Does your TLS have specifications pertinent to swept measurements?

Technical Note

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This technical note describes the parameters given in the specifications of the TLS that are pertinent to dynamic conditions (that is, swept measurements). In the past, these parameters were only guaranteed under static conditions, but they are now guaranteed for various sweep speeds as an add-on specification. This technical note presents experimental test results obtained using a B-series TLS module to demonstrate the reliability of the test setup, and introduce the features and functionality available.

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1. General Information

One of the important characteristics of a tunable laser source (TLS) is its sweep speed. With the introduction of Agilent Technologies' B-series TLS modules, our portfolio increased its maximum sweep speed to 80nm/s over the wavelength ranges which customers require, including the O-, E-, S-, C-, and L- bands. Improving sweep speed challenges the system uncertainties inherent in a swept-wavelength measurement system[1]. This effect can be seen in Diagram 1, where the most common setup for a stimulus test exhibits limited system bandwidth. Here, the frequency of the signal increases as the sweep speed is increased. This shows that the response times of the instruments used when sweeping through the wavelength range affect the accuracy of both the power and wavelength measurements obtained.

2.Dynamic Condition of Swept Measurement

- **Dynamic wavelength accuracy**: The dynamic *absolute* wavelength accuracy is the maximum difference between the wavelength logged under dynamic conditions and the actual wavelength. When measuring the differences between the actual and logged wavelength in swept mode, the dynamic *relative* wavelength accuracy is ±half the span between the maximum and minimum value of all differences.
- **Dynamic wavelength repeatability**: The random uncertainty in reproducing the logged wavelength when sweeping many times is expressed as ±half the span between the maximum and minimum of all values of this logged wavelength.
- **Dynamic power flatness**: When recording the actual output power of a TLS in swept mode, the dynamic power flatness is ±half the span between the maximum and minimum of the measured power levels. Dynamic *relative* power flatness is the high frequency component of dynamic power flatness, obtained by referencing the power measured at high sweep speed to the power measured at low sweep speed.
- **Dynamic power reproducibility**: The random uncertainty in reproducing the output power at the same actual wavelength referenced to the first sweep, when sweeping many times. It is expressed as ±half the maximum span over wavelength between the maximum and minimum of all actual values of these differences in power.

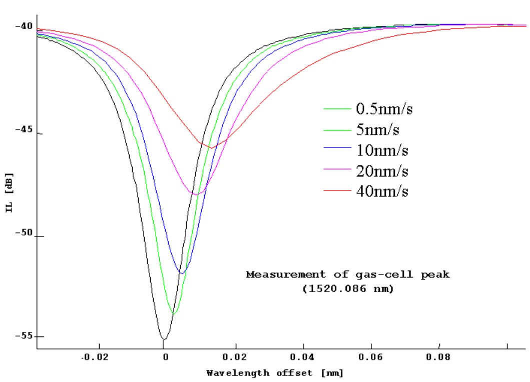


Diagram 1:
The distortion effect due to swept wavelength measurement. Differences in both amplitude and spectrum shift depend on the sweep speed. A 0.5nm/s sweep speed demonstrates the best accuracy but the overall component test time increases dramatically. These are stopband measurements that require a very low power range, bandwidth ~ 400Hz)

[1] V.Bertogalli et al.,"Testing passive DWDM components: uncertainties in swept-wavelength measurement systems", Proc. 2001 Optial Fiber Communication Conference (Optical Society of America, Washinton DC, 2001), paper THB6

3. Influences of the Dynamic Condition on your Test Setup

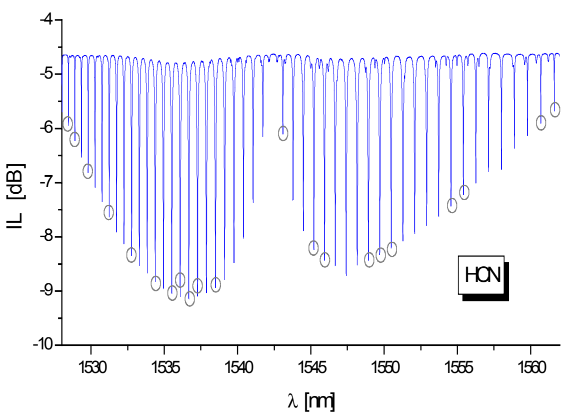
The spectrum distortion caused by the dynamic condition depicted in Diagram 1 shows both wavelength and power inaccuracies. These deviations can occur for two reasons: a wavelength measurement error (because the TLS has insufficient wavelength accuracy in the swept condition), or a power measurement error (caused by the signal exceeding the measurement bandwidth). To characterize device properties correctly, the swept test system must guarantee dynamic accuracy at high sweep speeds without sacrificing the test time. The following experimental test results demonstrate the reliability of the performance of both the wavelength and power properties of an Agilent B-series TLS. Note that for wavelength accuracy, the dynamic uncertainty is defined as the arithmetic sum of the static specification and an add-on value due to the dynamic condition. The total specification at dynamic condition is calculated as: $Total\ Spec_{Dynamic} = Spec_{Static} + addon_{Dynamic}$

	Specification under static condition	Add-on specification under dynamic condition (typ.)		
		at 5nm/s	at 40nm/s	at 80nm/s
Absolute wavelength accuracy	±10 pm	±0.4 pm	±1.0 pm	±2.5 pm
Relative wavelength accuracy	±5 pm, typ. ±2 pm	±0.4 pm	±0.8 pm	±2.0 pm
Wavelength repeatability	±0.8 pm, typ. ±0.5 pm			
		Specification under dynamic condition (typ.)		
Dynamic wavelength repeatability	—	±0.3 pm	±0.4 pm	±0.7 pm
	Specification under static condition	Dynamic relative power flatness (typ.)		
Power flatness versus wavelength Output 1 (low SSE)	±0.2 dB typ. ±0.1 dB	±10 mdB	±15 mdB	±30 mdB
Power flatness versus wavelength Output 2 (high power)	±0.3 dB typ. ±0.15 dB	±10 mdB	±15 mdB	±30 mdB
Dynamic power reproducibility (typ.)	—	±5 mdB	±10 mdB	±15 mdB

Table 1: Dynamic specification of 81680B tunable laser source, as of April 2002[2].

- **Wavelength Verification**

A NIST $H^{13}C^{14}N$ gas cell is used as a wavelength reference. By comparing the gas cell peak with the actual swept spectrum peak, the wavelength error can be seen as the offset from the reference wavelength defined by NIST shown in Table 2.



no.	*λ [nm]*	*no.*	*λ [nm]*
1	1528.4862	12	1543.1148
2	1528.9271	13	1545.2314
3	1529.8376	14	1545.9563
4	1531.2764	15	1548.9554
5	1532.8024	16	1549.7302
6	1534.4159	17	1550.5149
7	1535.5401	18	1554.5892
8	1536.1170	19	1555.4346
9	1536.7034	20	1560.7185
10	1537.2997	21	1561.6344
11	1538.5224		

Table 2: Selected peaks from a NIST $H^{13}C^{14}N$ gas cell with very small wavelength uncertainty (0.6 pm).

[2] "Agilent 81480/680/640B Agilent 81672/482/682/642B Tunable Laser Sources Technical Specifications" (5988-5508EN), Apr. 18, 2002

Repeated swept measurement results for the wavelength peaks in Table 2 are recorded, and the typical test result shown in Diagram 2 demonstrate the wavelength accuracy obtained at each peak. The dynamic relative wavelength accuracy is ±half of the wavelength error variation over the wavelength interval. The dynamic absolute wavelength accuracy is ± the maximum difference for all the recorded wavelength errors centered at 0 error. In our laboratory, a typical test result with the B-series TLS demonstrated about ±1.7pm dynamic *absolute* wavelength accuracy, ±1.5pm dynamic *relative* wavelength accuracy, and ±0.5pm dynamic repeatability measured with a 80nm/s sweep speed.

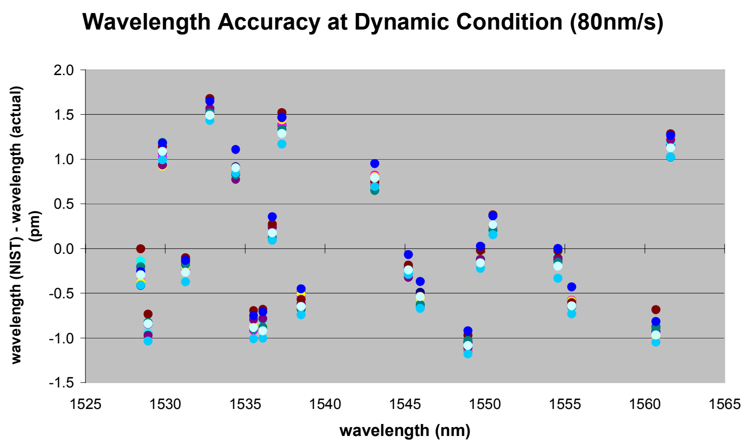


Diagram 2: Wavelength error at NIST gas cell peaks. The results of repeated swept measurement using a 80nm/s sweep speed are recorded at each peak wavelength. Typically, wavelength inaccuracy degrades further when the spectrum is swept over the wavelength range using the faster sweep speeds currently available in the market.

(data shown in the graph are recorded in a typical laboratory environment).

- **Power Verification**

Power stability over wavelength is critical for dynamic swept measurement applications. When the TLS is synchronized with the power sensor while sweeping over wavelength, the signal distortion caused by today's improved tuning speed affects not only the wavelength accuracy but also the signal amplitude.

The experimental result of dynamic power flatness over wavelength using a 80nm/s sweep speed is shown in Diagram 3. The ±0.1dB peak-to-peak absolute power difference between the Pmax and Pmin curves is called dynamic power flatness. Interference effects are minimized by using angled connectors and by protecting the setup from environmental effects such as vibration.

Here, the delta between the maximum and minimum absolute power spectrums in repeated measurements is 3mdB. The dynamic power reproducibility is ±half of this result, in this case ±1.5mdB. In any application based on the stimulus response test, it is necessary to have the lowest power reproducibility uncertainty possible because the laser should reproduce the same power level over repeated measurements. In addition, the test setup should guarantee the highest sweep speed possible to improve the yield without sacrificing the test time.

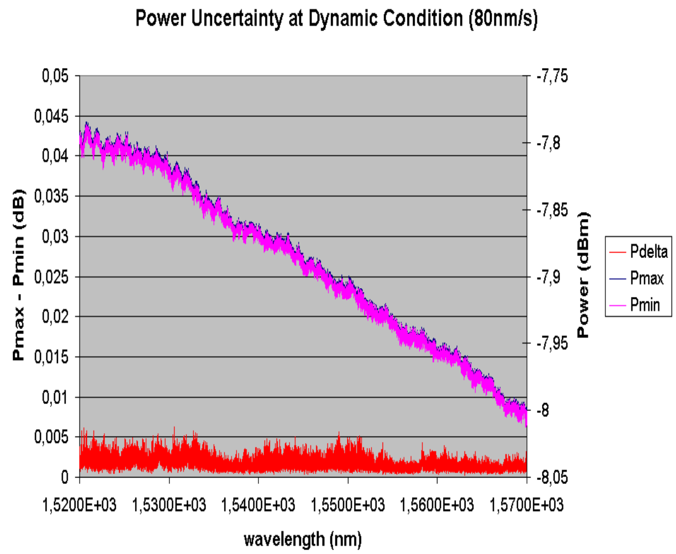


Diagram 3: Power stability test result when dynamically swept over wavelength. The diagram shows the minimum and maximum power spectrums for repeated measurements at – 8.5dBm low SSE power. The dynamic power flatness is the delta power (dB) over wavelength in one spectrum. For loss applications, this difference would be calibrated prior to the device measurement. Dynamic power reproducibility is shown as the delta (dB) between Pmax and Pmin.

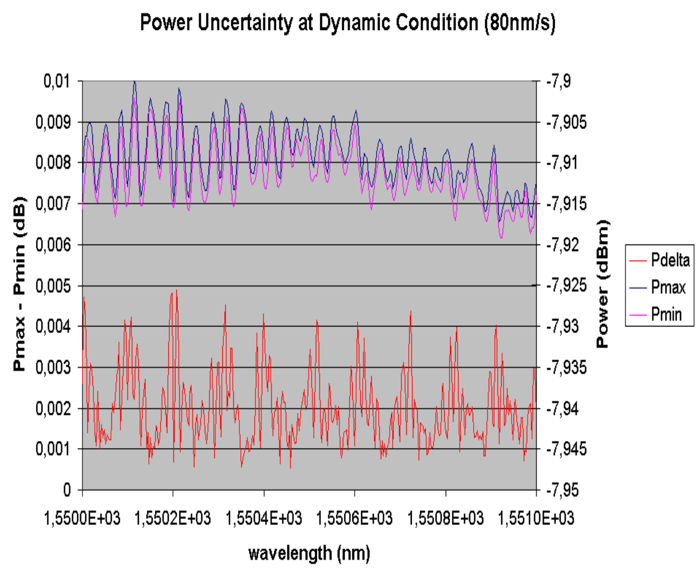


Diagram 4: The graph is enlarged to cover the 1550nm – 1551nm range to provide the power stability test result. Power flatness over this wavelength range shows the impact of interference effects (about 15mdB in both the Pmax and Pmin spectrums). However, the delta between Pmax and Pmin is less than 5mdB.

4. Optical Test Solution

One method of compensating for the distortion effects described here is to post process the measurement data, so optimally compensating for the system inaccuracy[3]. For example, absolute wavelength can be corrected by measuring the absolute wavelength accuracy of the test setup and calibrating out the wavelength error by data processing. Another approach is to validate the system integrity under dynamic conditions, especially wavelength and power accuracy.

Tunable Laser Sources

81600B (1440 – 1640nm)	81480B (1370 – 1495nm)	81672B (1260 – 1375nm)
	81680B (1460 – 1580nm)	81482B (1370 – 1495nm)
	81640B (1495 – 1640nm)	81682B (1460 – 1580nm)
		81642B (1495 – 1640nm)

For further information, please visit www.agilent.com/comms/oct

[3] "Agilent Technologies' enhanced version of Photonic Foundation Library raises the standards of testing", Agilent Techologies Palo Alto, Calif., Oct. 1, 2001 Press Release: www.agilent.com/go/news – Press Releases – Communications – October 2001

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Related Literature:

Agilent 81480/680/640B
Agilent 81672/482/682/642B
Tunable Laser Sources
Technical Specifcations
5988-5508EN

Agilent High Performance Tunable Laser Sources
5988-7213EN

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