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# pitfalls of beam profiling

Accurate beam profiling requires careful attention to beam acquisition, detector parameters, and data processing.

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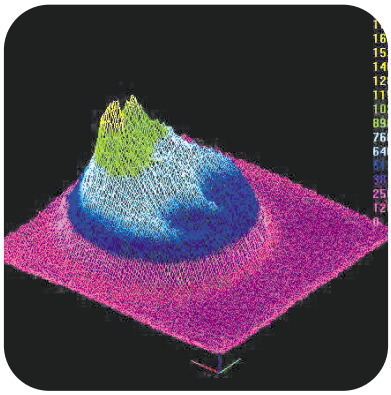
Perhaps the most basic laser beam diagnostic is a beam profile measurement. Successful beam profiling depends on careful attention to a number of conditions. The most important part of beam diagnostics is proper and correct beam sampling and analysis of the energy reaching the sensors.

The primary function of sampling is to obtain a small representative fraction of the beam. In order that the sampled energy is correctly viewed, it is critical that the sampling methods do not introduce artifacts. All reflecting surfaces of the splitting optics, for example, must be absolutely flat so the viewed beam will have the same profile as the actual beam. To avoid damage to the optics or thermal distortion that can introduce errors in the viewed beam, take care that the energy of the beam reaching the beam tap optics does not exceed either the damage threshold or the total allowable energy of the optics. The beam must not be significantly convergent or divergent for the measurements to be accurate. When sampling, also take care not to introduce polarization errors.

Proper alignment of the optics is also important. The angle of the sampling optics can distort the beam. Always make sure that the optics you use are at right angles to the beam whenever possible and that you view the beam orthogonal to the beam path.



Good sampling of a laser beam is the result of carefully chosen parameters.

Once the beam energy has been properly sampled, the next task is to ensure it is displayed correctly. If you're using a camera as a detector, you should be concerned with the pixel-to-pixel calibration of the camera. In addition, the pixel pitch of the camera array plays an important role in the resolution of the beam image. Since imaging chips are usually smaller than 8 mm × 6 mm, it is often necessary to resize the beam so that it fits on the sensor. Make sure that the beam can illuminate at least 100 pixel elements. Optics used to resize the beam must not introduce additional aberrations.

The sensitivity of an image sensor is wavelength dependent. If the system under test is monochromatic, it is only necessary to ensure that the detector is sensitive to the operating wavelength. For multi-wavelength or tunable systems, however, the profile recorded by the detector may not be the real profile. Charge-coupled-device (CCD) cameras can give misleading information if the wavelength of the beam causes false images in the array. For long wavelength systems like carbon dioxide lasers, for example, a pyroelectric array has been shown to be the most accurate device.

Take care to attenuate the energy reaching the camera sensor, if necessary, to prevent damage or saturation. Digitizing the signal is important, but in our opinion, there is little practical difference at this point between 8-bit and 12-bit digitizing. The beam structure is highly visible even at 256 levels of brightness, and adding the extra bits does not improve the situation.

## calculations

Once your detector captures an accurate beam image, the software can then process the information it receives. For some applications, a profile is merely used to optimize the beam. If you have a known beam shape, then other calculations apply.

The most frequent analysis is to calculate the beam widths along the x and y axes. A correct determination of beam diameter is critical in determining the efficiency of the laser operation. For a Gaussian beam, it is possible to determine the peak power or peak energy density of the beam using beamwidth and laser power or energy. For an alternate beam profile such as a top hat profile, a different calculation applies. Unless your beam is truly Gaussian, it is critical that the proper algorithm be used to determine the beam diameter. The two most common calculations are the 90/10 knife edge method, or the more popular D4 sigma calculation. The advantage of the latter is that the beam need not be Gaussian in order to obtain a correct diameter calculation. Care must be taken when performing this calculation, so make sure your software offers both methods.

In addition, the beam width is part of the measurement of the beam divergence, which predicts how large the beam will be at some point along the propagation path. Finally, the beam width must be made very accurately when determining the $M^2$ of the laser beam, which defines how close the beam is to a perfect Gaussian single mode. Advanced measuring software incorporates algorithms that compensate for camera noise and offset. It is a good idea to make sure that your beam profiling software also compensates for camera drift.

All the information collected is useless unless it is properly interpreted. Check with the analysis system vendor to see if they offer courses to improve your interpretation skills. This is often the best way to understand what you see. **oe**

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