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Optimizing the Test Setup for Threshold Calculation Repeatability Using the LPA-9080 Laser Parameter Analyzer

APPLICATION NOTE

ILX Lightwave
Photonic Test and Measurement

Understanding the LPA-9080 Laser Parameter Analyzer

Optimizing the Test Setup for Threshold Calculation Repeatability

This Application Note discusses the factors affecting the accuracy and repeatability of threshold current measurements using the ILX Lightwave LPA-9080 Parametric Analysis System, and offers guidelines for optimizing the test system for your application.

BACKGROUND

The ILX Lightwave LPA-9080 is a high-speed laser parameter analyzer with integrated current source, temperature controller, and power meter. Coupled with our versatile SPA-9000 Parameter Analyzer software, a powerful test system can be configured for a wide array of test applications.

The SPA-9000 software allows the test engineer to configure nearly every aspect of the L/I/V test, including four different methods for calculating threshold current. With such a large number of configuration options, the test engineer must be careful to optimize the test setup to achieve the required test accuracy, repeatability, and speed.

Other factors that affect test capability, falling into the following categories, must be also realized:

1) **Environmental factors, including**
   a. Short term temperature stability in test area
   b. Seasonal environmental fluctuations
2) **Hardware factors, including**
   a. Limitations of the measurement instrument, such as measurement resolution, accuracy, and noise
   b. Laser temperature control stability
3) **Software configuration, including:**
   a. Current step size
   b. Test speed, and dwell time at each current set point
   c. Data smoothing and sampling
   d. Threshold calculation method
   e. Power meter gain range setting

This application note focuses on the third category above, optimizing the software test setup for threshold repeatability.

In order to focus on optimizing the SPA-9000 software configuration for this application note, most of the outside factors were standardized. For example, the laser chip temperature was allowed to stabilize for 10 seconds before each L/I/V sweep and the fiber was left attached to the detector head for the duration of the test.

DISCUSSION

The best L/I/V test results are not necessarily achieved by choosing the smallest possible current step size for the sweep. ILX Lightwave has performed extensive testing to identify a method for quickly optimizing the L/I/V sweep parameters for measurement accuracy, repeatability, and test time.

A large number of test parameters can be adjusted in the SPA-9000 software, including:

1) Laser maximum power, which sets the power meter gain range
2) Temperature tolerance window
3) Nominal laser wavelength
4) Current step size
5) Step delay, or settling time
6) Number of samples per data point
7) Curve smoothing, or moving average, for dL/dI and d^2L/dI^2
8) Threshold calculation method

The number of different combinations of these test parameters is staggering. In order to make the optimization process manageable, several parameters can be removed from the optimization process by choosing intuitively relevant values.

1) **Laser maximum power.** In order to capture the entire L/I sweep in a single run, the laser should be run from 0 mA to I_{op}, which means the laser will reach the nominal rated power level. Therefore, the laser maximum power level should be set to a value slightly higher than P_{op}. Unfortunately this means the threshold power level will be near the bottom

of the scale in that power meter gain range, and therefore closer to the noise floor.

2) **Temperature tolerance window.** The temperature tolerance window determines the temperature at which the L/I sweep will begin. For example, the sweep won't begin until the chip temperature is within ±1°C of the set point for 2 seconds. The penalty for a very tight tolerance window is added settling time. The window used for these tests is ±0.25°C for 1.5 seconds, which is a compromise between temperature uniformity and settling time.

3) **Nominal laser wavelength.** The nominal wavelength value is used to determine the responsivity value for power measurements, so it is important that the correct value be entered. For most tests, a value within ±1nm of the actual wavelength at P_{op} is adequate.

The remaining test parameters all have a significant impact on threshold calculation repeatability, and were the focus of this study.

4) **Current step size.** The current step size determines the L/I sweep current resolution. For this study, two settings were used for the current step size: the minimum setpoint resolution for the LPA-9080 instrument; and 1% of the nominal threshold current.

Current step size has a major impact on threshold calculation repeatability. Too small current steps will introduce a greater amount of noise into the measurement-calculation algorithm. Too large current steps will make the data too coarse and obscure parametric detail in the threshold knee region.

5) **Step delay.** The step delay will cause the LPA-9080 to pause between current steps before making parametric measurements. This function is useful for noisy lasers, or lasers with long settling times, but the time penalty can be significant. The L/I/V sweep is conducted at approximately 14 ms per data point, including sweep and data download, so a 10 ms step delay will increase test time by approximately 70%.

6) **Sampling**. The sampling rate can typically be set to between three and nine points per current step with little impact on the test time because the analog-to-digital converter used in the LPA-9080 is very fast. Additional sampling helps to reduce measurement noise since the samples are averaged at each current step.

7) **Curve smoothing**. Curve smoothing can be applied to the first and second derivative lines and to the threshold calculation algorithm when using either derivative method. Small smoothing values (3 points) will help to reduce noise with little impact to threshold accuracy, but large values (9 or 11 points) will skew the threshold calculation and obscure details of the L/I characteristics.

8) **Threshold calculation method**. Four choices of threshold calculation algorithm are available with the SPA-9000 software: linear fit, two segment, first derivative, and second derivative. All but the linear fit are recognized in the Telcordia reliability assurance requirements, and the second derivative method is recommended.

For this study, the first and second derivative methods were characterized.

In order to develop a method for optimizing the test parameters, a series of tests was run on three different types of lasers while varying these test parameters. The three lasers were: a noisy and unstable 1408 nm pump, a very stable 1615 nm transmission laser, and a high power 980 nm pump. Over 150 L/I/V sweeps were run on each laser, and the threshold repeatability was characterized.

Table 1 shows the parameter combinations that were used for each test run.

Table 1
Parameter Combinations

		Minimum Step Resolution			1% Step Resolution		
	Nominal I_{th}	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
Current Step - 1408 nm	20 mA	0.01 mA	0.01 mA	0.01 mA	0.2 mA	0.2 mA	0.2 mA
Current Step - 1615 nm	10 mA	0.01 mA	0.01 mA	0.01 mA	0.1 mA	0.1 mA	0.1 mA
Current Step - 918 nm	260 mA	0.1 mA	0.1 mA	0.1 mA	2.6 mA	2.6 mA	2.6 mA
Samples per Data Point		3	9	3	3	9	3
Derivative Smoothing		11	3	3	11	3	3

For each parameter combination, the calclated threshold values for the first derivative and second derivative methods were recorded.

These values were then analyzed for standard deviation and average difference. Table 2 shows the standard deviation of the calculated threshold values.

Table 2
Derivative Threshold Repeatability

Standard Deviation in Calculated Threshold Current

		Minimum Step Resolution			1% Step Resolution		
	Nominal I_{th}	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
1408 nm	First Deriv	1.99%	12.68%	8.62%	0.68%	1.30%	1.56%
Ith = 20 mA	Second Deriv	10.95%	11.72%	12.65%	0.88%	0.72%	4.63%
1615 nm	First Deriv	0.09%	0.22%	0.28%	0.07%	0.03%	0.03%
Ith = 10 mA	Second Deriv	0.57%	2.53%	2.64%	0.04%	0.51%	0.56%
918 nm	First Deriv	0.22%	0.31%	3.30%	0.50%	0.00%	0.52%
Ith = 260 mA	Second Deriv	6.77%	11.21%	17.17%	0.73%	0.26%	0.51%

Figures 1 and 2 show the results of Runs 2 and 5, respectively, on the 918 nm laser. Notice the difference in measurement noise. Based on the standard deviation results in Table 2, the best second derivative threshold repeatability is generally achieved using a current step size of 1% of the threshold current (Runs 4, 5, 6). Step sizes smaller than 1% of I_{th} tend to be too noisy, and the calculation algorithm has a difficult time sorting out the actual second derivative peak from the artificial peaks caused by noise (see also Figures 5 and 6).

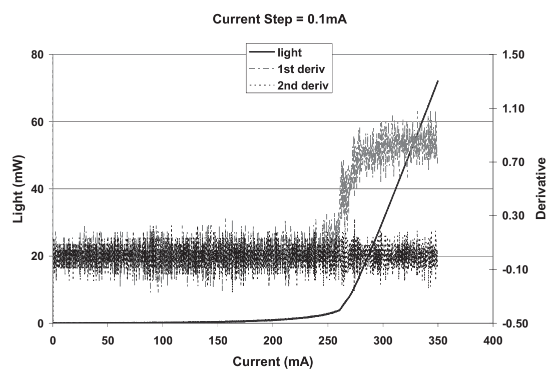

Fig. 1 Run 2, Current Step = 0.1 mA

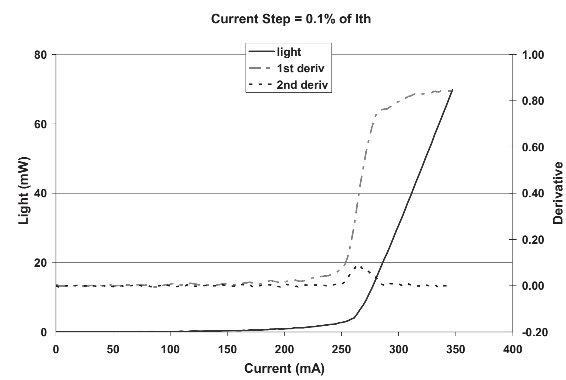

Fig. 2 Run 5, Current Step = 1% of I_{th}

One side effect of using a larger current step size is that some detail from the L/I curve, and therefore the derivative curves, will be obscured. This is especially obvious in Figures 3 and 4; the smaller step size in Figure 4 clearly shows a “kink” in the threshold knee that is not detected with the larger step size. In such cases, the test engineer must balance the tradeoff between higher resolution and lower threshold repeatability.

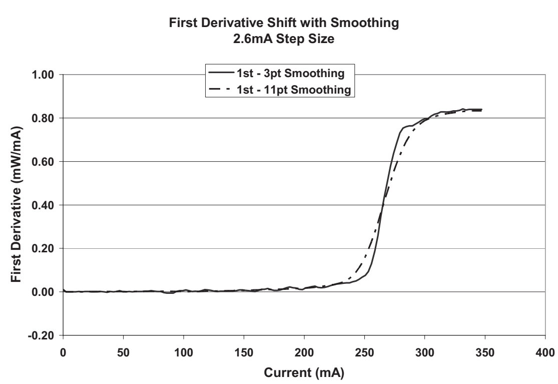

Fig. 3 First Derivative Smoothing 2.6mA Current Steps

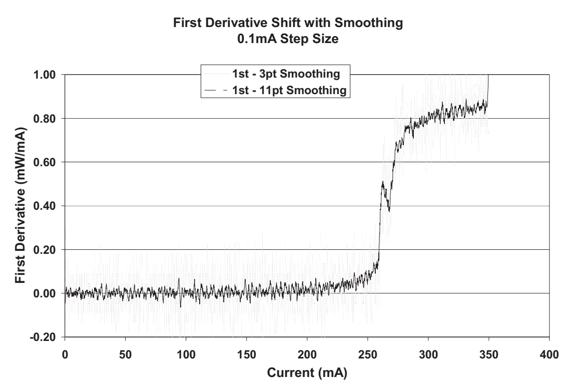

Fig. 4 First Derivative Smoothing 0.1mA Current Steps

Figures 5 and 6 illustrate the effects of current step size and smoothing value on the second derivative curve.

The last major test configuration variable is the threshold calculation method. The two linear methods are not recommended because of their strong dependence on the linearity of the L/I characteristics. Strong arguments exist for selecting one derivative method over the other, but Bellcore suggests the second derivative method.

The point at which the dL/dI curve reaches 50% of its maximum value is defined as the first derivative threshold current. This method is somewhat

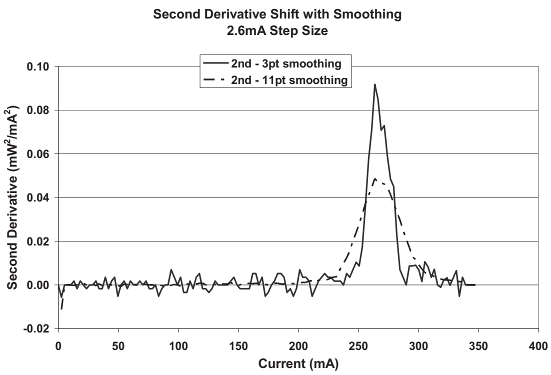

Fig. 5 Second Derivative Smoothing with 2.6 mA Current Steps

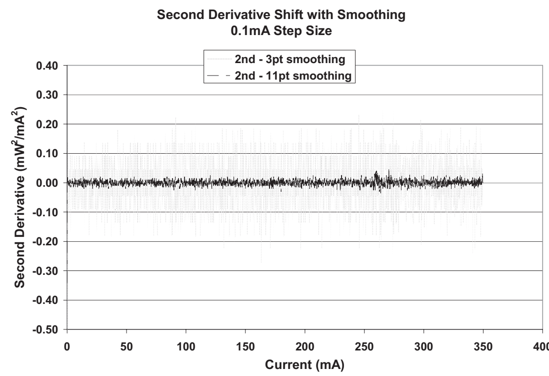

Fig. 6 Second Derivative Smoothing with 0.1 mA Current Steps

dependent on the slope efficiency of the laser. For lasers with lower slop efficiencies, the threshold may shift to a higher value. Lasers with very round threshold “knees” will exhibit greater Ith uncertainty with this method because the peak of the dL/dI curve is difficult to define.

The second derivative method defines the threshold as the point at which the slope of the L/I curve reaches its maximum rate of change. This method is not dependent on the spontaneous emissions of the laser, nor is it affected by the slope efficiency.

The linear methods of determining threshold current are not recommended since they are strongly dependent on the linearity of the laser before and after the threshold knee. Spontaneous emission levels will also affect the threshold calculation, especially when using the two-segment linear method.

CONCLUSION

There is no single best way to configure a laser diode L/I/V test with the SPA-9000 software. Some test configurations will achieve better threshold calculation repeatability than others, but at the trade-off of L/I- and derivative-curve detail. To develop a configuration that maximizes threshold repeatability requires the test engineer to optimize the test variables, and a good starting point is with a current step size of 1% of I_{th}. The true I_{th} value is not required for the setup; the nominal value for the laser diode model number is close enough. From this starting point, the step size can be adjusted to optimize the results per the test requirements by balancing repeatability, resolution, and test time.

The sampling value can be set to a higher number with little penalty in test time, and higher sampling values will help to reduce measurement noise.

Like the current step size, the curve smoothing value also requires optimizing to trade-off I_{th} calculation repeatability and measurement resolution and detail.

Finally, the second derivative threshold calculation method results in the most repeatable calculations. Some customers may require the first derivative method is used, and they should be made aware of the calculation repeatability tradeoff. The second derivative method is also recommended in the Bellcore “Introduction to Reliability of Laser Diodes and Modules” as well as Telcordia Technologies GR-3013-CORE standard.

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