Meterless Laser Power/Energy Measurement Simplifies Embedding

Traditional laser power and energy measurement instruments typically comprise a sensor head connected to separate meter electronics. While this approach offers flexibility, it can be difficult for system builders to embed this instrumentation into their own equipment, and may even waste valuable space in laboratory applications. Now, Coherent has applied microelectronics miniaturization technology to deliver next generation laser power and energy measurement solutions, where all the meter electronics are miniaturized and encapsulated within the sensor head cable. These so-called "meterless" products are smaller and more economical than conventional power and energy meters, yet involve no sacrifice in terms of performance. This makes these meterless products particularly attractive for use in embedded systems, simplifies their calibration and lowers total cost of ownership.

Traditional Power and Energy Meters

The most common embodiment of laser power and energy measurement instrumentation consists of a sensor head, which connects by a cable to a separate meter. For power sensing, the detector is usually either a thermopile or semiconductor photodiode, while pulse energy measurements are typically performed with either a pyroelectric or photodiode sensor.

Housing the meter electronics separately has enabled suppliers to offer the consumer a wide range of choices in terms of capabilities, features and price. For example, the simplest power meters may provide little more than just a power readout, while high-end meters may have various display options (digital for precision and analog style for laser optimization) and a host of other functions, including data logging and statistical analysis capabilities, as well as various computer interface options. Similarly, for energy meters, most manufacturers offer a spectrum of products with varying performance and features (such as absolute accuracy, interface options and the ability to perform pulse train statistics).

In some applications, especially those in which the meter is permanently embedded within a system, this traditional configuration may present disadvantages in terms of size or cost. For example, the physical size of traditional meters may limit the ability of the system builder to integrate them within their instrumentation. Furthermore, standalone meters include functionality such as displays and user controls, which increase their cost, but are usually not needed in integrated applications. Even for more traditional uses in the laboratory, as well as for field service personnel, the separate meter is often unnecessary. This is because instrument control, data display and data logging can be performed by a personal computer acting as a virtual meter.

Some meter providers have developed simplified interface modules specifically for embedded applications. These are more compact units that replace the traditional meter, and which lack a display and may eliminate some of the more sophisticated functions, such as data logging and statistics.

While more economical and smaller than traditional meters, these interface modules do not directly address the former's main limitations. Specifically, they must still be mechanically mounted somewhere within the system and require input and output connectors (from the sensor head and to the control computer). All this takes space and has associated cost for the system builder. In addition, the sensor head and the meter electronics must each be individually calibrated on two separate calibration stations. This introduces additional measurement uncertainty into the system.

OEMs, system builders and laboratory users have all told us that the interface module approach is not an ideal solution for their needs. Some of these users have addressed the problem themselves, designing their own signal processing electronics to take the raw, analog input from a sensor head (which provides a calibrated, raw voltage output), to produce a calibrated power and/or measurement. This requires amplifying the input signal from the sensor, performing an analog-to-digital conversion, and then transmitting the digital signal to a host computer.

The downside of this approach is that the user must gain all the knowledge that instrument manufacturers already have in terms of manipulating and amplifying the sensor signal with high precision, low noise and good stability. Furthermore, the user now assumes all the responsibility for ensuring accurate calibration and final measurement accuracy. Issues that must be dealt with in particular include utilizing the proper analog-to-digital resolution, supplying clean power to the device, and minimizing noise in the amplifier.

The Meterless Solution

Coherent developed its meterless line of laser sensors specifically to meet consumer demand for more compact and economical power and energy measurement instrumentation, while also providing a range of interface options that better satisfy the needs of both OEMs and laboratory users. Both PowerMax™ and EnergyMax™ sensors are available with either USB 2.0 or RS 232 interface. However, there are enough differences in the embodiments of these two products to merit discussing each individually.

PowerMax USB/RS

In Coherent PowerMax products, state of the art microelectronics miniaturization techniques have been utilized to integrate an entire power meter inside a USB 2.0 or RS-232 cable connector. With this unique innovation, PowerMax-USB/RS sensors have all the signal processing and power measurement electronics normally contained in a LabMax™ meter, but they now connect directly to a PC with plug and play functionality, and no external meter.

PowerMax products address all the issues previously identified with either mounting or powering separate meter electronics. Yet, they do not require the user or system builder to develop their own electronics. The PowerMax-USB is a totally plug-and-play device, which even draws its power from the USB connection, and the only power requirement for PowerMax RS-232 sensors is a +5 VDC input.

Figure 1. In the Coherent meterless products, all signal processing electronics are miniaturized and integrated within the sensor head cable.

Figure 2. In PowerMax sensors, all meter electronics are encapsulated within the USB connector itself.

While they offer greater simplicity and lower cost, PowerMax sensors do not sacrifice performance. For example, each sensor has built in, individually calibrated wavelength compensation, and the electronics provide all the measurement performance and accuracy of Coherent LabMax meters. Furthermore, since the sensor and meter electronics are integrated, only a single calibration is required, thus reducing cost of ownership for those who have their systems recalibrated annually.

The PowerMax–RS (RS-232) is primarily intended for those who wish to embed power measurement capability within an automated laser processing station, such as for cutting, welding, marking, scribing or inspection. These types of systems are often controlled by computers running a custom (non-Windows) operating system, and which communicate with the various sensors and controls in the equipment though serial links and commands.

PowerMax-USB sensors are ideal for other embedded applications, such as power measurement in manufacturing lines, laser burn-in racks and long-term reliability test benches. And, even lab users that utilize other computer-controlled instrumentation may find the lower cost and smaller size of the product advantageous. The PowerMax-USB is also an attractive alternative for field service personnel, since it eliminates the need to carry a separate meter, and technicians typically already have a laptop computer.

EnergyMax

In EnergyMax laser energy sensors, all meter electronics are miniaturized and integrated within a module that is part of the sensor head cable. Once again, a host computer is then used for instrument control, data acquisition and information display.

In addition, as is the case for PowerMax products, Coherent EnergyMax sensors are both less costly and smaller than traditional instruments, yet also offer improved performance. For example, they are now able to log data on every pulse at repetition rates of up to 10 kHz. Plus there have also been no sacrifices made in terms of accuracy and dynamic range. All this was achieved through careful design and the use of state-of-the-art microelectronics components, such as high-speed analog-to-digital converters and field-programmable gate arrays (FPGAs).

The new meterless EnergyMax sensors also facilitate pulse ratiometry. To accomplish this, two of the in-cable electronics modules are physically stacked and held together with magnets inside the enclosure. Snapping the two modules together causes pins on the top of one unit to contact those on the bottom of the other. This opens a communications channel between sensors, causing a unique tag to be added to the data for each laser pulse from both units. The software can then use these tags to identify synchronized pulses, and perform mathematical operations on them, such as dividing their energy values to obtain a ratio. This level of functionality and performance was previously only available in products that are more expensive. Furthermore, EnergyMax sensors support ratiometry at repetition rates of up to 1 kHz, which is faster than previously available from any instrument on the market.

Figure 3. For EnergyMax products, meter electronics are contained in a module in line with the sensor head cable.

Stacking (of up to four) EnergyMax sensors also enables all connected units to share both internal and external triggers. In the case of the internal trigger, the system software is used to set a threshold trigger level at an amount that is higher than the system noise, but lower than the expected energy level being measured. Specifically, the trigger level is defined as a percentage of the range of the detection system.

An external trigger input (Type SMB) is also available on each EnergyMax sensor. Only a single trigger input is needed when units are stacked. An SMB to BNC external trigger cable is even included with each unit.

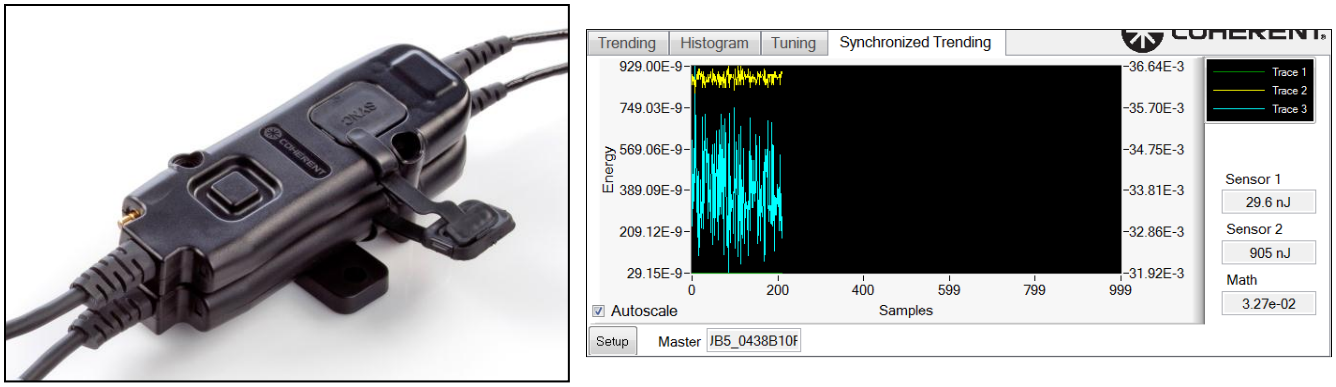

Figure 4. Multiple EnergyMax units can be stacked to enable ratiometry (above), and system software enables data from multiple channels to be monitored.

As with PowerMax sensors, EnergyMax products also lower calibration costs, which can be particularly important in medical systems, in which periodic calibration is required by law. This is because sensor heads and meter electronics are traditionally calibrated separately, but the integrated sensor/meter combination requires only a single calibration, cutting this cost in half.

Software and Interface

Coherent's PowerMax PC and EnergyMax PC products are supported by software packages that provide a virtual instrument interface for all meterless power and energy sensors, respectively. These applications enable the operator to take laser power or energy readings, log data and compute measurement statistics and trending. The PowerMax PC software also supports beam position sensing for quadrant thermopiles. In addition, PowerMax PC supports ratiometry between multiple sensors. However, unlike the EnergyMax products, ratiometry for PowerMax sensors is implemented entirely within the software. There is no need to physically connect the sensors so that they can share a common trigger.

The primary features of Coherent's PowerMax PC and EnergyMax PC software are shown in the accompanying screen captures of the main front panels – see figure 5. This screen provides an instantaneous readout of power or energy, as well as some basic measurement statistics (minimum, maximum, mean, standard deviation, etc.), and also enables the user to input various measurement parameters, such as sampling interval. If more than one sensor is connected to a single computer, then multiple instances of this screen can be opened at once to view the readings from each sensor simultaneously, as seen in figure 6. The screen capture in figure 7 shows how the output of multiple sensors can also be displayed together in a single screen allowing synchronized power ratiometry.

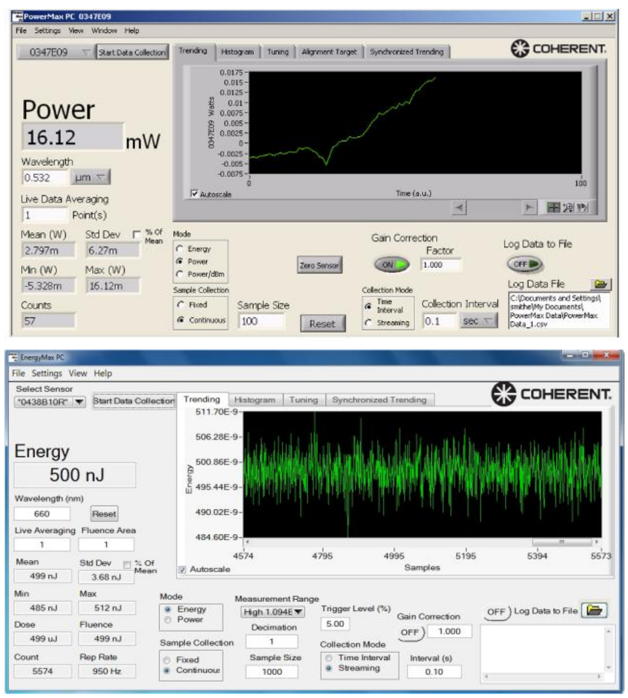

Figure 5: PowerMax PC and EnergyMax PC software main panels.

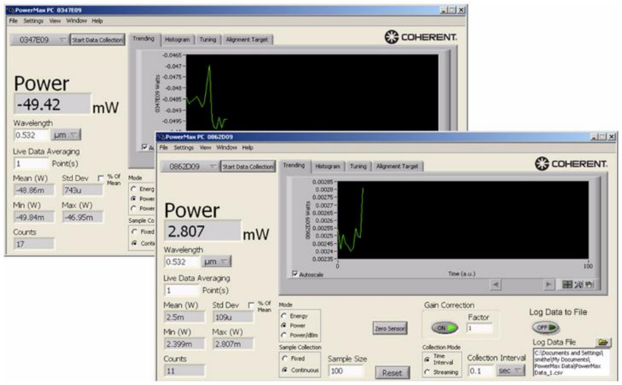

Figure 6: PowerMax PC Operating with multiple sensors in separate windows.

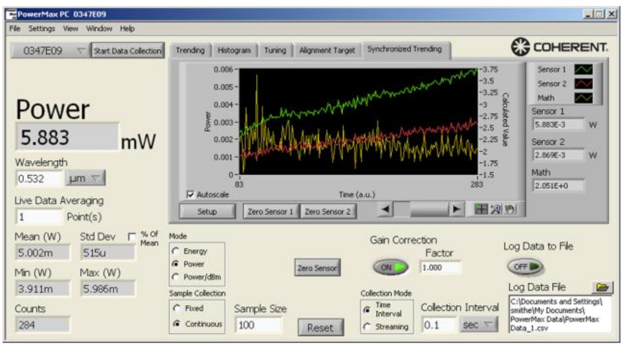

Figure 7: PowerMax PC operating with two sensors in ratiometry mode

All Coherent meterless sensors are available with either RS-232 or USB 2.0 connectivity. The serial (RS-232) interface has been found to be most popular amongst OEM integrators. Typically, industrial and medical laser systems utilize a programmable logic controller (PLC), rather than an embedded personal computer running Windows. Communication between the PLC and peripherals is usually accomplished by sending and receiving simple, SCPI standard compliant, ASCII commands, and this functionality is supported in the PowerMax-RS and EnergyMax-RS products. For these sensors, DC power can be supplied either through a separate adapter or through Pin 1 of the RS-232 cable. Because RS-232 connections do not self-configure, device connection is accomplished through a simple set of menus.

For system integrators and others who wish to write their own software, an extensive set of host interface commands is available to control all aspects of meter operation. Specifically, the supplied DLL driver supports simple ASCII remote interfacing host commands on both the USB and RS-232 connected sensors. To further simply the interface with the PowerMax and EnergyMax sensors, these are also recognized by Windows as a COM port, making it easy to address ASCII commands to them (Figure 8). In addition, a National Instruments LabView™ driver is supplied for easy LabView integration.

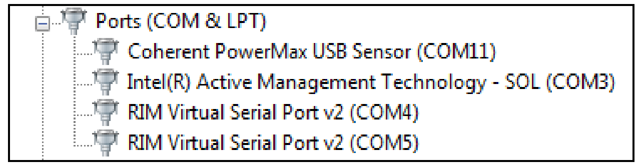

Figure 8: PowerMax-USB Connects as COM port (Shown in Windows Device Manager)

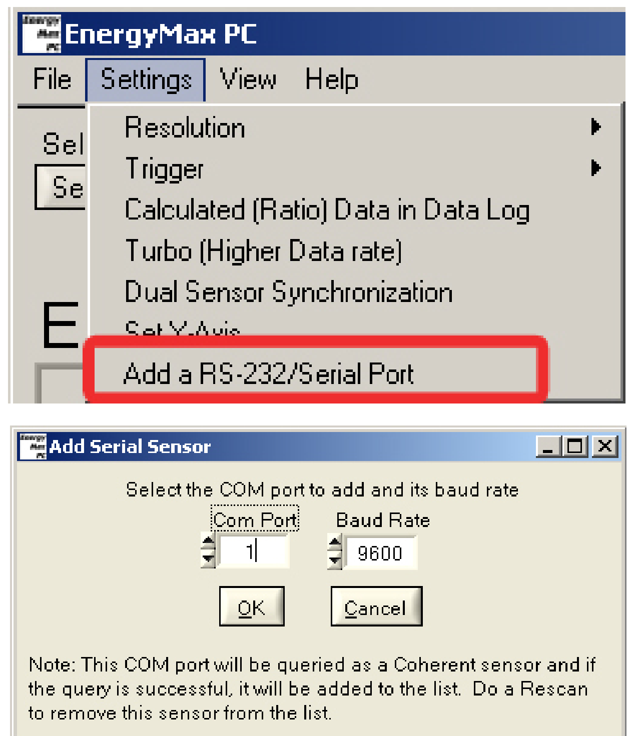

Figure 9. Connecting with an RS-232 sensor simply requires selecting the "Add a RS-232/Serial Port" option from the Settings menu, and then specifying a Com Port.

In conclusion, PowerMax and EnergyMax sensors represent a significant step forward in convenience and ease of use in laser measurement. With their unique combination of small size, high performance and lower cost of ownership, these products should benefit a wide range of users, including systems integrators, field service personnel and even laboratory users.

Understanding Laser Sensors

Coherent PowerMax products are available with both thermopile and quantum (photodiode) detectors. EnergyMax products are offered with either pyroelectric or quantum sensors. Each of these detectors provides different capabilities, and it is necessary to understand the characteristics of each in order to choose the right one for a specific application

Thermopile Sensors

Ideal for CW laser power, average power in pulsed lasers or total energy from a string of pulses.

Thermopile sensors absorb incident laser radiation and convert it into heat. This heat ultimately flows to a heat sink that is held at a near constant ambient temperature by either air or water-cooling. The temperature difference between the absorber and heat sink is converted into an electrical signal by an array of thermocouple junctions.

Thermal sensors work over an extremely broad spectral range, as well as a wide range of input powers. Thermal sensors also offer very uniform spatial response, and are unaffected by changes in beam size, position or uniformity. In order to obtain a measurable 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 Photodiodes

Ideal for low power measurements of CW lasers, and pulse shape characterization.

Semiconductor photodiodes convert incident photons into charge carriers (electron and holes), which can be sensed as current or voltage. Photodiodes offer high sensitivity and low noise, enabling them to detect very low light levels. They saturate above approximately 1mW/cm2, 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.

Photodiodes have a much more limited spectral range and 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 Sensors

Ideal for pulsed lasers.

Unlike all other thermal detectors, pyroelectrics measure the rate of change of the detector temperature, rather than the temperature value itself. As a result, the response speed of the pyroelectric is usually limited by its electrical circuit design and the thermal resistance of the absorptive coating. In contrast, other thermal detectors (such as thermopiles and bolometers) are limited by slower thermal response speeds, typically on the order of seconds. Pyroelectrics respond only to changing radiation that is chopped, pulsed or otherwise modulated, so they ignore steady background radiation that is not changing with time. Their combination of wide uniform spectral response, sensitivity and high speed makes pyroelectrics ideal choices for a vast number of electro-optic applications.

Pyroelectric detectors are primarily used for measuring absolute pulse energy. By utilizing the proper absorptive coatings, pyroelectric detectors can be optimized to detect pulse energy from the nanojoule to the multi-joule level, over wavelengths from the deep ultraviolet through the far infrared, and from single pulses to repetition rates of up to several kilohertz.

Laser Type	Measurement Needed	Power Range	Wavelength Range	Sensor Type
CW Laser	Average Power	10 nW to 50 mW 100 µW to >5 kW	250 nm to 1800 nm 0.19 µm to 11 µm	Optical Thermopile
Pulsed Laser	Average Power	100 µW to >5 kW	0.19 µm to 11 µm	Thermopile
Pulsed Laser	Energy Per Pulse	100 nJ to >10J	0.19 µm to 11 µm	Pyroelectric
Long Pulse Laser (>1 ms)	Single Pulse Integrated Energy	1 mJ to >300J	0.19 µm to 11 µm	Thermopile