

SPC helps evaluate laser beams

Statistical process control (SPC) is a means to enhance productivity and product quality in industrial manufacturing. It is usually imperative to maintain statistical control of every process step since the entire production reliability is only as good as the weakest link. To date, however, there has been no way to obtain statistical data on the laser itself in industrial laser processes.

An industrial laser can slowly deteriorate over time because of aging or drift in laser components such as flashlamps, laser rods, mirrors, power supply components, or drift in cavity mirror alignment. Some of these

UNTIL RECENTLY,
THERE HAS BEEN
NO WAY TO OBTAIN
STATISTICAL DATA
ON THE LASER
ITSELF IN
INDUSTRIAL LASER
PROCESSES.

CARLOS B. ROUNDY

can lead to laser mode changes, which are usually accompanied by an enlargement of the laser beam width, which means a lower intensity or brightness at the work surface. When this happens operators turn up the power to bring the process back to the functioning level. However, increasing power often further increases the laser mode content, which generates even larger spot sizes.

On the other hand, there may be other elements in the process that can change while the laser remains stable. An example is that the materials being processed could increase or decrease absorption or reflection of the beam. Another change might be caused during routine maintenance or wear of mechanical assemblies, which could cause a change in the relative position of the focused point.

The challenge in process control with lasers is in knowing what has changed. Under current operations, there is no way of knowing whether it is the laser that has changed, or if some other element in the

process caused a problem. The dilemma is knowing where to begin troubleshooting in the case of problems. This dilemma

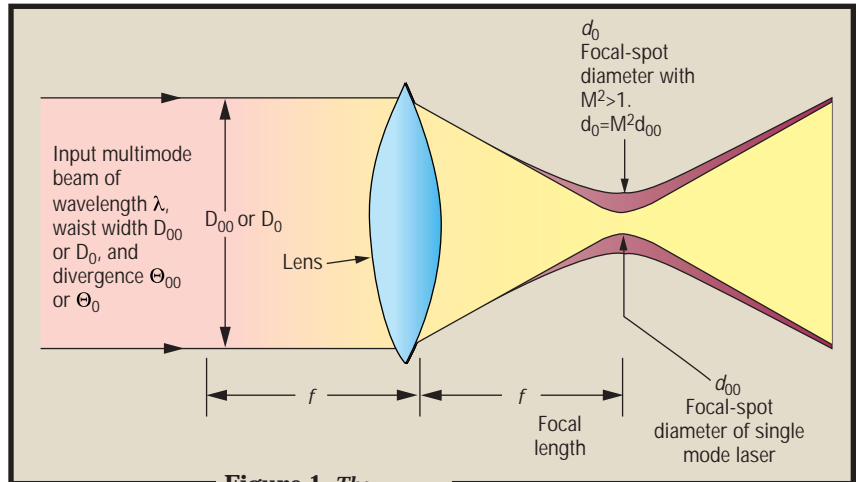


Figure 1. The diagram illustrates the effect M^2 has on the focusing characteristics of a laser beam.

results directly from the fact that there is no SPC on the laser itself.

Electronic beam analysis, which accurately measures laser parameters, can monitor pulse to pulse, or long-term laser beam stability. This can accurately predict whether or not there are pending problems with the laser. Alternatively, electronic beam diagnostics can accurately assure engineers that the laser is not a problem.

The most illuminating laser measurement There is one parameter that can most reliably reveal the overall performance of the laser. This is the beam propagation factor, called M^2 . As M^2 approaches 1, the focusability of the beam approaches the focusability of an ideal TEM_{00} Gaussian beam.

Figure 1 shows that the focused spot size, d_0 , is M^2 times larger than it would be for a pure TEM_{00} Gaussian beam of the same input width D_0 . Thus for a beam of $M^2 = 2$, the focused spot size is 2 times larger than would be obtained with a TEM_{00} beam. The brightness, which is proportional to the width squared, would be only one fourth of that achieved with a pure TEM_{00} beam. Thus, using this measurement an operator can predict precisely the brightness

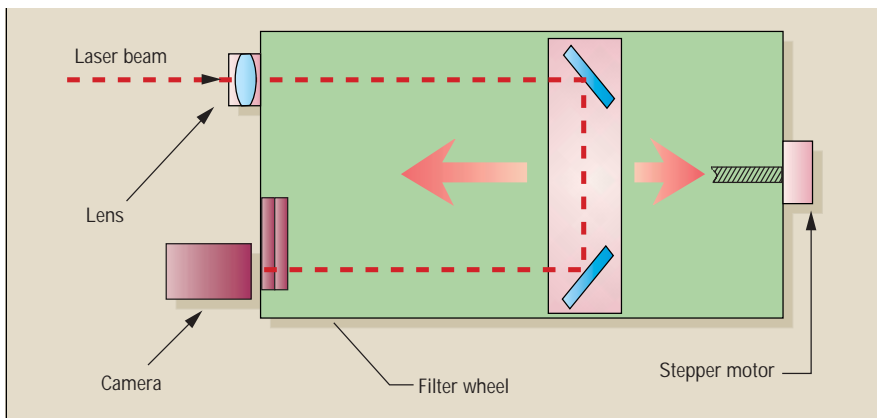


Figure 2. This M^2 measuring instrument allows a camera to make multiple beam-width measurements to calculate M^2 .

or irradiance of the beam at the work surface. M^2 is the one parameter that enables statistical process control on the laser itself, thus initiating statistical control on all subsequent operations.

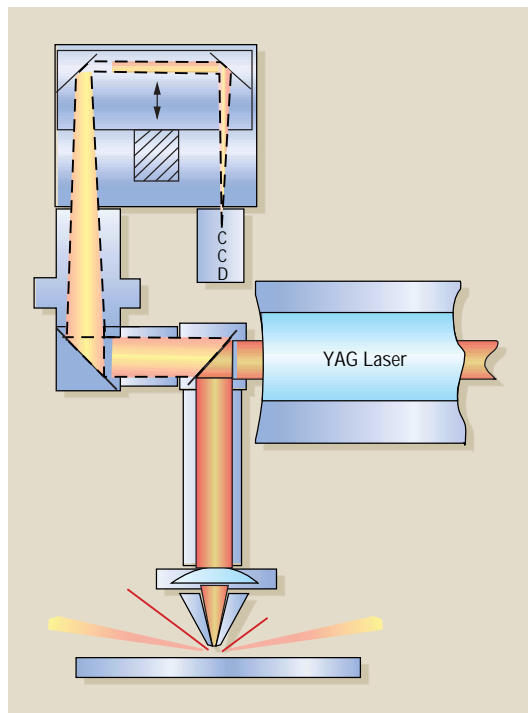
The use of M^2 has not been popular because measuring it is not an easy process. The ISO committee has defined a methodology, consisting of placing a lens of a known focal length in a laser beam, and then making a series of beam width measurements through the focused waist of the beam. Usually performing a curve fit to the measured data and calculating the M^2 parameters from the fit makes a more reliable measurement.

Measuring equipment

A number of commercial instruments are available to measure M^2 . One that follows the ISO standard has a focusing lens held at a fixed position in the beam, and the camera is effectively moved through the waist by mirror motion, as shown in Figure 2. Spiricon has developed specific industrial instrumentation, using this technique, that bolts directly and permanently to Nd:YAG lasers, as shown in Figure 3.

Once the laser has been tuned to the maximum efficiency, and the M^2 of the laser is well known, it is no longer necessary to leave the translation measurement device on that particular laser. However, it is desirable to track the M^2 at the same time the laser is processing materi-

als. Thus, an essential element in the instrumentation for industrial lasers is a beam-sampling device that splits out a very small fraction of the beam to be sent to the measurement instrumentation, while the majority of the beam is passed



directly to the work surface.

One option is a low-cost monitoring device, which can be mounted in place of the M^2 measurement instrument of Figure 3. The monitoring device continuously tracks the beam width, in the process generating statistical information on M^2 . This produces shot by shot and long-term statistical analysis to determine the stability and repeatability of the laser.

Once the M^2 measurement and monitoring instrumentation has been installed on the laser, operators can tune the laser to optimum operation and quantify the M^2 and other characteristics of the laser. During initial testing, a statistical profile of

The challenge in process control is knowing what has changed.

the laser stability can be generated. The operators can then develop range limits over which the laser can drift without affecting the manufacturing process. Then, when something in the process fails, a quick review of the laser performance will enable immediate identification of the problem.

Figure 3. A low-cost beam monitoring instrument can be permanently attached to industrial Nd:YAG lasers to aid in-process SPC efforts.

Using electronic laser beam diagnostics instrumentation, specifically on-line M^2 measurement instrumentation, the characteristics of industrial lasers can be accurately monitored. Thus, whenever a problem occurs in laser manufacturing, the operators have the ability to immediately decide whether to check the laser for deterioration or to check other parts of the process. It has been shown that this significantly reduces laser operating costs, which improves the profitability of the operation.

Additional reading:

See *Laser Focus World*, December 1999, pg.119, for an article giving a more-detailed explanation of M^2 .*

Carlos Roundy is president of Spiricon Inc., Logan, UT, (P) 435-753-3729, or president@spiricon.com or www.spiricon.com.