#12

The Differences Between Threshold Current Calculation Methods

APPLICATION NOTE

ILX Lightwave

Photonic Test and Measurement

Understanding the LPA-9080 Laser Parameter Analyzer

The Differences Between the Threshold Current Calculation Methods

This Application Note explains the four threshold calculation algorithms used in the ILX Lightwave SPA-9000 Parameter Analyzer Software, and why each method will result in a slightly different threshold value.

BACKGROUND

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

The SPA-9000 is configured to run the L/I/V test, and collects the raw data from the LPA-9080 after the L/I/V sweep is complete. Four different algorithms are available to calculate the laser threshold current:

1) Linear line fit
2) Two-segment line fit
3) First derivative of light vs. current
4) Second derivative of light vs. current

These four methods are recognized and described in the Bellcore standard *"Introduction to Reliability of Laser Diodes and Modules"* (SR-TSY-001369). Each method, even when used on the same data set, will typically generate slightly different values for the threshold current.

Some laser diode manufacturers have a preferred calculation method, or their customers require a particular method is used. In other applications, such as R&D or university environments, no particular method is prescribed. In these cases, the user needs to understand the differences between the methods, and why they give different results.

Understanding the factors that affect threshold calculation allows the user to choose the right method for particular applications, and leads to more effective and efficient use of test time and resources.

DISCUSSION

The four methods of threshold calculations each act upon a different characteristic of the L/I curve, so they will be described individually with ideal examples; Figure 1 shows an ideal L/I curve which will be used through the rest of this application note to illustrate the different threshold calculation methods. For these ideal examples, arbitrary current numbers are assigned so the methods can be compared.

The most critical portion of the graph is the threshold knee region. This is the point where the laser switches from strictly spontaneous emissions to lasing emissions, and the slope efficiency increases dramatically.

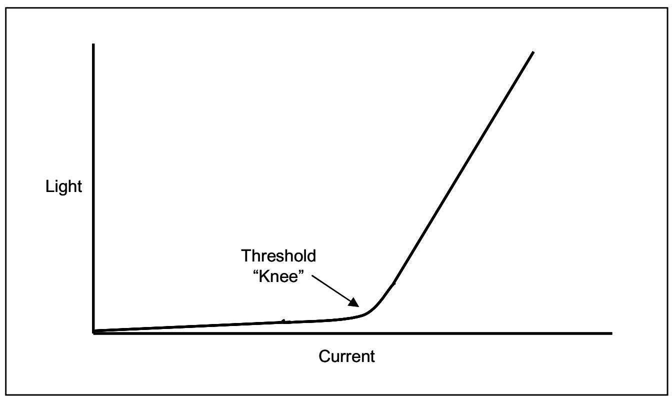

Figure 1   Ideal L/I Curve, with Derivative Curves

Linear Line-Fit Threshold Calculation

The linear fit method is the simplest, but potentially the most unreliable. This method simply extends a straight line down the lasing portion of the L/I curve until it intersects the horizontal axis. The intercept point is defined as the threshold current.

Figure 2 shows a close up of the threshold knee and the single line Linear Fit method of calculating threshold current.

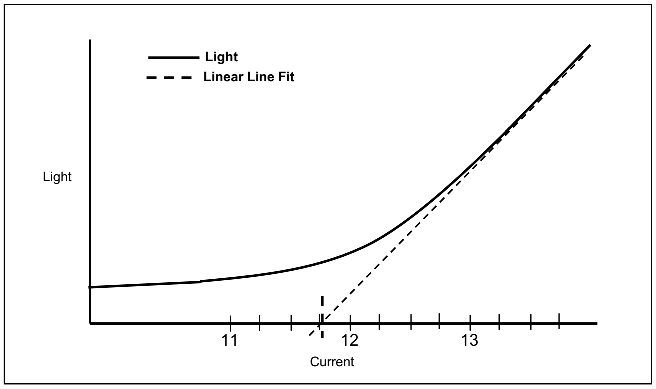

Figure 2 Linear Line-Fit

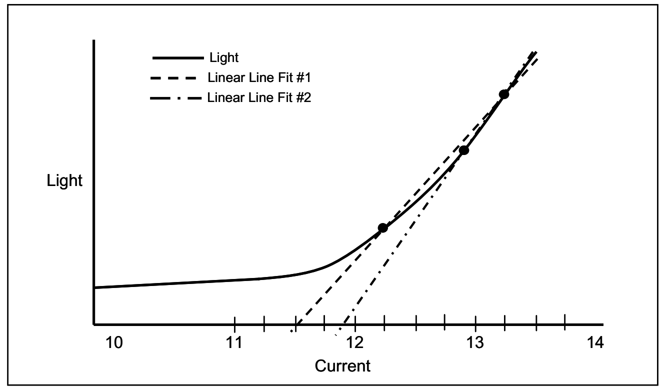

Figure 3 First-Point Selection, Effect on Calculated I_{th} Value

There are several serious disadvantages to the linear line-fit method:

1) The calculated I_{th} value is highly dependent on the slope efficiency of the laser. Less efficient lasers will have a lower calculated threshold value, especially when the threshold knee is rounded instead of very sharp. The slope efficiency may shift due to internal laser module properties or even because of improper light coupling to the photodetector used to measure light output.

2) If the linear line if based on a linear regression, then the proper start- and stop-points of the regression must be selected. If the regression uses data too near the threshold knee then the calculated threshold value will shift to a lower value. Conversely, if the regression starts too far from the knee, the line fit may be strongly influenced by non-linearities at higher powers.

3) If the linear line is based on a two-point fit, then the selection of the first point is critical. A point too low on the threshold knee and the x-intercept is shifted to a much lower cur rent value. Conversely, if the point is too high on the light curve then the linear line may be impacted by non-linearities at higher light output powers and the threshold value will be shifted. Figure 3 demonstrates these two cases.

Two-Segment Line-Fit Threshold Calculation

Figure 4 shows a close-up of the threshold knee region and the two-segment line fits. A line is fitted to the pre-threshold portion of the curve; a second line is fitted to the lasing portion in the same manner as the linear fit method. The point where the two lines intersect is projected down onto the current axis and labeled as I_{th} value.

This method is less sensitive to changes in slope efficiency than the linear method, but it is still somewhat sensitive to the method used for generating the linear lines. If two-point line fits are used, non-linearities can be amplified by projecting the lines.

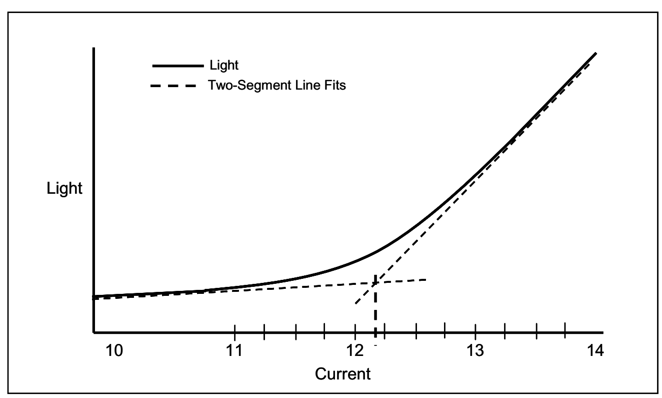

Figure 4 Two-Segment Line-Fit

First Derivative (dL/dI) Threshold Calculation

Figure 5 shows an ideal example of a first derivative threshold calculation. The threshold current is defined as the current at which the first derivative curve reaches ½ of the maximum value.

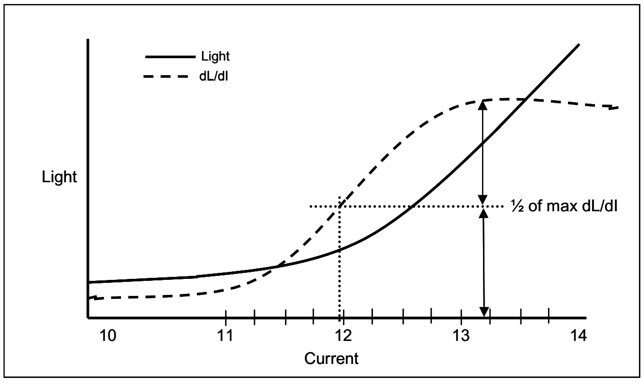

Figure 5 Ideal First Derivative Threshold Calculation

The first-derivative method is straight forward in most cases, but problems arise when the maximum of the dL/dI curve is not easily defined. Figure 6 shows an example of a dL/dI curve that continues to increase after the threshold knee, and does not have an apparent maximum.

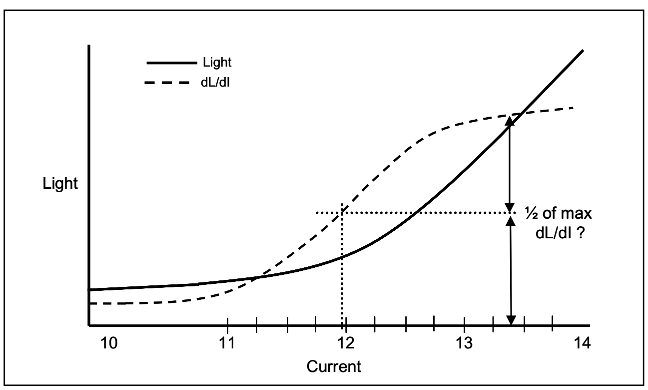

Figure 6 Continuously Increasing dL/dI

The problem of poorly defined first derivative maximum is exacerbated by measurement noise, which is a real problem encountered on any test system. Figure 7 shows the first derivative curve from a 918 nm pump laser. Notice that measurement noise at the dL/dI maximum level, as well as the lack of a clearly defined maximum point.

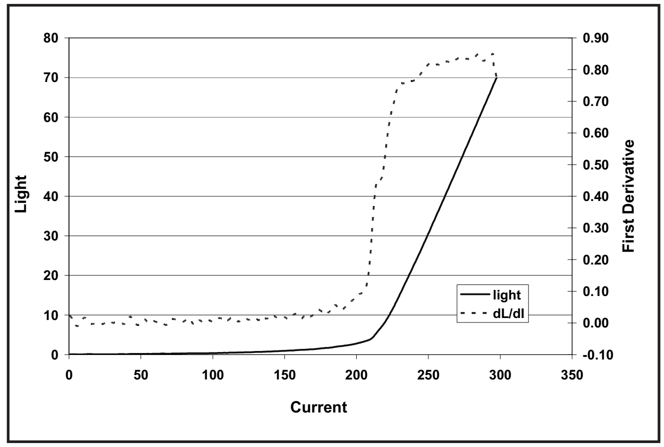

Figure 7 Real First Derivative Curve, with Noise

In this case the threshold calculation repeatability was poor because the noise value changed slightly from sweep to sweep. When the dL/dI maximum point is not repeatable then, of course, neither is the calculated threshold current.

Second Derivative (d^2L/dI^2) Threshold Calculation

The second derivative threshold calculation method is recommended by Bellcore and by Telcordia in the GR-3013-CORE Generic Requirements document. The method is illustrated in Figure 8. The second derivative method locates the point of maximum rate of change of the L/I curve, which is also the inflection point of the first derivative curve. It is not necessarily the same threshold point that is calculated using the first derivative method, however.

The second derivative method is insensitive to non-linearities before and after the threshold knee since those portions of the curve are not considered in the calculation.

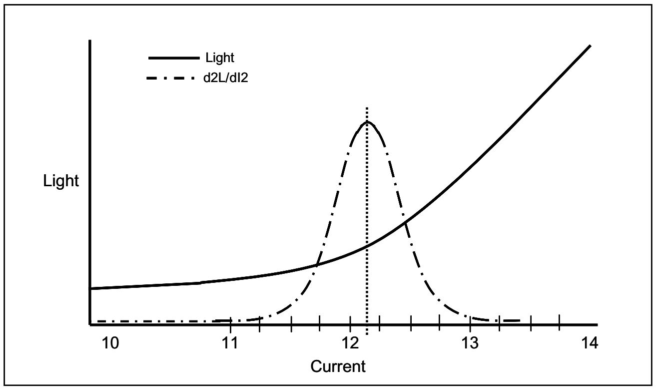

Figure 8 Ideal Second Derivative Threshold Calculation

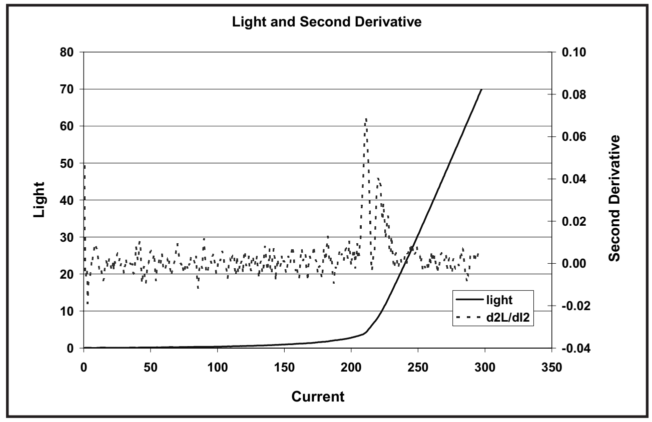

Figure 9 Second Derivative, Double-Peak

In testing real laser diodes, there can be a dual peak in the second derivative curve, with the second peak caused by a kink in the threshold knee (Figure 9, same laser as used to generate Figure 7). This possibility is acknowledged by the Bellcore document, and in most cases it is easy to determine which d^2L/dI^2 peak is real, even when using an automated test program to calculate I_{th}.

Automated Threshold Calculation

The second derivative calculation method does not guarantee reliable and repeatable threshold measurements, especially when automated test equipment is used to run the test. A number of test parameters need to be adjusted in order to reduce measurement noise, optimize test resolution, reduce test time, and balance other factors. A separate ILX Lightwave Application Note, titled “Optimizing the Test Setup for Threshold Calculation Repeatability,” addresses test configuration optimization issues.

CONCLUSION

The threshold calculation method you choose for your test application will depend on a number of factors:

- Does your customer require that you use a particular method?
- Are you calculating the threshold manually or with an automated system?
- How linear are the pre- and post-threshold portions of the L/I curve?
- How repeatable does the threshold calculation have to be?

Although all four calculation methods are recognized in the Bellcore document, the derivative methods are the most reliable and least affected by anomalous laser characteristics. The second derivative method is preferred by Bellcore, and is recommended in the Telcordia CORE document.

The ILX Lightwave LPA-9080 and SPA-9000 system were used to generate the following data from real laser diodes, and demonstrates that the threshold values are not the same for each calculation method, and the variation can depend greatly on the laser type and the characteristics around the threshold knee.

Table 1

Real Threshold Values (in mA)

Calculation Method	1615 nm DWDM P_{op} = 20 mW	918 nm Pump P_{op} = 1 W	1408 nm Pump P_{op} = 200 mW
Linear Fit	11.89	261.68	23.90
Two-Segment Fit	12.15	262.57	24.10
First Derivative	12.00	258.09	23.41

The following publications are available for download on at www.ilxlightwave.com.

White Papers

- A Standard for Measuring Transient Suppression of Laser Diode Drivers
- Degree of Polarization vs. Poincaré Sphere Coverage
- Improving Splice Loss Measurement Repeatability

Technical Notes

- Attenuation Accuracy in the 7900 Fiber Optic Test System
- Automatic Wavelength Compensation of Photodiode Power Measurements Using the OMM-6810B Optical Multimeter
- Bandwidth of OMM-6810B Optical Multimeter Analog Output
- Broadband Noise Measurements for Laser Diode Current Sources
- Clamping Limit of a LDX-3525 Precision Current Source
- Control Capability of the LDC-3916371 Fine Temperature Resolution Module
- Current Draw of the LDC-3926 16-Channel High Power Laser Diode Controller
- Determining the Polarization Dependent Response of the FPM-8210 Power Meter
- Four-Wire TEC Voltage Measurement with the LDT-5900 Series Temperature Controllers
- Guide to Selecting a Bias-T Laser Diode Mount
- High Power Linearity of the OMM-6810B and OMH-6780/6790/6795B Detector Heads
- Large-Signal Frequency Response of the 3916338 Current Source Module
- Laser Wavelength Measuring Using a Colored Glass Filter
- Long-Term Output Drift of a LDX-3620 Ultra Low-Noise Laser Diode Current Source
- Long-Term Output Stability of a LDX-3525 Precision Current Source
- Long-Term Stability of an MPS-8033/55 ASE Source
- LRS-9424 Heat Sink Temperature Stability When Chamber Door Opens
- Measurement of 4-Wire Voltage Sense on an LDC-3916 Laser Diode Controller
- Measuring the Power and Wavelength of Pulsed Sources Using the OMM-6810B Optical Mutlimeter
- Measuring the Sensitivity of the OMH-6709B Optical Measurement Head
- Measuring the Wavelength of Noisy Sources Using the OMM-6810B Optical Multimeter
- Output Current Accuracy of a LDX-3525 Precision Current Source
- Pin Assignment for CC-305 and CC-505 Cables
- Power and Wavelength Stability of the 79800 DFB Source Module
- Power and Wavelength Stability of the MPS-8000 Series Fiber Optic Sources
- Repeatability of Wavelength and Power Measurements Using the OMM-6810B Optical Multimeter
- Stability of the OMM-6810B Optical Multimeter and OMH-6727B InGaAs Power/Wavehead
- Switching Transient of the 79800D Optical Source Shutter
- Temperature Controlled Mini-DIL Mount
- Temperature Stability Using the LDT-5948
- Thermal Performance of an LDM-4616 Laser Diode Mount
- Triboelectric Effects in High Precision Temperature Measurements
- Tuning the LDP-3840 for Optimum Pulse Response
- Typical Long-Term Temperature Stability of a LDT-5412 Low-Cost TEC
- Typical Long-Term Temperature Stability of a LDT-5525 TEC
- Typical Output Drift of a LDX-3412 Loc-Cost Precision Current Source
- Typical Output Noise of a LDX-3412 Precision Current Source
- Typical Output Stability of the LDC-3724B
- Typical Output Stability of a LDX-3100 Board-Level Current Source
- Typical Pulse Overshoot of the LDP-3840/03 Precision Pulse Current Source
- Typical Temperature Stability of a LDT-5412 Low-Cost Temperature Controller
- Using Three-Wire RTDs with the LDT-5900 Series Temperature Controllers
- Voltage Drop Across High Current Laser Interconnect Cable
- Voltage Drop Across High Current TEC Interconnect Cable
- Voltage Limit Protection of an LDC-3916 Laser Diode Controller
- Wavelength Accuracy of the 79800 DFB Source Module

Application Notes

- App Note 1: Controlling Temperatures of Diode Lasers and Detectors Thermoelectrically
- App Note 2: Selecting and Using Thermistors for Temperature Control
- App Note 3: Protecting Your Laser Diode
- App Note 4: Thermistor Calibration and the Steinhart-Hart Equation
- App Note 5: An Overview of Laser Diode Characteristics
- App Note 6: Choosing the Right Laser Diode Mount for Your Application
- App Note 8: Mode Hopping in Semiconductor Lasers
- App Note 10: Optimize Testing for Threshold Calculation Repeatability
- App Note 11: Pulsing a Laser Diode
- App Note 12: The Differences between Threshold Current Calculation Methods
- App Note 13: Testing Bond Quality by Measuring Thermal Resistance of Laser Diodes
- App Note 14: Optimizing TEC Drive Current
- App Note 17: AD590 and LM335 Sensor Calibration
- App Note 18: Basic Test Methods for Passive Fiber Optic Components
- App Note 20: PID Control Loops in Thermoelectric Temperature Controllers
- App Note 21: High Performance Temperature Control in Laser Diode Test Applications

For application assistance or additional information on our products or services you can contact us at:

ILX Lightwave Corporation
PO Box 6310, Bozeman, MT 59771-6310
Phone: 406-556-2481 • 800-459-9459 • Fax: 406-586-9405
Email: sales@ilxlightwave.com

To obtain contact information for our international distributors and product repair centers or for fast access to product information, technical support, LabVIEW® drivers, and our comprehensive library of technical and application information, visit our website at:

www.ilxlightwave.com

ILX Lightwave
Photonic Test and Measurement