KEITHLEY

*Application Note Series*

Number 2418

# Making Pulsed Light Measurements with the Model 2520INT Integrating Sphere

## Introduction

The Model 2520INT integrating sphere is designed for use with the Model 2520 Pulsed Laser Diode Test System. The sphere's size (one inch in diameter) and built-in germanium detector were chosen to provide a fast detector rise time (<29ns) and the right amount of input signal attenuation (approximately 100×) for the Model 2520's photocurrent channel measurement ranges.

Indium gallium arsenide (InGaAs) is usually the detector material of choice for telecom applications that require extremely fast detector rise times (the time it takes for the detector signal to rise from 10% to 90% of its peak value). However, as a prerequisite for measuring absolute optical power with the Model 2520, a detector must be able to reach 100% of its peak value before the end of each pulse, i.e., the photocurrent output has to be "settled." When comparing detectors of the size needed for the Model 2520INT (≥2mm diameter), Keithley engineers found the germanium detectors investigated settled faster and exhibited linear output performance for much higher optical powers than the InGaAs detectors examined. This is likely due to a so-called diffusion current contribution, caused by light being absorbed outside the depletion region of the photodiode junction. This may be due to overfilling the detector inside an integrating sphere or to the different device geometries of the germanium and InGaAs detectors tested.

## LIV Measurements

Pulsed LIV (Light-Current-Voltage) laser diode testing is a typical application of the 2520INT/2520 combination. To obtain LIV curves, the laser drive current (I) is swept and the light output (L) and the voltage drop (V) across the laser are measured.

Several important laser performance characteristics can be obtained from an LIV curve, including the threshold current, the exact injection current value at which light output increases dramatically. This signals the onset of stimulated emission or lasing action. Threshold current increases with increasing temperature. The laser's slope efficiency (ΔL/ΔI) is another important piece of information. It is desirable for the laser to produce a large increase in light output for a small increase in injection current. Unfortunately, light output decreases with temperature, so the slope efficiency also decreases at higher temperatures. This makes thermal control a necessity during diode laser testing in continuous wave (CW) mode. Ensuring the laser's output is linear and kink-free is another purpose of LIV testing. Kinks are small bumps and abrupt, discontinuous changes in the slope of

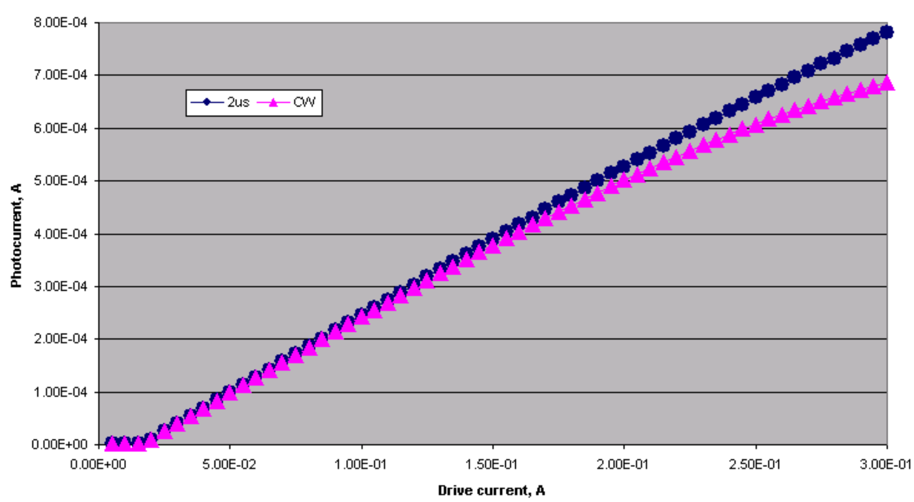


*Figure 1. LI curve of a non-cooled laser swept in CW (DC) and pulse mode. The decrease in output power due to junction heating becomes apparent at the higher drive currents.*

the LI curve.[1] Manufacturers base a laser's maximum output power rating on the linearity and absence of kinks in the LI curve.

It is important to obtain the LIV characteristics of a laser diode early in the production stage, before an active cooling device is added. Self-heating of the laser chip can be avoided by performing LIV sweeps in pulsed rather than CW mode. ***Figure 1*** shows a decrease in the measured photocurrent and, therefore, the optical power, in CW mode (without active cooling) compared to pulsed mode, particularly at the higher drive currents.

Threshold current values and the presence of kinks can be detected even if the photodetector is not calibrated or only measures a fraction of the optical power. However, slope efficiency and the determination of the maximum "kink-free" power output of the laser requires that the detector be calibrated and all the emitted radiation accounted for by the detector.

## Calibration Issues

Calibrating a photodetector or integrating sphere/detector system like the Model 2520INT means determining the photocurrent the detector system is expected to produce for a given optical input power at a particular wavelength. This is called the responsivity of the detector system and is expressed in units of A/W (Amperes/Watt). Unfortunately, a photodiode's responsivity varies with wavelength, so this calibration must be performed at close wavelength intervals over the range of interest. ***Figure 2*** is a typical responsivity or calibration curve for the Model 2520INT. The calibration is performed on the entire integrating sphere/detector system, so the attenuating effect of the integrating sphere is taken into account.

A calibration usually has to be performed over a wide range of wavelengths, so the source has traditionally been a monochromator with a halogen lamp with a spectrum that contains wavelengths from the visible to the infrared. The monochromator's diffraction grating acts as a filter and allows only certain bands of wavelengths to pass through the output slit. For the purpose of responsivity calibration, this bandpass is set to approximately 5nm. The calibration is performed by comparing the detector under test to a NIST (National Institute of Standards and Technology) traceable reference detector. Currently, calibration labs and NIST offer responsivity calibrations performed in CW mode only. NIST does not presently offer a detector responsivity calibration service performed with a pulsed source.

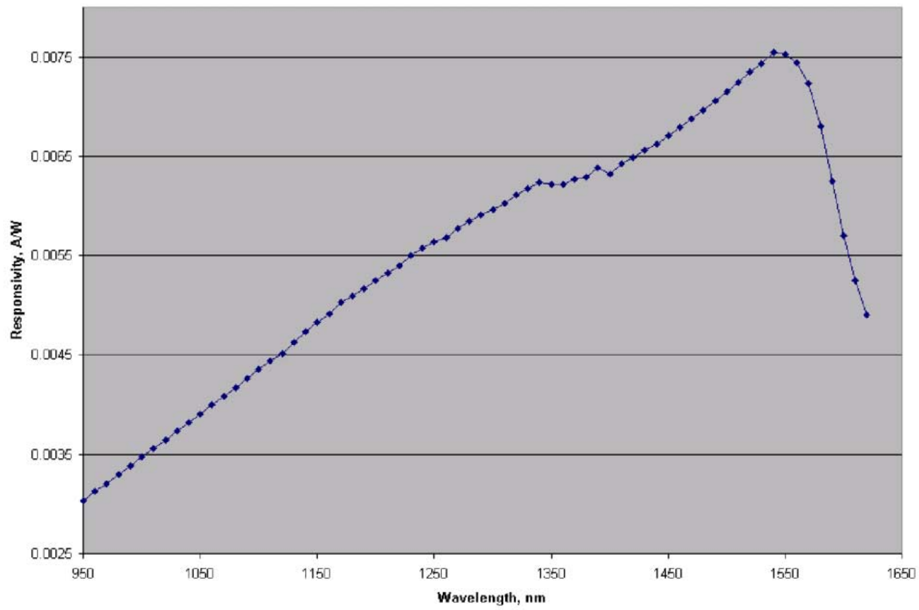


*Figure 2. Typical responsivity values for the Model 2520INT*

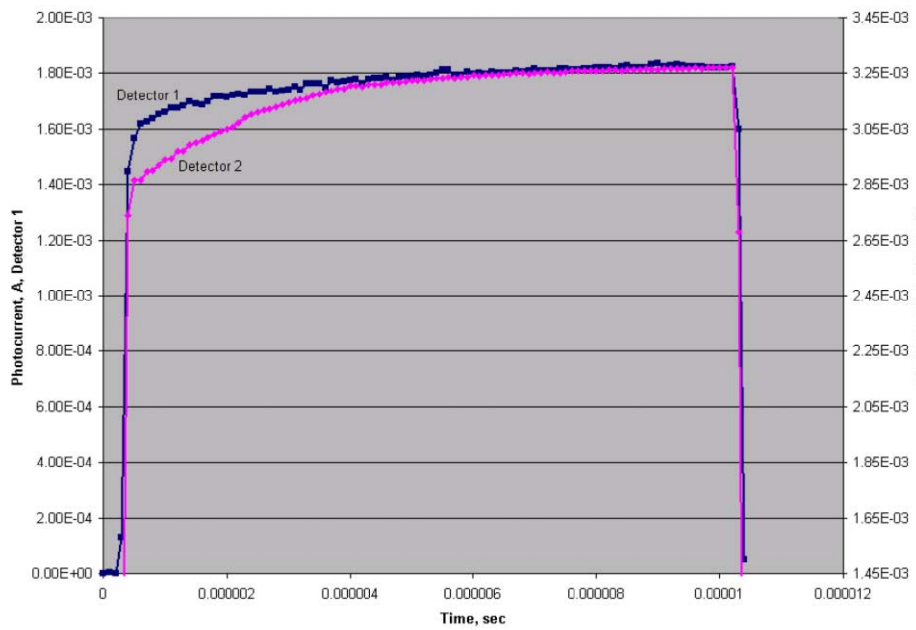


*Figure 3. Comparison of pulse shapes (10µs pulse width) of two different detectors with same active area, using the same laser and drive current. Note that the difference in photocurrent amplitude is mainly due to detector-laser positioning. Scale is the same for both y-axes to allow comparison of response times.*

[1] Bellcore, "GR-468-CORE—Generic Reliability Assurance Requirements for Optoelectronic Devices Used In Telecommunications Equipment," A Module of RQGR, FR-796, Issue 1, December 1998.

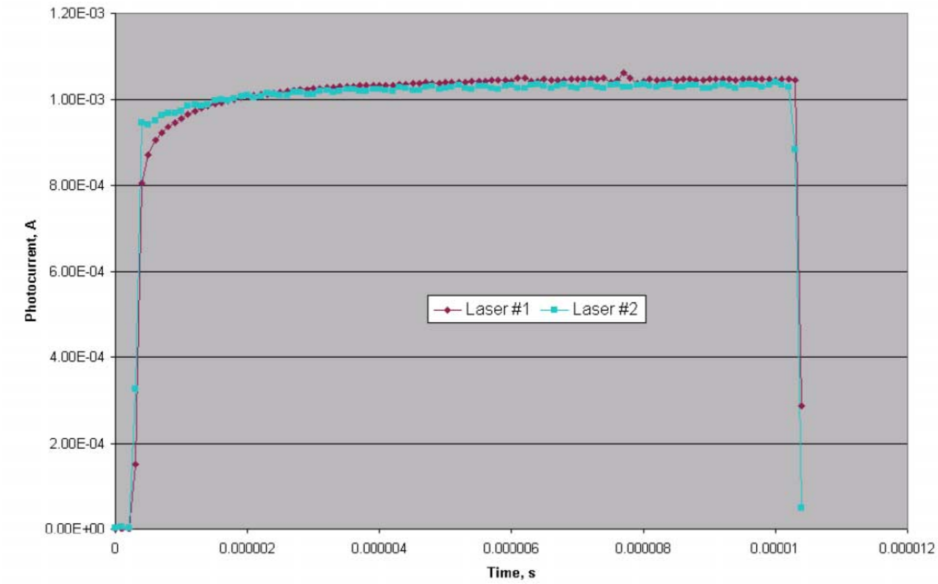


*Figure 4. Photocurrent pulse shapes (10μs pulse width) of two different lasers with same detector system.*

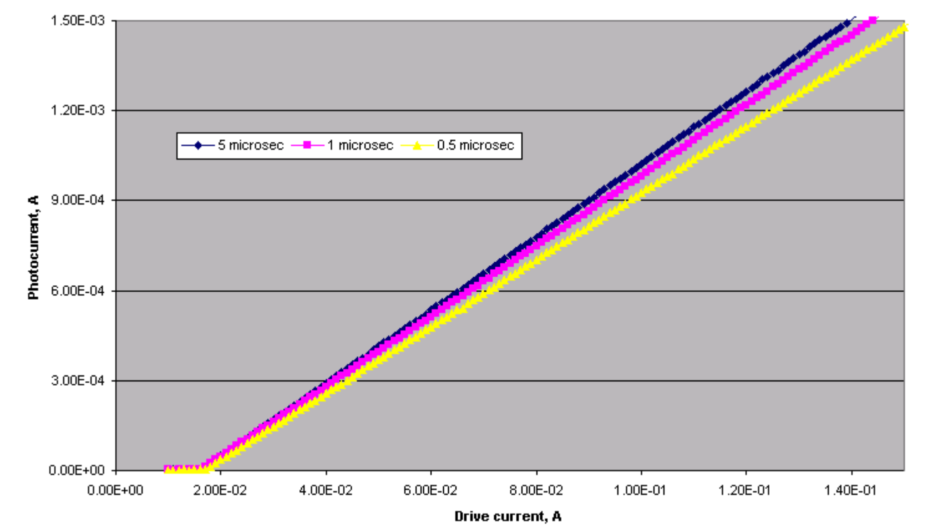


*Figure 5. LI curves using same laser and detector with three different pulse widths. Note that, in this case, shorter pulses cause the slope of the LI curve to be less steep because the photocurrent of each pulse was not settled.*

When a CW-calibrated detector is used for absolute power measurements of a pulsed source, it is important to be aware of possible differences in a detector's responsivity to CW and pulsed input signals, especially in the case of short pulse widths. The photocurrent pulse is influenced by the optical pulse from the laser and the detector system's response to that pulse. ***Figure 3*** shows different pulse shapes for the same laser and two different types of detectors with similar rise times, according to their specifications. ***Figure 4*** shows different pulse shapes for two different lasers with the same detector system and identical setup. The photocurrent pulse shape not only depends on the detector system's response, but also on the pulse shape of the laser output, which in turn depends on the source current pulse and the laser's response time.

## Practical Considerations

The shape of the photocurrent pulse is important for LIV sweeps. Ideally, the photocurrent pulse should have a perfectly flat top, representing a "settled" value equivalent to the photocurrent measured for the same CW power input value. To determine the final photocurrent value for each pulse, the Model 2520 applies a median filter algorithm to the data collected by its 10MHz A/D converter. If the photocurrent is still increasing at the end of the pulse, either because of the shape of the optical pulse or the response time of the detector system, then the measured power may be lower than the actual power. In this case, the shorter the pulse width is, the lower the measured optical power will be. If the photocurrent pulse were settled, the measured power would be representative of the actual optical power. ***Figure 5*** illustrates how this would cause an incorrect slope of the LI curve.

If 2520/2520INT users require absolute calibrated power measurements, they should evaluate individual photocurrent pulse shapes with their own laser sources at different pulse widths. This will allow the user to determine whether the displayed output power of each pulse is a "settled" value or whether this value would actually be higher if a longer pulse width was used (see ***Figure 6***). A downloadable Visual Basic demo program (available via www.keithley.com) for the Model 2520 allows the user to acquire individual pulse traces for this type of evaluation. In some cases, the pulse width required to provide an accurate power measurement for a particular setup may be longer than desirable. If this is the case, the user can infer from these pulse traces the percentage by which the power displayed is lower than it would be if the pulse width were long enough for the photocurrent to settle.

As a last consideration, the shorter the pulse width is, the higher the noise in the LIV data will be. The noise is higher at the shorter pulses simply because there is less data to be included in the reported measurement, so each data point has a large effect on the reported measurement.

The amount of noise tolerable depends on how the user defines kinks. If very short pulse widths cause general noise to be misinterpreted as kinks, it will be in the user's interest to run LIV sweeps at longer pulse widths.

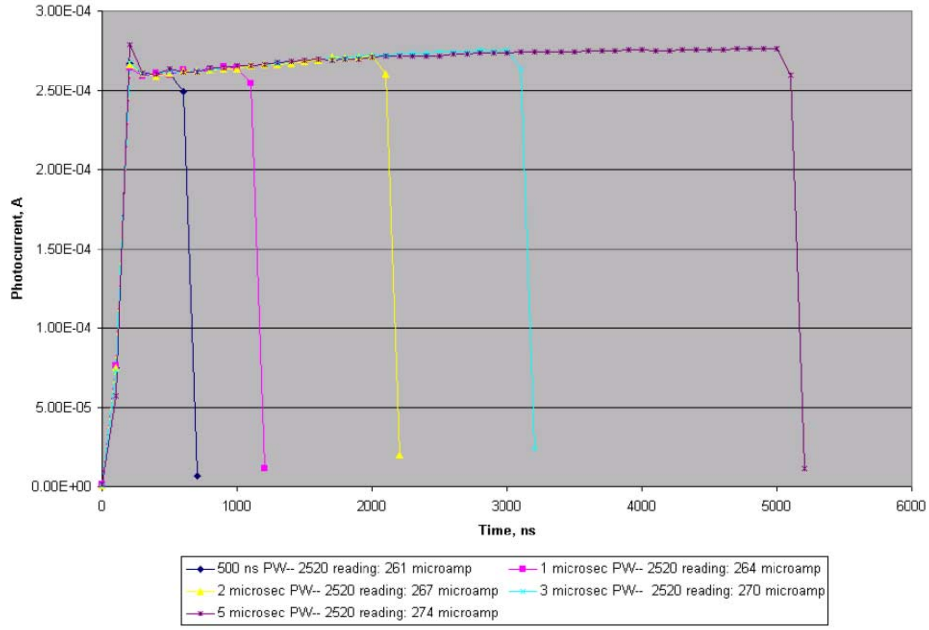


***Figure 6. Pulse shapes of the same laser at various pulse widths, showing that the photocurrent value reported can be lower for shorter pulses than for longer ones.***



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