Monolithic Integration DFB Laser Array by Angling Active Stripe and Using Thin-Film Stripe Heater*

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Abstract: Multi-wavelength quantum well DFB laser array has been fabricated on an InP substrate by angling the active stripe at an oblique angle to the axis of the grating lines and coating a Pt/Ti thin-film heater to change the laser temperature. Owing to the oblique angle, four single-mode lasing wavelengths around 1.55μm were obtained simultaneously. By changing the working of the thin-film heater, the DFB laser can be tuned continuously beyond a range of 2.2nm with 3.8nm/W of tuning efficiency while maintaining a side-mode suppression ratio (SMSR) more than 30dB.

Key words: DFB laser; lasers array; thin-film heater; tunable laser; WDM

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1 Introduction

For high-capacity wavelength division multiplexing (WDM) in optical fiber transmission systems, multi-wavelength light sources are needed to be operated at precisely-determined wavelengths with a fine separation of 0.8 or 1.6nm. Increasing efforts have been put into developing such sources and making them compact, reliable and inexpensive[1—4]. Monolithic integration of DFB laser and electroabsorption modulotor have been reported[5—7], but few about DFB Laser array in China. A 0.8nm wavelength separation in 1.55μm DFB laser corresponds to the grating pitch difference of 0.13nm. It is quite difficult to change the grating pitch at a step of 0.1nm by holographic technique; and

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the fabrication of a phase mask for printing DFB laser grating is expensive. DFB laser array had been fabricated by changing the ridge waveguide width, but careful wet-chemical etching was needed. Though a nice pattern can be generated by electron beam lithography, the technique of accurate control down to steps of 0.1nm and the repeatability of the grating pitch are quite difficult, with long-time writing required.

In this paper, we adopted a simple technique to alter the lasing wavelengths of DFB laser array without fabricating different grating pitches. It is accomplished by angling the active stripe at an oblique angle to the grating line[5]. In order to compensate the fabricating errors, such as stripe angle, stripe width and so on, a thin-film heater is coated around the stripe[6,7], which can change the active stripe temperature at small input power, and then the DFB lasing wavelength can be tuned to the required wavelength.

2 Device Structure

The InGaAsP multi-quantum well (MQW) structure of the active region was grown by AIXTRON-200 low-pressure MOCVD, which contains six 6nm-thick 1% compress-strain InGaAsP(λ= 1.6μm) wells separated by 9nm-thick − 0.3% tensile-strain InGaAsP (λ= 1.2μm) barriers. The MQW structure was sandwiched symmetrically with SCH composing a 50nm InGaAsP (λ= 1.2μm) and a 100nm InGaAsP (λ= 1.1μm) layer.

Figure 1 is a schematic diagram of an active stripe tilted at an angle θ to the axis of the grating line. In order to achieve a four-wavelength laser array with 0.8nm spacing, the oblique angles were set as 0, 1.84, 2.6 and 3.19 degrees at different lasing wavelengths. The 1.5μm-wide active stripes were formed by wet-chemical etching after the first order grating had been fabricated by holography, reactive ion etching (RIE) and wet chemical etching. The period of the grating was 242nm and the etching depth 70nm. Then p-InP/n-InP buried layer and p^+-InGaAs contact layer were grown by LP-MOCVD.

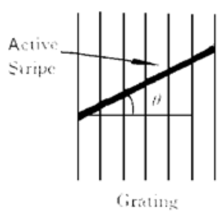

FIG. 1 Schematic Diagram of Arrangement of Active Stripe

The p-electrode was stripped by lift-off technique after the double channel near the active stripes and the isolation grooves had been formed by wet-chemical etching and a 0.2μm-thick SiO_2 been deposited by PECVD. Au film was then patterned in three areas: the high frequency electrode and two pads of the stripe thin-film heater. A 0.2μm-thick Ti and 0.04μm-thick Pt were then sputtered to serve as the thin-film heater near the active stripe, in order to avoid the increase of the parasitic capacitance. The film was stripped to 20μm in width by lift-off technique. The resistance of the heater was 17Ω.

Figure 2 is the schematic structure and the photograph of the array. The interval between the individual lasers in 250μm. The laser cavity is 300μm and both facets are just as being cleaved.

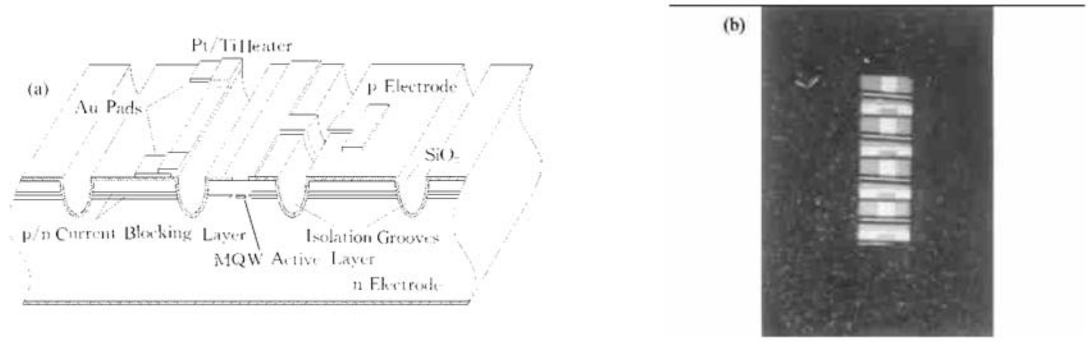

FIG. 2　Schematic Structure (a) and Photograph (b) of DFB Laser Array

3　Results and Discussion

The thresholds of the laser array components are 6—8mA, slope efficiency is from 0.146mW/mA to 0.152mW/mA, and series resistance is from 4.3Ω to 4.8Ω. The side mode suppression ratio (SMSR) are larger than 30dB for all array components. The spectrum parameters of the laser array are listed in Table 1.

Table 1　Spectrum Parameters of DFB Laser Array

Number	Angle/(°)	Wavelength at 1mW/μm	SMSR/dB	Wavelength at 8mW/μm	SMSR/dB
1	0	1.5572	30.0	1.5580	34.8
2	1.84	1.5593	38.0	1.5599	42.0
3	2.6	1.5606	34.0	1.5611	36.4
4	3.19	1.5637	34.0	1.5639	40.0

Square points and dot line from experimental and theoretical calculations in Fig. 3 plot the increase of DFB array lasing wavelength $\Delta\lambda_0$, from θ given to be 0, as a function of oblique angle θ, while a dash line from theoretical calculation also plots it as a function of increasing ΔΛ from the grating period Λ being 242nm. The results of theoretical calculation given by

$$\lambda_0 = \frac{2\Lambda N_{eff}}{m\cos\theta} \qquad (1)$$

In (1), N_{eff} is the effective reflective index of propagating mode in an active stripe and m is the grating order. In the calculation, a first-order grating m of 1 and an effective index

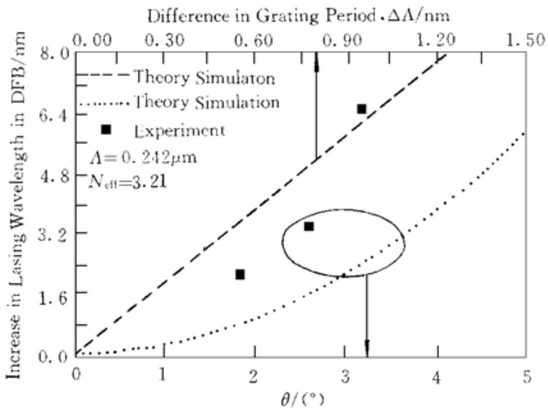

FIG. 3　Increase in Lasing Wavelength of DFB Laser Array Versus Grating Period (Dash Line) and Tilting Angle (Dot Line)

N_{eff} of 3. 21 are used. Comparing the dot line and the dash line, it is seen that because of the dependence of cosθ, wavelengths in WDM applications with a range of 2. 4nm and a 0. 8nm's separation can be controlled more easily by angling the stripe to less than 4° in angle-stripe DFB laser array than by fabricating a grating pitch difference of 0. 13nm, as has been calculated from (1).

There are some deviations between the experimental results and the theoretical calculation on increment of angle-stripe DFB laser array wavelengths at the angle in Fig. 3. It is by the material nonuniformity that the oblique angle errors in mask and especially, the different mesa widths are caused. The wet-chemical etching rate will be different on different crystal planes when the stripe are tilted at different angle. The wavelength variation of the stripe with different width was calculated by the effective reflective index methods, in the similar active structures and the same grating periods. For the active region width between 1. 2μm and 1. 8μm, the wavelength variation is 1. 94nm and will increase to 4. 35nm if the 1. 8μm active width is tilted 3. 19° and 1. 2μm one tilted 0°, as is a little larger than our experimental results 6. 5nm of wavelength variation in different angle-stripe DFB laser array components. In the calculation, the carrier induced index effect is omitted, which is an important method to alter the lasing wavelength and has been utilized in DFB laser array[4]. The stripe width uniformity can be improved by reactive ion etching, and the wavelength variation will fit the designed value.

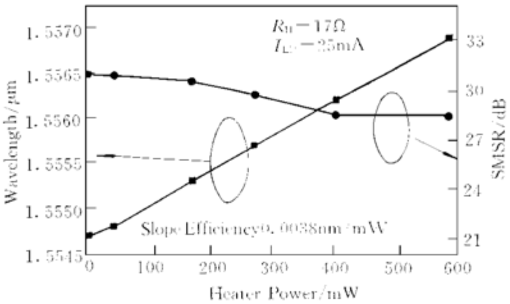

FIG. 4　Tuning (■) and SMSR (○) Characteristics of Tunable DFB Laser with Thin-Film Heater.

In order to compensate the fabricating errors in different components in angle-stripe DFB laser array, we use thin-film heater around the active stripe to tune the DFB laser wavelength. As the heater current increases, the active stripe temperature also increases and then the DFB lasing wavelength will shift to a longer wavelength. The tuning characteristics of the laser's wavelength are shown in Fig. 4 as a function of the input heater power. The wavelength continuously shift from 1554. 7nm to 1556. 9nm as the heater power increasing from 0 to 600mW and the SMSR of DFB laser is more than 28dB when the laser current keeps 20mA within the tuning range. The wavelength tuning efficiency of the laser is 3. 8nm/W and all the components of the DFB laser arrays can be used in 2. 5Gb/s system.

4　Conclusion

We have fabricated angle-stripe DFB laser array and the lasing wavelength can be tuned by a thin-film heater. The SMSR of the array is more than 30dB and the wavelength of the component can be continuously tuned 2.2nm by the thin-film heater. This device can be used in WDM system as a compact, reliable and inexpensive four-wavelength integrated source.

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