Measuring Average Power of Pulsed Lasers with Photodiodes

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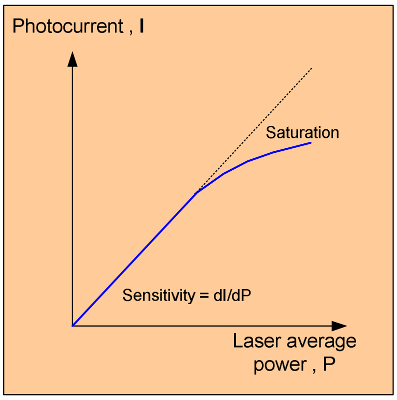
Background

When measuring average power using a photodiode detector such as PD300 or IS6-D-VIS, the maximum power or saturation power is determined by the maximal photocurrent that the photodiode can generate while still maintaining linearity. The saturation power is typically 3mW for a bare silicon photodiode. Adding attenuation in the form of a filter or through the use of an integrating sphere will naturally increase the saturation power of the sensor as a whole.

Recent development in VCSELs for applications in remote sensing, require measurement of average power during pulsed operation. When measuring average power of pulsed lasers, another mechanism may also affect the linearity of the photodiode. In this article we review this mechanism.

What is Saturation?

Saturation is a decrease in sensitivity (current per unit power) when the incident power exceeds a certain limit.



Photodiode Saturation in CW

When the photodiode is illuminated with CW laser radiation, there is a steady rate of carrier generation (electrons and holes). The electric field that exists inside the photodiode causes the electrons and holes to drift in separate directions towards the anode and cathode, giving rise to the photocurrent which is measured by the display unit. A small percentage of these carriers recombine before they leave the photodiode and thus do not contribute to the measured photocurrent. When the photocurrent reaches about 1mA, the voltage on the load resistance of the display unit starts to rival the potential between the separated photo-generated charges. The photodiode’s internal potential is insufficient to push additional current through the circuit and the photodiode response becomes saturated. ***The maximum power specifications of our photodiode sensors are derived from this consideration.***

Photodiode Saturation Due to Short Laser Pulses

When measuring average power of laser pulses, the measurement will be accurate if effectively all of the photo-generated charge exits the photodiode and contributes to the measurable current without undergoing recombination in the device. The discharge time of the photodiode is more relevant than the actual laser pulse width, which is often much shorter. Saturation occurs when the photo-generated charge density approaches a certain device-specific value and begins to increase the recombination rate. The laser pulse energy at which saturation occurs depends mostly on the response time of the photodiode, as it dictates how fast the charge carriers can leave the photodiode before they recombine with each other. Another important factor is bias voltage. A negative bias voltage applied to the photodiode will increase the effective potential of the separated photo-generated charges and cause the charge carriers to exit the photodiode faster. This increases both the photodiode response time and saturation pulse energy.

Experiment Results

PD300-UV and PD300-IR were tested with Spectra Physics VGEN pulsed lasers at 1064nm and 532nm. The results are presented in the following table. For each pulse energy, we compared the readings with and without a fixed 50% filter. The criteria for saturation was a decrease of 2% in the measured power without the filter relative to the reading expected based on the measurement made with the filter.

Sensor	wavelength	Pulse width	Saturation Energy
PD300-UV	532nm	20ns	1µJ
	1064nm	10,50,250ns	1µJ
PD300-IR	1064nm	10,50,250ns	0.75µJ

For longer pulses in the µsec and msec range, the saturation behavior moves towards CW, where instantaneous power dictates saturation. For ultra-short pulses in the femtosecond range, other mechanisms may affect saturation.

Saturation energy for other photodiode sensors

By measuring the saturation pulse energy of the basic photodiodes, we are able to calculate the saturation pulse energy of all our other photodiode power meters by taking into consideration the different attenuations that exist in each sensor. For example, an IS6-D-VIS integrating sphere that measures up to 30W, has an effective attenuation of 10,000 relative to a photodiode that measures up to 3mW. It's saturation pulse energy will therefore be 10,000 times higher.

While working with pulsed lasers, it is important to make sure that both that average power and the pulse energy do not exceed the maximum values.