Tunable Distributed Bragg Reflector Laser Fabricated by Bundle Integrated Guide*

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Abstract: The tunable BIG-RW distributed Bragg reflector lasers with two different coupling coefficient gratings are proposed and fabricated. The threshold current of the laser is 38mA and the output power is more than 8mW. The tunable range of the laser is 3.2nm and the side mode suppression ratio is more than 30dB. The variation of the output power within the tunable wavelength range is less than 0.3dB.

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1 Introduction

Wide tunable monolithic semiconductor laser is a key component for wavelength division multiplexed (WDM) networks and optical measurement systems. Due to the advantages inherent to the networks, a great number of different structures have been proposed in the literature during the last decade[1], such as the sampled grating (SG) structure[2,3], super structure grating (SSG)[4] etc. These structures have wide tunable range, while the SG laser and SSG laser own lower power and higher threshold current than those of distributed bragg reflector (DBR) or dictributed feed back (DFB) laser because of more interior loss. Some research groups reported their tunable lasers based on DBR, such as 17nm tuning range of France Telecom using three section DBR tunable laser[5], fabricated by the butt-jointed structure.

We proposed the tunable DBR lasers fabricated by bundle integrated guide (BIG), and by using the two different coupling coefficient(κ) DBR grating regions, and three steps of metal organic vapor phase epitaxy (MOVPE) growth. Tuning characteristic and the output power were measured with tuning Bragg grating current.

In this paper, we described the formation of the structure of BIG grown by three steps of MOVPE. The 3.2nm tunable range was at an output power of 6mW, and the output power was independent on the current of DBR during the tuning range. High side mode suppression ratio (SMSR>30dB) was achieved. The super performance was obtained by an ideal coupling between the active region and the passive DBR region by using the BIG technique.

2 DBR laser fabrication

Figure 1 shows the structure of a ridge waveguide DBR laser fabricated by using the BIG tech-

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nique, which includes three parts: active region(L_a = 300μm), low κ region(L_{b1}= 120μm), and high κ region(L_{b2}= 180μm).

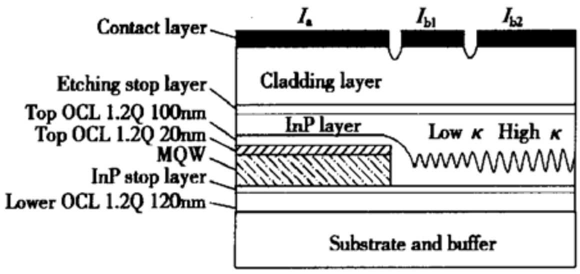

Fig. 1 Schematic diagram of DBR laser

The InGaAsP MQW structure contained six wells with 7nm thick and 1% compressive-strain InGaAsP(λ= 1.6μm). The wells were separated by the barriers with 10nm thick, − 0.8% tensile, and strain InGaAsP(λ= 1.15μm). The MQW structure was sandwiched with an undoped 100nm InGaAsP (λ= 1.20μm) lower OCL as well as an InP stop layer and an undoped 20nm InGaAsP(λ= 1.2μm) top OCL. The growth temperature was at 650℃ and the growth rate for InGaAsP was lower than 1.0μm/h by using LP-MOVPE.

The whole wafer was patterned selectively, wet-etched to InP stop layer, and then the 100nm InGaAsP(λ= 1.2μm) was grown onto the whole wafer, which was called BIG. The power coupling efficiency between the active and the passive guide region was around 95%, and the same material was used both waveguide and top OCL. While, butt-jointed DBR laser was using selective regrowth, and the material used as waveguide was not related to the top OCL material. Fabrication sequence for BIG DBR laser was easier than that for butt-jointed DBR laser. Two sections of a first-order grating with a different depth and a same 244nm period were formed on part of the wafer, in which the active region was removed by the selective etching. At last, a etching stop layer, a p-InP (N_d= 2×10^{18} cm^{-3}) cladding layer and a p^+-InGaAs(N_d= 1× $10^{19}cm^{-3}$) contact layer were grown on the whole wafer. The ridge waveguide structure and the electrode process were performed by standard techniques.

3 Results and discussion

The optical spectrum and P-I curve of DBR laser are shown in Fig. 2. The threshold current (I_a) of the device was 38mA. The output power was more than 8mW at 100mA. The tuning range of DBR laser was 3.2nm, and SMSR was more than 30dB during the current of rear Bragg grating (I_{b2}) turning from 0 to 10mA in the case of the current of front Bragg grating (I_{b1}) locking at 0.5mA, and the variation of output power was less than 0.3dB with the entire tuning range.

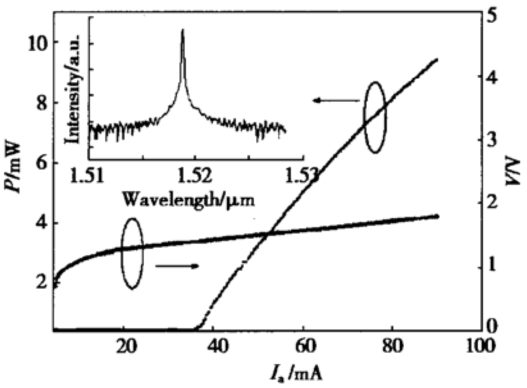

Fig. 2 P-I curve of tunable DBR LD

3.1 Tuning characteristics of DBR lasers

The tuning characteristics of this DBR laser were measured at different rear Bragg current (I_{b2}), while keeping a constant of the active driving current (I_a= 70mA) and the front Bragg grating region operation current (I_{b1} = 0.5mA). Figure 3 shows the main tuning range is the blue shift with the increase of the rear Bragg region current at 20mA. In this case, the tuning range is about 3.2nm blue shift, which is caused by the injected electron-hole plasma effect. However, when the current of rear Bragg is more than 20mA, the further increases of the carrier density is very difficult because of Auger recombination, and the further decrease of the effective index with increased carrier density are usually overshadowed by increasing thermal index shift, which is of opposite sign. That is why the red wavelength shift appeared when the I_{b2} is more than 20mA. In addition, from Fig. 1, the Bragg grating coupling coefficient of front grating is lower than that of rear one, which is the result of shallow and deep grating, respectively. Even though both current of front and rear Bragg grating contribute to the shift of the wavelength, the variation of the Bragg wavelength of rear grating region is found to be more sensitive with the injected carrier density compared with that of front grating. So, by tuning the current of front grating region, the jump of DBR mode can be adjusted more easily.

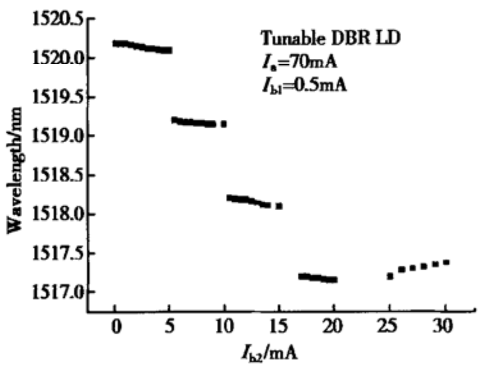

Fig. 3　Tuning characteristics of the tunable DBR laser with tuning current I_{b2}

3.2 Characteristics of SMSR

The SMSR is one of the most important characteristics of semiconductor laser, which is dependent on the current of DBR. In Fig. 4, the SMSR is more than 30dB over the whole tuning range at the output power 6mW, while locking I_{b1} at 0.5mA except for the mode jump regions. In Fig. 5, the SMSR is variable with I_{b1} when the currents of active region and I_{b2} are 70mA, 8mA separately. From Fig. 5, the maximum of SMSR is achieved by tuning the current of I_{b1}. The interval of mode jump is about 1.07nm, which is bigger than 0.8nm because of the smaller effective index grating.

3.3 Stable output power

The stable output power of tunable lasers is

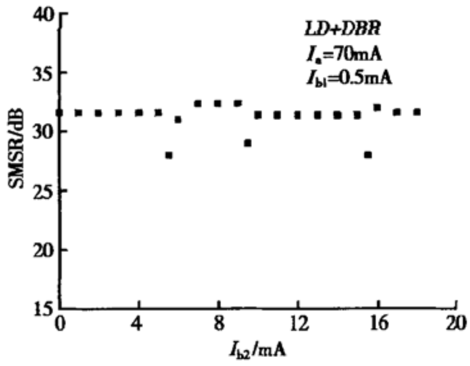

Fig. 4　SMSR curve of the DBR laser with Bragg grating current I_{b2}

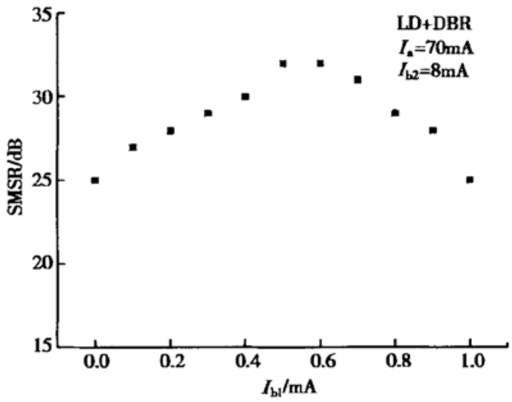

Fig. 5　SMSR curve of the DBR laser with Bragg grating current I_{b1}

an important factor in DWDM systems. In order to avoid the electric interference between active region and two Bragg grating regions, two isolation grooves are formed among active region. The typical resistance is 5kΩ between them. The isolated resistance will be increased to 30kΩ after the p^+-InGaAs contact layer is partially removed and multi-energy proton is selectively implanted in this region, which is sufficient to avoid current interference.

From Fig. 6, the output power is measured at I_a= 70mA, while locking the current of front Bragg grating region at 0.5mA and the current of rear grating region tuned from 0 to 16mA. The output power variation under this tuning range is about 0.3dB, and the stable output power is achieved.

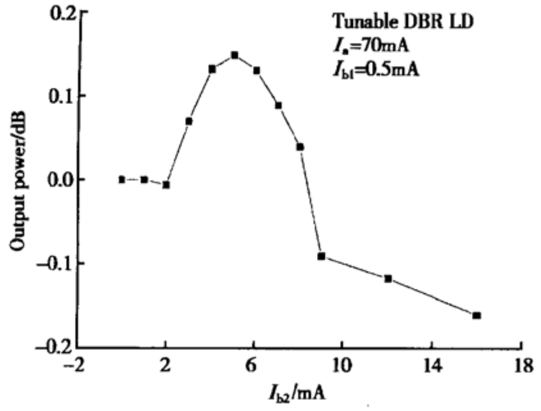

Fig. 6 Tunable DBR laser output power variation with Bragg current I_{b2}

4 Summary

A wavelength tunable laser with two different Bragg grating regions has been fabricated by the technique of BIG, which significantly improves the coupling efficiency between the active region and passive Bragg regions. It is verified that the wavelength tuning of the BIG-DBR laser can be achieved by controlling the Bragg regions current. The 3.2nm tunable wavelength range and four longitudinal modes with more than 30dB SMSR are realized. The variation of output power under the tuning range is about 0.3dB.

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BIG 结构的可调谐分布布拉格反射激光器*

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摘要: 提出并制作出一种可调谐 BIG-RW 结构的激光器, 该激光器包括两个不同耦合系数的 Bragg 光栅. 激光器的阈值电流为 38mA, 输出功率大于 8mW, 可调谐范围是 3.2nm, 边模抑制比(SMSR)大于 30dB, 在整个调谐范围内, 功率变化小于 0.3dB.

关键词: 可调谐激光器; DBR 激光器; BIG; 半导体激光器

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陆 羽 博士研究生, 主要从事采用 LP-MOCVD 生长多量子阱材料模拟优化 DBR 激光器、可调谐单模激光器光电子集成等工作.

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