

Operating Manual

Model WM100 and WM100B

Omega Meter Beam Profiler

THORLABS, Inc.
435 Route 206N
Newton, NJ 07860

(973) 579-7227 Phone
(973) 300-3600 Fax
<http://www.thorlabs.com>

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WEEE

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return “end of life” units without incurring disposal charges.

This offer is valid for Thorlabs electrical and electronic equipment

- sold after August 13th 2005
- marked correspondingly with the crossed out “wheelie bin” logo (see fig. 1)
- sold to a company or institute within the EC
- currently owned by a company or institute within the EC
- still complete, not disassembled and not contaminated

As the WEEE directive applies to self contained operational electrical and electronic products, this “end of life” take back service does not refer to other Thorlabs products, such as

- pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- components
- mechanics and optics
- left over parts of units disassembled by the user (PCB's, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

Waste treatment on your own responsibility

If you do not return an “end of life” unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

Ecological background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future. The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of live products will thereby avoid negative impacts on the environment.



Crossed out “wheelie bin” symbol

Section 1 - Specifications

Performance Specifications:

WM100 Beam Diameter ($1/e^2$):	20 μ m to 8mm
WM100B Beam Diameter ($1/e^2$):	20 μ m to 4mm
Resolution:	2 μ m
Accuracy:	$\pm 5\%$ of display or $\pm 1\mu$ m (whichever is higher)
Operating Wavelength:	
WM100	400 to 1000nm
WM100B	800 to 1800nm
Input Optical Power:	
Dynamic Range	100:1 (see Note 1 below)
WM100	10 μ W to 1mW @ peak response (950nm)
WM100B	6 μ W to 0.7mW @ peak response (1550nm)

Outputs:

Display:	4-digit, LED
Beam Profile:	Single axis, along scan direction, front panel BNC, 0 - 10V
Detector Output:	Scaled integrated knife edge, front panel BNC, 0 - 10V
Output Impedance:	600 Ω

Physical Properties:

Sensor:	
WM100	Silicon Photodiode
WM100B	Germanium Photodiode
WM100 Active Area:	10 x 10mm
WM100B Active Diameter:	$\varnothing 5.0$ mm
Input Aperture:	$\varnothing 0.5$ " (12.7mm) dia.
Scan direction:	Capable of rotating through 180°, detent stops at 0, 45, 90, 135, 180°
Input Optics Mount:	$\varnothing 0.535$ -40 Thread (compatible with Thorlabs SM05-series optics mounts).
Head mounting:	8-32 Tapped Hole (M4 for WM100-EC)

Remote Interface:

Protocol:	RS-232 (2-wire)
Handshaking:	None
Connector:	DB9F
Baud Rate:	9600 Baud
Format:	8 Data Bits, 1 Stop Bit, No Parity

General:

Operating Voltage:	115VAC / 230VAC, 50-60Hz
Operating Temperature:	10 to 40°C
Size - Optical Head	1.6" x 1.5" x 2"
- Controller	5.5" x 2.5" x 11.2"

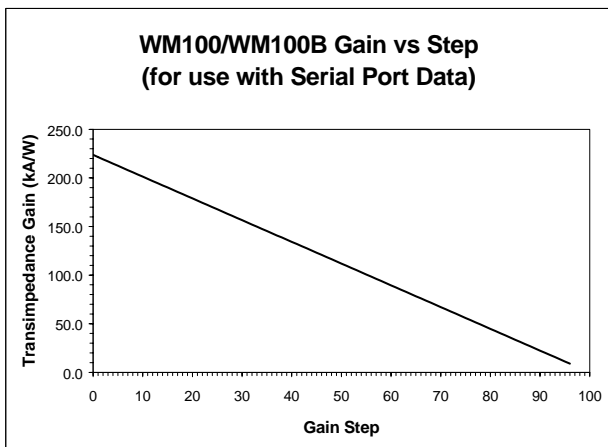
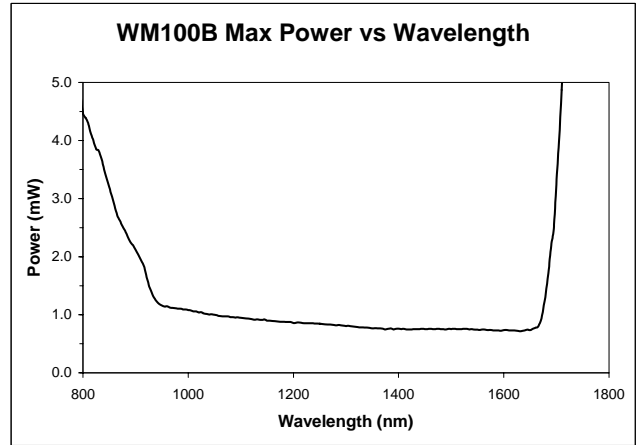
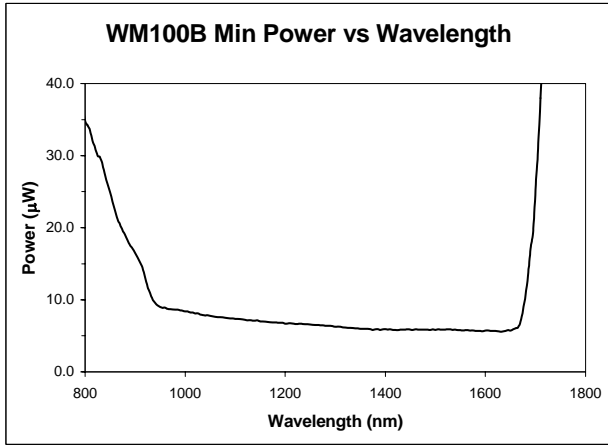
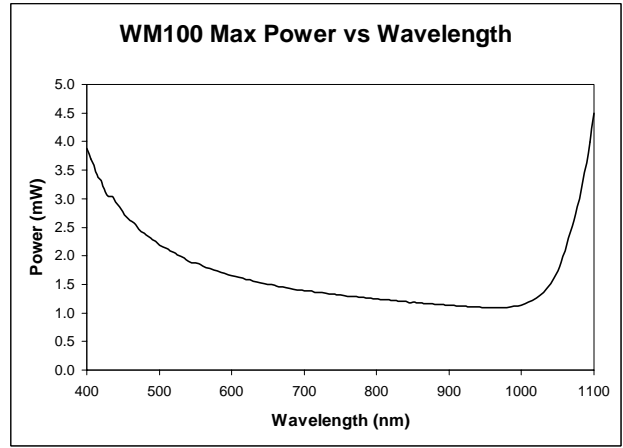
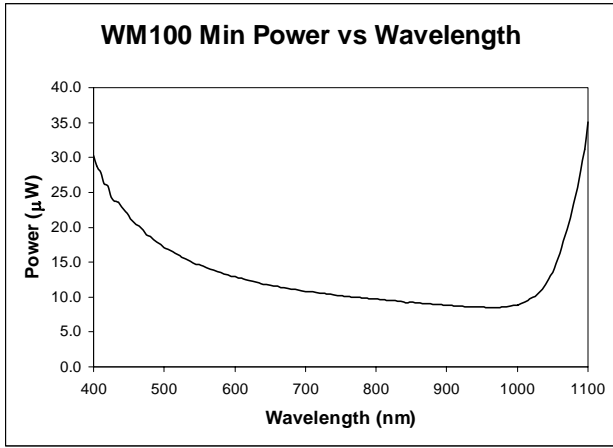
Accessories:

Light Shroud:	SM05L05
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Notes:

1. The dynamic range of the system is 100:1. To convert this into actual optical input power, the detector responsivity must be factored in. See section 2 for more details.

Section 2 – Wavelength Dependent Performance Data



Section 3 - WM100 Description

The WM100 is an easy-to-use, low-cost beam waist analyzer. Using a scanning knife-edge technique, the WM100 calculates the waist size of an input laser beam as defined by the $1/e^2$ intensity points and displays the result on a front panel digital display. An analog output of the beam profile is provided on a front panel BNC to monitor the measured beam. An RS-232 interface included with the WM100 allows remote operation of the instrument.

The principal of operation is based on calculating the beam waist size by measuring the rise-time of the integrated waveform of a scanning knife edge as it passes through the cross-section of the input beam. The linear speed of the knife-edge is simultaneously measured along with the rise time. A microprocessor computes the waist size from the measured rise-time and knife scanning speed, which is displayed on a large LED digital display. The WM100 is fully compliant with the ISO international standard for measuring beam widths (see reference 1.).

The WM100 uses a Silicon photo detector to measure beam waist sizes through the wavelength range of 400 to 1000nm, while the WM100B uses a Germanium photo detector to measure the beam waist through the range of 800 to 1800nm.

NOTE: The scanning knife edge technique used in the WM100 requires a CW input beam. The WM100 will not work with externally pulsed or mode-locked lasers. Also, excessive intensity noise on the input will lead to erroneous results (DPSS green lasers are notoriously noisy). The PROFILE OUT signal can be monitored to easily check for excessive noise.

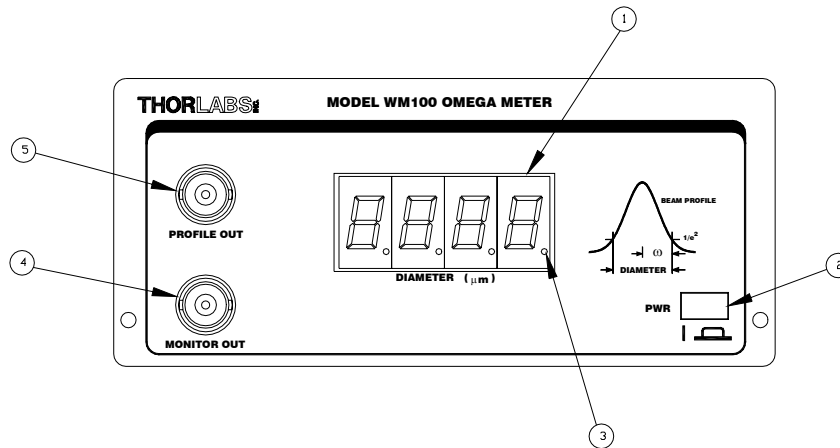


Figure 1. WM100 Front Panel

Feature	Description
1	Large LED digital display to display beam waist and diagnostic messages.
2	Main power switch.
3	Gain Set indicator (illuminated when the instrument gain is settled).
4	Monitor Out - the integrated waveform of the scanning knife-edge.
5	Profile Out - the beam profile along direction of knife-edge scan.

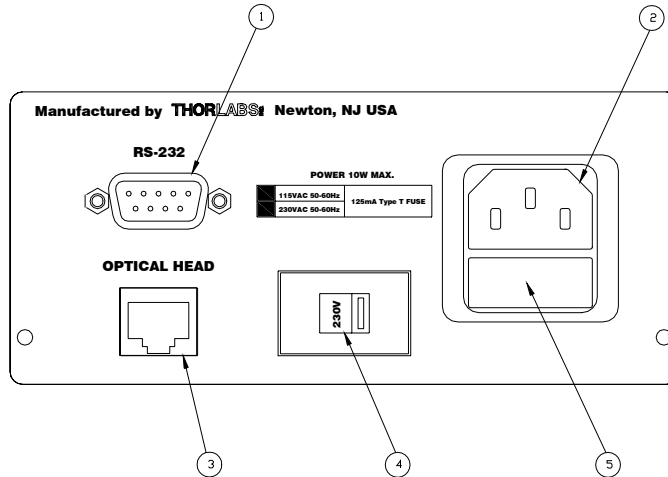


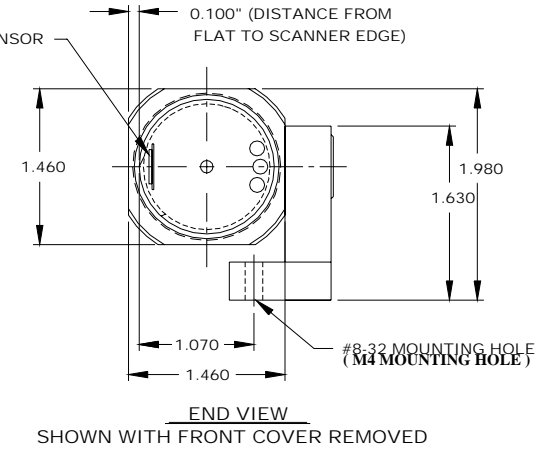
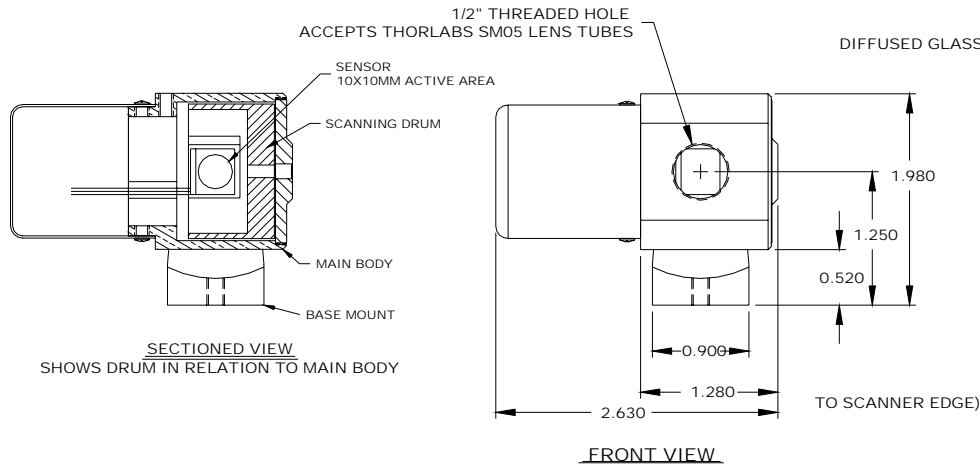
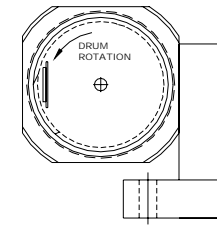
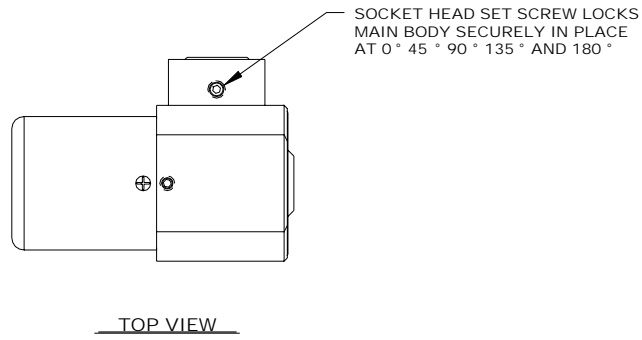
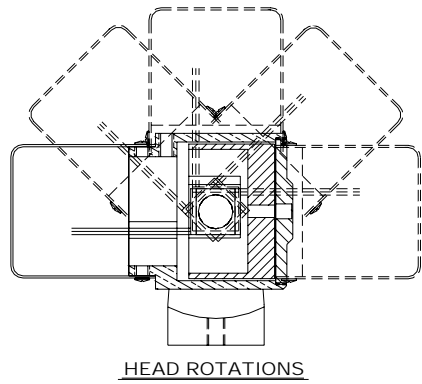
Figure 2. WM100 Rear Panel

Feature	Description
1	RS-232 Interface, DB9 female connector
2	AC Input
3	Optical head interface connector
4	Line voltage switch
5	Fuse tray

Figure 3. Connector Pinouts



RS-232 (DB9F)		Optical Head (RJ-45)	
1	N.C.	1	Motor -
2	RxD	2	Motor +
3	TxD	3	N.C.
4	DTR (internally tied to DSR)	4	N.C.
5	Signal GND	5	N.C.
6	DSR (internally tied to DTR)	6	N.C.
7	RTS (internally tied to CTS)	7	Photodiode Anode
8	CTS (internally tied to RTS)	8	Photodiode Cathode
9	N.C.		



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Figure 4. WM100 Optical Head

Section 4 - Setup

Optical Head Installation

The WM100 is a very easy system to set up. The optical head has an 8-32 tapped mounting hole (M4 for WM100-EC) on the bottom of the base, which is typically used by a threaded TR-series $\varnothing 0.5$ " post.

The optical head has a spring-loaded detent swivel which allows the scan direction to be rotated 0, 45, 90, 135, and 180° positions while keeping the beam centered on the detector. This is very useful since the scanning edge technique only measures the beam profile along a single axis. By easily rotating the head, a complete beam measurement can be made.

The optical head simply plugs into the RJ-45 modular connector on the rear panel.

Note: Before turning the unit on, verify that the operating voltage, indicated on the rear panel voltage selector switch, is correct. See 6.1 for more details.

Note: The WM100 AC input receptacle is designed for use with three-prong line cords to provide a positive safety earth ground to the unit. Use only with approved, three-prong line cords.

Section 5 - Operation

Operating the WM100 is as easy as plugging the head into the unit, turning the system on, and reading the measurements. The unit provides a number of diagnostic messages to help make using the unit easy.

5.1 Starting Up

To start the Omega Meter, press the POWER push button switch on the front panel. The digital display will first perform a lamp test with all of display segments lit, then it will briefly display the software revision number. If a beam is directed into the optical head aperture, the unit will attempt to measure the beam diameter and start displaying the measured value.

The WM100 uses a microprocessor-controlled automatic gain circuit to accommodate a wide dynamic range of signals. When a beam is first detected, the unit attempts to adjust the gain for maximum signal-to-noise ratio. If the optical power is either too high or too low, the unit will display a diagnostic message indicating so.

The display messages are described in the following section:

5.2 Display Messages

Lamp Test

At start-up, the unit will turn all digits on briefly to verify that the display is fully functional.

Software Rev

After the lamp test, the software revision number will be briefly displayed. Please be sure to take note of this number when placing any support calls.

Beam Diameter

During normal operation, the measured beam diameter is displayed on the four-digit display in units of microns (μm). This display starts immediately after start-up initialization unless an error condition occurs.

Gain Set Indicator

The right most decimal point is used as an indicator for the automatic gain control feature. While the CPU is adjusting the gain, the displayed diameter readings are not necessarily valid. During the gain adjustment cycle, the decimal point is turned off.

Once the CPU gain has the gain set, the decimal is turned on indicating that the displayed value is valid.

no b

No Beam - This message is displayed when a beam is not being detected (i.e. the laser is turned off or blocked). If this message appears, check the laser source.

o ld

Over Load - This message is displayed when the optical power exceeds the maximum allowable input power (see Section 2). The laser power will have to be attenuated by some means to make a measurement. Note: Thorlabs carries a full line of neutral density filters and optics mounts suitable for beam attenuation.

lo b

Low Beam - This message is displayed when a beam is detected but its power level is too low to make a reliable reading (see Section 2). The laser power will have to be increased to make a measurement.

....

This message is displayed on startup to tell the user that the circuit and microprocessor have properly initialized. At least 8 drum revolutions (approx. 1sec) must be made before the first reading or a message can be displayed.

nois

Noisy Beam – This message is displayed when a noisy beam is detected. A noisy input beam will cause the rise-time measurement to be erratic and unstable. The WM100 will average a set of incoming rise-times to give an accurate beam waste. If an unstable rise-time is seen, the processor will evaluate the next 20 rise-times before displaying the “nois” message.

Section 6 - Remote Interface

6.1 Connecting to Serial Interface

The WM100 is easily connected to a standard 9-pin serial port, commonly found on PCs using a Male-Female DB9 interface cable. The WM100 serial port is a sub-set of the RS-232 standard and does not use any handshaking, therefore, the hardware handshake lines RTS/CTS and DSR/DTR are internally jumpered (see Figure 3.).

The WM100 protocol is set to 9600 baud, 8 data bits, 1 stop bit, and no parity bit. Data is sent and received in standard ASCII representation using a new-line character (<CR> <LF>) as an end-of-line terminator.

6.2 Command Reference

A simple set of commands allows the WM100 to be operated remotely via the serial port. Since the WM100 does not use handshaking, it will reply to each command received with the command name enclosed in brackets (i.e. <dsp gain on>). This can be used by the remote system to verify proper serial port operation.

There are two modes in which the serial interface operates. In the *direct command mode*, the WM100 receives a single character command followed by an optional parameter and immediately executes the command. This is the mode typically used for remote operation of the unit.

The *diagnostic menu mode* displays a verbose listing of commands that are helpful in troubleshooting or optimizing the WM100 performance:

Direct Command Mode

Command Character	Command Description - Direct Command Mode	Return Values
C	Continuous waist measurements - once this command is issued, the WM100 echoes each displayed waist measurement to the serial port until stop command is issued.	<cont> \n waist ₁ \n waist ₂ \n ... waist _n \n
D	Enter Diagnostic menu - see description below.	<diag> \n
F	Freeze / Unfreeze display reading - issuing this command freezes the display and holds the last displayed value. Issuing the command again unfreezes the display. This is useful for photographing setups	<freeze on> \n or <freeze off> \n
G	Display / Don't Display the Gain values with the returned waist measurements.	<dsp gain on> \n or <dsp gain off> \n
S	Stop the continuous output	<stop> \n
W	Return a single Waist measurement.	waist ₁ \n
B	Bandwidth Limit On / Off (Versions 1.14 and older) - with the bandwidth limit on, the amplifier bandwidth is reduced which improves the signal-to-noise ratio for larger beam diameters. This is especially noticeable on the profile output. Newer units with V1.15 and higher adjust the bandwidth automatically at a beam waste of about 500 μ m (has hysteresis)	<bw lim on> \n or <bw lim off> \n
<p>The format of the returned waist value depends on whether the display gain mode is set or not.</p> <p>When the gain display is not on the return format is: w: xxxx\n (note the space between the colon and the first digit)</p> <p>When the gain display mode is on, the return format is: w: xxxx g: xxxx\n (note the addition space between the last digit and the "g")</p>		

Table 1. Direct Command Mode Summary

Diagnostic Menu Mode

When the "D" command is received, the WM100 goes into the diagnostic menu. In this mode, the photodiode transimpedance gain, and the samples per average value can be manually set while operating the unit. This mode is normally reserved for troubleshooting. For example, the integrated photodiode output signal can be monitored while manually changing the gain to verify the gain control is working properly.

After receiving the "D" command, the unit responds with a header and a series of prompts that guide the user through the controls available.

Example:

“D\n” received by WM100, the unit responds with

\n

\n

Thorlabs WM100 Diagnostic Menu - Revision x.xx\n (where x.xx is the current software rev level)

Gain (gggg) : (1) Up (2) Down\n (where gggg is the current gain value)

SPA (ssss) : (3) +1 (4) -1\n (where ssss is the current number of samples per average)

Cmd (0=quit)> Enter the diagnostic command 1-4, or 0 to quit.

Section 7 – Maintenance and Troubleshooting

7.1 Setting Line Voltage

The WM100 has a selectable AC input voltage. When operating from a 100-120VAC 50-60Hz supply, the voltage selector switch on the rear panel should be in the position with the 115V indicator showing (see Figure 2). When operating from a 220-240VAC 50-60Hz supply, the switch should be in the 230V position.

To change the operating voltage, make sure the unit is unplugged and, using a small screwdriver, slide the voltage selector switch to the appropriate setting.

7.2 Replacing Line Fuse

The WM100 uses a 20mm slow-blow style fuse rated at 0.125A / 250V. To gain access to the fuse, unplug the line cord and pry open the fuse holder with a small screwdriver. If the fuse is blown, replace only with the fuse rated for the unit.

7.3 Cleaning

The controller can be cleaned with a damp cloth and mild detergent. The optical head can be wiped with a lint-free cloth and isopropyl alcohol.

If the scanning drum edge gets fouled with dirt pick up, it can be wiped gently with a cotton swab soaked in isopropyl alcohol. If the drum edge shows any signs of damage, call Thorlabs for a replacement drum.

7.4 The drum does not rotate or a scraping noise can be heard from the optical head.

The optical head was designed with tight tolerances to keep the overall package size to a minimum. Under normal operation, the internal drum should spin freely without any type of scraping noise. The problem is easily remedied as follows:

1. Remove the 2 cover screws with a 0.050" hex wrench and carefully slide the cover off the optical head while feeding the interface cable into the cover. Avoid pulling the interface cable to prevent breaking the internal connections.
2. Using a 0.035" hex wrench, loosen the set screw(s) holding the motor in the housing just enough to re-position the motor.
3. Turn the WM100 power switch ON and re-position the motor until it turns freely. Before tightening the set-screws check that the detector is centered in the input aperture.
4. Replace the cover.

If this does not fix the problem, please call Thorlabs to arrange for an immediate replacement.

7.5 Why does the display toggle between “o ld” and “no b” when the laser is applied to the optical head?

The WM100/WM100B optical head drum needs to spin at a frequency of 10Hz \pm 0.5Hz for the microprocessor to make a proper measurement. The frequency will sometimes vary if the ambient temp is changed, or the frequency control potentiometer drifts. Measure the frequency of the "MONITOR OUT" signal and, if necessary, adjusted as described below:

1. If there is a scrapping noise in the optical head refer to B.3 before continuing.
2. Unscrew the 2 black Phillips head screws located at the bottom corners of the front panel.
3. Carefully allow the front panel assembly to drop below the unit so that the top cover can be can be slid off.
4. Slide the cover off.
5. Connect an oscilloscope or a DVM, capable of measuring frequency, to the front panel BNC marked "MONITOR OUT".
6. Find the blue potentiometer, RP3 of 0224-012 pcb, located toward the front left of the unit.
7. **Be careful since there are high voltages located toward the rear of the unit and the power on switch.** Plug the power cord into the IEC connector of the rear panel and turn the unit on.
8. Slowly adjust RP3 so that the oscilloscope or DVM reads a frequency of 10HZ.
9. Turn the unit off and unplug the power cord.
10. Slide the cover back on.
11. Install the front panel using the 2 black Phillips head screws.

7.6 Upgrading the Microprocessor

If the microprocessor revision level is changed, the unit can be upgraded as described below. **Since the WM100 includes static sensitive electronics, this procedure should only be preformed by qualified personnel.**

1. Unscrew the 2 black Phillips head screws located at the bottom corners of the front panel.
2. Carefully allow the front panel assembly to drop below the unit so that the top cover can be can be slid off.
3. Slide the cover off.
4. Find the microprocessor, marked U11 of 0224-012 pcb, located toward the front left of the unit. A label with the version number will be on the microprocessor.
5. Remove the microprocessor using a 44-pin PLCC extractor. Be very careful not to damage any of the socket pins.
6. Insert the new microprocessor into the socket.
7. Slide the cover back on.
8. Install the front panel using the 2 black Phillips head screws.

7.7 General Maintenance

The WM100 contains no other user-serviceable parts. If the WM100 appears to be damaged, please call Thorlabs. A customer service agent will arrange for a repair and issue a Return Authorization number. All returned units must have a Return Authorization number, which should be displayed, on the outside of the shipping package.

Appendix A - Application Notes

A.1 Correcting for Non-Gaussian Beams

In order to get the most accuracy from the WM100, it is important to understand a few basic concepts. The scanning knife edge technique is based on the ISO standard for beam measurements (see reference 1). The standard states that the beam diameter can be directly measured from the integrated signal of a knife-edge scanned across the beam to be measured. For true Gaussian beams ($M^2 = 1$), the beam diameter is twice the distance measured between the 16% and 84% integrated signal levels.

For non-Gaussian beams ($M^2 > 1$), the following correction factor needs to be applied to derive the actual beam diameter from the measured diameter:

$$d_{\sigma}(d_k, M_k) := d_k \cdot \frac{1}{M_k} \cdot [0.81 \cdot (M_k - 1) + 1]$$

Equation 1: Correction factor for non-Gaussian beams

Where: d_k = measured beam diameter
 M_k = times-diffraction-limit factor [$\sqrt{M^2}$]
 d_{σ} = corrected beam diameter

Thus, if the M^2 value is known for the source being measured, equation 1 can be used to derive the corrected beam diameter from the WM100 reading.

A.2 Measuring M^2

In section A.1, it was shown how to correct the measured beam diameter for non-Gaussian beams from the times-diffraction-limit factor, M^2 . The M^2 factor can be measured by focusing the multimode beam to a waist using an aberration-free convex lens and measuring the waist size with the WM100. A second diameter is measured in the far field from which the far-field divergence is calculated. The M^2 factor is then calculated using equation 2.

$$M^2 = \frac{\theta \cdot \pi \cdot \omega_o}{2 \cdot \lambda}$$

Equation 2: Deriving M^2

Where: θ = measured divergence
 ω_o = measured waist size (radius, not the diameter),
 λ = Wavelength of source

Appendix B - Frequently Asked Questions

B.1 Why is there a negative mirror image of the profile on the PROFILE output BNC signal?

The WM100 uses a spinning drum with a large aperture window to scan through the beam profile. The signal on the detector is an integrated signal of the profile. To reconstruct the profile the WM100 has a differentiating circuit, which will generate a positive going pulse on the leading edge and a negative going pulse on the trailing edge.

B.2 The front panel displays erratic messages (i.e. LO-B, NO-B, widely ranged numeric readings, or no display at all), what is going on?

The WM100 uses a scanning knife-edge technique, which is sensitive to intensity noise on the input beam during the knife-edge scan. The design trade-off (noise immunity vs. scanning speed & smallest detectable spot size) requires that we use a 1 MHz bandwidth to get down to the 10 μ m spot sizes. Thus, laser intensity noise up to 1 MHz may contribute to measurement errors if the amplitude of the noise is significant.

An easy way to determine if the laser source noise is the problem is to view the PROFILE output on an oscilloscope. If excess noise is present, it will show up on the trailing edge of the profile as seen below. The leading edge is typically less noisy (i.e. the total integrated signal is lower since the leading edge of the drum is covering most of the detector as it begins to sweep through the beam).

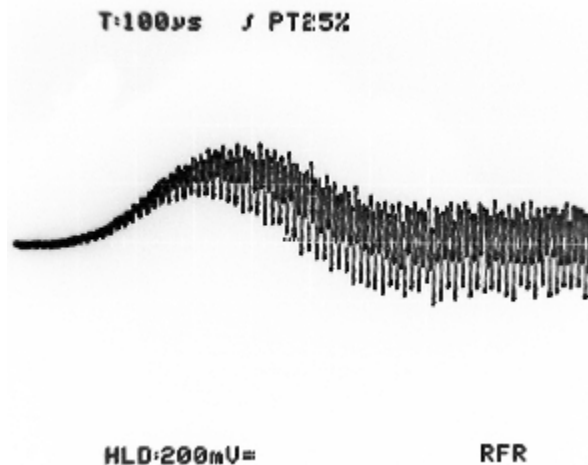


Figure 3. Typical profile of a noisy source

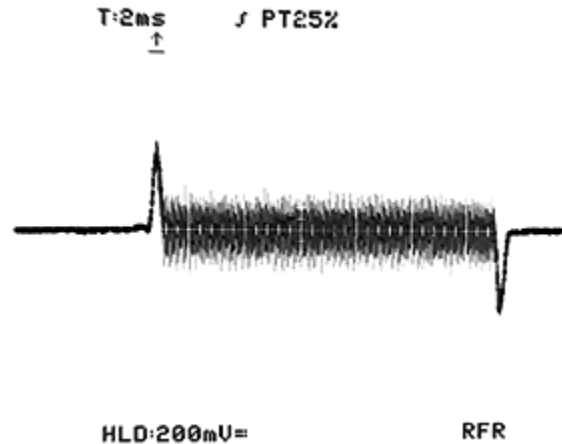


Figure 4. Typical profile of a noisy source showing negative pulse (note: the laser noise during the open aperture).

Many of the solid state lasers (particularly the SHG green laser modules) have significant intensity noise that may create problems for the WM100. Other potential sources of error include stray pump light that adds to the total optical signal on the detector (the WM100 uses a silicon photodiode that is sensitive from 350 nm to 1100 nm). Also, check that the ambient light is shielded from the wide FOV of the detector. The WM100 is shipped with a SM05L05, which helps baffle the FOV of the detector. Additional baffling may be required depending on the environment that the WM100 is being used in.

B.3 The drum does not rotate or a scraping noise can be heard from the optical head.

The optical head was designed with tight tolerances to keep the overall package size to a minimum. Under normal operation, the internal drum should spin freely without any type of scraping noise. The problem is easily remedied as described in section 7.4.

B.4 When I turn the unit ON the display shows a series of dots. What do they mean?

The dots indicate that the internal processor is getting data but cannot validate it. This occurs most frequently when the laser source is very noisy (see 2. above).

Note: earlier versions of the WM100 would simply blank the display, which was too easily confused with the unit being powered off. Therefore we included the dot display to indicate that the unit was powered up and waiting to validate the beam measurement.

B.5 What do the "E" error messages mean?

The "E" messages are like the dot display described above. They indicate that the measured beam diameter could not be validated. Check for excessive noise on the input beam.

The numbers included with the "E" display are not meaningful. They are simply artifacts of the last numeric display message and do not indicate any particular fault message.

B.6 How can I calculate the beam diameter from the raw signal?

The WM100 uses an automatically adjusting threshold detection circuit to measure the beam dynamics for the diameter calculation based on the ISO/DIS 11146 standard. The WM100 processor calculates the beam diameter

from these measurements and displays it on the front panel. Alternately, you can do the same measurement by measuring the rise time of the integrated output (MONITOR OUT) and using the following equation:

$$D = 2 * \pi * f * 16002 * Tr$$

Where:

D is the calculated $1/e^2$ beam diameter (μm)

f is the drum speed (Hz). It is usually 10 Hz but can be easily determined by measuring repetition rate of the MONITOR pulse output.

Tr is the rise time (16% to 84%) measured from the MONITOR output leading edge.

B.7 When using the WM100 with a HeNe laser, I get measurements that agree with what I expect. However, when using the WM100 with a blue or green laser I get LO-B messages or results that do not agree with what I would expect.

Assuming that the laser noise is not excessive (see 2. above) it is most likely that the laser power is too low (see Figure 2). The silicon photodiode has a reduced sensitivity at shorter wavelengths which degrades the minimum sensitivity to about $60\mu\text{W}$ for green (543nm) and $125\mu\text{W}$ for blue (458nm). Refer to the Min and max power vs. wavelength graphs located on page 3.

B.8 When using the WM100 with a 1.06mm source I get reasonable measurements at the larger diameters but a significant error at the smaller spot sizes.

The bandgap limit of silicon is about 980nm, which causes reduced quantum efficiency at longer wavelengths. This effect is exaggerated at smaller spot sizes where the higher intensity causes a local saturation in the diode response. This effect can be seen on the PROFILE output as an elongated tail on the falling edge of the beam profile.

For operation from 980nm to 1600nm, use the WM100B, which has a germanium photodiode.

B.9 How can I upgrade my WM100 to the latest version of firmware?

In most cases, this involves simply replacing one of the socketed ICs in the WM100 and can be done by the customer (refer to section 7.6). In some cases, we may need the unit back for a more involved upgrade. Contact the technical support group at THORLABS and the appropriate arrangements will be made.

B.10 Why does the display toggle between “o ld” and “no b” when the laser is applied to the optical head?

The WM100/WM100B optical head drum needs to spin at a frequency of $10\text{Hz} \pm 0.5\text{Hz}$ for the microprocessor to make a proper measurement. The frequency will sometimes vary if the ambient temp is changed or the frequency control potentiometer drifts. Measure the frequency of the “MONITOR OUT” signal and, if necessary, adjusted as described in section 7.5.

References

1. ISO/DIS 11146, 8/29/95, “Optics and optical instruments, Lasers and laser related equipment, Test methods for laser beam parameters: Beam Widths, divergence angle and beam propagation factor”
2. “Lasers - Theory and Practice”, J. Hawkes, I. Latimer, Prentice Hall, 1995