

User Notes

BEAMWATCH®-PLUS-45

NON-CONTACT BEAM PROFILER FOR MULTI-KILOWATT NIR
(950–1100nm) AND VIS (420–635nm) WAVELENGTH LASERS



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1 Safety Information

While BeamWatch itself does not present the user with any safety hazards, this instrument is intended for use with laser systems. Therefore, the user should be protected from any hazards that the laser system may present. The greatest hazards associated with laser systems are damage to the eyes and skin due to laser radiation.

1.1 Safety Procedures and Precautions

The following general safety precautions must be observed during all phases of operation of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this user note violates safety standards of intended use of the instrument and may impair the protection provided by the equipment. MKS Instruments, Inc. assumes no liability for the customer's failure to comply with these requirements.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT

Do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to an Ophir Calibration and Service Center for service and repair to ensure that all safety features are maintained.

OPTICAL RADIATION HAZARDS



BeamWatch is designed for use with high power lasers and therefore safety precautions must be taken. Users must be protected against accidental exposure. Exposure to personnel other than the user must also be considered. Hazards include direct beam exposure and reflected radiation. Protective eye shields and clothing must be worn.

ELECTRICAL HAZARDS



BeamWatch utilizes only low voltages, derived from the Ethernet and camera power supplies. Thus, there is little risk of electrical shock presented to the user.

When installing or removing any hardware from a PC, the power to the computer should always be disconnected. The computer should always be operated with its covers in place and in accordance with its manufacturer's recommendations. The computer should always be operated with a properly grounded AC power cord.

1.2 Symbols Used in This User Note

Definitions of NOTE and CAUTION messages used throughout this user note.

NOTE

The NOTE sign denotes important information. It calls attention to a procedure, practice, condition, or the like, which is essential to highlight.

CAUTION

The CAUTION sign denotes a hazard. It calls attention to an operating procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of all or part of the product.

2 Information

2.1 Introduction

BeamWatch® is the laser industry's first completely non-interfering beam monitoring system, which allows beam measurements without contacting the laser beam. Measurements are taken by imaging the Rayleigh scatter of the beam from the side using conventional cameras making BeamWatch ideal for measurements of high-power lasers. Ophir has measured beams up to 100 kilowatts.

BeamWatch provides simultaneous measurements of multiple profiles along the beam caustic in the camera field-of-view (FOV). The speed of measurement operates at video rates allowing for real-time determination of:

- Waist (focus spot) width and location
- Focal shift
- Centroid
- M^2 or K
- Divergence
- Beam Parameter Product
- Rayleigh length
- Relative power

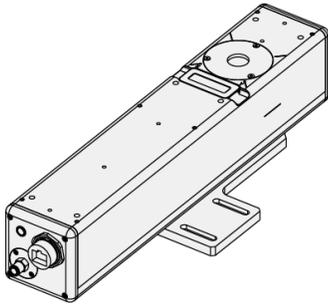
Real-time performance also allows for measurement of dynamic focal shift during laser startup.

The technique is based on Rayleigh scattering of laser light by oxygen and nitrogen molecules in the air as the beam propagates. Measurement of this scattered light provides an equivalent slit scan of the laser beam in the direction of the view observed. The scattered light is measured using conventional image capture systems.

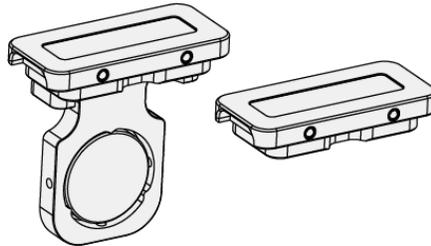
The standard optical system is calibrated and aligned for the NIR wavelength range. The BeamWatch PLUS model also measures visible wavelengths with the same device. Because the optical system focuses further away for shorter wavelengths, a delay glass is introduced which returns the system focus location back into the center of the aperture. Without the glass, the BeamWatch measures 950-1100nm wavelengths; with the glass inserted, the BeamWatch is now setup to measure 420-635nm wavelengths.

BeamWatch has GigE connectivity to standard personal computers for data acquisition, analysis, and display.

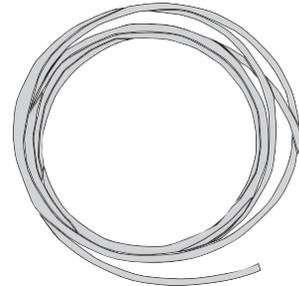
2.2 Equipment



BeamWatch-Plus-45



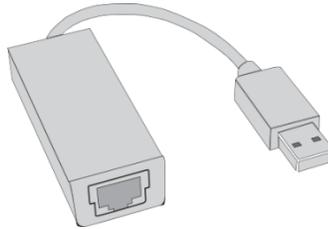
Glass Inserts



1/4" Polyurethane tubing 10ft



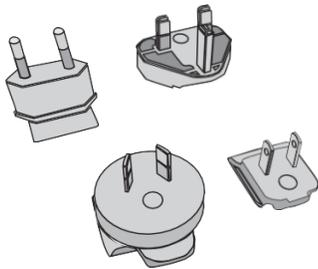
Ethernet Cable 4.5m



Gigabit to USB 3.0 Adapter



Power Supply Cable



Power Supply Adapter Kit



Alignment Tool



User documentation:

- BeamWatch-Plus-45 User Notes
- Calibration Certificate
- Quick Start Guide

2.3 Optional Equipment

We recommend one or more of these additional optional products (Not Pictured):

- BeamWatch Plus Deep Cup Aperture (SP98008)
- Locking Ethernet cable (SP90394)
- 10kW water cooled power sensor
- 30kW water cooled power sensor
- 100kW water circulated power sensor
- Juno® USB PC interface
- EA-1® Ethernet PC interface

Consult your Ophir Representative or call Ophir's Sales Department for ordering information.

2.4 Specifications

Table 1: BeamWatch-PLUS-45 Specifications

	BeamWatch-PLUS-45	
Beam Profiling		
Wavelength	420–635 nm	950–1100nm
Minimum <u>linear</u> power density ⁽¹⁾	230 W/cm	34 kW/cm
Minimum Power	3W	400W
Minimum focus spot	45 μm	
Field of view (FOV)	9.01mm x 2.99mm	
FOV resolution	5.5μm	
Maximum Rayleigh range	3mm	
Maximum beam diameter at entrance/exit ⁽²⁾	12.5mm	
Distance from input aperture to center of FOV ⁽³⁾	Nominal 39.7mm	
Accuracy ⁽⁴⁾		
Waist width (Spot size)	±5%	
Waist location	±125μm	
Focal shift	±50μm	
Beam parameter product	±2% RMS	
Divergence	±2% RMS	
M²	±2% RMS	
General		
Communication to PC	GigE Ethernet	

	BeamWatch-PLUS-45
Power	12 Volts DC, 1.67 Amps max, 100-240V AC
Particulate purge	Clean Dry Gas: approximately 35 PSI / 2.5 BAR; Particle size: < 5µm, oil and water free
Weight	3.9 kg
Dimensions	16 x 7 x 35in. (406.4 x 177.8 x 88.9mm)
Operating Temperature	10 to 40°C
Storage Temperature	-20 to 80°C
Operating/Storage Humidity	20 to 80%; relative, non-condensing
Compliance	CE, UKCA, China RoHS

(1) Linear Power Density calculated by Power / beam diameter.

(2) OEM solutions available for larger aperture needs.

(3) The deep cup accessory (SP98008) has a 12mm distance to the center of the FOV.

(4) Specified accuracy for beam tilt < 5°.

2.5 Operating Limits

The graphics below are intended to give a visual indication of the recommended operating space for BeamWatch-PLUS-45. If BeamWatch-PLUS-45 is operated outside of this space, it may be more difficult to see the curvature of the caustic or the beam may be large enough at the edges of the image that it is out of focus.

- Optimal has at least 3 Rayleigh lengths on both sides of the waist, with the waist at the center of the image
- Near Optimal has at least 3 Rayleigh lengths on one side of the waist, with the waist at the end of the image
- Acceptable has at least 1.5 Rayleigh lengths on both sides of the waist, with the waist at the center of the image

NOTE

When using these graphics, take the M^2 value and reference it against the waist width of the beam. If the beam falls within the plotted areas, then it is within the range for BeamWatch to give stronger results.

Use caution as the beam falls into the Acceptable range; these results are not as strong.

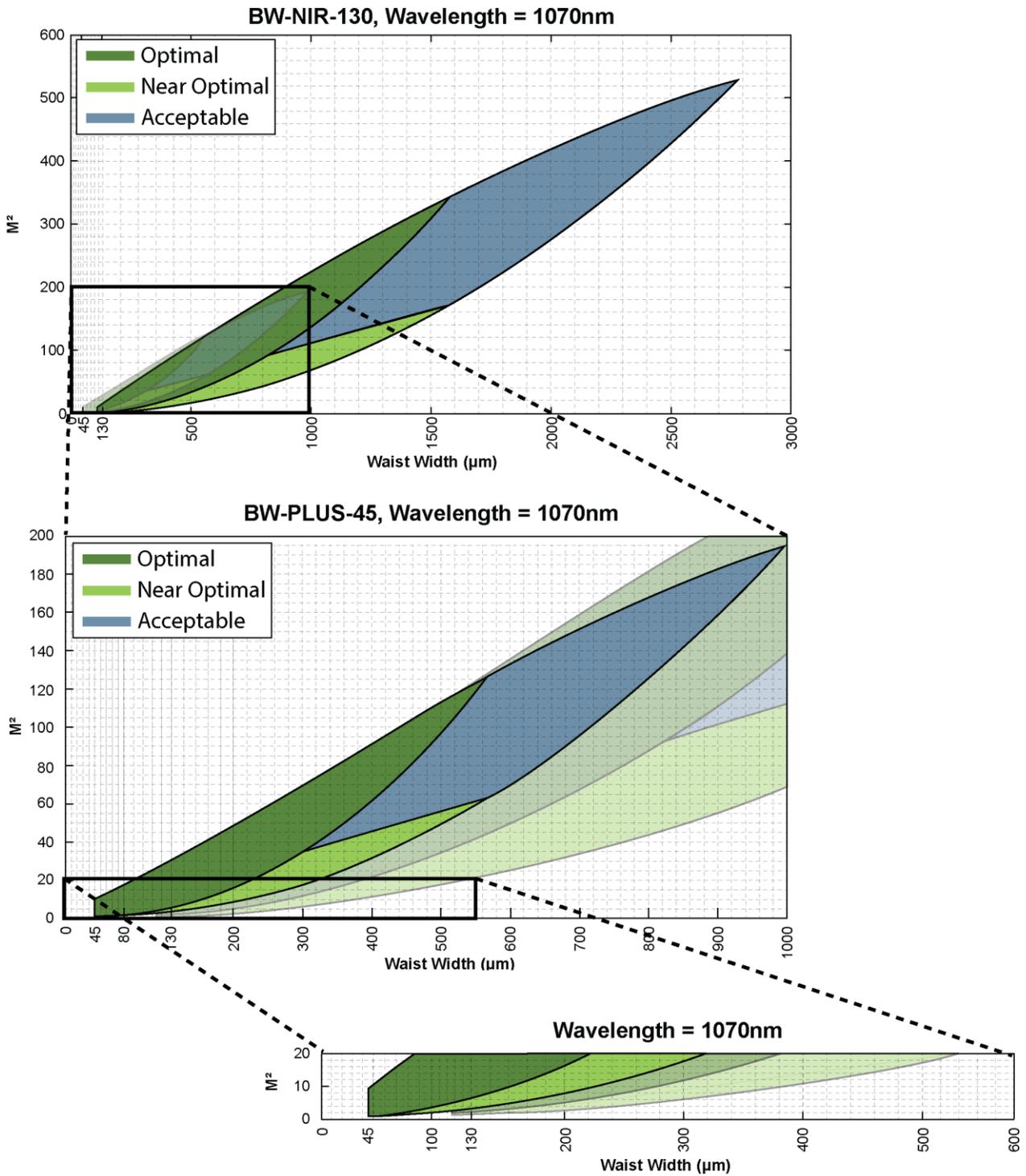


Figure 1: Operating Space Chart in the NIR Range

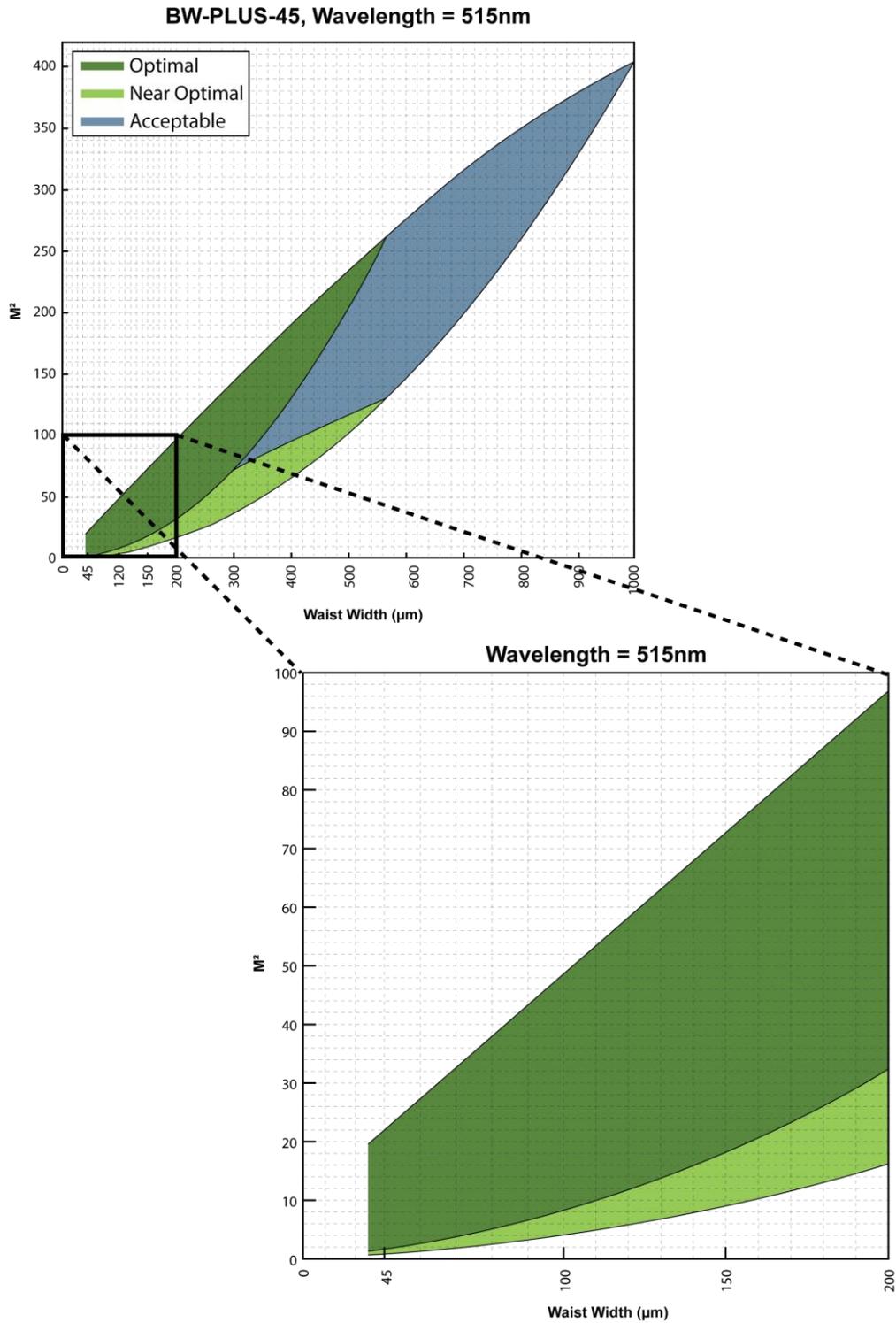


Figure 2: Operating Space Chart in the VIS range

Linear power density also plays a role in the operating space. The charts below show the required minimum power vs. focus spot size for a Gaussian beam.



Figure 3: Minimum Linear Power Density in the NIR Range



Figure 4: Minimum Linear Power Density in the VIS Range

The equation to estimate the maximum spot size is derived from the linear power density equation:

$$\text{Linear Power Density} = \frac{P_{ave}}{D_0}$$

Where P_{ave} is the average beam power and D_0 is the diameter of the beam at the waist location.

3 Hardware Configuration

This chapter provides instructions to setup and start using your BeamWatch.

3.1 BeamWatch Initial Setup

The BeamWatch unit must be mounted to a stable surface where the laser can pass through the entrance and exit apertures unobstructed. The device may be mounted horizontally or vertically to meet the needs of the application.

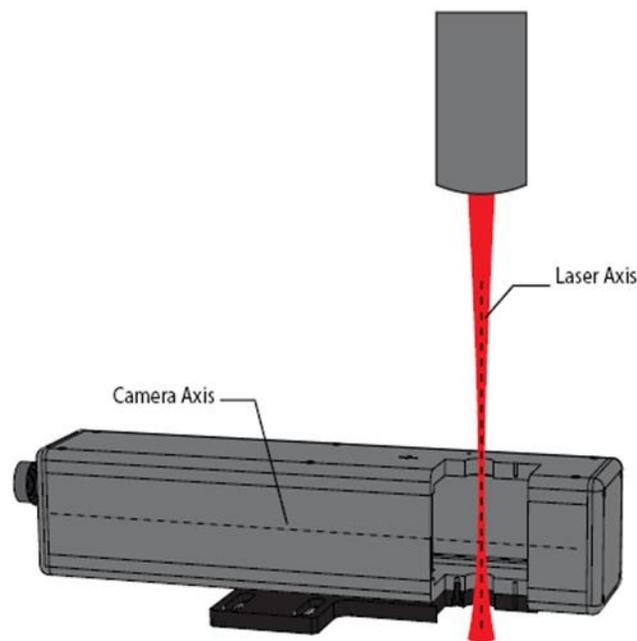
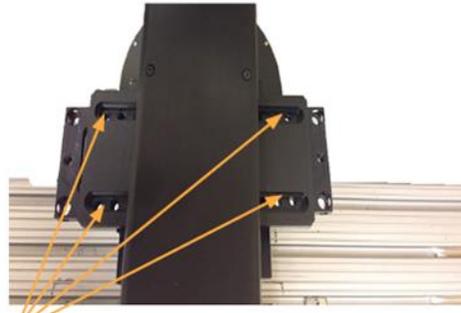


Figure 5: BeamWatch Alignment

Position the BeamWatch unit at the nominal focus position along the laser axis, and make sure the beam waist is as close to the camera axis as possible. There is a scribe mark on the side of the device that references this position. The calibrated distance from the top of the BeamWatch to the center of the detector array can be found on the calibration sticker.

To obtain results within $\pm 5\%$ accuracy, the camera must be aligned perpendicular to the beam with minimal tilt ($< 5^\circ$) in all directions and the beam must lie in the plane of the camera focus. Use either a translation stage or the laser robotics to facilitate the positioning of the beam in the camera focus plane.

Once in the desired location, secure the unit with four $\frac{1}{4}$ -20 or M6 screws in the slots, two on each side (Figure 6). If not mounted in a fixed position, measurement error and/or damage to the unit may occur.



Secure with 1/4-20 or M6 Screws

Figure 6: BeamWatch Mounting

After the BeamWatch is mounted, measure the distance from any desired reference point on the laser delivery head to the top face of the BeamWatch as shown in Figure 7. This value is the distance of the laser and must be entered into the software during setup (refer to the BeamWatch Software User Guide).

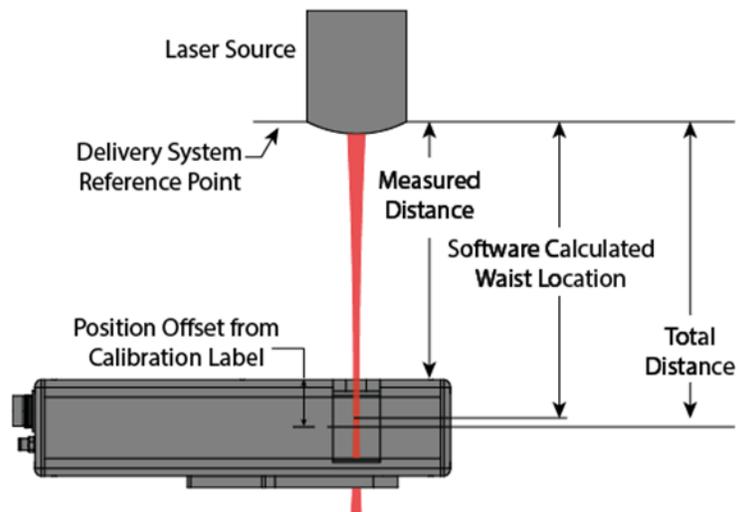


Figure 7: Description of BeamWatch Measurement Distances

3.1.1 Mounting for Elliptical Beams

There is no automated method for finding the major and minor axes of an elliptical beam. The BeamWatch unit must be manually rotated to find these axes. After the software is installed and the beam is centered in the BeamWatch unit, rotate the unit around the beam while viewing the Waist Width result in the software until max/min values are found. For best measurements, rotate the BeamWatch until the major and minor axes of the beam are aligned with the X and Y axes of the software. It is irrelevant which of the BeamWatch axes views the major or minor axes of the beam.

3.1.2 Cup Aperture

For systems with a short distance between the beam delivery head and the focal plane, users can purchase the deep cup aperture accessory (SP98008). This cup allows the delivery head to protrude into the BeamWatch device up to 27.5mm while minimizing scattered light. The focus position must be within the camera FOV to obtain accurate measurements.

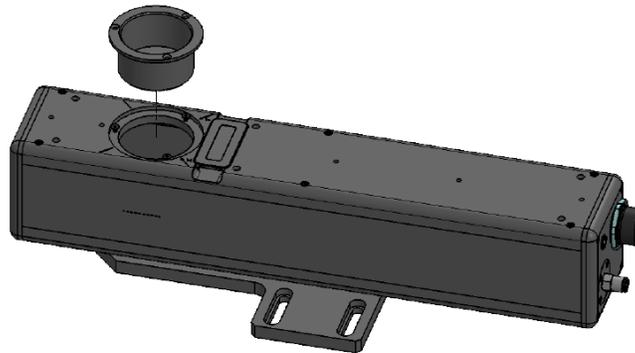


Figure 8: BeamWatch Plus with Cup Aperture

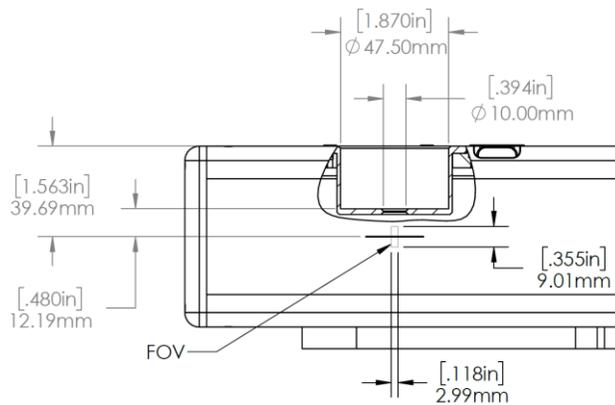


Figure 9: Cup Aperture Dimensions

3.2 Beam Dump

A suitable beam dump is required. An Ophir Power Sensor rated for the power of the laser is recommended. Other options are acceptable, but must have minimal backscatter, such as a cone type or black absorber power sensor. Contact your Ophir representative for additional information.

3.3 Particulate Removal

The industrial laser environment has high levels of particulates that must be removed from the camera FOV to obtain accurate results. With BeamWatch, this is accomplished by generating a laminar flow region at the camera

FOV using a clean, dry gas source. Air, Nitrogen, or Argon is recommended at approximately 10 SLPM (35 PSI / 2.5 BAR). Connect the provided ¼" hose to the gas source as shown in Figure 10.

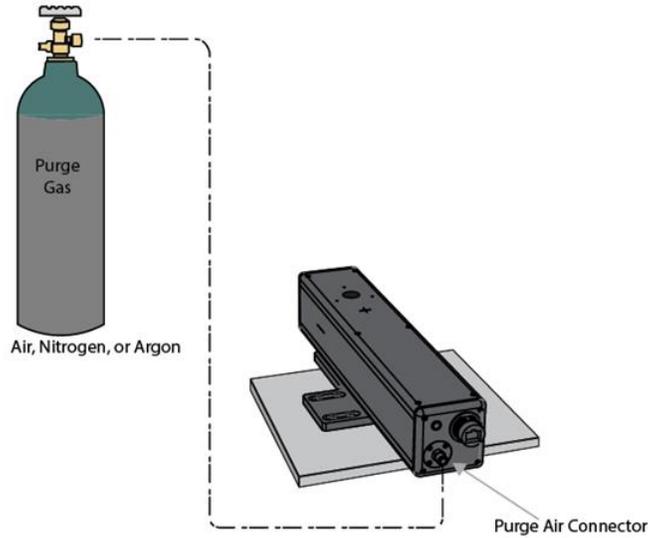


Figure 10: Particulate Purge Connections

3.4 BeamWatch Electrical Connections

Refer to the connection diagram in Figure 11 for the steps below.

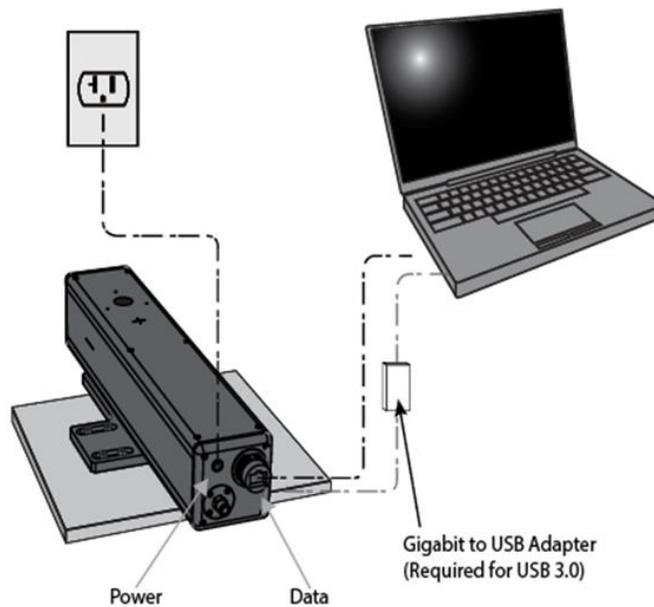


Figure 11: Power and Data Connection

1. Connect the provided power cord to the power port on the BeamWatch unit.
2. Connect the remaining end into a surge protected 100-240 VAC outlet.
3. Connect one end of the provided Ethernet cable to the data source on the BeamWatch unit.
4. Connect the remaining end into an Ethernet port on the PC, or connect to the Gigabit to USB adapter and connect the adapter to a USB 3.0 port.

3.5 Wavelength Insert

The BeamWatch Plus device requires specific inserts to be in place for operation in the NIR or VIS wavelength ranges. The insert affects the camera focus location and beam alignment. Install the correct insert for the intended operating wavelength region.



Figure 12: Wavelength Inserts

Replacement inserts are available upon request.

- Replacement Insert for VIS – SP98006
- Replacement Insert for NIR – SP98007

3.6 Beam Alignment

1. After installing and launching the software, apply the purge gas at approximately 10 SLPM (35 PSI / 2.5 BAR).
2. If not already installed, insert the alignment tool into the BeamWatch with the cutout side facing the camera as shown. Ensure the alignment tool is flush with the top.

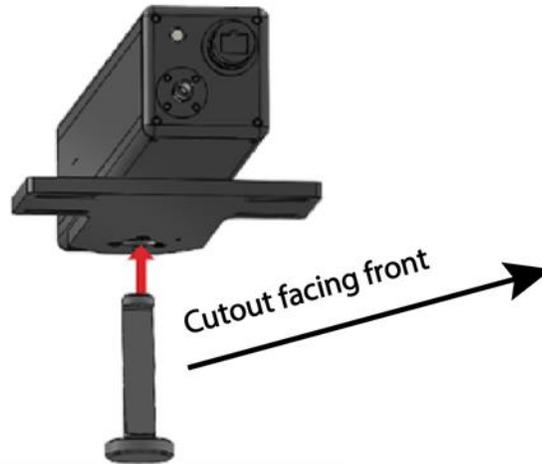


Figure 13: Alignment Tool with the Cutout Facing Front

NOTE

For accurate results the beam must be aligned with the center of the input aperture, perpendicular to the top of the unit. A beam offset in any direction can produce inaccurate results.

3. Apply the guide beam.
4. Start the BeamWatch software and enable the **Crosshair** located at the top of the **2D Beam Display toolbar** (Figure 14).

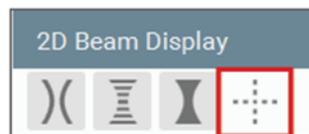


Figure 14: Crosshair Icon in the 2D Beam Display Toolbar

5. Turn on the alignment beam and center it on the alignment tool by adjusting either the beam or the BeamWatch unit, with the beam perpendicular to the BeamWatch as shown below.

CAUTION

The BeamWatch alignment tool is intended for use with low power alignment beams. Severe damage can occur if the high-power beam is enabled when the alignment tool is in place.

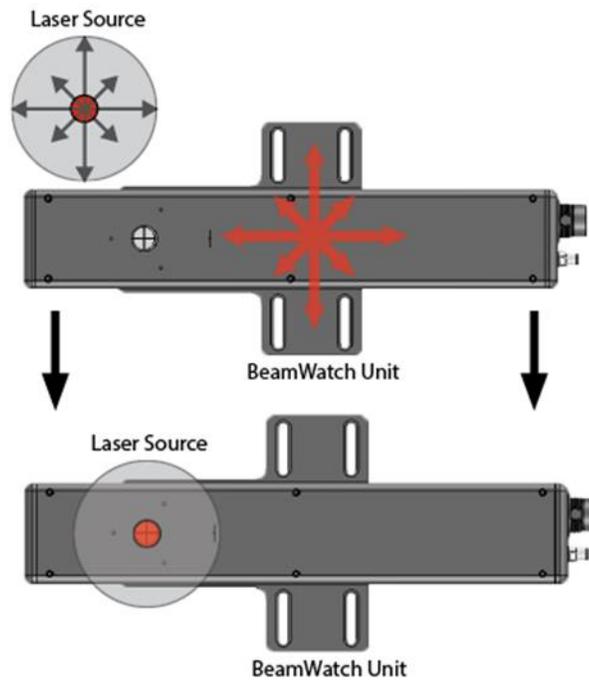


Figure 15: Alignment of the BeamWatch Device

6. The beam is displayed in the BeamWatch software as an ellipse as shown in the images below. It may be necessary to adjust the **Exposure** and/or **Frame Summing** to bring the alignment beam to a viewable level.
7. If the beam is centered on the crosshair as shown in the properly centered example, the beam is aligned. If the beam is not centered, adjust the angle the beam enters the BeamWatch. Figure 16 shows beam deviations and the resulting displays.

NOTE

The angle of the beam is exaggerated for clarity.

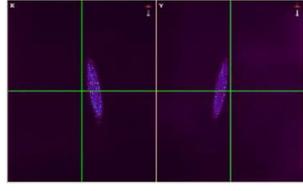
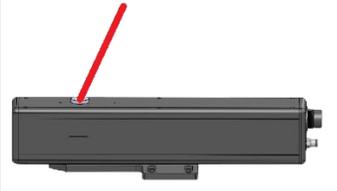
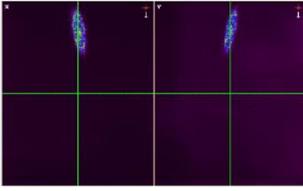
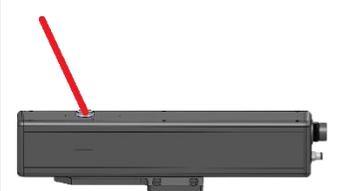
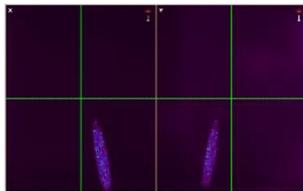
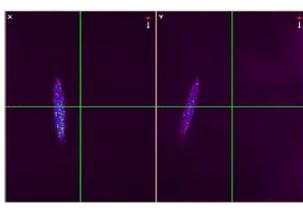
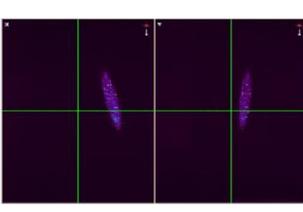
Alignment	Illustration	2D Display
Properly centered		
Beam angled away from camera		
Beam angled toward camera		
Beam angled toward the left		
Beam angled toward the right		

Figure 16: Beam Display when Using the Alignment Tool

3.7 Final Alignment Steps

Refer to Figure 17 for the following steps.

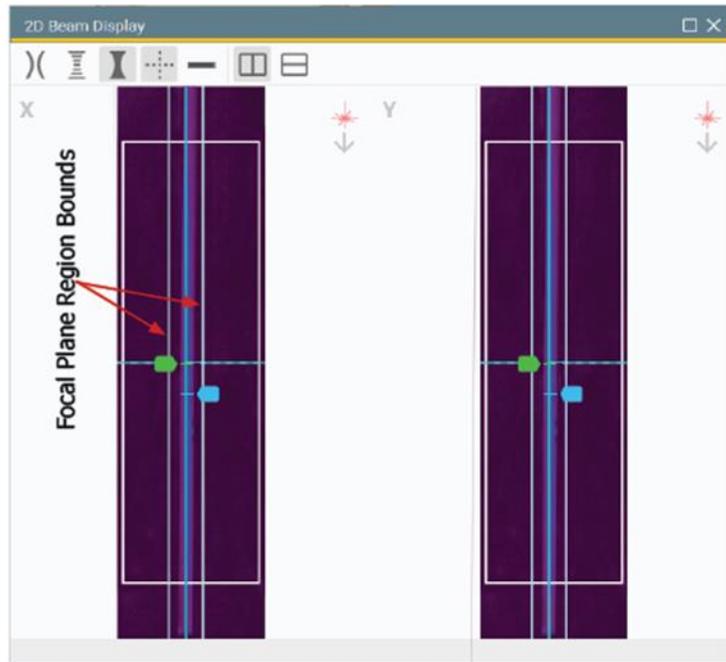


Figure 17: Alignment Bounds in the 2D Beam Display Window

1. Once the beam is aligned remove the alignment tool and switch from the guide beam to the high-power beam.
2. Enable **Live Playback** from the **Source** ribbon in the software. Enter the **Wavelength** into the **Laser** panel.
3. Adjust the gas level until a minimum number of particulates can be seen. This may be an iterative process. Particulates appear as a streak of high intensity light when viewing the beam, often saturating the image. A weak flow is not effective, and too strong of a flow can become turbulent.
4. Check the **2D Beam Display** and make sure the beam falls within the **Focal Plane Region Bounds** ($\pm 350\mu\text{m}$). The beam should be aligned within these bounds, in both views, to get the strongest results.

Figure 18 shows how various degrees of misaligned beams appear on the screen.

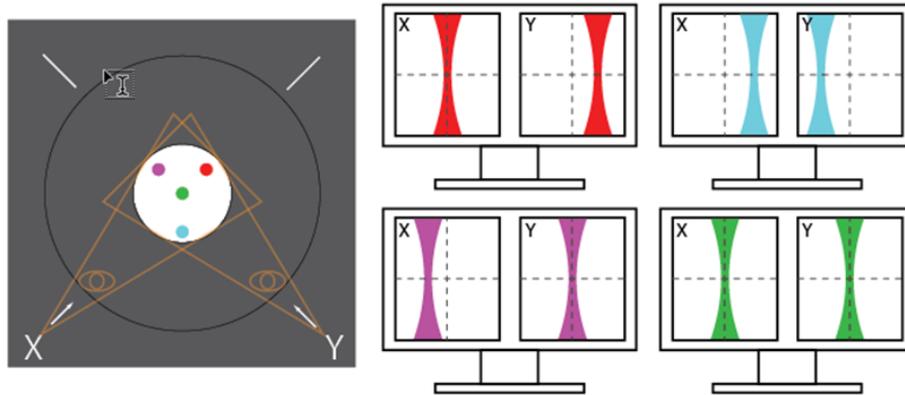


Figure 18: Diagram of Misaligned Beams

- The **red** beam is off in the view of the Y axis. It needs to be moved down and left to center.
- The **blue** beam is off in both axes and appears close to the insides of the views. It needs to be moved up to center.
- The **purple** beam is off in the view of the X axis. It needs to be moved down and right to center.
- The **green** beam represents a perfectly aligned beam.
- The **orange** lines represent the field of view of each axis.

3.8 Storing the Device

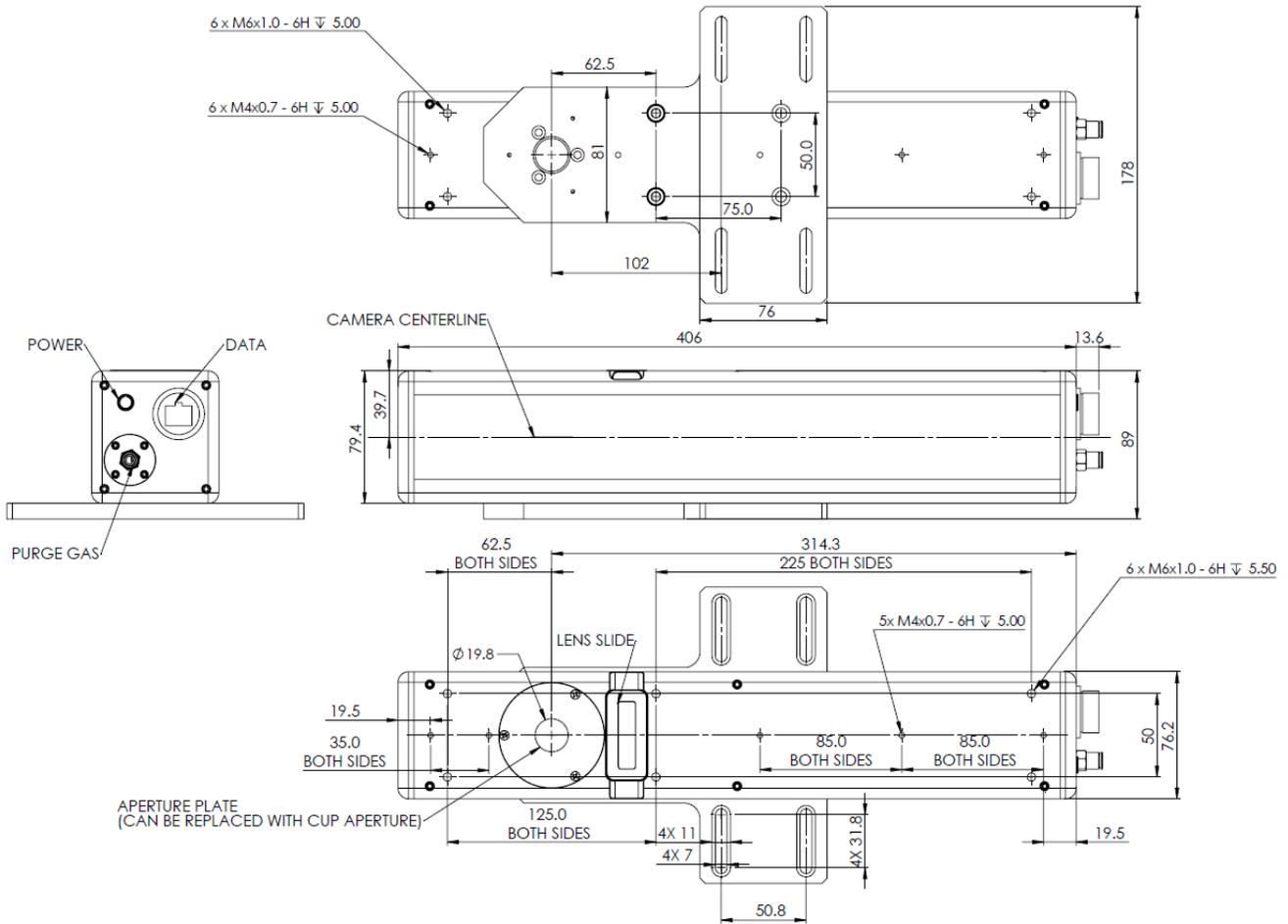
1. After data collection has completed turn off the beam.
2. Re-insert the alignment tool (Figure 19).



Figure 19: Reinserting the Alignment Tool

3. Turn off the purge gas. Always turn the purge gas off after the alignment tool has been re-inserted. The alignment tool protects the unit from contamination when not in use.
4. If needed disconnect the purge gas and electrical connections and remove the unit from the working area.

4 Dimensions



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