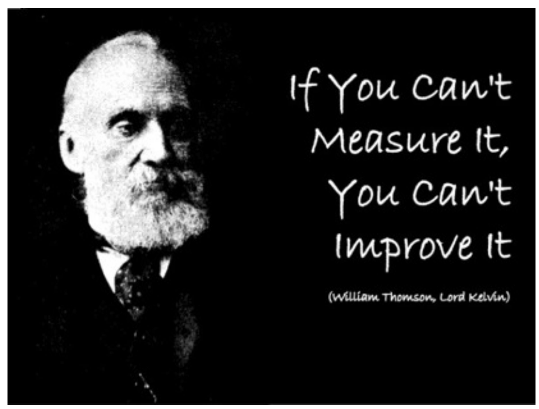
5 Situations Where Laser Performance Measurement is Necessary

Measuring the performance of a laser has possible for a number of years and is accomplished with a variety of techniques. These electronic laser measurement solutions give the laser user more relevant, time-based data that shows trends in laser performance rather than single data points. While these solutions have provided laser users with the ability to present data in a simple and easy to understand manner, the application of the data still seems to be unclear to many laser users.

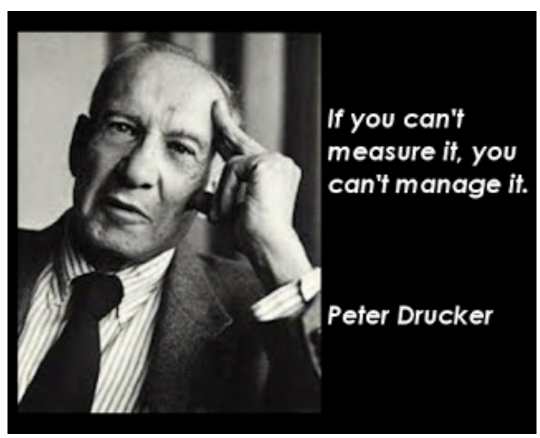
- How often should data be collected?
- What measurements should be tracked?
- When this data is collected, what should be done with it?



These are all good questions that are frequently asked, regardless of how the specific laser system is being used.

Why Measurement Is Important

The importance of measurement is reflected in a number of well-known quotes related to understanding and improving a process. In the 19th century, British physicist and engineer William Thomson, 1st Baron Kelvin, said when speaking of physical science,"…When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind." He is also accredited with the quote "If you can't measure it, you can't improve it." Similarly, Austrian-born educator, author, and management consultant



Peter Drucker has said of corporate management, “If you can’t measure it, you can’t manage it.” When applying these principles to improving processes and systems where a laser is involved, there are several parameters that can be measured. Here we will focus on how and when the laser user applies this data.

MIT Mechanical Engineering Professor Seth Lloyd is credited with the quote, “Nothing in life is certain except death, taxes, and the second law of thermodynamics.” While most everyone is concerned with death and taxes, some of us are concerned with the second law of thermodynamics, “Matter will always seek a way to revert from order to disorder because of the transfer of energy, and, as a result, a system's ability to do work decreases over time.”

Even with today’s noteworthy advances in laser source and laser system technologies, because laser systems are made up of physical matter, components of laser systems will always seek a way to revert to their natural states…degradation of those components. And because these components change over time, the changes must be measured so the process can be controlled and efficiently managed.

Measurement Over the Life of a Laser
Early in the life of a laser, laser manufacturers use measurement solutions during development to understand how changes in the design of the laser affect performance. Once the system design is optimized, the customer usually wants to see data or specifications about how the product is designed to perform; this data includes performance measurements. This data is (or should be) also referred to several times over the life of the laser.

When a laser is ready to be used for its designed purpose, the way that the laser light is applied to the material being processed is usually measured as a function of **Power Density** (known as Energy Density when discussing pulsed lasers, but the concept is the same.) Power Density is expressed as watts per centimeter squared – W/cm^2 (joules per centimeter squared for Energy Density – J/cm^2), where Watts is a unit of the laser power being applied and centimeter squared is the unit of area that relates to the size of the beam being applied. Depending on the application of the laser, the laser power can be very high (even measured in kilowatts) and the beam can be focused down to a very small size (usually measured in thousands of a millimeter, or microns – μm). In the case of very high laser power and very small beam sizes, the Power Density can be expressed in gigawatts per centimeter squared (GW/cm^2).

Laser power and **beam size** can change over time due to reasons mostly related to the second law of thermodynamics. When either laser power changes or the beam size changes, the way that the laser light interacts with the material being processed (Power Density) changes. And when the Power Density changes, the laser system is no longer processing the material as it was designed.

Once the laser system is ready to be applied, there are five times in the lifecycle of a laser system where the collection and application of laser performance measurement data are critical to the expected outcome of the process.

1. Application Development

Engineering the laser application can sometimes be a long, involved process. There are often several laser parameters that can be changed to affect the way that the laser light interacts with material. However, looking at it as simply as possible, the application of the laser comes down to how much laser light is being applied and how large the beam size is at the point of processing. When discussing pulsed laser applications, it is also important to understand, through measurement, what the shape of each pulse is and the duration of each pulse as these parameters will also affect the outcome of the process.

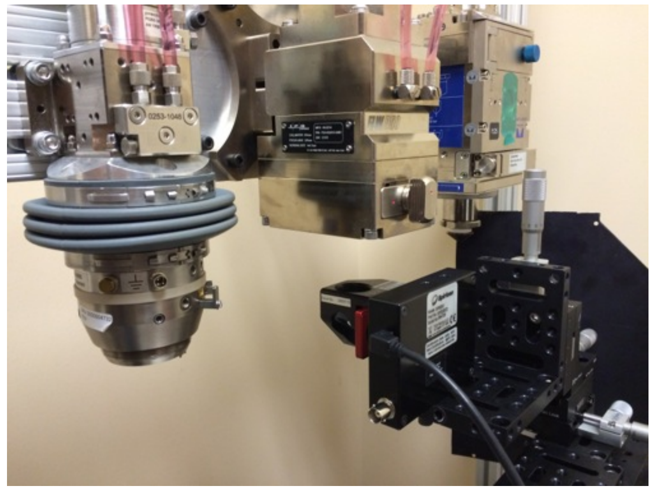


Fig 1. Taking beam profiles on an applications lab laser

The measurement of laser performance at this stage of the laser's life cycle is important. In the event that the end user's laser loses efficiency over time, is improperly maintained, or suffers a catastrophic failure, the return to this benchline set of measurements can be achieved through measurement of the production laser and the adjustment of laser parameters during its maintenance period to return it to its healthy state.

2. Laser Source Integration

Development of the laser application is typically performed with an efficient, optimized laser system in a lab setting. Once the application is developed, the parameters are transferred to another identical or similar laser that will be integrated into the end user's system. Even though these two lasers may be of the same make and model, they are two different lasers, comprised of two different sets of components. The only way these variables can be managed is through a comparison of the measurements between the two systems to ensure that the output power, the size of the beam, and the shape of the beam are the same.

Before transferring this application to the laser in the field, it is important to characterize its performance during application development to ensure that it will closely match the processing laser once it's integrated into the field. Measuring the **output power** (or energy) at the work site, along with the **size and shape** of the laser's **focused spot**, will result in a **Power (or Energy) Density** value. And again, if a pulsed laser application is being developed, characterizing the pulse shape, duration, and frequency is also important since these laser characteristics directly correlate with how the laser interacts with the material.

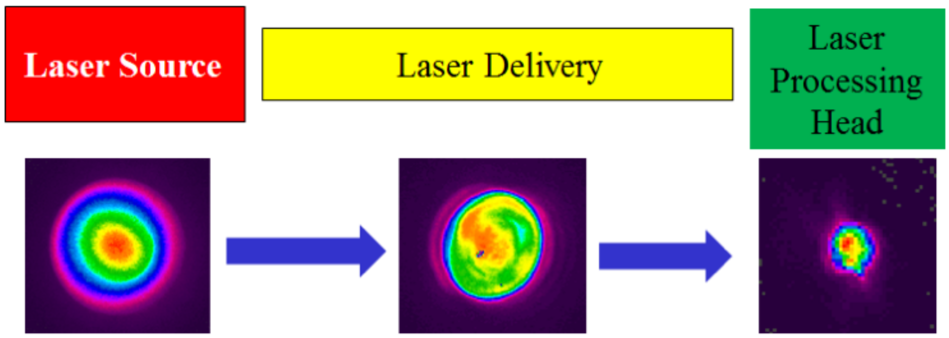


Fig 2. Different beam profiles taken at different places on the laser system beam path; illustrates how the laser can change as it travels through the system

3. System Runoff, Delivery, & Movement

Transfer of the laser from the OEM or integrator to the end user is often a daunting series of tasks. The general purpose of this step is to prove to the customer that the laser system is operating as designed. Since these laser systems are usually considered a significant investment, there are usually several criteria that need to be met before the system is accepted. Measuring the laser and comparing these measurements to the measurements taken during the application development phase will validate the system and prove to the customer that the laser source and the system in which it is integrated into will perform as designed.

An additional step that is often part of this process is the acceptance of the system after it has been installed at the customer's facility. Once the system has been proven to perform as designed, the system must be either partially or fully disassembled to be delivered to its home, and then prepared for employment. Doing so can change the integrity of the laser system. So once again, measurements must be performed to validate that the system is performing as designed.

Finally, any time that the laser system is moved from one place to another by the end user, there is usually disassembly and reassembly required. This too can affect system integrity, as it did during system delivery. It is highly recommended that measurements be taken on the laser system both before and after the movement of the system, to verify that its performance is consistent after its move.

4. Periodic Measurements During Deployment

Once the laser application has been developed, built and delivered, and employed in production, even if laser measurements have been taken all along the way, the system is not in the clear. At this longest stage of the laser's life is where the second law of thermodynamics has the most effect. At some point in this laser system's life, one or more of its components are going to degrade. It may be quick, or it may take months or even years, but something will go wrong with the system because physical decomposition is inevitable.

There are many causes of failure in laser system components. Most of the time, the cause can be traced back to the harsh environments in which many of these systems operate. Industrial lasers which process material, for example cutting, drilling, and welding, produce a significant amount of debris during the process. This process debris, if not maintained properly, can cause severe damage to the laser components closest to the process, such as the protective cover glass, beam path bellows, and even optics or mirrors, in severe cases. Another source of problems with component degradation is the laser itself. Some wavelengths of light are very hard on system components; the results in the need to constantly monitor system efficiency.

No matter how the laser is used, measuring its performance is crucial at this, the longest stage of the laser's life. Regardless of the laser source, system, or its application, the **Power/Energy Density** always defines how the laser interacts with the process. The degradation of laser systems components will ultimately result in a reduction in system efficiency. **Laser power** will likely decrease over time because laser optics and mirrors gradually absorb more laser light. And because of the thermal effects that this absorption results in, the laser's optics will slightly change **shape** and the **focused spot** will experience changes in size or location with respect to the process (known as "focus shift"). Reduction in laser power in conjunction with inconsistencies in laser spot size reduces Power Density. This efficiency loss will eventually cause the system to fail to process altogether. Periodic measurement of the laser system is the best way to manage these changes and to better predict when corrective maintenance needs to be performed on the system.

5. Preventative & Corrective Maintenance

Keeping the laser system operating at the designed performance level can only be achieved through a comprehensive maintenance routine, with a goal of protecting the laser, one of the company's most valuable investments. Laser OEMs and systems integrators have information on how to properly maintain the systems they supply. And measurement of the laser system should be part of the routine.

The establishment of the laser application, as well as the delivery and employment of the system, should included a set of measurements of the system. It is a recommended practice that during preventative maintenance routines, measurements be taken both before and after the maintenance. Those measurements should be compared to verify an increase or at least a maintenance of system efficiency, and with the initial measurements taken to validate that the system is once again operating at an efficient state.

Even well maintained systems can experience catastrophic failure of one or more of the systems components. The sources of failure include faulty components, components installed incorrectly, improper operation of the laser system, and more. The overall failure of this complex system may or may not be a problem with the laser. If the cause of the failure is unknown, this is where the measurement of the laser (if the laser can be operated) is vital to the troubleshooting process. However, if the cause of the failure is known to be a problem with the laser source, the measurement of the laser can usually very quickly reveal the problem with the laser. If electronic measurement tools are being used (such as an electronic power meter or a camera or scanning-slit based beam profiling system), viewing the laser performance real-time often helps the laser technician pinpoint the source of the problem. For example, cracks in an output coupler will result in a rapid decrease in laser power as well as a rapid increase in laser beam size.

The values and benefits of measuring laser system performance aren't always recognized or appreciated at first glance. This is especially true in a production environment where time is money and the laser system is only valuable when it is producing parts. It is important to understand the way that laser light interacts with material, to realize that the quality of this process depends on maintaining consistency in this interaction, and that consistency can only be maintained by measuring its performance. By applying laser performance measurement practices at every stage of a laser system's life cycle, consistent and efficient processing can be achieved and this valuable tool can be better protected.

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