# High Power Laser Measurement: Cooling Methods

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*This article explains why choosing the right heat control method is one of the most important considerations when choosing a suitable laser power measurement sensor for your needs. It will review the different cooling technologies used in high-power laser measurement sensors. It will also examine the changing requirements of the cooling system as the power levels of the laser increase, and consider how these are met by fan and water cooling methods. In addition, this article will compare the different cooling requirements of a pulsed laser measurement sensor and a continuous wave (CW) laser measurement sensor, and discuss the technologies that make it possible to use a non-forced cooled sensor - a sensor without a fan or water cooling – to measure high-power lasers.*

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Measurement of high-power lasers requires efficient heat control in power meter sensors. Choosing the right heat transfer method is a critical step in configuring a reliable, accurate high-power laser meter.

## *Convection and conduction*

**Convection** is a process in which heat transfers from once place to another via fluid, i.e. Water or Air.
There are two different types of convection– Natural and Forced convection.
**Natural convection** is when heat is transferred without any additional force moving the fluid, so the fluid moves naturally by gravity only. Examples include the movement of steam coming out from a hot cup of tea, and the movement of cold and hot water in a cup – being less dense, the hot water moves towards the top while the cold water moves towards the bottom. The hot water, now at the top, transfers its heat to the air and cools down, while the cold water at the bottom heats up, and the resulting current continuously moves the heat out of the cup.
**Forced convection** is when a force is added to increase the movement of the fluid, such as adding a fan or a water pump.

With **Conduction**, heat is transferred within a solid material, where the rate of heat transfer is pretty much constant (depending on the thermal conductivity of the specific material and the geometric design of the solid). With convection, on the other hand, there is much more opportunity to optimize the heat evacuation rate.
For example, this can be done by controlling the speed of the fluid (using forced convection), changing the dimension of the area that is in contact with the fluid, controlling the fluid's temperature and more.
This is the reason that forced convection is the most commonly used heat transfer method for removing heat from our high-power sensors.

## *Water Vs fan cooling*

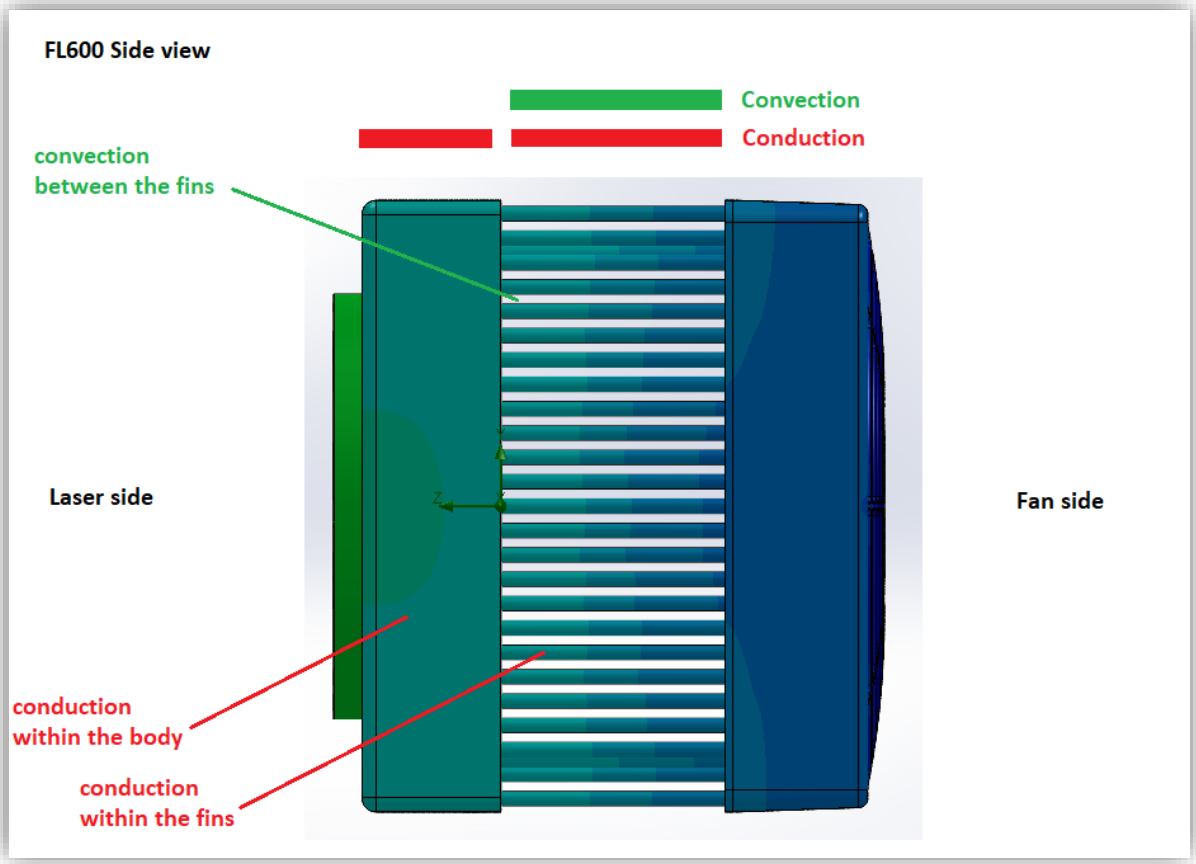
Using a fan, the natural convection process - that transfers heat from the fins to the air - is significantly upgraded to a forced convection process, which increases the airflow on the fins placed on the back of the senor. The increased airflow removes more heat from the fins. This method can be further enhanced by using a fan with higher Cubic Feet per Minute (CFM) airflow rates. Eventually a bottleneck is reached, the limiting factor being the heat conduction (within the sensor fins) that forms a part of the whole heat transfer chain process. (picture: 1.a.)

Another constraint when using a fan is the acoustic noise, where higher CFM rates will generate higher levels of noise along with higher airflow rates within the user's workstation environment.

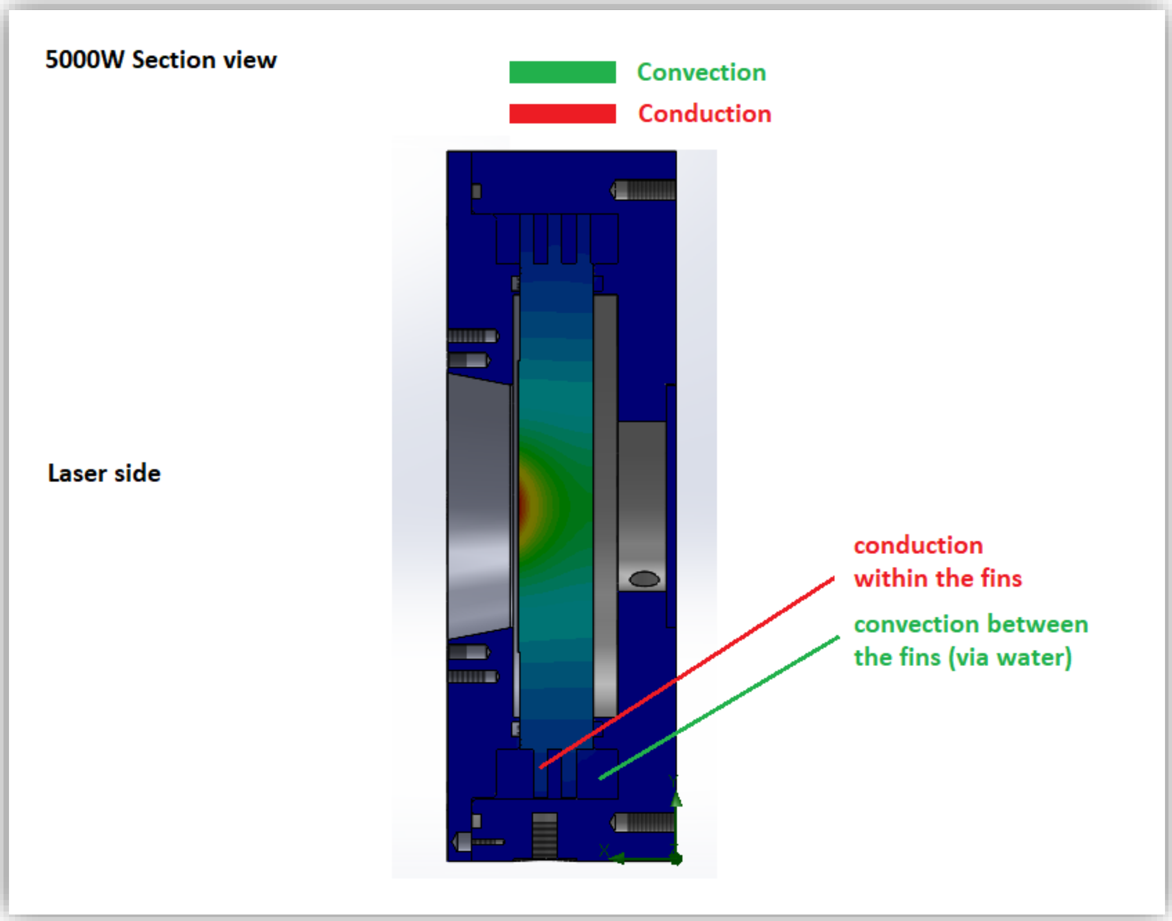
The above mixed heat transfer chain process, starting with conduction inside the fins (causing the bottleneck mentioned above) and ending with forced convection removing heat from the fins to the air, illustrates the difference in heat evacuation rates using forced convection compared to conduction.

At higher laser power levels, water-cooled forced convection is the method of choice for an efficient heat evacuation process. Similar to the case of the fan, increasing the heat evacuation rate is done by increasing the water flow rate, i.e. moving more water through the sensor to evacuate more heat. However, a water cooling system has an additional degree of freedom that fan cooling systems lack: the water input temperature can be controlled and set to a specific temperature using a chiller.
Using this cooling method, the forced convection process is less constrained because there is less conduction within the sensor and, of course, no acoustic noise. (pictures: 1.a & 1.b)

It is important to be aware that water-cooling systems have constraints of their own. In order for the sensor to operate properly, a number of parameters must be kept within the correct range, such as water flow rate and water temperature. More important perhaps are the **stability** of the water flow rate and temperature. The type of water is no less significant; the interplay between the ions present in the water and the water's pH level can affect the risk of corrosion in the sensor's water channels. A detailed discussion of how to get the best performance from water-cooled sensors can be found in the article "How to Use Water Cooled Ophir Sensors" on the Ophir website.




Picture 1.a.




Picture 1.b.

## *Cooling process in short exposure vs. continuous exposure laser measurement sensors*

As discussed above, using higher powers will increase the need for forced convection within the cooling process.
Some consideration, however, shows that this is mostly relevant when using CW lasers, while the power is constantly flowing in the sensor without any significant breaks in the power rate.
Controlling a high-power laser's exposure time, i.e. the time that the power meter is exposed to the laser, makes it possible to measure a high-power laser using a non-forced cooled sensor.

The concept is based on controlling the total amount of heat entering the sensor. If the amount of heat absorbed by the sensor is such that the sensor is able to dissipate it using natural convection only, then the measurement can be done without any need for forced convection methods i.e. without fan or water cooling.
High power laser energy enters the sensor and the exposure interval allows enough time for the heat to evacuate from the sensor with conduction and natural convection only.

## *So how to choose?*

To answer this, it is necessary to look at the whole picture surrounding the laser workstation.
Aspects that need to be taken into consideration include:

1. Q: What is the power range used while measuring the laser?
   *A: The boundary between fan and water-cooled sensors is around 1kw, CW. Above this power, water cooling is necessary.*
2. Q: Is the measurement done by a short exposure to the laser?
   *A: If the measurement is done with a short exposure, it is possible to extend the power range of a non-water cooled sensor due to the lower heat generated from a short exposure compared to the heat generated from a continuous exposure to the laser. For example, the Ophir Pulsed Power Sensors and Helios (a high power industrial laser power meter designed for integration into automated factory environments) can measure 12kw without any forced convection cooling*, by *limiting the exposure to the laser to less than 1s. The power is measured by (automatically) dividing the measured energy by the time duration of the laser exposure.*
3. Q: What is the ambient temperature in the environment of the workstation?
   *A: If it is too hot, the fan will not be efficient, and water cooling would be the preferred option.*

Once the sensor's heat control technologies are clearly defined, and any constraints imposed by the laser's and workstation's environments have been taken into account, choosing the sensor is much easier.

To help you choose the most suitable sensor for your laser, the following list summarizes the basic "pros and cons" for each cooling method and compares them to those of the pulsed measurement sensors.

- **Fan cooled sensors**:

  PROS:
  - Convenient - No water tubes around the laser workstation which can restrict the orientation of the Power Meter (this is helpful if the meter is moved often)
  - Can be used in water free environment
  - Less maintenance (e.g. no concerns about water type or flow conditions)

  CONS:
  - Lower power levels compared to water-cooled sensors
  - Noise (the fan can reach 59dba for the "FL1100" 1.1KW sensor at maximum power)
  - Cooling ability is dependent on ambient temperature
  - Needs space for airflow

- **Water cooled sensors**:

  PROS:
  - Can reach higher powers than fan-cooling
  - Quiet
  - Cooling ability is not dependent on ambient temperature

  CONS:
  - Needs space for a chiller or other water source
  - Plastic water pipes – restrains orientation of power meter in the workstation
  - Maintenance – Constraints regarding chiller, water type and flow conditions

- **Pulse to power sensors: non-forced cooled sensors:**

  PROS:
  - High powers for short exposures
  - Convenient - No water tubes around the laser workstation
  - Less maintenance (e.g. no concerns about water type or flow conditions)
  - No noise

  CONS:
  - Short exposures only - Not suitable for CW

Conclusion

Since most of the laser beam's power entering the power meter is converted to heat, heat control is indeed one of the most important aspects that need to be considered when choosing your laser power meter sensor. Understanding the different cooling processes and their strengths and limitations will help you to choose the most suitable power meter for your application.