Offset quantum-well method for tunable distributed Bragg reflector lasers and electro-absorption modulated distributed feedback lasers

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A two-section offset quantum-well structure tunable laser with a tuning range of 7 nm was fabricated using offset quantum-well method. The distributed Bragg reflector (DBR) was realized just by selectively wet etching the multiquantum-well (MQW) layer above the quaternary lower waveguide. A threshold current of 32 mA and an output power of 9 mW at 100 mA were achieved. Furthermore, with this offset structure method, a distributed feedback (DFB) laser was integrated with an electro-absorption modulator (EAM), which was capable of producing 20 dB of optical extinction.

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Tunable distributed Bragg reflector (DBR) lasers are essential components for future optical fiber communication systems[1]. A tunable laser can replace a large number of distributed feedback (DFB) lasers as sparing source in wavelength division multiplexing (WDM) systems. Moreover they allow flexible switching and routing for distributed data in future network[2].

There are several methods for integrating gain section with DBR section, such as butt-joint method, bundle method, and quantum-well intermixing (QWI) method[3−5]. However, both the bundle and butt-joint methods require re-growth for more than one time[3,4]. The QWI method generally requires ion implanting and annealing processes[5]. While the offset quantum-well method reported in this letter just requires one more time selective wet etching than ordinary DFB laser.

The lower waveguide of our tunable laser is a thick bulk material with narrow band-gap, which can also be used for electro-absorption modulator (EAM) due to the Franz-Keldysh (F-K) effect[6]. So an EAM integrated with the DFB laser is also reported in this letter[7,8].

The two devices have the same epitaxial structure. The lower waveguide is a 300-nm-thick, 1.43-μm wavelength quaternary (1.43Q) material with a band-gap of 0.87 eV. Above the lower waveguide is the multi-quantum-well (MQW) active layer. There is a 15-nm-thick InP etching-stop layer sandwiched between them.

The schematic structure of the tunable DBR laser is shown in Fig. 1. The gain section is 300 μm long, and 240 μm for the DBR section. The DBR mirror waveguide is acquired by selectively wet etching the MQW layer and upper waveguide of the epitaxial structure. The grating depth of the DBR is about 80 nm with about 90 cm^{-1} coupling coefficient. Then the ridge waveguide structure and electrode were formed after one more time growth of the P-type InP and the InGaAs contact layer. Figure 2 shows the P-I relationship of the DBR laser. The threshold current is 32 mA and the output optical power is about 9 mW at 100-mA driving current. The tuning characteristics of the DBR laser were measured

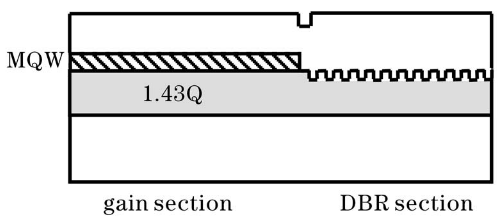

Fig. 1. Schematic structure of tunable DBR laser.

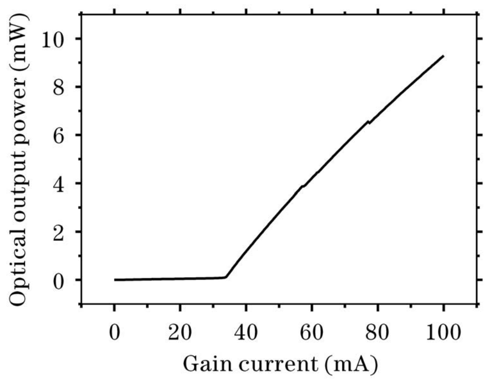

Fig. 2. P-I relationship of DBR.

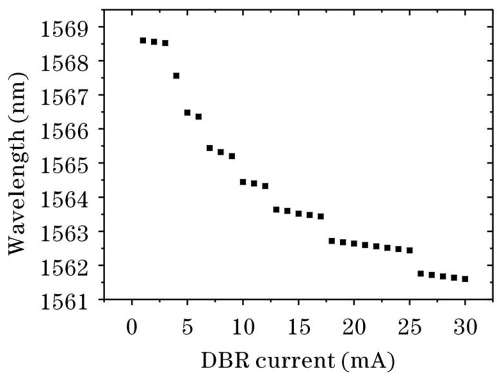

Fig. 3. Wavelength versus DBR current.

at a gain driving current of 80 mA. The tuning range of the DBR laser was shown in Fig. 3. The tuning range is about 7 nm of blue shift, which is mostly caused by the injected electron-hole plasma effect[9]. There is not phase section in the DBR laser, so the wavelength tuning is discontinuous. It is because that for some wavelength the cavity mode cannot coincide with the DBR reflectivity peak. The side mode suppression ratio (SMSR) is over 30 dB during the whole tuning range. In order to increase the tuning range, a thicker waveguide of the DBR region should be adopted,

$$\Delta\lambda/\lambda = \Gamma\Delta n/n, \tag{1}$$

where Γ accounts for the overlap of the optical mode with the region of index change, and $\Delta n/n$ is determined by the waveguide layer and doping condition. However, there is a trade-off between tuning range and other lasing performance. An EAM integrated with a DFB laser (EML) is fabricated with the similar process, as shown in Fig. 4. The EAM section is 240 μm long. The MQW layer and upper waveguide of the EAM region were etched away. When appling the reverse bias voltage, the absorption of EAM is induced by the F-K effect of the 1.43Q bulk material layer. The lasing wavelength of the EML is 1560 nm and the threshold is 28 mA. Figure 5 shows the spectrum of EML. The extinction ratio of

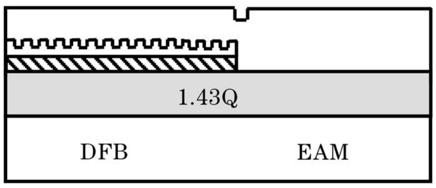

Fig. 4. Schematic structure of EML.

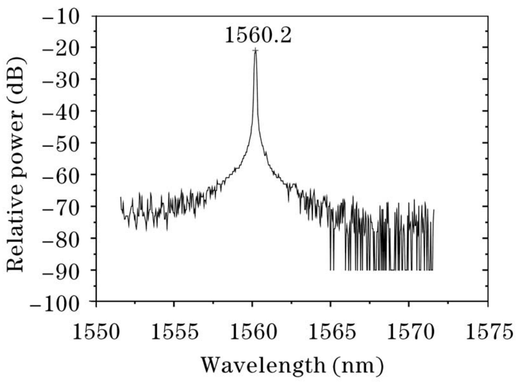

Fig. 5. Spectrum of EML.

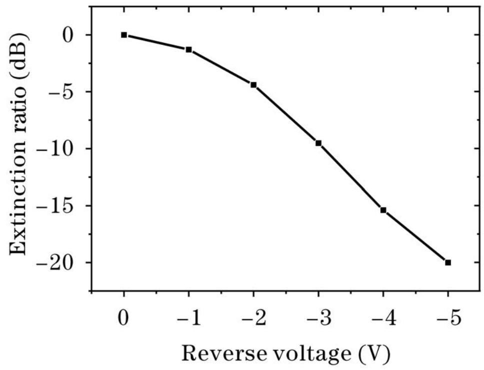

Fig. 6. Extinction ratio versus reverse voltage.

the modulator as a function of reverse bias voltage is shown in Fig. 6. When applying a reverse bias voltage of 5.0 V, a 20-dB extinction ratio was obtained.

In conclusion, this letter demonstrated a tunable laser and an EAM integrated with a DFB laser using the same epitaxial structure. The fabrication process is comparatively easy. For this tunable laser, a 7-nm tuning range is achieved with a SMSR greater than 30 dB. The EAM can provide 20-dB extinction ratio at 5-V reverse voltage.

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