KEITHLEY

Application Note Series

Number 2428

Pulsed LIV Testing of Low Power Optical Devices with an Amplified Integrating Sphere and the Model 2520

Introduction

LIV characterization is an important and commonly used way to verify the performance of all types of laser diodes, including tunable laser diode modules (LDMs) and vertical cavity surface emitting lasers (VCSELs). High quality DC LIV production test solutions have been available on the market for some period. However, the increasing emphasis on reducing manufacturing cost by testing laser diodes at the bar or chip level, prior to integration into a temperature-controlled module, requires robust, easy-to-use pulsed LIV test solutions. To meet this challenge, Keithley developed the Model 2520, the first integrated, compact, half-rack instrument that combines all the source and measurement capabilities needed to perform pulse and DC LIV (light intensity-current-voltage) testing of laser diodes. Tight synchronization of source and measurement capabilities ensures high measurement accuracy with pulse widths as short as 500 nanoseconds.

The Model 2520INT Integrating Sphere is designed to perform optical power measurements when used with the Model 2520. When connected to the Model 2520 with a low noise triax cable, the Model 2520INT allows the Model 2520 to make direct, high accuracy measurements of a laser diode's optical power at the instrument's minimum pulse width capability. The specially designed germanium detector and low attenuation factor of the one-inch diameter sphere support a usable optical power range of 14.5mW to 3W @ 1480nm when used with the Model 2520's 10mA photocurrent range. This configuration is adequate for relatively high power devices, such as pump lasers and Raman amplifiers. In order to measure lower power devices, such as transmitters and VCSELs, additional current amplification is required, which can be provided by adding a preamplifier between the Model 2520-INT and the photocurrent input of the Model 2520. This application note addresses the selection and performance of a suitable preamplifier, and provides assembly guidelines and test results for a complete measurement system.

Theory, System Design, and Configuration

Accurate pulsed optical power measurements with a Model 2520-INT/preamplifier require the detector to operate in the linear operating region and a risetime that's significantly shorter than the pulse width. The first requirement is met if the input power to the sphere is less than 3W. ***Figure 1*** shows the digitized laser voltage and photocurrent measurements of a single pulse from the data buffer of the Model 2520. The voltage and photocurrent are digitized at 10MS/s with 14-bit resolution. The estimated 10–90% risetime of the detector/preamplifier system is approximately 140ns and, for a 1µs pulse, the magnitude of the photocurrent pulse varies less than 2% from t=500ns to t=1µs. Given that the two requirements stated previously are satisfied, the overall responsivity of the Model 2520-INT/amplifier system is the responsivity of the sphere at the wavelength of interest multiplied by the overall current gain of the preamplifier. In this case, the overall current gain is the transimpedance divided by the output impedance (50Ω) provided by a series resistor in the coaxial cable between the preamplifier and the photocurrent input of the Model 2520.

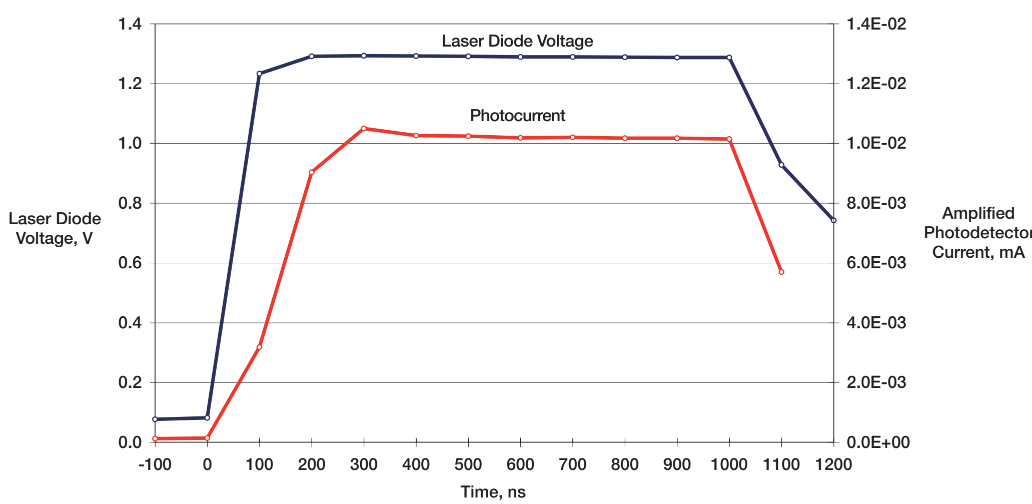

Figure 1. Digitized laser voltage and photocurrent of a single 1µs pulse retrieved from Model 2520 measurement buffer.

The performance of a high frequency transimpedance amplifier is strongly affected by input capacitance, so the design of the preamplifier, the detector specifications, and the interconnection between the detector and preamplifier must be carefully considered. Several factors are important to a successful design:

1. The detector diameter and material must be selected to:
   a. Provide adequate current output at the wavelength of interest, i.e., responsivity.
   b. Meet risetime requirements.
   c. The detector(s) complying with (a) and (b) should have the lowest possible capacitance.
2. Use a reverse bias voltage, if possible, to reduce detector capacitance and improve the transient response.
3. Minimize interconnect length, including the use of connectors, etc., between the detector and preamplifier.
4. Certain amplifier circuit topologies are less sensitive to input capacitance than others. Compare the manufacturer's performance specifications and choose a model with high gain flatness vs. input capacitance.

The preamplifier chosen for this investigation, the Femto HCA-S, is a custom version of the HCA Series. Its bandwidth and frequency response are relatively independent of detector capacitance when compared with competing designs on the market. The specified 3dB bandwidth (±5%) is guaranteed up to the maximum rated detector capacitance. ***Figure 2*** shows the typical dependence of gain on input capacitance for an HCA preamplifier, the HCA-100-M-20K. The input capacitance rating for this particular amplifier is 20pF.

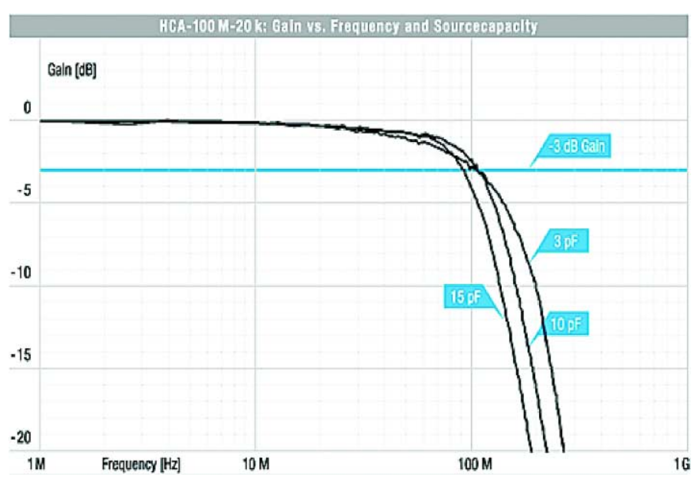

Figure 2. Typical dependence of gain on input capacitance for a Femto HCA type preamplifier, the HCA-100-M-20K.

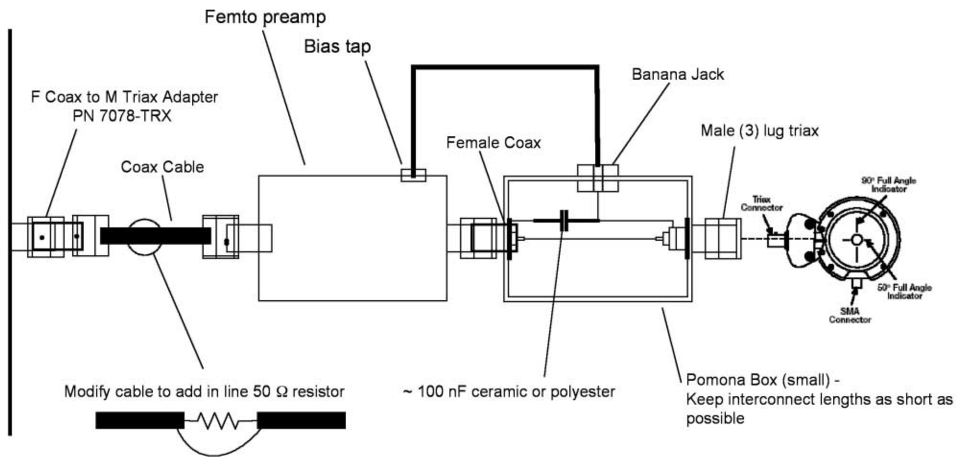

Figure 3. Schematic representation of the system, including the adapter with the bias connection to interface the integrating sphere to the preamplifier.

Additional differences between the standard and custom preamplifiers include the bandwidth (4MHz), the transimpedance (2.5×10^4), and input capacitance (500pF max.).

Figure 3 is a schematic representation of the system, including the adapter with the bias connection to interface the integrating sphere to the preamplifier. The output of the transimpedance amplifier is connected to the input of the Model 2520 with a coax cable modified by the addition of a 50Ω series resistor. This matches the output impedance of the preamp (50Ω) to the input of the Model 2520, a virtual short. The coax cable should be kept as short as possible by locating the remote testhead as near to the test fixture as possible. A reverse bias is applied to the detector with the built-in bias source of the preamp via the lead with the banana jack.

Test System Performance

All measurements and tests are performed on the 20mA range of the Model 2520 using a Nortel LC111H laser operating at 1542nm with a risetime of 300ps. The detector reverse bias is set to 3V and the dark current offset is set to 0.00mA on the Model 2520 display with the bias and offset adjustments provided on the preamplifier. If desired, a bias voltage as high as 5V, as specified by the detector manufacturer, may be applied to increase transient response.

The optical measurement uncertainty due to current measurement noise is calculated from the digitized photocurrent measurements taken during a 100µs pulse with the entrance port to the sphere covered. The pulse generates 1000 measurements on photodiode current channel #1. The standard deviation of the 1000 measurements is calculated and converted to the optical noise using:

$$\sigma_{optical} = \frac{\sigma_{electrical}}{R_{\lambda=1540nm}}$$

In this case, $\sigma_{optical}$ is the optical noise in watts, $\sigma_{electrical} = 8.04 \times 10^{-6}$ amps is the standard deviation of the 1000 photocurrent measurements, and $R_{\lambda=1540nm}$ = 3.77A/W is the responsivity of the integrating sphere and preamp. Using the previous equation, the optical measurement uncertainty due to noise in the pulsed mode is $\sigma_{optical}$ = 2.1µW.

Figure 4 shows the DC optical power of the LDM measured with the Agilent optical multimeter and the preamplifier output current into a 50Ω load. The maximum optical output of the laser with a drive current of 140mA is approximately 3.3mW.

An estimate of the optical dynamic range of the system is calculated using:

$$D = 10 \cdot \log_{10} \frac{I_{out}\,(max)}{R_{\lambda=1540nm} \cdot 3\sigma_{optical}}$$

with $3\sigma_{optical}$ = 6.3µW as an approximation of the noise floor and I_{out} (max) = 30mA, the maximum output current of the preamplifier, which yields D ~30dB.

Figure 5 shows the pulsed LIV sweep of the laser with a pulse length of 500ns and a filter setting of 10. A relatively clean first and second derivative and well-defined threshold are evidence of a high quality laser and relatively low optical and electrical measurement noise.

Figure 6 shows the effect of laser drive current pulse width on the optical output power. The conversion efficiency increases as the pulse width decreases and the thermal load on the chip is reduced. Filtering may be used, up to 100 readings/measurement, to reduce measurement noise, especially for very short pulse widths.

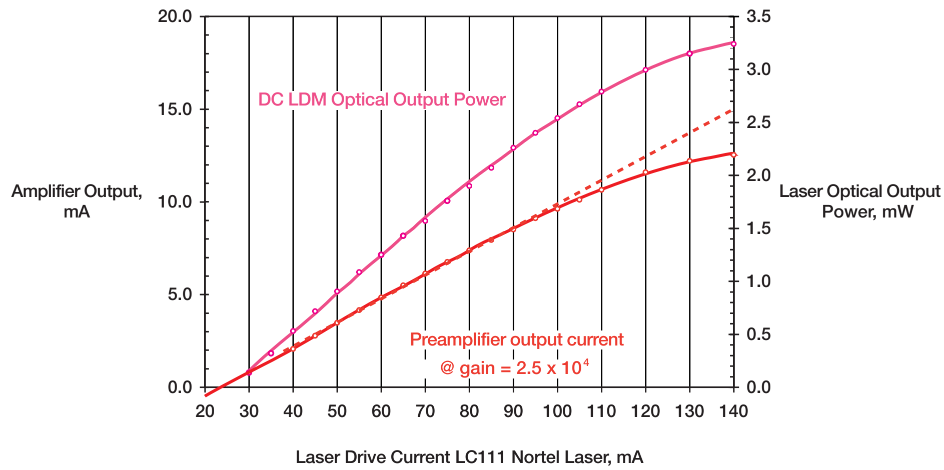

Figure 4. DC optical power of the LDM measured with the Agilent optical multimeter and preamplifier output current into a 50Ω load.

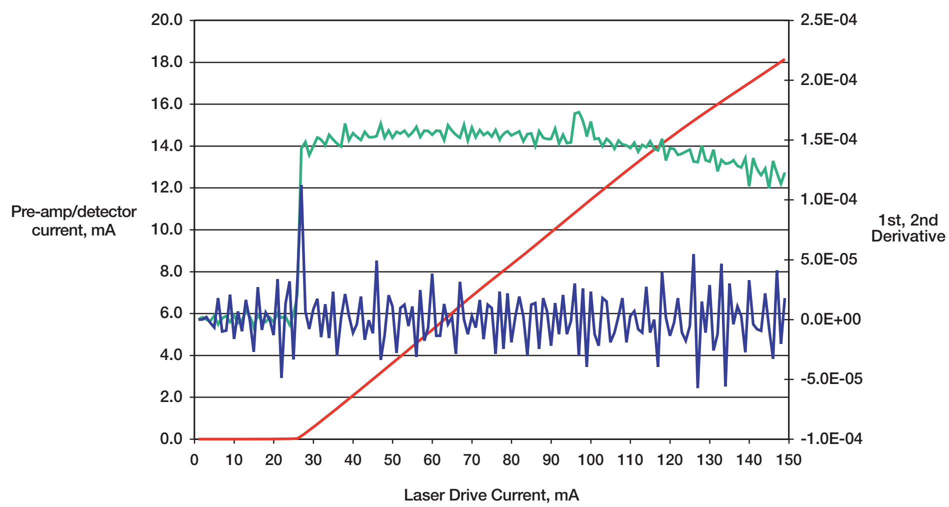

Figure 5. Pulsed LIV sweep of the Nortel LC111H laser with a pulse width = 500ns and filter = 10.

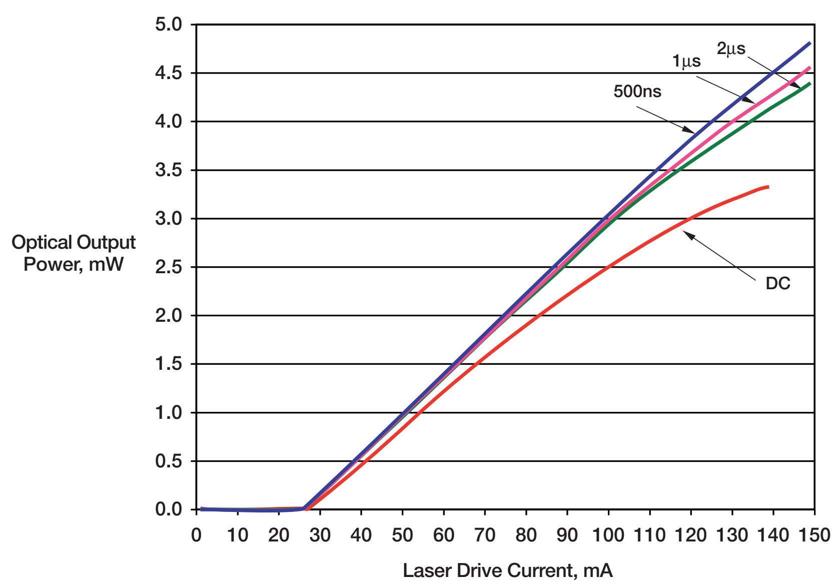

Figure 6. Laser optical output power at DC and pulse widths of 500ns, 1µs, and 2µs with a laser drive current from 1mA to 150mA.

Test System Safety

Many electrical test systems or instruments are capable of measuring or sourcing hazardous voltage and power levels. It is also possible, under single fault conditions (e.g., a programming error or an instrument failure), to output hazardous levels or activate a laser, even when the system indicates no hazard is present. These high voltage and power levels make it essential to protect operators from any of these hazards at all times.

ALWAYS review test system designs with the facility's safety manager and laser safety officer.

Protection methods include:

- Design test fixtures to prevent operator contact with any hazardous circuit.
- Make sure the device under test is fully enclosed to protect the operator from any flying debris.
- 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.

Equipment List

- Model 2520 Pulsed LIV SourceMeter instrument
- Model 2520-INT Pulsed Integrating Sphere
- BNC cable
- 50Ω resistor, 100nF ceramic or polyester capacitor
- Small Pomona box with male BNC and male triax feedthrough connectors and female banana jack
- Male banana plug
- Femto Model HCA-S custom preamplifier available from Femto GMBH (www.femto.de) with these specifications:
  - Bandwidth = 4MHz
  - Maximum input capacitance = 500pF
  - Gain = 2.5×10^4

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