Achieving Standardized Measurements with BeamWatch AM

David K. Moser, M.Sc. Physics - Optical Engineer & Jed Simmons, Ph.D. - Physicist

Industry-Focused Design

BeamWatch AM is the newest member of Ophir-Spiricon's family of beam monitoring systems. It has been designed specifically for use in the additive manufacturing industry to provide non-interfering real-time beam measurement at the location of the working plane. Rigorous testing has been performed to ensure it meets the specifications detailed in Table 1 to the right.

Table 1 - BeamWatch AM Specification

Beam Profiling	
Wavelength	1060-1080 nm
Minimum Power density	1.5 Megawatts/cm^2 (50µm spot at 30 W.)
Minimum Focus Spot	50 microns
Maximum Beam diameter at entrance/exit	6 mm (4.5 mm using the Halo Aperture)
Communication to PC	USB 2.0 & USB 3.0
Power	110 - 220 Volts AC 50/60Hz
Particulate Purge	Clean dry gas varies by operations

Power Meter/Beam Dump	
Measured Power	30 W to 1000 W
Maximum Power Exposure	1000 W for 2 minutes
Precision	±3%
Cool-down Time	20 minutes with fan cooling if used to maximum exposure

General	
Weight	17 lbs
Dimensions	7.03in x 4.96in x 7.16in 178.57mm x 126mm x 181.92mm

Rayleigh-Scatter Technology

As with other BeamWatch models, a real-time non-contact measurement is obtained by relying on the Rayleigh-scattering properties of the most common air molecules: nitrogen and oxygen. This is a well-documented technique utilized in everything from chemical solution analysis to atmospheric LIDAR studies. By capturing the proportionally scattered laser light with a camera placed transverse to the beam's path, BeamWatch can provide the equivalent of simultaneous scanning slit measurement slices along the entire FOV of the camera.

Extensively Tested for Accuracy

Since the raw Rayleigh-scatter data is only proportionally representative of actual beam measurements, some processing is performed in order to improve signal-to-noise and reduce variance. As with our other applications, this process includes some basic data filters and a background subtraction to ensure that the measurements reported provide a precise representation of the beam. Additionally, we utilize a proprietary data model to account for the signal-to-noise differential between the edges and center of the beam section selected for study. This differential occurs due to a combination of factors including lens selection, beam divergence, and the design of the BeamWatch AM device itself. The entire system has been extensively tested to ensure accuracy and reproducibility in a variety of conditions. A comparison of measurements taken with the NanoScan 2, our ISO 11146 compliant full-contact scanning slit beam profiler, and the BeamWatch AM Rayleigh-scatter beam profiler shows similar results to each other. This is presented in the chart (Table 2) below.

Table 1 - NanoScan 2 (NS 2) and BeamWatch AM (BW AM) Data Comparison

		X Dimension		*Y Dimension*	
	Units	**NS 2**	**BW AM**	**NS 2**	**BW AM**
Waist width (13.5%)	*microns*	52.5	50.6	53.2	54.4
Divergence	*milliradians*	30.4	30.7	31.2	30.4
Rayleigh length	*millimeters*	1.7273	1.6504	1.7047	1.7925
M^2	*N/A*	1.1608	1.1278	1.2068	1.2022

Compliance with International Standards

The NanoScan 2 has been previously shown (see the NanoScan 2 User Guide for more information) to be compliant with ISO 11146 for the measurements in Figure 2. It follows that the direct comparison above forms the foundation of the claim to compliance for BeamWatch AM. This is the best approach due to the fact that BeamWatch AM is cutting-edge technology for which established standards do not currently exist. We can claim compliance with ISO 11146 by showing that the various methods used throughout the measurement process conform to ISO, and the results match with another verifiably compliant source, in this case, the NanoScan 2.

The largest component of the previously mentioned proprietary model that is used for post-background-subtraction baseline correction involves a Fourier transform method as recommended by ISO 11146-3 section 3.4. Since BeamWatch AM measures a significant length of the beam at once, including the waist, initial determination of beam waist location, beam width, divergence angles, and beam propagation ratios are easily obtained from a hyperbolic fit along the propagation axis. This procedure is detailed in ISO 11146-1 section 9, and is functionally equivalent to measuring at hundreds of locations along the beam separately with the NanoScan 2. Two items of note here are the positioning

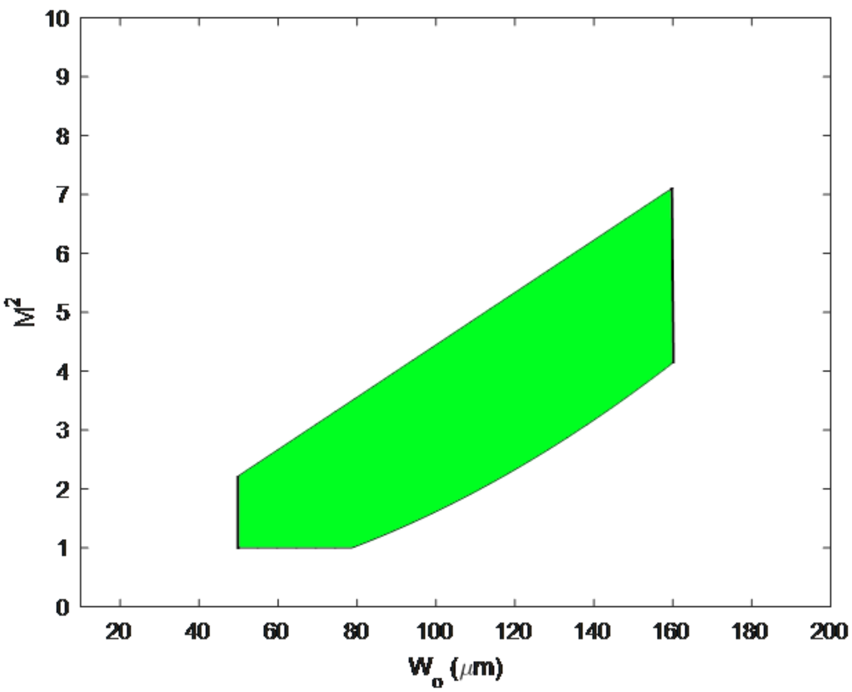

Figure 1 - BeamWatch AM Operating Space Chart

requirements of the fitting method, as well as the fact that the method applies only to beams that are stigmatic or simply astigmatic. As for the latter caveat, we assume our target users to be utilizing round fibers and any astigmatism induced by delivery heads to be simple. It is the user's responsibility to determine if their beam is an appropriate candidate for use in BeamWatch AM. However, an operating space chart has been provided in Figure 1 to the right for further assistance.

In order for the beam to provide all necessary data points required for an ISO-compliant fit, the waist must be positioned such that more than two full Rayleigh lengths on at least one side of the waist are within the camera's field-of-view. This may require an off-center positioning of the beam waist under certain conditions, but such a positioning does not negatively impact measurement accuracy. Initial measurements in the fit are based off the moving-slit method, and a correction for D4σ is then applied as per ISO 11146-3 section 4, equation #69. It follows that a corrected M^2 and divergence can be reached by applying equation #63 and the definition of M^2. The software highlights measurements as ISO whenever this data-fitting requirement is met, and falls back on a simple direct calculation of these variables if attempts to fit fail. This can help the user know if they need to adjust the relative position of their laser with respect to the BeamWatch AM unit.

Conclusion

As demonstrated, the BeamWatch AM Rayleigh-scatter measurement technology can be used to analyze the properties of a laser beam without having the beam incident on the sensor. Despite the technology's infancy and the lack of official standards for the approach to data acquisition and treatment, a comparison of results with those from the widely-accepted scanning-slit technology of the NanoScan 2 demonstrates that the BeamWatch AM can achieve ISO-compliant measurements when used correctly. A further examination of the methods used to obtain and refine the data further validates the claim that BeamWatch AM measurements meet ISO 11146 standards.

For more information on BeamWatch, see:
http://www.ophiropt.com/laser--measurement/beam-profilers/products/High-Power-Beam-Profiling/BeamWatch