Widely Tunable Sampled-Grating DBR Laser *

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Abstract: The 3-section SG-DBR tunable laser is fabricated using an ion implantation quantum-well intermixing process. The over 30nm discontinuous tuning range is achieved with the SMRS greater than 30dB.

Key words: sampled-grating; distributed Bragg reflector laser; comb-like spectrum; wavelength tuning
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1 Introduction

Tunable lasers will be key components in future wavelength-division-multiplexing (WDM) transmission and photonic switching system. The classical tunable laser is the distributed bragg reflector (DBR) laser[1]. In this structure an integrated Bragg reflector performs the wavelength tuning selection. By current injection in the Bragg section the laser wavelength can be tuned. The tuning range of these lasers is normally in the order of 5~10nm[1,2], limited by the refractive index change caused by current injection ($\Delta\lambda/\lambda = \Gamma\Delta n/n$), where Γ accounts for the overlap of the optical mode with the region of index change, n is the refractive index in the Bragg section. $\Delta n/n$ is usually no more than 0.01. To achieve wider tuning range, several tunable laser structures were introduced[3], such as super-structure-grating (SSG) DBR laser[4], grating-assisted codirectional coupler (GACC) laser[5], grating coupler sampled reflector (GCSR) laser[6], sampled-grating DBR (SG-DBR) laser[7]. All of these structures can achieve tuning range of 40~60nm. The fabrication of GCSR laser is difficult, so it is hard to integrate with other components. The SSG-DBR laser needs expensive electron-beam etching grating technology. Sampled-grating DBR (SG-DBR) lasers are one of the most promising tunable lasers for WDM applications since they can provide both wide tuning range and high mode suppression ratio[7]. Moreover, the fabrication procedure is also relatively simple compared to other structures.

2 Tuning mechanism of SG-DBR

The sampled-grating is a conventional grating with grating elements removed in a periodic fashion. Figure 1 shows a schematic structure of sampled-grating. L_s is sampled period and L_g is the grating burst for each sampled period. Due to the sampling of the grating, the reflectivity of a SG reflector exhibits several peaks, regularly spaced around the main peak corresponding to the Bragg wavelength, as shown in Fig. 2. We call the reflectivity of the SG reflector comb-like spectrum. The peaks spacing of the comb-like spectrum is defined

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by the following relation: $p = \frac{\lambda^2}{2n_g L_s}$[7]. The main peak reflectivity is determined by the formula: $R = \tanh^2(\kappa L_G)$, κ denotes the coupling coefficient of grating, L_G is the total length of grating in one mirror. And the envelope of the reflective widens as the L_g/L_s is reduced. The reflectivity spectrum of the sampled-grating can be computed using transfer-matrix method[8].

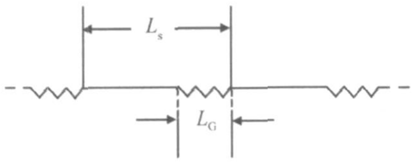

Fig. 1 Schematic structure of sampled grating

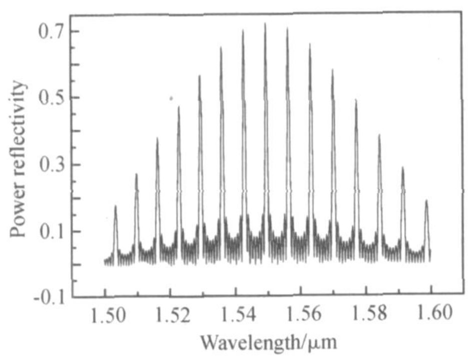

Fig. 2 Reflectivity of SG-DBR reflector

Figure 3 shows a schematic structure of our 3-section SG-DBR. The gain section is sandwiched by two SG-DBR mirrors. The two SG-DBR reflections are designed with slightly mismatch of peaks spacing, so that only one pair of reflective peak can be aligned. And lasing occurs at the pair of reflective peaks that are aligned. When a small index changes in one mirror, the adjacent reflective peaks will come into alignment. So the small index change causes a large mount lasing wavelength tuning. The tuning between the reflective peaks can be obtained by inducing identical index changes in the two mirrors.

The laser has three sections: a 400μm-long gain section and two sampled-grating mirrors, the back mirror contains ten 57μm sampling periods and the front mirror has six 55μm sampling periods, for both sampled periods $L_G = 7\mu m$. The peaks spacing in the front-SG is 6.804nm and 6.565nm for the rear-SG if the Bragg wavelength is 1550nm.

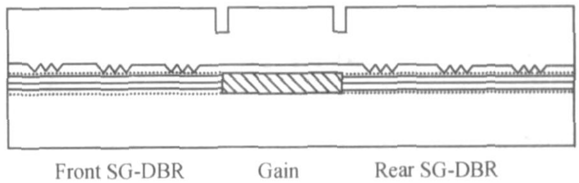

Fig. 3 Schematic structure of 3-section SG-DBR

3 Fabrication process

The fabrication involves two steps of MOVPE growth and an ion implantation induced disordering (IID) quantum well intermixing (QWI) process which blueshift the quantum well band edge to create nonabsorbing sections for the sampled-grating mirror[9,10].

The epitaxial base structure was grown on (100) oriented n-IP substrate using low pressure MOCVD. The active region is strained multi-quantum well structure, which is sandwiched by step separate confinement heterostructure (SCH) of 1.2Q and 1.1Q waveguide. Above the upper 1.1Q waveguide are a 120nm IP mask layer and a 300nm implant buffer layer.

The gain region was masked with 5μm of resist, and the ion implant was carried out using P^+ at an energy of 100keV with a dose of $5 \times 10^{14} cm^{-2}$. The implant buffer layer was designed to completely capture the ion implant, creating vacancies far from the active region. The vacancies were then diffused through the quantum well region during a 680 ℃ rapid thermal anneal (RTA), so the quantum well interfaces were smoothed causing an increase of quantized energy level in the well, due to a reduction of the As concentration in the well. A blue shift of 90nm was measured by room temperature photoluminescence. The implant buffer layer was then removed by wet etching leaving a planar surface.

The 120nm InP layer was used as sampling mask. After the holographic exposure, the sampled-grating mirrors were defined by reactive ion etching (RIE) and chemical etching, 80nm. Then the InP mask layer was etched away. Figure 4 is the SEM picture of the sampled-grating.

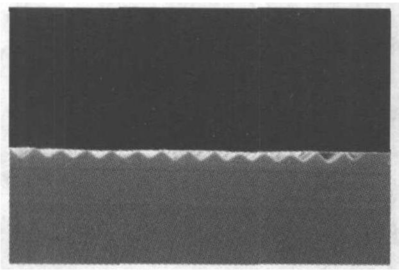

Fig. 4　SEM picture of sampled-grating

Then the ridge waveguide structure and electrode were performed after the p-type InP and the InGaAs contact layer regrowthing.

4　Results

Figure 5 is the *P-I* relationship of the SG-DBR laser. The threshold current is 37mA and the output optical power is about 9.5mW at 200mA driving current. The twisting of the curve dues to the mode hopping when the injecting current increases.

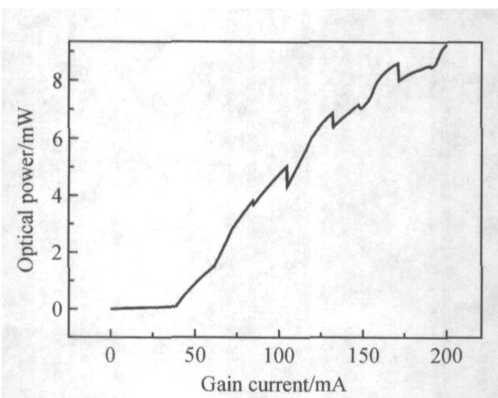

Fig. 5　*P-I* curve of the SG-DBR laser

Figure 6 shows the tuning range obtained by current injection in the back SG-reflector. The tuning range is above 30nm. The side mode suppression ratio maintains over 30dB. Figure 7 shows the superimposed spectrum of tuning range.

The wavelength tuning is discontinuous since the Bragg section is not optimized well. The injection causing index change is too small so that the comb-like spectrum shifting can not cover the peaks spacing. Furthermore, the phase section is indispensable for the quasi-continuous tuning of any DBR laser because the lasing occurs only when the cavity mode coincides with the reflectivity peaks.

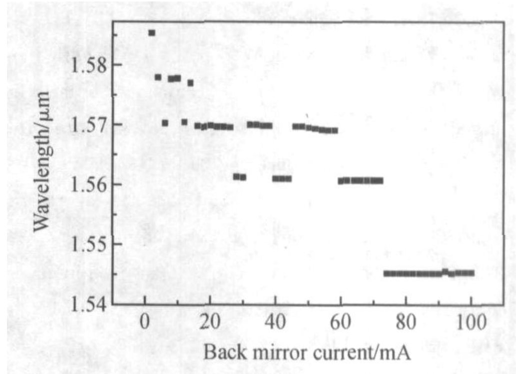

Fig. 6　Wavelength tuning with rear SG-reflector current

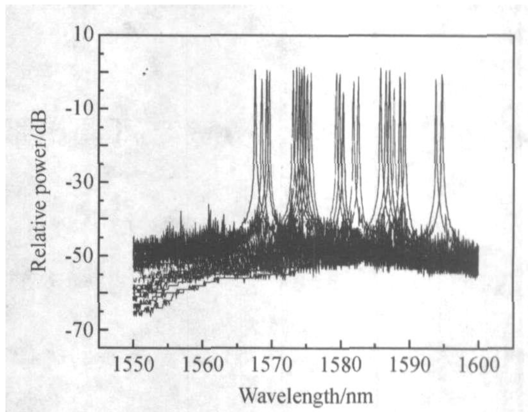

Fig. 7　Supperimposed spectra of 3-section SG-DBR laser

5　Conclusion

We apply implant-enhanced intermixing to fabricate the 3-section SG-DBR laser. The over 30nm discontinuous tuning range is achieved and the corresponding SMRS is greater than 30dB.

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宽带可调谐取样光栅 DBR 激光器 *

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摘要: 利用离子注入量子阱混杂技术,成功研制了三段取样光栅(SG)-DBR 激光器. 器件不连续调谐范围超过 30nm ,边模抑制比大于 30dB.

关键词: 取样光栅; 分布布拉格反射激光器; 梳装光谱; 波长调谐

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