Application Note

ReliaTest L/I Threshold Calculations

mks | Newport™

Introduction

This technical note describes two out of the four algorithms utilized by ReliaTest to calculate the threshold current of a laser from an L/I curve as measured with the LRS-9434 Laser Diode Reliability and Burn-In Test System.

Background

The LRS-9434 Laser Diode Reliability and Burn-In Test System is capable of generating L/I curves with up to a maximum of 500 points respectively. The ReliaTest software operates the LRS-9434 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 Generic Reliability Assurance Requirements for Optoelectronic Devices used in Telecommunications Equipment (Telcordia GR-468-CORE).

Device temperature dependency (also described as characteristic temperature) and operating temperature stability could have a significant impact on threshold calculation accuracy and repeatability. The LRS-9434 test system was designed to minimize temperature impacts, through engineering considerations and end user adjustment settings in ReliaTest. For more information on threshold current repeatability, characteristic temperature, and temperature impacts, please refer to our Technical Note: Repeatability of Laser Diode Threshold Current Measurements in the LRS-9434.

Furthermore, our ReliaTest software ensures that no false thresholds are reported in the final L/I dataset. By creating an upper limit of the data to analyze, based upon a percentage of the full scale maximum current of the sweep, rollovers and L/I kinks are ignored, and only true threshold knee values are represented.

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-9434 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 is automatically determined by ReliaTest based on the number of points measured during the LIV.

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-9434 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.

Calculating LIV Device Analysis Parameters

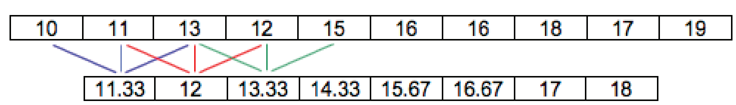
When using ReliaTest to calculate LIV parameters such as maximum power, V_{op}, P_{op}, and I_{op} for example, ReliaTest will utilize the second derivative threshold to determine a more accurate threshold voltage (regardless of the user set threshold method). When performing an LIV, ReliaTest will calculate threshold for all methods available. If the second derivative threshold calculation is not accurate then LIV parameters can be calculated incorrectly for noisy devices.

Smoothing the Data Points

Smoothed data points are calculated by performing a moving window (or box-car) average along the data. Since the smoothing size is not settable by the user, smoothing values are pre-determined depending on the number of steps and resolution / step size set by the end user.

Example:

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
Δ Light	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-9434 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
Δ Light	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
Δ Light	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 (Δ Light)	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:

   $$y_n = \mathrm{a}x_n^{\ 2} + bx_n + \mathrm{c}$$

   $$a = \text{-}1$$

   $$b = 13.25$$

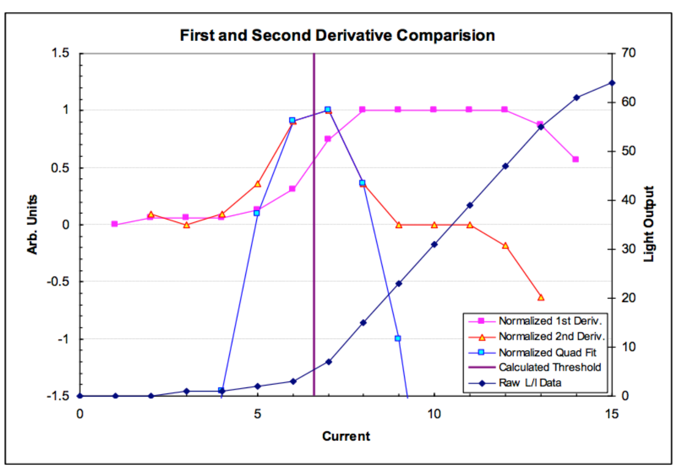
   $$c = \text{-}41$$

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 on at www.ilxlightwave.com.

White Papers

- A Standard for Measuring Transient Suppression of Laser Diode Drivers
- Calibration and Traceability Ensure Measurement Accuracy
- Degree of Polarization vs. Poincaré Sphere Coverage
- Improving Splice Loss Measurement Repeatability
- Laser Diode Bum-In and Reliability Testing
- Power Supplies: Performance Factors Characterize High Power Laser Diode Drivers
- Simplifying Parametric Analysis of Laser Diodes
- Reliability Counts for Laser Diodes
- Reducing the Cost of Test in Laser Diode Manufacturing

Technical Notes

- Accuracy and Repeatability of Power Measurements Using the FPM-8220
- 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
- Callendar-Van Dusen Equation and RTD Temperature Sensors
- Clamping Limit of an LDX-3525B Precision Current Source
- Connecting Your Laser to the LDP-3830
- Determining the Polarization Response of the FPM-8220
- Effects of Cabling and Inductance When Pulsing High Power Laser Diodes
- Facility Power Requirements for the LDX-36000
- Four-Wire TEC Voltage Measurement with the LDT-5900 Series
- Guide to Selecting a Bias-T Laser Diode Mount
- High Power Linearity of the OMM-6810B and OMH-6790B Detector Heads
- Large-Signal Frequency Response of the 3916338 Current Source Module
- Laser Wavelength Measuring Using a Colored Glass Filter
- LDC-3736 Laser Protection
- LDM-4982 and 4984 Quick Setup Guide
- LDP-3830 Independent Current Limit
- LDP-3830 Laser Protection
- LDP-3830 Pulse Performance
- LDT-5900C Temperature Stability
- LDT-5910C PID Control Quick Start
- LDT-5940C Voltage Measurement Techniques
- LDX-3232 Modulation Bandwidth
- LDX-36000 CQW Pulse Characteristics
- Long-Term Output Stability of an LDX-3620B Laser Diode Current Source
- Long-Term Output Stability of an LDX-3525B Precision Current Source
- LRS-9434 Temperature Set Point Accuracy
- LRS-9434 Temperature Coefficient
- LRS-9434 Threshold Current Measurement Repeatability
- LRS-9434 and LMS-9406 Transient Protection
- LRS-9550 Device Temperature Algorithm
- LRS-9550 Fixture Temperature Range
- LRS-9550 Laser Drive Current Setpoint Accuracy
- LRS-9550 Laser Eye Safety Features
- LRS-9550 Water Quality Guidelines
- Measurement of 4-Wire Voltage Sense on an LDC-3916 Controller
- Measuring the Power and Wavelength of Pulsed Sources Using the OMM-6810B Optical Multimeter
- Measuring the Wavelength of Noisy Sources Using the OMM-6810B
- Minimum Temperature Range of the LDM-4405
- Minimum Temperature Control Range of the LDM-4982M / LDM-4894T
- Nominal PID Constants for the LDT-5900 Series Controller
- Output Current Accuracy of an LDX-3525B Precision Current Source
- Paralleling Laser Diodes
- Pulse Parameters and LDP-3830 Control Modes
- Quick Start: Modulation a Laser Diode Driver
- Repeatability of Wavelength and Power Measurements Using the OMM-6810B Optical Multimeter
- Square Wave Modulation of the LDX-3500B
- Stability of the OMM-6810B Optical Multimeter and OMH-6727B InGaAs Power/Wavehead
- Temperature Control Range of the LDM-4409
- Temperature Measurement Using a Linearized Thermistor Network
- Temperature Stability Using the LDT-5948 / LDT-5980
- Thermal Resistance of the LDM-4409
- Thermistor Constant Conversions: Beta to Steinhart-Hart
- Triboelectric Effects in High Precision Temperature Measurements
- Tuning the LDP-3840B for Optimum Pulse Response
- Typical Long-Term Temperature Stability of a LDT-5525 TEC
- Typical Output Drift / Noise of an LDX-3412
- Typical Temperature Stability of the LDT-5500B
- Using Status Event Registers for Event Monitoring
- Using the Dual Modulation Inputs of the LDX-3620B

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

Technical Notes continued

- Using the LDM-4984 with the LDP-3840B
- 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

Application Notes

- App Note 1: Controlling Temperatures of Diode Lasers 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 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 16: Measuring Wide Linewidth Source with the OMH-6700B Series Waveheads
- 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
- App Note 22: Modulating Laser Diodes
- App Note 23: Laser Diode Reliability and Burn-In Testing
- App Note 25: Novel Power Meter Design Minimizes Fiber Power Measurement Inaccuracies
- App Note 26: ReliaTest L/I Threshold Calculations
- App Note 27: Intensity Noise Performance of Semiconductor Lasers
- App Note 28: Characterization of High Power Laser Diode Bars
- App Note 29: Accelerated Aging Test of 1310 nm Laser Diodes
- App Note 30: Measuring High Power Laser Diode Junction Temperature and Package Thermal Impedance
- App Note 31: Mounting Considerations for High Power Laser Diodes
- App Note 32: Using a Power/ Wavehead for Emitter Level Screening of High Power Laser Diode Bars
- App Note 33: Estimating Laser Diode Lifetimes and Activation Energy
- App Note 34: Using USB Through Virtual COM Ports
- App Note 37: Measuring and Reducing Noise Using an LDX-3620B Ultra Low Noise Laser Diode Current Source
- App Note 38: Achieving Millikelvin Temperature Stability

www.newport.com/ilxlightwave
+1-800-459-9459 | +1-406-556-2481