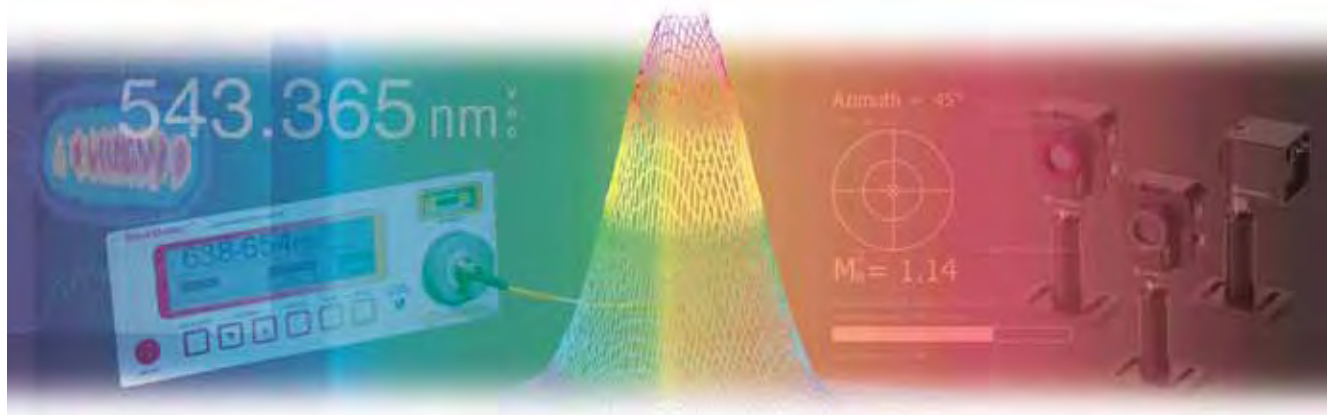


# Beam Diagnostics Introduction

## Introduction to Laser Beam Diagnostics

In today's fast-paced photonics market it is important to understand the technical specifications of highly complex laser systems and their applications. As well as analyzing the power or energy, it is also useful to understand the shape, intensity profile, and propagation of a laser beam. For over 25 years Coherent has developed precision instruments that measure,



### Beam Profilers

As a laser beam propagates, changes in the laser cavity, as well as changes in divergence and interactions with optical elements, cause the width and spatial intensity of the beam to change in space and time. Spatial intensity distribution is a fundamental parameter for indicating how a laser beam will behave in any application. And while theory can sometimes predict the behavior of a beam, tolerance ranges in mirrors and lenses, as well as ambient conditions affecting the laser cavity and beam delivery system, necessitate verification.

Two types of beam profilers are available: those that use special cameras as the beam detectors (these are excellent for fast and detailed analyses of the intensity profile of pulsed and CW lasers); and systems that use moving knife-edges (these have a large dynamic range and can accurately measure small and focused beams). Coherent has both of these types available: the camera-based LaserCam-HR on pages 74 to 75 and an advanced knife-edge system—BeamMaster—on pages 85 to 87.

### Beam Propagation

The Coherent ModeMaster beam propagation analyzer established an entirely new laser beam quality parameter that is now an ISO standard.  $M^2$  is recognized as describing both how “close-to-perfect Gaussian” a beam is, and also how well the beam can be focused at its intended target.

### Wavelength Meter

For many high performance tunable laser systems, or those using laser diodes, it is important to measure the wavelength. The WaveMaster laser wavelength meter accurately measures the wavelength of both CW and pulsed lasers of any repetition rate to an accuracy of 5 picometers. See page 94 for additional specifications for the WaveMaster.

Summary of Product Primary Measurement Capabilities	Model	BeamView Analyzer	BeamMaster	ModeMaster	WaveMaster
Wavelength		–	–	–	CW + Pulsed
Power / Energy		–	CW	–	–
Beam Position		CW + Pulsed	CW	CW	–
Propagation $M^2$		–	–	CW	–
Beam Profiles					
2D		CW + Pulsed	CW	CW	–
3D		CW + Pulsed	CW	–	–
Page Number		76	85	88	94

# LaserCam-HR

## Introduction to Camera-Based Beam Diagnostics

Coherent BeamView Analyzer systems are the recognized leader in software, hardware and optical components for laser beam analysis. Constant product improvement based on customer feedback, and innovation from beam analysis experts, have made BeamView Analyzer products the first choice for laboratory, factory and field measurements.

The key elements of a typical camera-based beam profiling system are the camera itself, Coherent Beamview analysis software running on an appropriate computer and, when necessary, beam attenuation optics. The key choice to make is matching the appropriate camera technology to your application.

Coherent beam diagnostic cameras are specifically designed or modified for laser analysis. They provide low noise, maximum linearity, and uniformity of response—needed for maximum measurement accuracy. All of these diagnostic cameras accept C-Mount optical accessories and are delivered without a cover (glass/plastic window) over the sensor array. Instead, a LDFP (Low-Distortion Face Plate) filter is supplied with each camera—a laser-grade neutral density filter made of glass specified and polished specifically for laser diagnostic analysis. The LDFP filter is mounted in a standard C-Mount ring and provides attenuation of ambient room light so that the camera can be used with normal room lights.

Coherent offers three families of cameras. Lasercam II and LaserCam IIID cameras use analog and digital interfacing respectively. The latest edition, LaserCam HR, is based on USB technology.

### USB 2.0 Beam Diagnostic Camera Family

Coherent pioneered the ease-of-use of digital USB 2.0 bus-powered, high-resolution, large-area cameras requiring only a single cable for both video transfer and camera power. The LaserCam-HR family of beam diagnostic cameras now includes the LaserCam-HR-UV and the LaserCam-HR-InGaAs models, extending the measurement spectrum from the deep ultraviolet to the near-infrared wavelengths.

The same features, performance and convenience previously available only for wavelengths covered by the LaserCam-HR are now available to users of excimer lasers, telecommunication sources and military laser systems. With a broad spectral range covering 190 nm to 1700 nm, there is a LaserCam-HR camera profiler system ideally suited for nearly any demanding laser measurement application.

### Important Considerations

- Ease-of-use connectivity
  - High-speed USB 2.0 Interface
  - USB bus-powered low voltage operation
- Broad spectral range
  - LaserCam-HR            300 nm to 1100 nm  
                                  (400 to 1100 nm with LDFP)  
                                  (190 to 355 nm with BIP-12F)
  - LaserCam-HR-UV        DUV to 355 nm
  - LaserCam-InGaAs        900 nm to 1700 nm
- Large dynamic range
- Coherent Adaptive Pixel Technology (CAPT)
- Digital output through USB 2.0 eliminates the need for an interface card (frame-grabber)
- High-accuracy beam diameter calculations
- Excellent beam spatial uniformity
- BeamView 4.4 application software



- Variable camera exposure time
- Compact size
- High-speed image capture rates (15 to 25 frames per second)
- Pass/Fail TTL level output
- RS-232 and TCP/IP communication protocols
- Comprehensive LabVIEW library suite for the majority of BeamView-USB software functions
- All LaserCam-HR camera systems are RoHS compliant

### Coherent Adaptive Pixel Technology

Coherent tests each LaserCam-HR camera through a process called CAPT (Coherent Adaptive Pixel Technology). This uses a calibrated lightsource and a digital look-up table to give pixel-to-pixel linearity correction. In addition, any identified “hot” pixel is corrected by averaging the value of the four directly surrounding pixel intensities. Finally, the noise levels are carefully monitored through both a background noise subtraction and a user-selectable bias noise offset level. The CAPT process optimizes the performance of the camera array, directly improving beam measurement accuracy, especially with beam diameter calculations.

Multiple channel camera support of different LaserCam-HR camera models is available for all three LaserCam-HR camera types (UV, visible, and InGaAs).

Variable camera exposure time available with the entire LaserCam-HR camera family allows imaging of higher repetition rate sources and lets the user decrease/increase the signal intensity levels using exposure time instead of external attenuation. This feature is especially suited for the LaserCam-HR-InGaAs, with its impressive spatial uniformity characteristics.

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# Beam Diagnostic Cameras

## LaserCam-HR and LaserCam-HR-UV



LaserCam-HR



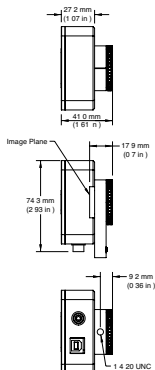
LaserCam-HR-UV

### Features

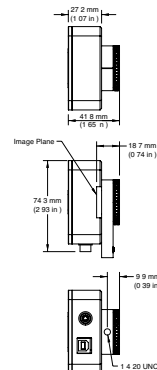
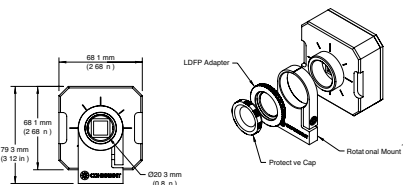
- USB 2.0, 10-bit digital output
- Large-area CMOS array, 8.5 x 6.8 mm
- Compact 68 x 68 x 34 mm package
- Coherent Adaptive Pixel Technology (CAPT) pixel-by-pixel offset, linearity and blemish correction
- CW and pulsed operation including external triggering
- Variable exposure time
- User-variable trigger delay
- Long-term UV sensor stability (with the LaserCam-HR-UV camera)
- C-mount thread for additional accessories

Device Specifications	Model	LaserCam-HR	LaserCam-HR-UV
Sensor Elements (pixels)		1280 x 1024	
Effective Pixel Resolution (µm)		—	20 x 20
Pixel Size (µm)		6.7 x 6.7	
Sensor Active Area (mm)(H x V)		8.5 x 6.8 (2/3 inch format)	
Spectral Range (nm)		300 to 1100 (without LDFP) 400 to 1100 (with LDFP included) 190 to 355 (with BIP-12F accessory)	190 to 355
Beam Diameters (mm)		0.2 to 6.0	0.5 to 6.0
Glassless Sensor		Low Distortion Face Plate is removable	
Low-Distortion Face Plate (LDFP, LDFP-UV)		Laser-grade ND filter, OD = 2.5 at 632.8 nm	UV-grade ND filter, OD = 3.0 at 248 nm
Electrical Interface		USB 2.0	
Capture Modes		Continuous (CW), pulsed	Continuous (CW), pulsed
Variable Exposure Time		1 msec to 1 sec, default at 10 msec	
Pulsed Mode Trigger Methods		Trigger In (TTL)	
Maximum Pulse Trigger in Rate (Hz)		100 (without averaging adjacent pulses)	
Maximum Frame Rate (FPS)			
Live video, no calculations		15	20
Capture with calculations		10	15
Damage Threshold		32 mJ/cm <sup>2</sup> (without LDFP) at 1064 nm	200 µJ/cm <sup>2</sup> (without LDFP-UV) at 248 nm
CW Saturation		40 mW/cm <sup>2</sup> (with LDFP) at 633 nm 16 µW/cm <sup>2</sup> (without LDFP) at 633 nm 800 mW/cm <sup>2</sup> (with LDFP) at 1064 nm 320 µW/cm <sup>2</sup> (without LDFP) at 1064 nm	90 mW/cm <sup>2</sup> (with LDFP-UV) at 248 nm 90 µW/cm <sup>2</sup> (without LDFP-UV) at 248 nm
Pulsed Saturation		8 mJ/cm <sup>2</sup> (with LDFP) at 1064 nm 3.2 µJ/cm <sup>2</sup> (without LDFP) at 1064 nm	5 mJ/cm <sup>2</sup> (with LDFP) at 248 nm 5 µJ/cm <sup>2</sup> (without LDFP) at 248 nm
USB 2.0 Cable		6 ft. standard A/B cable included	
Trigger Connector		BNC receptacle (trigger cable included)	
Part Number		1098577	1149004

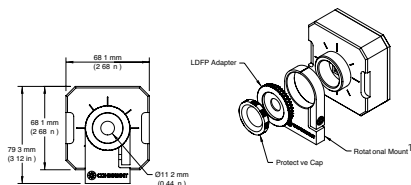
<sup>1</sup> Order part number 1086828 for metric mount.



LaserCam-HR



LaserCam-HR-UV



# Beam Diagnostic Cameras

## LaserCam-HR-InGaAs

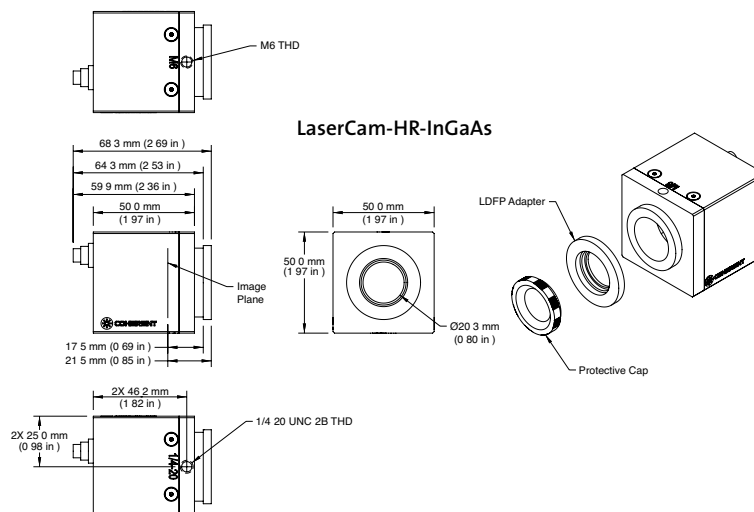


LaserCam-HR-InGaAs

### Features

- USB 2.0 large-area, InGaAs sensor, 9.6 mm x 7.7 mm
- 14-bit digital output providing >1000:1 optical dynamic range
- Outstanding linearity error of <1%
- 30  $\mu\text{m}$  x 30  $\mu\text{m}$  pixel pitch
- Compact 50 x 50 x 68 mm package
- CW and pulsed operation including external triggering
- Coherent Adaptive Pixel Technology (CAPT) pixel-by-pixel offset, linearity and blemish correction
- Variable exposure time, 20  $\mu\text{sec}$  to 25 msec
- User variable trigger delay
- C-mount thread for additional accessories

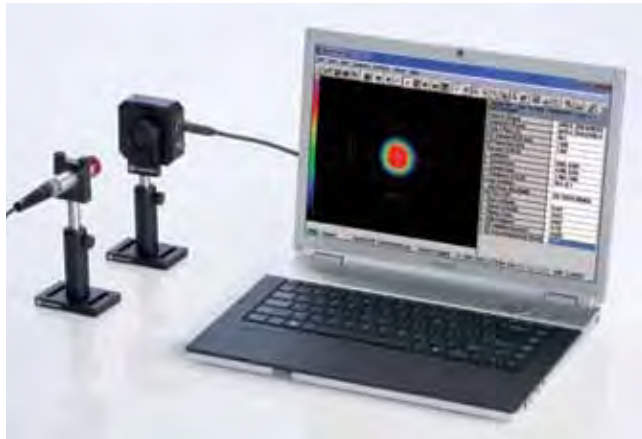
Device Specifications	Model	LaserCam-HR-InGaAs
Sensor Elements (pixels)		320 x 256
Pixel Size ( $\mu\text{m}$ )		30 x 30
Sensor Active Area (mm)(H x V)		9.6 x 7.7
Spectral Range (nm)		900 to 1700
Beam Diameters (mm)		0.5 to 6.0
Glassless Sensor		Low Distortion Face Plate is removable
Low-Distortion Face Plate (LDFP)		Laser-grade ND filter, OD = 2.5 at 632.8 nm
Electrical Interface		USB 2.0
Capture Modes		Continuous (CW), pulsed
Variable Exposure Time		20 $\mu\text{sec}$ to 25 msec, default at 1 msec
Pulsed Mode Trigger Methods		Trigger In (TTL)
Maximum Frame Rate (FPS)		25 (live video, no calculations), 15 (capture with calculations)
Saturation		
	CW (at 1064 nm)	3.5 mW/cm <sup>2</sup> (with LDFP), 50 $\mu\text{W}$ /cm <sup>2</sup> (without LDFP)
	CW (at 1523 nm)	350 $\mu\text{W}$ /cm <sup>2</sup> (with LDFP), 30 $\mu\text{W}$ /cm <sup>2</sup> (without LDFP)
	Pulse (at 1064 nm)	5 $\mu\text{J}$ /cm <sup>2</sup> (with LDFP), 0.08 $\mu\text{J}$ /cm <sup>2</sup> (without LDFP)
USB 2.0 Cable		6 ft. standard A/B cable included
Trigger Connector		BNC receptacle (trigger cable included)
Part Number		1149002



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# BeamView Analyzer Software

## Introduction to BeamView-USB Software



To monitor, analyze and archive laser beam images, BeamView Analyzer software is recognized as the leading laser beam profiling software. It has been designed to provide the maximum flexibility, speed, and user friendliness. Coherent offers two BeamView Analyzer software packages for maximum flexibility: BeamView Digital 3.2 is provided along

### Features

- High-speed USB 2.0 camera interface (BV-USB software only)
- Supports all three LaserCam-HR camera types
- Remote control interface
- Over 30 numerical analysis functions
- Multiple image import and export formats
- Automatic background noise subtraction
- Pass/Fail fault settings, alarms, configurable setups
- Easy-to-use, intuitive user interface
- BeamView Digital: Windows XP only
- BeamView-USB: Windows XP, Vista 32-bit, Vista 64-bit (with LaserCam-HR and LaserCam-UV cameras only), Windows 7 32-bit, Windows 7 64-bit (with LaserCam-HR and LaserCam-UV cameras only). 64-bit compatibility was released in BeamView 4.4.2.

with LaserCamIIID digital cameras. BeamView-USB 4.4 is included with all LaserCam-HR USB 2.0 cameras and provides additional new features.

## BeamView-USB Analyzer Software

### BeamView-USB Analyzer Software

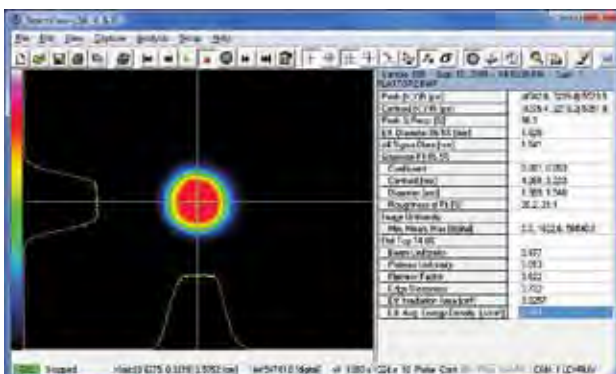
The latest release of the BeamView-USB 4.4 software includes several new features that extend the analytic capabilities of the LaserCam-HR laser beam diagnostic systems. These new features, not available with Analog or Digital BeamView Analyzer Software, include:

- Supports both 10-bit and 14-bit LaserCam-HR camera types
- Multiple LaserCam-HR camera types can be connected to a single system
- Flat-top beam analysis
- Adjustable trigger delay
- Report generation
- Variable exposure time
- LabVIEW drivers
- RS-232 and TCP/IP remote communication protocols

### Flat-Top Beam Analysis

Six additional calculations are now available with BeamView-USB software for flat-top beam analysis. These calculations are based on the ISO 13694:2000 standards. The six calculations allow greater flexibility for the analysis of applications involving flat-top beam shapes. They also may assist in the analysis of beam uniformity of excimer and Nd:YAG lasers in the near field. The six new calculations are:

- Plateau Uniformity
- Flatness Factor
- Edge Steepness
- Beam Uniformity
- Effective Irradiation Area
- Effective Average Power/Energy Density



Screen shot of a flat-top beam image



Image of dialog box for flat-top calculations.

# BeamView Analyzer Software

## BeamView Analyzer Software Features

### Adjustable Trigger Delay

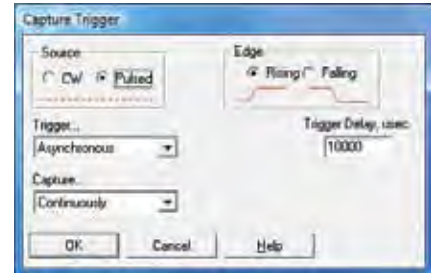
A new adjustable Trigger Delay feature in the BeamView-USB 4.4 software lets users add default trigger delay to the LaserCam-HR camera. This assists by providing additional flexibility when firing the camera from an external trigger source such as the SYNC Output of a laser.

### Adjustable Exposure Time

The camera exposure time is adjustable through the camera settings menu for all LaserCam-HR camera models.

### Report Generation

BeamView-USB includes a single-page report that can be sent directly to a printer, saved to a file (.txt), or converted to an Adobe .pdf file by using a pdf file converter. A simple screen print option is available from the same friendly dialog box used to generate a report.

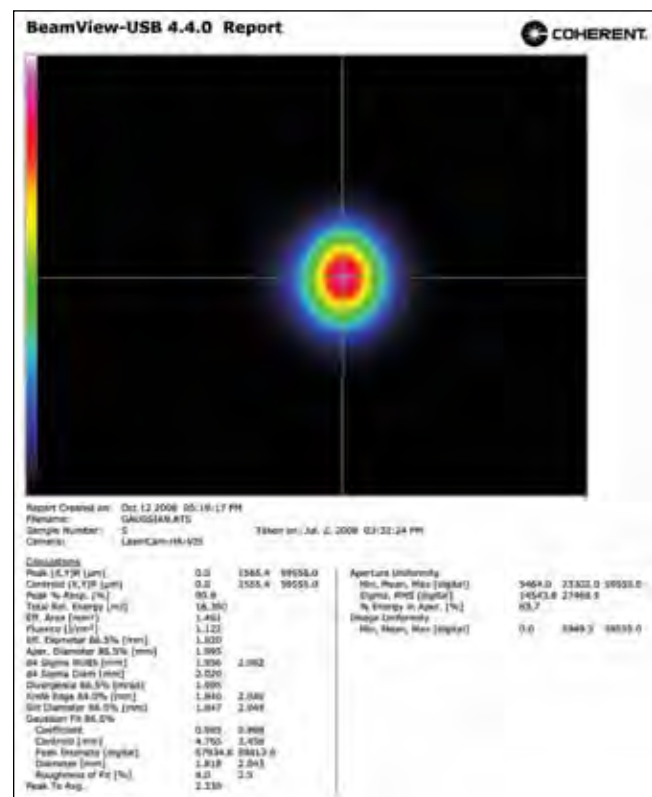


Screen shot of Capture/Trigger dialog box showing Trigger Delay setting

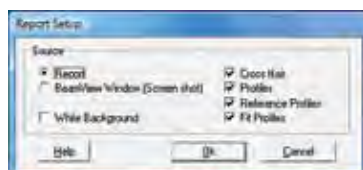
## BeamView System Performance Optimization

All BeamView Analyzer software provides several functions that optimize the optical dynamic range available in the camera to achieve maximum measurement accuracy. The Automatic Background subtraction feature measures and stores the background noise "image" and automatically

subtracts individual pixel noise levels from all subsequent laser images prior to analysis. The system also automatically monitors the background noise level to warn of changes that may effect measurement accuracy.



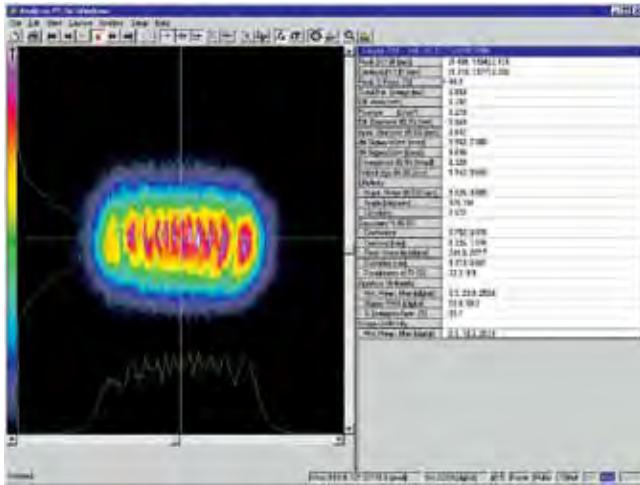
Screen shot of Print Screen dialog box and actual report



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# BeamView Analyzer Software

## BeamView Analyzer Software Features



### Real-Time Laser Monitoring and Alignment

The Live Video mode provides a continuously updated image of the beam (~20 Hz to 25 Hz, depending on the speed of the processor) displayed in shades of gray or pseudo-color. This mode is ideal for monitoring the laser and observing changes in the form and structure of the beam as it is adjusted. It also allows for real-time tuning to achieve optimum beam profile quality and laser-cavity alignment. While operating in this mode, no beam or statistical data are displayed, but if Run is activated, the image is stored and can be analyzed later.

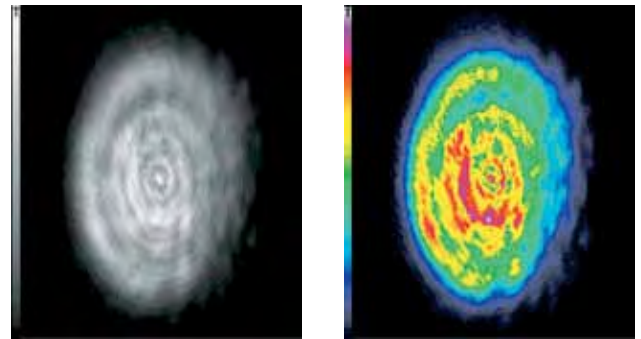
### 2D and 3D Intensity Plots

The Run command switches the BeamView Analyzer from the Stop or Live Video mode to continuous operation, which provides capture, analysis and display of beam image data. The view area of the computer monitor provides a choice of 2D or 3D images. The 2D contour maps and the 3D isometric plots display laser beam intensity profiles in a choice of color and gray-scale styles (fixed and autoscaling to a peak) and sizes

### BeamView Analyzer Software Additional Features

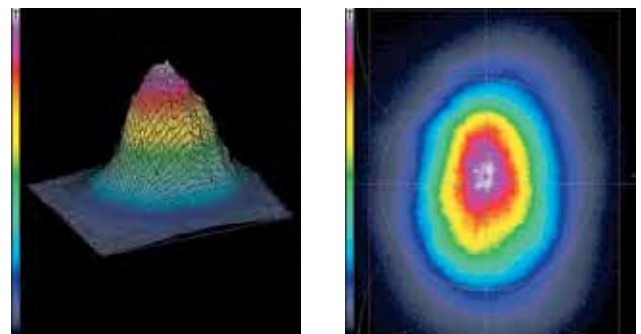
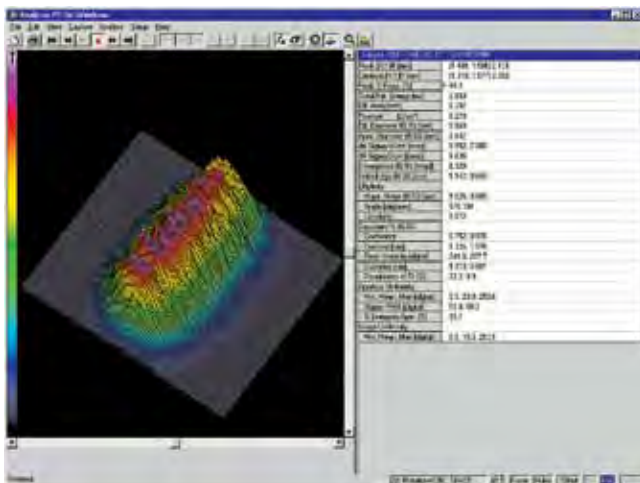
The following BeamView Analyzer features are common among both BeamView software platforms:

- More than 25 different numerical analysis functions
- Several different profile views
- Multiple image import and export formats
- Import and export of results data and profile data
- Pass/Fail settings and user-selectable fault actions



The Live Video mode

(continuous zoom and pan control). The 2D maps can be shown with or without profiles (and Gaussian fit), reference position, variable aperture and rotatable crosshairs (with auto peak and auto centroid location). The 3D isometric plots can be displayed with transparent, hidden or solid wires, and can be rotated and viewed from different tilt angles.



Choice of 3D and 2D images

BeamView Analyzer display with 3D image and ISO-compatible results

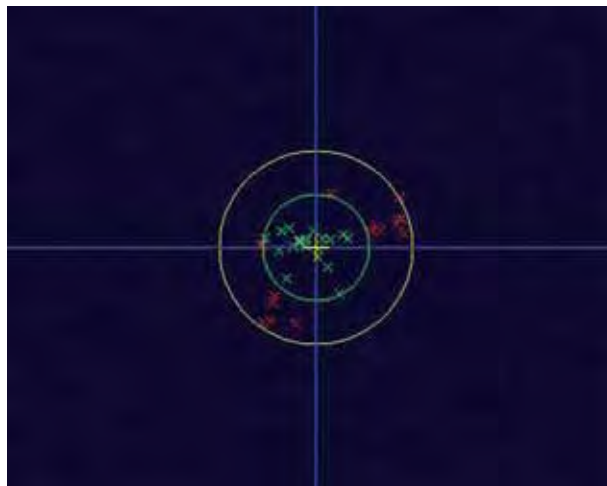
# BeamView Analyzer Software

## BeamView Analyzer Software Features

### Beam Stability

The continuous on-line statistical analysis display shows results of all, or a combination of, functions and pass/fail parameters for all captured samples and accumulated results. The user can scroll through the analysis results of individual images, and also view the minimum, maximum and sigma (standard deviation) values. This makes comparing individual samples to the time-dependent statistical data easy. Thus, the jitter and stability of parameters, such as power, energy, pointing direction, ellipticity and beam size, etc., can be analyzed simultaneously with a polar beam wander plot.

Continuous on-line statistical analysis display



Polar beam wander plot screen

### Remote Control

The BeamView Analyzer provides remote control and data transfer through the host computer's RS-232 (and TCP/IP with BeamView-USB). A complete control and data transfer command set is provided to allow users to develop their own remote control application for interfacing with the BeamView Analyzer software platform. The BeamView-USB software package includes a full suite of LabVIEW libraries for remote access to most BeamView features at a host computer running LabVIEW.

### Beam Analysis and Statistics

BeamView Analyzer software calculations are compatible with the International Standards Organization (ISO) guidelines for laser beam measurement:

- Peak and centroid beam position
- Beam ellipticity including angular position and major/minor axis information
- Circularity
- $D4\sigma$  diameters and widths
- Gaussian fit including coefficient, centroid, and "roughness of fit"
- Aperture fit and uniformity
- Total/relative power
- Peak power/energy density
- Percent power within an aperture

The BeamView analyzer system also includes several other analysis features listed in the BeamView Analyzer Software Features Summary on page 80.

### Pass/Fail Analysis

Pass/fail analysis allows simultaneous real-time monitoring of all, or any one of the analysis results against user-specified minimum/maximum limits. Any combination of, or all the fault actions can be activated to signal a test failure, initiate a visual alarm, an audio alarm, stop data capture, reject/save a failed sample, and generation of a TTL trigger pulse output signal.



Calculations Pass/Fail test settings

Fault Actions Dialog Box

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# BeamView Analyzer Software

## BeamView Analyzer Software Features Summary

### Analysis, On-Line Pass/Fail Tests

- Centroid position/wander
- Peak intensity/position
- Peak-to-average intensity
- Beam diameter/widths (selectable):
  - Second moment ( $\delta_4$  Sigma)
  - Knife-edge
  - Slit
  - Aperture diameter
  - Effective diameter
- Flat Top analysis (new in BeamView-USB 4.4):
  - Beam uniformity
  - Plateau uniformity
  - Flatness factor
  - Effective irradiation area
  - Edge steepness
  - Effective average power/energy Density
- Gaussian fits with:
  - Correlation coefficient
  - Diameter
  - Centroid
  - Peak intensity
  - Fit roughness
- Ellipticity at intensity slice:
  - Major and minor axis diameter
  - Circularity (major/minor)
  - Axis orientation (rotation)
  - Auto align profiles to axis
- Aperture analysis for circular, square, rectangular and elliptical beams:
  - % power/energy in aperture
  - Uniformity in aperture
  - Aperture/diameter tracking
- Selectable calculation area
- On-line statistical analysis (all results):
  - Minimum, average, maximum
  - Sigma (standard deviation)
- Pass/Fail test with fault action (all results):
  - Ratio
  - Audio/visual alarms
  - Save/reject images
  - TTL pulse out
  - Stop data capture
- Image averaging
- Peak energy/power density
- Relative energy/power
- Effective area
- Divergence at % energy/power

### Interactive Display Functions

- On-line help
- Report generation (new in BeamView-USB 4.4):
  - Report (.pdf)
  - BeamView window (screen capture)
- Stored image paging
- Reference profile select
- Reference coordinate set
- Background subtraction
- Run/stop data analysis
- Control of cursors, profiles, aperture, position, rotation and size
- Live video on/off
- 7 zoom levels
- Image and profile autoscale modes
- Auto peak/centroid locate
- A/D converter control (analog only)
- "Hot" function keys

# BeamView Analyzer Software

## BeamView Analyzer Software Features Summary

### Image Capture and Storage

- Pulsed or CW (continuous) analysis
- Multi-channel (not simultaneous) camera input
- Support for multiple camera types (new in BeamView-USB 4.4)
- Adjustable camera exposure time (new in BeamView-USB 4.4)
- Image storage to:
  - PC RAM drive
  - PC hard drive
- RS-232 and TCP/IP communication protocols
- Comprehensive suite of LabVIEW libraries
- Multiple trigger modes:
  - External (asynchronous, trigger input)
  - Autotrigger to a selected level
  - Synchronous (trigger output, BeamView Digital and Analog software only)
- 3 resolution modes with BeamView-USB 4.4 with the LaserCam-HR and LaserCam-HR-UV cameras:
  - 1280 x 1024 x 10
  - 640 x 512 x 10
  - 640 x 512 x 8
- 1 resolution mode with BeamView-USB 4.4 with the LaserCam-HR-InGaAs camera:
  - 320 x 256 x 14
- 3 resolution modes with BeamView Digital:
  - Frame (752 x 480 pixels)
  - Full-Field (376 x 240 pixels)
  - Half-Field (188 x 120 pixels)
- Various capture modes:
  - Continuous
  - Time interval
  - On command (keypress)
- High-speed sample mode capture
- Profile storage
- Configuration storage with password protection
- Image data file formats in binary (bin), ASCII (img), bmp, jpg, png, tif

### Calibration Functions

- Fully automatic background map correction (pixel-by-pixel) with bias offset
- Automatic background monitor and warning
- Automatic A/D offset/gain set (analog only)
- Optical scale factor (magnification/reduction)
- Far-field optic focal length
- Camera pixel size (horiz. and vert.) (analog only)
- Power/energy calibration factor

### Standard Graphics Feature

- Contour map with profiles/aperture overlay:
  - 3 plot types (contour/2D, 3D, Polar)
  - 4 scaling levels (fixed, scale-to-peak, low intensity, high intensity)
  - 4 style settings (gray, smooth, sharp, shaded bands)
- Live video mode
- Calculation inclusion area display
- Profile/peak/centroid position cursor
- Graphic zoom
- Auto-scale 2D or profile intensity
- Polar beam wander plot
- On/off axis simultaneous display of:
  - Position cursor
  - Cross-section profiles
  - Gaussian fit profiles
  - Reference profiles
  - Aperture overlay for:
    - Beam uniformity
    - % energy/power
- Rotatable color 3D isometric plot
  - 360°, 90° rotate/tilt
  - Hidden/transparent wire
  - Selectable wire density
  - Solid or single color
  - Auto-rotate mode

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# Beam Diagnostic Accessories

## Laser-Grade Attenuation Optics for Cameras



Attenuation Optics and Accessories

### Features

- Laser-grade attenuation optics
- Compatible with all Coherent beam diagnostic cameras
- Virtually undistorted and interference-free attenuation
- Variable and fixed attenuation for beams up to 2000W/cm<sup>2</sup> or 50J/cm<sup>2</sup>
- C-Mount threads couple directly to cameras

Most cameras are too sensitive for direct viewing of laser beams. For example, a typical diagnostics camera saturates at only  $\sim 0.5 \mu\text{W}/\text{cm}^2$  power density (at  $\sim 633 \text{ nm}$ ) or at  $\sim 9 \text{ nJ}/\text{cm}^2$  (at  $1064 \text{ nm}$ ) pulsed energy density. If the camera has an electronic shutter, it can be used for some CW beam attenuation, but there is more flexibility in using optical attenuation. Any attenuation optics introduced in the beam path must be manufactured to exacting specifications. The optics must be laser-grade substrate, and use the proper flatness and wedge to avoid etaloning and fringing, so that the beam is not distorted by the introduction of the attenuation. We offer attenuation optics that are designed to these specifications and packaged for use with our cameras.

Typical attenuations are 1:1 to 400,000:1, but even larger attenuations are possible. All Coherent diagnostic cameras accept C-Mount optics and accessories, and are delivered without a standard window in front of the sensor array. Such windows are liable to distort the optical beam. However, a LDFP (Low-Distortion Face Plate) filter is supplied with each camera purchased from Coherent. The LDFP is a laser-grade optic specified and polished for diagnostics use. It is mounted in a housing with C-Mount threads and provides attenuation of room light so that the camera can be used with the lights on. For operation below 400 nm, the LDFP must be removed.

The Continuously Variable Attenuator Modules (C-VARM and UV C-VARM) contain two wedge attenuators that are continuously variable and a step attenuator that allows attenuation from  $10^7:1$  down to  $3000:1$ . The C-VARM and UV C-VARM can be finely adjusted to achieve both precise attenuation levels and maximum use of the camera's optical dynamic range.

The Variable Attenuator Module (VARM) is a triple-wheel filter holder that contains three filters per wheel. The filters are made to our exacting specifications for transmission value and material quality. The VARM is adjustable in attenuation in 64 discrete steps of approximately 16% reduction each time from  $400,000:1$  down to  $1:1$ . The VARM can be easily returned to exactly the same attenuation level as previously used.

The BeamCUBE Fixed-Attenuator Modules (BCUBE and UV-BCUBE) provide fixed attenuation and beam pickoff for performing diagnostics on high-power laser sources. The BCUBE and UV-BCUBE utilize the front surface reflection from an uncoated laser mirror to achieve beam samples at 2% to 10% of the incident radiation, depending upon beam polarization. Multiple BCUBEs can be coupled together for even higher fixed attenuation levels.

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# Beam Diagnostic Accessories

## Attenuation Optics for Cameras

BCUBE, UV-BCUBE, VARM, C-VARM, UV C-VARM and all other Coherent cameras have female C-Mount threading, making them easy to connect with the male C-Mount connection flange provided with each attenuator. Also, all attenuators have 1/4-20 tapped holes for independent post or plate mounting.

The C-Mount flanges (threaded rings) also have a female RMS microscope thread. This allows a microscope objective to be coupled to the attenuators and extension barrels in order to create a flexible close-up imaging system for analysis of small/focused beams, fiber optics, laser diodes or LEDs.

### Avoiding Multi-Filter Beam Distortion

The wavefront distortion through a number of optical filters can be calculated by taking the square root of the sum of the squares of the wavefront distortion of the individual components. For example, if the individual optics are made to  $\lambda/10$  specifications and six are used, a total  $\lambda/4$  RMS wavefront distortion will be introduced to the beam:

$$\sqrt{0.1^2 + 0.1^2 + 0.1^2 + 0.1^2 + 0.1^2 + 0.1^2} = 0.25$$

In general, a camera cannot sense less than  $\sim\lambda/4$  total distortion in the beam, so if a series of filters is used, they must be made to very exacting laser-grade specifications. Attenuating optics from Coherent are manufactured to better than a  $\lambda/10$  surface specification, so at least six optics in series can be used. Calculate the Low-Distortion Face Plate (LDFP) and each BCUBE as one optic, and the VARM or C-VARM as three optics each.



VARM, LaserCam-HR-InGaAs, C-VARM, BCUBE, C-Mount Flanges and Barrel

### Attenuator Selection

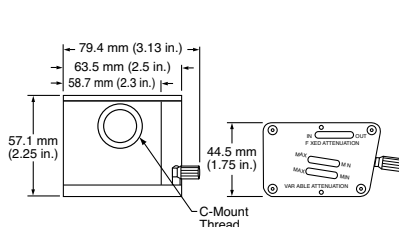
Attenuation is selected on the basis of power density in  $W/cm^2$  or energy density in  $J/cm^2$ . The attenuation from the camera's Low-Distortion Face Plate (LDFP) will allow an average power density of up to  $1.2 \text{ mW/cm}^2$ . There are then only two more steps to attenuation selection:

- 1) Choose either the VARM or the C-VARM for up to  $1W/cm^2$ .
- 2) In addition or alternatively, use a BCUBE beamsplitter module to pick off between 2% and 10% of the beam (depending on polarization and wavelength).

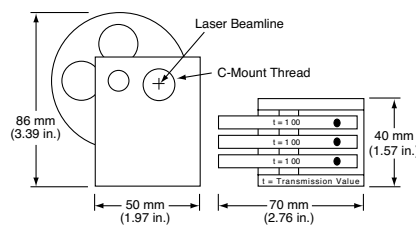
Device Specifications	Model	VARM	C-VARM	UV C-VARM	BCUBE	UV-BCUBE	BARREL SET (Barrels, 3 C-Mount Flanges)
Wavelength							
Min. (nm)		380	380	190	380	190	—
Max. (nm)		2200	2200	1100	2200	2200	—
Attenuation							
From		$4 \times 10^5:1$	$10^7:1$	$10^5:1$	50:1	50:1	—
To		1:1	3000:1	300:1	10:1	10:1	—
Aperture (mm)							
		19	17	17	19	19	—
Max. Power Density ( $W/cm^2$ )							
		1*	1*	1*	$2.0 \times 10^9$	$2.0 \times 10^9$	—
Max. Energy Density ( $J/cm^2$ )							
		0.1*	0.1*	0.008	50	50	—
Damage Limit							
( $W/cm^2$ )		$5 \times 10^7$	$5 \times 10^7$	—	$2.5 \times 10^9$	$2.5 \times 10^9$	—
( $J/cm^2$ )		10	10	0.008	50	50	—
Beam Offset (mm)							
		—	—	—	4.0	4.0	—
Part Number							
		33-3328-000	33-3336-000	33-6859-000	1098403	1098466	1098426

\* The maximum power and energy density listed are the levels at which thermal lensing occurs.

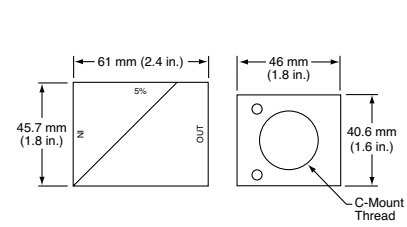
### C-VARM and UV C-VARM



### VARM



### BCUBE and UV-BCUBE



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# Beam Diagnostic Accessories

## Extreme-UV Beam Intensity Profiler (BIP) Optics

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BIP-5000Z and BIP-12F attached to a LaserCam-HR



BIP-5000SPL Beamsplitter

### Features

- UV operation from 10 nm to 355 nm
- Choice of 12 mm or 30 x 40 mm diameter apertures
- Operation with BeamView Analyzer Systems

These Extreme-UV Beam Profiler Optics use UV-to-visible fluorescence converter face plates to couple the input laser beam to any appropriate Coherent camera. Any of our visible wavelength range cameras can be used with the Beam Intensity Profilers.

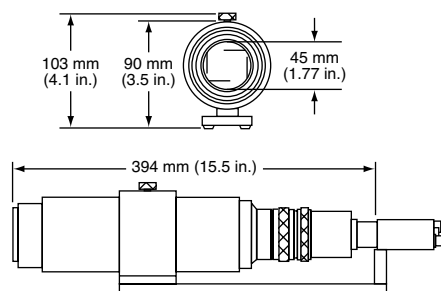
The Beam Intensity Profiler BIP-12F is a compact system accepting beams up to 12 mm in diameter from 10 nm to 355 nm. The front of the BIP-12F has a C-Mount thread, which allows it to be used in conjunction with the UV BeamCube when high-power attenuation is needed for the spectral region 190 nm to 355 nm (see Laser-Grade Attenuation Optics for Cameras on page 82). The Beam Intensity Profiler BIP-5000Z has a zoom magnification range of 6:1 to 1:1 and accepts beams up to 30 mm by 40 mm from 10 nm to 320 nm. It comes with the mount shown.

### BIP-5000SPL Beamsplitter

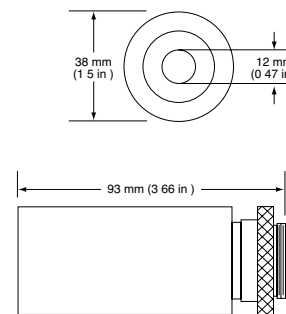
When laser beam power or energy density exceeds recommended ranges, this beamsplitter provides additional high-power attenuation capability for the BIP-5000Z. It provides a right-angle pick-off function and attaches to the entrance aperture of the BIP-5000Z.

Device Specifications	Model	BIP-12F (2:1)	BIP-12F (1:1)	BIP-5000Z	BIP-5000SPL
Wavelength (nm)		10 to 355		10 to 320	10 to 320
Aperture (mm)		Ø12		30 x 40	Ø50
Resolution (camera-dependent)(µm)		20		70	–
Saturation					
at 193 to 248 nm		10 mJ/cm <sup>2</sup>		30 mJ/cm <sup>2</sup>	–
at 308 nm		50 mJ/cm <sup>2</sup>		50 mJ/cm <sup>2</sup>	–
Sensitivity		5 µJ/cm <sup>2</sup>		5 µJ/cm <sup>2</sup>	–
Damage Threshold					
CW		5W/cm <sup>2</sup>		1.5W/cm <sup>2</sup>	10W/cm <sup>2</sup>
Pulsed		500 mJ/cm <sup>2</sup>		600 mJ/cm <sup>2</sup>	50 J/cm <sup>2</sup>
Uniformity Over Aperture (%)			5		–
Image Persistence (fluorescence lifetime)		500 ns		5 µs	–
Image Magnification		2:1	1:1	6:1(Zoom) to 1:1	–
Part Number		33-3468-000	1053418	33-3484-000	33-3492-000

BIP-5000Z



BIP-12F



# BeamMaster

## Knife-Edge Beam Profiler



BeamMaster System (rotational mount shown is an option and is not included)

BeamMaster is a high-precision, multiple knife-edge scanning laser beam profiler which can be configured to sample, measure and display cross-sectional profiles and/or 2D and 3D image plots in real time up to 5 Hz. Selectable averaging of 1 to 20 samples provides noise reduction and maximizes measurement accuracy. Data can be collected, displayed, stored and continuously streamed to the RS-232 port. All screen images can be captured and stored, or be printed to any Windows-supported printer.

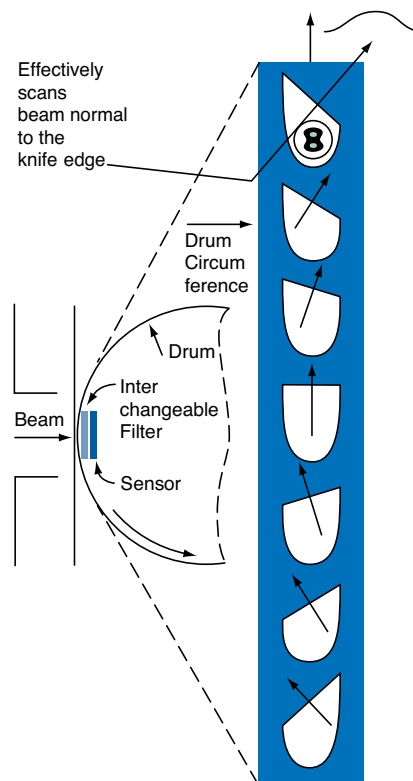
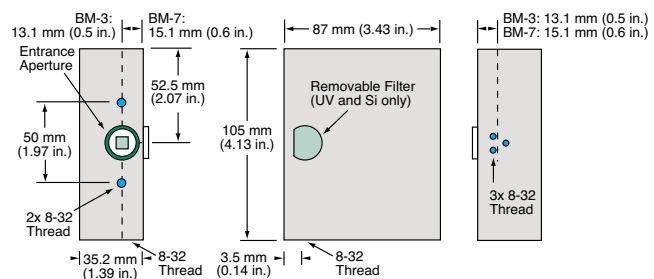
BeamMaster can measure focused beam spots as small as 3  $\mu\text{m}$  with 0.1  $\mu\text{m}$  resolution and has an aperture as large as 9 mm with 1  $\mu\text{m}$  resolution for larger beams. Measurements can be made from 190 nm to 1100 nm (Si-Enhanced) and from 800 nm to 1800 nm (InGaAs). Input powers can be as low as 10  $\mu\text{W}$ . There is automatic gain control and two internal distortion-free optical attenuation filters are included (Si-Enhanced models)

### Multiple Knife-Edges for Greater Resolution and Accuracy

BeamMaster is an advancement over the more common types of beam profilers, which use two orthogonal knife-edges or slits to scan the beam profile. The BeamMaster model BM-7 uses seven individual knife-edges on a rotating drum to scan the beam through seven different axes in a single rotation. This provides more accurate measurements of the true beam shape and dimensions by tomographically combining the data from all seven scans to reconstruct a profile of the beam. This technique also makes locating the angular orientation of elliptical beam major/minor axes much easier than searching by rotating the sensor head around the optical beam axis. For applications with circular or near-Gaussian beams, the lower-cost BM-3, with only three knife-edges, is also available.

### Features

- CW laser beam shape, power and position measurements
- Beam sizes from 3  $\mu\text{m}$  to 9 mm with 0.1  $\mu\text{m}$  resolution and high dynamic range
- Real-time Windows display, analysis and data logging system
- Wavelengths from 190 nm to 1800 nm



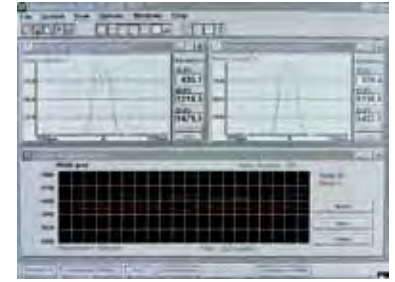
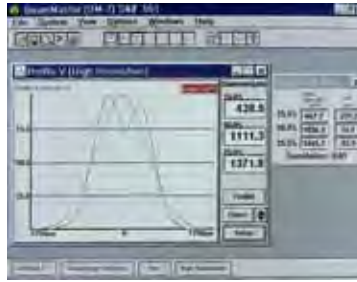
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# BeamMaster

## Knife-Edge Beam Profiler

### Beam Profiles and Widths

On each rotation of the drum, BeamMaster captures and processes the data from the passage of the seven knife edges across the beam (three knife edges with BM-3) as power, position and profile information. This information can be displayed every rotation, be strip-charted, and be sent to file or to the RS-232 port. Two orthogonal profiles can be displayed and the beam widths can be digitally displayed for any three user-chosen clip levels. A Gaussian-fit profile can be overlaid on any chosen measured profile and the fit and correlation parameters can be displayed.



To obtain the maximum profile detail, the system automatically centers the profile and zooms to display ~3 times the beam width, and the profile intensity data is autoscaled (optional) to fit the display height. Added detail can be obtained in a special high-resolution mode. This mode is very useful for analyzing beams that are either far from Gaussian in shape or smaller than 100  $\mu\text{m}$ .



### Beam Position and Ellipticity

The beam centroid position can be continuously monitored relative to the center of the sensor area, along with the beam shape, ellipticity (major and minor axes) and angular orientation. A zoom function is available and the user can choose the clip level and strip-chart the position (X and Y) data to monitor short-term or long-term, time-dependent stability or drift.



### Power Measurement

The beam power can be displayed either as a digital readout or in combination with an analog "needle." Units can be chosen as  $\mu\text{W}$ , mW or dBm, and the user can offset the zero and zoom in on any part of the power range. Attenuator (filter) files can be selected, and a test range can be selected and displayed to monitor beam power within specific limits, with optional audio alarms.

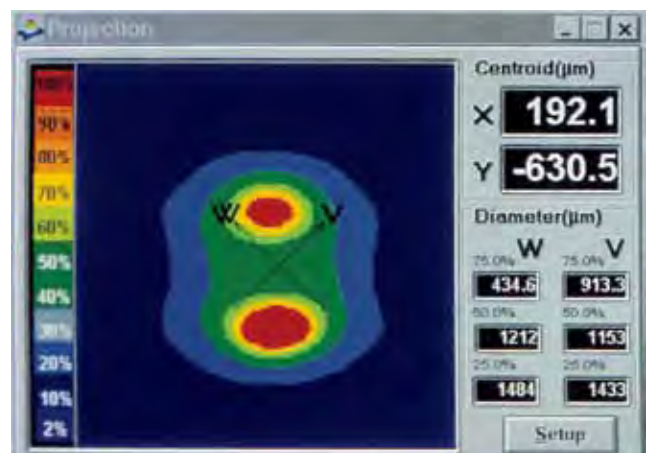


### Data Collecting and QA Testing

Data regarding beam size, position and power can be continuously displayed in analog, digital and strip chart forms on the computer screen. Data can also be logged to a data file in real time for later processing or test report generation. Pass/Fail testing can be performed on measured results for acceptance within specific tolerances. Files can be transferred to another computer with an RS-232 link or data can be transferred in real time. All screen images also can be captured and stored as BMP or JPG files or can be printed to any Windows printer.

### 2D and 3D Intensity Plots

The projection function provides either a 2D or 3D view of the beam intensity profile. The projection is created using reconstructive tomography. The same method is used to produce 3D images with X-ray systems. The more knife edges, the greater the level of detail that can be obtained. For a beam distribution that is significantly non-Gaussian, such as that from a diode laser, the standard seven-knife-edge system can reconstruct a plot that closely matches the real beam. When examining near-Gaussian beams, the three-knife-edge system gives an accurate intensity distribution.



BeamMaster 2D Intensity Plot

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# BeamMaster

## BeamMaster Accessories

The 2D contour maps and the 3D isometric plots can be displayed with or without scan axis and grids, and the isometric plots can be rotated for easier viewing of the detailed structure.

### BeamMaster System Components

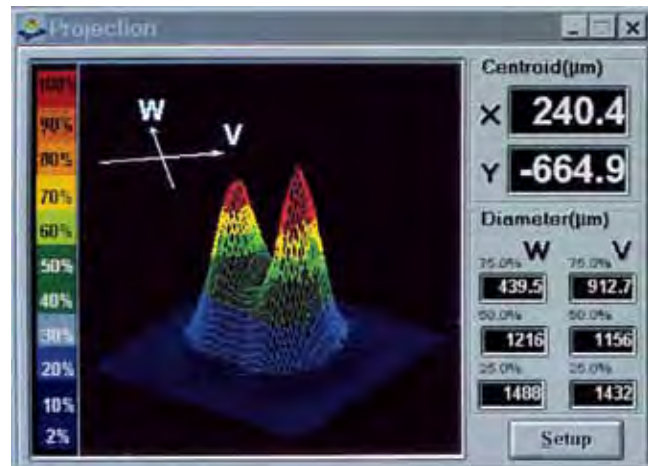
Each BeamMaster system consists of a sensor head, complete with a 1.8 m cable, a 1/2-length (187 mm) 32-bit PCI card to plug into a PC computer, complete Windows software on a CD-ROM disk, a printed instruction manual, a 0.5" mounting post (threaded 8-32), and optical filters (for Si-Enhanced).

### Optical Filters

The BM-7 and BM-3 Si-Enhanced heads come with two neutral density filters. NG4 and NG9 filters (complete with transmission curves) are provided to extend the power range of the heads from 5 mW to 1W in the 400 nm to 1100 nm range. The NG4 filter comes pre-installed and provides ~10% transmission at 633 nm. The NG9 filter is in a protective filter case and provides ~0.5% transmission at 633 nm. There is no filter in the BeamMaster InGaAs head configurations.

### Computer Requirements

The user provides a Pentium PC (586 or higher, 233 MHz) operating Windows 2000 or XP with a free PCI card slot. The system should have 32 megabytes of RAM, a CD-ROM drive, ~20 megabytes of free hard-disk memory, and a display resolution of 800 x 600 or higher.



BeamMaster 2D Intensity Plot

### BeamMaster Accessories

An optional mount is available to enable rotation of the BeamMaster sensor head about the optical axis. This mount has a 360-degree calibrated scale with a locking screw. An optional C-Mount Adapter Plate allows the attachment of any C-Mount, threaded optical accessory, such as a BCUBE high-power attenuator pickoff optic (see the Beam Diagnostics Accessories section on page 82).

Device Specifications	Model	BeamMaster
Measurement Rate (Hz)		5
Wavelength Range (nm)		190 to 1100 [BM-7 Si-Enhanced, BM-3 Si-Enhanced] 800 to 1800 [BM-7 InGaAs (3 or 5 mm), BM-3 InGaAs (3 mm)]
Sensor Aperture		9 mm square [BM-7 (Si-Enhanced)] 5 mm circular [BM-3 (Si-Enhanced)] 3 mm circular [BM-3 and BM-7 (InGaAs)] (optional BM-7 InGaAs 5 mm available)
Minimum Beam Size (µm)		15 (BM-7 all models) 3 (BM-3 all models)
Beam Size Resolution		1 µm for beams >100 µm in size (0.1 µm for beams <100 µm in size)
Position Measurement Resolution (µm)		1
Position Measurement Accuracy (µm)		±15
Beam Width Measurement Accuracy (%)		±2
Beam Power Range		10 µW to 1 W (with supplied internal filters), saturation 0.1 W/cm <sup>2</sup> without filter, 20W/cm <sup>2</sup> with NG9 filter [BM-7, BM-3 (Si-Enhanced)] 10 µW to 5 mW (no filters provided), saturation 0.1 W/cm <sup>2</sup> [BM-3 InGaAs, BM-7 InGaAs]
Relative Power Measurement		0.1 µW resolution
Sensor Head Weight (g)		56 g
Part Number		
	1037702	BeamMaster BM-7 Si-Enhanced
	1037699	BeamMaster BM-3 Si-Enhanced
	1037710	BeamMaster BM-7 InGaAs (3 mm)
	1037712	BeamMaster BM-7 InGaAs (5 mm)
	1037708	BeamMaster BM-3 InGaAs (3 mm)
	1038024	BeamMaster Rotation Mount
	33-7147-000	BeamMaster C-Mount Adapter Plate
	1037713	BeamMaster PCI Upgrade Kit

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# ModeMaster PC

## M<sup>2</sup> Beam Propagation Analyzer



### Features

- Measurement and display of CW laser divergence, M<sup>2</sup> (or k) and astigmatism
- Beam sizes 0.2 mm to 25 mm
- Wavelengths from 220 nm to 15 μm
- Determination of waist location and diameters (including D4σ diameter) and Rayleigh range
- Angular and translational beam-pointing stability

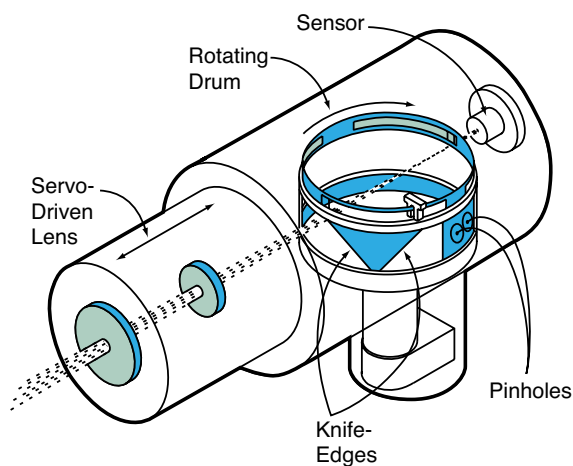
### How Does the ModeMaster PC Work?

The ModeMaster PC head is a dual-knife-edge beam profiler integrated with a diffraction-limited precision scanning lens, which is translated along the beam propagation axis. The lens focuses the beam to create an internal beam waist, and the two orthogonal knife edges (X and Y), which are mounted on a rotating drum, measure the beam diameter and beam axis location at 256 planes along the beam waist as the lens is translated. The powerful ModeMaster PC software then derives the M<sup>2</sup> factor, the size and location of the beam waist, the far-field divergence angle, the pointing direction, astigmatism and asymmetry, and the Rayleigh range.

Measurements also include ISO D4σ, second moment, knife-edge, slit and D86 beam diameters. The entire measuring process occurs in less than 30 seconds.

The ModeMaster PC also provides special weighting functions to help eliminate effects on measurement accuracy due to intermittent beam noise, vignetting or other transients during the focus scan. Real-time displays allow laser peaking or adjustment for minimum M<sup>2</sup>, divergence, maximum power density, far-field pinhole profiles and pointing angle.

### Complete Geometric Beam Characterization Along the Laser Beam Path



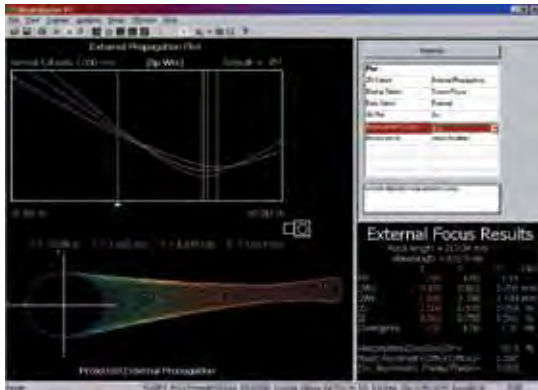
- Beam Quality – M<sup>2</sup>
- Beam Diameter
- Waist Diameter & Location
- Divergence Angle
- Rayleigh Range
- Pointing Stability
- Power Density
- Beam Profiles
- Second-Moment Diameters
- Astigmatism
- Waist Asymmetry
- Divergence Asymmetry

Beam propagation is concerned with the energy distribution in a beam and the change of that distribution along the beam path. The ModeMaster Beam Propagation Analyzer established a new laser beam quality parameter, M<sup>2</sup>, which

has now become an ISO measurement standard. M<sup>2</sup> describes how close to “perfect-Gaussian” a laser beam is, and can be used to predict the beam size, beam shape and the smallest spot that can be created from the beam further downrange.

# ModeMaster PC

## M<sup>2</sup> Beam Propagation Analyzer



Beam Propagation Display

Coherent pioneered M<sup>2</sup> beam propagation analysis with the ModeMaster system a decade ago. Now, the new ModeMaster PC Laser Beam Propagation Analyzer combines all the ISO-compliant accuracy and powerful features needed for measuring M<sup>2</sup> and other beam propagation analysis functions for CW lasers. It also provides the added flexibility and value of a personal computer to provide optimum user control, data processing, storage and results display.

The ModeMaster PC includes a Universal Serial Bus (USB) control/interface console and Windows software for operation with Windows 2000 or XP). The ModeMaster PC is also compatible with all existing ModeMaster systems, allowing legacy ModeMaster system users to easily upgrade their systems for use on a supported PC computer.

## Easy Beam Alignment

The precision 5-axis head mount and beam position display of the ModeMaster PC provide easy angular alignment and translational centering of the lens and scan axis to the beam propagation path.

## Second-Moment Diameters

Beam diameter is a critical parameter in beam propagation measurements. Second-moment diameters ( $D_{4\sigma}$ ) give the best theoretical answers for beam propagation calculations. The ModeMaster PC measures second-moment diameters directly. The ModeMaster PC software also includes conversion algorithms from its knife-edge measurements to second-moment diameter measurements that are valid for stable resonator modes with M<sup>2</sup> of 1 to 4 (covering most commercially available lasers). Also included are conversions to D86 and slit diameters to allow comparison to other measurements.

## Real-Time Power Density Adjustment

In most laser applications it is not laser power that does the work but power density. Using the ModeMaster PC, the point of maximum power density can be quickly located. A convenient power density tuning screen displays power density as a pseudo-analog "tune bar," giving real-time feedback as the laser mirrors are adjusted.

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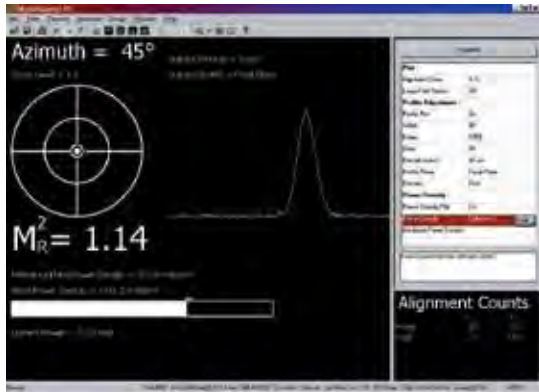
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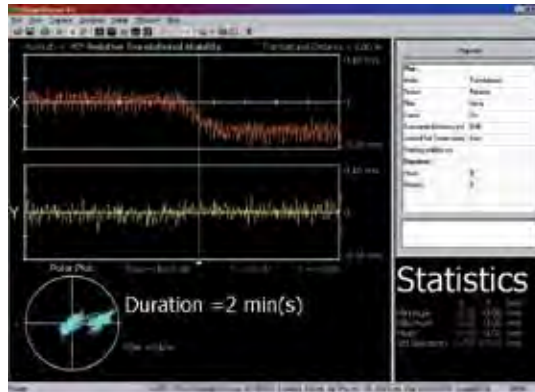
Model Name Index

# ModeMaster PC

## M<sup>2</sup> Beam Propagation Analyzer



Real-Time Display



Pointing-Stability Display

### Real-Time M<sup>2</sup> and Beam Profiles

The ModeMaster PC provides real-time measurement and display for fine tuning M<sup>2</sup> and many other beam propagation parameters, as well as the near-field or far-field pinhole intensity beam profiles.

### Beam-Pointing and Translational Stability

ModeMaster is able to measure and display both translational (parallel to the beam axis) or angular (from a pivot point) beam movement over a period of 2 minutes to 24 hours. The angular pivot point of the beam axis (often a single optical surface) can be located along the beam path. Statistical analysis of the beam axis location and angle are displayed for both the X and Y axes. Three levels of filtering reduce noise and increase the sensitivity of pointing-stability measurements.

### Expanded Online Help

The ModeMaster PC provides complete online help. Help messages also suggest corrective measures when beam parameter limits are exceeded.

### Upgrading to the ModeMaster PC

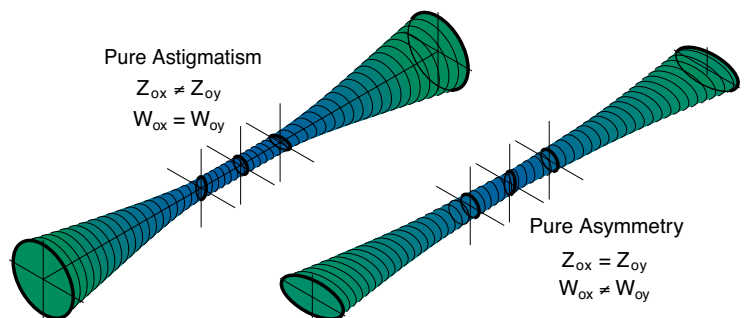
All previous versions of the ModeMaster systems can be upgraded to the ModeMaster PC. The original console unit and the LabMaster display are simply replaced with the ModeMaster PC Control/Interface Module and Software, installed in a user-supplied compatible PC computer. All original ModeMaster scan heads are fully compatible and can be plugged into the ModeMaster PC Control/Interface Module, which can be ordered separately with the software.

### RS-232 Interface

The ModeMaster PC can provide measured beam data, analysis results and focus scan control (through the RS-232 interface) for remote data logging, results monitoring and measurement control.

## Beam Astigmatism and Asymmetry

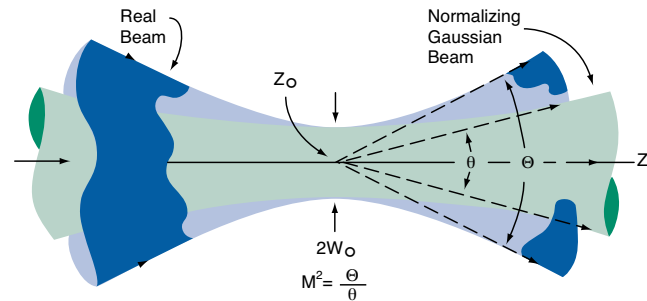
Changes in the shape of a propagating beam can be astigmatic, asymmetric or both. The beam shown at the near right has pure astigmatism; the waists ( $W_0$ ) in the horizontal and vertical directions are the same size, but occur at different propagation distances ( $Z_0$ ). In asymmetric beams (far right) the two waists occur together, but are of different diameters. The ModeMaster PC provides complete analysis of these beam characteristics.



# ModeMaster PC

## Laser Beam Quality

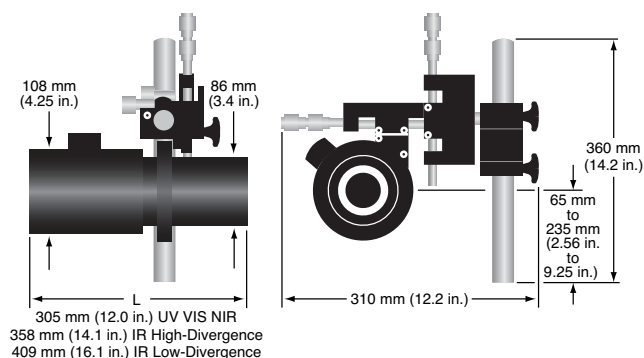
The closer an actual laser beam is to diffraction-limited, the more tightly it can be focused, the greater its depth of field, and the smaller the diameter of the beam optics can be to transmit the beam.  $M^2$  is the ratio of the divergence of the actual beam to that of a theoretical diffraction-limited beam of the same waist size in the TEM<sub>00</sub> mode. Thus, the angular size of the beam in the far field will be  $M^2$  larger than calculated for a perfect Gaussian beam.



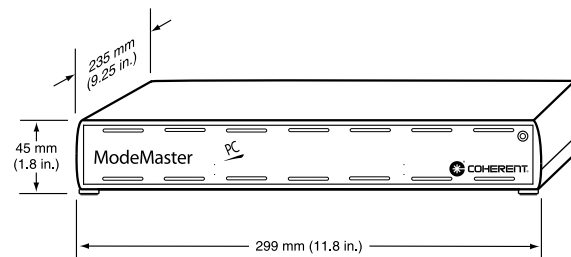
$$\Theta = M^2 \times 2\lambda / (\pi W_0), \text{ FOR A BEAM WAIST DIAMETER } 2W_0.$$

Device Specifications	Model	ModeMaster PC
	Accuracies	
	Waist Diameter (%)	±2
	Waist Location	±8% of input beam Rayleigh Range
	Beam Quality – $M^2$ (%)	±5
	Divergence (%)	±5
	Beam Translation	±5% of waist diameter +0.1 mm
	Pointing Angle	±5% of divergence +0.04 mrad
	Azimuth Angle Readout	±2°(10 to 200°)
	Knife-Edge Clip Levels	User-adjustable 0% to 100% in 1.5% steps
	ModeMaster PC Control/Interface	<8 Hz ( $M^2$ , divergence, power density, waist diameter, profiles)
	Module Update Rate	
	Analog Outputs	Detector signal output, 0 to 13V maximum A/D control signal out, 0 to 5V pulse Trigger (syncs to drum rotation), 0 to 5V pulse
	Digital Outputs	RS-232 interface. Front and back knife-edge widths and pinhole profiles available in digitized form via RS-232
	Power	100 to 240 VAC, 47 to 63 Hz, 40W maximum

### Scan Head and Precision Mount



### Control/Interface Console

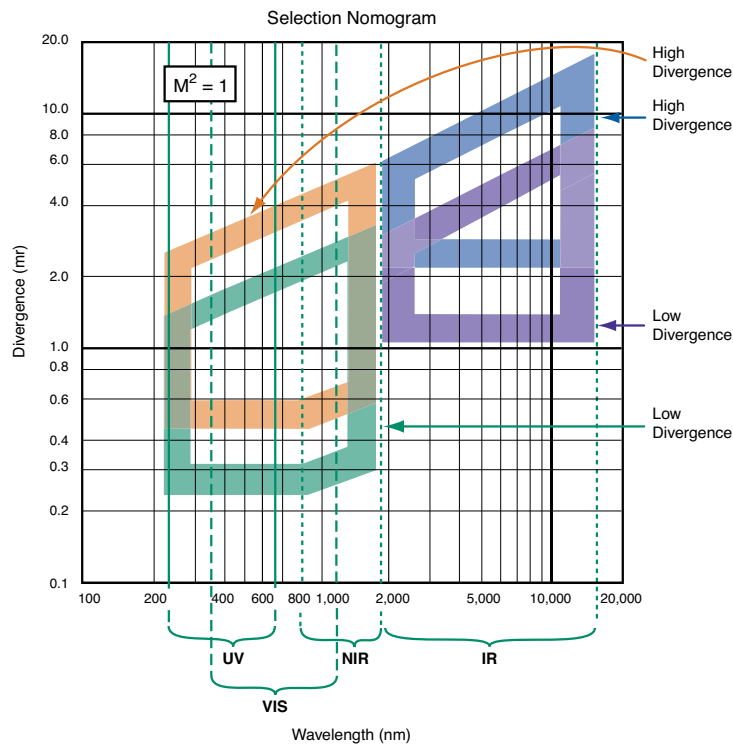


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# ModeMaster PC

## Selecting a ModeMaster PC System Configuration

ModeMaster PC systems are available in eight standard configurations (all include scanning head, 5-axis mount, USB control/ interface console, cables, PC software and manual). All configurations provide measurements in four wavelength ranges, with two divergence ranges (high-divergence and low-divergence) within each wavelength range. Use the following steps, along with the Selection Nomogram Chart and Configuration Table (below), to select a ModeMaster PC configuration.



1. Choose between the four spectral ranges: UV (220 to 680 nm), VIS (340 to 1000 nm), NIR (800 to 1800 nm) and IR (1800 to 15,000 nm).
2. Determine the approximate divergence of your laser beam and use the Selection Nomogram (Divergence vs. Wavelength) Chart to select the low-divergence or high-divergence configuration.
3. Confirm that your beam size is <25 mm diameter for the low-divergence configuration or <12 mm for the high-divergence configuration.
4. Use the table below to determine the part number of the ModeMaster PC configuration selected, and to verify all other beam specifications.
5. If more than one ModeMaster PC configuration appears to be needed in order to cover all required beam parameter ranges, optional Scanning Head Modular Components can be ordered to change the configuration of the ModeMaster PC system to cover other ranges (see next page for details).

## Standard Configuration

Name	UV Low-Divergence	UV High-Divergence	VIS Low-Divergence	VIS High-Divergence	NIR Low-Divergence	NIR High-Divergence	IR High-Divergence	IR Low-Divergence
Model	MM-1	MM-1S	MM-2	MM-2S	MM-3	MM-3S	MM-4	MM-5
Spectral Range (µm)	0.22 to 0.68		0.34 to 1.00		0.80 to 1.80		1.80 to 15	
Detector Type	Silicon				Germanium		Pyroelectric	
<b>INPUT BEAM REQUIREMENTS AT TEST WAVELENGTH</b>								
Test Wavelength <sup>1</sup>	351 nm		514 nm		1.06 µm		10.6 µm	
Minimum Power <sup>2</sup>	7.5 mW <sup>3</sup>		2.5 mW <sup>3</sup>		2.5 mW <sup>3</sup>		400 mW	
Maximum Power <sup>2</sup>	10W <sup>3</sup>		25W <sup>3</sup>		2.5W		20W	
Noise	<2% RMS and <5% peak-to-peak							
Min. Divergence (mrad)	0.24	0.46	0.24	0.46	0.25 <sup>5</sup>	0.47 <sup>5</sup>	2.7	1.3
Max. Divergence (mrad) <sup>4</sup>	1.7	3.2	2.0	3.6	2.7	5.0	14	7.2
Max. Beam Diameter (mm) <sup>6</sup>	25	12	25	12	25	12	12	25
Part Number	33-1843-000	33-2106-000	33-2221-000	33-2239-000	33-2387-000	33-2395-000	33-2429-000	33-2437-000

<sup>1</sup> Wavelength-dependent quantities are input power levels, and minimum and maximum divergence (see Notes 2, 5, 6).

<sup>2</sup> Power levels are proportional to the inverse of the spectral response of the detector. The silicon detector peaks at 900 nm and is at half-peak sensitivity at 510 nm and 1050 nm. The germanium detector peaks at 1500 nm and is at half-peak sensitivity at 1100 nm and 1650 nm. The pyroelectric detector has a flat spectral response.

<sup>3</sup> These limits can be reduced by a factor of 10 (higher sensitivity) by user-removal of the light-restricting aperture in front of the detector.

<sup>4</sup> The maximum divergence limit is fixed by the inability to accurately locate the internal waist when the internal beam diameter growth (over the span of the drum) is too slight.

Limits shown are for  $M^2 = 1$  and test wavelength; limits scale as the square root of  $M^2$  (test wavelength).

<sup>5</sup> Minimum divergence in this wavelength range scales as the square root of  $M^2$  (test wavelength).

<sup>6</sup> Diameters are approximate; divergence takes precedence in choosing options. Refer to nomogram.

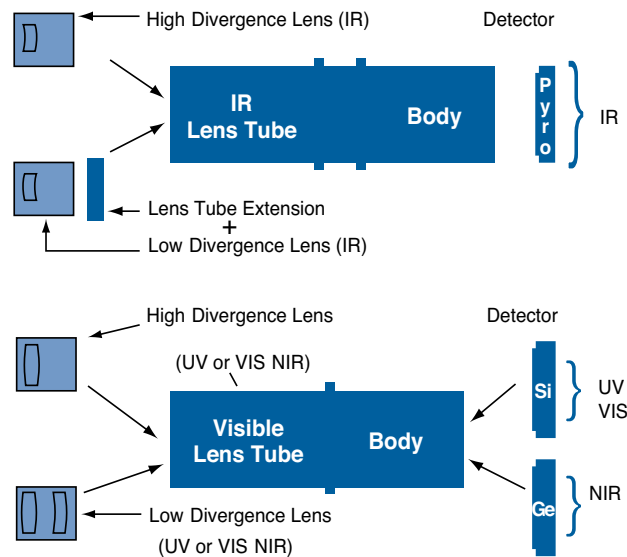
# ModeMaster PC

## Complete Geometric Beam Characterization Along the Laser Beam Path

### Components for Other Wavelength and Divergence Ranges

The body design of the ModeMaster PC scanning head has modular lens and detector sets that allow quick changes to other wavelength or divergence ranges to meet your measurement needs.

The IR body can only be used with the IR (pyroelectric - pyro) detector and either the low-divergence or high-divergence IR heads. The UV-VIS-NIR body, however, can be used in any of the UV, VIS or NIR spectral regions with the appropriate detector (silicon-Si for the UV and VIS; germanium-Ge for the NIR) and low- or high-divergence lenses. The UV lens can be used with the silicon detector and the VIS-NIR lens can be used with either the silicon or germanium detector.



Part Number	Description	Spectral Region(s)	Scan Head Body
33-2072-000	Silicon Detector (0.22 to 1.0 $\mu\text{m}$ )	UV, VIS	UV-VIS-NIR
33-2080-000	Germanium Detector (0.8 to 1.8 $\mu\text{m}$ )	NIR	UV-VIS-NIR
33-2098-000	Pyroelectric Detector (1.8 to 20 $\mu\text{m}$ )	IR	IR
33-2114-000	High-Divergence Lens Kit	UV	UV-VIS-NIR
33-2130-000	Low-Divergence Lens Kit	UV	UV-VIS-NIR
33-2122-000	High-Divergence Lens Kit	VIS, NIR	UV-VIS-NIR
33-2148-000	Low-Divergence Lens Kit	VIS, NIR	UV-VIS-NIR
33-2155-000	High-Divergence Lens Kit	IR	IR
33-2166-000	Low-Divergence Lens Kit	IR	IR

## ModeMaster PC M<sup>2</sup> Beam Propagation Analyzer (standard system configuration)

Part Number	Description	Spectral Range
33-1843-000	ModeMaster PC System <sup>1</sup>	UV, Low-Divergence
33-2106-000	ModeMaster PC System <sup>1</sup>	UV, High-Divergence
33-2221-000	ModeMaster PC System <sup>1</sup>	VIS, Low-Divergence
33-2239-000	ModeMaster PC System <sup>1</sup>	VIS, High-Divergence
33-2387-000	ModeMaster PC System <sup>1</sup>	NIR, Low-Divergence
33-2395-000	ModeMaster PC System <sup>1</sup>	NIR, High-Divergence
33-2437-000	ModeMaster PC System <sup>1</sup>	IR, Low-Divergence
33-2429-000	ModeMaster PC System <sup>1</sup>	IR, High-Divergence
33-1710-000	ModeMaster PC Control/Interface Console and Software	-

<sup>1</sup> All ModeMaster systems include scan head, mount, control/interface console and software.

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