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ReliaTest L/I Threshold Calculations

APPLICATION NOTE

ILX Lightwave®

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ReliaTest L/I Threshold Calculations

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Understanding the First and Second Derivative Threshold Algorithms

Introduction

This technical note describes two of the algorithms utilized by ReliaTest to calculate the threshold current of a laser from an L/I curve as measured with the LRS-9424 Laser Diode Reliability and Burn-In Test System.

Background

The LRS-9424 Laser Diode Reliability and Burn-In Test System is capable of generating L/I curves with up to a maximum of 1000 points. The ReliaTest software operates the LRS-9424 and manages the data from these L/I plots. ReliaTest calculates the threshold current from the L/I plots using four methods: Second Derivative, First Derivative, Two-Segment Fit, and Single-Line Line-Fit. The second derivative, first derivative, and two-segment fit algorithms are defined by the Bellcore standard fro Optoelectronic Devices used in Telecommunications Equipment (Telcordia GR-468-CORE and GR-3013-CORE).

First Derivative Threshold Algorithm Overview

The first derivative algorithm defines the threshold current as the drive current at which the first derivative of light output reaches 50% of the peak value. The following steps outline the procedure for calculating the threshold current of a single laser using the first derivative algorithm:

1) Generate the L/I curve from one laser with the LRS-9424 system.
2) Smooth the data points.
3) Calculate the first derivative, dL/dI.
4) Find the maximum dL/dI value.
5) Calculate 50% of the maximum value.
6) Find the I value (current in terms of mA) from the dL/dI graph that corresponds to one half of the maximum dL/dI.
7) This I value is the value of the threshold current.

The calculation method for determining the derivative is susceptible to high-frequency noise; therefore the data is smoothed prior to the derivative calculation. The amount of smoothing can be configured in ReliaTest. Please refer to “Smoothing the Data Points” for more information on this topic.

Second Derivative Threshold Algorithm Overview

The second derivative algorithm defines the threshold current as drive current at which the second derivative of light output is at the maximum value. The maximum value of the second derivative is the point of maximum change in the L/I curve. The following steps outline the procedure for calculating the threshold current of a single laser using the second derivative algorithm:

1) Generate the L/I curve from one laser with the LRS-9424 system.
2) Smooth the data points.
3) Calculate the first derivative.
4) Smooth the first derivative.
5) Calculate the second derivative by calculating the derivative of the first derivative, d^2L/dI^2.
6) Find the maximum d^2L/dI^2 value.
7) Fit the three points around the maximum d^2L/dI^2 value to a parabolic function.
8) Find the maximum value of the parabola. The maximum is defined as the point where the slope of the parabola equals zero.
9) The parabolic maximum is an interpolated point that represents a more accurate maximum d^2L/dI^2 value.
10) Determine the I value (current in terms of mA) of the parabolic maximum point.
11) This I value is the threshold current.

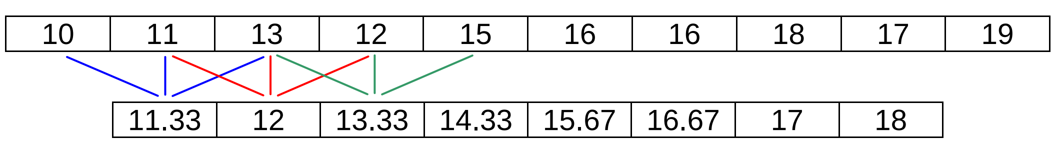
Just as in the first derivative algorithm, the accuracy of the threshold current is dependent on noise. Smoothing the data is a reliable method for mitigating the effect of high-frequency noise. Noise can be magnified during the derivative calculation; therefore the first derivative data is smoothed before being used to calculate the second derivative. Please refer to “Smoothing the Data Points” for more information on this topic.

Smoothing the Data Points

Smoothed data points are calculated by performing a moving window (or box-car) average along the data. When configuring an LIV, the user may enter an amount to smooth the data. By default, the amount is 10. The moving average window is comprised of the average of 10 data points. The average of those 10 data points is saved as one position in the smoothed data point array.

Example:

User-defined smoothing window: x = 3



Calculating the Derivative

To calculate the derivative of an array of data points, ReliaTest iterates through the array and determines the slope between each point in the array.

Example:
Array of measured light over the array of current (L/I):

Current	5	6	7	8	9	10	11	12	13	14
Light	10	11	12	12	14	16	17	18	18	19

Array of the first derivative of light

Current*	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5
ΔLight	1	1	0	2	2	1	1	0	1

*Laser current value for derivative (slope) calculations is defined to be the midpoint of each line segment whose slope is being calculated. Since current is constantly increasing as the independent axis, the change in current per point can be ignored in all further calculations. Doing so allows for the derivatives to maintain their positional information in current.

Stepping Through the Second Derivative Algorithm

This section details the steps for calculating the threshold current using the second derivative algorithm. A set of example data is used to illustrate how the data is calculated at each step. The example data is a simplified set of data from an L/I curve.

1) Generate the L/I curve from one laser with the LRS-9424 system.

Current	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Light	0	0	0	1	1	2	3	7	15	23	31	39	47	55	61	64

2) Smooth both current and light data points. Assume a smoothing window of 2.

Current	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5
Light	0	0	0.5	1	1.5	2.5	5	11	19	27	35	43	51	58	62.5

3) Calculate the first derivative.

Current	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ΔLight	0	0.5	0.5	0.5	1	2.5	6	8	8	8	8	8	7	4.5

4) Smooth the current and light first derivative values.

Current	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5
ΔLight	0.25	0.5	0.5	0.75	1.75	4.25	7	8	8	8	8	7.5	5.75

5) Calculate the second derivative by calculating the derivative of the first derivative.

Current	2	3	4	5	6	7	8	9	10	11	12	13
Δ(ΔLight)	0.25	0	0.25	1	2.5	2.75	1	0	0	0	-0.5	-1.75

6) Find the maximum d^2L/dI^2 value.

Maximum d^2L/dI^2 value = 2.75

7) Find the I value from the L/I data that corresponds to the maximum d^2L/dI^2 value.

Current where d^2L/dI^2 is 2.75 = 7

The last two steps are performed to obtain a more accurate threshold value. This is especially useful if the current step size chosen for the L/I data generation is relatively large.

8) Perform a 3-point parabolic fit to the L/I data centered about the maximum d^2L/dI^2 value. ReliaTest uses the three points around and including the maximum d^2L/dI^2 value (Point 1: 6, 2.5; Point 2: 7, 2.75; Point 3: 8; 1). These three points are used in place of X and Y to solve for variables A, B, and C in the following equation:

$$y_n = ax_n^2 + bx_n + c$$

a = -1

b = 13.25

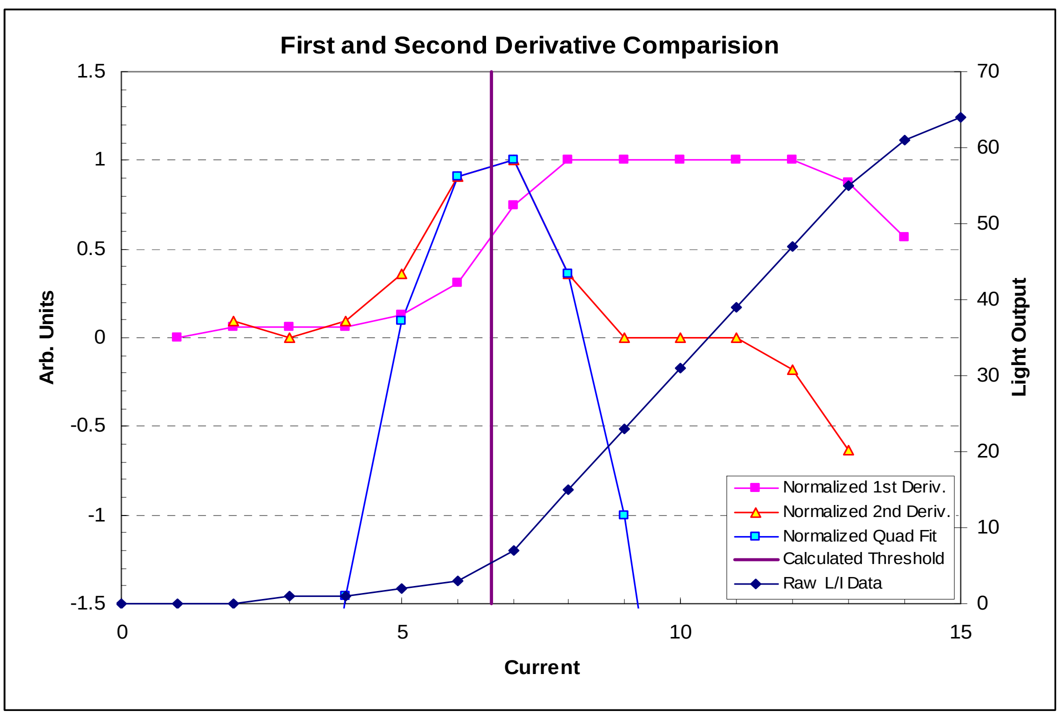
c = -41

9) With A, B, and C defined, we now have the parabolic function that defines the threshold region of the second derivative of the LIV data. The threshold is where the slope of the parabolic equation is zero. The threshold can be found by solving for X in the derivative of the parabolic equation where Y = 0.

$$\frac{dy}{dx} = 2ax_{thresh} + b = 0$$

Threshold Current (x_{thresh}) is 6.625

The following figure graphically shows the example data, normalized and plotted simultaneously.



The following publications are available for download 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
- Laser Diode Burn-In and Reliability Testing
- Power Supplies: Performance Factors Characterize High Power Laser Diode Drivers
- Reliability Counts for Laser Diodes
- Reducing the Cost of Test in Laser Diode Manufacturing

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 Multimeter
- 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

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