# A double wavelength DFB laser with an identical active area for CWDM

**Hongyun Xie (谢红云), Wei Wang (王 圩), Fan Zhou (周 帆),**
**Jing Bian (边 静), Baojun Wang (王宝军), and Lufeng Wang (王鲁丰)**

*State Key Laboratory on Integrated Optoelectronics, Institute of Semiconductors,*
*Chinese Academy of Sciences, Beijing 100083*

Received October 25, 2004

A novel distribute feedback (DFB) laser which gave two different wavelengths under two distinct work conditions was fabricated. The laser consists of two Bragg gratings with different periods corresponding to wavelength spacing of 20 nm in an identical active area. When driving current was injected into one of the different sections separately, two different wavelengths at 1542.4 and 1562.5 nm were realized. The side mode suppression ratio (SMSR) of 45 dB or more both for the two Bragg wavelengths were achieved. The fabricating process of the laser was just the same as that of traditional DFB laser diode. This device can be potentially used in coarse wavelength division multiplexer (CWDM) as a promising light source and the technology idea can be used to enlarge the transmission capacity in metro area network (MAN).

*OCIS codes:* 140.0140, 130.3120, 060.0060.

Coarse wavelength division multiplexer (CWDM) is a kind of multiplexing used in wideband fiber optic communication system. The channel spacing of 20 nm was standardized by ITU-T (International Telecommunication Union) according to ITU-T G.694.2 spanning for the S-, C-, and L-band (1270—1610 nm)[1]. The initial requirement for devices used in CWDM is low cost and simplicity. Multiple distribute feedback (DFB) laser modules in parallel or varied Bragg grating in DFB laser array were fabricated to realize the multiple wavelengths light source. However DFB laser module in parallel requires a complex fabricating process[2], e-beam writing to realize varied Bragg grating is expensive. A novel and simple approach was presented in this paper to achieve multiple wavelengths in one DFB laser diode. The new device includes two Bragg gratings in series possessing different periods fabricated by the modified holographic exposure. At present, the device realizes lasing distinctly at 1542.4 and 1562.5 nm.

For DFB laser, the Bragg wavelength depending on the structure parameters of grating (for the first-order structure)[4] is

$$\lambda_{\mathrm{B}} = 2n'_{\mathrm{eff}}\Lambda, \tag{1}$$

where $\lambda_{\mathrm{B}}$ is the Bragg wavelength in free space, $n'_{\mathrm{eff}}$ represents the real part of the effective refractive index of the waveguide structure without the grating, $\Lambda$ is the period of the grating structure. Changing one of the values of $n'_{\mathrm{eff}}$ and $\Lambda$ or changing them simultaneously provides the way of acquiring two distinct wavelengths in one laser diode. To realize different lasing wavelengths in one DFB laser active area, we prefer changing the Bragg grating period, which is only relevant to the grating fabrication. In the other hand, an excellent single-mode performance and equal power level for the different wavelengths are highly demand for light source used in CWDM[5]. The DFB laser should, at first, meet the two demands mentioned above. Two factors, one is the single-mode performance, including the reduction of the serial interaction between the element lasers, and the other is to acquire equal power level of the two element lasers, were considered during the design. A way of modifying the Bragg grating and modifying the laser structure of the traditional DFB laser by the modified holographic exposure was chosen to realize those purposes.

The modified holographic exposure included four steps. Firstly, the area for first grating with period A was defined while the remaining area for second grating with period B was protected with InP. Secondly, the first grating was fabricated in relevant area by the traditional holographic exposure. Then polyimide was used to protect the first grating and the area for the second grating was defined. Last, the second grating was realized in relevant area also by the traditional holographic exposure.

The DFB laser was fabricated on InP substrate. As shown in Fig. 1, the InP buffer layer, the lower waveguide layer of InGaAsP ($\lambda_{\mathrm{PL}}$ = 1200 nm, 120-nm thickness), and the thin (about 60 – 70nm) bulk InGaAs active layer were grown by low pressure metal organic vapor phase epitaxy (MOVPE) at 665 °C successfully. The thin bulk active layer possesses a certain tensile strain to ensure a broad gain spectrum band (about 108 nm) and the central wavelength was fixed at 1570 nm[6]. The upper waveguide layer is same as the lower one, which provides the symmetrical and fine optical confinement to laser diodes. We assemble the DFB laser on the identical buffer layer, lower waveguide layer, and active layer. The varied Bragg gratings are fabricated in the upper waveguide layer by the modified holographic exposure. After fabricating the two varied gratings, the InP cladding layer and the InGaAs contact layer were grown in the second step epitaxy. At last, the ridge etching, ion implantation, sputtering p-electrode (Ti/Pt/Au), and vaporizing n-electrode (Au/Ge/Ni) were completed successfully. Figure 2 depicts the whole device structure. The ridge width of the laser array is about 2 $\mu$m. The total device length is about 500 $\mu$m and each laser section is 250 $\mu$m. For the device, the excellent electrical and optical separations are necessary between the two sections to keep the steady single-mode output of each one. He$^+$ ion implanted into the isolation part of 50 $\mu$m between the two sections and the independent electrode contributes to the electrical separation, while the optical separation benefits from the anti-reflection (AR) coating in the front and back facets. The front section of the device has the shorter period corresponding to the shorter wavelength; the other grating possessing longer periods is fabricated in the rear section lases at the longer wavelength. Figure 3 shows the sweep electron microscope (SEM) of the two Bragg gratings with different periods.

Here, please note that the arrangement of those two Bragg gratings was adopted to achieve excellent single-mode performance and qui-equal light power level. When the rear section was lased at the longer wavelength and large amount of photos transmitted the front section and then emitted from the front facet, the energy of each photo was lower than that of the shorter wavelength of the front Bragg grating. Thus, the suppression of lasing action in the front section was achieved. So single-mode performance was ensured by this arrangement. However, at the same time, the strong absorption loss of this 250-$\mu$m front section was not avoided. As a result, the threshold current, the light power, and the efficiency of the rear section were affected seriously. So the $\lambda_{\mathrm{PL}}$ of the material was fixed at 1570 nm to make the rear section acquire larger gain, and the device can work under normal condition.

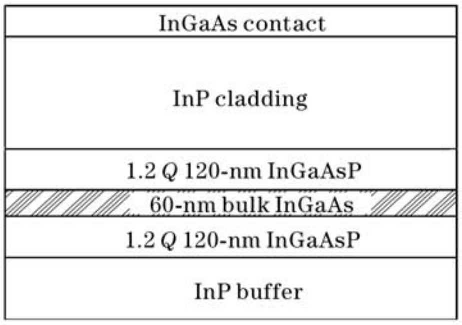

Fig. 1. The material structure of the DFB laser diode.

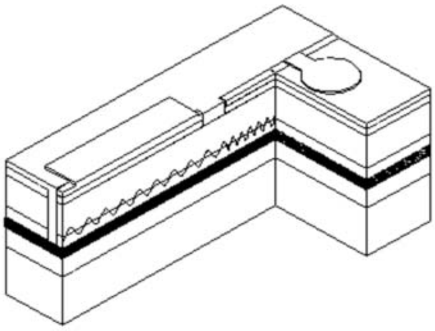

Fig. 2. The whole device with different gratings possessing varied periods.

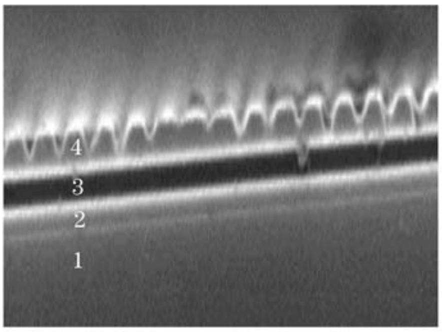

Fig. 3. The SEM of the Bragg grating in the device. 1: the buffer layer, 2: the lower waveguide layer, 3: the active layer, 4: the upper waveguide layer.

In measurement, we bias the front section of the device and leave the rear section unbiased at first. Figures 4(a) and (b) show the $P$-$I$ graph and the lasing spectrum for the front section, in which the grating period is shorter than that of rear one. The lasing wavelength is 1542.4 nm and the side mode suppression ratio (SMSR) of the DFB laser diode reaches to 45 dB. Figure 5(a) depicts the $P$-$I$ curve of the rear DFB laser when varying the injected currents of 0, 20, 30, and 40 mA in the front section of the device, respectively. From Fig. 5(a), we can find that when the injected current was lower than or just equal to the threshold current of the front section, it can be used as a semiconductor optical amplifier (SOA) to amplify the light coming from the rear section. However, because of the absorption loss, the threshold current and the light power were still worse than those of the front section. The lasing spectrum of the rear laser is shown in Fig. 5(b), the wavelength is at 1562.5 nm and the SMSR is up to 45 dB. The standard channel spacing of 20 nm of CWDM was achieved in this device when considering the wavelength tolerance of ±3 nm according to ITU-T G.694.2.

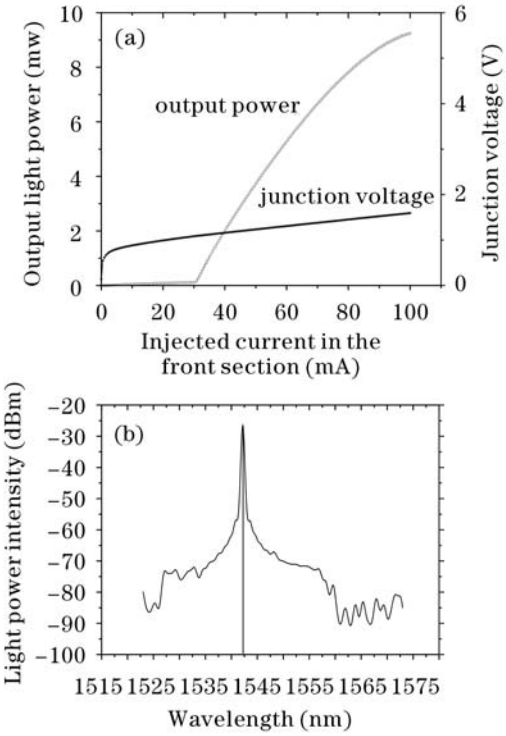

Fig. 4. (a) $P$-$I$ graph of the front DFB laser with shorter wavelength; (b) the lasing spectrum of the front DFB laser with shorter wavelength, peak wavelength $\lambda_{\mathrm{p}} = 1542.4$ nm.

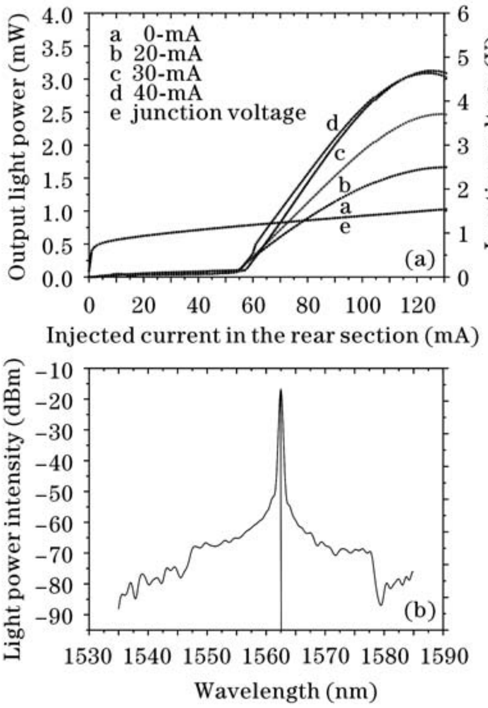

Fig. 5. (a) *P-I* graph of the rear DFB laser with longer wavelength under different injected currents in the front section; (b) the lasing spectrum of the rear DFB laser with longer wavelength, peak wavelength $\lambda_p = 1562.5$ nm.

In conclusion, we have designed and fabricated a novel DFB laser with two Bragg gratings in the identical active area. A modified optical holographic exposure was employed to fabricate the two different period gratings in the identical waveguide layer. Two stable distinct single longitudinal modes of 1542.4 and 1562.5 nm with SMSR of 45 dB were realized when the independent current was injected into the front and rear sections of the device, respectively. The fabricating processing of the laser array is as simple as that of the traditional DFB laser diode. The excellent performance of the device such as the stable output power and high SMSR single-mode of each Bragg grating, can ensure it to be potentially used in the CWDM communication system. The technique for realizing the DFB laser provides a foundation for fabricating the more complicated matrix laser array and other optical integrated devices.

This work was supported by National “973” Project of China (No. G20000683-1), the National Natural Science Foundation of China (No. 90401025), and the National “863” Program of China (No. 2002AA312150). H. Xie’s e-mail address is hyxie@red.semi.ac.cn.

## References

1. R. Lauder and R. Halgren, “Key applications for CWDM in the metro network” http://lw.pennnet.com.
2. S.-W. Ryu, S.-B. Kim, J.-S. Sim, and J. Kim, in *Proceedings of OFC2002* ThGG84 (2002).
3. S. Kim, Y. Chung, S.-H. Oh, and M.-H. Park, IEEE Photon. Technol. Lett. **16,** 15 (2004).
4. M.-C. Amann and J. Buus, *Tunable Laser Diodes* (Artech House, Boston, London, 1998) p.41.
5. J. Hong, H. Kim, F. Shepherd, C. Rogers, B. Baulcomb, and S. Clements, IEEE Photon. Technol. Lett. **11,** 515 (1999).
6. S. Wang, H. Zhu, Z. Liu, R. Zhang, Y. Ding, L. Zhao, F. Zhou, J. Bian, L. Wang, and W. Wang, Chin. Opt. Lett. **2,** 359 (2004).