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, characterize, and monitor these laser parameters for thousands of customers around the world.

### 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 88 to 89 and an advanced knife-edge system—BeamMaster—on pages 99 to 101.

### Beam Propagation
The Coherent ModeMaster beam propagation analyzer established an entirely new laser beam quality parameter that is now an ISO standard. M² 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 108 for additional specifications for the WaveMaster.

#### Summary of Product Primary Measurement Capabilities

<table>
<thead>
<tr>
<th>Model</th>
<th>BeamView Analyzer</th>
<th>BeamMaster</th>
<th>ModeMaster</th>
<th>WaveMaster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>CW + Pulsed</td>
</tr>
<tr>
<td>Power</td>
<td>—</td>
<td>CW</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Beam Position</td>
<td>CW + Pulsed</td>
<td>CW</td>
<td>CW</td>
<td>—</td>
</tr>
<tr>
<td>Propagation M²</td>
<td>—</td>
<td>—</td>
<td>CW</td>
<td>—</td>
</tr>
<tr>
<td>Beam Profiles</td>
<td>2D</td>
<td>CW + Pulsed</td>
<td>CW</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>3D</td>
<td>CW + Pulsed</td>
<td>CW</td>
<td>—</td>
</tr>
<tr>
<td>Page Number</td>
<td>88</td>
<td>99</td>
<td>102</td>
<td>108</td>
</tr>
</tbody>
</table>
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.

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
- 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
- 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 light source 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.
Beam Diagnostic Cameras

**LaserCam-HR and LaserCam-HR-UV**

### Features

- **USB 2.0, 10-bit digital output**
- **Large-area CMOS array, 8.5 mm x 6.8 mm**
- **Compact 68 x 68 x 34 mm package**
- **Metric and English mounts included**
- **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

<table>
<thead>
<tr>
<th>Model</th>
<th>LaserCam-HR</th>
<th>LaserCam-HR-UV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor Elements (pixels)</td>
<td>1280 x 1024</td>
<td>20 x 20</td>
</tr>
<tr>
<td>Effective Pixel Resolution (µm)</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Pixel Size (µm)</td>
<td>6.7 x 6.7</td>
<td></td>
</tr>
<tr>
<td>Sensor Active Area (mm)</td>
<td>8.5 x 6.8 (2/3 inch format)</td>
<td>190 to 355</td>
</tr>
<tr>
<td>Spectral Range (nm)</td>
<td>300 to 1100 (without LDFP)</td>
<td>400 to 1100 (with LDFP included)</td>
</tr>
<tr>
<td>Beam Diameters (mm)</td>
<td>0.2 to 6.0</td>
<td>0.5 to 6.0</td>
</tr>
<tr>
<td>Glassless Sensor</td>
<td>Low Distortion Face Plate is removable</td>
<td></td>
</tr>
<tr>
<td>Low-Distortion Face Plate (LDFP, LDFP-UV)</td>
<td>Laser-grade ND filter, UV-grade ND filter,</td>
<td>OD = 2.5 at 632.8 nm, OD = 3.0 at 248 nm</td>
</tr>
<tr>
<td>Electrical Interface</td>
<td>USB 2.0</td>
<td></td>
</tr>
<tr>
<td>Capture Modes</td>
<td>Continuous (CW), pulsed</td>
<td>Continuous (CW), pulsed</td>
</tr>
<tr>
<td>Variable Exposure Time</td>
<td>1 msec to 1 sec, default at 10 msec</td>
<td></td>
</tr>
<tr>
<td>Pulsed Mode Trigger Methods</td>
<td>Trigger in (TTL)</td>
<td></td>
</tr>
<tr>
<td>Maximum Pulse Trigger Rate (Hz)</td>
<td>100 (without averaging adjacent pulses)</td>
<td></td>
</tr>
<tr>
<td>Maximum Frame Rate (FPS)</td>
<td>Live video, no calculations</td>
<td>15</td>
</tr>
<tr>
<td>Capture with calculations</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Damage Threshold (mJ/cm²)</td>
<td>32 mJ/cm² (without LDFP) at 1064 nm</td>
<td>200 µJ/cm² (without LDFP-UV) at 248 nm</td>
</tr>
<tr>
<td>CW Saturation (mW/cm²)</td>
<td>40 mW/cm² (without LDFP) at 633 nm</td>
<td>90 mW/cm² (with LDFP-UV) at 248 nm</td>
</tr>
<tr>
<td></td>
<td>16 µW/cm² (without LDFP) at 633 nm</td>
<td>90 µW/cm² (with LDFP-UV) at 248 nm</td>
</tr>
<tr>
<td></td>
<td>800 µW/cm² (with LDFP) at 1064 nm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>320 µW/cm² (without LDFP) at 1064 nm</td>
<td></td>
</tr>
<tr>
<td>Pulsed Saturation (mJ/cm²)</td>
<td>8 mJ/cm² (with LDFP) at 1064 nm</td>
<td>5 mJ/cm² (with LDFP) at 248 nm</td>
</tr>
<tr>
<td></td>
<td>3.2 µJ/cm² (without LDFP) at 1064 nm</td>
<td>5 µJ/cm² (without LDFP) at 248 nm</td>
</tr>
<tr>
<td>USB 2.0 Cable</td>
<td>6 ft. standard A/B cable included</td>
<td></td>
</tr>
<tr>
<td>Trigger Connector</td>
<td>BNC receptacle (trigger cable included)</td>
<td></td>
</tr>
<tr>
<td>Part Number</td>
<td>1098577</td>
<td>1149004</td>
</tr>
</tbody>
</table>
Beam Diagnostic Cameras

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 μm x 30 μm 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 μsec to 25 msec
- User variable trigger delay
- C-mount thread for additional accessories

Device Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>LaserCam-HR-InGaAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor Elements (pixels)</td>
<td>320 x 256</td>
</tr>
<tr>
<td>Pixel Size (μm)</td>
<td>30 x 30</td>
</tr>
<tr>
<td>Sensor Active Area (mm) (H x V)</td>
<td>9.6 x 7.7</td>
</tr>
<tr>
<td>Spectral Range (nm)</td>
<td>900 to 1700</td>
</tr>
<tr>
<td>Beam Diameters (mm)</td>
<td>0.5 to 6.0</td>
</tr>
<tr>
<td>Glassless Sensor</td>
<td>Low Distortion Face Plate is removable</td>
</tr>
<tr>
<td>Low-Distortion Face Plate (LDFP)</td>
<td>Laser-grade ND filter, OD = 2.5 at 632.8 nm</td>
</tr>
<tr>
<td>Electrical Interface</td>
<td>USB 2.0</td>
</tr>
<tr>
<td>Capture Modes</td>
<td>Continuous (CW), pulsed</td>
</tr>
<tr>
<td>Variable Exposure Time</td>
<td>20 μsec to 25 msec, default at 1 msec</td>
</tr>
<tr>
<td>Pulsed Mode Trigger Methods</td>
<td>Trigger In (TTL)</td>
</tr>
<tr>
<td>Maximum Frame Rate (FPS)</td>
<td>25 (live video, no calculations), 15 (capture with calculations)</td>
</tr>
</tbody>
</table>

Saturation

- CW (at 1064 nm) | 3.5 mW/cm² (with LDFP), 50 μW/cm² (without LDFP) |
- CW (at 1523 nm) | 350 μW/cm² (with LDFP), 30 μW/cm² (without LDFP) |
- Pulse (at 1064 nm) | 5 μJ/cm² (with LDFP), 0.08 μJ/cm² (without LDFP) |

USB 2.0 Cable | 6 ft. standard A/B cable included |

Trigger Connector | BNC receptacle (trigger cable included) |

Part Number | 1149002 |
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 flexibility, speed, and user friendliness.

Features
- High-speed USB 2.0 camera interface
- 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
- Windows XP, Vista 32-bit, Vista 64-bit, Windows 7 32-bit, Windows 7 64-bit

BeamView-USB Analyzer Software

BeamView-USB software includes features that extend the analytic capabilities of the LaserCam-HR laser beam diagnostic systems:
- 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
- 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
The adjustable Trigger Delay feature 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.

BeamView System Performance Optimization

BeamView 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.
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 (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.

BeamView Analyzer Software Additional Features
• More than 25 different numerical analysis functions
• Several different profile views
• Import and export of results data and profile data
• Pass/Fail settings and user-selectable fault actions
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.

Remote Control
The BeamView Analyzer provides remote control and data transfer through a TCP/IP or RS-232 connection on the host computer. 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 an example LabVIEW VI 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
- D4σ 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

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.

Polar beam wander plot screen

Fault Actions Dialog Box

Continuous on-line statistical analysis display

Calculations Pass/Fail test settings
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 (d4 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
- 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
- “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
- Adjustable camera exposure time
- RS-232 and TCP/IP communication protocols
- Multiple trigger modes:
  - External trigger input
  - Autotrigger to a selected level
- 3 resolution modes 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 the LaserCam-HR-InGaAs camera:
  - 320 x 256 x 14
- 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
- Optical scale factor (magnification/reduction)
- Far-field optic focal length
- 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

• Toll Free: (800) 343-4912 • Tel: (408) 764-4042 • Fax: (503) 454-5727
Beam Diagnostic Accessories

Laser-Grade Attenuation Optics for Cameras

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/cm² or 50J/cm²
• 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 ~0.5 µW/cm² power density (at ~633 nm) or at ~9 nJ/cm² (at 1064 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 $10^3:1$ 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.
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 λ/10 specifications and six are used, a total λ/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 ~λ/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 λ/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.

**Attenuator Selection**

Attenuation is selected on the basis of power density in W/cm² or energy density in J/cm². The attenuation from the camera’s Low-Distortion Face Plate (LDFP) will allow an average power density of up to 1.2 mW/cm². There are then only two more steps to attenuation selection:

1) Choose either the VARM or the C-VARM for up to 1W/cm².
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**

<table>
<thead>
<tr>
<th>Model</th>
<th>VARM</th>
<th>C-VARM</th>
<th>UV C-VARM</th>
<th>BCUBE</th>
<th>UV-BCUBE</th>
<th>BARREL SET (Barrels, 3 C-Mount Flanges)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min. (nm)</td>
<td>380</td>
<td>380</td>
<td>190</td>
<td>380</td>
<td>190</td>
<td>–</td>
</tr>
<tr>
<td>Max. (nm)</td>
<td>2200</td>
<td>2200</td>
<td>1100</td>
<td>2200</td>
<td>2200</td>
<td>–</td>
</tr>
<tr>
<td>Attenuation</td>
<td>From</td>
<td>4 x 10⁻¹⁻¹</td>
<td>10⁻¹⁻¹</td>
<td>10⁻⁵⁻¹</td>
<td>50⁻¹⁻¹</td>
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</tr>
<tr>
<td>To</td>
<td>1.1</td>
<td>3000⁻¹⁻¹</td>
<td>300⁻¹⁻¹</td>
<td>10⁻¹⁻¹</td>
<td>10⁻¹⁻¹</td>
<td>10⁻¹⁻¹</td>
</tr>
<tr>
<td>Aperture (mm)</td>
<td>19</td>
<td>17</td>
<td>17</td>
<td>19</td>
<td>19</td>
<td>–</td>
</tr>
<tr>
<td>Max. Power Density (W/cm²)</td>
<td>1⁻¹</td>
<td>1⁻¹</td>
<td>1⁻¹</td>
<td>2.0 x 10⁻⁹</td>
<td>2.0 x 10⁻⁹</td>
<td>–</td>
</tr>
<tr>
<td>Max. Energy Density (J/cm²)</td>
<td>0.1⁻¹</td>
<td>0.1⁻¹</td>
<td>0.008</td>
<td>50⁻¹⁻¹</td>
<td>50⁻¹⁻¹</td>
<td>–</td>
</tr>
<tr>
<td>Damage Limit</td>
<td>(W/cm²)</td>
<td>5 x 10⁻⁷</td>
<td>5 x 10⁻⁷</td>
<td>–</td>
<td>2.5 x 10⁻⁹</td>
<td>2.5 x 10⁻⁹</td>
</tr>
<tr>
<td>(J/cm²)</td>
<td>10⁻¹⁻¹</td>
<td>10⁻¹⁻¹</td>
<td>0.008</td>
<td>50⁻¹⁻¹</td>
<td>50⁻¹⁻¹</td>
<td>–</td>
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<tr>
<td>Beam Offset (mm)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>4.0</td>
<td>4.0</td>
<td>–</td>
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<tr>
<td>Part Number</td>
<td>33-3328-000</td>
<td>33-3336-000</td>
<td>33-6859-000</td>
<td>1098403</td>
<td>1098466</td>
<td>1098426</td>
</tr>
</tbody>
</table>

*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**

---

**Beam Diagnostics Accessories**

**Attenuation Optics for Cameras**

**Device Specifications**

<table>
<thead>
<tr>
<th>Model</th>
<th>VARM</th>
<th>C-VARM</th>
<th>UV C-VARM</th>
<th>BCUBE</th>
<th>UV-BCUBE</th>
<th>BARREL SET (Barrels, 3 C-Mount Flanges)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min. (nm)</td>
<td>380</td>
<td>380</td>
<td>190</td>
<td>380</td>
<td>190</td>
<td>–</td>
</tr>
<tr>
<td>Max. (nm)</td>
<td>2200</td>
<td>2200</td>
<td>1100</td>
<td>2200</td>
<td>2200</td>
<td>–</td>
</tr>
<tr>
<td>Attenuation</td>
<td>From</td>
<td>4 x 10⁻¹⁻¹</td>
<td>10⁻¹⁻¹</td>
<td>10⁻⁵⁻¹</td>
<td>50⁻¹⁻¹</td>
<td>50⁻¹⁻¹</td>
</tr>
<tr>
<td>To</td>
<td>1.1</td>
<td>3000⁻¹⁻¹</td>
<td>300⁻¹⁻¹</td>
<td>10⁻¹⁻¹</td>
<td>10⁻¹⁻¹</td>
<td>10⁻¹⁻¹</td>
</tr>
<tr>
<td>Aperture (mm)</td>
<td>19</td>
<td>17</td>
<td>17</td>
<td>19</td>
<td>19</td>
<td>–</td>
</tr>
<tr>
<td>Max. Power Density (W/cm²)</td>
<td>1⁻¹</td>
<td>1⁻¹</td>
<td>1⁻¹</td>
<td>2.0 x 10⁻⁹</td>
<td>2.0 x 10⁻⁹</td>
<td>–</td>
</tr>
<tr>
<td>Max. Energy Density (J/cm²)</td>
<td>0.1⁻¹</td>
<td>0.1⁻¹</td>
<td>0.008</td>
<td>50⁻¹⁻¹</td>
<td>50⁻¹⁻¹</td>
<td>–</td>
</tr>
<tr>
<td>Damage Limit</td>
<td>(W/cm²)</td>
<td>5 x 10⁻⁷</td>
<td>5 x 10⁻⁷</td>
<td>–</td>
<td>2.5 x 10⁻⁹</td>
<td>2.5 x 10⁻⁹</td>
</tr>
<tr>
<td>(J/cm²)</td>
<td>10⁻¹⁻¹</td>
<td>10⁻¹⁻¹</td>
<td>0.008</td>
<td>50⁻¹⁻¹</td>
<td>50⁻¹⁻¹</td>
<td>–</td>
</tr>
<tr>
<td>Beam Offset (mm)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>4.0</td>
<td>4.0</td>
<td>–</td>
</tr>
<tr>
<td>Part Number</td>
<td>33-3328-000</td>
<td>33-3336-000</td>
<td>33-6859-000</td>
<td>1098403</td>
<td>1098466</td>
<td>1098426</td>
</tr>
</tbody>
</table>

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

---

**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 λ/10 specifications and six are used, a total λ/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 ~λ/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 λ/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.

**Attenuator Selection**

Attenuation is selected on the basis of power density in W/cm² or energy density in J/cm². The attenuation from the camera’s Low-Distortion Face Plate (LDFP) will allow an average power density of up to 1.2 mW/cm². There are then only two more steps to attenuation selection:

1) Choose either the VARM or the C-VARM for up to 1W/cm².
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).
Beam Diagnostic Accessories

Extreme-UV Beam Intensity Profiler (BIP) Optics

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 98). 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.

<table>
<thead>
<tr>
<th>Device Specifications</th>
<th>Model</th>
<th>BIP-12F (2:1)</th>
<th>BIP-12F (1:1)</th>
<th>BIP-5000Z</th>
<th>BIP-5000SPL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength (nm)</td>
<td>10 to 355</td>
<td>10 to 320</td>
<td>10 to 320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aperture (mm)</td>
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<td>30 x 40</td>
<td>Ø50</td>
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<td></td>
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<tr>
<td>Resolution (camera-dependent) (µm)</td>
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<td>70</td>
<td></td>
<td></td>
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<tr>
<td>Saturation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 193 to 248 nm</td>
<td>10 mJ/cm²</td>
<td>30 mJ/cm²</td>
<td>–</td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 308 nm</td>
<td>50 mJ/cm²</td>
<td>50 mJ/cm²</td>
<td>–</td>
<td></td>
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<tr>
<td>Sensitivity</td>
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<td>5 µJ/cm²</td>
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<tr>
<td>Damage Threshold</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>CW</td>
<td>5 W/cm²</td>
<td>1.5 W/cm²</td>
<td>10 W/cm²</td>
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<tr>
<td>Pulsed</td>
<td>500 W/cm²</td>
<td>600 W/cm²</td>
<td>50 J/cm²</td>
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<tr>
<td>Uniformity Over Aperture (%)</td>
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<tr>
<td>Image Persistence</td>
<td>500 ns</td>
<td>5 µs</td>
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<td></td>
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<td>(fluorescence lifetime)</td>
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</tr>
<tr>
<td>Image Magnification</td>
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<td>1:1</td>
<td>6:1 (Zoom) to 1:1</td>
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</table>

BIP-5000Z

BIP-12F

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

Knife-Edge Beam Profiler

Features

- CW laser beam shape, power and position measurements
- Beam sizes from 3 μm to 9 mm with 0.1 μm resolution and high dynamic range
- Real-time Windows display, analysis and data logging system
- Wavelengths from 190 nm to 1800 nm
- USB interface
- Windows XP, Vista 32-bit, Vista 64-bit, Windows 7 32-bit, Windows 7 64-bit

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 via USB. All screen images can be captured and stored, or printed.

BeamMaster can measure focused beam spots as small as 3 μm with 0.1 μm resolution and has an aperture as large as 9 mm with 1 μm 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 μW. 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.
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, strip-charted, and sent to a file. 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. Note: Unlike the PCI version, the USB model is always in high resolution mode for maximum detail.

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 µW, 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. All screen images also can be captured and stored as BMP or JPG files.

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.

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

BeamMaster Accessories

BeamMaster System Components
Each BeamMaster system consists of a sensor head, complete with a 1.8 m cable, USB interface module to plug into a PC computer, complete Windows software on a CD-ROM disk, a 0.5" mounting post (threaded 8-32) and stand, 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.

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 97).

<table>
<thead>
<tr>
<th>Device Specifications</th>
<th>Model</th>
<th>BeamMaster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement Rate (Hz)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Wavelength Range (nm)</td>
<td>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)]</td>
<td></td>
</tr>
<tr>
<td>Sensor Aperture</td>
<td>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)</td>
<td></td>
</tr>
<tr>
<td>Minimum Beam Size (µm)</td>
<td>15 (BM-7 all models) 3 (BM-3 all models)</td>
<td></td>
</tr>
<tr>
<td>Beam Size Resolution</td>
<td>1 µm for beams &gt;100 µm in size (0.1 µm for beams &lt;100 µm in size)</td>
<td></td>
</tr>
<tr>
<td>Position Measurement Resolution (µm)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Position Measurement Accuracy (µm)</td>
<td>±15</td>
<td></td>
</tr>
<tr>
<td>Beam Width Measurement Accuracy (%)</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td>Beam Power Range</td>
<td>10 µW to 1 W (with supplied internal filters), saturation 0.1 W/cm² without filter, 20W/cm² with NG9 filter [BM-7, BM-3 (Si-Enhanced)] 10 µW to 5 mW (no filters provided), saturation 0.1 W/cm² [BM-3 InGaAs, BM-7 InGaAs]</td>
<td></td>
</tr>
<tr>
<td>Relative Power Measurement</td>
<td>0.1 µW resolution</td>
<td></td>
</tr>
<tr>
<td>Sensor Head Weight (g)</td>
<td>56 g</td>
<td></td>
</tr>
<tr>
<td>Part Number</td>
<td>1224014 BeamMaster BM-7 Si-Enhanced - USB interface 1224012 BeamMaster BM-3 Si-Enhanced - USB interface 1224018 BeamMaster BM-7 InGaAs (3 mm) - USB interface 1224020 BeamMaster BM-7 InGaAs (5 mm) - USB interface 1224016 BeamMaster BM-3 InGaAs (3 mm) - USB interface 1038024 BeamMaster Rotation Mount 33-7147-000 BeamMaster C-Mount Adapter Plate</td>
<td></td>
</tr>
</tbody>
</table>
**ModeMaster PC**

**M² Beam Propagation Analyzer**

**Features**
- Measurement and display of CW laser divergence, $M^2$ (or k) and astigmatism
- Beam sizes 0.2 mm to 25 mm
- Wavelengths from 220 nm to 1800 nm
- 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 $M^2$ 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 $M^2$, divergence, maximum power density, far-field pinhole profiles and pointing angle.

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

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, $M^2$, which has now become an ISO measurement standard. $M^2$ 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.
Beam Propagation Display

Coherent pioneered $M^2$ 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 $M^2$ 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 XP, Vista, and 7. 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 $M^2$ 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.
ModeMaster PC

M² Beam Propagation Analyzer

Real-Time Display Pointing-Stability Display

Real-Time M² and Beam Profiles
The ModeMaster PC provides real-time measurement and display for fine tuning M² 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.

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 (W0) in the horizontal and vertical directions are the same size, but occur at different propagation distances (Z0). 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.

Pure Astigmatism

\[ Z_{ox} = Z_{oy} \]
\[ W_{ox} = W_{oy} \]

Pure Asymmetry

\[ Z_{ox} = Z_{0y} \]
\[ W_{ox} = W_{0y} \]
## 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$_{00}$ mode. Thus, the angular size of the beam in the far field will be $M^2$ larger than calculated for a perfect Gaussian beam.

$$\Theta = M^2 \times 2\Delta / (\pi Wo), \text{ for a beam waist diameter } 2Wo.$$ 

<table>
<thead>
<tr>
<th>Device Specifications</th>
<th>Model</th>
<th>ModeMaster PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist Diameter (%)</td>
<td>±2</td>
<td></td>
</tr>
<tr>
<td>Waist Location</td>
<td>±8% of input beam Rayleigh Range</td>
<td></td>
</tr>
<tr>
<td>Beam Quality – $M^2$ (%)</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td>Divergence (%)</td>
<td>±5</td>
<td></td>
</tr>
<tr>
<td>Beam Translation</td>
<td>±5% of waist diameter ±0.1 mm</td>
<td></td>
</tr>
<tr>
<td>Pointing Angle</td>
<td>±5% of divergence ±0.04 mrad</td>
<td></td>
</tr>
<tr>
<td>Azimuth Angle Readout</td>
<td>$\Theta$ (0 to 200°)</td>
<td></td>
</tr>
<tr>
<td>Knife-Edge Clip Levels</td>
<td>User-adjustable 0% to 100% in 15% steps</td>
<td></td>
</tr>
<tr>
<td>ModeMaster PC Control/Interface</td>
<td>&lt;8 Hz ($M^2$, divergence, power density, waist diameter, profiles)</td>
<td></td>
</tr>
<tr>
<td>Module Update Rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog Outputs</td>
<td>Detector signal output, 0 to 13V maximum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A/D control signal out, 0 to 5V pulse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trigger (syncs to drum rotation), 0 to 5V pulse</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>100 to 240 VAC, 47 to 63 Hz, 40W maximum</td>
<td></td>
</tr>
</tbody>
</table>

### Laser Beam Quality

- **Scan Head and Precision Mount**
- **Control/Interface Console**
ModeMaster PC systems are available in six standard configurations (all include scanning head, 5-axis mount, USB control/ interface console, cables, PC software and manual). These configurations encompass three 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 three spectral ranges: UV (220 nm to 680 nm), VIS (340 to 1000 nm), and NIR (800 nm to 1800 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).
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 UV-VIS-NIR body 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

- **33-1843-000**: ModeMaster PC System 1
- **33-2106-000**: ModeMaster PC System 1
- **33-2221-000**: ModeMaster PC System 1
- **33-2239-000**: ModeMaster PC System 1
- **33-2387-000**: ModeMaster PC System 1
- **33-2395-000**: ModeMaster PC System 1
- **33-1710-000**: ModeMaster PC Control/Interface Console and Software

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

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**Standard Configuration**

<table>
<thead>
<tr>
<th>Name</th>
<th>UV Low-Divergence</th>
<th>UV High-Divergence</th>
<th>VIS Low-Divergence</th>
<th>VIS High-Divergence</th>
<th>NIR Low-Divergence</th>
<th>NIR High-Divergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>MM-1</td>
<td>MM-15</td>
<td>MM-2</td>
<td>MM-25</td>
<td>MM-3</td>
<td>MM-35</td>
</tr>
<tr>
<td>Spectral Range (µm)</td>
<td>0.22 to 0.68</td>
<td>0.34 to 1.00</td>
<td>0.80 to 1.80</td>
<td>0.80 to 1.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detector Type</td>
<td>Silicon</td>
<td>Germanium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**INPUT BEAM REQUIREMENTS AT TEST WAVELENGTH**

- **Test Wavelength**: 351 nm, 514 nm, 1.06 µm
- **Minimum Power**: 75 mW³, 2.5 mW³, 2.5 mW³
- **Maximum Power**: 10 W¹, 25 W¹, 2.5 W
- **Noise**: <2% RMS and <5% peak-to-peak
- **Min. Divergence (mrad)**: 0.24, 0.24, 0.24
- **Max. Divergence (mrad)**: 1.7, 3.2, 0.25
- **Max. Beam Diameter (mm)**: 25, 12, 25

**POWER & ENERGY**

- **M2 Beam Propagation Analyzer (standard system configuration)**

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1. Wavelength-dependent quantities are input power levels, and minimum and maximum divergence (see Notes 2, 3, 4).
2. 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.
3. The germanium detector peaks at 1500 nm and is at half-peak sensitivity at 1100 nm and 1650 nm.
4. 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.
5. Limits shown are for M² = 1 and test wavelength; limits scale as the square root of M² (test wavelength).
6. Minimum divergence in this wavelength range scales as the square root of M² (test wavelength).
7. Diameters are approximate; divergence takes precedence in choosing options. Refer to nomogram.
ISO/IEC 17025:2005 Accredited
Coherent’s Wilsonville, Oregon calibration laboratory is fully accredited to ISO/IEC 17025:2005 by ACLASS, a brand of the ANSI-ASQ National Accreditation Board and recognized internationally by ILAC, APLAC, and IAAC. ISO 17025 is the single most important metrology standard for test and measurement products, and external accreditation is a formal recognition that a calibration laboratory is using valid and appropriate methods and is competent to carry out specified tests or calibrations.

Scope of Accreditation
The scope of accreditation applies to the laser/electrical calibration of nearly all the company’s catalog pyroelectric laser energy sensors, thermopile laser power sensors and meter electronics. Pages in this catalog that contain products that fall within the scope of accreditation are clearly identified by the combined ILAC-MRA/AClass mark shown below:

The formal scope of accreditation can be found on the Coherent website at http://www.coherent.com within Company tab > Quality. It can also be found within the ACLASS website at http://www.aclasscorp.com. Click the “Search Accredited Organizations” button on their homepage.

ISO 17025 is an international standard that governs calibration labs. It requires labs demonstrate that they operate a quality management system that controls the processes and documentation, including auditing and corrective action processes. It also requires adherence to rigorous technical requirements that ensure valid results are generated.

In terms of specific technical requirements, ISO/IEC 17025 ensures that a company:

• maintains testing facilities and equipment to specified standards
• ensures protocols are fully documented
• trains workers to an appropriate level of competence
• confirms validity and appropriateness of methods, especially so-called “non-standard” methods such as those used to calibrate laser measurement equipment, which have been developed internally
• uses accepted mathematical methods for calculating results
• verifies that purchased test equipment meets proper requirements, and that all equipment used to produce accredited calibrations has itself received ISO 17025 accredited calibrations
• has a traceable path of calibration to independently maintained national or international standards
• provides both as received and outgoing testing data to customers in an approved format
• ensures the calibration certificate meets the requirements of the standard

The outcome of all these efforts is that customers can have confidence that a laboratory achieves verifiably correct results, and that these results will be reported in an unambiguous manner.
Limited Warranty
Coherent, Inc., warrants to the original purchaser that its laser power and energy meters and sensors are free from defects in materials and workmanship and comply with all specifications, active at the time of purchase, for a period of twelve (12) months. Coherent, Inc., will, at its option, repair or replace any product or component found to be defective during the warranty period. This warranty applies only to the original purchaser and is not transferable.

Extended Warranty
Coherent, Inc., offers original purchasers of laser power and energy meters and sensors an extended twelve month warranty program, which includes all parts and labor. In order to qualify for this warranty, a Customer must return the Product to the Company for recalibration and recertification. The Company will recertify the Product, provide software upgrades, and perform any needed repairs, and recalibrate the Product, for a fixed service fee. If the Product fails and is returned to the Company within one year following the date of recalibration and recertification service, the Company will, at its option, repair or replace the Product or any component found to be defective.

Contact Coherent or visit www.Coherent.com/LMC for additional details and warranty limitations.

Obtaining Warranty Service
In order to arrange for warranty service or annual recalibration, first contact your closest Coherent service center to obtain a Return Material Authorization (RMA) number.

USA
Phone: 800 343 4912
Fax: 503 454 5727
E-mail: LMC.sales@coherent.com

Asia
Phone: 813 5635 8680
Fax: 813 5635 8701
E-mail: LMC.sales@coherent.com

Europe
Phone: 49 6071 9680
Fax: 49 6071 968499
E-mail: LMC.sales@coherent.com

Detailed instructions for preparing and shipping your instrument can be found below.

Instructions for Returning Equipment for Service and Calibration
To prepare your instrument, meter or sensor for return to Coherent, attach a tag to the unit that includes the name and address of the owner, the contact individual, the serial number, and the RMA number you received from Customer Service.

Wrap the product with polyethylene sheeting or equivalent material. If the original packing material and carton are not available, obtain a corrugated cardboard shipping carton with inside dimensions that are at least 6 in. (15 cm) taller, wider, and deeper than the product. The shipping carton must be constructed of cardboard with a minimum 375 lbs. (170 kg) test strength. Cushion the instrument unit in the shipping carton, using 3 in. (7.5 cm) of packing material or urethane foam on all sides, top, bottom, and between the carton and the instrument or sensor. Seal the shipping carton with shipping tape or an industrial stapler.

Shipping addresses for our repair and calibration facilities are given below:

USA
Coherent Laser Measurement and Control Service Center
Attn: (your RMA number)
27650 SW 95th Avenue
Wilsonville, OR 97070
USA

Europe
Coherent (Deutschland) GmbH
Dieselstr. 5b
D-64807 Dieburg
Germany

Asia
Coherent Japan
Toyo MK Building
7-2-14 Toyo
Koto-Ku, Tokyo
135-0016 Japan