Why and How to Profile Challenging Laser Applications

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We introduce three techniques for monitoring the critical characteristics of the beam as the laser is used in three very different applications: (a) VSCEL / Laser Diode Mode and beam divergence, (b) Additive Manufacturing lasers used is 3D SLM / SLS, and (c) Fiber welding / heat treating / cleaning lasers.

This article will introduce three techniques that monitor the critical characteristics of the beam as the laser is used in three very different applications.

The first technique is to measure the distribution of light from laser diodes or a light source where the light is emanating from a micro-planar surface or edge. Though the light spreads quickly from these devices, the central rays are easy to accurately detect. The measurement is complicated by the shallow-angle rays of light that occur on the edges of the light cone. These rays are more easily reflected from detector surfaces, thus are typically under-reported in most direct-to-camera beam profiling techniques. The Ophir Wide Beam Imager (WB-I) provides a large measurement area where these rays are correctly measured.

The second laser measurement technique is for use with laser metal powder bed 3D printing. Technologies used here are known as direct metal laser sintering (DMLS) and direct metal sintering (DMS), where a three-dimensional object is "printed" one very thin layer at a time. These types of applications require control of the location of the focused laser spot as well as knowledge of the irradiance or power density of the delivered beam. The Ophir BeamWatch AM continuously monitors the laser beam about the focal region, measuring the size and location of the focus spot referenced to the powder bed surface without touching the beam in the process.

The third laser measurement technique enables the measurement of the size and location of the focus beam profile of multi-kilowatt industrial fiber lasers. The Ophir BeamGage system with LBS-300HP high power laser beam attenuator helps to locate the focal plane. In this case, by measuring one plane at a time along the beam's path with the ability to measure the extremely high irradiance of a focused multi-kilowatt laser.

Let's take a look at these three scenarios in more detail.

Accurately Measuring Highly Divergent Lasers

The Ophir Wide Beam Imager (WB-I) consists of the diffuser, tube, mounting sleeve, and mounting for a BeamGage camera. The Camera is connected to the WB-I tube and the image through a USB cable to a PC running the Ophir BeamGage laser beam profiling software.

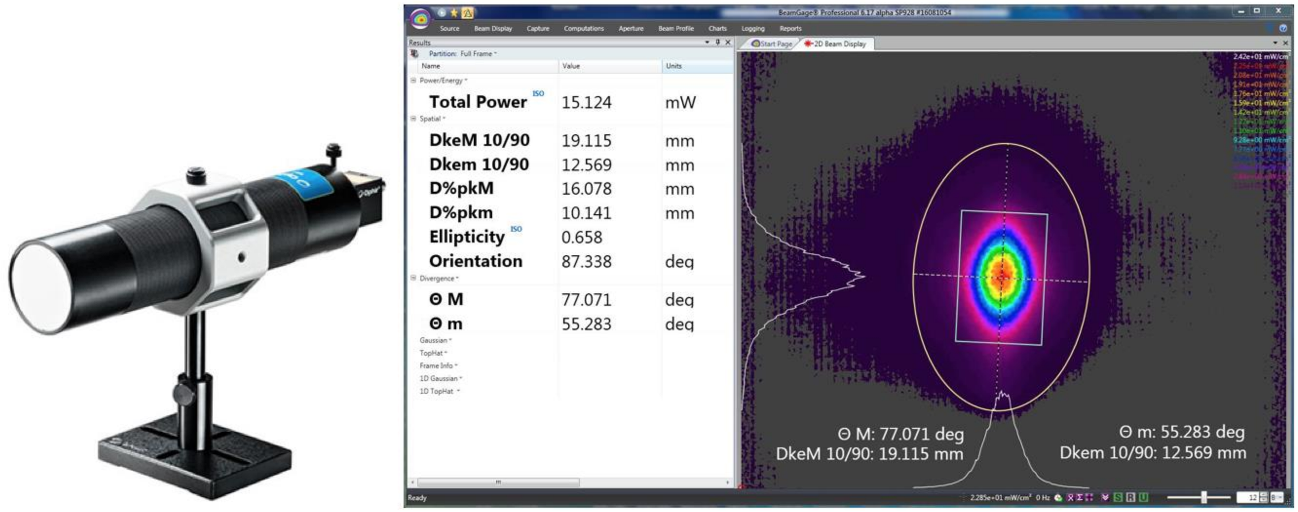


Figure 1. Ophir Wide Beam Imager and BeamGage profiling software.

The laser or light source under test may be mounted on a translation stage so the distance from the emitter to the measurement plane can be easily known. This distance is used to help calculate the angle of divergence of the source under test. Most semiconductor lasers exhibit a fast and a slow divergent axis. The beam profiling software can automatically find the major axis and provide divergence angle measurements for both the major and orthogonal minor axis.

The WB-I is an accessory for Ophir's BeamGage laser beam profiling systems. It enables measurement of the spatial intensity profile of light coming from point sources of light, such as VSCELs with very high divergence up to 70 degrees half angle. Beams from 10mm up to the maximum allowed by a 45mm aperture can be measured. The WB-I accessory requires a BeamGage system such as the BGP-USB3-SP920s which includes a CCD camera and the professional version of Ophir's BeamGage beam profiling software suite.

The WB-I extends the application of the SP920s camera up to 200 Watts with a 45mm active area. The diffuser was selected for its ability to accurately absorb thus permit the measurement of the very shallow rays from highly divergent light sources. Most sensors do not measure these shallow rays correctly as they are readily reflected by the surface of sensors.

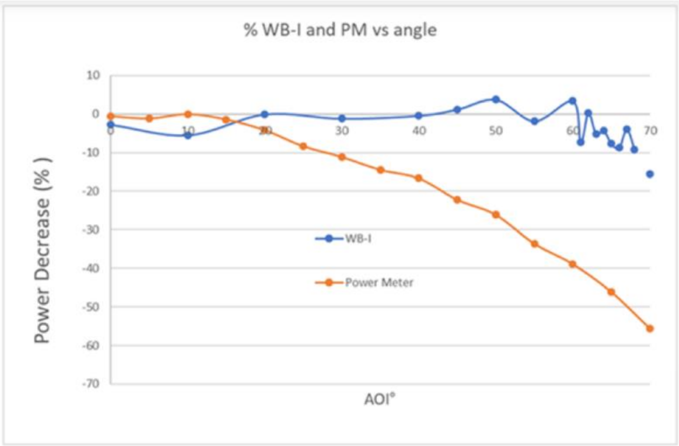


Figure 2. Linearity of Ophir WB-I energy distribution for angled light compared to the measurements of a photodiode sensor.

Here the rays with angles up to 70 degrees are measured at +5/-10% vs the response of a silicon photodiode, which is down by >50%. Accurate measurement of these high angle rays is critical to the high-fidelity measurement of the source under test.

So why the need for a Wide Beam Imager for measuring divergent sources? Because the system provides accurate measurements of the far field spot size, ellipticity, mode, and divergence angles, and can help you to understand how these important parameters change with current and temperature.

Measuring Lasers Used in Additive Manufacturing

The Ophir BeamWatch AM (BWAM) is designed specifically for use in additive manufacturing applications. It uses a unique technique to measure the focal region by looking orthogonally at the laser beam. The system uses atmospheric or Rayleigh scattering of the delivered beam to determine the location on the beam waist or focus location and spot size at the work surface. The beam is imaged from the side in two orthogonal views. Since these views are centered about, above and below, where the beam would normally be delivered to metal powder, the BeamWatch "sees" the beam and can easily measure its size as it goes through focus. After the focal region is viewed, the beam is de-focused onto a power sensor, thus the tool is completely self-contained. From side views provided by the BeamWatch camera, the analysis software determines location of the beam waist and any changes in its position or spot size relative to the work surface.

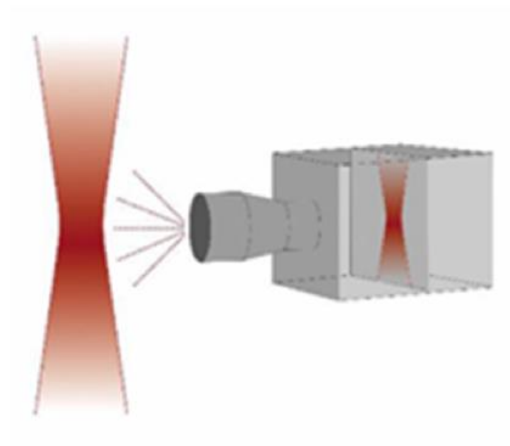
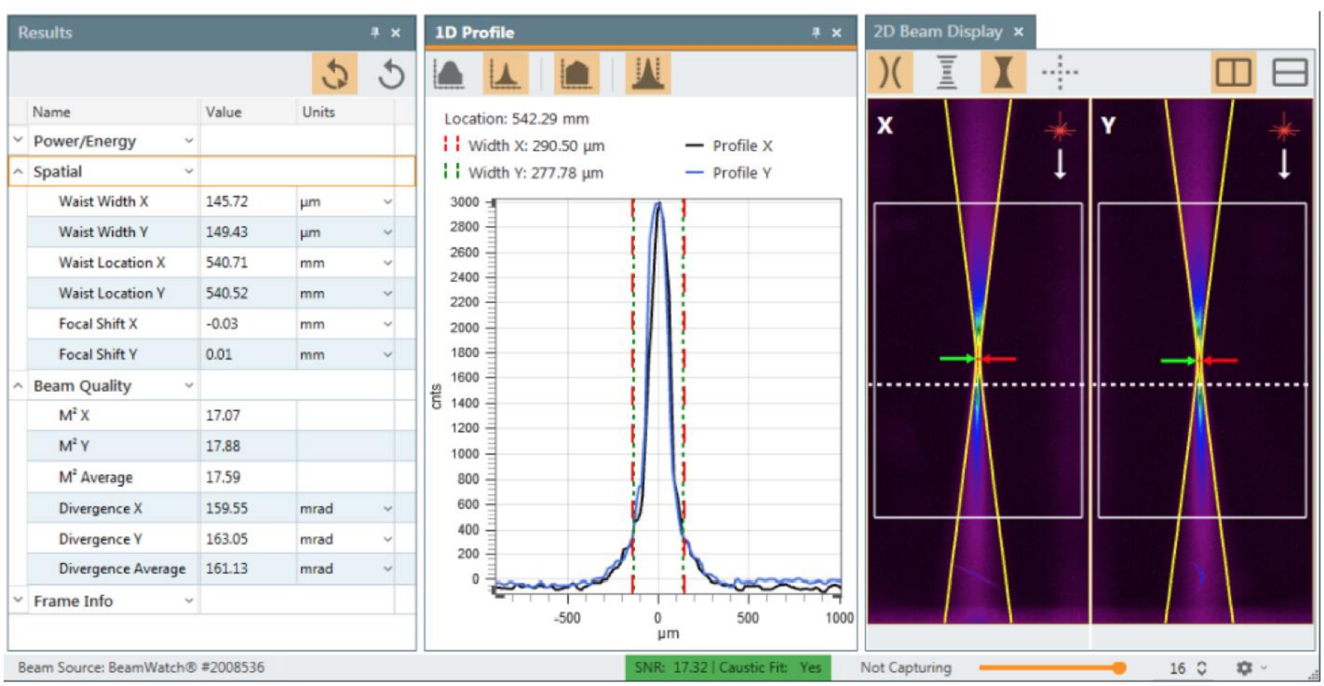


Figure 3. The Ophir BeamWatch AM is a 3D Additive Manufacturing Metal Powder Printing laser beam diagnostics device.

The BWAM contains a 600-Watt air cooled laser power sensor. The laser power measurement is displayed in the BeamWatch application and is updated with each video frame. The power is also used to calculate the power density the laser is providing to the work plane.



Results **1D Intensity at 2D Cursor** **2D False Color X & Y Views**

Figure 4. BeamWatch AM determines the location on the beam waist or focus location and spot size at the work surface.

Rapid updates of the BWAM measurements allow the user to observe any movement in the location of the focal plane. Sometimes contamination of the sacrificial cover glass or beam delivery optics will cause the focal plane to shift over time.

The BWAM will alert the user of any changes in the location of the delivered beam before decreases in the laser irradiance levels can negatively impact the build process. The BeamWatch software application permits the saving, retrieval, and comparison of current and historic laser performance from each system. Built-in statistical analysis and a report generator help the user to communicate AM system performance to a wider audience.

View Size and Mode of Multi-kW Fiber Lasers at Focus

Industrial fiber lasers can deliver truly awe-inspiring power densities when their beams are focused. Irradiance levels that exceed 1 million Watts per cm² are often needed to perform the high-speed welding and cutting for which these lasers are famous. While placing MW/cm² on any beam measurement tool is not currently practical, it is now possible to measure these incredibly intense focused spots indirectly.

Figure 5. The Ophir LBS-300HP-NIR beam splitter allows measurement of NIR focused or collimated beams up to 5kW or 15MW/cm^2.

The Ophir LBS-300HP-NIR is a beam sampling attenuator accessory from the BeamGage family of beam profiling products. It uses two orthogonally placed, front surface beam splitters made from highly transparent, very low scattering fused silica. These unique, very high-power beam splitters each provide a ~0.1%, high fidelity sampled beam while absorbing less than 0.1% of the incident laser energy. With two beam splitters, the sampled beam of ~0.0001% is polarization-independent, meaning it does not preferentially sample one polarization over the other. This design permits the optical attenuation of ND:Yag and fiber lasers with average powers up to 5,000 Watts and power densities incident on the first beam splitter of up to $15MW/cm^2$.

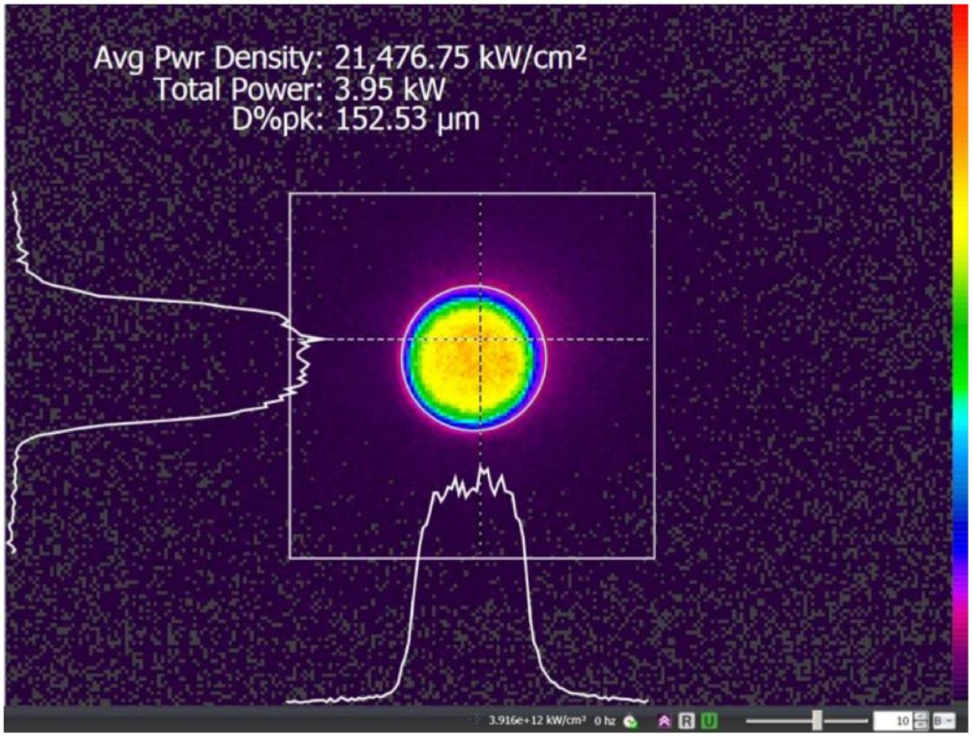


Figure 6. Beam profile of focused 4kW Fiber Laser - Average Power Density $21.4MW/cm^2$.

In Figure 6, a 5kW fiber laser is monitored at focus. The 152.5um spot has a chisel profile as the fiber end is imaged when in focus. Away from focus, the profile is more Gaussian, or bell-shaped. The addition of the LBS-300HP-NIR to BeamGage beam profiling accessories allows camera-based laser measurements of the very high average power levels of focused multi-kilowatt lasers. This enables industrial laser users to assure beam delivery optics and cover-slides are clean and performing correctly. Changing process conditions can be detected quickly and resolved before they impact the quality of the product.

Figure 7. Ophir LBS-300HP-NIR and camera measuring 5kW Fiber Laser.

Conclusion

Ophir brings innovation to make quantitative laser beam analysis easy and effective. New products and accessories provide the tools to keep laser processes efficient and to deliver important insights into laser performance for laser systems designers and users.