gSKIN® Application Note: Laser Power

Determine laser power with an easy-to-use, fast, and small thermal sensor

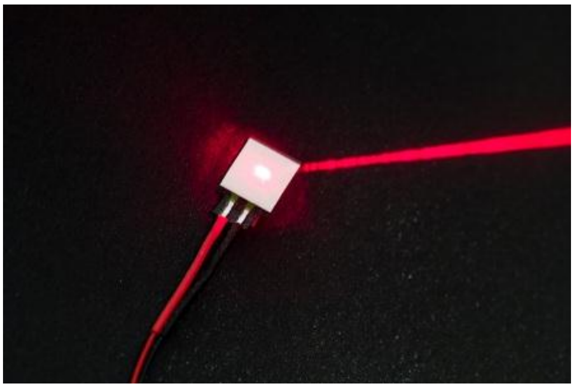
In your processes or experiments you want to be sure that you know the values of all relevant parameters exactly. When using lasers, it is crucial to monitor how much power is provided to a system in order to ensure trouble-free process operation. Even more importantly, the safety of staff and equipment is based on this knowledge.
The gSKIN® sensors allow you to determine the power of your laser by the following features:

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

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

High homogeneity
"Precise output values with a large tolerance for beam position."

Broad range of laser types
"The thermal sensor can be used in continuous wave (CW) and long pulse lasers of all wavelengths."



Applications

The gSKIN® sensors are used as design-in components in two main fields. First, laser OEMs use it for Continuous Laser Power Measurement (CLPM). Second, the gSKIN® sensors are integrated in external laser power measurement devices for sporadic laser beam characterization.

Continuous Laser Power Measurement (CLPM)
For Continuous Laser Power Measurement (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 laser:** CLPM information gives your systems the ability to control laser properties instantly resulting in uniform production performance.
- **Medical laser:** Accurate CLPM simplifies fulfilling the safety demands for medical technology equipment.
- **Laser projector:** In the field of high-end laser projectors, CLPM ensures continuous monitoring of safety relevant parameters.
- **Laser systems used in R&D:** CLPM allows perfect correlation of measurement result and excitation characteristics. This is crucial for a meaningful interpretation of R&D experiments.

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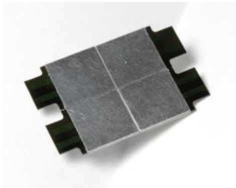
External Laser Power Measurement
In all laser applications, laser parameters need to be checked regularly. In these cases, the gSKIN® sensors are integrated in:

- **External power meters:** The robust, small, and fast thermal sensor elements allow manufacturing the 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 measurement location and time.
- **Beam positioning and profiling modules:** With the split gSKIN® sensors, it is possible to obtain valuable information about beam position and beam uniformity. To that end, two options exist: If space is not a limiting factor, arranging multiple gSKIN® sensors in the area of the laser spot, is the low effort option. In applications with limited space, the split gSKIN® 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

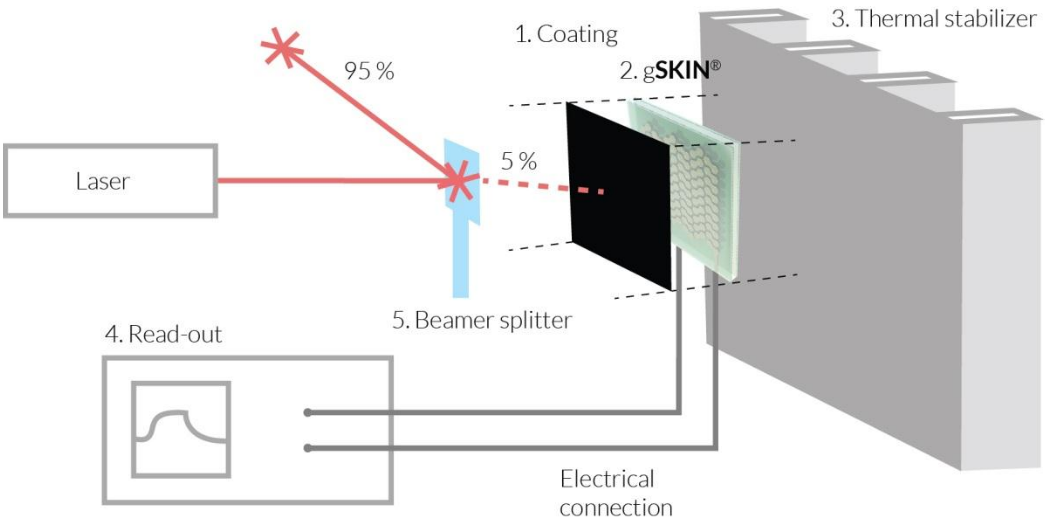


Figure 1: Overview of a typical CLPM setup. The beam splitter is optional and not needed in many external applications (e.g. for low laser powers)

1. **Coating:**
   When the laser impinges on the coating, it is absorbed and converted into heat in the thin coating layer on the sensor surface. For highest precision, it is suggested to defocus the laser beam during the measurement to a spot size of ≥ $1 mm^2$. The coating should be chosen based on the desired characteristics of the measurement. An optimal coating has a wavelength independent material emissivity. Table 1 shows the three different options available.

	Response time	Power resolution	Laser power, impinging
No coating	+++	+	up to 3.5 W
Aluminum	++	+	up to 17 W
Black absorber	++	+++	up to 10 W

Table 1: Different coating options. Please contact us directly to receive detailed information about the most suitable solution in your application.

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 typically mounted onto a thermal stabilizer. The stabilizer keeps the backside temperature of the gSKIN® sensor at a constant value and serves as the support base. The size and type of the stabilizer most suited in your setup, depends on the laser power which impinges on 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 elaborate options include heat spreaders, fans, and water cooling. 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 as a sandwich. This leads to a robust measurement unit and good thermal coupling between each layer. A good thermal contact is crucial to achieve high response times and accuracy. With the materials listed in Table 2 you can establish a good thermal contact in such a sandwich construction.

Option	Description/Instruction
Thermal paste	Thermal pastes offer good thermal contact when applied appropriately. The paste should be spread homogeneously across the whole area to avoid air pockets in the layer. The thinner the layer the better the coupling. In order to provide mechanical stability, the sensor should be mounted with scotch tape or double-sided adhesive on one edge.
Thermally conductive adhesive	Adhesives offer lower thermal coupling, but yield a better mechanical stability. They are typically employed under elevated temperature and pressure. For the exact instructions, refer to the respective material data sheet.

Table 2: Mounting options for good thermal coupling. For general usage, we recommend thermal paste.

4. **Read-out electronics:**
The output signal of gSKIN® sensors is an analog voltage signal. Silver-plated copper wires are used as electrical connection cables.
For read-out of the analog voltage signals, you can use your electronics, greenTEG electronics, or a multimeter. The resolution of the read-out electronics has a big influence on the laser power measurement resolution. To resolve the complete power spectrum, the read-out solution should have a voltage resolution of 1 µV. Table 3 compares the three read-out options.

Option	Description
Your read-out electronics	For integration in final products (i.e. for CLPM or external power heads), the combination with specifically adapted electronics is inevitable. The adaption to your system strongly depends on your overall design.
greenTEG electronics	We provide specifically developed electronics to measure laser power in the mW range. Contact us for more information.
Multimeter	Optimal for infrequent usage, especially for testing. Depending on your needs, a multimeter with data transmission via USB or Bluetooth is needed.

Table 3: Options for electronic read-out of power measurement.

The measured voltage V_{out} is proportional to the incoming laser power P_L:

$$P_L = V_{out} / S_L \qquad [W]$$

where S_L is the sensitivity of the sensor in V/W. The calibration constant S_L is provided together with the sensor.

5. **Beam splitter (optional):**
If you use gSKIN® sensors for CLPM, a beam splitter is required. The beam splitter with the desired ratio is placed along the beam path in front of the gSKIN® sensor. To maintain the power of the main beam as high as possible, chose a minimal ratio. Consider that the beam impinging the sensor should be sufficiently high to yield a meaningful measurement resolution.

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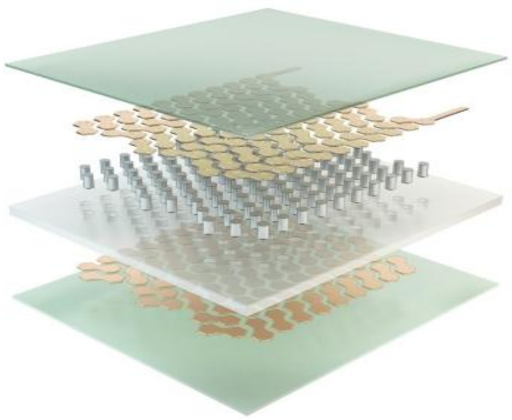
Appendix 1: Sensor specifications



In Figure 2 illustrates the structure of the gSKIN® sensor schematically.

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 it is waterproof.

The sensor can be customized to system and application specific requirements. Appendix 5 gives an overview of customization options.

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

	Standard gSKIN®	**gSKIN® sensors portfolio**
Detector type	Thermal absorber	Thermal beam positioning & profiling
Dimensions[1] [mm x mm]	8.5 mm x 8.5 mm	3 mm x 3 mm to 40 mm x 40 mm (shape customizable)
Power Range Min / Max [W]	100 µW / 17 W	
Max. Average Power Density [W/cm^2]	200 W/cm^2	
Noise Equivalent Power [µW]	2 µW	
Response Time (0-95%) [s]	0.8 s	0.1 s
Sensitivity S_L [2] [mV/W]	~ 30 mV/W	
Spectral Range [µm]	0.19 – 25 µm	Different absorptive coatings
Operating Temperature Range Min / Max [°C]	-50 °C / 150 °C	
Cooling method	Conduction, convection (see 3. Thermal stabilizer)	
Calibration Accuracy [%]	+/- 5 %	+/- 1 %
Homogeneity [%]	+/- 1 %	
Linearity with Power [%]	+/- 1 %	

Table 4: gSKIN® thermal sensors specifications.

[1] The sensor dimensions correspond to the absorber and active area.
[2] The sensitivity S_L is determined in thermal calibration (see corresponding datasheet for detailed information). For most accurate results, we recommend an optical calibration once integrated in your system.

Appendix 2: Material list

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

- gSKIN® sensor
- Coating
  - No coating
  - Aluminum
  - Black absorber
- Thermal stabilizer
  - System housing
  - Block of aluminum
  - Heat spreader
  - Fan
  - Water cooling system
- Thermal coupling
  - Thermal paste
  - Thermally conductive adhesive
- Read-out electronics
  - Your read-out electronics
  - greenTEG electronics
  - Multimeter
- Beam splitter (optional)

Appendix 3: Homogeneity

For correct measurement results, it is crucial that the sensor output voltage does not vary upon changes of the laser spot position. 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.

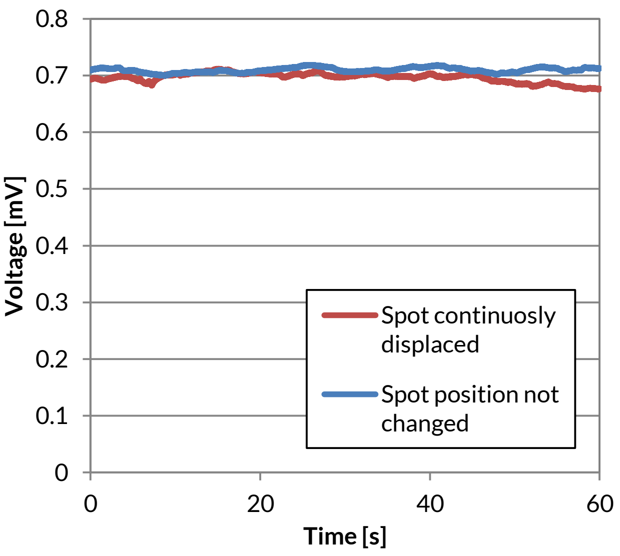


Figure 3: Time and spatial dependence of gSKIN® output voltage shows the high homogeneity of the sensor.

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 S_L of 35.1 mV/W.

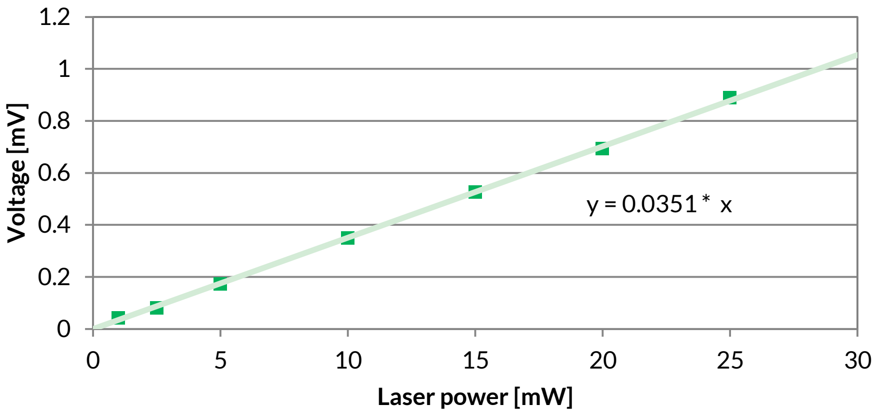


Figure 4: Output voltage of a standard gSKIN® sensor as a function of the incident laser power.

Appendix 5: Customization options

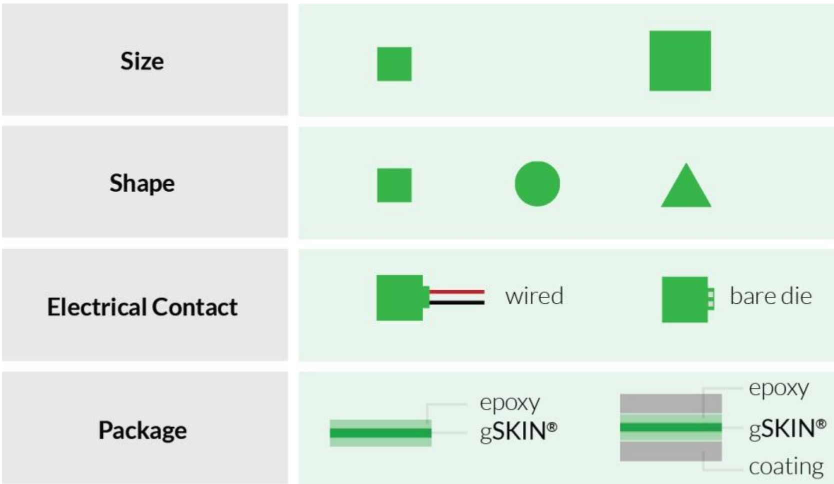


Figure 5: Customization options of size, shape, electrical contact and package.

Document information

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