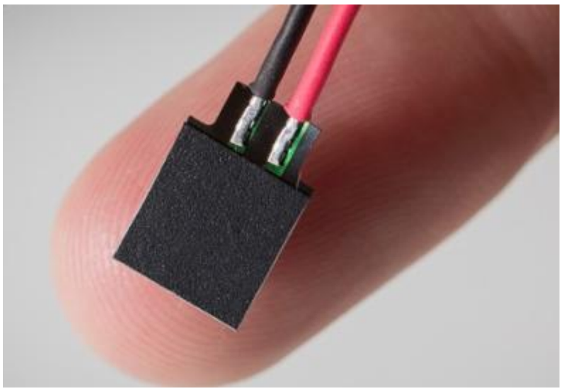
gSKIN® Application Note: Thermopile sensor for laser power monitoring

Integrate our thermopile sensor for fast and precise laser power measurement

greenTEG's thermopile technology enables the characterization of laser power parameters, ranging from few microwatts (µ*W*) to several watts (W). The thermopile is sensitive to the electromagnetic spectrum between ultraviolet radiation (UV) and infrared radiation (IR).

The gSKIN® Sensors feature:



Fast response time
"Fast measurements with response times in the sub-second range."

Small geometry & thin
"Compact integration into laser systems, sensor heads and handheld devices using minimal space."

Various designs and sizes
"Depending on the specific application, the design and size of the sensor can be chosen."

Broad range of laser types
"Wide applicability for continuous wave (CW) operation as well as for long pulse laser systems of all wavelengths (190 nm – 14 µm)."

Applications

In the field of photonics, the gSKIN® Sensors are used as design-in components in two main applications. Firstly, they provide valuable information used in OEM laser systems for Continuous Laser Power Measurements (CLPM). Secondly, the gSKIN® Sensors are integrated in external laser power meters for sporadic laser beam characterization.

Continuous Laser Power Measurement (CLPM)
For CLPM, the gSKIN® Sensors are used in different laser systems. Integrating the sensor in laser systems is especially interesting for average power measurements in:

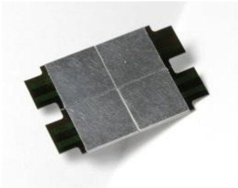
- **Cutting, welding, and soldering lasers:** CLPM information gives your systems the ability to control laser properties instantly, resulting in consistent production performance.
- **Medical lasers:** Accurate CLPM simplifies response to safety demands for medical technology equipment.
- **Laser projectors:** In the field of high-end laser projectors, CLPM ensures

continuous monitoring of safety relevant parameters.

- **Laser systems used in R&D:** CLPM allows for perfect correlation of measurement results and excitation characteristics. This is crucial to meaningful interpretation of R&D experiments.

External Laser Power Measurement
In all laser applications, laser parameters need to be maintained and monitored regularly. In these cases, the gSKIN® Sensors are integrated in:

- **External power meters:** The robust, small and fast thermal sensor elements allow the fabrication of highest performing laser power meters.
- **Hand-held devices:** The compact structure of the gSKIN® Sensors is ideal for integration in hand-held devices. These devices offer great flexibility with regards to positioning, as well as to the frequency of measurement.
- **Beam positioning and profiling modules:** With the gSKIN® Array Sensors, it is possible to obtain valuable information about beam position and beam uniformity. If space is not a limiting factor, multiple gSKIN® Sensors can be arranged in the area of the laser spot. In applications with limited space, the gSKIN® Array Sensor is more suitable. It integrates two or more sensors within one sensor module, and thus lets you add beam positioning and profiling features without additional effort and space requirement.



Measurement setup

Figure 1 shows the overview of a typical CLPM setup. The beam splitter is optional and not needed in many external applications (*e.g.* for low laser powers).

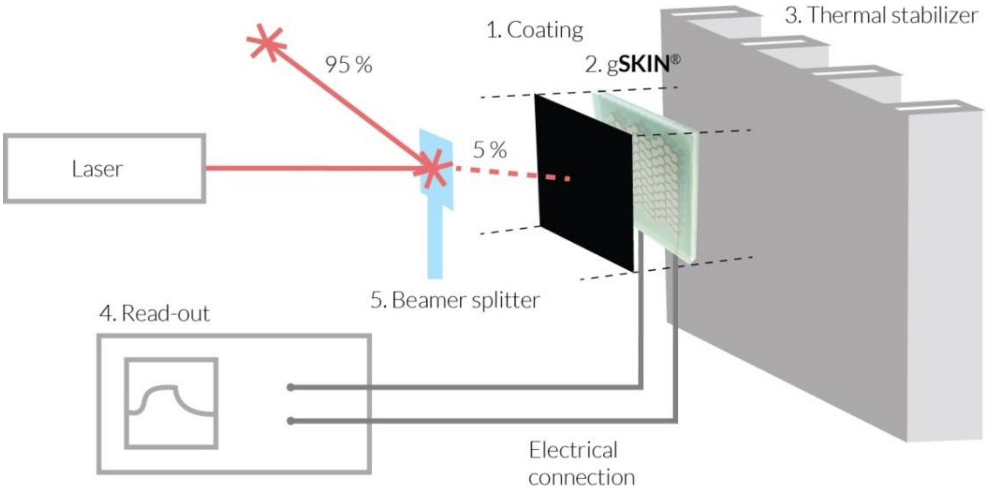


Figure 1: Overview of a typical CLPM setup. The measurement setup consists of a coating, sensor, thermal stabilizer, read-out device, and optionally a beam splitter.

greenTEG AG Technoparkstrasse 1 8005 Zürich, Switzerland T: +41 44 632 04 20 F: +41 44 632 14 62 info@greenTEG.com greenTEG.com

1. **Coating:**
When the laser strikes the thin coating layer of the sensor, its power is absorbed and converted into heat. For highest precision, it is suggested to defocus the laser beam during the measurement to a spot size of ≥ $1mm^2$. The coating should be chosen based on the desired characteristics of the measurement. An optimal coating has a wavelength independent absorption efficiency. Depending on the requirements we provide the sensor with an aluminum package (e.g. gSKIN® - XE 23 9C or gSKIN® - XE 23 9C) or a broad band absorptive coating (e.g. gSKIN® - XE 43 9R or gSKIN® - XE 43 8R).

2. **gSKIN® Sensor:**
gSKIN® Sensors transform incoming laser radiation into an analog voltage signal. In most applications, the voltage signal is in the range of a few mV. For optimal physical integration, choose the size and shape of the power sensor according to your existing system design. Customization options are described in Appendix 5.

3. **Thermal stabilizer:**
The sensor is mounted onto a thermal stabilizer (e.g. gSKIN® MOUNT-1371). The stabilizer keeps the backside temperature of the gSKIN® Sensor at a constant (lower) value and serves as a supporting base. The size and type of the stabilizer most suited to your setup, depends on the laser power which should be measured with the sensor. For minimal design adaptions, the housing of your laser system can be used as a simple stabilizer. Accordingly, a small aluminum block (50 cm^3) is sufficient for laser powers up to 1 W. More complex options include heat spreaders, fans and water cooling systems. We offer thermal simulations to support you in choosing the best solution for your application.

Thermal coupling
For optimal results, the coating, the gSKIN® Sensor, and the thermal stabilizer are assembled in a sandwich type compression manner. This leads to a robust measurement unit and good thermal coupling between each layer. A good thermal contact is crucial to achieving high response times and optimal accuracy. Using the materials listed in Table 1 you can establish a good thermal contact in such a construction.

Option	Description/Instruction
Thermal paste (e.g. gSKIN® MOUNT-1212)	Thermal pastes offer good thermal contact when applied appropriately. The paste should be spread homogeneously across the whole area to avoid air pockets within the layer. The thinner the layer the better the coupling. In order to provide mechanical stability, the sensor should be additionally fixed with single or double-sided adhesive tape.
Thermally conductive adhesive (e.g. gSKIN® MOUNT-1211)	Adhesives offer lower thermal coupling, but provide better mechanical stability. They are typically employed under elevated temperature and pressure. For the exact instructions, refer to the respective material data sheet.
Thermally conductive glue (e.g. gSKIN® MOUNT-1213)	Thermally conductive glue is suitable for applications where additional mechanical stability is required. Like the thermal paste, it generates a strong thermal coupling and adapts to surface inhomogeneities. Refer to the specific datasheet for curing instructions.

Table 1: Mounting options for good thermal coupling. For general usage, we recommend thermal paste.

4. **Read-out:**
The output signal of gSKIN® Sensors is an analog voltage response. If the analog input of your read-out electronics has a resolution of 1 µV, you can directly record the output signal.

greenTEG offers different electronic components to facilitate the read-out: In order to reach a signal in the mV range, a low-noise amplifier was developed. Further, the analog signal can be digitalized to provide a digital interface. Contact us for further information.

The incoming laser power Φ is proportional to the measured voltage U:

$$\Phi = U / Z_0 \qquad [W]$$

where Z_0 is the sensitivity of the gSKIN® Sensor in V/W and obtained from a calibration. For highest precision we recommend to calibrate the sensor when integrated into the system. Z_0 can be determined by greenTEG on request.

5. **Beam splitter (optional):**
For CLPM, a beam splitter is required. The beam splitter is placed along the beam path in front of the gSKIN® Sensor. In order to maintain the power of the main beam as high as possible, choose a minimal ratio of the incident and reflected power density. Consider that the power of the beam striking the sensor should be within the specified power range for the respective sensor.

Appendix 1: Sensor specifications

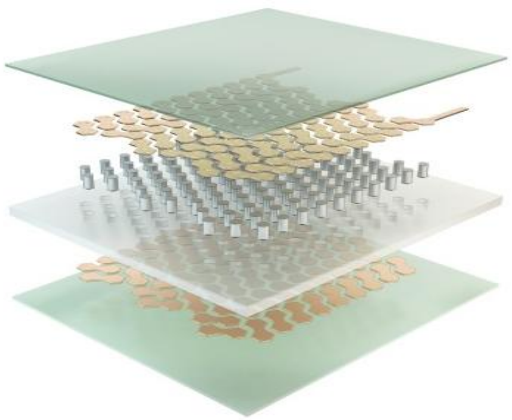


Figure 2: Explosion view of a standard gSKIN® sensor.

Figure 2 illustrates schematically, the structure of the gSKIN® Sensor.

The thermal sensor consists of axially aligned semiconductor thermocouples connected in series. These thermocouples are embedded in a polymer matrix (transparent in Figure 2).

The sensor is electrically insulated with a layer of epoxy (green in Figure 2). This layer also ensures that the sensor is waterproof.

Many properties of the sensor can be customized to your specific system and application requirements. Appendix 5 gives an overview of customization options.

Appendix 2: Material requirements

This list includes the necessary items to assemble the measurement setup described in this application note.

- gSKIN® Sensor
- Coating
  - Aluminum (e.g. gSKIN® - XE 23 9C or gSKIN® - XE 23 9C)
  - Black absorber (e.g. gSKIN® - XE 43 9R or gSKIN® - XE 43 8R)
- Thermal stabilizer
  - System housing
  - Block of aluminum
  - Heat spreader (e.g. gSKIN® MOUNT-1371)
  - Fan
  - Water cooling system
- Thermal coupling
  - Thermal paste (e.g. gSKIN® MOUNT-1212)
  - Thermally conductive adhesive (e.g. gSKIN® MOUNT-1211)
  - Thermally conductive glue (e.g. gSKIN® MOUNT-1213)
- Read-out electronics
  - Your read-out electronics
  - Additional greenTEG electronics
- Beam splitter (optional)

Appendix 3: Homogeneity

For correct measurement results, it is crucial that the sensor output voltage does not vary with changing the position of the laser. Figure 3 illustrates two time-dependent traces of the output voltage.

For the red solid line, the laser spot was moved from the center towards the upper edge of the sensor during the measurement. A distance of 3 mm was covered within this period.

In contrast, while recording the blue solid line, the laser spot was fixed in the center of the sensor.

Both traces show a standard deviation below 1% of the signal and no dependency on the beam position is detectable. This illustrates that the homogeneity of the sensor is high and no beam alignment is necessary to obtain reliable power values with the gSKIN® Sensors.

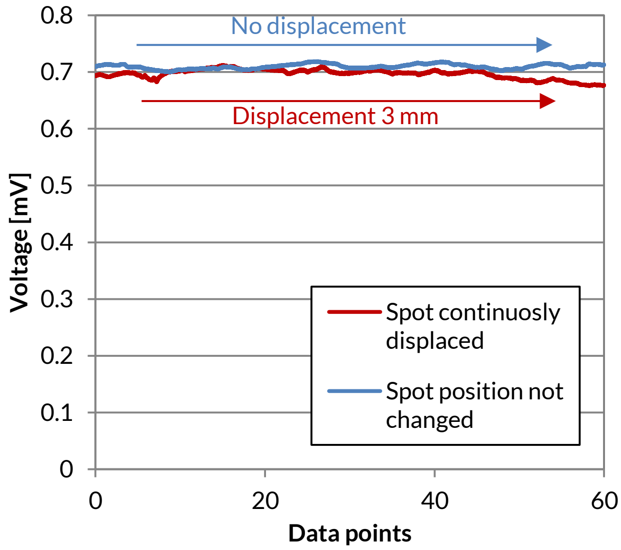


Figure 3: Spatial dependence of gSKIN® output voltage shows the high homogeneity of the sensor.

Appendix 4: Linearity

Figure 4 shows the power dependent output voltage of a standard gSKIN® Sensor. The linear fit to the data points (green squares) features ±1 % accuracy. The slope of the graph in Figure 5 shows a sensitivity Z_0 of 21.1 mV/W.

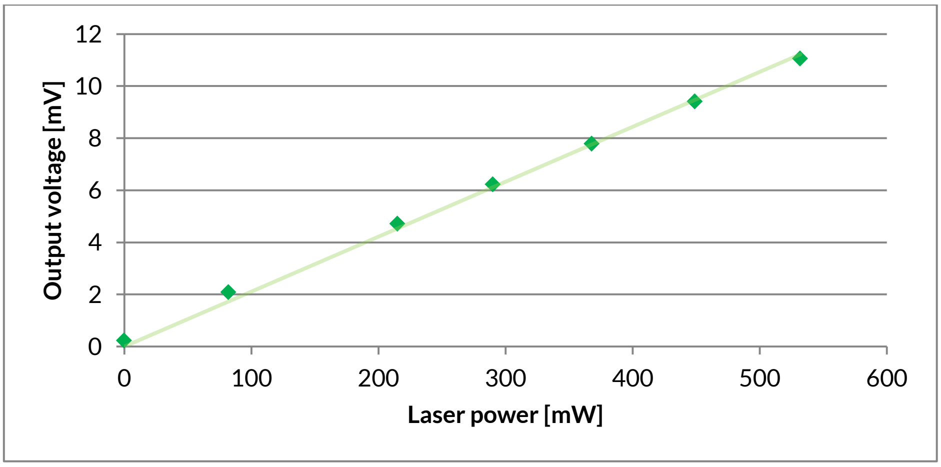


Figure 4: Output voltage of a standard gSKIN® sensor as a function of the incident laser power.

Appendix 5: Customization options

For optimal integration in your laser systems, the gSKIN® sensor should be customized. Figure 5 gives an overview of customization options.

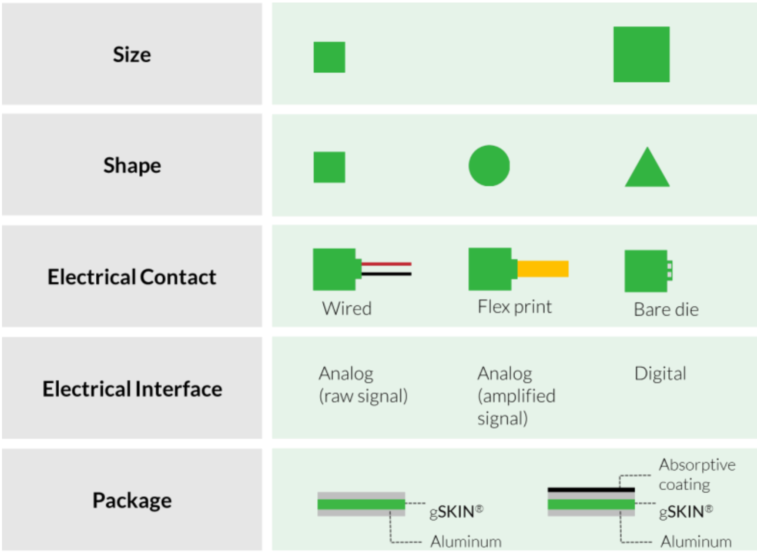


Figure 5: Customization options of size, shape, electrical contact, electrical interface and package.

Document information

Pictures by greenTEG AG and flickr

Revision History

Date	Revision	Changes
19. July 2013	1.16 (preliminary)	Initial revision
10. February 2014	2.00	