Chapter 3
Measurement and Analysis of Characteristics for SG-DBR Lasers

3-1 Light-Current (L-I) Characteristics

The experimental setup is shown in Fig. 3-1. The measurement system consists of the SG-DBR laser integrated with the SOA, the temperature controller, the optical isolator, the power meter, and the multi-channel current source. The computer was used to control the currents applied to each section of the laser, the laser temperature, and to record the optical power measured by the power meter. We use the labview as the control software. The control panel shown in Fig. 3-2 includes some functions which we can operate all the instruments. Besides, we can clearly look at the measurement results in the control panel. All the information where we controlled the multi-channel current source and the power meter are also shown in Fig. 3-2. The gain current is change by 0.1 mA step. We scanned characteristics of optical power by setting the gain current from 0 mA to 100 mA. The laser temperature is controlled at 25^{0}C. The results are saved in the computer

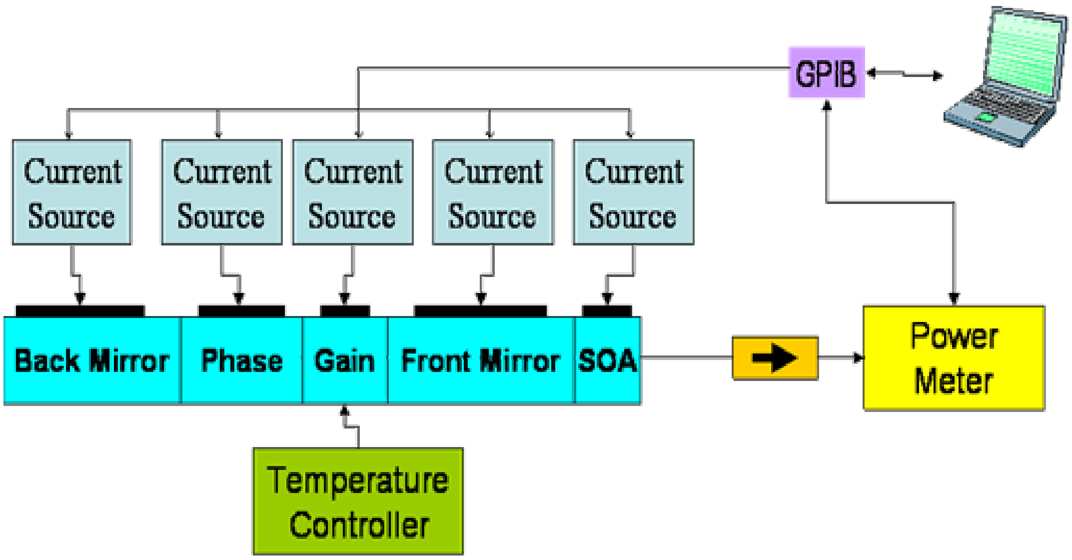

Fig. 3-1 The experimental setup for the measurement of L-I curves

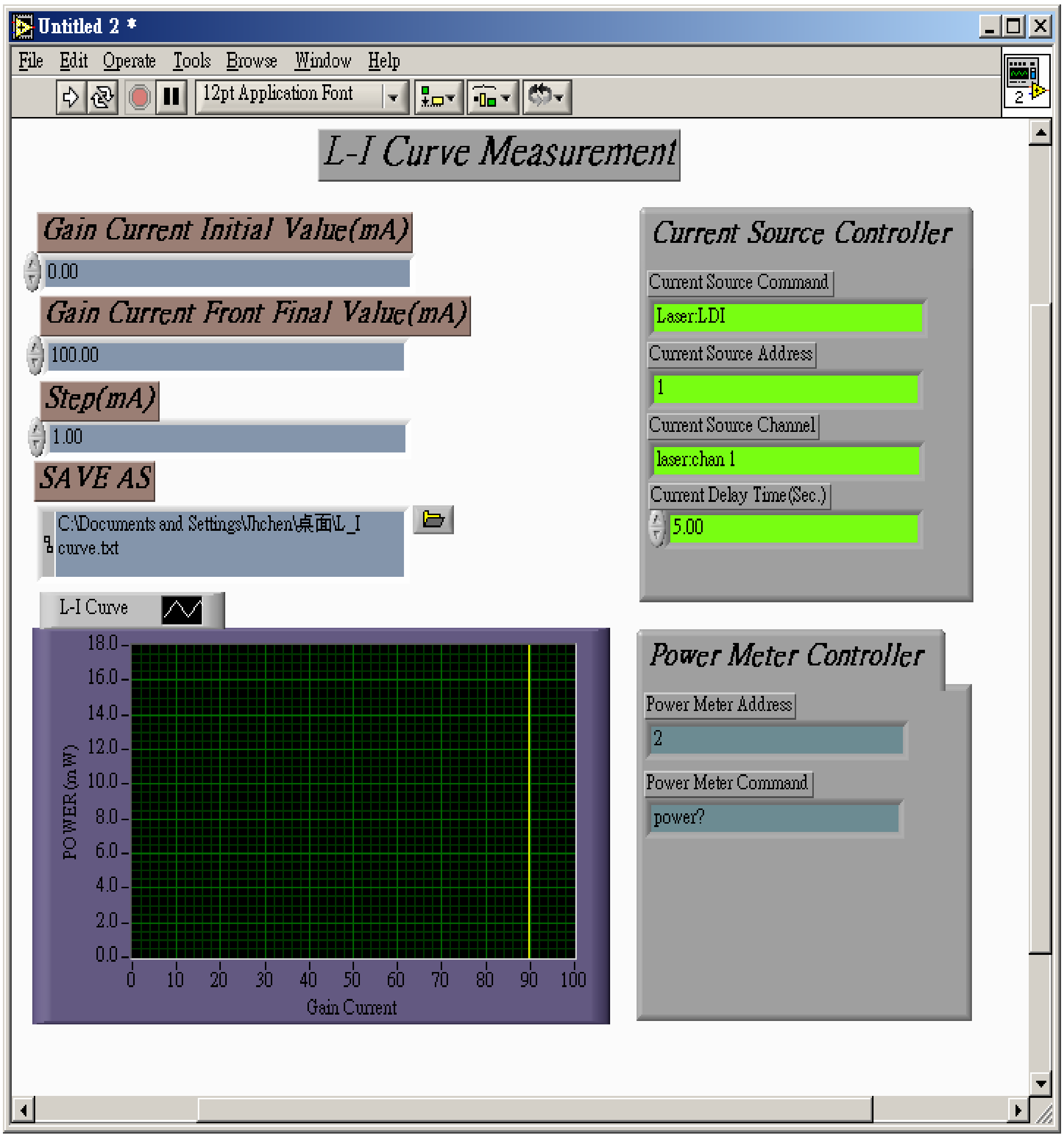

Fig. 3-2 The control panel for L-I curves measurement

Figure 3-3 shows the L-I curves for three different values of SOA currents, which are 60 mA, 80mA, and 100 mA, without tuning currents injection in SG and phase sections at 25^{0}C. We find the threshold current is 31 mA, and a maximum output power of 16 mW is achieved for I_{gain}=I_{SOA}=100mA. Furthermore, we observed the power increased when the SOA current is increased and the curves are not linear because of gain saturation.

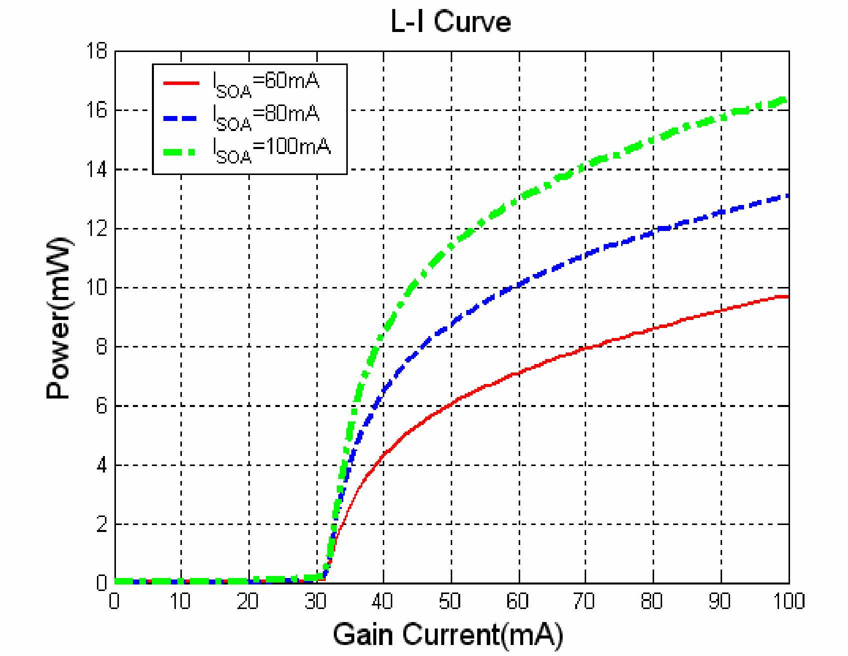

Fig. 3-3 L-I curves for I_{SOA} =60mA, 80mA, 100mA at 25^{0}C

3-2 Wavelength Tuning Characteristics

The experimental setup is illustrated in Fig. 3-4. The multi-channel current source was used to drive the laser for the tuning tests and the spectra were measured using the optical spectrum analyzer (OSA). The computer was used to control the currents applied to each section of the laser, the laser temperature, and to record the oscillation wavelength, optical power, and side mode suppression ratio (SMSR) measured by the OSA. The function of the isolator is to prevent the laser from damage as a result of the reflection light. The control panel is shown in Fig. 3-5. Here, the front SG section current I_F and the back SG section current I_B were changed by a 0.5 mA step. We scanned characteristics of oscillation wavelengths, output power and side mode suppression ratio (SMSR) by setting the current of the front SG section from 0 mA to 30 mA and that of the back SG section from 0 mA to 45 mA. The gain current I_g, the SOA current I_{SOA} and the phase-control current I_p were fixed at 80mA, 80mA and 0.33mA, respectively. The laser temperature was controlled at 25^{0}C and the resolution the OSA is 0.01 nm.

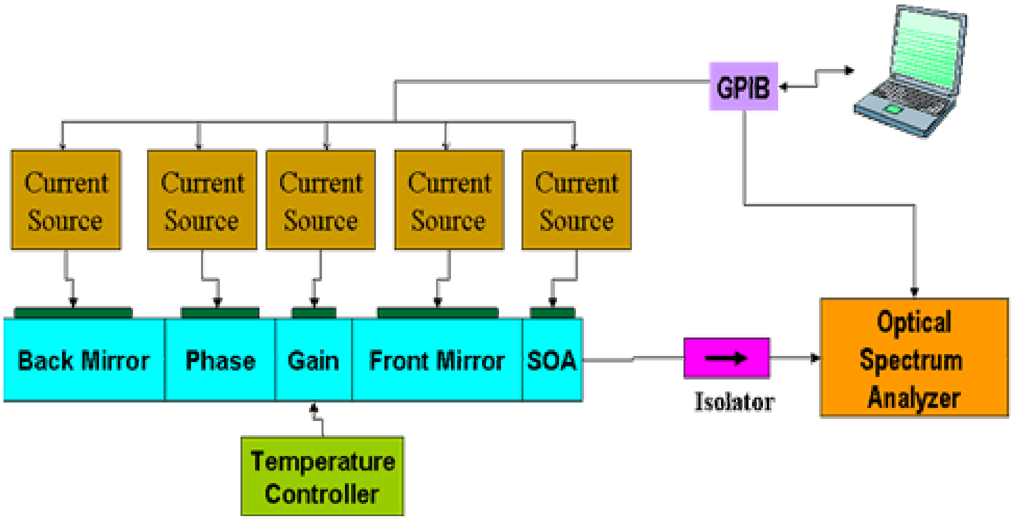

Fig. 3-4 The experimental setup for wavelength tuning characteristics

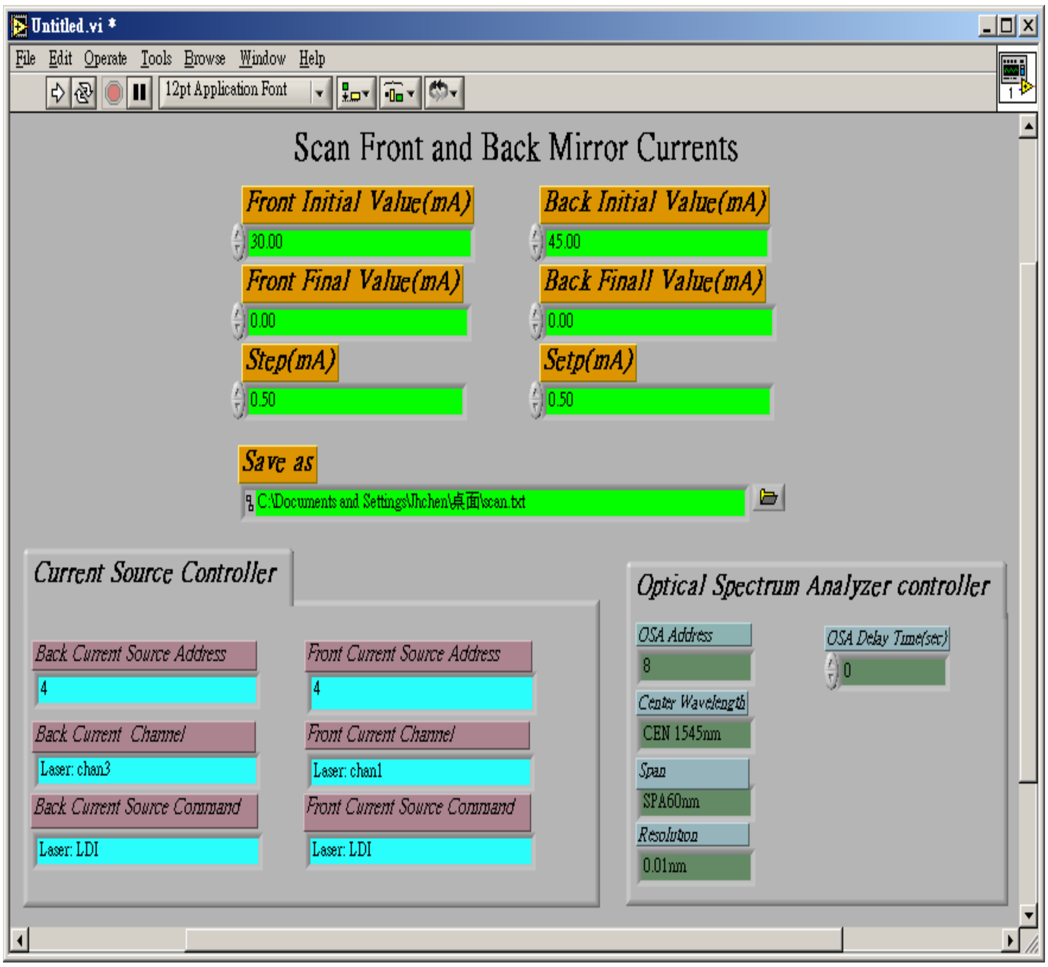

Fig. 3-5 The control panel for contour maps measurement of oscillation wavelengths, output power and side mode suppression ratio (SMSR)

The contour of the oscillation wavelengths is shown in Fig. 3-6. The laser can operate at arbitrary wavelengths from 1521 nm to 1573 nm, included C band, by controlling the two tuning currents at 25^0C. What is more, we observed there are many 'cells' which represent lasing modes and the centers of cells are the best operation points of the laser. The contours of the output optical powers and SMSR are shown in Fig. 3-7 and Fig. 3-8. The powers are greater than 7 dBm of all the tuning range and the SMSR exceeds 40 dB. In Fig.3-8, we also find the maximums of the SMSR are corresponding to the centers of cells in Fig. 3-6.

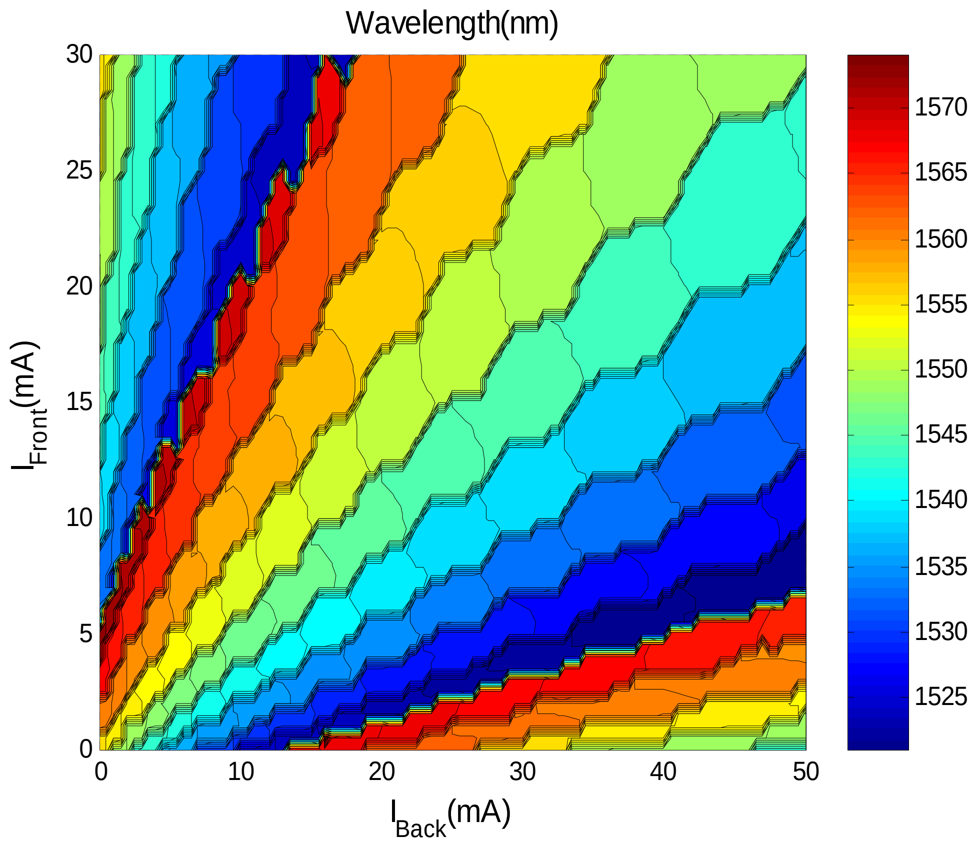

Fig. 3-6 The Contour map of measured oscillation wavelengths

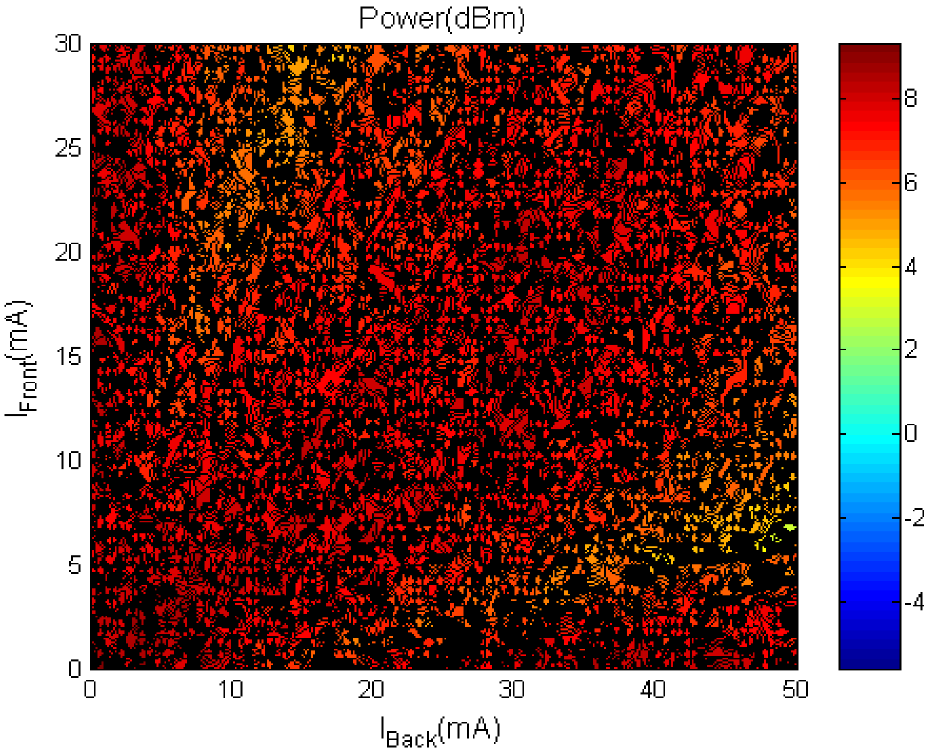

Fig. 3-7 The Contour map of measured output power

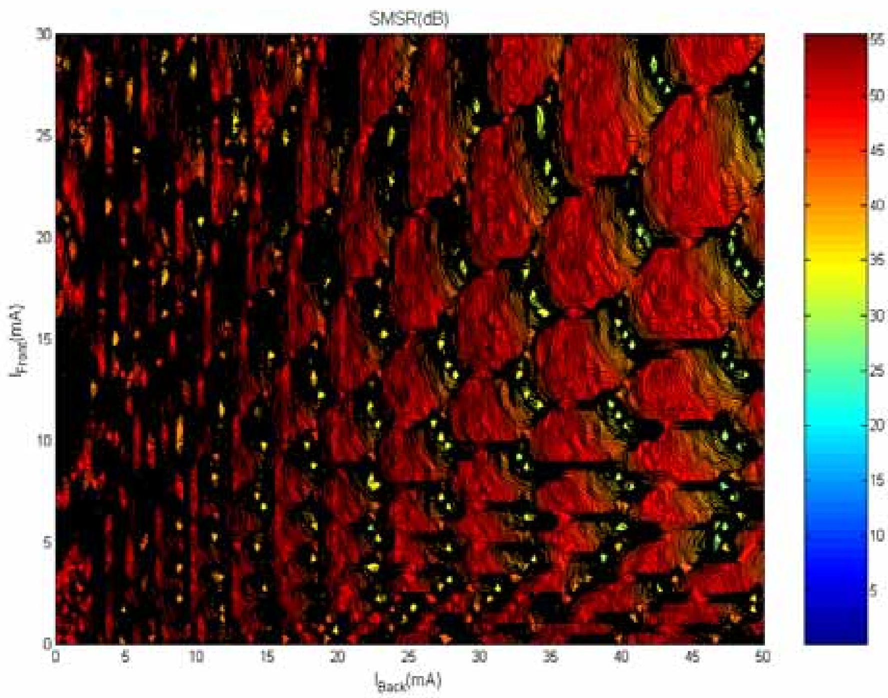

Fig. 3-8 The Contour map of measured side mode suppression ratio

The wavelength tuning characteristics using one tuning SG section are shown in Fig. 3-9 and Fig. 3-10. In the measurement, the gain current I_g, the SOA current I_{SOA} and the phase-control current I_p were fixed at 80mA, 80mA and 0.33mA, respectively. Besides, either the front or back SG section current was changed in 0.1 mA steps.

Figure 3-9 shows the tuning range and SMSR obtained by the current injection in the back SG reflector: In the beginning, a blue shift is observed corresponding to an index change of the back SG reflector with the shorter reflectivity peak spacing. Besides, we find eleven different coincidences are obtained between the two reflectivity combs led to eleven wavelength channels with a mode spacing of 6.5 nm. The maximums of SMSR happened when peaks of front and back SG reflectors are aligned. Similarly, Figure 3-10 shows the red shift available for the current injection in the front SG reflector as a result of an index change of the front SG reflector with the longer reflectivity peak spacing. Furthermore, we observed nine different coincidences are obtained between two reflectivity combs resulted in nine wavelength channels with a mode spacing 5.7 nm. As a whole, SMSR exceeds 35 dB in the tuning range.

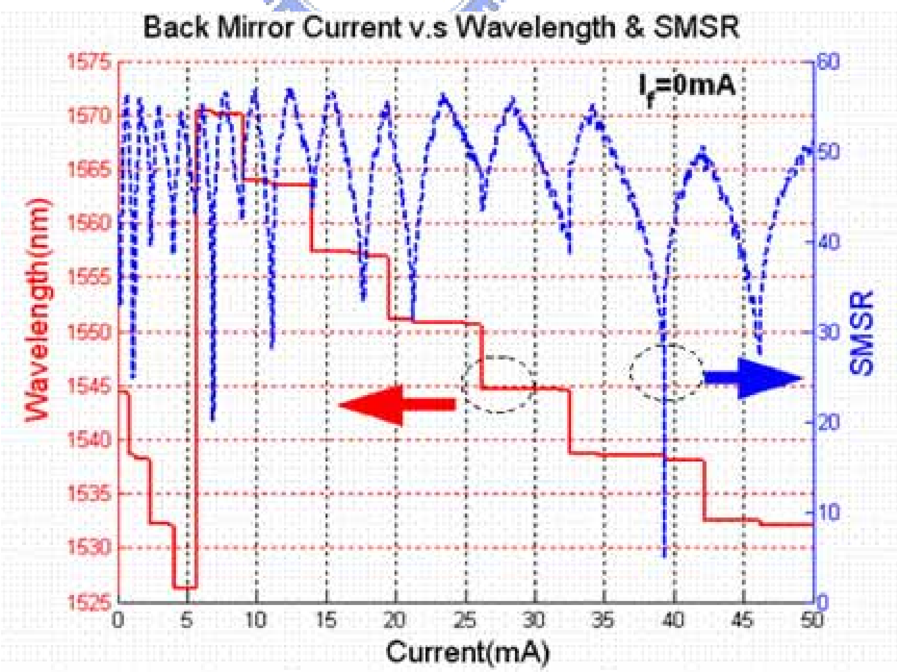

Fig. 3-9 Coarse tuning and SMSR measured versus current injection in the back SG section

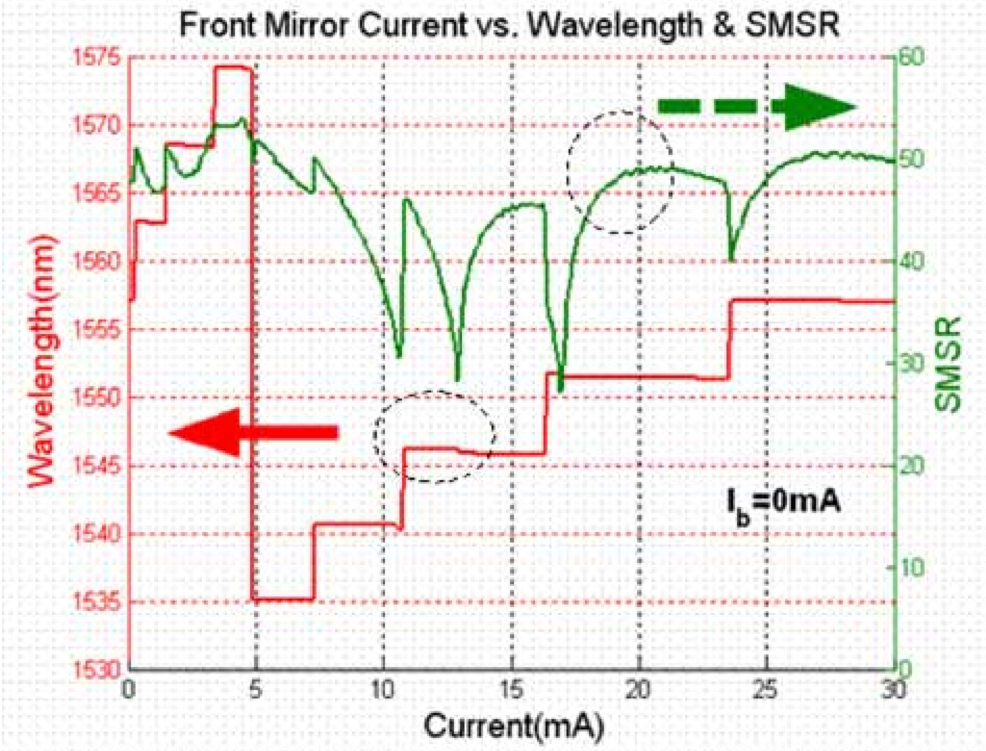

Fig. 3-10 Coarse tuning and SMSR measured versus current injection in the front SG section

The below will discuss the characteristics of the SG-DBR laser for the ITU-T specified grid frequencies. The experimental setup is similar to that shown in Fig. 3-4. In the measurement, the gain current I_g, the SOA current I_{SOA} and the phase-control current I_p were fixed at 80mA and 80mA, respectively. The resolution of the OSA is 0.01 nm and the laser temperature was controlled at 25^0C. We obtain the current seetings of the front SG, the back SG and the phase sections by hand. Figure 3-11 shows the lookup table of the front SG, the back SG, and phase currents for 40 different wavelength channels. When we want to tune the specified grid frequency, we can set the corresponding currents of three passive sections by using the table. Tuning the currents of the front SG, the back SG, and the phase sections, we were able to tune the laser to 40 different wavelength channels spaced at 100 GHz.

AAA1061Y Look-up Table

Igain=79.5mA ISOA=80.5mA T=25.01 OSA span=4nm resolution=0.01nm unit: nm mA

ITU Channels vs. Front, Back, and Phase Mirror Currents

Channel	Standard wave.	front curr.	phase curr.	back curr.	Channel	Standard wave.	front curr.	phase curr.	back curr.
C20	1561.42	1.06	5.18	33.3	C41	1544.53	15.38	4.92	29.1
C21	1560.61	3.11	1.48	1.4	C42	1543.73	20	8.22	42.7
C22	1559.79	4.76	4.3	3.7	C43	1542.94	0.39	0.74	3.7
C23	1558.98	7.02	0.12	6.5	C44	1542.14	1.45	2.71	6.6
C24	1558.17	12.32	12.64	10.2	C45	1541.35	2.48	5.13	11.1
C25	1557.36	17.19	0.09	14.8	C46	1540.56	4.27	3.84	15
C26	1556.55	20.7	6.52	22.8	C47	1539.77	8.47	6.93	21.1
C27	1555.75	0.04	0.36	0.1	C48	1538.98	10.75	5.1	28.6
C28	1554.94	1.6	6.91	1.5	C49	1538.19	15.15	4.95	1.7
C29	1554.13	2.37	0.55	4.2	C50	1537.4	23.77	8.18	3.7
C30	1553.33	5.21	0.05	6.4	C51	1536.61	28.93	6.19	6.4
C31	1552.52	7.17	1.68	9.9	C52	1535.82	1.33	6.12	10.2
C32	1551.72	12.47	0.09	15.6	C53	1535.04	3.46	0.3	15.4
C33	1550.92	16.81	1.63	20.13	C54	1534.25	4.53	1.77	21.7
C34	1550.12	20.86	0.78	30.4	C55	1533.47	7.7	4.74	28.2
C35	1549.32	30.51	4.46	1.6	C56	1532.68	12.24	4.34	1.8
C36	1548.51	1.24	1.02	3.5	C57	1531.9	17.39	2.22	3.9
C37	1547.72	2.56	2.54	6.9	C58	1531.12	22.13	4.74	7.2
C38	1546.92	4.76	6.61	10.1	C59	1530.33	0.64	5.45	10.3
C39	1546.12	7.99	0.52	14.8	C60	1529.55	1.87	9.94	15.6
C40	1545.32	10.15	7.06	22.8					

Fig. 3-11 The lookup table of the front SG, the back SG, and phase currents for 40 different wavelength channels

The power and the side mode suppression ratio versus wavelength channels are shown in Fig. 3-12. The operating points, where the output side mode suppression ratio (SMSR) and the output optical power are at least 40 dB and 7 dBm, respectively are chosen. The respective set of tuning currents for each accessible wavelength channel is shown in Fig. 3-13. It is shown that the reflector current curves repeat, which correspond to the spacing of the reflection peaks from the sampled gratings in the laser's reflector sections. We observed that the peaking spacings of the front SG and the back SG are about 6 nm

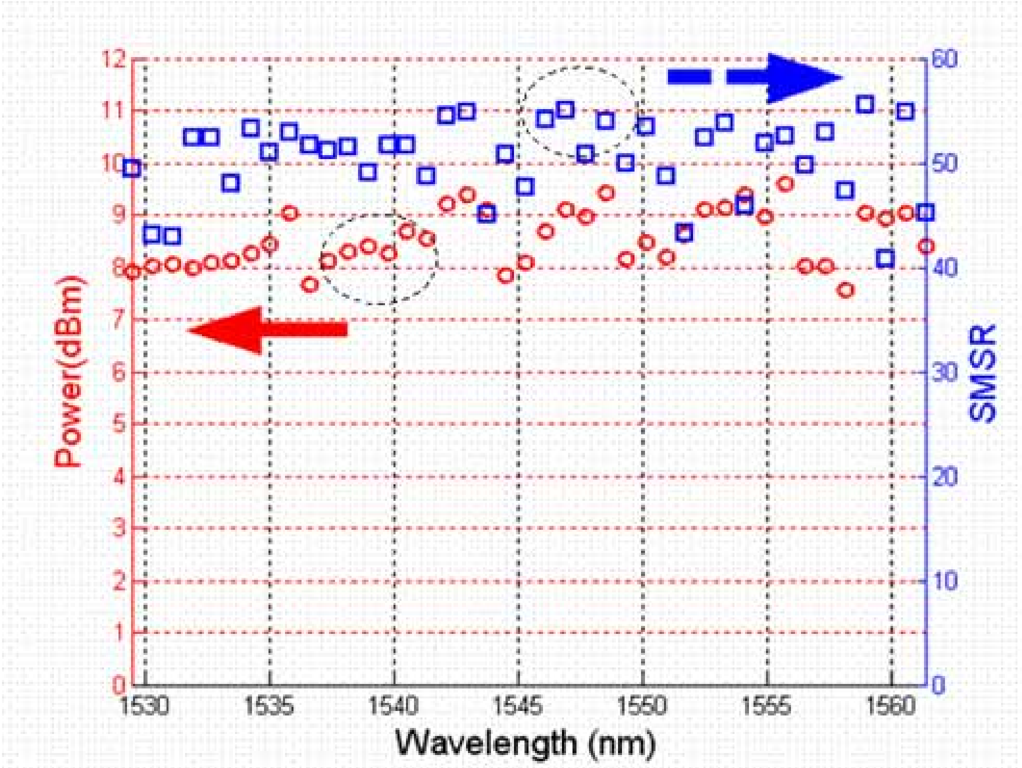

Fig. 3-12 The power and the side mode suppression ratio versus wavelength channels

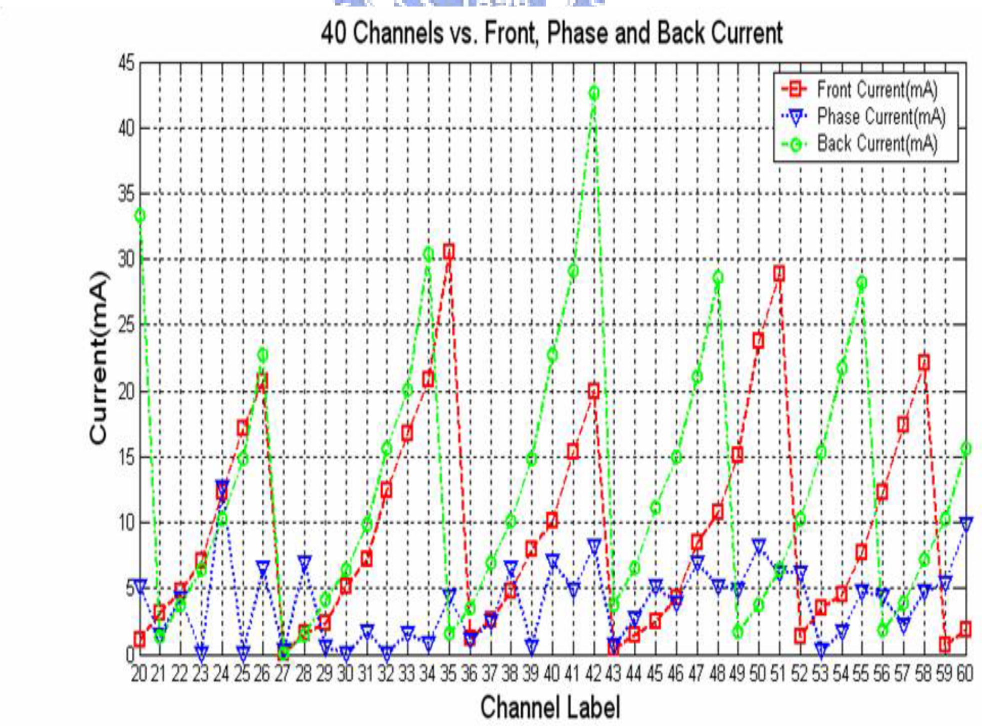

Fig. 3-13 The respective set of tuning currents for each accessible wavelength channel

Further, we test the stability of the 40 Channels. The control panel is shown in Fig. 3-14. This program can help me to test the stability of wavelength. We use random tests for 1000 times, and measure the wavelength by the optical spectrum analyzer. In the measurement, the gain current I_g, and the SOA current I_{SOA} were fixed at 80mA and 80mA, respectively and the laser temperature was fixed at 25^0C.

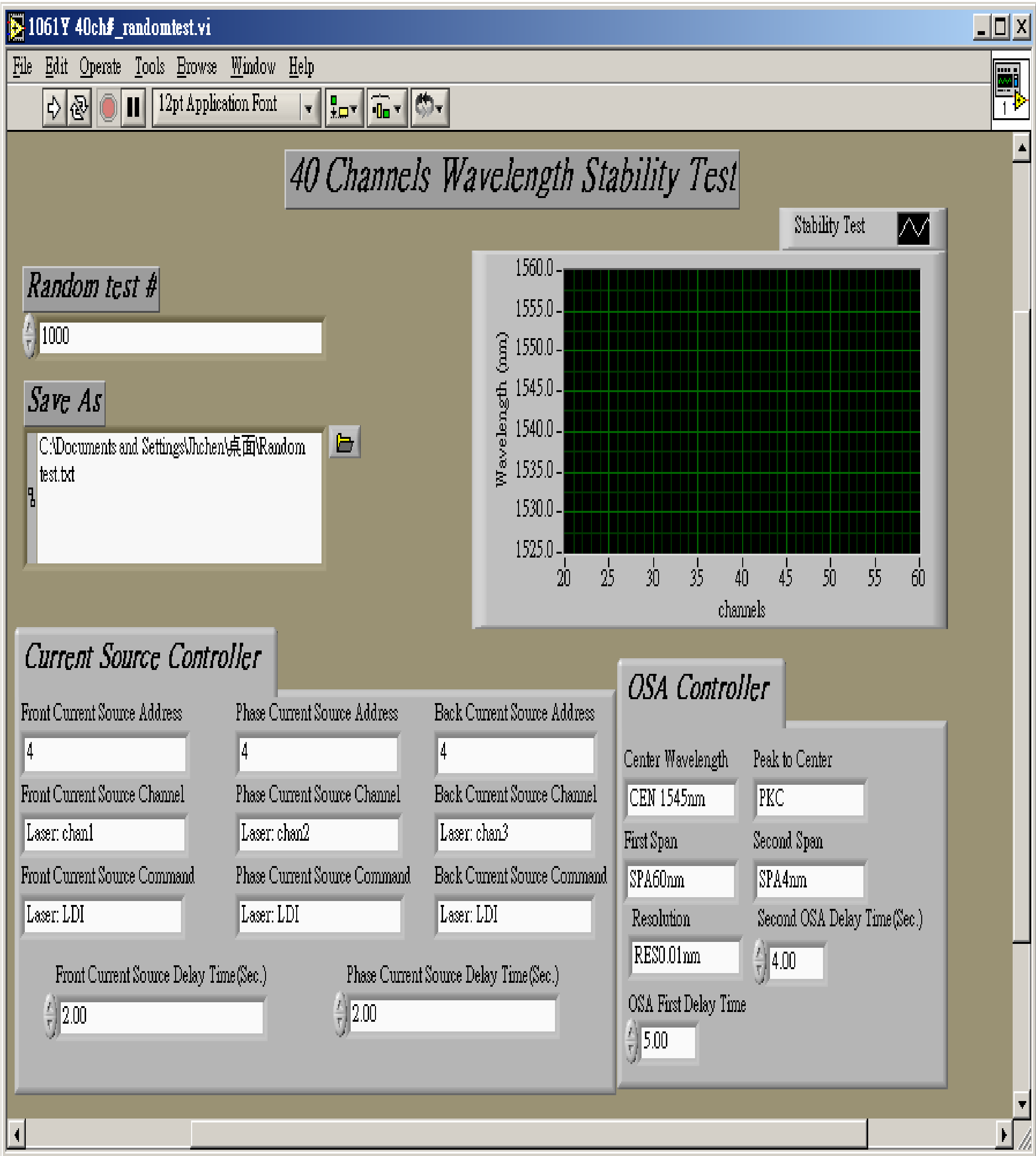

Fig. 3-14 The control panel for the test of 40 accessible wavelength channels

Figure 3-15 shows the deviation of the measured output wavelength values from the original wavelength assignment is about 0.01 nm (about 1 GHz). We have not yet noticed any significant wavelength drift over a period of several hours.

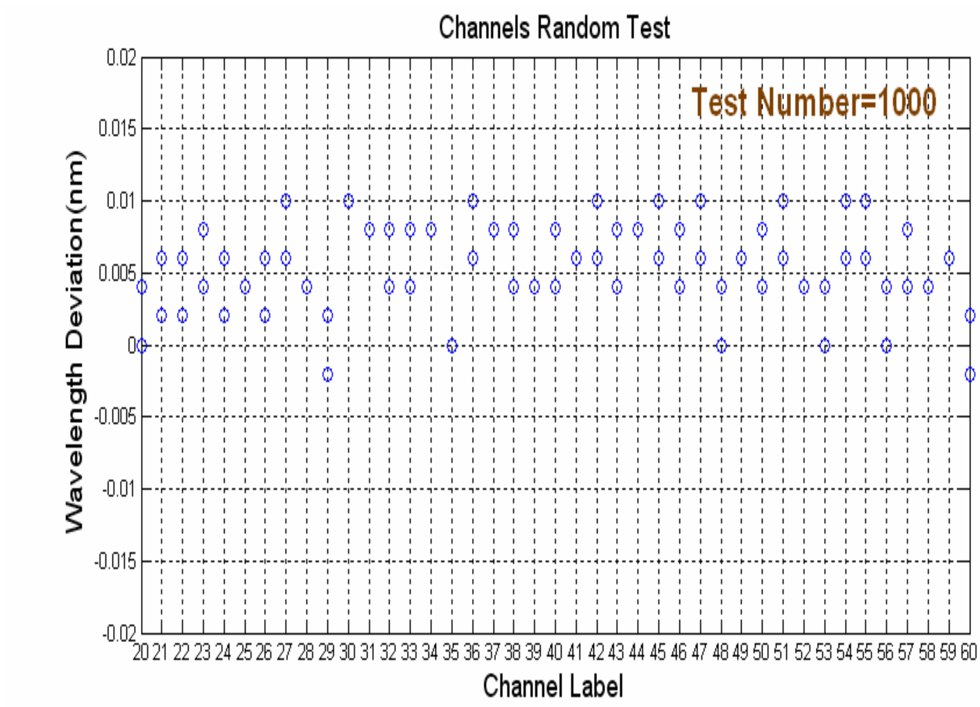

Fig. 3-15 The deviation of the measured output wavelength values forms the original wavelength assignment

3-3 Linewidth Characteristics

Linewidth is often defined in terms of the full-width half-maximum (FWHM) of the optical field power spectrum. Grating-based optical spectrum analyzers (OSAs) don't offer the measurement resolution required for laser linewidth measurement, so alternative characterization methods must be used. We used the optical heterodyne method to measure linewidth. This method offers exceptional sensitivity and resolution. The key component required for these measurements is a stable, narrow linewidth reference laser. The experimentsl setup for measuring laser linewidth is illustrated in Fig. 3-16. In this setup, the tunable laser is acted as the reference laser and the SG-DBR laser is viewed as the signal laser. The tunable laser is tuned appropriately and then its optical frequency is fixed during the measurement. In Fig 3-16, light form the tunable laser is combined with the SG-DBR laser under the experiment. Polarization state converters are placed in the both the tunable laser path and the SG-DBR laser path in order to align the polarization state of the tunable laser to that of the SG-DBR laser under the experiment. The coupler combines the two fields, delivering half the total power to each output port. One port leads to a photo detector which detects the interference beat tone,

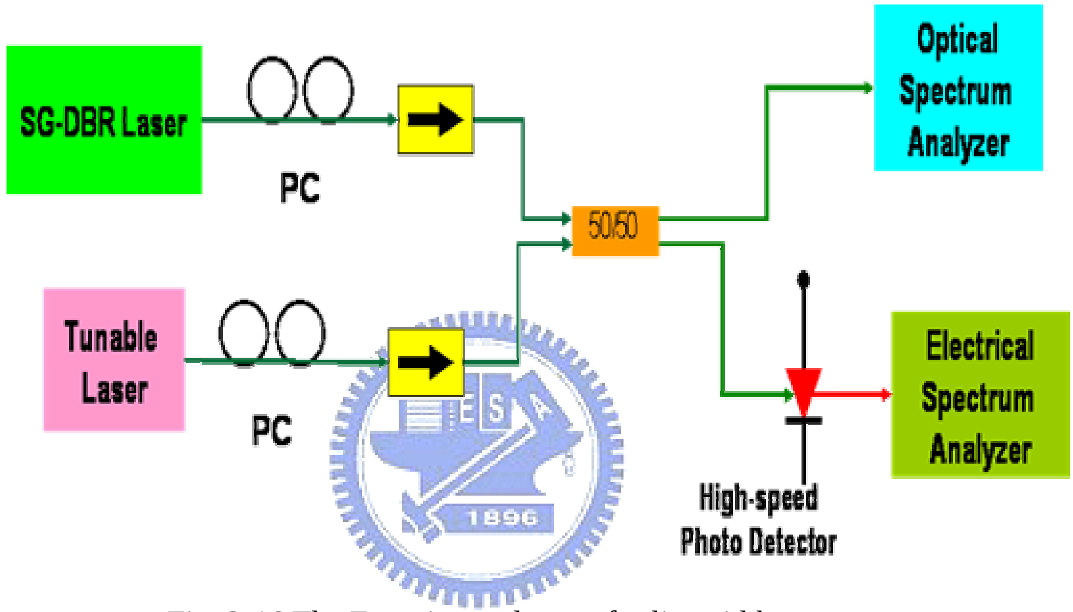

Fig. 3-16 The Experimental setup for linewidth measurement

converting it to an electrical tone. Note that the tunable laser frequency must be tuned close to the SG-DBR laser frequency to allow the mixing product to fall within the bandwidth of typical detection electronics. A course alignment of the tunable laser wavelength is performed using an optical spectrum analyzer (OSA). This creates a heterodyne beat tone between the tunable laser and each of the frequency components in the signal spectrum of the SG-DBR laser as indicated in Fig 3-17. Thus each frequency component is translated to a low-frequency interference term described by:

$$i(t) = \Re[P_{SG-DBR}(t) + P_{tunable\,laser} + 2\sqrt{P_{SG-DBR}(t) * P_{tunable\,laser}} *$$
$$\cos(2\pi(\upsilon_{SG-DBR} - \upsilon_{tunable\,laser} + \Delta\phi))]$$
$$\Delta\phi = \phi_{SG-DBR}(t) - \phi_{tunable\,laser}(t)$$

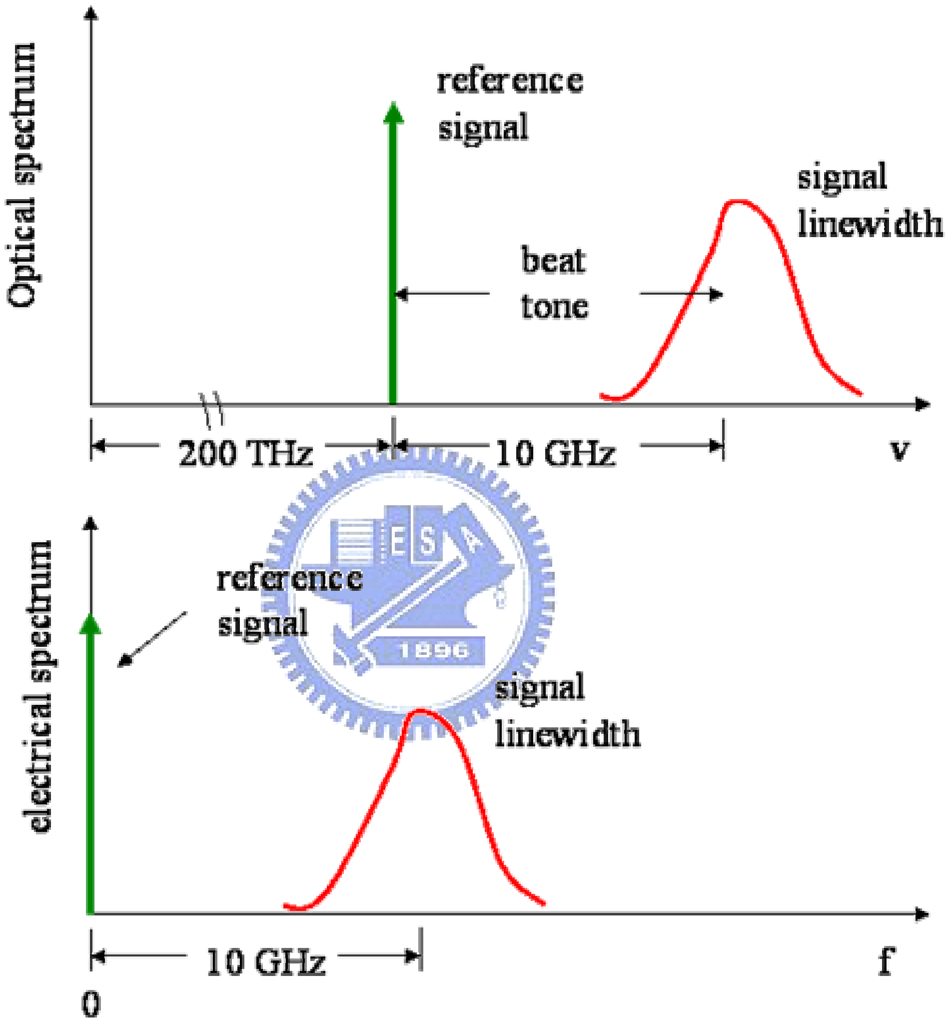

Fig. 3-17 The mixing process in terms of beat-tone slices mixed down to low frequencies that can be analyzed with electronic instrumentation

The beat spectrum of two lasers separated in optical frequency by 9.45 GHz is shown in Fig. 3-18. The full-width half-maximum, FWHM, linewidth of a laser is often measured with respect to an assumed Lorentzian spectral shape. Besides, we find FWHM is 4.7 MHz.

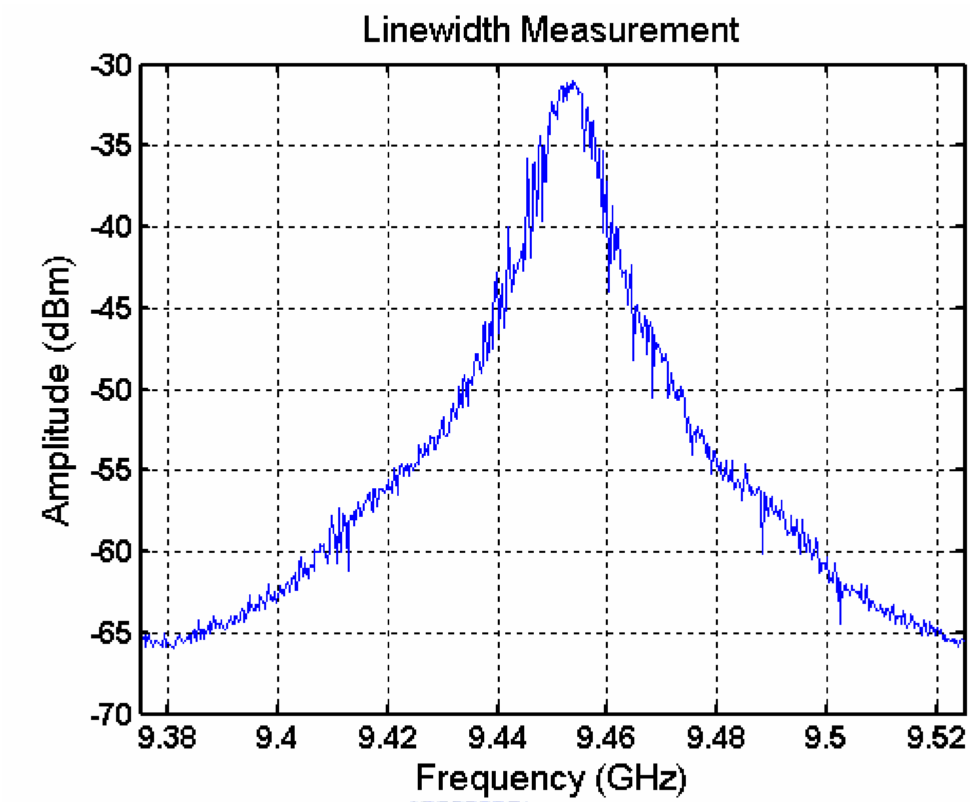

Fig. 3-18 The beat spectrum of SG-DBR and reference lasers

3-4 Wavelength Switching Characteristics

The experimental setup is shown in Fig. 3-19. High-speed programmable logic devices were used as look up tables to store the digital current settings of different tuning sections in order to access all the wavelength channels. These digital current settings were converted into analog current by 12-bit digital-to-analog converters. The driver board shown in Fig. 3-20 accepts wavelength switching instruction at the front end of the driver board and the electronics will drive the laser to switch its output wavelength. To measure the switching times to a particular channel, we center a band pass filter at its wavelength and output waveforms were measured by using the oscilloscope. In the measurement, the gain current I_g and SOA current I_{SOA} were fixed at 80mA and 80mA, respectively and the laser temperature was fixed at 25^0C

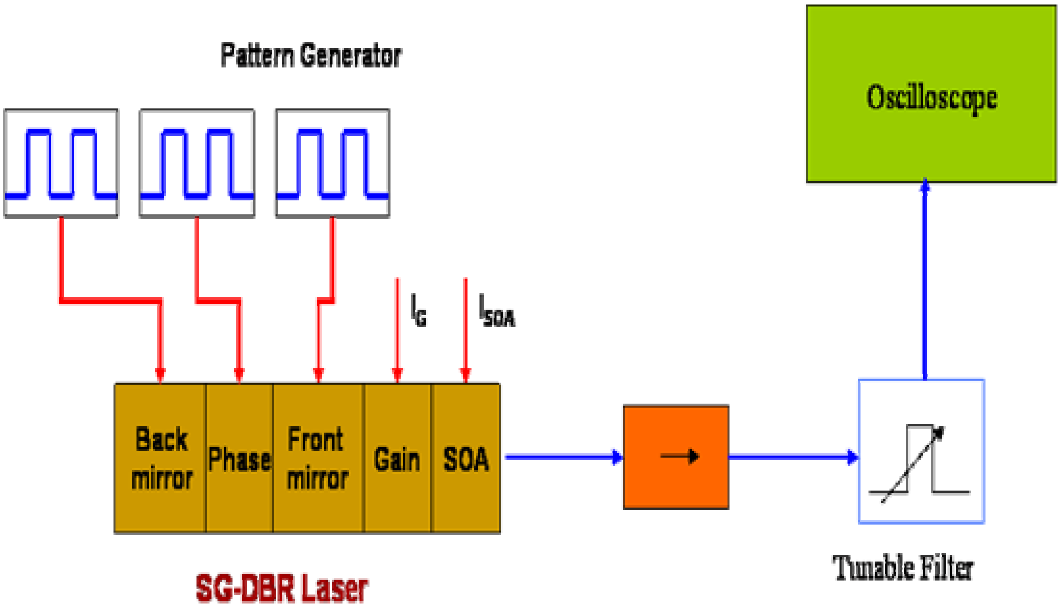

Fig. 3-19 The Experimental setup for wavelength switching

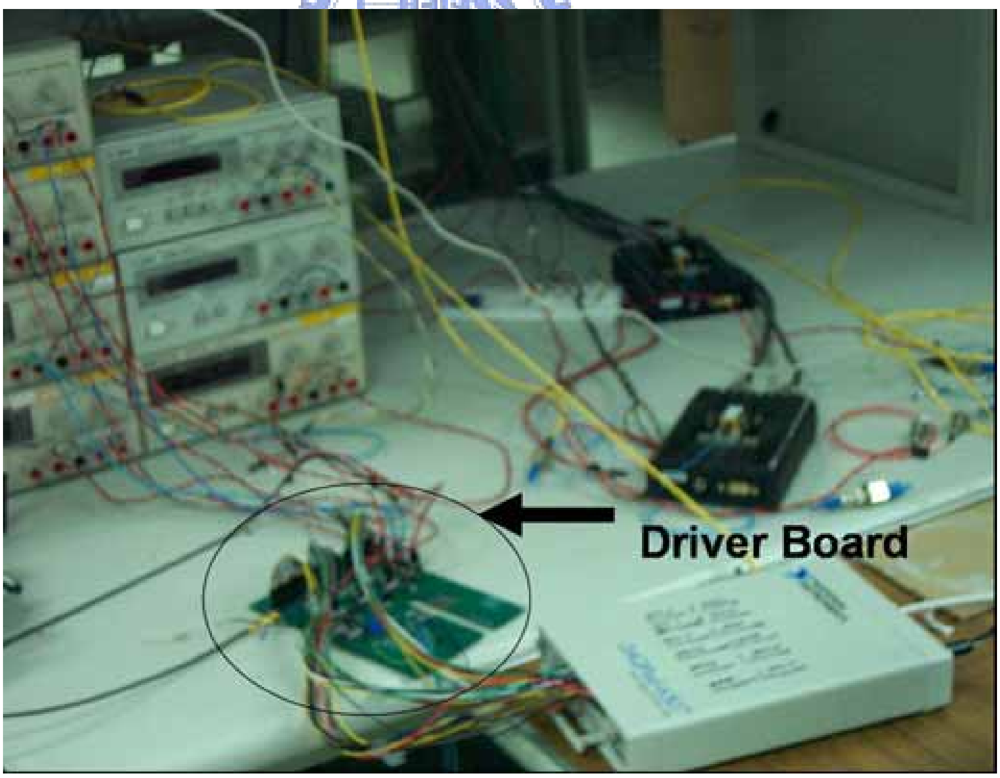

Fig. 3-20 The laser driver board

The channel switching time is defined as the time interval between the original channel turned off and the new channel turned on. It is illustrated in Fig. 3-21. We have measured the wavelength switching performance of this fast wavelength tunable transmitter. Figure 3-22 and Figure 3-23 shows the measured output waveform for switching between ITU channel C42 (1543.73 nm) and C31 (1552.52 nm), which was spaced 8.8 nm. The switching time from channel C42 to C31 is 31 ns. However, the switching time from channel C31 to C42 is 200 ns.

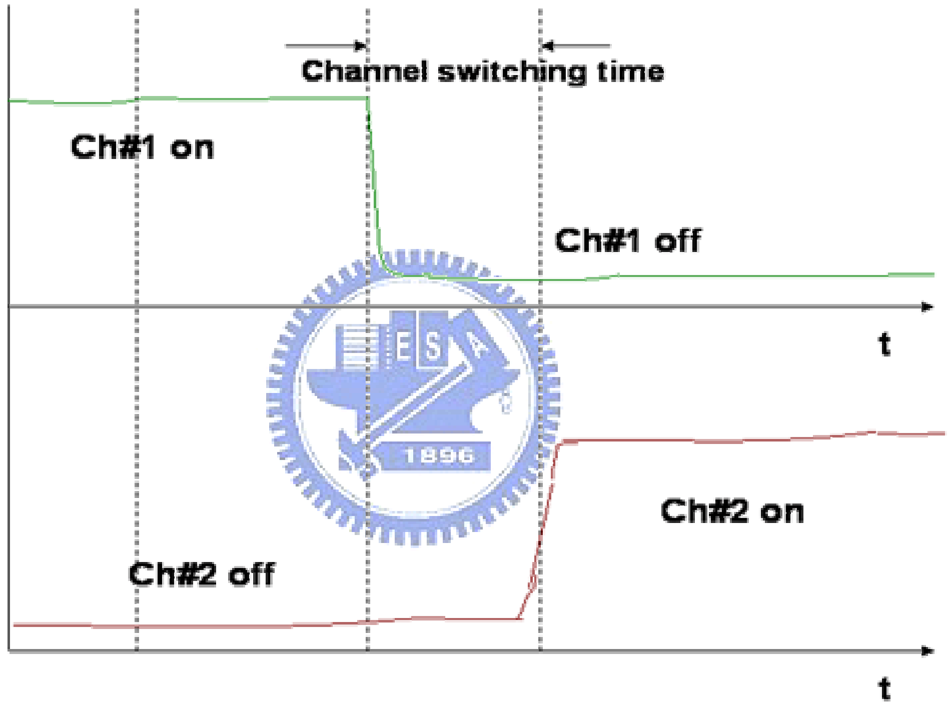

Fig. 3-21 The illustration for the definition of wavelength switching

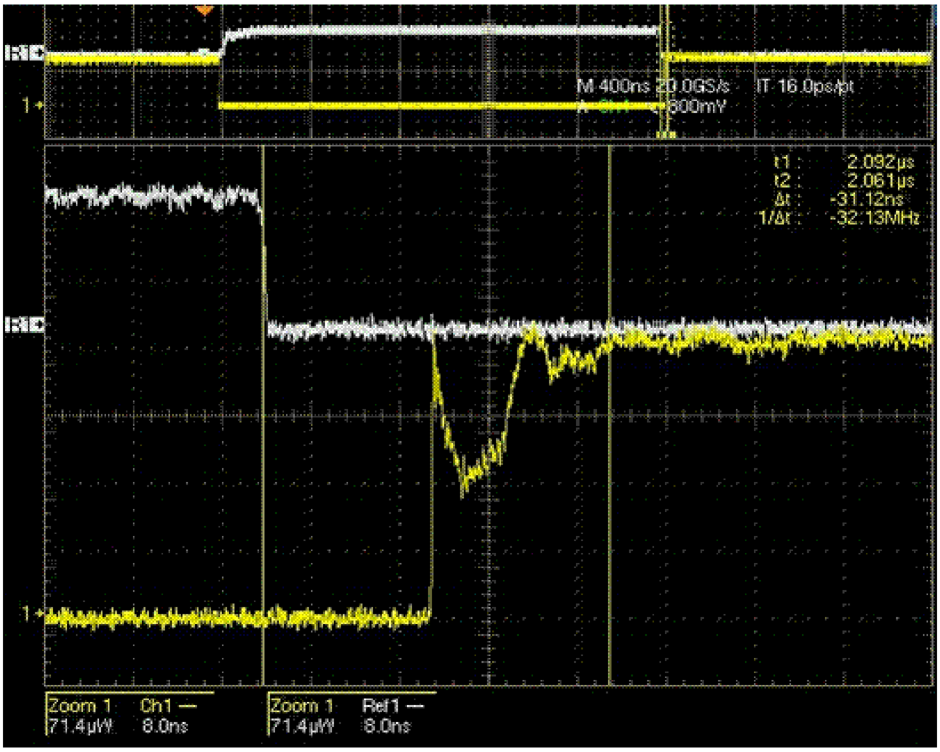

Fig. 3-22 The output waveform for switching from ITU channel C42 (1543.73 nm) to C31 (1552.52 nm)

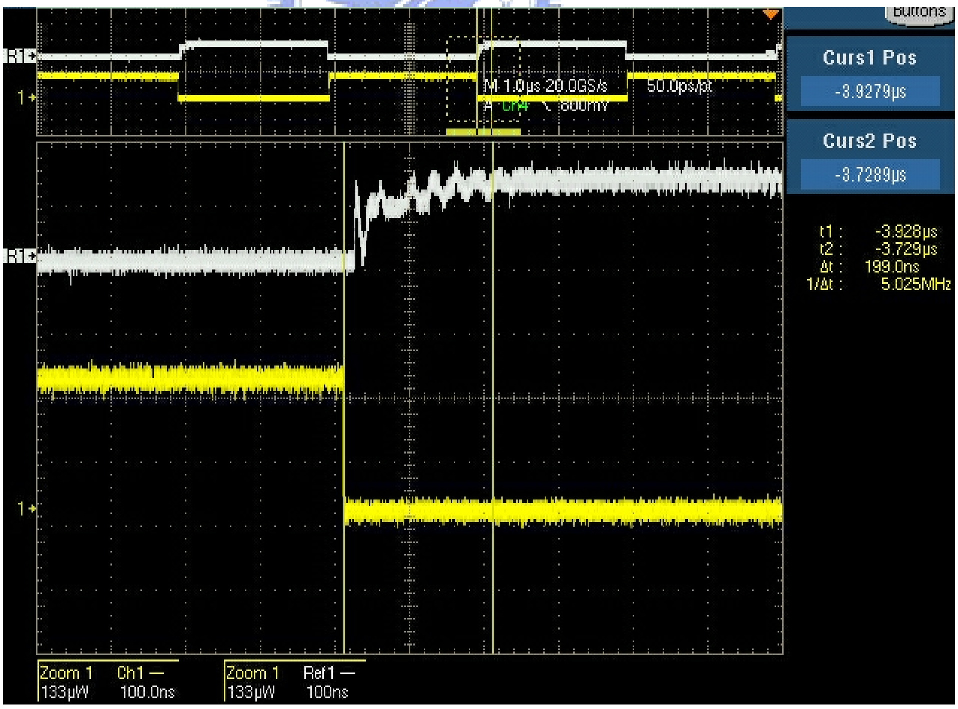

Fig. 3-23 The output waveform for switching from ITU channel C31 (1552.52 nm) to C42 (1543.73 nm)