Applied Mechanics and Materials Vols. 284-287 (2013) pp 2593-2597
© (2013) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.284-287.2593

Analysis, Selection and Control of Optimal Driving Current Combinations in Wavelength Switching for DBR Lasers

Hsien-Wei Tseng[1,a], Yang-Han Lee[2,b], Chih-Yuan Lo [2,c], Chao-Chung Huang [2,d], Ming-Hsueh Chuang[3,e], and Yih-Guang Jan[2,f]

[1] Department of Computer and Communication Engineering, De Lin Institute of Technology, Tucheng District, New Taipe City, Taiwan, 23656, R. O. C.

[2] Tamkang University, Department of Electrical Engineering, Tamsui, District, New Taipe City, Taiwan,25137, R.O.C.

[3] Dept. of Electronic Engineering, National Taiwan University of Science and Technology, Taiwan.

[a]hsienwei.tseng@gmail.com, [b]yhlee@ee.tku.edu.tw, [c]lo.billman@gmail.com, [d]huacc121@gmail.com, [e]a67828@gmail.com, [f]yihjan@mail.tku.edu.tw

Keywords: Distributed Bragg Reflector Laser (DBR laser), Dense Wavelength Division Multiplexing (DWDM).

Abstract. In this paper we exploit a basic type of three-stage Distributed Bragg Reflector (DBR) laser that by adjusting its input driving currents in the tri-electrode to generate signals with wavelengths that are in the International Telecommunication Union (ITU)-Band. Many driving current combinations can generate the same ITU wavelength; we will consider in this paper the situation when the input currents are restricted within certain range and to find for all those input current combinations that generate output signals with wavelengths locating in the ITU defined wavelength range. And we will through simulations to determine which set of current combinations will generate the shortest switching time. We will also propose a new current control method, when we know in advance the signal will be switched to certain band, to determine the best current switching combinations that resulting in faster and shorter switching time than that of the conventional system structure which has the drawback that it has only one fixed current combinations for each channel.

Introduction

It used light emitting diode (LED) as the transmitter module in the early stage of optic fiber communication system and it has been replaced by laser diodes. With laser source it has the characteristics of coherent and monochromatic; it has relatively low chromatic dispersion than the LED when it passes through the optic fiber and consequently it can transmit longer distance in optic fiber to make it as the choice of the light source in optic fiber communication system.

It can, by using multiplexing technique, simultaneously transmit many signals in one channel with the purpose of increasing the transmission rate. In Wavelength Division Multiplexing development it allows to simultaneously transmit many different wavelengths signals in the same optic filer to improve extremely the wideband characteristic of optic fiber [1]. The introduction and successful application of Erbium Doped Fiber Amplifier (EDFA) make it a breakthrough in the development of optic fiber communication system. It can be classified into two classes in wavelength division multiplexing, namely, the Coarse Wavelength Division Multiplexing (CWDM) and Dense Wavelength Division Multiplexing (DWDM). In CWDM system it multiplexes four wavelengths of 2.5 Gbps with wavelength separation of 20 nm to generate an output signal with a capacity of 1 Gbps, while in DWDM the separation of wavelength can be less than 1nm and it divides the 1550 nm wavelength into many wavelength segments and consequently in the same bandwidth it can multiplex more channel bandwidths and transmit more signals to increase its transmission rate from 2.5 Gbps to tens of Gbps or even hundreds of Gbps and effectively improves the communication capacity of optic fiber communication system.

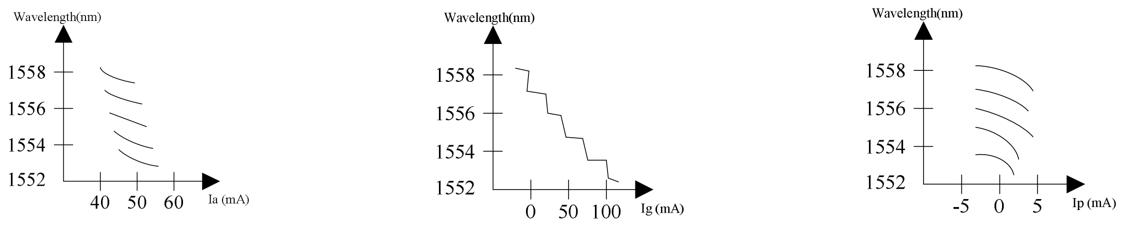
Relative to CWDM, DWDM has larger transmission capacity and when it transmits many signals simultaneously it needs the separation of less than 1 nm between channels and it also has a stringent requirement in the wavelength stability. Although it has many studies covering the methodologies of how to maintain wavelength stability in optic fiber communication system [2], it will be more effective by reducing the subsequent procedures in the wavelength stability operation if we can improve the output wavelength stability of the laser source; consequently we need a tunable laser with accurate and stable wavelength [3]. From technique point of view the Distributed Feed-back (DFB) Laser and Distributed Bragg Reflector (DBR) laser are the most matured laser fabrication processes [4-7]. It uses thermal modulation method to tune the laser bandwidth in DFB laser and because it has longer modulation time and shorter tunable bandwidth range; it usually makes DBR laser as the selected laser source for optic fiber communication system.

It uses current modulation to adjust the output laser wavelength in DBR laser, we propose in this paper a new method to control the input current in DBR laser to improve the drawback of the conventional wavelength adjustment method to effectively attain the optimization of the wavelength switching process.

Basic Characteristics of DBR Laser

From the discussion of three-stage DBR Laser in the above, each electrode current has its own function, the input current Ia of the Active Region provides the gain for the output laser power but in reality when the current Ia varies it will generate temperature gradient that resulting in the variation of the output laser wavelength. If we control the input currents of the three-stage DBR Laser; such as adjusting one electrode current and holding the other two electrodes currents the variation of the wavelength will be discontinuous. When we adjust the current Ig then the output laser wavelength will be changed in a step form, the output wavelength continuously varies in a small wavelength segment and then jumps to another continuous band. By only adjusting Ia (fix Ip and Ig) or Ip (fix Ia and Ig) it will have the same result as the wavelength changes in a short continuous interval and then jumps to another level. Generally speaking the wavelength can only continuously change for less than 1 nm by adjusting one electrode current, while by adjusting Ip and Ig the wavelength can continuously change over 3 nm and the discontinuous wavelength change can reach 5.8 nm as shown in Fig. 1.

From various theoretical studies and experimental tests it can increase the wavelength variation range for the three-stage DBR Laser around the 1550 nm band. From theoretical studies it reveals that for DBR Laser the continuous wavelength can change over 4nm range while for discontinuous wavelength change it can be around 10 nm [8]



(a) Fix Ip and Ig to Adjust Ia (b) Fix Ia and Ip to Adjust Ig (c) Fix Ia and Ig to Adjust Ip

Fig. 1 The Result of Fixing Two Electrodes Currents and Adjusting One Electrode Current in Three-stage DBR Laser.

Simulation Structure and the Analysis of Current Combinations

Current Sweeping Simulation

After the intrinsic physical parameters have been determined for DBR Laser, the functional block diagram for simulation is proposed. As shown in Fig. 2 it is from right to left are the Grating Region, the Phase Region and the Active Region and the input currents Ig, Ip and Ia are injected into the regions respectively.

The current Ia in the Active Region is fixed at 40 mA and since the Grating Region current Ig makes the wavelength varying in a wider range, we will gradually increase the current Ig and then fix it to observe how the wavelength varies when Ip is gradually increasing.

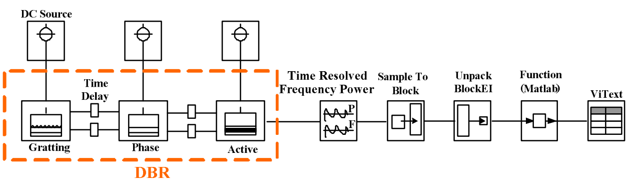


Fig. 2 The Simulation Functional Block Diagram of Current Sweeping.

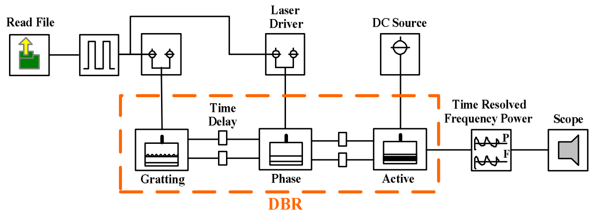


Fig. 3 The Simulation Functional Block Diagram for Wavelength Switching.

The Switching Simulation of Current Combinations

From the resulting current combinations (Ig and Ip), we will perform the simulations of the channel switching time when one current combination is switched from one channel into another current combination for another channel with the purpose of finding the switching time required and their steady state behavior, the simulation has the functional block diagram as shown in Fig. 3.

We then measure the required switching time when one current combination is switched into another current combination, as shown in Fig. 4 is the sample simulation when one current combination in CH1 is switched into CH3. In the calculation of the switching time it starts from the transformation time of the driving current until the wavelength is completely jumping into the range of the CH3 wavelength $\pm$0.02nm and this time, 51.2 ns, is the switching time of switching from CH1 to CH3. Different current combinations have different switching times even they are switched from the same CH1 to CH3.

The Optimization of Wavelength Switching

In the previous section we discussed the conventional method in the selection and the determination of current combinations. It selects a fixed current combinations Ig and Ip for each channel. But in this method of selection it has a problem in the switching from CH1 to CH4, as shown in Fig. 5, the best current combinations of Ig and Ip, is A1 switching to D1 but when switching from A1 to CH3 the current combinations selected by using the conventional method is not the best current combinations when it switches from CH1 to CH3, in other words the best current combinations switching from CH1 to CH3 is not A1 switching to C1 (for example it might be A2 switching to C2). And by the same reason the best current combinations is not necessarily D1 switching to B1 (for example it might be D2 switching to B2).

The Optimal Control Method in the Wavelength Switching

As described in the above section it appears that when it switches CH1 to CH2 the best current combinations is A1 switching to B1 but the reverse is not true the best current combinations is not B1 to A1 when CH2 is switched to CH1. In order to impair this situation in the reverse operation we increase the number of current combinations for each channel and by proper control of the current combinations to attain the possibility of effectively reducing the channel switching time.

From the simulation results as described in Section 3.1 and for easy in the following demonstration we select five sets of current combinations for each channel, as shown in Table 1.

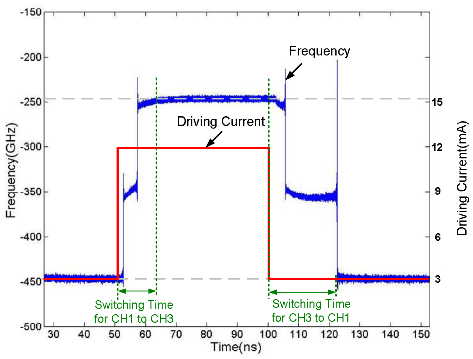


Fig. 4 The Simulation Result of Wavelength Switching from CH1 to CH 3.

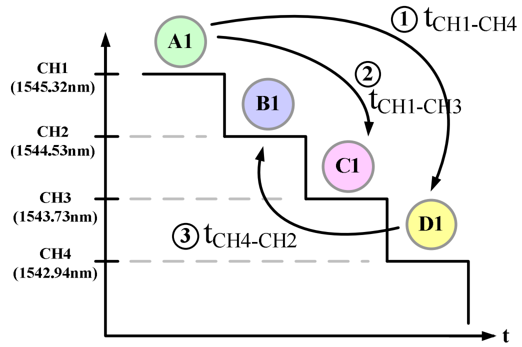


Fig. 5 The Illustration of the Selection of Current Combinations in Wavelength Switching in the Conventional Method.

Table. 1. The Current Combinations Generating ITU Band Channels

(Set)	Ig (mA)	Ip (mA)	Wavelength(nm)
CH1(1545.32nm)			
A1	2.6	5.2	1545.32569
A2	2.8	2.4	1545.32798
A3	3	5.2	1545.32205
A4	3.6	5	1545.32604
A5	4.4	8.6	1545.32133
CH2(1544.53nm)			
B1	4.8	5.4	1544.53517
B2	5	5.4	1544.53461
B3	5.2	5.4	1544.53215
B4	6	5.2	1544.53769
B5	6.2	5.2	1544.53164
CH3(1543.73nm)			
C1	8.2	9.4	1543.73301
C2	11	5	1543.73192
C3	12	4.8	1543.73639
C4	12.2	4.8	1543.73181
C5	13	4.6	1543.73809
CH4(1542.94nm)			
D1	14	2.2	1542.94834
D2	15.2	8.4	1542.94918
D3	18.2	4.4	1542.94711
D4	18.4	4.4	1542.94233
D5	18.4	7.8	1542.94811

The Optimal Control Method in the Wavelength Switching

As described in Section 4.1 we know that if we increase the number of current combinations it is possible to reduce the channel switching time comparing with the conventional method by using only one current combination for each channel. But after we find the best current combinations for the round trip switching between any two channels and try to combine these currents together it reveals that it will have some time wasted in the switching in the same channel as shown in Fig. 6. It becomes more complicate as more channels are considered.

From simulation tests we realized that they are many current combinations that having 0 ns switching times in each channel, we then try to find the current combinations that having zero switching times in the same channel before we are trying to find the best current combinations in the two channels switching; we then use these current combinations and follow the method as described in Section 4.1 to find the best current combinations in the round trip switching between two channels, it has results as shown in Fig. 7.

Conclusion

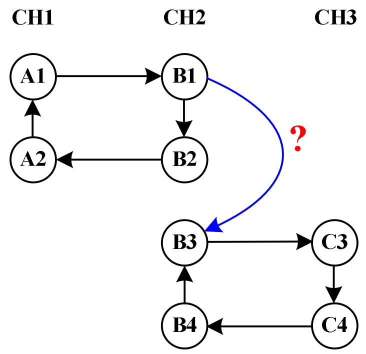


Fig. 6 The Possible Problem when it Increase Two Channels to Three.

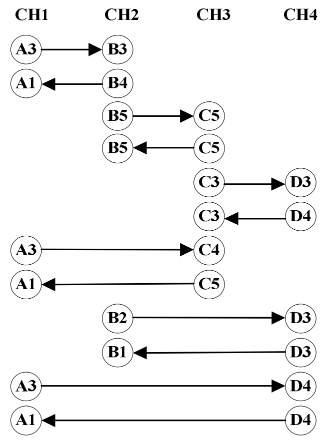


Fig. 7 Current Combinations for the Shortest Time Switching.

In this paper we simulated in DBR Laser all those current combinations of Ig and Ip that generated channels with wavelengths conforming to the ITU band when the current Ia is fixed at 40 mA, Ig is varied from 0 mA to 20 mA and Ip is varied from 0 mA to 10 mA. It has determined that in these currents ranges it has four channels conforming to the ITU band. We then simulated the channel switching times when different current combinations are considered; we increased the number of current combinations in each channel to resolve the possible problems of using only one current combination in each channel. We then verified that the optimal average switching time is around 8.5 ns comparing with the switching time of 15.5 ns of using the conventional method when switching from channel A to channel B, it has improved and reduced the optimized switching time by almost half when comparing with the conventional method and we also anticipate that the difference in switching time will become larger when the number of channels is increased.

References

[1] S.V. Kartalopoulos, in: Introduction to DWDM technology. *New Jersey: IEEE Press, (2000)*

[2] Y.H. Lee, Y.S. Chou, Yi.G. Jan, C.L. Yang, M.H. Chuang and S.W. Tzeng, in: Applying Robust Controller for Wavelength Stabilizer,*in Optical Network, 2005 Symposium on Technology Fusion of Optoelectronics and Communications (STFOC '05)*, Taipei, Taiwan, R.O.C., (2005) pp. 98-99,.

[3] L. Coldren and S. Corzine, in: Continuously-tunable single-frequency semiconductor lasers, *Quantum Electronics, IEEE Journal* , (1987) pp. 903-908.

[4] P. Xing, H. Olesen and B. Tromborg, in: Atheoretical model of multielectrode DBR lasers, *Quantum Electronics, IEEE Journal*, (1988) pp. 2423-2432.

[5] S. Murata, I. Mito and Kobayashi K., in: Tuningranges for 1.5 µm wavelength tunable DBR lasers, *Electronics Letters*, (1988) pp. 577 – 579.

[6] N.P. Caponio, M. Goano, I. Maio, M. Meliga, G.P. Bava, G. Destefanis and I. Montrosset, in: Analysis and design criteria of three-section DBR tunable lasers, *Selected Areas in Communications, IEEE Journal*, (1990) pp. 1203 – 1213.

[7] Y.H. Lee, C.L. Yang, M.H. Chuang, H.W. Tseng, Y.S. Chou, H.W. Tsao and S.L. Lee, in: Analysis and Selection of Optimum Driving Current Combinations for Tunable Wavelength Laser, *Microwave and Optical Technology Letters*. (2006) pp. 1417-1423.

[8] J. Buus, M.C. Amann and D.J. Blumenthal, in: *Tunable Laser Diodes and Related Optical Sources*, (Second edition) Wiley inter-science.