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White Paper

# Meterless Laser Energy Measurement Concept Lowers Cost and Simplifies Integration

**In Coherent's EnergyMax laser energy sensors, all meter electronics are miniaturized and integrated within the sensor head cable. This approach particularly facilitates their use in embedded systems, simplifies calibration, and lowers total cost of ownership.**

## Introduction and Overview

Laser energy measurement specifically refers to quantifying the total energy contained in a single laser pulse, or train of laser pulses. Most commonly, this is accomplished with a pyroelectric detector, which is based on a ferroelectric crystal having a permanent electrical polarization. Incident light heats the crystal, changing its dipole moment and causing current to flow. This electrical signal is processed through carefully calibrated meter electronics to yield the 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.

Silicon photodiodes are also used for laser pulse energy measurement. These are quantum detectors in which incident photons create charge carriers (electron and holes) that can be sensed as current or voltage. Photodiodes are very sensitive to low light levels, thus enabling measurement of pulse energies in the sub-nanojoule to microjoule level, and can operate at very high repetition rates. However, silicon detectors are only sensitive to light over the 190 nm to 1100 nm spectral region.

## Traditional Energy Meters

Traditionally, a laser energy measurement instrument consists of a pyroelectric or photodiode sensor head connected via a cable to meter electronics housed in a separate, standalone box. This approach delivers tremendous flexibility.

Specifically, a consumer may purchase one or more sensor heads, each optimized for a different type of power measurement (e.g. deep UV excimer lasers, high energy Nd:YAG lasers, etc.). These are then mated with meter instrumentation that is obtained separately. Here, again, the consumer has a wide choice in terms of available performance and features (such as absolute accuracy, interface options, and the ability to perform pulse train statistics).

However, there are a growing range of applications in which this traditional approach is less than ideal. For example, pulsed lasers having repetition rates below 10 kHz are now used in a wide range of industrial processing and therapeutic medical systems. Typical examples are flat panel display repair and annealing, laser ablation mass spectrometry, and other high precision materials processing, and a variety of medical procedures, including LASIK eye surgery, photo-disruptive eye treatments, aesthetic applications and dental uses.

Equipment builders for these applications often need to embed laser energy sensors at several points within an instrument to monitor both laser output and the delivered energy at various places in the downstream optics. This ensures process consistency for industrial applications, and guarantees safety in medical procedures.

The physical size of traditional meters limits 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 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.

## The Meterless Concept

Coherent has developed the EnergyMax series of "meterless" laser energy sensors to meet the demand for more compact and economical energy measurement instrumentation, while also providing a range of interface options that better satisfy the needs of both OEMs and laboratory users. Specifically, Coherent's range of laser energy sensors is now available in a configuration in which all meter electronics are miniaturized and integrated within the sensor head cable itself as seen in Figure 1. A host computer is then used for instrument control, data acquisition and information display.

While the new meterless EnergyMax sensors are both less costly and smaller than traditional instruments, they also offer improved performance. For example, they are now able to log data on every pulse at repetition rates of up to 10 kHz. In the past, most Coherent meters sampled the data up to 10 kHz and were able to log data on every pulse up to 1 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).

***Figure 1. In the Coherent EnergyMax-USB and -RS products, meter electronics are miniaturized and integrated within the sensor head cable.***

The new meterless EnergyMax sensors also facilitate pulse ratiometry. To accomplish this, two of the in-cable electronics modules are physically stacked, which causes pins on the top of one unit to contact those on the bottom of the other as shown in Figure 2. 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. Again, this level of functionality and performance was previously only available in more expensive products. Furthermore, EnergyMax sensors support rationmetry at repetition rates of up to 1 kHz, which is faster than previously available from any instrument on the market.

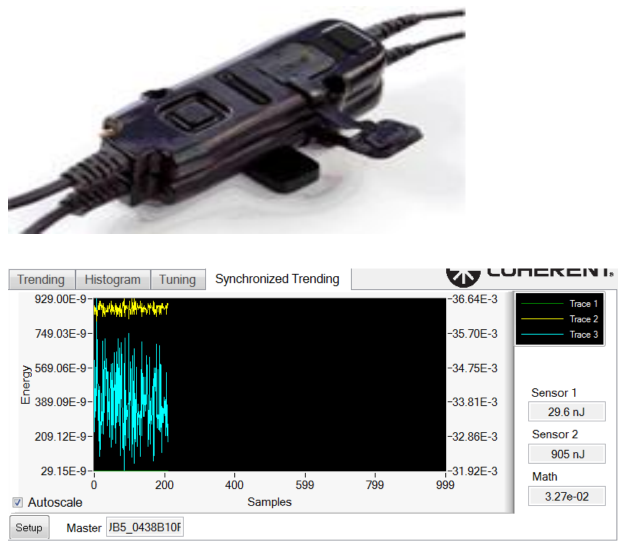


***Figure 2 Multiple EnergyMax units can be stacked to enable ratiometry (above), and system software enables data from multiple channels to be monitored.***

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 maximum 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 included with each unit.

Meterless sensors 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.

**Interface Capabilities**

All meterless EnergyMax sensors are available with either RS-232 or USB 2.0 high speed 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 EnergyMax-RS products. For EnergyMax RS sensors, DC power can either be supplied 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 as shown in Figure 3.

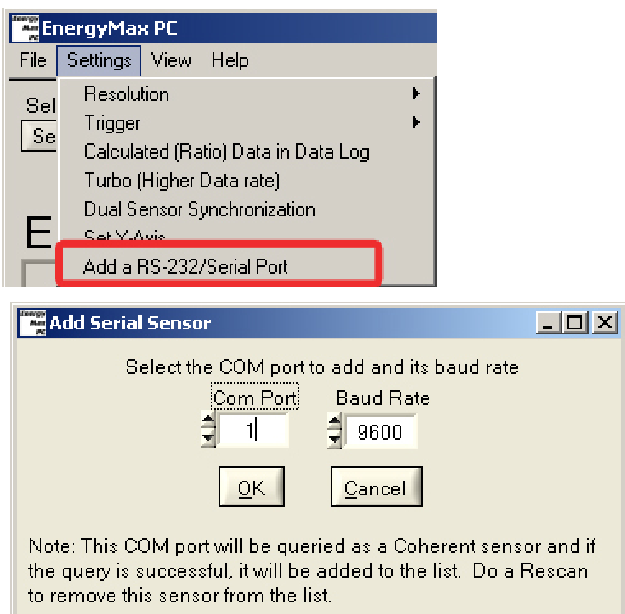


***Figure 3. Connecting with an EnergyMax-RS sensor simply requires selecting the "Add a RS-232/Serial Port" option from the Settings menu, and then specifying a Com Port.***

The EnergyMax-USB configuration is more targeted towards laboratory users and field service personnel, who are often already using a PC for other tasks. EnergyMax-USB are "plug and play," that is, they install and configure themselves upon connection to the host computer, and power for the device is supplied through the USB connection itself.

Coherent supplies Windows based software for use with EnergyMax-USB sensors, providing a virtual instrument interface for the sensors, enabling the user to set sensor parameters, take laser energy readings, log data, and compute measurement statistics, such as trending (Figure 4) histograms (Figure 5), and tuning (Figure 6). Alternatively, LabView drivers and ASCII host interface commands are available to permit those who wish to write their own software to acquire and directly manipulate data and statistics, query the sensors, and address all control aspects of meter operation.

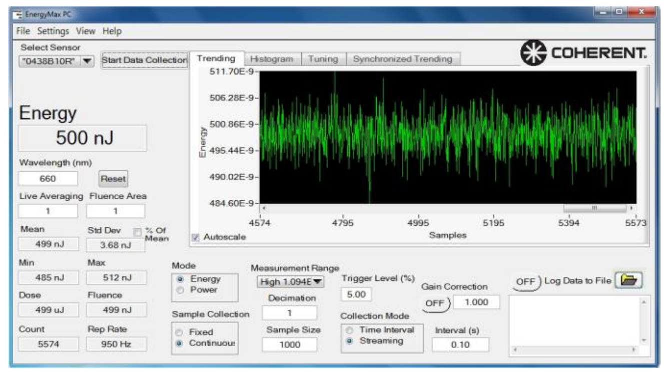


***Figure 4. The operating mode and data collection parameters for the sensor are chosen on the main screen, and acquired data can be viewed in various ways, such as a plot of energy vs. time.***

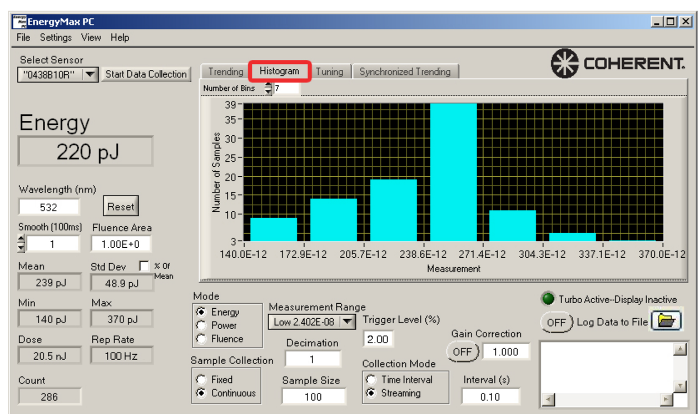


***Figure 5. The statistics capabilities of EnergyMax sensors allow histograms to be plotted dynamically.***

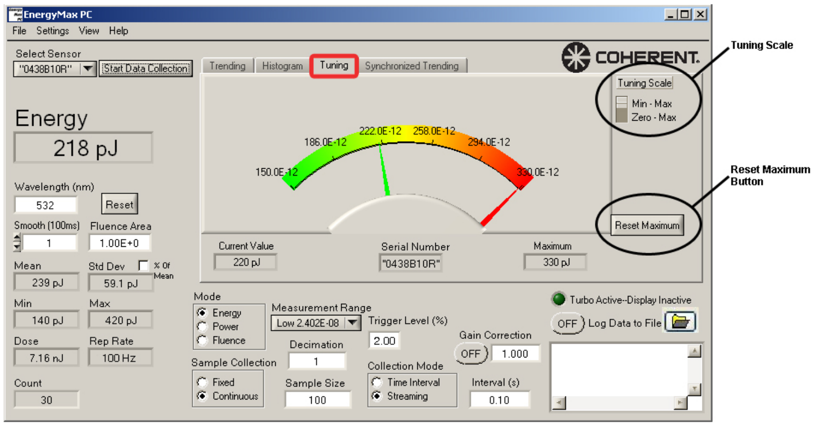


***Figure 6. An analog needle style display is included to facilitate laser and optics adjustment.***

## Conclusion

In conclusion, miniaturized laser energy measurement instrumentation now delivers greater functionality and improved performance to both OEMs and lab users, while also lowering purchase price and operating costs. Making high precision laser energy measurements more accessible should facilitate further refinement of a wide range of processes that utilize pulsed lasers.