Damage Threshold of kW Thermopile Power Sensors

A Coherent Applications Note

Introduction

A thermopile detector, commonly used for commercial laser power sensors, absorbs incident laser power and heats up, resulting in a temperature rise. This generates an electrical signal through the thermocouple arrays arranged around the detector.

There are several failure modes that can cause thermal fracture of the detector's absorptive coating and melting of the substrate material. In many cases this will result in changes of the sensor's sensitivity. This can occur because the power density is too high, the water flow rate is too low, the total input power is above the maximum power rating, or a combination of these.

Definition of Damage Threshold

The damage threshold for a power sensor is defined as the maximum applied laser power density below which no permanent change to the performance of the sensor is observed. Usually damage threshold is specified as an irradiation power per unit area for CW lasers: kilowatts per square centimeter or kW/cm^2. An incident power density higher than the damage threshold will overheat the sensor, thereby permanently damaging the laser absorbing surface and changing the sensitivity of the sensor. Therefore, it is crucial to choose a power sensor whose damage threshold is above the maximum power density created by the laser beam.

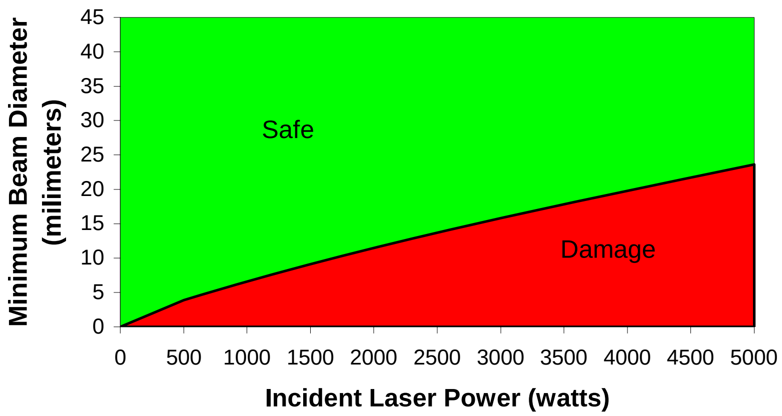
Damage Mechanism

When struck by a laser beam with a power density below, but close to, the damage threshold, the sensor may appear bleached or slightly discolored on the exposed surface. This generally is not an indication of damage, and a sensor in this condition can function accurately for a long time.

As the power density is increased, the irradiated surface begins emitting visible light -- first weak red and then bright white light. The visible light emission is usually initiated on some weak spots where thermal conduction is relatively low, optical absorption is relatively high, and micro-cracks are present. Normally the white light emission indicates that permanent damage is occurring, which in many cases will lead to a thermal runaway, a phenomenon of spreading the damage quickly to the entire beam area.

Non-Gaussian Beams

The PM-model and LM-model kW sensors are able to measure smaller beams if the laser is not Gaussian because the peak power densities are not intense. The following chart outlines the safe beam sizes for typical CO2 and Nd:YAG kW lasers.



Beam Diameter and Flow Rate for non-Gaussian Beams

Power	1/e^2 Beam Diameter	Flow Rate*
1 kW	> 7 mm	4 LPM (1 GPM)
2 kW	>12 mm	7.5 LPM (2 GPM)
3 kW	>15 mm	7.5 LPM (2 GPM)
4 kW	>15 mm	15 LPM (4 GPM)
5 kW	>18 mm	15 LPM (4 GPM)
>5 kW	Contact factory for assistance	

*Abbreviations: LMP = liters per minute, GPM = gallons per minute

Laser Beams with near-Gaussian Profiles

The sensor is most susceptible to damage from laser beams that approach a Gaussian profile. Coherent has performed finite element analysis (FEA) thermal modeling on the PM-model kW sensors, followed by live testing of a fiber laser that is nearly Gaussian, to confirm the safe operating conditions listed below with these types of lasers. It is extremely important to monitor the beam diameter and water flow rates list below when measuring lasers of this type.

The PM5K is recommended for measurement of any Gaussian beams greater than 3 kW. It PM5K has been shown to withstand Gaussian beams under these conditions:

Beam Diameter and Flow Rate for Gaussian Beams

Power	1/e^2 Beam Diameter	Flow Rate*
1-2 kW	>15 mm	15 LPM (4 GPM)
3 kW	>15 mm	15 LPM (4 GPM)
4 kW	>20 mm	15 LPM (4 GPM)
5 kW	>26 mm	15 LPM (4 GPM)
>5.5 kW	Will damage with Gaussian beam	

*Abbreviations: LMP = liters per minute, GPM = gallons per minute

If your laser is on the borderline of the damage threshold limits mentioned above, the follow-up tips can help prevent damaging the sensor.

Ramp kW Power in Steps

During operation it is recommended the power be slowly ramped up in 1 kW increments, instead of instantly exposing the absorber to 5 kW. The absorber can be damaged if it is instantly exposed to a beam near its damage threshold limit. Hold each 1 kW increment for approximately 5 seconds to allow time for the temperature to stabilize.

Watch for Signs of Damage

As the power is ramped up it is possible to watch for signs of damage. If there is any non-uniform orange glowing points (the peaks of high spots on the coating), the damage point is nearly reached.

Once the glow becomes a uniform round glow the damage point has been reached. The glow will become a more intense red as damage occurs. **The laser must always be turned off immediately if any uniform round glowing is observed.** If a very bright white light is observed the coating has been ablated from the surface and the metallic disk itself is melting.