Repeatability of Laser Diode Threshold Current Measurements in the LRS-9434

OVERVIEW

This technical note presents the results of measurement repeatability of threshold current on a batch of laser diode samples using the LRS-9434 Laser Reliability and Burn-In Test System. Additional system ReliaTest software features and operating environment considerations are noted to best mitigate possible sources of variation of the end user's test results.

BACKGROUND

Change in threshold current (I_{th}) is commonly used as a pass/fail criteria for screening laser diodes during production burn-in. Generally, lasers with a shift in threshold of greater than 10% would be removed from the production run and scrapped. In order to optimize yield through the burn-in and test process, it is important to ensure the utmost repeatability of threshold current measurements.

Ideally, repeated threshold current measurements performed on the same laser operated under the same conditions should yield identical results. In practice, measurement system noise and instability lead to some variation in measurement results. For good performance, the test system should be capable of measurement repeatability that is about 5 to 10 times better than the pass/fail screening criteria that will be used. In the case of a 10% screening criteria, the threshold measurement repeatability should be better than ±1% to ±2%.

ILX Lightwave's LRS-9434 Laser Diode Reliability and Burn-In Test System

There are three common analysis methods to calculate laser diode threshold current as defined by the Telcordia standard for Generic Reliability Assurance Requirements of Optoelectronic Devices Used in Telecommunications Equipment (GR-468-CORE, Issue 2, September 2004). They are the two-segment fit, first derivative, and second derivative methods.

For this experiment, we chose a fourth, alternative method to calculate the threshold current, known as linear line-fit. Using this method, threshold current is determined as the intercept to the axis, extrapolated from the linear active region of the laser L-I curve. This method is the simplest, yet potentially the most unreliable process. This experiment was performed to represent a worst-case scenario, with an external data processing calculation to check the results provided by the ReliaTest software.

The LRS-9434 is capable of performing threshold current calculations using any four of these methods. In our ReliaTest software platform, we typically choose to display the second derivative method in our graphed results, as this is the most preferred for accuracy and repeatability. Though only one method result is graphed, respective data is collected on all four variations during an L-I curve measurement.

Figure 1 shows a close-up of the threshold knee and the linear line-fit method used in our external calculations.

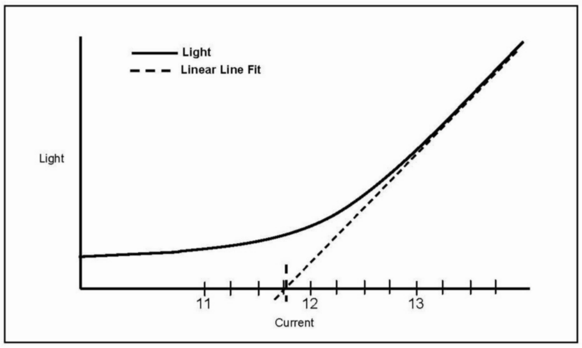

FIGURE 1 – Typical L-I curve and simplified linear line-fit method

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Figure 2 shows a typical L-I curve and ideal second derivative curve used for calculating the threshold in ReliaTest. This method is preferred by Telcordia guidelines, as it is insensitive to non-linearities present in the curve before and after the threshold knee. For more information on threshold calculation methods, please refer to our Application Note #12: The Differences Between Threshold Current Calculation Methods.

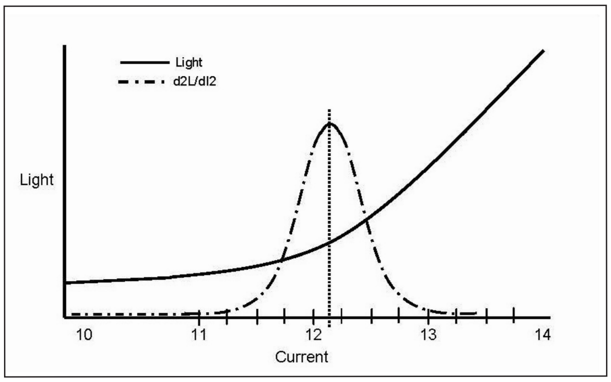

FIGURE 2 – Typical L-I curve and an ideal second derivative curve of a laser diode

MEASUREMENT SETUP

Repeatability measurements were performed using an ILX Lightwave LRS-9434 Laser Reliability and Burn-in Test system on a batch of laser diodes as shown in the following table:

Laser Application	Type of Laser Package	Nominal Output Power and Wavelength
Optical Transceiver	Chip on Carrier (CoC)	10mW, 1550nm

TABLE 1 – Laser diode used in repeatability measurements

For each measurement set, a batch of 256 laser diode samples were mounted into eight fixtures (32 devices per fixture), fully populating two Control Measure Module (CMM) shelves of the LRS-9434 system. After the data was collected, the fixtures were rotated to the next two CMM shelves. For each test, the fixture temperature was maintained at 60°C.

L-I curve data was obtained by sweeping the laser diode current to the maximum rated operating current, in steps of 0.2mA. Other setup parameters were the following: temperature window tolerance: ±0.1°C; temperature settling period: 0 seconds; device temperature settling enabled for 32 devices.

To measure repeatability, an in-situ L-I test was performed, with seven such iterative L-I measurements performed to determine the percentage of threshold repeatability for a single device in a single test position. The measurements were performed back-to-back, to avoid potential age degradation affecting the repeatability data.

The resulting raw data was sent to an external algorithm for the linear line-fit calculation, and compared against the seven ReliaTest iterations for a standard deviation result, for the final repeatability value for that test position. The resultant percentage was added to a histogram bin value, with over 1000 finalized data points added to the histogram graph, as shown in Figure 4.

With the cumulative percentage equating to our confidence interval (also known as an equated coverage factor at k = 2, as an expanded uncertainty value), at a 95% value, our collected measurement data resulted in an I_{th} repeatability value of ≤ 0.75%, well within industry standard expectations.

VARIATION SOURCES AND MITIGATION

There are two main potential sources for variations in I_{th} measured data, with subsequent subfactors:

1) **Actual device I_{th} variation**
   a. Device temperature dependency
   b. System fixture movement
2) **Measurement I_{th} variation**
   a. Number of steps
   b. Temperature settings
   c. Device count adjustments

Before considering any variations introduced in the measurement system and software calculations, actual device I_{th} variations must be taken into account. One such dependency is best expressed as the characteristic temperature (T_0) of the device, which is based upon the laser chip material, thermal resistance values, associated geometry of the laser and its package, etc. The characteristic temperature can be derived from L-I measurements, with following equation:

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$$T_0 = \frac{T_U - T_D}{\ln\left(\frac{I_{thTU}}{I_{thTD}}\right)}$$

Where T_U represents the upper range temperature test point (typically 85°C), T_D represents room temperature testing at 25°C, with respective I_{th} measurement data points. As threshold current increases exponentially with increased temperature, knowing your device's characteristic temperature (or temperature sensitivity) is helpful in determining its actual I_{th} variation.

In our experiment, we were using typical transceiver integrated laser diodes, which had a relatively nominal characteristic temperature (between 60 to 85°C). For test loads that have a higher temperature sensitivity (e.g., diodes with a characteristic temperature less than 55°C), subtle changes to the LRS-9434 thermal control plate and air flow may cause significant threshold variations. In these circumstances, the end user can use tighter software tolerances in the Temperature Control settings in ReliaTest, as shown in Figure 3, and explained in more detail later in this document.

It is also recommended to avoid inserting and removing neighboring fixtures on the same or adjacent CMM shelf during an L-I measurement in a test fixture position. This can potentially cause shifts in the air flow, with an instantaneous device temperature shift, which could create an actual device I_{th} variation.

For measurement I_{th} variation, the most significant factor in the software configuration is setting the number of current step points. In ReliaTest, the end customer can set the desired number of step points for the full L-I sweep, with the current step size, sweep time, and curve smoothing automatically adjusted for the test. Setting too few step points will result in a larger current step size, with the resultant curve being too coarse, thus obscuring parametric detail in the threshold knee region. Setting too many step points will introduce a greater amount of noise into the measurement-calculation algorithm, as well as an increased smoothing factor. For more detailed information on how ReliaTest performs its internal threshold calculations based upon the step points, please see Application Note #26: ReliaTest L/I Threshold Calculations.

Temperature control settings in the software consist of test temperature setpoint value, temperature window tolerance, and temperature settling tolerance period defined by the user during test creation, as shown in Figure 3. Increasing the temperature settling tolerance period will allow for proper thermal stability prior to L-I measurements while, conversely, a reduced period may also result in lower repeatability. Prior to starting the test, ensure that the temperature setpoint is at least at a 5°C differential to the ambient temperature read by ReliaTest, for proper thermal control plate enabling and temperature settling. Furthermore, confirm that the 'Settle Temperature For Tolerance Period Between LIV' option is checked in the temperature control settings.

In the case where end users may be testing a fewer device count than the fixture's full capacity (e.g. 16 lasers populated in a 32-capacity fixture), there is also another potential source for repeatability errors. It is recommended that in reduced capacity loading, the end user employs the ReliaTest option to state the number of devices to temperature settle in the fixture, as seen in Figure 3.

CONCLUSIONS

As can be seen from the results in Figure 4, with a properly configured ILX test system, customers are able to achieve an I_{th} repeatability of ≤ 0.75%, with a confidence interval of 95%. This is based upon over 1000 tested device positions within an LRS-9434 Laser Reliability and Burn-In test system, with each test position having seven iterative measurements, tested at a temperature of 60°C. The threshold current measurements provided by the LRS-9434 are highly repeatable and easily satisfy the requirements for typical burn-in screening used in laser diode testing.

For optimal performance, ILX Lightwave® recommends an annual calibration cycle on the individual current sources integrated into each LRS-9434 CMM shelf. Contact your local sales representative for more information on available service options.

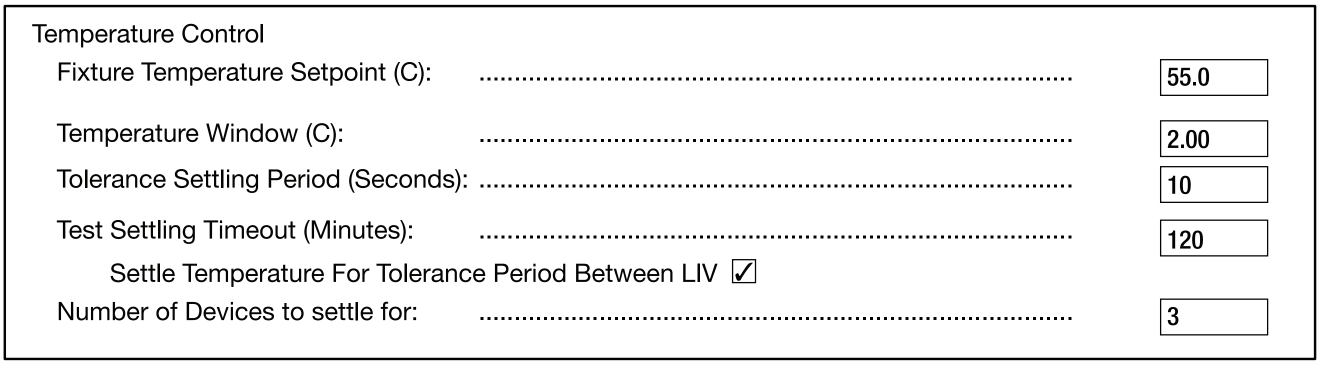

FIGURE 3 – Temperature Control Features in ReliaTest

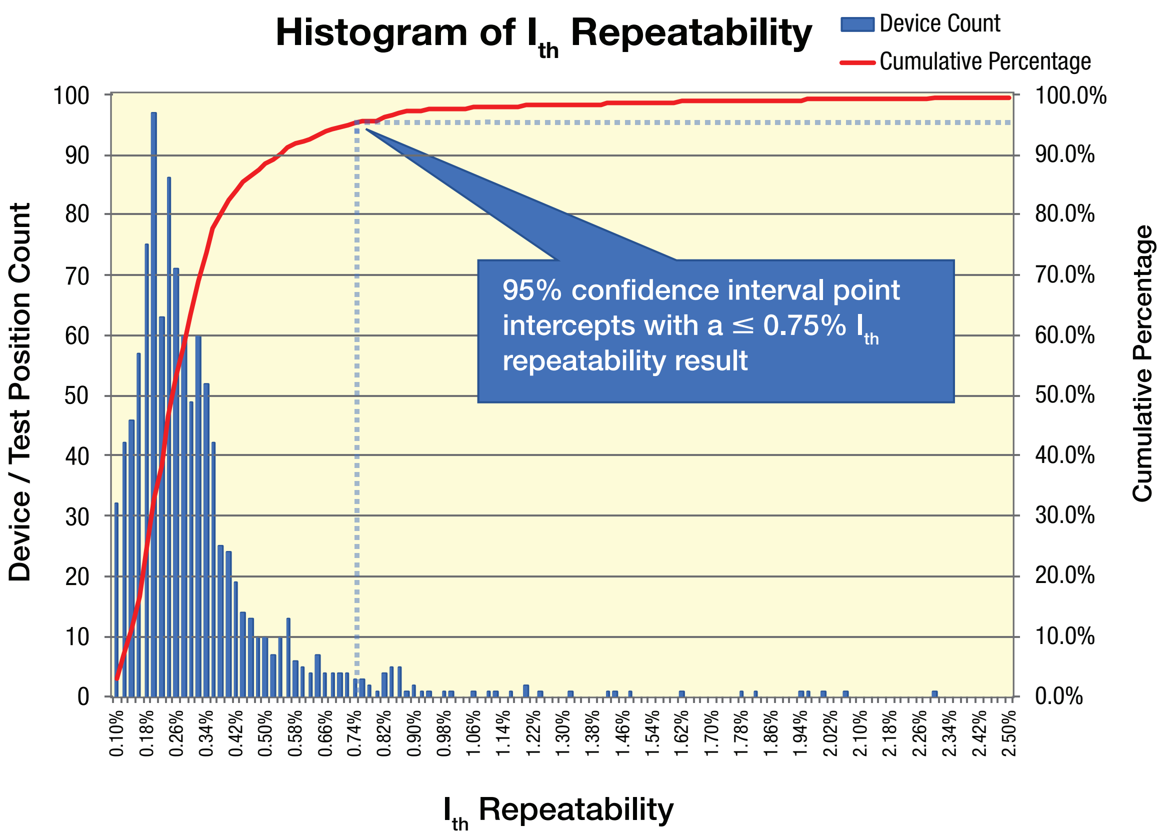

FIGURE 4 – Histogram Results of LRS-9434 System I_{th} Repeatability