# Meeting Measurement Challenges For Low-Power, Pulsed, Or Modulated Light Sources

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Traditionally, power meters have been used for continuous-wave (CW) light sources in conjunction with photodiode or thermopile detectors for average power measurements, while energy meters and pyroelectric detectors have been used for pulsed laser beam applications.

Recent advancements in photonics technologies have broadened the applications horizon into many different areas. An increasingly larger number of complex and diverse forms of light sources are designed into various systems and experimental setups. These complex light sources drive the need for more sensitive and versatile power measurement capabilities with unprecedented accuracy.

It is particularly challenging to measure a low-average-power pulsed light source, such as an LED or a low-power laser diode, especially when the electrical designers do not know the detailed optical characteristics of the light source. In addition to average optical power, many other parameters about the light source are important to obtain. For instance, what does the optical signal look like? Key information such as shape, frequency, and power level is needed to determine the system power budget and the overall system performance, as well as to validate the effectiveness of lower cost components. It is also important to identify which signal characteristics the detector or the detection system will measure. Researchers and engineers are interested in the pulse width and pulse shape of the signal.

Typically, one would use an optical power meter to measure the pulse energy or the average power by using a meter and a National Institute of Standards and Technology (NIST)-calibrated detector. A biased detector, connected to an oscilloscope, would be used to determine the pulse shape and to measure frequency and other temporal information.

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Recent developments in power meter technology have now enabled decent temporal signal measurements, eliminating the need for multiple instruments. One of the most advanced power meters in the market has been designed by Newport Corporation, Model 2936-C. This state-of-the-art, dual-channel optical power meter has several sophisticated features that allow the user to achieve various measurements, including frequency measurements of pulses up to 250 kHz (see *figure 1*).


**Figure 1:** Newport Corporation's optical power meter Model 2936-C with the 918D Series Photodiodes allows various measurements for pulsed or modulated light input as well as continuous wave.

## Analog And Digital Filtering

The analog filter is an electronic, low-pass filter implemented on an optical power meter while the digital filter averages the most recent 10, 100, 1,000, or 10,000 samples. The 2936-C optical power meter has selectable 5 Hz, 1 kHz, 12.5 kHz, and 250 kHz low-pass filters. An optical power meter is essentially an amp meter with very low noise and high accuracy. Therefore, the proper filter setting would make a huge impact on the signal response of the optical meter. For the best CW measurement or average power measurement of a modulated/pulsed light source, the heaviest filtering would be utilized, i.e., the 10,000 point digital filter with the 5 Hz analog filter. For a modulated or pulsed signal, an appropriate analog filter must be selected to obtain the best waveform, while the digital filter must not be used at all. Moreover, applying the digital and the analog filters on the pulsed or modulated input signal effectively averages out the signal.

**Statistics And Time Plot**

Robust statistical measurement capability, such as average, minimum, maximum, and standard deviation is a standard feature in many optical power meters nowadays. With a photodiode detector, Newport's 2936-C power meter can log a data point every 0.1 msec, up to 250,000 data samples per channel, which can be easily stored on a USB thumb drive for further analysis using a spreadsheet program like Excel. In addition, the collected data can be viewed in a scope-like time plot directly from the meter display, as shown in *figure 2*. One can easily see whether the input signal is the expected form or if it is distorted due to overly heavy analog filtering, excessive noise, or any other external influences.

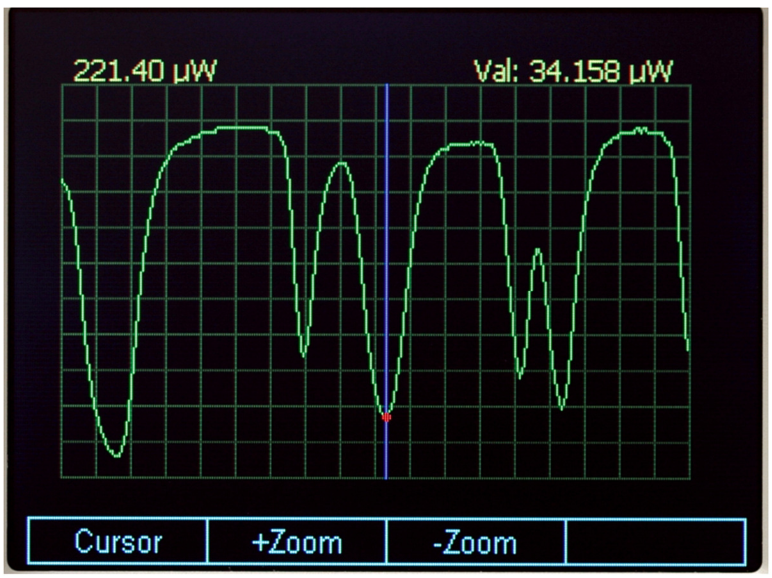


**Figure 2:** The time plot of the data stored by the internal sample storage.

**Peak-To-Peak And RMS Measurement**

With the fast 250 kHz sampling rate of the 2936-C, modulated and pulsed signals can be measured in the Peak-to-Peak Mode. The power meter will determine the difference between the maximum and the minimum value within the given time window, which can be defined by the user. For different measurement ranges of the power meter, there are trade-offs between bandwidth and noise level. Therefore, when using large bandwidth ranges, it is important that the signal being measured has large enough power to ensure a good signal-to-noise ratio. The RMS (root mean square) measurement is another measurement mode available in the 2936-C optical power meter.

**Triggering**

Triggering is an especially useful feature when synchronizing the measurement with an external event. Typically, an external event generates a pulsed light output, whose value can be measured in the CW or Peak-to-Peak mode. In the Newport 2936-C power meter, it is possible to set the trigger to be responsive to an external transistor-transistor logic (TTL) signal, the press of a soft key trigger by the user, or to a computer command.

**Testing And Results**

To illustrate some of the features and capabilities available with the Newport optical power meter, a series of tests were run with a 50% duty cycle to compare the performance of a Newport 818-BB-21 fast-biased detector to a Newport 818-SL/DB semiconductor detector. The repetition rate for all tests was 1 kHz with a pulse width of 500 µs.

We connected the 818-BB-21 detector directly to channel 1 of the oscilloscope. The 818-SL/DB detector was connected to the 2936-C optical power meter. We then connected the analog output of the 2936-C to channel 2 of the oscilloscope.

With a 50% duty cycle we noticed nearly identical waveforms when comparing the output of the 818-BB-21 to that of the analog output of the 2936-C (see *figure 3*). To measure CW power, we used the 2936-C digital filter set to 10,000 samples and the analog filter set to 5 Hz. The 2936-C measured a CW power of 67.76 µW and peak-to-peak power of 134.5 µW. The peak power as measured by the 2936-C (no filters, manual range mode) is in close agreement with the theoretical peak power.

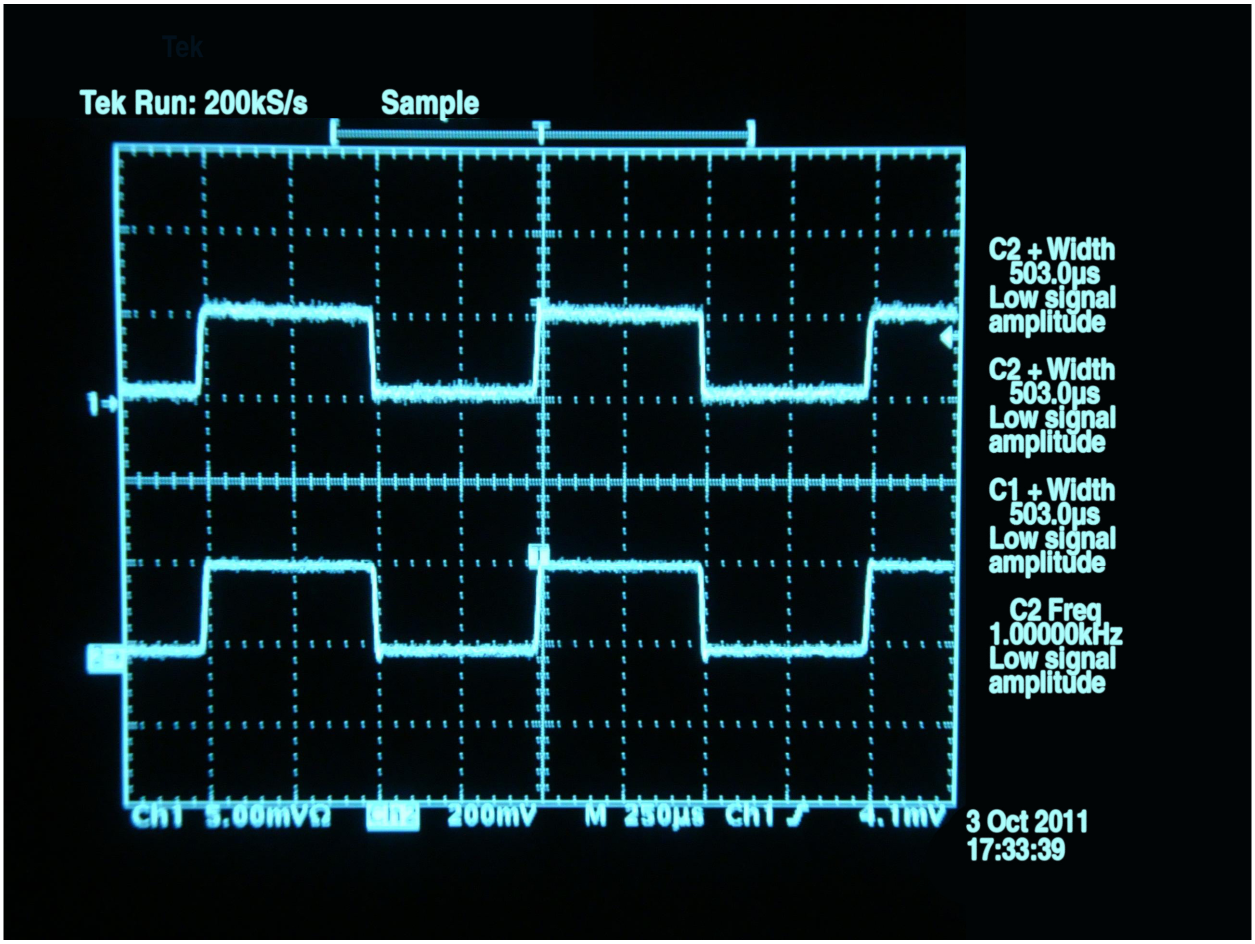


**Figure 3:** Measurement comparison of a pulsed optical signal, 1 kHz repetition rate with a 50% duty cycle, as measured by a Newport Model 818-BB-21 biased detector (top waveform) and an 818-SL/DB (bottom waveform) silicon photodiode detector.

In conclusion, recent improvements in optical power meter technology enable more complex measurements, such as power measurement of low-power pulsed or modulated light sources. We constructed a simple pulsed light source measurement using a Newport optical power meter and a fast-biased detector. Comparable pulse shapes and the resultant NIST-traceable average optical power in the CW measurement mode and the amplitude in the Peak-to-Peak mode were clearly demonstrated.