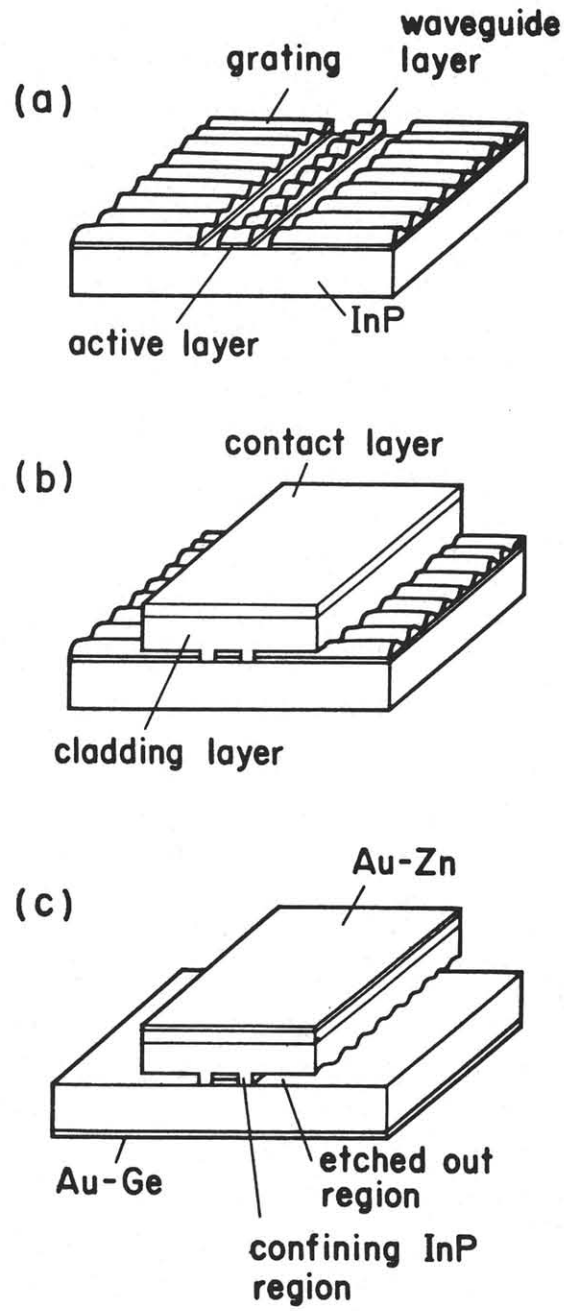

Fig. 2 The fabrication procedure for SA-CM lasers

etching of the side quaternary regions was performed using H_2SO_4:H_2O_2:H_2O etchant (Fig. 2c). The active region was protected by the burying InP regions from undercut etching.

After the self-aligning process, Au-Zn p-contact metal and Au-Ge n-contact metal were deposited on the contact layer and lapped InP substrate.

High-Speed Performance

For high frequency response, the parasitic capacitance must be reduced to less than a few picofarads[3]. Stray InP junction capacitance of the SA-CM DFB lasers was only 1.6pF for 250μm cavity length. The high frequency impedance of the SA-CM DFB lasers was measured using a HP8510A network analyser. Figure 3 shows the Smith chart plot of S_{11} input reflection coefficient for 0.045GHz - 20GHz frequencies. Inductance and resistance were determined to be 0.4nH and 4.2 ohm. The RC rolloff frequency was estimated to be in excess of 20GHz.

Direct high frequency modulation of the SA-CM DFB lasers was investigated using a HP8510A network analyser. As a light detector, a mesa pin photodiode with 13GHz bandwidth which was measured by an optical heterodyne method[9] was used. Small signal frequency responses for different output powers are shown in Fig. 4. A 3dB bandwidth of 13GHz (limited by the response of the photodetector) was obtained at an output power of 12mW. This is the widest value ever reported for 1.5μm wavelength DFB lasers. The laser was not limited by parasitics.

Pulse response of the SA-CM DFB lasers was measured using pulse pattern generator (Anritsu MP1601A) and sampling osciloscope (Tektronix 7904). Figure 5 shows a NRZ eye-pattern at 5Gbps. The wide opening of the eye was directly measured from the photo detector output.

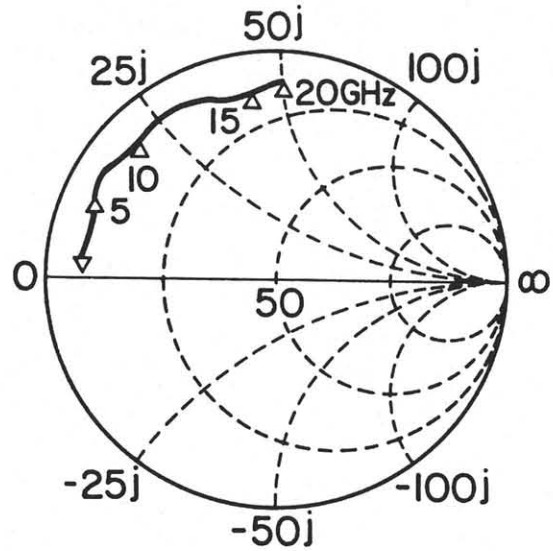

Fig. 3 The Smith chart plot of S_{11} input reflection coefficient

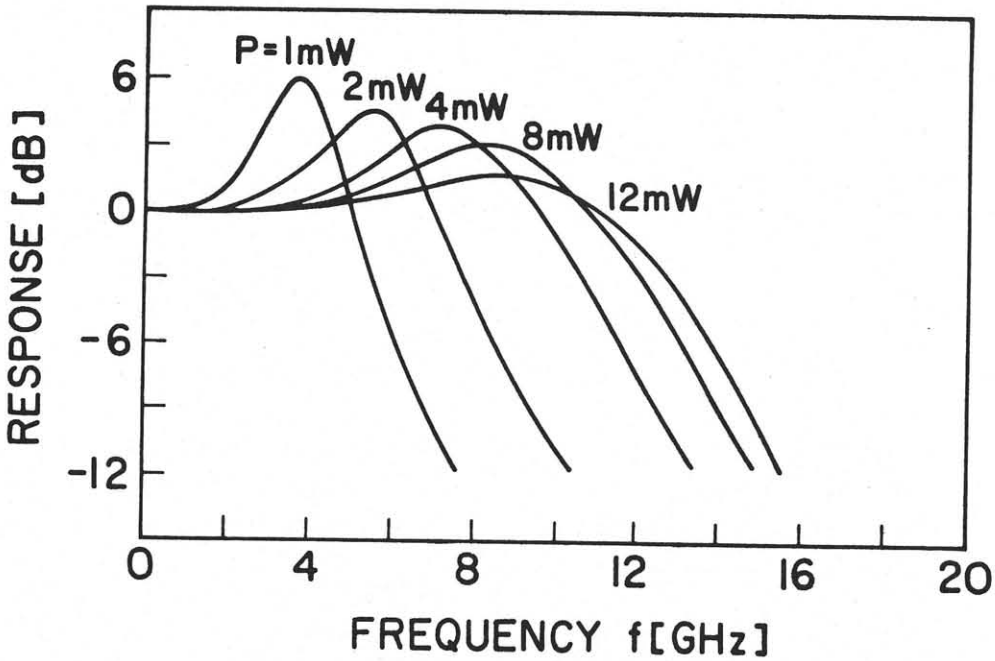

Fig. 4 Small signal frequency responses for different output powers

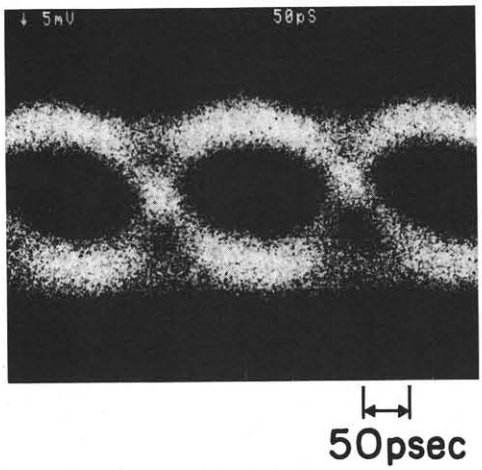

Fig. 5 A NRZ eye-pattern at 5Gbps

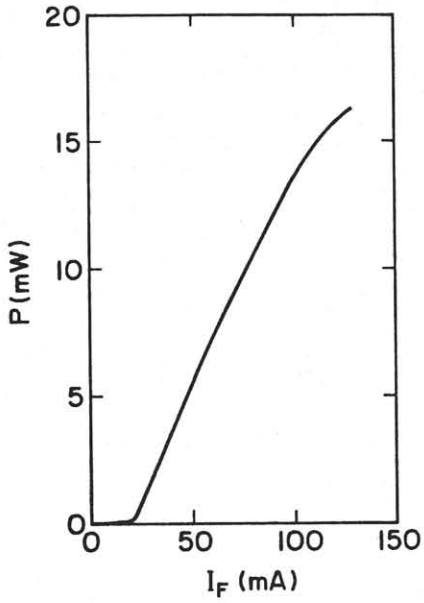

Fig. 6 I-L characteristic of SA-CM DFB laser

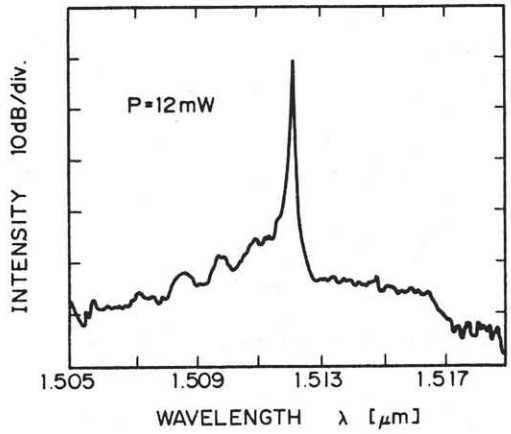

Fig. 7 Lasing spectrum of SA-CM DFB laser

Other lasing characteristics of the SA-CM DFB lasers were measured. The I-L characteristics is shown in Fig. 6. The typical threshold current and external differential quantum efficiency were 19.8mA and 21% per facet for 250μm cavity length at room temperature. Figure 7 shows a lasing spectrum at an output power of 12mW. The lasing wavelength was 1.51μm and the side mode suppression ratio was greater than 30dB.

Conclusion

MOCVD grown 1.5μm wavelength SA-CM DFB lasers with self-aligning micro structures were developed. A 3dB bandwidth of 13GHz was obtained and 5Gbps NRZ operation was demonstrated.

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