
By John McCauley, Midwest Regional Sales Manager, Ophir-Spiricon, LLC

Whether you’re new to lasers or you’ve been working with them for some time, you may be wondering what all the fuss is over laser beam profiling. Why worry about the quality of the laser beam that you’ve just put into production? Or, if you think your process is humming along nicely, why fix what isn’t broken? You might think that laser beam quality has more than likely been addressed at the research and development stage of the laser you have, or even at the manufacturing or integration stages of the system that you’ve received. You might be correct about that and hopefully you are. However, you might be surprised (as I was) to learn that this is not always the case.

Often, the person responsible for the laser treats it much like they would their own car. If it turns on when they want to drive and gets them where they need to go, they’re not worried about much else. If something goes wrong, they take it to a specialist to fix the problem and they’re not that interested in what makes it purr under the hood. They know they have to get the oil changed, the tires rotated, and fill the washer fluid now and then. Others like to tinker, get to know their automobile to can save themselves much time and many dollars by enabling themselves with the knowledge to fix problems that arise. Similarly, you may see the laser is a magic box that you bought to perform a task that you don’t care to mess with when things go wrong. Or you’re a savvy laser user that knows how to tinker under the hood to optimize your laser’s performance. At any rate, beam profiling can be an extremely valuable practice when implemented into your laser’s planned, preventative, or corrective maintenance routines.

Laser beam profiling can be described as using an imaging device to capture and display the spatial intensity of a laser’s energy. The software that is interfaced with this imaging device will then perform attribute measurements such as beam size, beam wandering, peak energy to centroid (or the geometrical center of the beam) location, and measure other beam characteristics. You can even incorporate an average power or energy per pulse measurement to calibrate these measurements (as provided by the most current technology). Bottom line is that it can be as simple or as complex as you want it to be, but the benefits of implementing laser beam profiling practices can be very beneficial at the end-user stage of a laser’s life.

How exciting it is to pull that new car off the lot, to smell that new car smell and to feel it purr as you buzz down the road. Almost immediately, you’re eager to take that car, almost identical to the other ones that moved down the assembly line, and make it your own. You might find
yourself asking, “What can I do to get the best gas mileage?” or “How can I get this baby to get up and go?” To get those types of questions answered, you’ll need to know something about your new vehicle, or get the advice from someone who does. Either way, you’ll need tools to make these kinds of enhancements.

**Laser Optimization**

A laser is no different (even though you probably don’t hear anyone commenting on a “new laser smell”). Depending on the process, the laser’s mode, or structure of energy distribution, should be optimized for that process. For instance, a Gaussian, or “cone-shaped” mode, with a relatively high peak power near the centroid of the beam, should be achieved for marking, etching, micro-welding, and some cutting applications. A flat-top mode should be achieved for most welding applications. And a TEM$_{01}$* (or “donut”) mode is common for high-powered cutting lasers. Several different factors come into play when trying to optimize your laser’s mode: process parameters, optical alignments, and condition of laser components are just a few.

Hopefully, when you bought your laser, a set of parameters were optimized ahead of time for your process, and the alignment and condition of the laser’s components were optimized as well. And, as with any piece of machine tooling, additional parameter and alignment optimizing should be performed during installation, as well as monitoring and validating during day-to-day operation. Your laser can often give you very relevant feedback, such as internal average power monitoring, which will sometimes give you a good indication of how your laser is performing. However, seeing and understanding what is happening with your laser at the workpiece is by far the best indicator to ensure optimal laser performance.

For industrial lasers, power or energy monitoring at the workpiece, in conjunction with a “focused spot analysis” (or “FSA”) should be incorporated into your maintenance and monitoring practices because it takes all of your laser system’s components into consideration and gives you the means of objectively analyzing and adjusting real-time, in some cases, the entire laser system because it is external to the laser. Internal power monitoring usually gives you an indication of only a portion of your laser’s system, often only the resonator. Similarly, if you are only monitoring the performance of your car’s engine, you’d never know when you have transmission problems until it is too late.

Also, if you’ve worked around lasers enough, you know that over time these same process parameters don’t always translate continued laser efficiency. For instance, you might find that weld penetration hasn’t remained consistent over time or that you might have to be running parts at a slower rate to obtain the same results. “When the beam isn’t doing the job, we usually turn up the power,” is a common comment that has been made by shop foremen. Without knowledge of what a laser does at different power levels, you might be tempted to think or even do the same thing. However, simply increasing the laser’s power level doesn’t always correlate into higher beam quality.

Figure 1 shows a laser’s profile at three different power levels. You’ll notice that at the lower power setting, the laser’s energy intensity is not that high, and with the increased power setting of the middle image, the laser’s energy seems to be optimized. However, with the laser at its highest power setting in the third image, the laser’s mode appears to fall apart, greatly decreasing
its efficiency. If you’ve worked with lasers long enough, you have heard the phrase “optimizing a laser for power.” This means an average power measurement is taken external to the laser with a power meter while the “tweaking” of the laser takes place until the laser’s average power is at its highest value. In the case of Figure 1, the laser’s power measurement would be the highest at the third setting, but that certainly would not be an optimal laser setting.

Over time, your car’s tires wear thin or even start to make strange noises to the point where it’s unsafe to drive. The carbon builds up on the spark plugs or they corrode to a point where your gas mileage starts to decrease. Fluids start to become viscous or break down to the point where they cause their subsystem not to perform as efficiently as they were designed to. The car still works, but it’s time for a tune-up. Your laser’s efficiency, too, will depend on frequent and consistent monitoring in order to determine when it’s time for its tune-up. Just like a car, if these indications go unaddressed or unnoticed, the result can be catastrophic.

A veteran laser user knows that he does not want his Nd:YAG’s flash lamp to reach the end of its life, unless he wants to spend the next six to eight hours cleaning out broken glass from his resonator’s cavity, sponging up water, and cleaning optics. A laser’s crystal, optics, and other components can degrade over time resulting in a decrease in performance. Laser beam profiling will provide the laser user with the most objective means to monitor and track these changes over time. Beam profiles can then be linked to degradation of these components and planned maintenance can then be organized around or adjusted for the tracking of beam profiles. Figure 2 shows beam profiles from the same laser. The image on the left shows a mode
structure which is fairly uniform. The image on the right shows a beam profile, taken some time later, which shows a mode structure that has become relatively unstable with normal use. Some laser users who have incorporated beam profiling into their maintenance practices have found that by taking frequent beam profiles, they can extend maintenance periods because the efficiency of their laser actually lasts longer than expected; this ultimately results in decreased scheduled laser down time. Also, laser performance can be optimized with the use of beam profiling to maintain, or in the case of parameter optimization, even increase throughput.

You may even find yourself in a situation where laser validation is important, or even necessary, whether it be an internal or external need. For example, some entities must validate their laser or process that involves the laser to maintain ISO compliance or to satisfy certain FDA regulations. External power/energy measurement and beam profiling are the most effective ways to comply with industry standards.

When selecting such laser measuring and analyzing tools, it is important to ensure that you have the most accurate tools in the industry. For instance, the patented, ISO standard of setting a baseline for the beam profiling imaging device is known as UltraCal™. What UltraCal™ does is analyze the electronic noise on the imaging device as well as detect any ambient lighting in the beam profiling environment. Then it sets that noise level at the baseline in the analyzing software. When a beam is presented to the imaging device, any rise in intensity that is seen will be a result of only the laser’s beam. Also, the amount of data that is collected from the laser can affect the accuracy of a measurement. For instance, the smaller the pixel size and the quicker the data capture rate of the camera that is used for imaging the beam, the more data can be collected and analyzed. The most recent technology will even allow the laser user to capture beam profiles and power/energy measurement at the same time, in the same software platform, and allow the software to calibrate the beam profile with the corresponding power/energy measurement.

Even if there is no requirement for laser performance monitoring, it has been documented time and again that beam profiling should be incorporated into laser maintenance routines. Since beam profiling at the workpiece is the most objective and comprehensive way to measure beam
quality, beam profiles can be correlated into part-to-part consistency and ultimately be a means of ensuring less scrap or, even worse, recalled parts.

**Preventing Laser Problems**

If you’ve been driving a car long enough, chances are you’ve had that day when you’ve pulled out of the driveway to see a large red or bright green or brownish-black puddle on the driveway leaving that sickening feeling in your stomach and possibly even making you late for work that day. You may have seen that white or blue smoke roll out of the back tailpipe at one time or another. Just like any car, lasers have components that will catastrophically fail, either completely taking the laser down or greatly decreasing the laser’s productivity to a point where something must be done to bring it back online. If you’re an experienced laser user, you might be able to recognize and analyze the symptoms and know what needs to be done quickly fix the problem, in which case you’ve saved your company a relatively large sum of money that day. If you’re the one who has not taken the time or been trained to troubleshoot such problems, you are more the likely at the mercy of the laser manufacturer or integrator that has provided you with that particular system. In that case, the costs associated with hiring an outside entity to restore your laser are often times very high.

![Focused Spot of Marking Laser With Severe Fiber Misalignment](image1)

![Focused Spot of Same Marking Laser After Fiber Realignment](image2)

When a laser is operating as desired, and your friendly local sales engineer demonstrates a beam profiling system for you and reviews the cost of such a system, it may not seem to be worth it at the time, especially in these economic times. In retrospect, when the laser has gone down and the checks are being written to the one who will be restoring the system, the costs of the tools and training in order to bring that maintenance in-house will seem like a bargain and one that would have paid off time again. A similar feeling might be the one where the diagnosis of a broken timing chain is given and the “if I had only” thoughts go through your head when low-cost preventative actions could have been taken instead of paying a repair bill of a few thousand dollars. In fact, the costs of purchasing laser power/energy measurement, beam profiling, and other diagnostics tools in conjunction with training on laser maintenance makes more sense in poor economic times than in better times since preventative maintenance costs often times outweigh corrective maintenance costs.

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**Beam Profiling: Effective, Practical, Simple**

Most times, what prevents a laser user from adapting beam profiling into their maintenance practices is the perception of it being a complicated process. Think back to the time when you first learned how to change your own oil. You may have had the same thoughts. It may have appeared to be a complicated procedure even though others had told you that it was relatively simple. After taking on the job, you probably came to agree with them. The same can be said about beam profiling. Those familiar with and who frequently perform the process will tell you that it really is a simple concept and, more importantly, one that will eventually reap money- and time-saving benefits.

Most industrial laser users will agree that the most relevant place in your beam path to obtain information about your laser is at the workpiece. Using beam profiling, in conjunction with power/energy measurement at the workpiece (preferably within the same software platform), to optimize your process parameters and beam path component alignments after the initial delivery of your system can ensure or even increase the quality of your beam. This way you will start off with maximized throughput and low scrap rates. You will also be armed with the ability to validate the laser, removing it as a variable during process validation for given periods of time or for batch runs, whether the internal or external validation is required or not. This laser beam analysis will also help you ensure that your beam quality stays high with respect to the inevitable degradation of laser components. And it will allow you to better predict laser downtime, even prolonging planned maintenance cycles. Finally, if (or when) your laser suffers a catastrophic failure of one of its components, if you have been properly trained, you will now have additional tools available to quickly troubleshoot and restore your laser system, ultimately saving your company money and further ensuring your own job security. The laser, to some, just as an automobile, can be perceived as a tool powered by magic, but only if you don’t have the tools and knowledge to know what is going on under the hood.
Author Bio

John McCauley is the Midwest Regional Sales Manager for Ophir-Spiricon and joined them in January of 2009. Since 1998, his background has been as an end user of, and an Applications Engineer working with laser marking and engraving systems.

About Ophir-Spiricon, LLC

Established in 1978, Ophir-Spiricon is part of the Ophir Optronics Laser Measurement Group. The Laser Measurement Group provides a complete line of instrumentation including power and energy meters, beam profilers, and spectrum analyzers. Dedicated to continuous innovation in laser measurement, the company holds a number of patents, including Ultracal™, the baseline correction algorithm that helped establish the ISO 11146-3 standard for beam measurement accuracy. The company’s modular, customizable solutions serve manufacturing, medical,
military, and research industries throughout the world. For more information, visit http://www.ophir-spiricon.com.