Laser products are currently available over an extremely broad range of operating regimes and output characteristics. For example, there are laser sources all the way from the deep ultraviolet to the far infrared, lasers with continuous output and those with pulsed output of only a few femtoseconds in duration, and lasers having just a few milliwatts of power to those that deliver tens of kilowatts. Because of this diversity, together with the disparate measurements needs of various applications, a number of different technologies are currently employed for laser power and energy measurements. This article reviews the basic laser sensing technologies now on the market, and is intended to help readers select the best solution for their specific measurement needs.

Definitions
The most commonly measured laser parameters are power and energy, but the exact definition of these terms may vary by laser type or application. For continuous wave (CW) lasers, that is, lasers whose output is continuous and not pulsed, the most commonly measured parameter is average power, usually just referred to as power. This is measured in watts and defined in the traditional sense as energy divided by time.

For pulsed lasers, there are several ways to characterize the output, depending upon the exact nature of the delivered pulses. Pulse energy is the total (integrated) energy content of one pulse. Average power is then defined as pulse energy times the repetition rate (assuming that pulse energy is constant from pulse to pulse). Peak power is also often of interest. The simplest way to define peak power is pulse energy divided by pulse duration, but actual peak power of a laser pulse depends upon the specifics of the pulse shape.

Sensor Types
There are quite a variety of laser power and energy measurement products commercially available, and choosing the right one for a specific application can sometimes seem daunting. For example, Coherent alone manufactures over 100 different laser sensors, and more than a dozen separate meters. However, this selection process can be broken down into a few simple steps. The first of these help you choose an optimum sensor. A similar checklist then enables meter (electronics) selection.

Sensor selection itself is based on two factors. Specifically, these are the parameters to be measured (e.g. average power, or energy per pulse), and, next, the characteristics of the laser under test (e.g. total power/energy output, repetition rate, average power/energy density). The following provides some guidance relating to these two factors for the most common sensor types, namely thermal, semiconductor and pyroelectric sensors.

<table>
<thead>
<tr>
<th>Laser Type</th>
<th>Measured Quantity</th>
<th>Measurement Range</th>
<th>Optimal Sensor Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Power/Energy</td>
<td>Wavelength</td>
<td></td>
</tr>
<tr>
<td>CW Laser</td>
<td>Average Power</td>
<td>1 nW to 5 W</td>
<td>0.19 µm to 1.8 µm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 µW to 10 kW</td>
<td>0.15 µm to 11 µm</td>
</tr>
<tr>
<td>Pulsed Laser</td>
<td>Average Power</td>
<td>100 µW to 10 kW</td>
<td>0.15 µm to 11 µm</td>
</tr>
<tr>
<td></td>
<td>Energy Per Pulse</td>
<td>100 µJ to 100 J</td>
<td>0.15 µm to 11 µm</td>
</tr>
<tr>
<td></td>
<td>Single Pulse Integrated Energy</td>
<td>100 µJ to 20 J</td>
<td>0.15 µm to 11 µm</td>
</tr>
</tbody>
</table>
able temperature difference between the sensor and the heat sink, the sensor head is designed for relatively slow heat flow between the two. Consequently, thermal sensors have relatively slow response time and are therefore best suited for measuring CW laser power, average power in pulsed lasers or total energy from a string of pulses. They can also be used to measure energy of a single long pulse.

Semiconductor sensors utilize photodiodes that convert incident photons into charge carriers (electron and holes), which can be measured as current or voltage. Photodiodes offer high sensitivity and low noise, enabling them to detect very low light levels. However, they saturate well below 1 W/cm² of incident power, so attenuating filters must be used when operating at higher powers. Photodiodes have a fast response time, and are thus useful for looking at pulse shapes.

There are several different semiconductor material systems used for constructing photodiodes because each has a relatively limited spectral range. These sensors also exhibit lower spatial uniformity than thermal sensors. The latter can affect the measurement repeatability of non-uniform beams or of beams that wander over the detector surface between measurements.

Pyroelectric detectors utilize a ferroelectric crystal that has a permanent electrical polarization. Incident light heats the crystal, thus changing its dipole moment and causing current to flow. Because current only flows while the dipole moment is changing, and not when it has reached a steady state condition, pyroelectric detectors are only used to directly measure pulsed lasers (to measure CW lasers a physical beam chopper must be utilized). Pyroelectric detectors are usually preferred over semiconductor sensors for measuring pulsed lasers for a number of reasons. For example, they offer superior speed, they can directly measure higher power because they do not saturate, they demonstrate good spatial uniformity, and also have a very broad spectral response. The table summarizes which sensor type is most typically appropriate for a variety of common laser measurement tasks.

**Meter Electronics**

Meter electronics convert the raw electrical signal from the laser sensor to a format that can be visually displayed or digitally manipulated. Laser power and energy meter manufacturers offer products that cover a wide range of options in terms of functionality and cost. Products from most suppliers can be divided into those that measure only power, those that measure only energy, and those that measure both power and energy. Power-only and energy-only meters offer simplicity and economy, and are often the most physically compact. More advanced features and capabilities are often only available in dual (power and energy) meters, so these products may have to be considered, even if the application is purely for a single measurement type (power or energy).

Laser measurement is often performed along with other data acquisition tasks, especially in instrumentation and production line settings, and a central, host computer may be used to perform data logging and analysis. In these cases, interface options are also a significant consideration. The USB 2.0 interface is the most widely used for most modern personal computers, and offers the requisite data transfer speed for the majority of applications. However, many production applications are serviced by dedicated microprocessors using a serial interface to communicate with various other sensors and controls, so sometimes this older interface type is required.

In terms of performance, the most important performance characteristic is usually the noise floor of the instrument, since this will determine the ability to make low light level measurements and set the absolute accuracy of the device. For energy only meters,
the defining performance characteris-
tic is typically the maximum repetiti-
on rate. When the meter is used as a stand 
alone instrument, such as in laboratory or 
field service settings, it may be neces-
sary to have built in capabilities for 
logging data, and the ability to per-
form various statistical calculations on 
stored entries. For example, more 
sophisticated energy meters can pro-
vide calculated values for irradiance, 
fluence and other quantities, in additi-
on to just total energy. Recently, Coherent has introduced a 
product in which all the meter elec-
nronics are miniaturized and integrated 
into the USB or RS-232 connector on 
the sensor. The device is then con-
trolled and read through a virtual inst-
strument application running on a com-
puter. Because these »meterless« 
sensors are both smaller and more 
economical than traditional products, 
they are particularly useful for embed-
ded applications, for space and weight 
sensitive applications (e. g. field ser-
vice), or where a host computer is 
 already being used to control instru-
ments and data acquisition (such as a 
burn-in racks).

In conclusion, today’s laser power and 
energy sensors are capable of delive-
ing very high accuracy and precision. 
Commercially available products co-
ver a wide gamut of performance, fea-
tures and cost, and choosing the right 
product for a specific application 
requires understanding both the un-
derlying technology and the capabili-
ties of individual products.

INFO

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