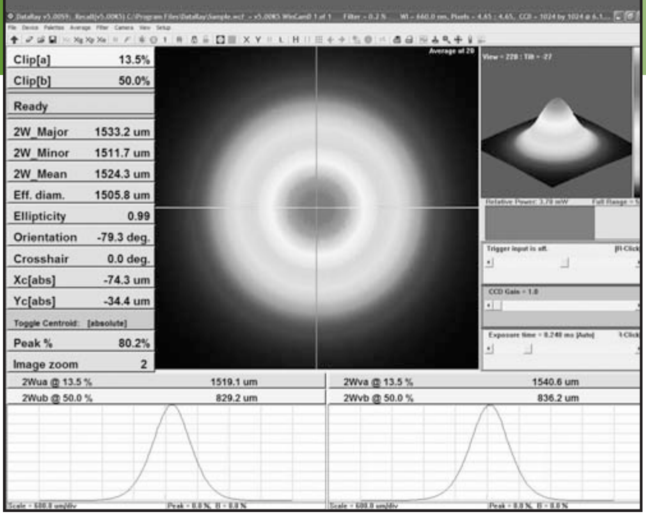
Measurement of Beam Profiles



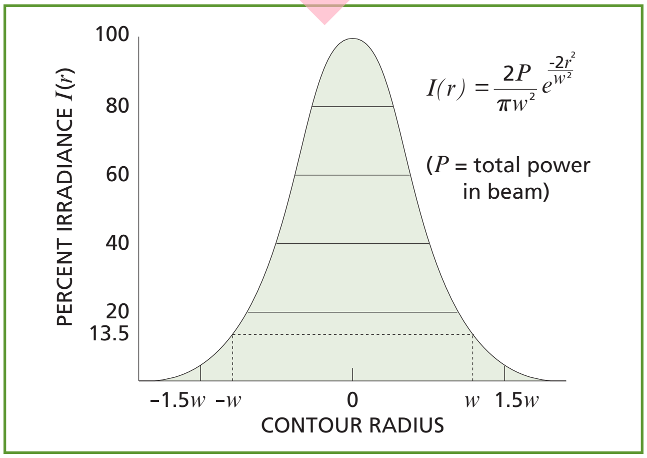
Clip[a]	13.5%
Clip[b]	50.0%
Ready	
2W_Major	1533.2 um
2W_Minor	1511.7 um
2W_Mean	1524.3 um
Eff. diam.	1505.8 um
Ellipticity	0.99
Orientation	-79.3 deg.
Crosshair	0.0 deg.
Xc[abs]	-74.3 um
Yc[abs]	-34.4 um
Toggle Centroid:	[absolute]
Peak %	80.2%
Image zoom	2

2Wua @ 13.5 %	1519.1 um	2Wva @ 13.5 %	1540.6 um
2Wub @ 50.0 %	829.2 um	2Wvb @ 50.0 %	836.2 um

As a laser beam propagates, its width and spatial intensity distribution will change in space and time owing to changes in the laser cavity and divergence, as well as interaction with optical elements. Spatial intensity distribution is one of the fundamental parameters that indicates how a laser beam will behave in an application. Laser printing, material processing, fiber-optic coupling, optical data storage, laser pumping, and photochemistry are some of the applications whose efficiency depends on a laser's spatial intensity profile and beamwidth. Theory can sometimes predict the behavior of a beam, but manufacturing tolerances in lenses, and mirrors, as well as ambient conditions affecting the laser cavity, necessitate verification. Consequently, it is crucial for researchers, system designers, and laser manufacturers to be able to measure these parameters accurately.

DEFINING BEAMWIDTH

The boundaries of optical beams are not clearly defined and, in theory at least, extend to infinity. Consequently, the dimensions of a beam cannot be defined as easily as the dimensions of hard physical objects. The commonly used definition of beam width is the width at which the beam intensity has fallen to $1/e^2$ (13.5%) of its peak value when measured in a plane that is orthogonal to the optical axis. This is derived from the propagation of a Gaussian beam and is appropriate for lasers operating in the fundamental TEM$_{00}$ mode. Many lasers, however, exhibit a significant amount of beam structure, and applying this simple definition leads to problems. Therefore, the ISO standard specifies the beam width as the $1/e^2$ point of the second moment of intensity, a value that is calculated from the raw intensity data and which reduces to the common definition for a Gaussian beam.



Gaussian profile of a TEM$_{00}$ mode (note the beam radius w at the $1/e^2$ (13.5%) intensity level)

MEASURING BEAMWIDTH

There are three main types of beam-profiling instrumentation: camera-based systems, knife-edge scanners, and slit scanners. Each has specific advantages and disadvantages. Different measurement techniques may result in slightly different results; therefore, it is critical that comparative measurements be made with the same technique.

Camera-Based Profilers

Camera-based profilers, which use a two-dimensional array of square or rectangular pixels as the imaging element, instantly record and display the

Beam Profiler Comparison Matrix

Description	WinCamD™ (CCD)	WinCamD™ (CMOS)
Part Number	13 SKD 574, 575	13 SKD 583, 584
Method of Measurement	CCD imager	CMOS imager
Measures	Image & profiles	Image & profiles
Measures with Accessories	Beam divergence	Beam divergence
Beam Requirements	cw & pulsed	cw & pulsed
Spectral Range Options (detector dependent)	350–1150 nm	300–1150 nm
Measured Beam Width (detector dependent)	50 μm–3 mm	50 μm–4.6 mm
Saturation Power (wavelength and diameter dependent)	100 mW @633 nm for 1-mm beam	100 mW @633 nm for 1-mm beam
Dynamic Gain Range	44 dB electronic shutter	44 dB electronic shutter
Beam Position Resolution	1 μm	1 μm
Beam Position Accuracy	±1 μm	±1 μm
Data Update Rate	5 Hz	5 Hz
Computer Interface	Port-powered USB 2.0	Port-powered USB 2.0

►

spatial and intensity information that impinges on the detector surface, providing a true three-dimensional profile of the beam. Camera-based profilers may be used with pulsed or cw lasers. Their resolution, in most cases, is limited by pixel size, restricting measurements to beams in excess of 60 μm. The μBeam™ profiler measures beams as small as 5 μm in diameter but is limited to a maximum beam size of 50 μm or less.

Knife-Edge and Slit Profilers

These instruments generate a profile by mechanically moving a slit aperture or knife-edge across the beam. Knife-edge profilers measure the portion of the beam that is not blocked by the knife and differentiate the result; slit profilers measure the amount of light passing through a narrow slit and integrate the result. A calculated beam profile is then displayed, based on the raw power data. In both systems, assumptions are made about the shape and uniformity of the beam being measured. These systems can measure beams as small as 0.5 μm, but they do not give information as complete as that given by camera-based systems. Three-dimensional tomographic reconstructions based on seven-blade scans are much more accurate than the three-dimensional reconstructions made by three-blade scans or seven-blade nontomographic scans.

M^2 Measurements

M^2 attachment (13 SKD 611) is designed to measure the beam propagation factor

$$k = \frac{1}{M^2} = \frac{\lambda}{\pi W_0 \theta}$$

where λ is the wavelength of the beam, W_0 is the beam waist, and θ_0 is the far-field divergence of the beam. If $k=M=1$, the beam is Gaussian. If k<1 ($M^2>1$), the beam is not Gaussian, but all of the standard Gaussian propagating formulas may be used with appropriate modifications. To calculate the propagation factor, M^2 meters first focus the beam and then measure the beam diameter both at the focus and at multiple points on either side of the focal point. A hyperbolic curve is fitted to the data points and various parameters are calculated including M^2, far-field divergence, beam waist, and beam waist location. The higher the number of data points is, the greater the accuracy will be.

μBeam™	BeamScope™-P8	Beam’R2™	BeamMap2™	BeamMap2 ColliMate™	BeamAlyzer™
13 SKP 80x	13 SKD 8xx	13 SKD 7xx	13 SKD 7xx	13 SKD 72x	13 SKP 7xx
CCD imager	Scanning slits or pinhole	Scanning slits	Multiplane scanning slits	Multiplane scanning slits	Scanning knife-edge
Image & profiles	x-y profiles	x-y profiles	Real-time x-y-z profiles, focus, divergence, pointing, M^2	Real-time x-y-z profiles, focus, divergence, pointing, M^2	x-y profiles, focus
n/a	2D image & M^2	n/a	n/a	n/a	n/a
cw & pulsed	cw; pulsed >5 kHz	cw; pulsed >100 kHz	cw; pulsed >100 kHz	cw; pulsed >100 kHz	cw
350–1310 nm	190–1150 nm 800–1800 nm 1800–3700 nm	190–1150 nm 650–1800 nm	190–1150 nm 650–1800 nm	190–1150 nm 650–1800 nm	190–1100 nm 400–1100 nm 800–1800 nm
0.5 μm (FWHM)	0.5 μm–25 mm	0.5 μm–3 mm	0.5 μm–4 mm	100 μm–4 mm	3 μm–9 mm
—	700 mW	400 mW	400 mW	40 mW	5 mW @633 nm 1 W @633 nm with NG9
—	42.5 dB	40 dB	40 dB	40 dB	—
—	1 μm	1 μm	1 μm	1 μm	1 μm
—	±1 μm	±1 μm	±1 μm	±1 μm	±15 μm
10–30 Hz	1–2 Hz	5 Hz	5 Hz	5 Hz	5 Hz
USB 2.0 / Stand-alone	USB 2.0	Port-powered USB 2.0	Port-powered USB 2.0	Port-powered USB 2.0	USB 2.0 / Stand-alone