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Industrial Paper

Novel thin-gilm based laser measurement technology PowerMax-Pro enables one million times faster measurements

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Abstract

Coherent has designed a novel, thin-film technology (Patent #9,012,848) released to market as PowerMax-Pro which rapidly senses thermal changes due to incident laser energy. PowerMax-Pro represents a dramatic technological advancement in laser power measurement that combines the broad wavelength sensitivity, dynamic range and laser damage resistance of a thermopile with the response speed nearing that of a semiconductor photodiode.
In these new PowerMax-Pro sensors, heat flows vertically through a microns thick film, rather than radially to the edge of the device over a distance of several centimeters. The result is a measurement response time on the order of microseconds, compared to a minute for traditional thermopiles and calorimeters at kilowatt power levels. The high response speed (µs) of PowerMax-Pro sensors is particularly advantageous in commercial applications for currently up to 6kW full power, where it enables CW laser power and pulsed laser energy to be sampled much more frequently, resulting in increased throughput and improved process control.

Keywords:Laser Measurement; Fast Laser Power Measurement; Transversal Thermo-Electric Measurement Technology; PowerMax-Pro; Response Time < 10µs; Measure One Million Times Faster

1. Novel Laser Power Measurement Technology with High-Speed Response of < 10µs

Traditionally over the past several decades, measurement of laser power has been done with one of the three generally known and existing technologies: High-sensitivity photodiodes incorporated in semiconductor power sensors for the power range of nW to hundreds of mW, thermopile power sensors for the power range of µw thru multi-kW, and pyroelectric sensors used to measure the energy of pulsed lasers and light sources from nJ to Joules and up to tens of kHz repetition rate. All of these three laser power / energy measurement technologies are preferably used for certain measurement tasks where the respective technical properties dominate.

Semiconductor laser power sensors are ideal for measuring temporal profile at high pulse repetition frequency. On the other hand, they are often limited thru their small apertures, these sensor easily saturate, and they have a limited λ range.

Thermopile laser power sensors can measure full CW power, up to multi kW range. They are highly durable, but they are too slow to resolve temporal pulse behavior of laser pulses.

Pyroelectric laser energy sensors measure full energy of individual pulses, but their drawback is that they don't measure CW or high duty cycle laser power, and that they have no ability to resolve temporal energy distribution within pulses.

Combining the best capabilities of each of these technologies into one new technology, patented by Coherent (Patent 9,012,848), enabled the transverse thermoelectric measurement technology that is called PowerMax-Pro.

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This new technology enables

- Fast time resolved power and energy measurements
- measuring full CW power up to currently 6kW, in < 10µs,
- measuring full energy of individual pulses,
- fast measurements of temporal pulse profiles,
- single sensor for both power and energy measurements
- high damage threshold and peak power

1.1. Technology

How does this new Revolutionary Transverse Thermoelectric Technology work?

Traditional thermopile sensors are based on radial thermopile physics. A ceramic absorber coating is applied to a metal disk in a very homogeneous layer. Ag/Bi thermocouple junctions are then applied in series onto the disc in an annular pattern.

The laser that hits this disk heats up the coating which then flows radially to the heat sink, through and across the thermocouple junctions. The heat differential across the hot and cold thermocouple junctions generates a voltage, and the voltages from all of the thermocouples in series are added up, resulting as response signal. This whole process takes a few until some ten seconds, until a stable measurement signal is finally created. See figure 1 and equation (1).

The new Transverse Thermoelectric Thin Film Multilayer technology works differently. A complex multi-layer thin-film containing a superconducting oxide detector layer generates an off-diagonal Seebeck thermoelectric effect. The off-diagonal Seebeck terms gives rise to atomic layer thermopile material. See figure 2. This thin film stack is only a few µm thick, and is applied to a metallic base material (e.g. copper). Laser light that hits this surface is immediately transferred through the active layer to the metallic base plate, thus enabling high heat flux loads to be measured, while a perpendicular electronic field and current flow is generated between the detector electrodes. Since this thickness is only a few µm thick, the measurement signal is then created nearly immediately! E.g. A short heat flux path in the film leads to a fast response time. See figure 3 and equation (2).

Many new measurement possibilities are becoming possible with high power Transverse Thermoelectric Technology

- Instant Average Power
  - No need to wait for sensor to stabilize. Saves time.
- Modulated Laser Pulse Analysis
  - The energy in modulated pulses can be measured by integrating energy under the power curve in software or in the meter hardware.
- Fast Peak Power
  - Fire a short duration burst of energy from a modulated or CW laser to measure the power quickly.
- Time Resolved Power Measurements
  - Trace the power curve for modulated lasers >10 usec.

Illustrations

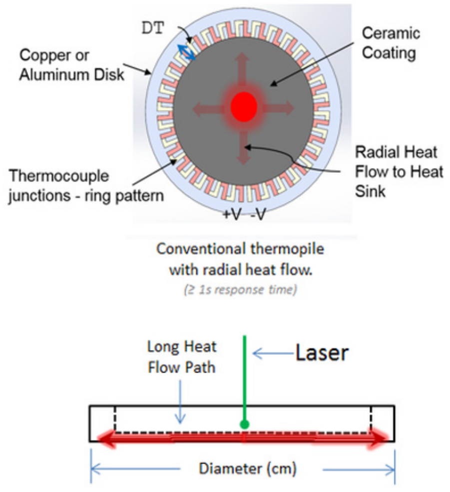


Fig. 1 Conventional thermopile with radial heat flow

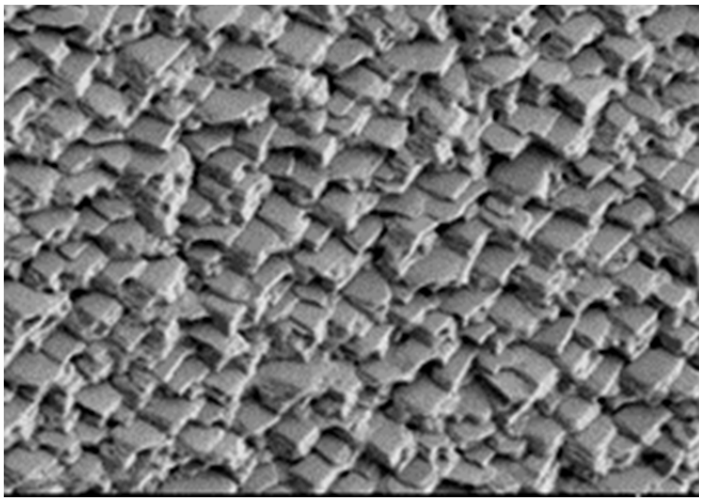


Fig. 2 SEM Scan of Transverse Thermoelectric Film

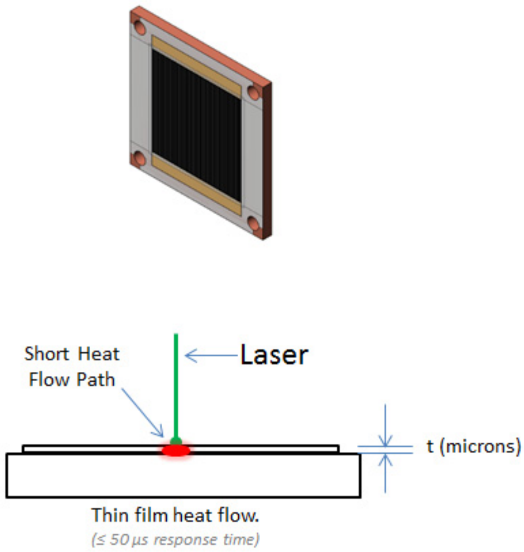


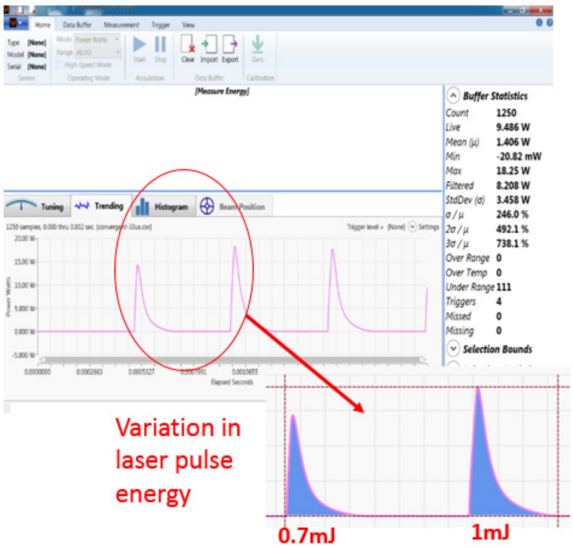
Fig. 3 Transverse Thermoelectric Thin Film Heat Flow

1.2. Benefits and Major Advantages

Fast measurements enable numerous economic benefits, in various and numerous laser based industrial and scientific applications.

With this new technology, one million times faster measurements can be done, enabling savings in costs and time. Some of the benefits might be: Reduce cycle times, increase output, ultra-fast power measurements (for laser tuning, laser power output optimization, ideal fiber coupling, etc.), reduce failure rates, increase efficiency, characterize the „behavior“ of a laser, during activation / deactivation operation, discover details about single pulses to improve laser treatment strategies and many more. The following figures shall give an idea how CW and pulsed lasers can now be measured “time resolved”, from 50mW thru 6kW, in the spectral range of 400nm thru CO2 at a sensor response time of < 10µs - at full power!

Illustrations:



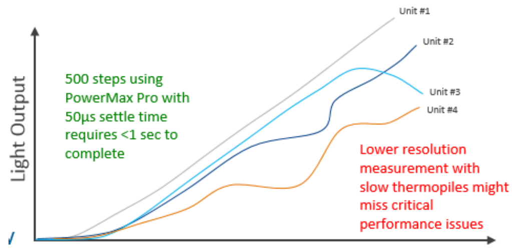


Fig. 4 CO2 laser for dental treatment – detect pulse variation

Fig. 5 Laser / Diode characterization

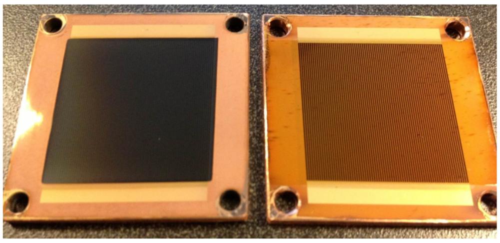


Fig. 6 Thin-film thermoelectric layer on CU base material.

2. Equations

Radial Thermopile Physics:

$$t_{rise} \propto (Diameter)^2 \qquad (1)$$

Transverse Thermoelectirc Physics:

$$t_{rise} \propto thickness^2 \qquad (2)$$

3. Copyright

PowerMax-Pro is a Coherent patented technology. Patent 9,012,848.