Manufacturing Trends Drive Advancements in Laser Beam Measurement Technology

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Products to measure the performance of lasers were first employed by sophisticated laser users who had a strong understanding of the behavior of light and what to expect from the measurements that were produced. These users were typically PhD level researchers and scientists who devoted their careers to understanding a laser's characteristics and applications. As a result, early laser measurement products were mostly suitable for laboratory environments and not necessarily designed to withstand harsh industrial environments. As laser applications have evolved, so has the typical laser user.

Today, lasers are used in a wide variety of environments in an ever-increasing number of applications. From mapping objects in front of a vehicle at thousands of times per second to pointing multiple kilowatts of light at a flying object for the purposes of disabling it, lasers are becoming more commonplace. As a result, developers of these laser-based products now realize the importance of measuring the laser's performance. Let's take a look at the latest trends.

Industrial Laser Measurement

One example is the development of laser measurement products for industrial laser users. At their core, laser measurement products utilize complex electro-mechanical technologies. But this type of equipment does not fare well when subjected to dust and debris coming from industrial lasers processes if they're not designed to. When encased in a protective housing with IP-rated physical connections and an actuated shutter to allow laser light to pass into the analysis device which closes when not in use, this delicate equipment can then operate and last longer in harsh surroundings.

Figure 1. The Ophir Ariel is a self-contained, convection-cooled power meter. It provides laser power based on a short-duration measurement and can send the reading via Bluetooth to a paired device.

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Real-Time Control and Industry 4.0

Another trend that has driven advancements in laser measurement technologies is the increasing need for real-time feedback from industrial processes. Internet-of-Things, or "IoT", technologies have allowed machines to communicate more freely, resulting in the sharing of more data than before. The increased sharing of data has shown process and manufacturing engineers that gathering data about a process in real-time creates smart processes that can be improved by in-process, or "in-situ", adjustments of key parameters.

But it can be tricky to collect and analyze real-time, in-situ data on a laser's behavior. In-process laser analysis can be performed, however, with current technologies it is usually performed on some but not all of the laser system. For instance, while the laser is processing the intended material, it simply cannot be measured and analyzed in its entirety.

In-process measurements are usually performed by collecting a small percentage of the laser light through, for example, known percentage of leakage from a reflection optic and analyzing the amount of light through a power reading or a beam profile analysis of laser shape, size, geometry, etc.

At-process measurements are performed when the laser is taken off-line, usually between part runs or during maintenance periods on the laser system. The downtime while the laser is not producing parts is a drawback to this method of laser analysis. However, by using this method, the entire laser at the work site is analyzed, which is a more true representation of how the laser is processing the material.

Additive Manufacturing

Regardless of the laser process, it is important to have time-based measurements of how the laser is interacting with the process. There are many laser performance parameters that can be measured, but the most direct way of looking at how the laser processes material is measuring Power Density.

Power Density is generally defined as the amount of laser light (laser power expressed in a unit of Watts) versus the size of the beam at the process (surface area of the beam size expressed in centimeters squared). A desired result for the material being processed will correspond to a Power Density measurement. For instance, to properly weld steel requires a Power Density somewhere in the neighborhood of 5-10 MW/cm^2. Too low a Power Density and the materials don't join. Too high a Power Density and the material is destroyed.

Because of changes in material properties of the components which make up the laser system, both laser power and beam size can change during laser-on time. Understanding measurements for both laser power and beam size on a time scale is also important to maintaining consistency in the process. Keeping the changes that can happen with laser power and laser beam size at the process can and should be minimized through proper operation and maintenance of the laser system.

One example of this is the user of lasers in additive manufacturing (AM) processes. AM has been around for many years, but has only recently been considered a practical means of production. As a result, more laser users are gathering information about these processes and looking for more in-depth understanding of the processes - both in R&D and Production phases of a laser's life cycle. Understanding short-term and long-term changes to Power Density through laser measurements have helped laser users better understand their processes. With the knowledge of how the laser performs, both during laser-on time and across the life of the laser, laser engineers are better equipped during the development of the process, the employment of the process, and the maintenance of the process.

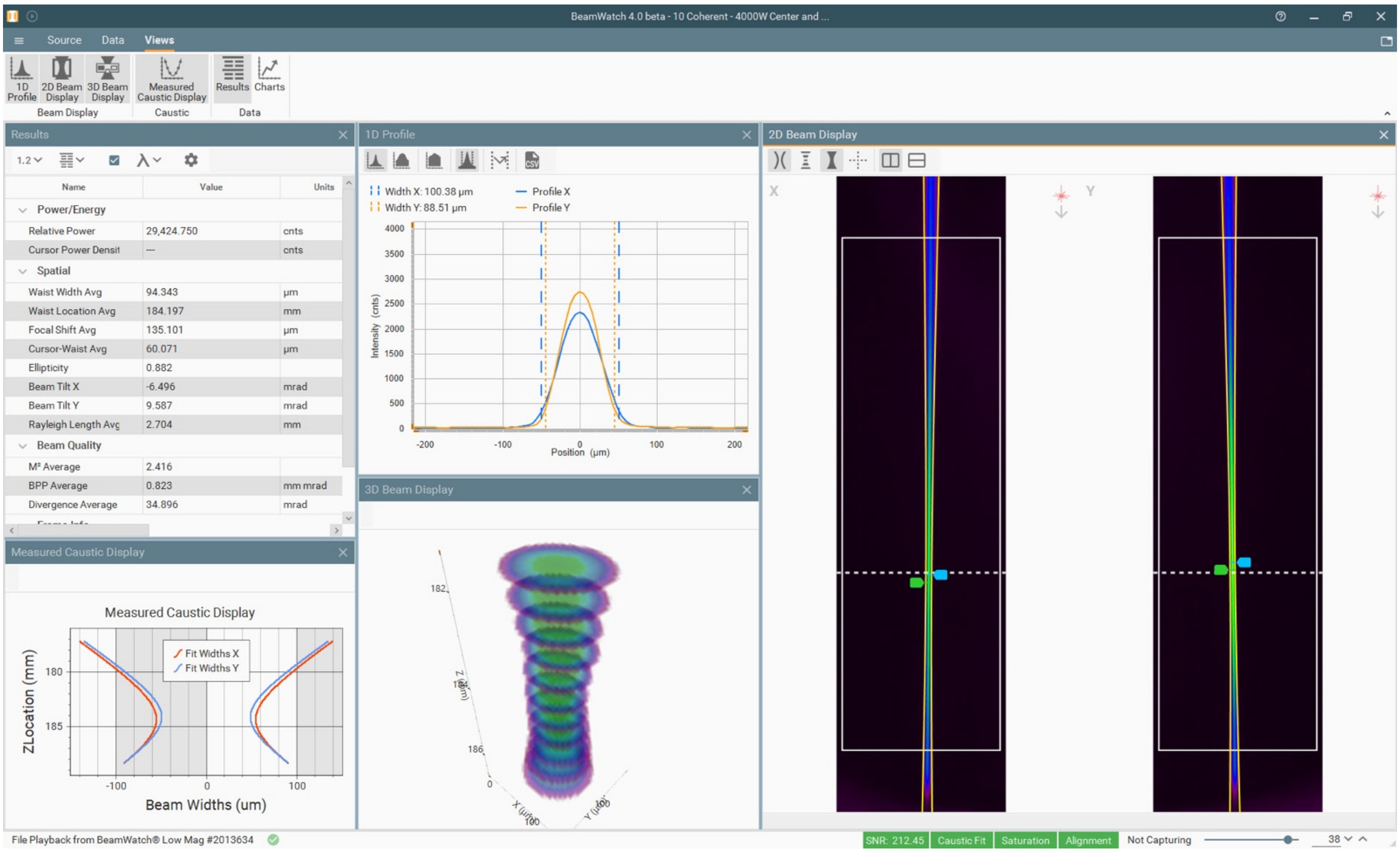

Figure 2. Additive Manufacturing requires consistent laser performance over relatively long periods of time, especially during the build of larger parts that use exotic metals. If the laser fails to perform consistently, there is a risk of materials not properly joining.

Cycle Times and Thermal Effects

Additive Manufacturing experts are continuously improving systems and will soon reach the point where it will make sense to seriously consider AM systems in place of legacy production processes. When developing faster cycle times, one approach is to increase the power of the laser which yields faster printing speeds. Increasing the power of the laser, however, introduces additional limitations on the system, mainly an increase in the risk of focus shift due to thermal effects on components in the beam path. Thermal effects are usually exhibited when a component becomes contaminated or starts to age. The component will unintentionally absorb more laser light than designed causing it to increase in temperature and change shape. When the shape changes, it causes the intended location of the focused spot to change location with respect to the process. The end result is an increased beam size at the process causing a reduction in Power Density.

Laser engineers working with increasing laser powers must realize this and understand that, with this scenario, it is even more important to know how their lasers are behaving through more frequent measurements performed on the system, specifically short-term and long-term laser power and focused spot location trends. These measurements provide the laser engineer with the knowledge that the laser is performing consistently and the overall process will be more stable during part builds and over the life of the laser.

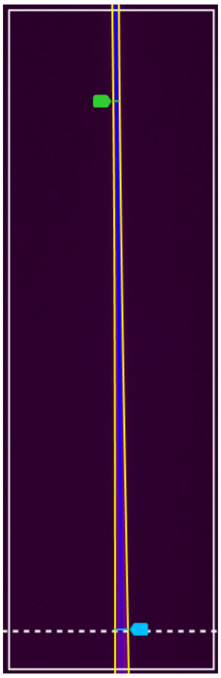

Figure 3. Focused spot location, with respect to the build plane, is critical to the success of the part build. Any shifts of the focused spot from thermal effects on the laser system can result in a loss of material joining.

Adaptation of Latest Technologies

There are still and adaptation of new laser measurement technologies can often be met with reluctance on the part of the laser engineer. In some cases, legacy technology, which may be considered "tried and true", is not presenting an accurate representation of laser behavior. It is surprising how organizations invest in million-dollar high-power laser systems yet the measurement of their performance is handled with technology from the 1970's and 1980's. These products present the laser engineer with incomplete and subjective data. Yes, they're cheap and simple, but the laser users are, in fact, depriving themselves of critical knowledge about the laser's performance.

The development of ways to monitor laser performance is ever-evolving. The current approaches to measuring lasers, in-situ and at-process, are either-or approaches. Some companies are getting creative and coming up with ways to more closely monitor these laser parameters. But to be able to measure the laser at the process during the process is something that is on our minds and being actively worked on.

About the Author

John McCauley is Sr. Business Development Manager for MKS Ophir with a focus on automotive and directed energy applications. From 2009 to 2016, he served as their Midwest Regional Sales Manager and Product Specialist for all markets. Since 1998, his background has been as an end user of, and an Applications Engineer working with, laser marking and engraving systems. He has also worked closely with several mid-Indiana metal fabricating customers. He can be reached at john.mccauley@mksinst.com.