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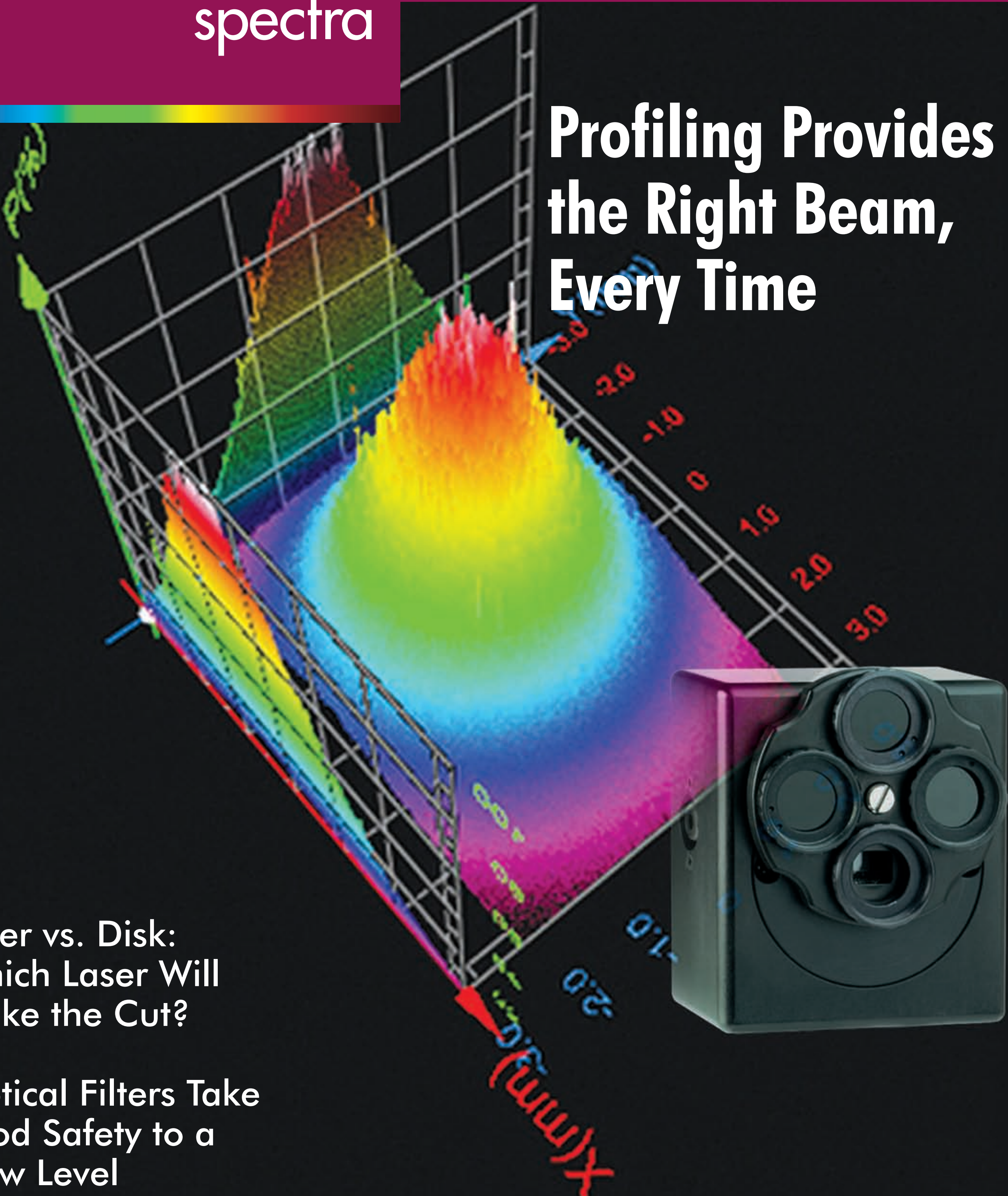

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Profiling Gets You the Right Beam, Every Time

BY MARIE FREEBODY, CONTRIBUTING EDITOR

Whether the application is industrial, medical, military or scientific, diagnosing a problem in your optical system can be confusing, time-consuming and costly. Beam profiling can help.

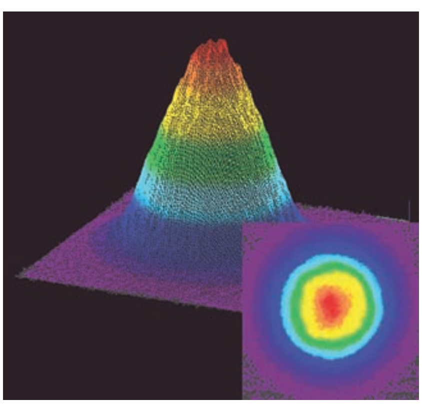
There can be few frustrations greater than finding that your laser-based optical system is not working as well as expected, or that it is failing altogether. But a possible solution literally goes straight to the source: Measuring the beam quality of the optical system could reveal that the beam power is not spatially distributed as expected, or that the size of the beam is not as expected.

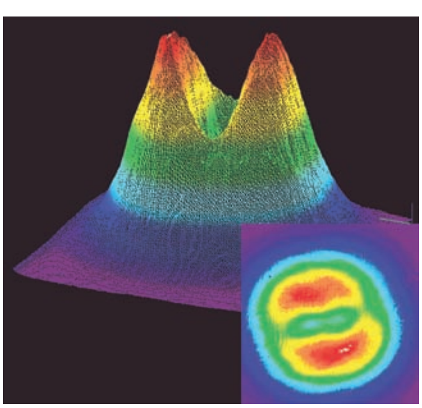
Once the beam profile is corrected, the performance of most laser processes can be improved: Industrial processing produces less scrap, medical procedures are more precise, military devices can have greater effectiveness, and scientific experiments can be more accurate.

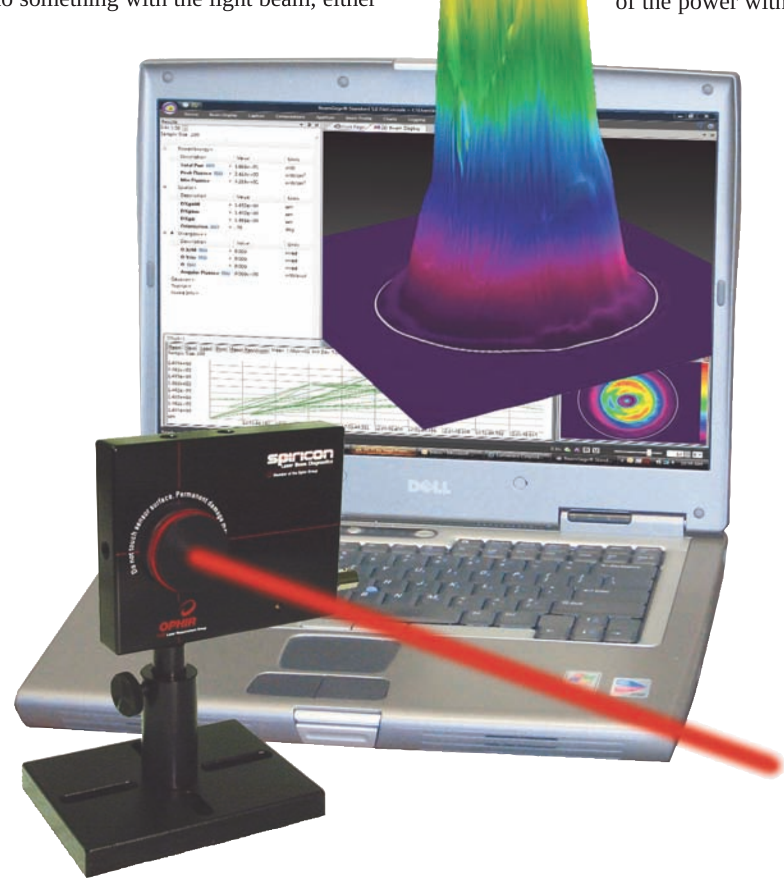
"People working with lasers are trying to do something with the light beam, either as the raw beam or, more commonly, modified with optics," said Gary Wagner, president of Ophir-Spiricon of Logan, Utah. "Whether it is printing a label on a part, welding a precision joint or repairing a retina, it is important to understand the nature of the laser beam and its performance.

"Laser beam profiling provides the tools to characterize the laser and know precisely what the beam is doing at the point of the work, and if the optics are having the desired effect."

The problem is that lasers are like lightbulbs – their output is constantly changing. The instantaneous or average power/energy, or the spatial distribution of the power within the







Camera-based systems capture the entire beam profile by using a CCD or CMOS camera, which provides a real-time 2- and 3-D image of the beam. Images courtesy of Ophir-Spiricon.

cross section of the laser beam, can change over time.

Sebastian Krollmann, a marketing communications officer at Thorlabs, advises that whenever the power density of the laser beam is important, analysis of the beam profile should be considered.

"Beam profiling provides detailed information about the quality of laser beams with respect to the spatial distribution of the optical power density in a 2-D plane perpendicular to the beam," he said.

Get in line

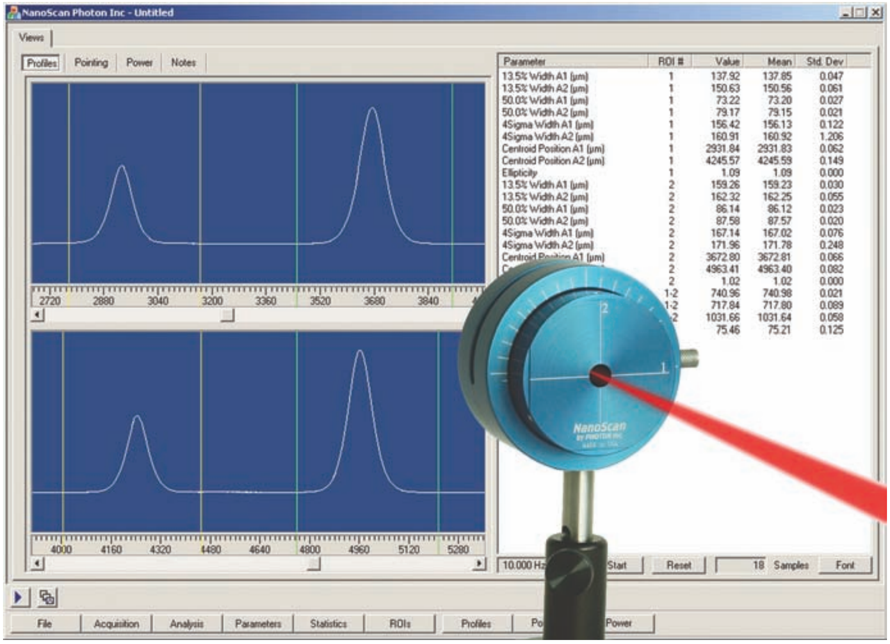
An inconsistent output beam can be problematic or even dangerous in some laser applications. Welding calls for the power distribution to be evenly spread across the beam in what is known as a flattop distribution. If the distribution is higher in the center than on the sides (as in a Gaussian distribution), the laser could be too hot in the center of the weld, causing piercing, and too cold on the edges, making a poor weld.

"Without beam profiling, laser owners are not certain of how the laser power is distributed across the beam. With a beam profiler, they can set up and quickly check to make sure the power distribution is what they need for consistent application. If not, any adjustments can be made before they start their production," Ophir-Spiricon's Wagner said. "By doing this, they can reduce their scrap, improve quality and decrease their time to get the job done."

When it comes to medical applications, however, the collateral damage caused by an unwanted beam could be much more serious. In lasik surgery, for example, if the laser power changes from day to day or from month to month, the depth of the cut will be shallower or deeper than the surgeon intends.

Jay Jeong, a product manager at Newport Corp. of Irvine, Calif., offers the perspective that beam profilers have done more than improve the performance of individual optical systems; he asserts that the devices have been instrumental in the growth of the photonics industry as a whole.

"I believe the broad applications of beam profiling methods enabled lasers to be adopted, improved and fine-tuned in real-life applications," he said. "The applications that strongly impacted consumers early on, such as laser welding (in automobile manufacturing, for instance) and machining (labeling), readouts (bar-code readers) and medical applications, are the key contributors to the growth of the optics and photonics industry."



One large advantage in using a scanning slit profiler is that beams can be viewed directly with little or no power attenuation needed. Courtesy of Ophir-Spiricon.

> *When it comes to medical applications, the collateral damage caused by an unwanted beam could be serious.*

Sizing up beam profilers

A beam's size, shape, expected intensity distribution and divergence can all be characterized by profilers, but selecting the right profiler depends upon the task; the application determines the most important aspects of the beam one wants to analyze, which may be the maximum intensity, homogeneity, the beam's special shape or a combination.

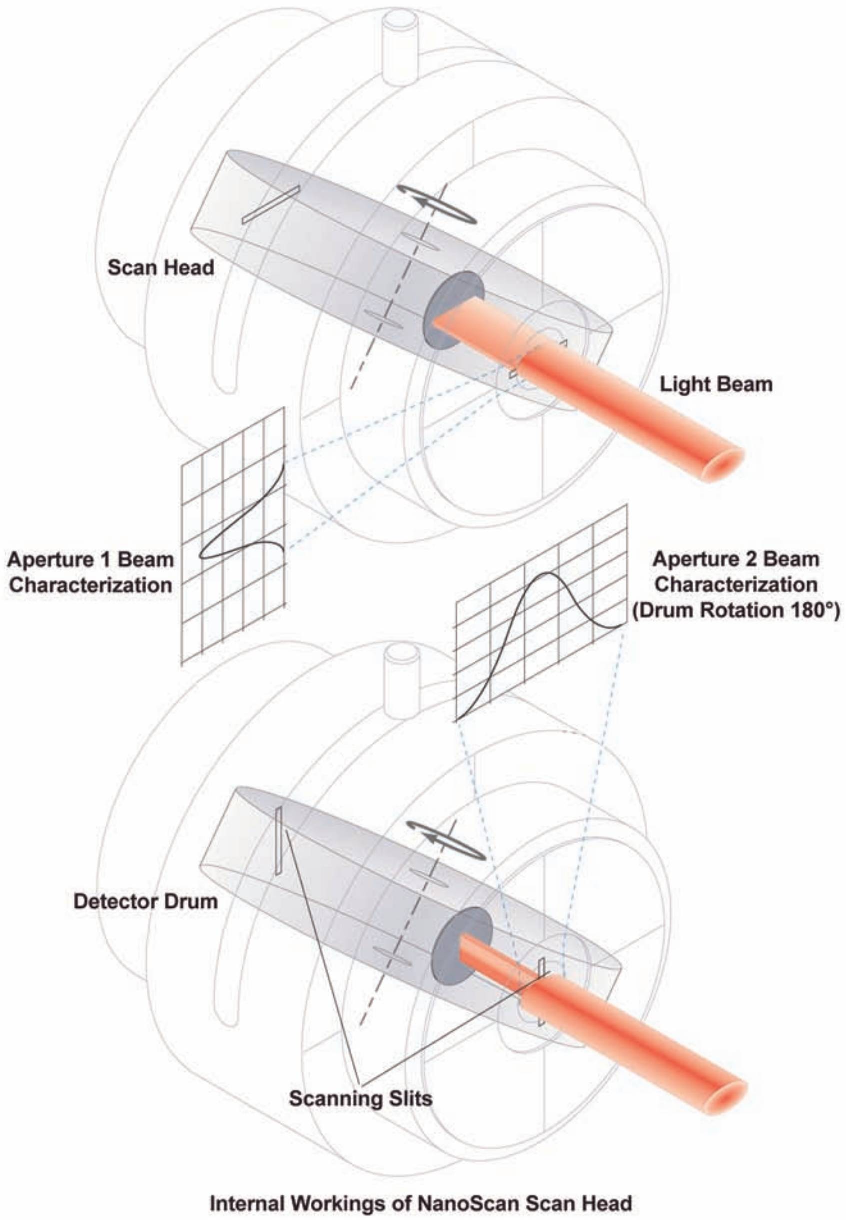
The camera-based beam profiler is one of the most common types. Newport Corp.'s CCD-based beam profiler, for example, is its most popular product. The camera-based systems capture the entire beam profile by using a CCD, CMOS or infrared camera, which provides a real-time 2- and 3-D image of the beam.

Although confined to the ultraviolet to very near infrared wavelength range, camera-based profilers allow for near-real-time monitoring of the beam's alterations as the laser's cavity mirrors are adjusted. Wagner explains that this type of dynamic laser monitoring is particularly useful for applications such as welding or cutting.

"It is well documented that the beam's power distribution changes during the first half-second or second in a multisecond application," he said. "Another example would be to monitor the focused spot position from the nozzle opening. We know that the focused spot distance changes as power changes or as the optics get dirty and worn. Using a beam profiler, the user can periodically monitor focused spot position and adjust the machine's setting to cope with these dynamic process changes."

Camera-based systems should be used when a true 2-D profile is of importance, such as for analysis of non-Gaussian beams. They are also preferable for pulsed sources. While the systems are flexible and intuitive, the downside is that the camera pixels can saturate and become damaged from too much power.

For a more precise intensity measurement, use slit- or knife-edge-based systems. They consist of a single photodetector with moving slits that construct the beam profile based on direct measure-



The scanning slit beam profiler moves a narrow slit in front of a photodetector through the beam under analysis. Courtesy of Ophir-Spiricon.

Once the beam profile is corrected, most laser processes can be improved. "The broad applications of beam profiling methods enabled lasers to be adopted, improved and fine-tuned."

ments of focused and collimated beams.

Compared with camera-based profilers, scanning slits are not as restricted by wavelength. They can be equipped with different detectors and so can measure beams at any wavelength from the ultraviolet to the far-infrared (around 200 nm to beyond 100 µm).

Also, they can measure beams as small as 4 µm to as large as 20 mm. One of the big advantages for scanning slits is that the laser can be viewed many times without any power attenuation, which is useful for direct viewing of the focused spot.

"The assumed beam profile departs from the theoretical shape; therefore, the resultant calculations bear more errors," said Newport's Jeong. "However, they can handle smaller beams or higher-power beams without additional attenuation optics."

But for beams that are high power, very small or rotationally symmetric, slit-based profilers are called for.

Pyroelectric matrix arrays use pyroelectric cameras to operate across the broadest wavelength range of any camera system for beam profiling. With responses from 13 nm to 3 mm in wavelength, they are a good choice for the deep-ultraviolet, mid-infrared and far-infrared applications. They have 100-µm pixel pitch, so for getting the most accurate measurements, they are limited to beams above 1 mm in size.

Goniometric radiometers are specially designed to make measurements of highly divergent beams such as those of laser diodes, vertical-cavity surface-emitting lasers, LEDs and bare fiber. Characterizing these types of beams allows for proper coupling of the light to other devices, or helps design optical systems to modify the beams for use in other applications.

Even though the goal of using a beam profiler is to characterize the laser beam, Jeong says that the user first must have some knowledge of the laser beam he is working with, such as its intensity, spot size, shape and wavelength, along with other characteristics.

"Otherwise, the laser beam profiler can be saturated or damaged, or produce unreliable data," he said. "Therefore, it is important to do some preliminary qualitative beam profile measurements by using laser sensor cards or thermal papers, or even visual observations as well as quantitative optical power measurements."

The shape of the future

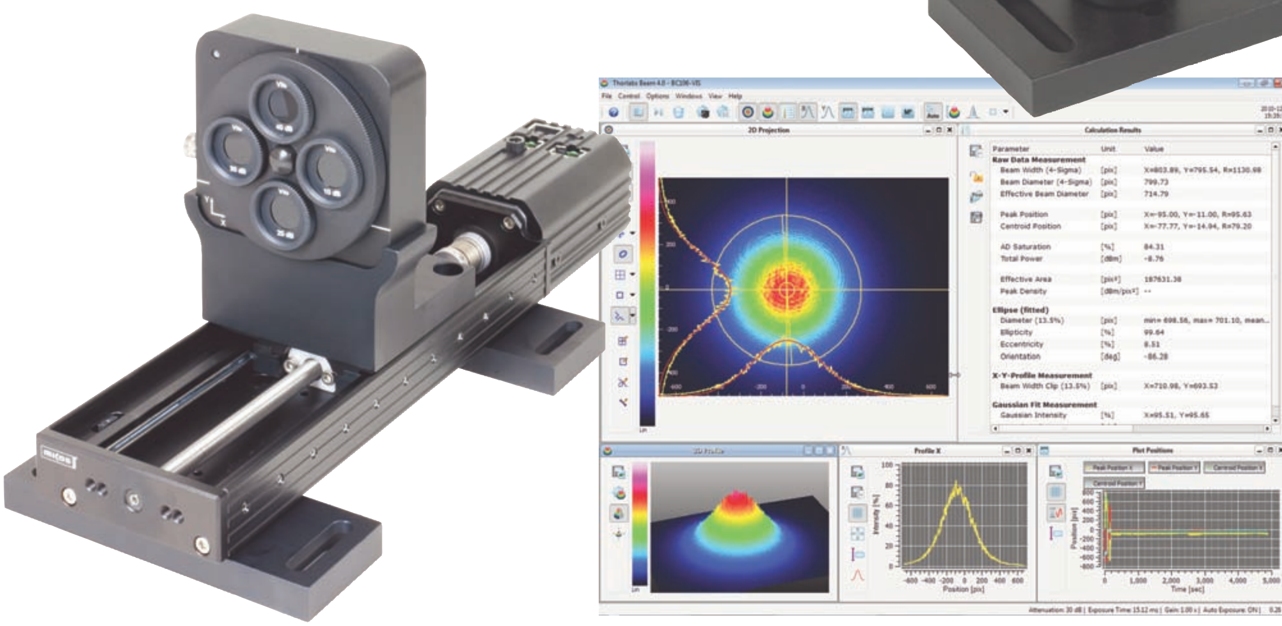
As computers become more powerful and software advances, interpretation of measurements made by beam profilers is expected to improve.

The current trend includes more automation, integrated pass/fail criteria for manufacturing, and video capturing. Future software releases will include functions and data acquisition capabilities that are even more sophisticated.

"The latest advances are related to the upgraded software interfaces to meet the needs of 64-bit operating systems," Wagner said. "Some of these have new Microsoft ribbon bar structures that make it easier to customize and use to position windows and results in the way the customer sees fit."

Ophir-Spiricon recently introduced an enterprise version of its BeamGage camera-based software. A Gigabit Ethernet camera can be remotely run from a BeamGage-enabled computer somewhere else on an intranet.

Historically, acrylic plastic is put in front of the beam to make a 3-D representation of the profile. Caution: Burning acrylic plastic produces carcinogenic fumes! Courtesy of Ophir-Spiricon.



For Thorlabs' beam profilers, optional extension kits for automated M^2 beam quality analysis are available. The software package can be downloaded for free from the company's website. Shown here is the BC100 series camera profiler. Images courtesy of Thorlabs.

"We see this as a fantastic advantage for labs and universities that want to have either (a) many cameras run from a single version of BeamGage, or (b) a camera shared by many users running multiple versions of BeamGage from anywhere in the world," Wagner said.

In terms of hardware advances, many attenuation schemes are being designed to meet customers' needs with ever-increasing power and energy. This is continually a challenge as powers have increased to greater than 50 kW for some of the new fiber lasers.

According to Thorlabs' Krollmann, an important challenge when it comes to developing camera profilers is improving the accuracy of the baseline in relation to background noise.

The accuracy of the baseline plays a crucial role when using the profiler for M^2 measurements to determine beam quality through analysis of multiple profiles along the beam path, he said.

Advances in camera technology are expected to reduce the cost of beam profilers. For example, thanks to heavy use in consumer products, CMOS cameras are improving quickly and are increasingly being adopted in profiling systems.

Newport's Jeong believes that beam profilers will take advantage of the slightly more slowly evolving, but nevertheless exciting, advances that are taking place in scientific camera technology.

"These include larger chip size, improved signal-to-noise ratio or dynamic ranges, higher frame rates and broader wavelength ranges," he said.

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