

# High Throughput DC Production Testing of Laser Diode Modules and VCSELs with the Model 2602B System SourceMeter® Instrument

## Introduction

Laser diodes (LDs) and VCSELs (Vertical Cavity Surface Emitting Lasers) are the primary components used in optical communications, spectroscopy, and a host of other important applications. As the demand for these applications grows, so does the need for the basic components themselves. This demand requires greater emphasis on developing accurate, cost-effective production test strategies.

A typical LD module consists of a laser diode and a back facet monitor photodiode. Temperature-controlled LD modules also include a thermoelectric controller (TEC) and a thermistor to facilitate precise regulation of the LD's operating temperature, as illustrated in **Figure 1**. (High speed LD modules may also carry an integrated modulator chip that's not shown in **Figure 1**.)

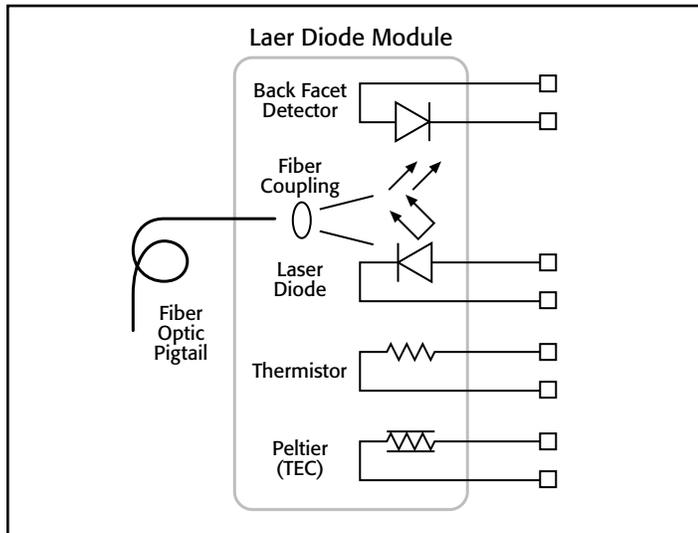


Figure 1. Typical laser diode module

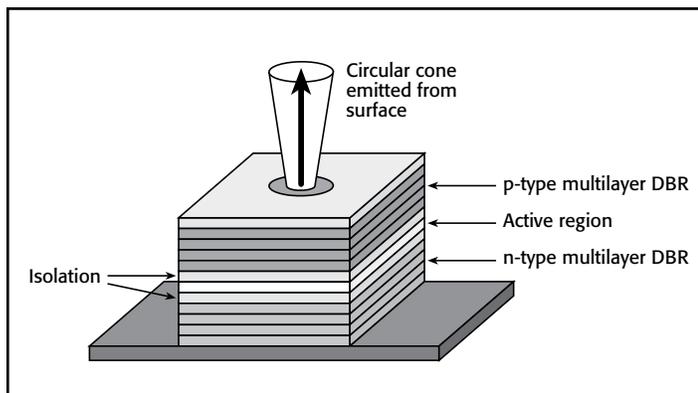


Figure 2. A Simplified VCSEL Structure (Source: Kartalopoulos).

A VCSEL has a more complicated semiconductor structure than a standard laser diode, but typically a less complicated package. A classic cross-section of a VCSEL is shown in **Figure 2**. Unlike edge-emitting laser diodes, the VCSEL can be tested on wafer. This presents new opportunities and challenges in testing that will be addressed later in this application note.

It's important to remember that, with either device type, there are many steps taken in the manufacturing process. The value-added nature of each step in manufacturing dictates testing each component prior to the next assembly step. For example, the cost of scrapping a complete laser module due to a failed back facet monitor photodiode is much greater than the cost of providing 100% testing of the photodiode component prior to the assembly step. High speed, flexible test solutions are essential to minimize the cost of the test.

This note details a few cost-effective DC test systems that provide the high throughput required in today's production environments.

## Test Descriptions

During DC testing, the specifications of interest for the typical laser diode (LD) or VCSEL module include:

- Laser forward voltage
- Kink test or slope efficiency ( $dI/dI$ )
- Threshold current
- Monitor (back facet) reverse-bias voltage
- Monitor (back facet) current
- Monitor (back facet) dark current
- Optical output power

The most common subset of the DC characteristics can be measured in a test known as the *LIV test sweep*. This fast and inexpensive DC test identifies failed assemblies early in the test process, so expensive non-DC domain test systems are more cost-effective when testing the remaining higher yield components. **Figure 3** shows a common instrument configuration used to perform the LIV test sweep.

## LIV Test Sweep

### Forward Voltage Test

The forward voltage ( $V_F$ ) test verifies the forward DC characteristics of the LD. Current ( $I_F$ ) is swept and voltage drop across the LD is measured.

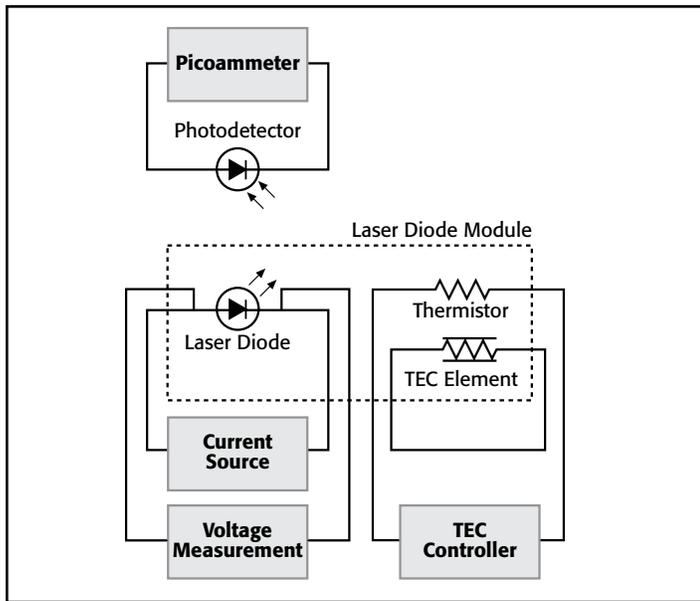


Figure 3. Block diagram of LIV instrumentation.

Some high powered LDs may require current ( $I_F$ ) sweeps up to 2–3A, usually in increments of 1mA. Most need sweeps up to 1A with 0.5mA or 0.25mA steps. Time per test sweep should be in the range of a few milliseconds. The typical measurement range is 0–10V and microvolt-level resolution is required.

VCSELs are typically lower powered devices requiring current ( $I_F$ ) sweeps up 30mA, with current steps of  $1\mu\text{A}$ .

For this test, we can use one channel of the Model 2602B Dual Channel System SourceMeter instrument to source current to the laser and measure the corresponding voltage drop.

### Light Intensity Measurement

Light intensity ( $L$ ) measurements verify the light output of the LD. Light output power increases as drive current is increased and the output of this test is usually displayed in milliwatts.

For DC-based light measurement, a reverse-biased photodiode is exposed to the output of the laser diode. This radiation is absorbed, and a current is produced by the detector. This resulting photodiode DC current is measured with a picoammeter or electrometer (a highly refined DC multimeter). However, the photocurrent can also be measured with a Source-Measure Unit (SMU) as long it offers an acceptable low current measurement range. Typically, a measurement range of 100nA is more than adequate for many lasers.

The returned photocurrent can then be used to determine the optical power of the device under test. Optical power measurements require a calibrated detector or integrating sphere. The calibration information, or responsivity ( $R$ ), is a wavelength dependent value determined during the calibration process.

To calculate the optical power from a photocurrent, use the following equation:

$$L = I_p/R$$

where:  $L$  = Optical power of the light source (watts)

$I_p$  = Current from the detector. Commonly called photocurrent (amps)

$R$  = Responsivity of the detector at the wavelength of choice (amps/watt)\*.

\* The responsivity curve is provided when the detector or sphere/detector assembly has been calibrated.

So, the current measured by the detector is divided by the responsivity of the detector at the wavelength of interest. The result is the optical power impinging on the detector.

### Lasing Threshold Current Test

The threshold current is the current at which the LD starts lasing. One technique for threshold determination is the second derivative technique. The threshold for this method is defined as the first maxima of the second derivative of the light output and is a calculation based on the light measurement ( $L$ ). This is highlighted in *Figure 4*.

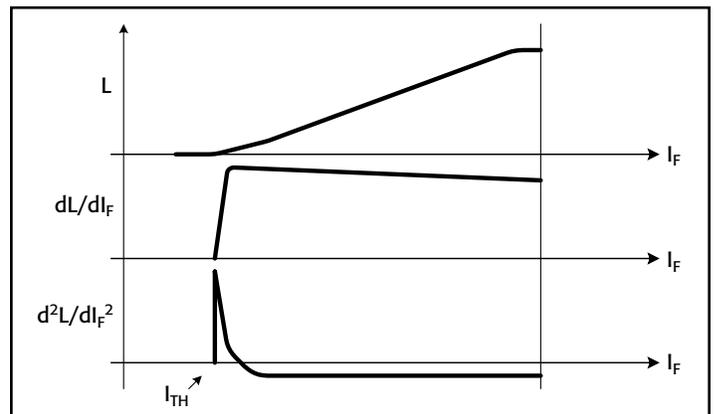


Figure 4. Graphical Calculation of Threshold Current

### Back Facet Monitor Diode (BFMD) Test

This test verifies the response of the back facet detector photodiode (also reverse-biased) to increase light output of the LD as the drive current is increased. Typical current measurement range is 0–100mA and the required resolution is 0.1mA. This measurement is typically performed with a picoammeter or electrometer, but can be measured with an SMU as long as it offers an acceptable low current measurement range. Typically, a measurement range of 100nA is more than adequate for low powered optical devices.

In this test, we can use the second SMU channel of the Model 2602B System SourceMeter instrument. The SMUB channel can bias the photodetector (if needed) and measure the photocurrent simultaneously. Or, we can add a single-channel SMU (like the Model 2601B) or a simple picoammeter (like the Model 6485) to measure the back facet photocurrent.

### Kink Test/Slope Efficiency

This test verifies the proportionality of the relationship between the drive current ( $I_F$ ) and the light output ( $L$ ) as depicted in

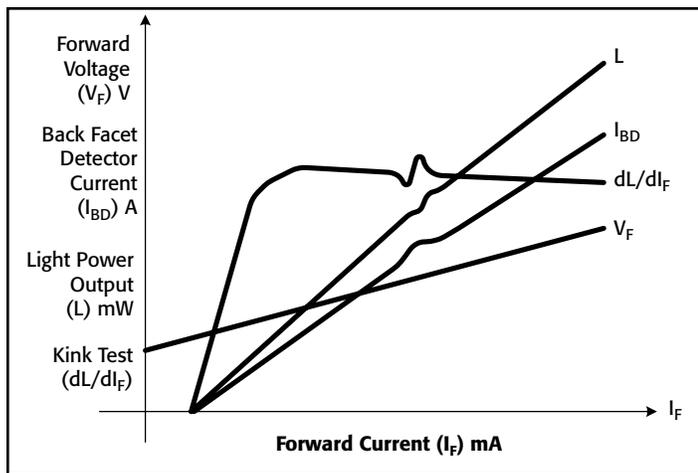


Figure 5. Typical Suite of LIV Curves

Figure 5. The relationship between the drive current ( $I_F$ ) and the light output power ( $L$ ) should be linear about the nominal operating range. If the relationship is truly linear over the tested range, the first derivative of the curve will be a nearly horizontal line. This is graphed as  $dL/dI_F$ . The first derivative will tend to amplify any bumps or kinks in the light/current ( $L$ - $I$ ) curve. If this curve has any significant “kinks” or, in other words, is not smooth, the laser is considered defective. If operated at the  $I_F$  value corresponding to the “kink,” the light output will not be proportional. The maximum value of the second derivative of the  $L$  vs.  $I_F$  curve can be used to calculate the threshold current, which is the value of the drive current at which the LD starts “lasing” or outputting significant light.

The kink and slope efficiency of a particular device are also calculations based on the analysis of the light measurement ( $L$ ).

### Temperature Testing

The LIV test is often performed at more than one laser diode temperature. In some cases, the LD is tested at both the nominal temperature and the extremes of the device specification, such as  $-40^\circ\text{C}$ ,  $25^\circ\text{C}$ , and  $85^\circ\text{C}$ . Another common strategy is to perform the LIV test at several temperatures, such as  $5^\circ\text{C}$ ,  $10^\circ\text{C}$ ,  $15^\circ\text{C}$ ,  $20^\circ\text{C}$ ,  $25^\circ\text{C}$ ,  $30^\circ\text{C}$ , and  $35^\circ\text{C}$ . Then, these families of LIV curves are analyzed to ensure the device meets the specification.

### Test System Configuration

Figure 6 shows an overview of an LIV test system that includes a Model 2602B, a Model 2510-AT Autotuning TEC SourceMeter instrument, and a PC equipped with a GPIB interface card.

The Model 2602B is a dual-channel Source-Measure Unit (SMU) capable of sourcing either a voltage or current and simultaneously measuring voltage and current. This provides a convenient “one-box” package for LIV testing by allowing one SMU channel to source current to the Device Under Test (DUT) and measure the voltage while the other SMU channel is monitoring the photocurrent of the detector near the DUT.

The Model 2510-AT Autotuning TEC SourceMeter controls the TEC element and maintains stable module temperature.

The PC programs the meters via the GPIB bus, coordinates the execution of the test, collects, and analyzes the measurement results.

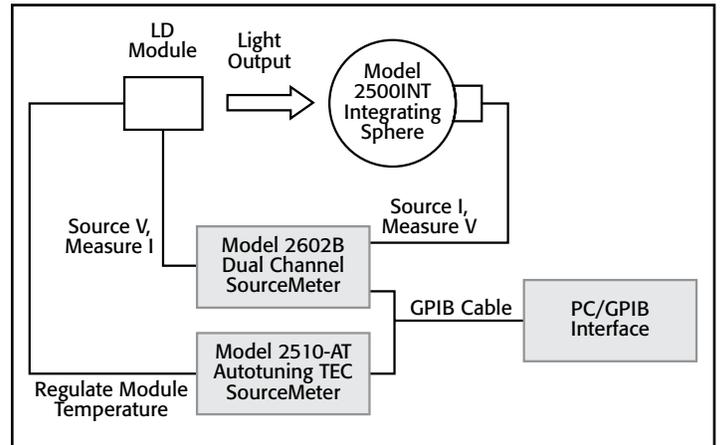


Figure 6. Typical LIV Test Setup for an LD Module. The 2602B is used to characterize the module and monitor the light output while the 2510-AT is controlling the module temperature.

### Programming your test for speed: TSP™ by Keithley Instruments

With many instruments, the PC controls all aspects of the test. In each element of a test sequence, the instruments must be configured for each test, perform the desired action, and then return the data to the controlling PC (Figure 7). The controlling PC then must evaluate the pass/fail criteria and perform the appropriate action for binning the device under test. Each command sent and executed consumes precious production time and lowers throughput.

Obviously, a large percentage of this test sequence is consumed by communicating information to and from the PC. Series 2600B instruments offer the unique ability to increase the throughput of complicated test sequences dramatically by decreasing the amount of traffic over the communications bus. In these instruments, the majority of the test sequence is embedded in instrument. The Test Script Processor (TSP) is a full-featured test sequence engine that allows control of the test sequence, with internal pass/fail criteria, math, calculations, and control of digital I/O (see the Test Sequence with 2602B illustrated in Figure 8). The TSP can store a user-defined test sequence in memory and execute it on command. This limits the “set-up” and configuration time for each step in the test sequence and increases throughput by lessening the amount of communications to-and-from the instrument and PC.

Here is a simple step-by-step process for programming the Model 2602B:

1. Create the script.
2. Download the script to the instrument.
3. Call the script to run.

The 2602B script can be written/downloaded in the provided Test Script Builder Software or downloaded to the instrument

using another program such as Visual Basic or LabVIEW. See the 2602B User's Manual for more information on programming the 2602B.

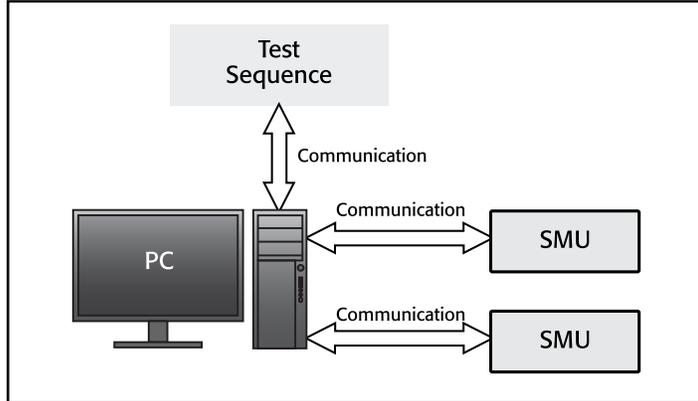


Figure 7: PC control of standard instruments.

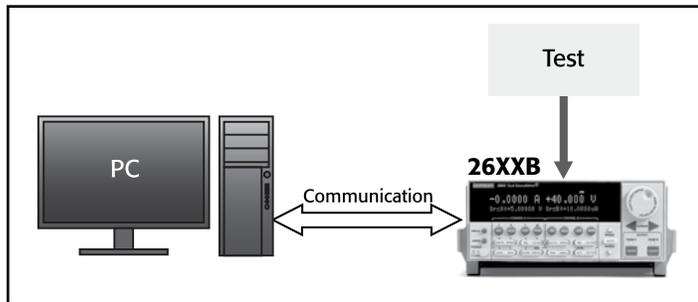


Figure 8. Use of the embedded Test Script Processor (TSP) in the Model 2602B to store the test sequence. Note decreased communications traffic.

## Test Sequence

With the LD in the test fixture socket, the operator initiates the LIV test sequence via the computer controller.

1. The Model 2510 is commanded to set the desired temperature for the test.
2. The script is executed. The Model 2602B SMUA biases the LD; it sweeps from zero to 100mA in 1mA steps while SMUB measures the current from the photodetector. Both SMUs then record their respective measurements and print them to the computer.
3. Data return.

## Model 2602B System SourceMeter Setup

The entire LIV test can be written as a test sequence or script. In that script, the SMU Channel A (SMUA) of the Model 2602B is programmed to sweep from 0mA to 100mA in 100 steps of 1mA each. After each new current value is applied to the LD, SMUB measures light output by measuring photodiode current directly.

The Model 2602B is a full SMU, and can therefore deliver a voltage bias to the detector in conjunction with measuring the current from the photodiode. Some detectors will require different bias voltages. The bias source is programmable from 0V to 40V. The current range for the photocurrent channel is set to

20mA. This is a typical back facet detector current range for an LDM. When using an integrating sphere/detector pair, the range limit is likely to be 20 $\mu$ A or 200 $\mu$ A.

## Example LIV Script

The following program can be downloaded to the instrument as a text file (.txt) using an application such as LabVIEW or Visual Basic. It's also possible to use the Test Script Builder script editing tool that's provided at no charge with the instrument. It allows users to create, download, and edit scripts, as well as providing a good troubleshooting tool for applications development. It's provided on the product CD, as well as through Keithley's website ([www.keithley.com](http://www.keithley.com)).

```
function LIVTest() --Defines function for Main Test

--Local Variables for SMUA (LD Channel)
local l_irange = 100E-3 --Current Source Range
local l_ilevel = 0 --Initial Source Value
local l_vcpl = 6 --Source Compliance

--Local Variables for SMUB (PD Channel)
local l_vrange = 6 --Set SMUB (PD Channel) voltage bias range
local l_vlevel = 0 --Set voltage bias
local l_icmpl = 10E-3 --

--Shared Local Variables
local l_nplc = 0.001 --Integration rate of measurement

--Local Sweep variables
local l_start = 0.001 --Sweep start current
local l_stop = 0.06 --Sweep stop current
local l_steps = 100 --Number of steps in sweep
local l_step = (l_stop - l_start) / (l_steps - 1) --Current step size
local l_source_val = l_start --Source value during sweep
local l_i = 1 --Iteration variable

--Data Tables
local l_curr = {} --Create data table for sourced current
local l_volt = {} --Create data table for measured voltage
local l_photocurr = {} --Create data table for photocurrent

reset() --reset instrument

display.smub.measure.func = display.MEASURE_DCAMPS
--Toggle to get SMUB to show current

--Configure SMUA (LD) source and measure settings
smua.source.func = smua.OUTPUT_DCAMPS
smua.source.rangei = l_irange
smua.source.leveli = l_ilevel
smua.source.limitv = l_vcpl
smua.measure.rangev = l_vcpl

smua.measure.nplc = l_nplc
smua.measure.autozero = smua.AUTOZERO_OFF

--Configure SMUB (PD) source and measure settings
smub.source.func = smub.OUTPUT_DCVOLTS
smub.source.rangev = l_vrange
smub.source.levelv = l_vlevel
smub.source.limitsi = l_icmpl
smub.measure.rangei = l_icmpl

smub.measure.nplc = l_nplc
smub.measure.autozero = smub.AUTOZERO_OFF

smua.source.output = smua.OUTPUT_ON --Enable Output
```

```

smub.source.output = smub.OUTPUT_ON

timer.reset() --Reset Timer

--Execute LIV sweep
for l_i = 1, l_steps do
  l_volt[l_i] = smua.measure.vandstep(l_source_val) --LD voltage
  measurement and step source
  l_curr[l_i] = smua.measure.i() --LD source measurement
  l_photocurr[l_i] = smub.measure.i() --PD measurement
  l_source_val = l_source_val + l_step --Step source value
end--for

l_test_time = timer.measure.t() --Stop timer

--Call function printData() and pass parameters to function
printData(l_steps,l_volt,l_curr,l_photocurr,l_test_time)

smua.source.output = smua.OUTPUT_OFF --Disable SMUA
smub.source.output = smub.OUTPUT_OFF --Disable SMUB
smua.measure.autozero = smua.AUTOZERO_AUTO --Enable Autozero
smub.measure.autozero = smub.AUTOZERO_AUTO --Enable Autozero

end--function LIVTest()

function printData(steps,volt,curr,photocurr,testtime)
--Print Data to output queue

--Local Variables
local l_steps = steps
local l_volt = volt
local l_curr = curr
local l_photocurr = photocurr
local l_testtime = testtime
local l_datatime

timer.reset() --Timestamp

print("Voltage Data (V):")
for l_i = 1, l_steps do
  print(l_volt[l_i])
end

print("") --Space
print("Source Current Data (A):")
for l_i = 1, l_steps do
  print(l_curr[l_i])
end

print("") --Space
print("Photocurrent Data (A):")
for l_i = 1, l_steps do
  print(l_photocurr[l_i])
end

print("")--Space
print(string.format("Test time per part = %f", l_testtime))
print(string.format("Test time per step = %f", l_testtime/
l_steps))

l_datatime = timer.measure.t() --Stop datatimer
print(string.format("Data Print time = %f", l_datatime))
--display.clear()
--display.settext("Test Complete")

end --function printData()

LIVTest() --Run Test

```

Once the functions *LIVTest()* and *printData()* have been downloaded to the instrument, they can be run simply by calling them.

## Calling the function:

Using the Keithley GPIB driver and Visual Basic 6, the call to run an LIV test would look something like this:

```
Call Send(kth2602B, "LIVTest()", status) 'run function LIVtest()
```

where kth2602B is the instrument address.

## Return the data:

The function *printData()* places three sets of data (L, I, and V) into the output queue, along with some header information and spaces to separate the data columns.

To retrieve the data from the output queue, it's necessary to enter the data. There are different commands to do this, but here is an example using Visual Basic and a Keithley GPIB driver:

```

For i = 1 To n
  Call enter(Data, 1000, Length, kth2602B, status)
  ' Get info back from meter
Loop

```

where n = the number of entries returned. Each print statement is an entry to the output buffer.

Keep in mind that the output buffer is limited to a maximum number of bytes and entries. When the least of these two conditions is met, the buffer is filled and will not accept new entries until data has been removed.

## Model 2510 TEC SourceMeter Instrument Setup

The Model 2510 is programmed for a given temperature sensor, TEC, and set point temperature. Before the controller brings the laser diode module to the target temperature, the AC resistance of the TEC is measured and displayed.

Below is an example of controlling the 2510-AT with Visual Basic and a Keithley 488 GPIB driver.

```

'Reset Instruments
send(kth2510, "**rst", status) 'reset TEC controller

'Setup Peltier Current Limit
send(kth2510, ":sens:curr:prot:lev 1.0", status)
'Setup Temperature Sensor
send(kth2510, ":sens:temp:tran ther", status) 'use thermistor
send(kth2510, ":sens:temp:curr:auto on", status)
'auto sensor current level
send(kth2510, ":sens:temp:ther:range 1e4", status) '10K ohm Ther.
send(kth2510, ":sour:temp:spo 25.0", status)
'set temp. to 25C, Read Peltier AC Ohms
send(kth2510, ":outp on", status) 'turn on output
send(kth2510, ":meas:res:ac?", status) 'measure AC ohms
enter(strData, 100, intLength, kth2510, status) 'enter reading
txtTECRes.Text = strData 'display on screen

'Begin controller Laser Diode Temperature
send(kth2510, ":outp on", status)

```

## Start Sweep

To start the sweep, the outputs of all the instruments are first turned on. Once the temperature stabilizes, then the external program can call the *LIV\_Test()* function. This is done by sending the following string to the 2602B:

```
send(kth2602B, "LIV_Test()", status)
```

## Read Trace Buffers

```
'query trace buffers
send(kth2500, ":fetch?", status)
send(kth2420, ":trace:data?", status)
'enter data
enter(strData, 4000, intLength, kth2500, status)
enter(strData, 2000, intLength, kth2420, status)
```

## Pass/Fail Analysis

The three data streams that make up the forward voltage trace, the LD back facet detector current trace, and the external photodiode current trace are mathematically manipulated to quantify the threshold current, quantum efficiency, and maximum differential ohms excursion. These numbers are compared to expected values to determine the quality of the LD.

Depending on the noise content of the data streams, it may be necessary to perform filtering operations before performing calculations such as  $dL/dIF$ .

## Example Program

Keithley Instruments has developed an example script in order to perform an LIV test. To obtain a copy of the program, visit Keithley's website (<http://www.keithley.com>).

## System Expansion

### Telecom LD Module Pin-Outs

Telecom LD modules from a given manufacturer often have more than one pin-out configuration. A variety of LD module pin-outs can be easily accommodated via computer control by routing all the instrumentation signals through a Keithley switch mainframe and the appropriate plug-in switch cards. The switch also allows the instruments to make complex isolation and quiescent power measurements.

For low channel counts, the Model 7001 Switch Mainframe with two slots is recommended. Medium density can be achieved using the Model 7002 10-slot mainframe. For applications with very high device counts, the highest density switching platform Keithley offers is the Model 3706A System Switch mainframe.

### Modulation Inputs

LD modules are often equipped with modulation or attenuation control inputs. The addition of a Model 2400 or Model 2601B SourceMeter instrument to bias the attenuation input may be required to perform the basic LIV test sweep.

### Forward Voltage Test

The forward voltage is the result of the majority carrier current flow and is therefore a function of the semiconductor material and the temperature of the junction.

The forward voltage test can be performed on the LD as well as the back facet photodiode to determine the forward operating voltage of the semiconductor junction. Typically, a Model 2602B System SourceMeter instrument is configured to source a sufficiently small current (to prevent damage), then measure the resulting voltage across the junction. Given that most detectors use semiconductor materials with temperature coefficients of

about  $2\text{mV}/^\circ\text{C}$ , the temperature of the junction must be known or controlled.

## Reverse Breakdown Voltage Test

As the reverse bias voltage is increased, the velocity of the minority carriers crossing the junction is increased. At a given reverse voltage, the energy of the charge carriers is sufficient to result in ionization by collision. This voltage is known as the reverse breakdown voltage. If the current at this voltage is carefully limited, the junction will not be destroyed.

The reverse breakdown voltage test can be performed on the LD and the back facet photodiode. A non-destructive reverse breakdown test can be performed by sourcing  $-10\mu\text{A}$  and measuring the resulting junction voltage. The Model 2602B SourceMeter instrument is ideal for this measurement.

## Leakage Current Test

The reverse-biased semiconductor junction (at a lower potential than the breakdown voltage) has a leakage current made up of minority carriers crossing the depletion region. The magnitude of the leakage current is dependent on electronic charge, doping density, junction area, and temperature. Leakage currents of the laser diode and the back facet photodiodes can be tested with a Model 2602B System SourceMeter instrument. Typically, 80% of the reverse breakdown voltage is applied to the junction and the resulting leakage current is measured.

For the photodiode, this test also serves as the dark current measurement. With the LD bias held to zero, the dark current is measured by applying a bias to the junction and measuring the current flow. During this measurement, it is critical that stray photons don't impinge upon either the LD or back facet photodiodes.

## Thermistor Test

The thermistor of a typical LD module has a nominal resistance of  $10\text{k}\Omega$  at  $25^\circ\text{C}$ . In normal operation, the thermal stability of the module is more critical than the absolute temperature value.

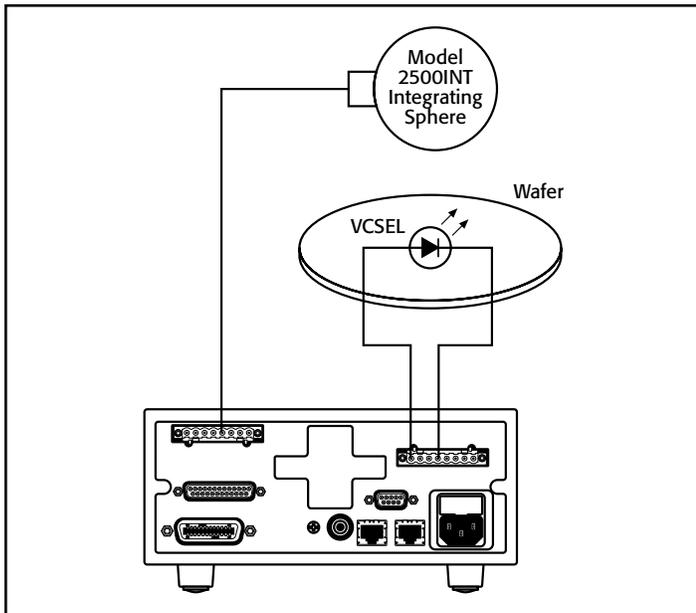
A number of techniques can be used to test the thermistor:

1. Hold the temperature of the LD module to a known value and simply measure the resistance of the thermistor.
2. Thermally couple a characterized thermistor to the LD module, allow the assemblies to reach a thermal equilibrium, and compare the characterized thermistor's resistance with the LD thermistor's resistance.
3. Set a range of resistance values that is wide enough to accommodate the temperature of the LD module in the manufacturing process. To avoid self-heating of the thermistor, it is important to keep the power dissipation to a minimum. Typically, a constant current of  $10\mu\text{A}$  to  $100\mu\text{A}$  is sourced and the resulting voltage measurement is used to derive resistance.

## Wafer Testing

VCSELs are the only type of lasers that lend themselves to testing at the wafer level. **Figure 9** illustrates a simple test system for testing VCSELs on the wafer. A wafer prober makes the electrical connection to each device through a probe card. The prober station also positions the optical detector directly over the devices. The characterization is then performed using a single Model 2602B Dual Channel System SourceMeter instrument.

If the probe card can connect to many devices simultaneously, then a system similar to the one illustrated in **Figure 6** can be constructed to test all of the devices each time the probe card makes contact with the wafer. Due to the high number of devices on a wafer, a scanning approach to testing multiple devices may be too time consuming. Using many pairs of instruments to test multiple devices in parallel is often the optimum solution for applications that require high throughput. For expanded testing solutions, see the following sections that discuss multiplexing as well as parallel instrument configurations for expanded test capabilities.



**Figure 9:** Typical 2602B VCSEL test on wafer.

## Multiple Device Testing

### TEC Test and Control

Many LD modules are equipped with a thermoelectric cooler (Peltier device). Typically, a TEC controller is used to control the temperature of the module during the LIV test sweep. It is also possible to verify the functionality of the TEC device by modulating the temperature set point and verifying the thermistor resistance after the new temperature is reached.

Excessive mechanical shear loads are probably the most common failure mechanisms in Peltier devices. During handling and mounting of the Peltier device, mechanical shear loads can cause de-lamination or breakage of some or all of the elements in the device. A simple AC or reversing DC resistance test can

determine the health of the Peltier before and after mounting in the LD module. A direct current resistance measurement would be inaccurate due to self-heating of the elements and the resulting thermal offsets. The Model 2510-AT TEC SourceMeter instrument can provide the necessary bipolar current source and voltage measurement capability to facilitate this measurement.

### Isolation Test

Use of a switch matrix facilitates isolation tests between the various components of the LD module. For instance, the thermistor's electrical isolation from the LD can be tested by applying a potential between the thermistor and the LD while holding both terminals of the thermistor and both terminals of the LD at the same potential to prevent current flow through the individual components.

## Methods and Techniques

### Cabling

Cabling must be optimized for accuracy and test speed. High quality, low noise cable is required for all measurements. The cable characteristics for the LD drive signal are much different from those of the photodiode signals.

The photodiode signal is generated by sourcing several volts and measuring the current flow in the nanoampere range. At such low currents, it is critical to use a low noise shielded cable to optimize the signal-to-noise ratio. Using the shortest length of cable will also improve the signal-to-noise ratio by reducing leakage and induced currents, as well as minimizing capacitance.

The slew rate ( $dV/dt$ ) of the LD drive signal is a function of the semiconductor junction. The junction voltage will change only a few millivolts for a current change of tens of milliamps. As a result of the low slew rate requirements, the capacitance of the LD drive signal cable is not as critical to the application as the voltage drop across the cable as it carries up to 3A. A large gauge cable will help reduce the voltage drop over the length of the cable while having minimal impact on the speed of the test.

In all cases, the cabling must be shielded and as short as possible to reduce noise and capacitance. Lower noise means less integration time is required for each measurement and the test sweep will be faster.

## Typical Sources of Error

### Junction Self-Heating

As test times get longer, the semiconductor junction of the VCSEL will tend to get increasingly hot. The forward voltage test tends to be susceptible to junction self-heating. As the junction heats, the voltage will drop or, more importantly, the leakage current will increase during the constant voltage test.

Therefore, it is important to keep the test time as short as possible without sacrificing measurement accuracy or stability. The instruments in the SourceMeter® family allow users to configure the device soak time before the measurement, as well as the amount of time the input signal is acquired. The

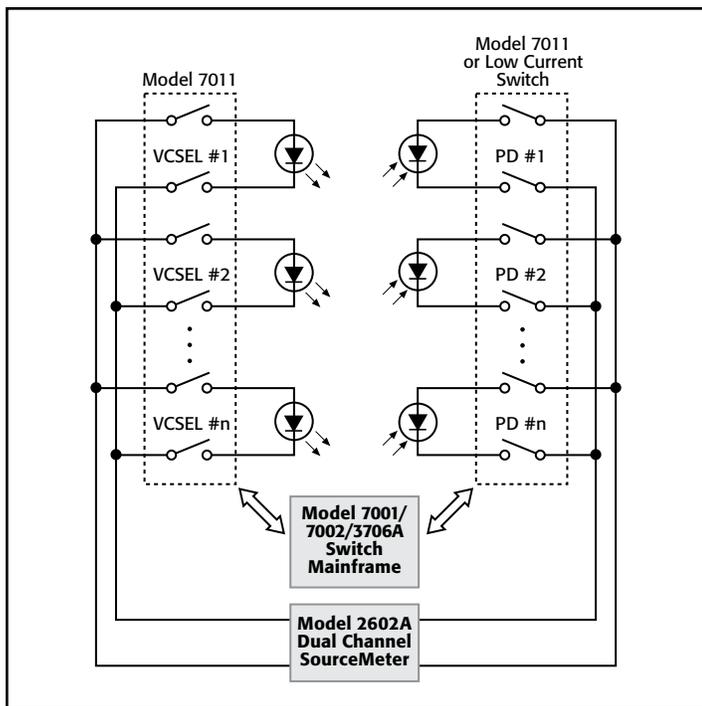


Figure 10. Multiple device testing using a switch.

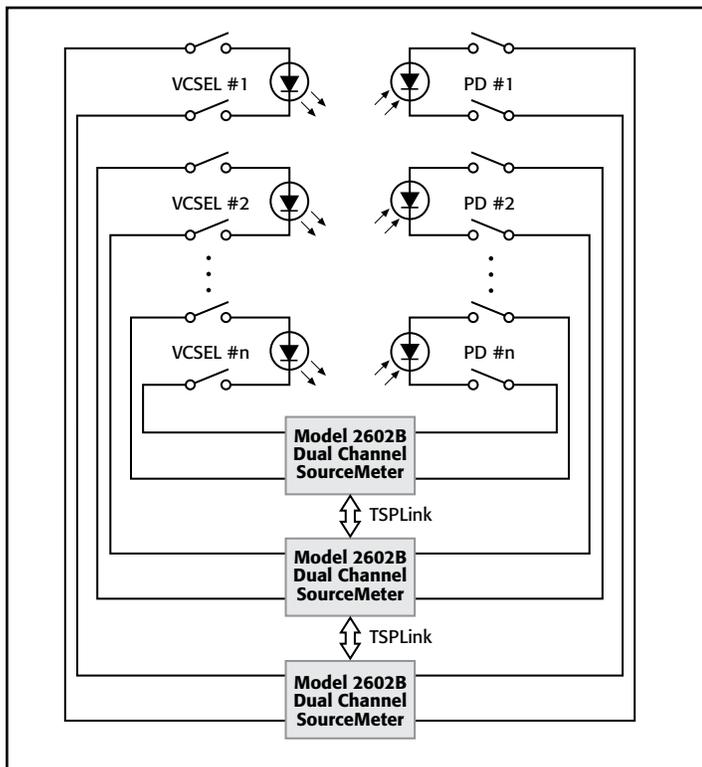


Figure 11. Parallel test configuration using multiple Model 2602B System SourceMeter instruments.

soak time allows any circuit capacitance to settle before the measurement begins. The measurement integration time is determined by the number of power line cycles (NPLC). If the input power is at 60Hz, a 1 NPLC measurement would require 1/60 seconds, or 16.667ms. The integration time defines how

long the analog-to-digital converter (ADC) acquires the input signal. Usually, the integration time chosen represents a trade-off between speed and accuracy.

Typical soak times for the VF test range from 1ms to 5ms, and 5ms to 20ms for the light/current (L-I) test. These short test times help reduce errors due to junction self-heating. It's possible to characterize the junction heating characteristics by performing a series of tests and varying only the soak time with each repetition of the test.

### Leakage Currents

In addition to the nominal leakage characteristics of the cabling and DUT fixturing, conductive contamination of the fixture will increase over time, producing leakage currents. Techniques to minimize leakage may be required when measuring low currents or when using low current photodiodes.

One technique for minimizing leakage current is to use a guarded fixture. In a guarded fixture, the region near the DUT is held at the same potential as the Output HI signal. This reduces the potential difference between the DUT and the leakage paths. For a more detailed explanation of the Guard and Guard Sense signals, see the Keithley white paper titled "Obtaining More Accurate Resistance Measurements Using the 6-Wire Ohms Measurement Technique," available on Keithley's web site.

### Electrostatic Interference

High resistance measurements, like those made using photodiodes, may be affected by electrostatic interference from charged objects. It may be necessary to use an electrostatic shield (Faraday cup) to eliminate electrostatic effects. For more information, see the section titled "Low Current Measurements" in the sixth edition of Keithley's *Low Level Measurements Handbook*.

- Double insulate all electrical connections that an operator could touch. Double insulation ensures the operator is still protected, even if one insulation layer fails.
- Use high reliability, fail-safe interlock switches to disconnect power sources when a test fixture cover is opened.
- Where possible, use automated handlers so operators do not require access to the inside of the test fixture or have a need to open guards.
- Provide proper training to all users of the system so they understand all potential hazards and know how to protect themselves from injury.
- It is the responsibility of the test system designers, integrators, and installers to make sure operator and maintenance personnel protection is in place and effective.

### Light Interference

Stray light entering the optical fiber or the integrating sphere will skew the test results. Take care to ensure that all components are properly shielded at all wavelengths that could affect the conductance of the semiconductor junctions. This is especially critical for dark current measurements of the photodiode.

## Equipment List

### Basic Equipment

- Model 2602B Dual Channel System SourceMeter instrument (laser diode bias and photocurrent measurement in one box)
- Model 2510-AT TEC SourceMeter instrument (laser diode temperature control)
- Model 2500INT-xx series Integrating sphere and detector (xx = SI for wavelengths of 190–1100nm, xx = GE for wavelengths of 900–1670nm).
- 7007-3 IEEE-488 (GPIB) Cable (1 required)
- IEEE-488/GPIB interface card: KUSB-488B, KPCI-488LPA, or equivalent

### Expansion Equipment

- Model 2602B System SourceMeter instrument (laser diode and photocurrent sources and measurements in one box)
- Model 2601B Single Channel System SourceMeter instrument or Model 6485 Single Channel Picoammeter (Optional Back Facet Monitor measurement)

- Model 7001 (2-slot), Model 7002 (10-slot), or Model 3706A System Switch Mainframe
- Model 7053 High Current Switch Card (to route Model 2602B and Model 2510 outputs)
- Model 7158 Low Current Scanner Card (to route Model 2602B photocurrent input)
- Model 3722 Dual 1×48, High Density Multiplexer Card (to route Model 2602B laser diode and photocurrent source and measure signals)
- A suitable PC and software are also required to implement an LIV test sweep.

## Conclusion

Not only does DC testing of LD modules reduce manufacturing cost by identifying failed components early in the manufacturing process, it can also play a critical role in accelerated lifecycle testing. Many LD manufacturers offer high reliability LD parts that have successfully endured days of LIV type testing at elevated operating temperature to identify unstable parts prior to incorporation in subsystems destined for undersea operation.

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