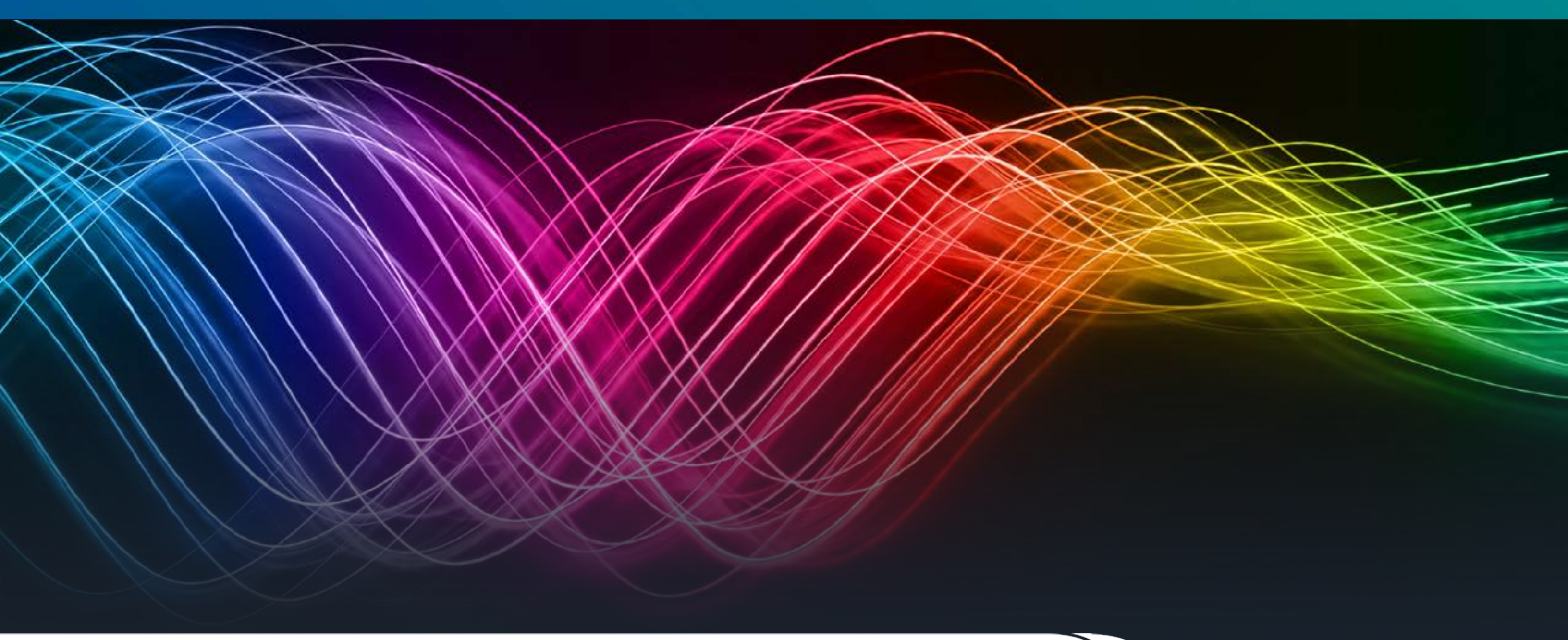


WHITE PAPER

Laser Diode Characterization and Its Challenges

What is Light-Current-Voltage (L-I-V) Test?

The light-current-voltage (L-I-V) sweep test is a fundamental measurement that determines the operating characteristics of a laser diode (LD). Usually, a “laser diode module” is a combination of a laser diode and a photo detector (PD). The PD monitors the light output and provides feedback to control the laser power. It is an important process to determine the quality and performance of the laser diode through validating the “performance linearity” before it passes through production and goes to market.

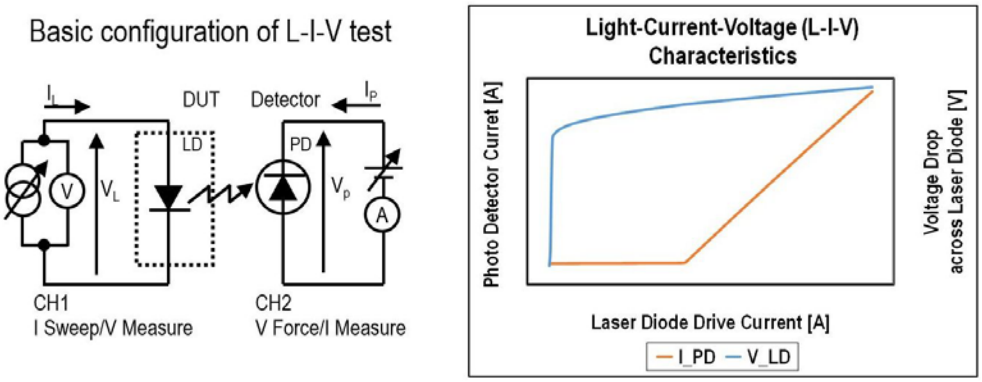


Figure 1: Configuration of L-I-V test and its characteristic

In the L-I-V test, a sweep current from µA to mA is applied to the laser diode. The intensity of the resulting emitted laser is measured using a photo detector. The output current of the photo detector is compared with the input current values. The intensity of the resulting emitted laser is calculated based on the measured photo detector current. In addition, the voltage drop across the laser diode is measured simultaneously. As you can imagine, this requires multiple instruments to be connected to the two separate devices—the laser diode and the photo detector (Figure 1). It is critical for the multiple instruments to be synchronized with each other in order to get accurate results.

Why Evaluate L-I-V Characteristics?

Light-current-voltage (L-I-V) characteristics are used to determine the laser's operating point. In other words, they determine drive current at the rated optical power and the threshold current where lasing begins.

One of the key objectives of the light-current-voltage curve measurement is to capture "kink" phenomena (a sharp twist) of the laser diode throughout the sweep current range. Ideally, the optical output power should be directly proportional to the drive current input over the nominal operating range.

However, unexpected step, discontinuity, and nonlinearity of the characteristics causes undesirable mode hopping and/or harmonic distortion in the analog signal that is transmitted over an analog fiber optic link (refer to Figure 2). So, it is important for module characterization to capture these undesirable phenomena as early as possible to improve production yield.

The light-current-voltage test can verify the linearity of the relationship between the drive current and the light output power, and help us to detect failing devices in the early stages of production.

The light-current-voltage test verifies the linearity of the relationship between the drive current and the light output power

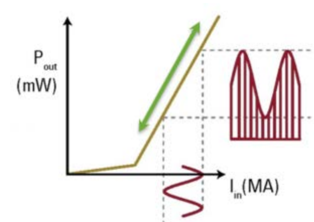
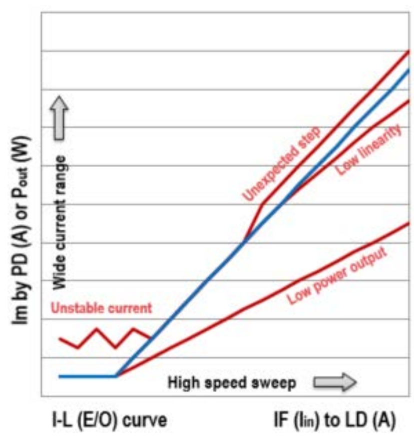
Linearity is Key for Communication	Detecting Failure Devices in Early Stage of Production
Responsivity Rs (W/A)= $\Delta P_{out} / \Delta I_{in}$ 	

Figure 2: Linearity of drive current and output power

Slope efficiency

The first derivative of the light-current-voltage characteristics, commonly expressed as slope efficiency, is also used since it tends to amplify “kink” phenomena. The slope efficiency curve helps you find tiny abnormalities that you cannot see from the light-current characteristics (refer to left graph of Figure 3). The “kink” phenomena can be easily spotted as a peak on the slope efficiency curve if there are any abnormalities. (Refer to right graph of Figure 3)

However, if the light-current characterization is made under too much measurement noise, the noise on the slope efficiency also becomes large enough to bury the “kink” phenomena on the characteristics. So, it is very important for the light-current-voltage test system to make measurements with low enough noise to detect the “kink. “Otherwise, it is very difficult to detect device failures through measurements.

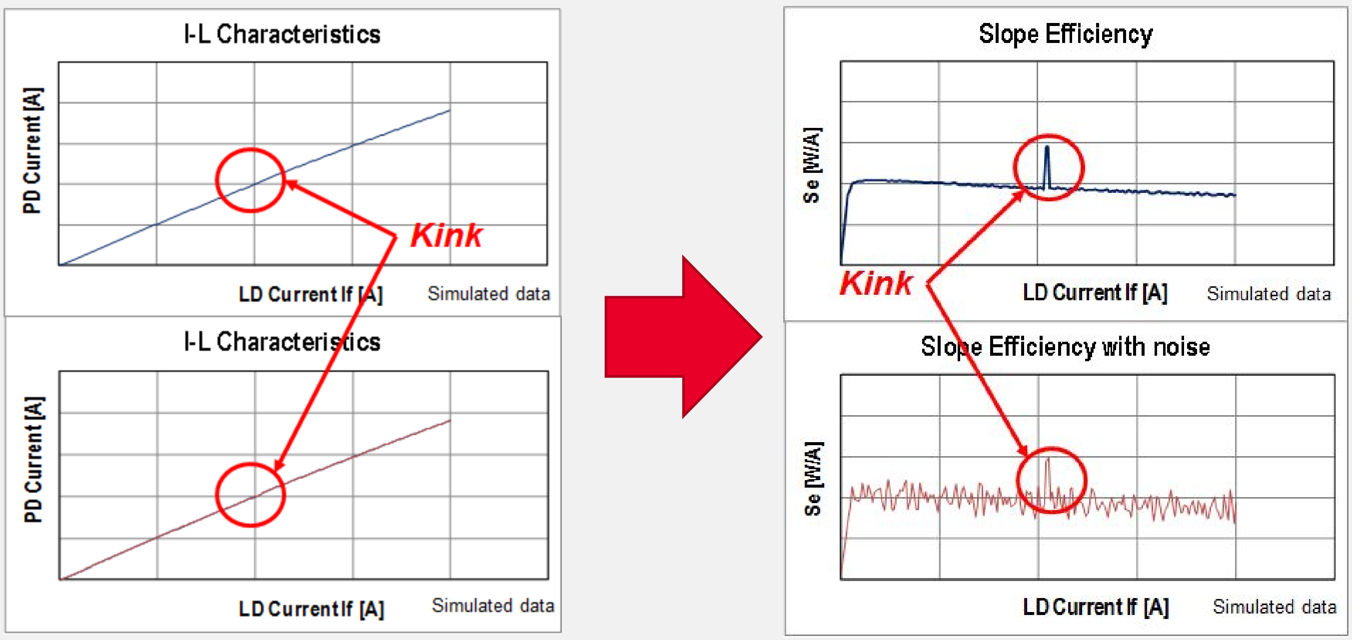


Figure 3: Slope Efficiency Derived from L-I-V curve to capture “Kink” phenomena

Challenges in L-I-V Characterization

As discussed earlier, one of the key objectives in measuring light-current-voltage characteristics is to evaluate the linearity of the optical output power to the drive current input and capture "kink" phenomena over the nominal operating range.

There are several challenges to evaluate the linearity accurately.

1. The drive current input must be swept across a wide range, typically from µA to sub A, so 5 digits of dynamic range are required.
2. The sweep current step must be small enough not to miss any kink phenomena. Typically, it requires more than 1,000 points per sweep to evaluate its linearity.
3. The aperture time must be long enough to have sufficient measurement accuracy and resolution.

However, these factors require long test times to accurately make a light-current-voltage characterization. Since the throughput is critical, especially in production, test speed is one of the most important factors for light-current-voltage testing. If characterization takes a long time, the issue of self-heating may arise.

A laser diode's characteristics are strongly affected by temperature. The threshold current varies significantly with temperature and the laser efficiency also falls off with increasing temperature. So, it is important to make the measurement time as short as possible to prevent self-heating from affecting the measurement results. Otherwise, accumulated heat will affect the characteristics more strongly as the drive current increases.

The Keysight B2900A Series of SMUs (Source Measure Units) has fast sweep measurement speed and is an ideal solution for production test that requires voltage or current sweep measurements. It has the specification below that meet the L-I-V characterization's requirement.

Key Specifications of B2900A SMU to Counter LIV measurement Challenges
1. Fast measurement speed for production test
2. Range of up to ±210 V and ±3 A (DC) / ±10.5 A (pulsed) provides wider coverage for testing a variety of devices
3. Measurement resolution of 10 fA and 100 nV (6-½ digit) for better source and measurement performance
4. Quick benchtop testing, debug, and characterization

SMUs Improve Measurement Efficiency

Let's look at the advantages the SMU gives you over other types of conventional equipment.

Look at the example on the left side of Figure 4. Notice that using conventional benchtop instruments requires the measurement functions of force and measure for both voltage and current at several points on the device under test (DUT). The set-up of various instrumentation and connections can get quite complicated. You have to set up power supplies, current supplies, meters, etc.

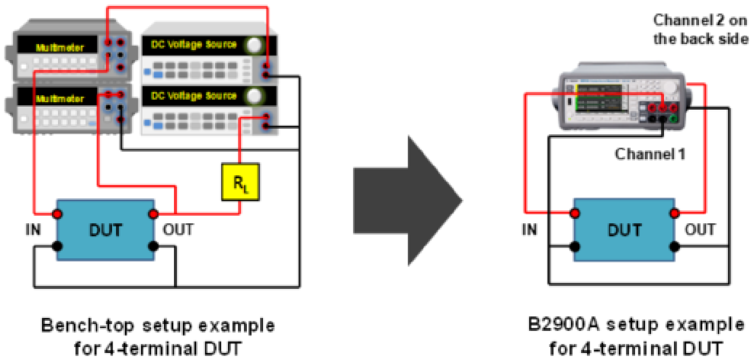


Figure 4: Set Up of Conventional Instruments vs Using SMU

Test results of a Precision SMU vs. a Conventional SMU

After understanding the measurement challenges of the L-I-V test, let's look at how a B2900A precision SMU performance as compare to a conventional SMU. The table in Figure 5 shows a sweep speed comparison between B2900A and conventional SMU in a real-world situation. The voltage drop of a laser diode is similar to standard semiconductor diodes and is often measured during electrical characterization. These measurements were made under the same conditions for the Keysight B2900A and other conventional SMU.

The drive current was swept from 0 A to 300 mA with 2,500 sweep points. The voltage drop across the laser diode was measured with 20 µs aperture time under a 3.5 V limit setting to protect the device. The measurement results are well-correlated with each other.

From the test, Keysight B2900A finish the measurement within 200 msec. However, the conventional SMU spent 380 msec under the same measurement conditions as the B2900A Series SMU.

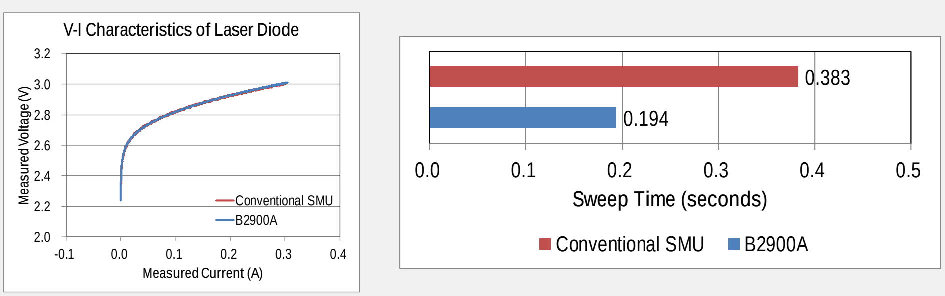


Figure 5: Sweep Measurement speed of N2900A vs. Conventional SMU

The table in Figure 6 below show the maximum speed with which the SMU can perform a sweep measurement and transfer the result through a GPIB connection. As you can see, in one second Keysight B2900A Series SMU measure twice as much as conventional SMUs.

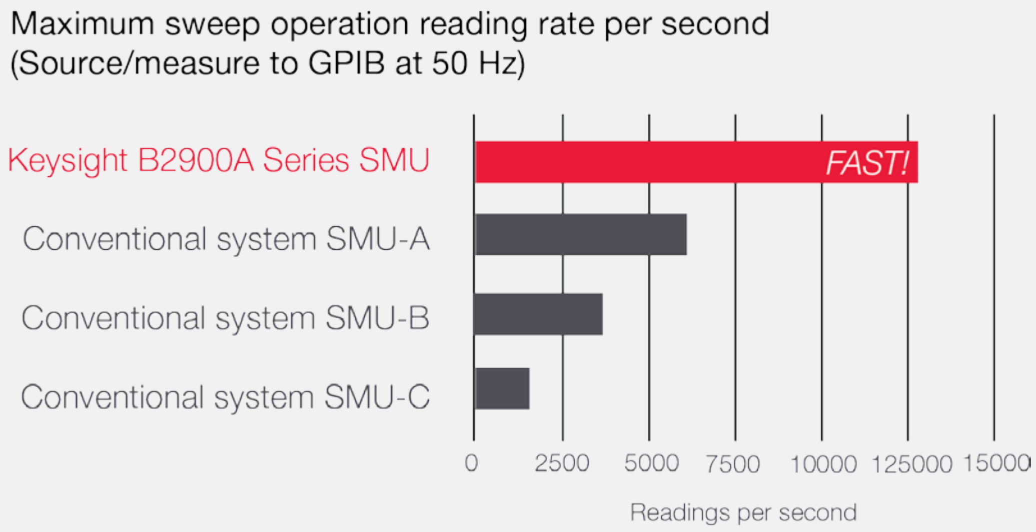
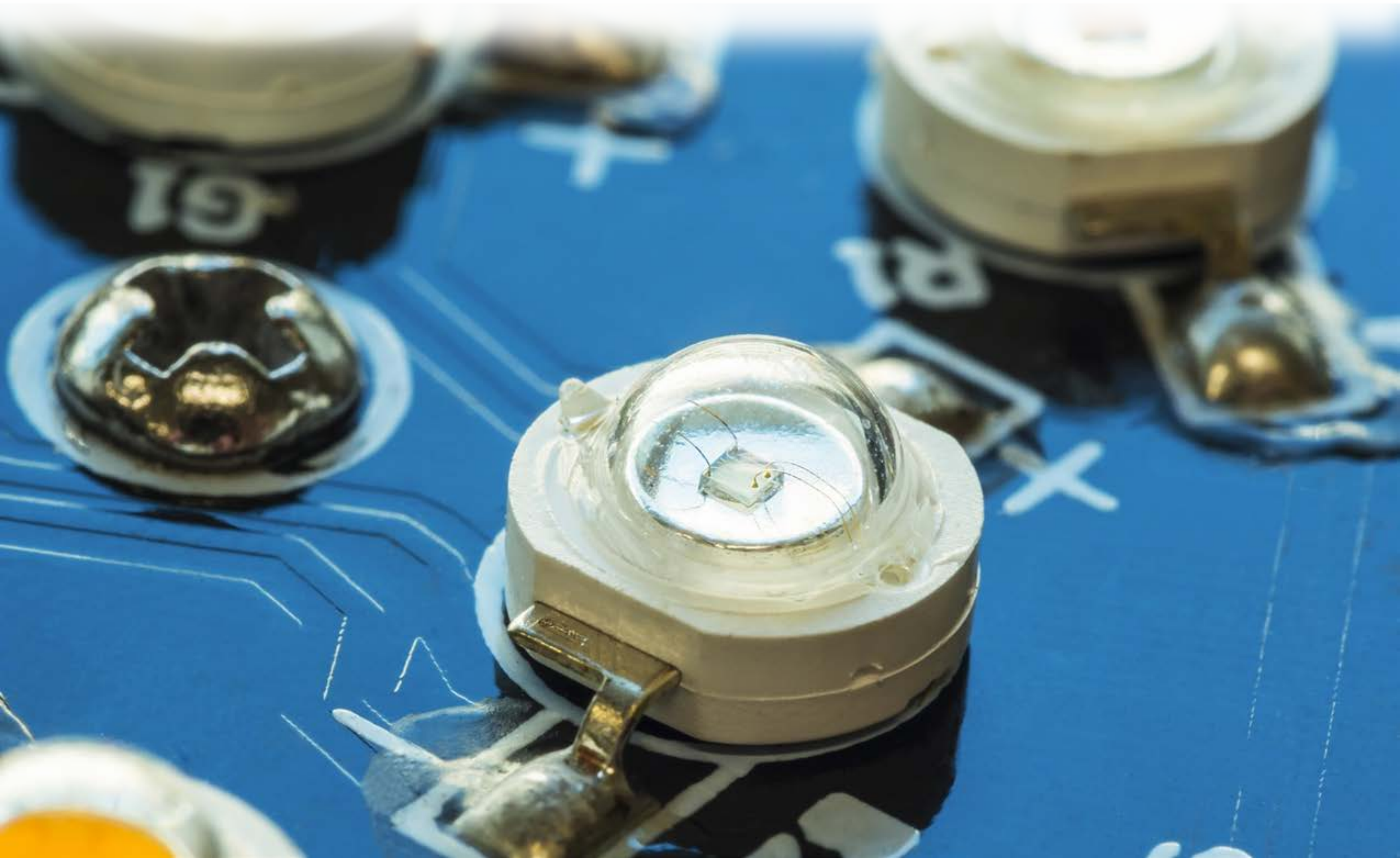


Figure 6: Measurement speed of B2900A vs Conventional SMU



Accurate and Stable Test Results with a Low Noise Floor

Electrical noise in measurements can severely dampen the accuracy and resolution of the measurement results. Figure 7 below show the measurement results of the photo-diode forward-bias characteristics using both the conventional SMU and the Keysight B2902A.The voltage drop across the diode was swept from 0 V to 2 V with 2,500 sweep points. The current measurement was made with 20 µsec aperture time using 10 mA fixed measurement range operation to minimize the measurement time.

You can easily see from the results that the noise floor of the B2902A on the current-voltage measurement is over 10 times lower than the conventional SMU. In a light-current-voltage measurement, the optical output power of the laser diode should be measured through the photo diode current measurement.

Use fixed-measurement-range operation to minimize the measurement time because range changes require extra time. It also prevents self-heating from affecting the laser diode characteristics during measurement.

So, it is important for the measurement instruments to have not only high measurement resolution but also low noise floor, which helps you get accurate and stable test results with shorter measurement time.

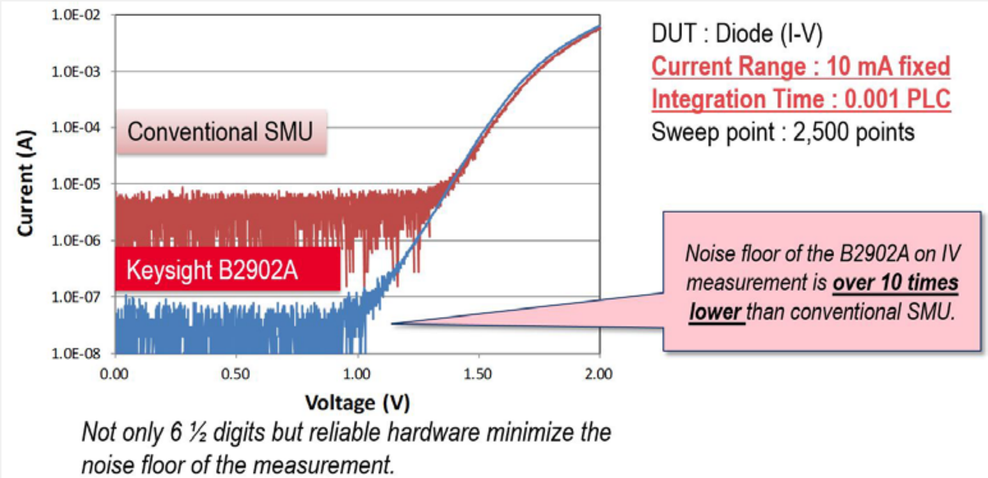
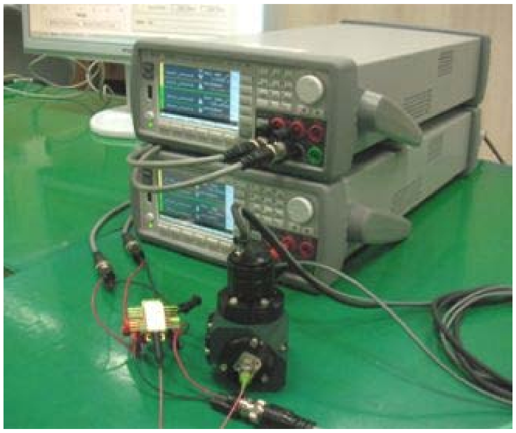


Figure 7: Noise floor of B2900A and conventional SMU

Laser Diode LIV Test Set Up

Figure 8 show a typical set up of a benchtop test system for light-current-voltage characterization of a laser diode. Most laser diode packages include a back-faced monitor photo diode that is used as a feedback source for the laser-drive circuits.

The optical output power must be measured in front of the laser diode with the external photo detector through an integrating sphere. So, the test system is required to have three channels of SMUs for the laser diode, the back-faced monitor photo diode, and the external photo diode, respectively.



Conclusion

In this white paper, we discussed what an LIV Test for laser diodes is and the significance of L-I-V test in detecting defects in early production stages. We also discuss the measurement challenges of this test. These include wide driving current range, small sweep current steps and measurement speed. We concluded with the difference in test results between a high precision SMU and a conventional SMU. A good SMU with fast measurement speed, wide current range, low noise floor and quick analysis tool will help you get accurate and stable results with shorter measurement time. For more information about Keysight's precision SMUs, kindly visit www.keysight.com/find/smu

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus

KEYSIGHT TECHNOLOGIES

This information is subject to change without notice. © Keysight Technologies, 2018, Published in USA, October 29, 2018, 5992-3166EN