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1.0 Introduction and Features

Wafer mapping sensors are used to detect the presence or absence and slotting errors (such as cross-slots) of semiconductor wafers in processing equipment. They are typically mounted on robot arms or other wafer handling devices.

EX-QS wafer mapping sensors are general-purpose wafer mapping sensors that excel at detecting even the most difficult to detect dark or coated wafers. EX-QS sensors can be used for notched or flatted wafers of any standard size. They can scan at the wafer center as well as aimed off center.

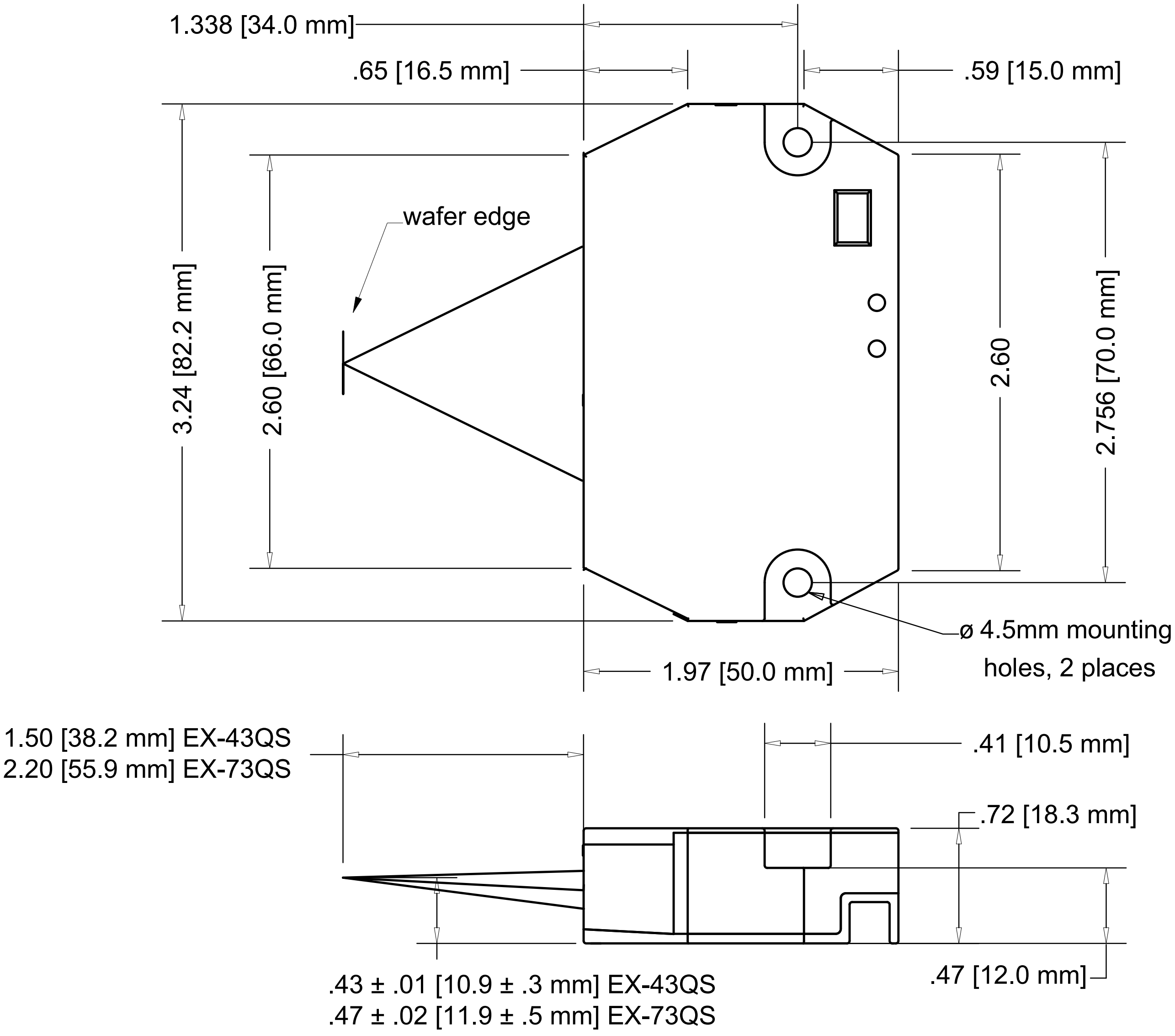
EX-QS sensor features include:

- Excels at detecting dark or coated wafers at factory gain setting
  - Laser transmitters and receivers fine-tuned for maximum sensitivity while still maintaining Class 1 status (CDRH)
- Reliably detects cross-slotted and ultra-thin wafers
  - Thin laser stripe (0.05 mm) combined with multiple apertures and spatial filtering reduces noise, improving mapping accuracy
- Insensitive to interference from the mapping environment
  - Beam geometry and built-in ambient light filter minimize stray reflections and ambient lighting influences
- Accommodates all SEMI standard wafers, regardless of size or edge geometry, through patented dual and wide beam technologies
- Easy to use “off-the-shelf” direct interface requires no amplification or signal conditioning
- Available in two standoff distances:
  - EX-43QS 1.5"
  - EX-73QS 2.2"
- Non-intrusive wafer mapping solution protects valuable wafers from inadvertent crashes
- No moving parts that can result in particulate contamination

2.0 Dimensions

Figure 1 shows the dimensions for the sensor.

Figure 1 - EX-QS Sensor Dimensions



3.0 Specifications

Table A lists the specifications for the EX-QS sensors.

Table A - Sensor Specifications

	EX-43QS	**EX-73QS**
Method of detection	Dual Wide Beam	
Optimum detecting distance	1.5" (38.1 mm)	2.2" (55.9 mm)
Maximum detecting range	1.4" to 1.6"	2.05" to 2.35"
Supply voltage	9 to 24 VDC	
Current consumption	130 mA typical, 200 mA max.	
Light source **at exit port** **at CDRH aperture**	2 X 850 nm diode lasers 2 X 0.600 mW max. 0.077 mW max.	
Laser class	Class 1 (CDRH)	
Detectable objects	Transparent, opaque, and mirror-surfaced objects	
Laser spot size	10 mm x 0.05 mm	16 mm x 0.06 mm
Working angle range	± 16 degrees relative to the sensor front surface	± 11 degrees relative to the sensor front surface
Operation	Light-On/Dark-On switch, Enable switch, Gain setting	
Response time	400 µs max.	
Minimum pulse width	1 ms, 5 ms (factory default), or 10 ms	
Indicator	Laser power - Red LED, Output Signal - Green LED	
Control output	Open collector NPN (low true) or PNP (high true) options. 80 mA max.	
Connections	Standard 16", 4-conductor, un-terminated cable. Custom lengths and factory-installed connectors available.	
Temperature limits	Operating: 32 to 104ºF (0 to 40ºC) Storage: -20 to 130ºF (-30 to 55ºC)	
Materials	Lenses: glass, plastic; Case: aluminum	

3.1 Available Options

3.1.1 EX-QS Standard Options

Table B lists the standard options available for ordering and the part number modifier for each. For more information on part numbers, see Section 3.1.3 on page 5.

Table B - EX-QS Sensor Standard Options

Option	Description	Part Number Modifier
Positive Enable (see Section 5.3.4 on page 16)	Allows the laser's Enable circuitry to be activated by pulling the enable line to +VIN instead of ground.	P
PNP Output (see Section 5.3.3 on page 14)	With this option the sensor is configured for PNP output where a P-channel MOSFET is connected to +VIN.	D
Resistor option (with NPN or PNP output) (see Section 5.3.3 on page 14)	With this option, an internal 10 Kohm resistor is connected to the collector output to act as a pull-up resistor (NPN option) or as a pull-down resistor (PNP option).	U
1 ms Minimum Output Pulse	With this option, the minimum output pulse width is set to 1 ms. The default, 5 ms, is appropriate for most applications.	-01
10 ms Minimum Output Pulse	With this option, the minimum output pulse width is set to 10 ms. The default, 5 ms, is appropriate for most applications.	-10

3.1.2 Connectors

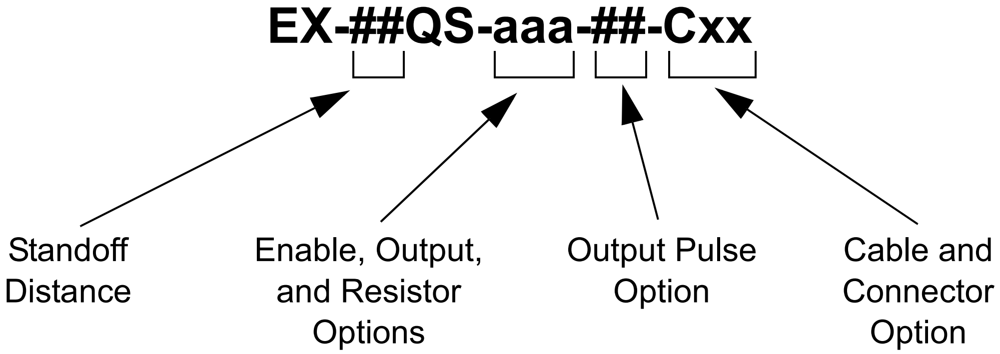
Unless otherwise specified, all sensors ship with a 16-inch, un-terminated cable. You can place custom orders for different cable lengths and for cables shipped with factory-installed connectors. Contact Technical Support (see page ii) to discuss your needs for connectors and custom cable lengths. Cables with connectors or custom lengths are identified by adding -Cxx to the part number (see Section 3.1.3 on page 5), where *xx* is a unique two-digit number for each custom configuration.

To identify connector and cable specifications on a sensor from the field, please contact Technical Support (see page ii) with the sensor's part number. If the part number for a sensor does not include a -Cxx modifier, the sensor was sold with the standard cable option.

3.1.3 Sensor Part Numbers

The CyberOptics Semiconductor part number for a sensor is printed on the side label. All sensor part numbers conform to the format shown in Figure 2.

Figure 2 - Part Number Format



Example 1: EX-43QS-PD-01

43	1.5″ standoff distance
P	Positive enable
D	PNP output
-01	1 ms output pulse

This sensor has the default enable circuit, optional PNP output, and no internal resistor.

Example 2: EX-73QS-U-10-C05

73	2.2″ standoff distance
U	Pull-up resistor
-10	10 ms output pulse
C05	Custom cable length and connector configuration

This sensor has the default enable circuit and NPN output with the optional internal (pull-up) resistor.

4.0 Installation

4.1 Unpacking the Sensor

> ***Warning:*** *Any contact with the lenses could result in severely degraded optics performance.*

Check the model number of the sensor against the model number recommended for the equipment and against the model number ordered. Inspect the sensor for signs of damage. Keep sensor in its plastic bag until you are ready to install it.

Report any damage to:

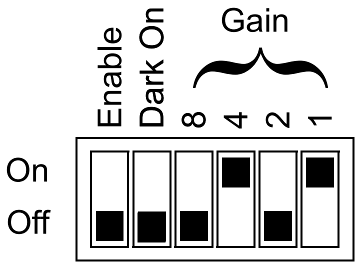
CyberOptics Semiconductor
9130 SW Pioneer Court, Suite D
Wilsonville, OR 97070
503-495-2200
800-366-9131
503-495-2201 (fax)
CSsupport@Cyberoptics.com

4.2 Installing the Sensor

Use this installation procedure to check for proper setup, wiring, alignment, and operation. The following procedure is intended to demonstrate the most common setup and wiring for EX-QS sensors.

1) Set the Enable and Dark On DIP switches on the top of the sensor as required. For specific instructions on the controls, see Section 5.2 on page 11. Figure 3 shows typical settings.

Figure 3 - DIP Switch Settings

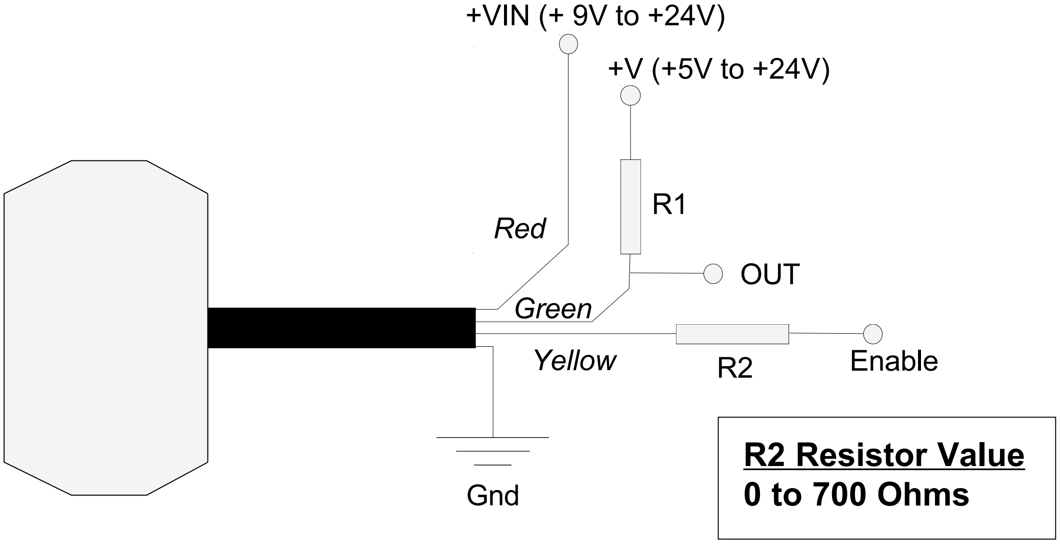


The example at left illustrates the settings:
Sensor Always Enabled
Light On
Gain 5

Note: EX-QS sensors are set to optimum gain at the factory. If adjustment is required, contact Technical Support (see page ii).

2) The EX-QS sensor typically ships with no connector. Using the following wiring instructions and Figure 4 on page 8, install the appropriate connector on the sensor:
   A) Red wire to power, +9 V to +24 V.
   B) Black wire to Ground.
   C) Green wire is the output. Refer to Section 5.3.3 on page 14.
   D) Yellow wire to remote enable. Refer to Section 5.3.4 on page 16. If Enable (see Figure 3) is set to Off, the yellow wire is not required. The current limiting resistor, R2, used with previous model sensors is not required. However, the sensor will work with R2 (up to 700 ohms) installed in the wiring external to the sensor.

Figure 4 - Typical Connection



3) Confirm that the gain is set to the appropriate level. CyberOptics Semiconductor recommends using the factory setting for most applications. The factory gain setting is 5, or 8:Off, 4:On, 2:Off, 1:On. If you believe gain adjustments are required, please contact CyberOptics Semiconductor Technical Support (see page ii).

4) Mount the EX-QS sensor on the robot or loadport door, and set up for proper offset and alignment.
   A) Apply power to the sensor, and the Red LED illuminates.
      Wave your hand in front of the sensor, and the Green LED will illuminate.
   B) Set the sensor to the correct standoff distance for the EX-QS model (see *Optimum detecting distance* in Table A on page 3).

> ***Warning:*** *CyberOptics Semiconductor strongly recommends that EX-QS sensors be used only at the specified standoff distance. Sensor optics and geometry are carefully matched to the specified standoff distance, so that the sensor will respond to wafers throughout (and beyond) the range of variations in wafer parameters. Outside the specified standoff distance, sensor response to wafers is degraded, and the sensor will not respond correctly to the full possible range of wafer parameters.*

   C) Set the sensor's alignment for the correct single- or multiple-pass scans. For single-pass scans, an on-axis scan is recommended for maximum detection robustness. For mapping implementations where multiple-pass scans are utilized, space the scan passes such that each scan pass falls within the recommended working angle range (see *Working angle range* in Table A on page 3). If you have a question regarding the optimum working angle range for your specific application, please contact CyberOptics Semiconductor Technical Support (see page ii).

Note: CyberOptics Semiconductor has developed an Alignment Card to assist in the proper setup and calibration of the EX-QS sensor. To obtain an Alignment Card and Instructions, contact CyberOptics Semiconductor Technical Support (see page ii).

Warning: *Do not touch the sensor's emitter or receiver surfaces. Touching these surfaces might result in serious impairment to the sensor's performance.*

D) Using the appropriate robot setup procedure, teach the robot position(s) for wafer sensing. Note that anytime a sensor is installed or re-installed, the position(s) should be re-taught to the robot.

4.3 Mechanical Installation Overview

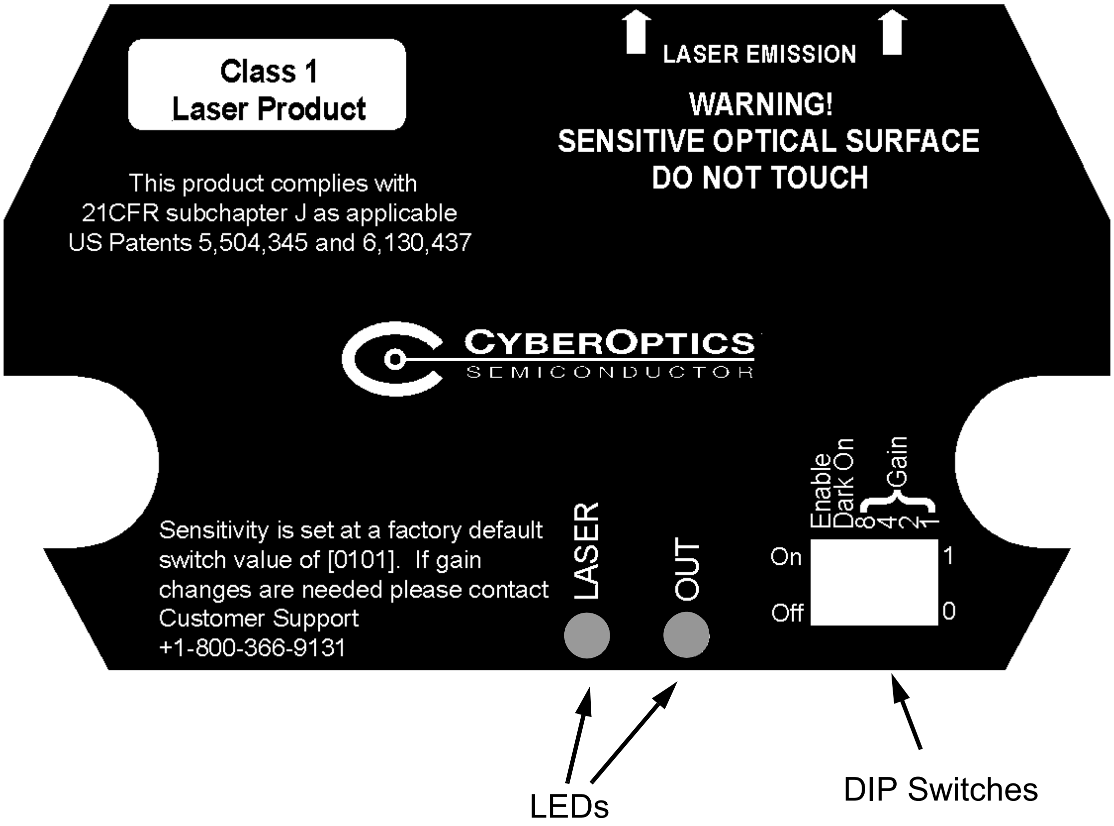
- For a dimensional drawing with mounting hole alignment, see Section 2.0 on page 2.
- For proper alignment, see Section 7.4 on page 21.
- For setting switches, see Section 5.2 on page 11.
- To ensure correct connector wiring, check other equipment manuals.

5.0 Indicators, Controls, and Connections

5.1 Indicators

EX-QS sensors have two LED indicators and six DIP switches. Figure 5 shows the label on the top of the sensor, indicating the locations of the LEDs and DIP switches.

Figure 5 - Indicators and Controls



5.1.1 OUT Signal Indicator

The OUT indicator (green LED) is a visual representation of the output signal. In the Light On mode, the signal indicator illuminates and the output signal is asserted whenever an object is detected; in the Dark On mode, the LED illuminates whenever no object is detected.

5.1.2 Laser On Indicator

The LASER indicator (red LED) illuminates when the laser diode is emitting radiation.

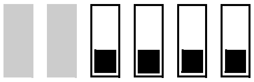
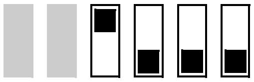
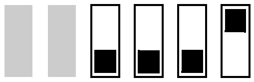
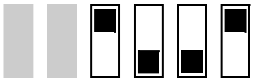
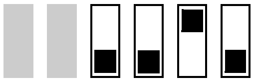
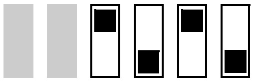
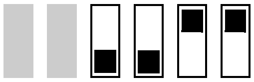
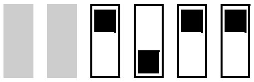
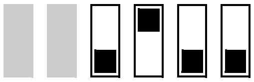
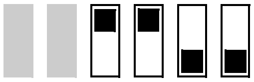
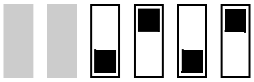
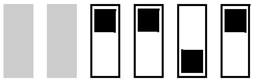
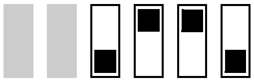
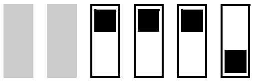
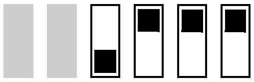
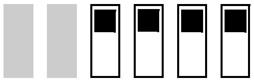
5.2 Controls

Figure 5 on page 10 shows the location of the six DIP switches that control Enable mode, Dark On mode, and Gain. Figure 3 on page 7 shows a typical example of the DIP switch settings. The switches are described in more detail below.

5.2.1 Gain

You can set the Gain to any of 16 levels (0 - 15). Table C lists the DIP switch settings (see Figure 3 on page 7 and Figure 5 on page 10) for each level. The electrical Gain is set for optimal performance at the factory. Before making any changes to the Gain setting, please contact CyberOptics Semiconductor Technical Support (see page ii).

Table C - Gain DIP Switch Settings

Gain Level	**Switch Positions** **8 4 2 1**	**Gain Level**	**Switch Positions** **8 4 2 1**
0		8	
1		9	
2		10	
3		11	
4		12	
5 (factory setting)		13	
6		14	
7		15	

5.2.2 Detection Mode Switch (Dark On)

In Dark-On (On position) detection mode, the output signal is asserted when an object is not present or the reflected pulses are not strong enough to register in the receiver. In Light-On (Off position) detection mode, the OUT signal is asserted when an object is present within the detecting range and reflected light pulses are detected in the receiver. For more detail on the OUT signal, see Section 6.3 on page 18.

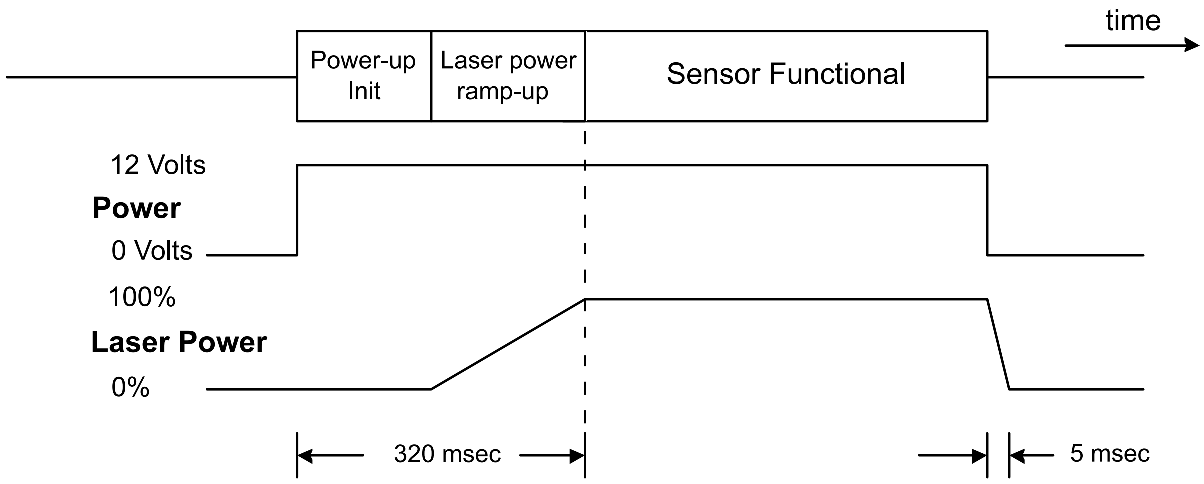
5.2.3 Remote Enable Switch

The Enable switch controls whether the sensor is always enabled or is enabled remotely using the yellow wire. With the Enable switch in the Off position, the sensor is controlled by the Power line (red wire), and the Enable line (yellow wire) is not used. The top part of Figure 6 on page 13 shows the timing for Enable Off. After power-on, there is an initial reset period of 200 ms (maximum). Following the reset period, the sensor is immediately enabled, followed by a period of 120 ms (maximum) during which the lasers are ramped up to full power. After that time, the sensor is fully functional.

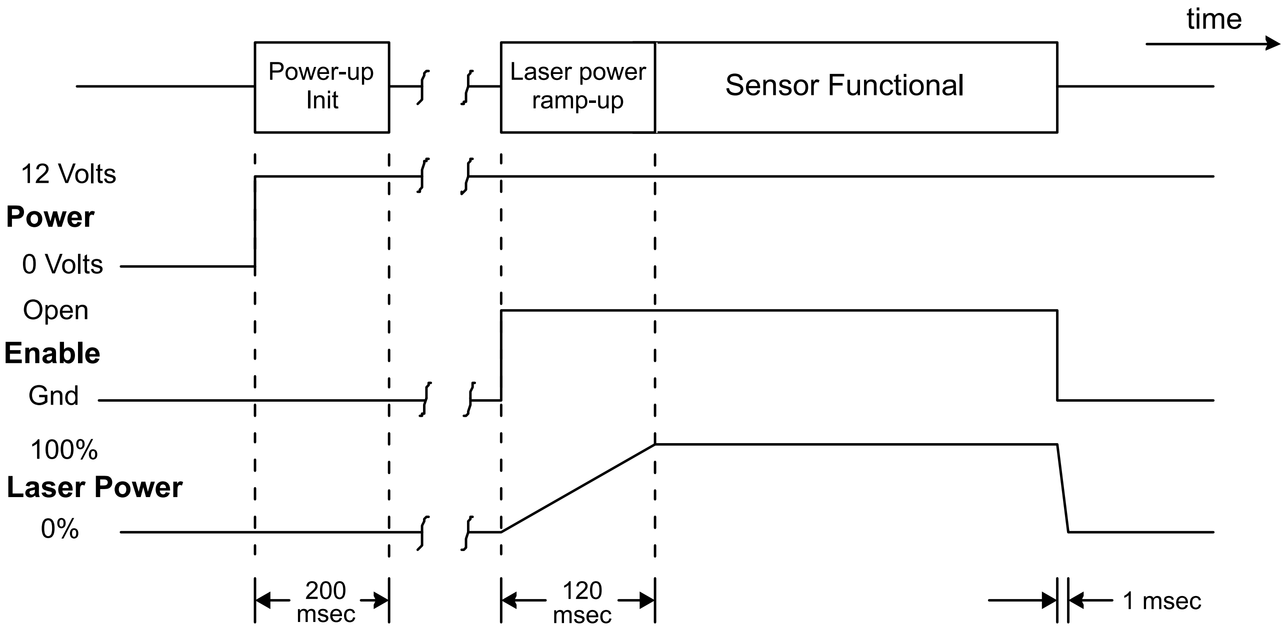
With the Enable switch in the On position, the laser radiation is controlled by the Enable input signal (yellow wire) while the sensor power remains on. Use this method in applications requiring a shorter delay between enabling the laser and measuring the signal. The bottom part of Figure 6 on page 13 shows the timing for Enable On. When the Enable signal is asserted (after the initial power-up time) there is a period of 120 ms (maximum) during which the laser power is ramped up to full power. After that time, the sensor is fully functional. When using the Enable signal to control the sensor, if Enable is applied at the same time as power-on, or within 200 ms of power-on, the timing is the same as if the remote enable were not used.

The detection capability of the sensor is active as soon as the lasers begin to power up (at Enable assert for Enable On; at the end of power-on reset for Enable Off). A strongly reflective object in front of the sensor can cause the sensor to assert the OUT signal even before the lasers reach full power. You should not have any object in the field of view when the lasers are powering up.

Figure 6 - Remote Timing



Remote Enable Off: Sensor is enabled immediately after power-up init.



Remote Enable On: Enable may be applied any time after power up init.

5.3 Connections

The sensor has four connections: +VIN, GND, OUT, and Enable.

5.3.1 +VIN (Power Input) (Red Wire)

EX-QS sensors can operate with the input voltage between +9 and +24 VDC on the red wire. The maximum current drawn is 100 mA with the lasers on, or 50 mA with the lasers off, exclusive of current output on the detect wire, which is user controlled.

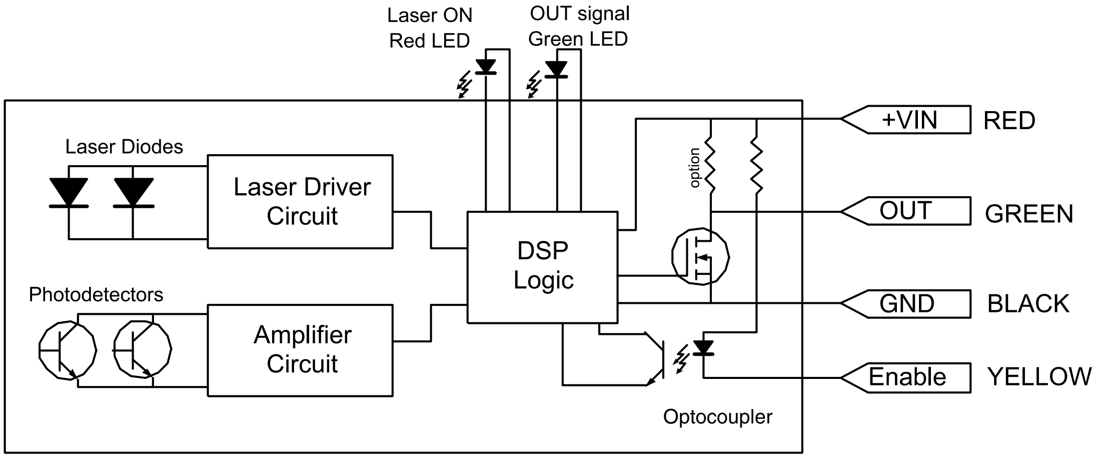
5.3.2 GND (Common Return) (Black Wire)

The black wire is the common return line for the +VIN, OUT, and Enable connections. EX-QS sensor cases are connected to the GND connection to ensure that the internal circuitry is shielded from electromagnetic interference. Insulate the sensor case from any equipment that might generate large currents in the case or ground connection.

5.3.3 OUT (Sensor Output) (Green Wire)

The standard output is NPN open collector and is actually an N-channel MOSFET connected to ground, as shown in Figure 7. The drain must be connected through a pull-up resistor (see Figure 4 on page 8) to a source of positive voltage (+5 to +24 V). The resistor should have a value chosen to limit the transistor current to 80 mA or less (typical value is 10 Kohm). The output can then be observed as a voltage-level change at the sensor output (sensor side of the resistor). If there is no connection to voltage, there will be no noticeable change in the voltage on the OUT connection when the sensor is operating. If you order the internal pull-up resistor option, a 10-Kohm resistor is connected to the open drain output and no external resistor is required.

Figure 7 - NPN Output (Standard)



As a factory option, you can order the sensor configured with a PNP output. In this case, the output is a P-channel MOSFET connected to +VIN, as shown in Figure 8 on page 15. The drain must be connected through a pull-down resistor to ground. The resistor should be chosen to limit the current to 80 mA or less (typical value is 10 Kohm). The output can then be observed as a voltage-level change at the sensor output (sensor side of the resistor). If there is no resistor pull-down to ground, there will be no noticeable change in the voltage on the OUT connection when the sensor is operating. If you order the internal pull-down resistor option, a 10-Kohm resistor is connected to the open drain output and no external resistor is required.

Figure 8 - PNP Output (Optional)

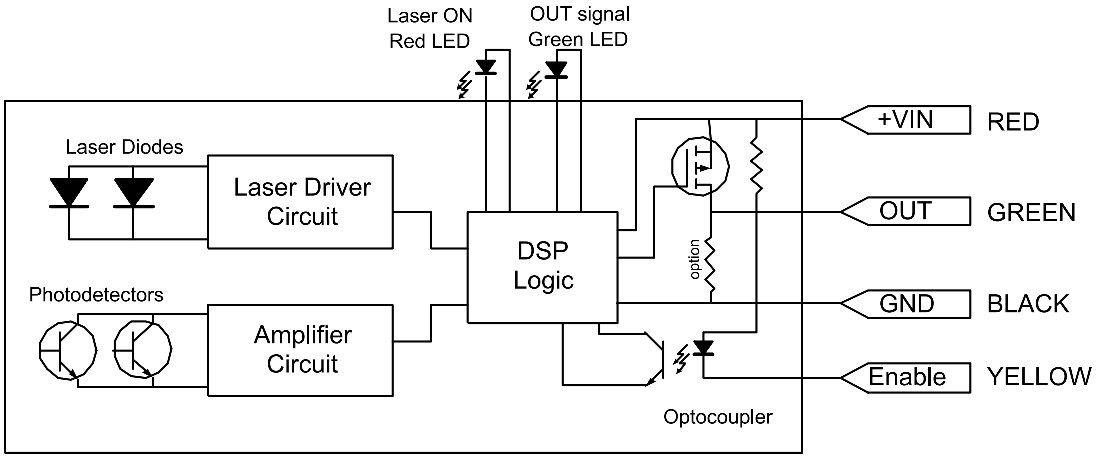


Table D summarizes the state of the green LED and OUT signal under various conditions. In Light-On mode, the green LED is on when an object is detected, and off when no object is detected. In Dark-On mode, the green LED is on when no object is detected, and off when an object is detected. The OUT signal is asserted when the green LED is on. With the NPN option the OUT signal is low when asserted. With the PNP option the OUT signal is high when asserted.

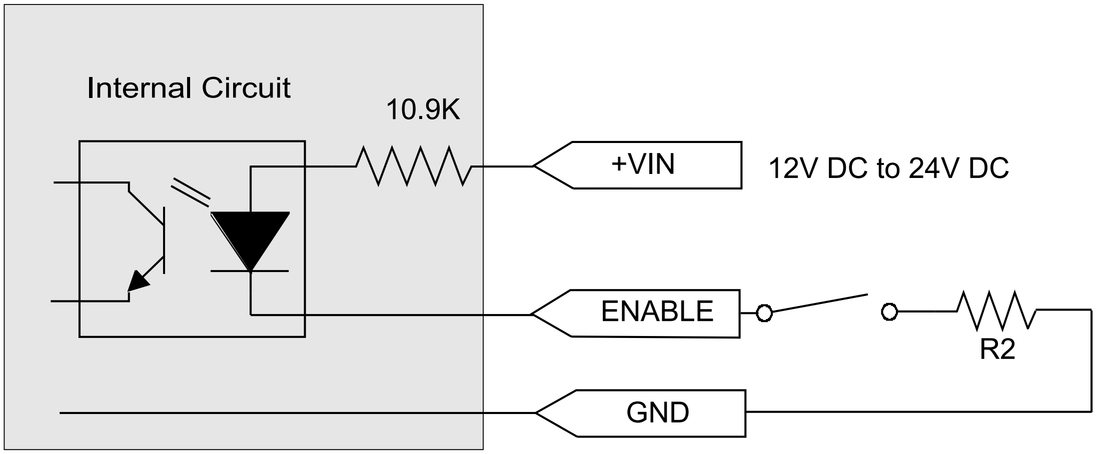
Table D - Output Signal Summary

Mode	**Output**	**Object**	**Green LED**	**OUT signal**
Light-On	NPN	No object Object detected	Off On	High Low
	PNP	No object Object detected	Off On	Low High
Dark-On	NPN	No object Object detected	On Off	Low High
	PNP	No object Object detected	On Off	High Low

5.3.4 Enable (Yellow Wire)

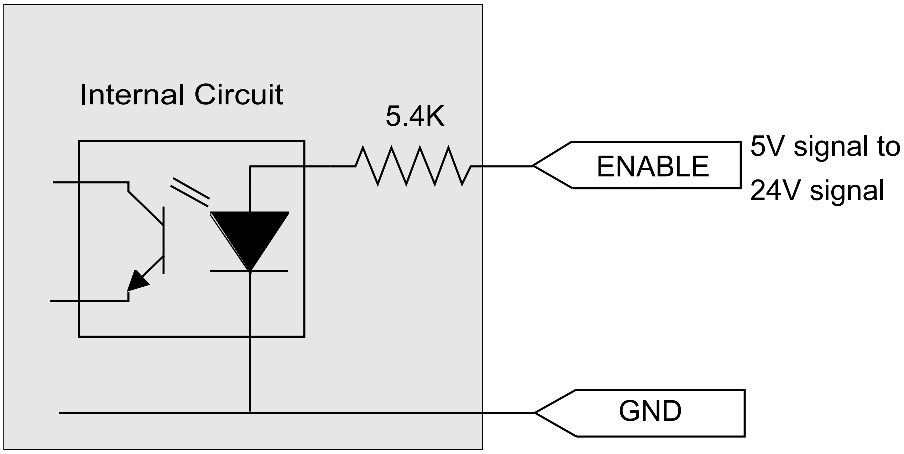
In the standard configuration (see Figure 9), the laser enable circuitry is connected internally through a 10-Kohm resistor to +VIN. If the Enable switch is set to Off, the Enable line has no effect on operation. Up to 700 ohms can be used in the external resistor at R2.

Figure 9 - Enable Input Signal (Standard)



You can also order the sensor with a positive-enable option (see Figure 10). R2 is not required in either configuration.

Figure 10 - Enable Input Signal (Positive Enable Option)



6.0 Theory of Operation

EX-QS sensors have three main subsystems: laser transmitter, receiver, and signal processor. The combination of the three subsystems allows for reliable and robust wafer detection in a multitude of environments and in a small package size. The circuitry is a combination of both analog and digital.

6.1 Laser Transmitter

The transmitter in each EX-QS sensor includes two infrared (850 nm) laser diodes. Each diode has an integral photo-detector for control of the laser output over various operating temperatures. The output of each laser is set at the factory to comply with the Center for Devices and Radiological Health (CDRH) limits on Class 1 lasers. (Class 1 lasers have the lowest operating power of any CDRH class, and Class 1 regulations are the least restrictive.) The sensors have no user-accessible adjustments for altering the laser power.

Each laser diode operates from a closed-loop driver that modulates the laser. The modulation signal is a square wave at approximately 8 KHz. The modulation allows EX-QS sensors to synchronously detect the return signal from the wafers and greatly increases the detector sensitivity.

The laser optics are identical for both lasers. The optics for the EX-43QS are designed to create a laser spot at the focal point that is approximately 10 mm wide and 0.05 mm tall. The two laser transmitters are both aimed from one side of the sensor to a common focal point in front of the sensor. The laser optics are mounted with a slight upward tilt of approximately three degrees. This eliminates undesired reflections from the backs of wafer carriers and makes the sensor insensitive to reflections from structure on the top surface of the wafer.

6.2 Receiver

The two receiver channels contain high-sensitivity phototransistors in identical “telescope” systems that each look at the same spot illuminated by the laser transmitters. Each receiver has a relatively large, ½-inch diameter collector lens and an ambient light filter to block visible light. The two receivers are on the opposite side of the sensor from the laser transmitters and respond to light entering only within a ± 10-degree angle from the optical axis of each telescope. The receiver and transmitter beams cross at the target distance at a relatively high angle. This minimizes sensitivity of the sensor to objects at other distances. Transmitter light that is reflected from somewhere other than at the target distance is very unlikely to be reflected back into the receiver telescopes at the required angle for collection. The optical axes of the detectors are also tilted upward approximately three degrees to match the axes of the lasers. This makes EX-QS sensors insensitive to stray reflections from cassettes and FOUPs.

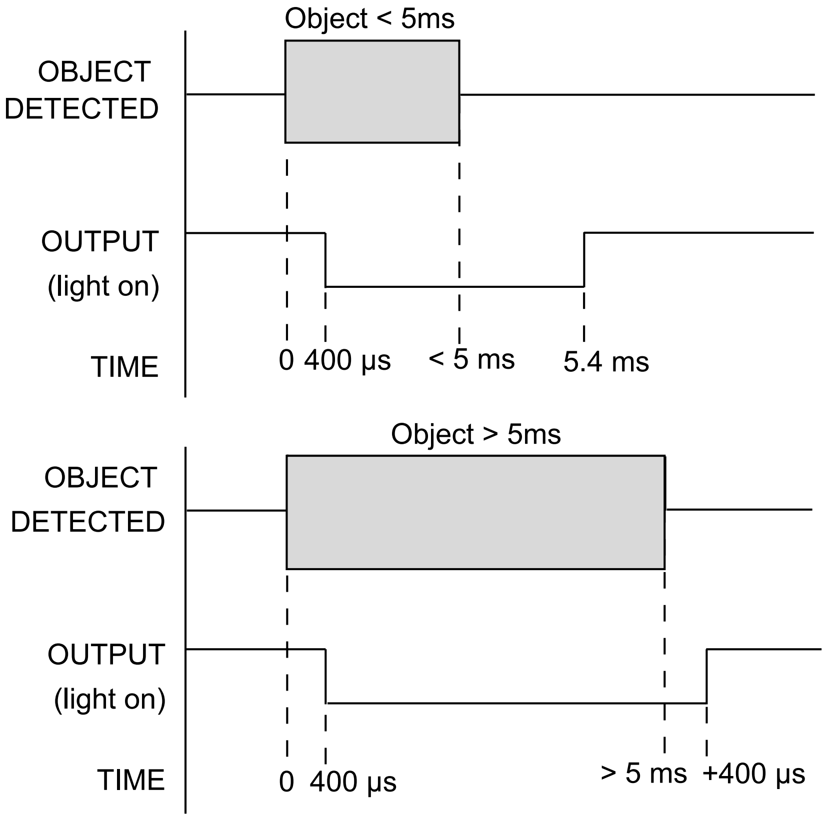
6.3 Signal Processor

The signal processor subsystem in its simplified form has two inputs and one output. One input is the 8-KHz square wave signal that drives the laser diodes. The other input is the output of the receiver subsystem. The signal processor quantizes the received signal and compares this to the 8-KHz square wave at the points where the 8-KHz square wave changes sense (goes high or goes low). A match is found if the quantized signal is in the correct state. When matches are found in two consecutive cycles of 8 KHz, and if there are no incorrect transitions of the quantized signal, the OUT signal is asserted. This reduces the frequency of false detection caused by noise. When OUT is asserted, it stays asserted until there are three cycles without a correct signal match, or there are three incorrect transitions of the quantized signal. This effects a form of hysteresis; in asserting OUT, the processor is intolerant of noise, but once OUT is asserted, the processor is slightly more tolerant of noise. This reduces the effect of noise in the received signal to cause OUT output chatter or spurious transitions that are sometimes called drop-outs.

Background light modulated at any other frequency is ignored. The sensor requires at least 250 μs to respond to a detection event, because the processor requires matches on two consecutive cycles before asserting the OUT signal.

EX-QS sensors also feature a minimum output time response circuit. Small or moving objects detected at high speeds could generate very short output pulses. To make these short output pulses “visible” to slower equipment, the minimum output pulse width is set to 5 ms. Objects smaller than 5 ms (in terms of the time in front of the sensor) will always generate an output pulse 5 ms wide (as shown on Figure 11 on page 19, Object < 5 ms). Larger objects will generate a pulse of the object width (Figure 11 on page 19, Object > 5 ms). This minimum output pulse width is factory preset to 5 ms. As an option, output pulse widths of 1 ms and 10 ms are available.

Figure 11 - Output Timing



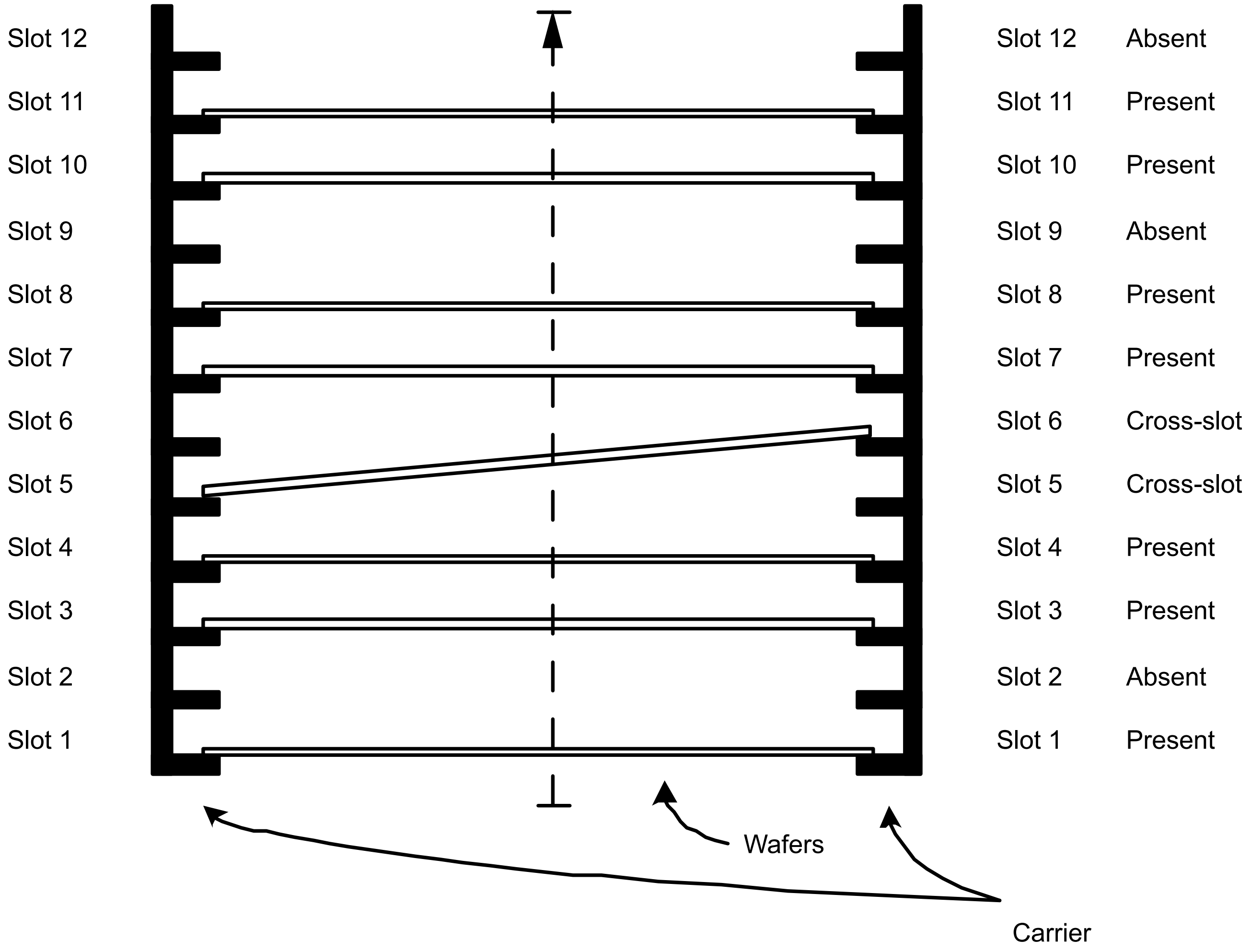
7.0 Guidelines for Setup and Use

The guidelines below will ensure optimum wafer mapping sensor performance.

7.1 Wafer Mapping Overview

A sensor is moved relative to a wafer carrier during wafer mapping. Each scan starts with the sensor before the first wafer slot and ends with the sensor beyond the last slot (see dotted line in Figure 12). Scans may be upward or downward, but should always be in the same direction to minimize mechanical backlash, sensor latency, and sensor hysteresis effects. The sensor indicates with the OUT signal when a wafer is detected. The OUT signal has only two possible states. Software receives data indicating the relative position of the sensor and the wafer carrier slot. A wafer map is a list of the states of wafer carrier slots. Slots are numbered starting from the bottom of a carrier, starting with the number 1. The carrier illustrated in Figure 12 has the following map (from the bottom): Present, Absent, Present, Present, Cross, Cross, Present, Present, Absent, Present, Present, Absent.

Figure 12 - Wafer Placement in Wafer Carrier



7.2 Sensitivity

The EX-QS sensor sensitivity is set at the factory for the optimum detection of wafers of all sizes, thicknesses, and coating types. In some cases, sensitivity adjustments might be necessary. Before adjusting the EX-QS gain, contact CyberOptics Semiconductor Technical Support (see page ii).

7.3 Ambient Light

EX-QS sensors include an ambient-light filter that blocks visible and some infrared light from the phototransistor. The ambient-light filter is composed of RG-9 filter glass. RG-9 is a high-pass filter that blocks light below 720 nm. This filters out the effects of fluorescent and other lighting found in most fabs.

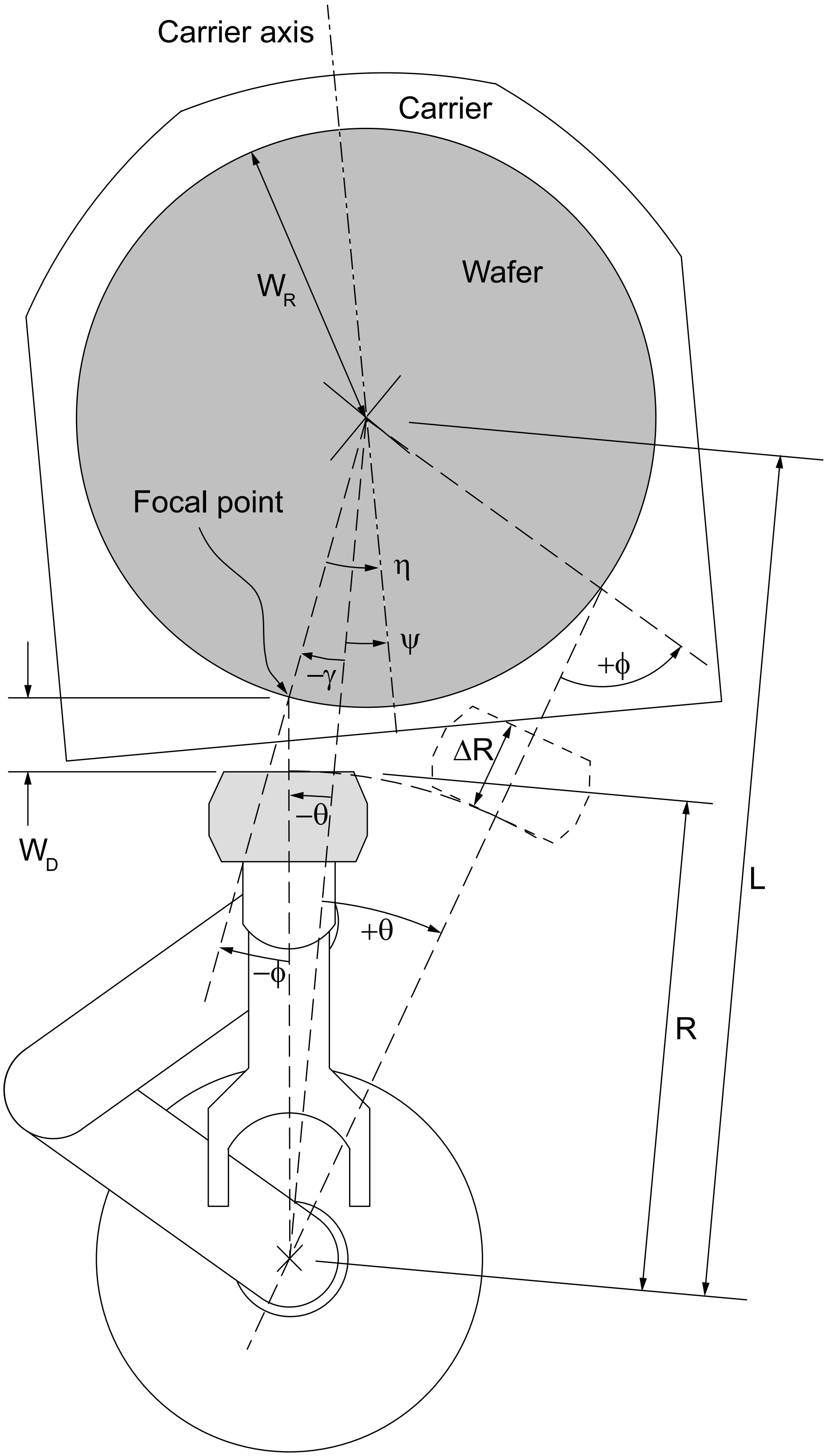
7.4 Alignment

EX-QS wafer mapping sensors require proper alignment with respect to target wafers in order to assure optimum performance. Each sensor model has a recommended working angle range that the sensor must stay within during operation. The working angle, ϕ, is defined to be the angle of the sensor face with respect to the tangent line on the wafer edge. This is equivalent to the angle between the axis of the sensor and a line drawn to the wafer center from the point where the axis intersects the wafer edge. When the sensor is directly facing the wafer, the working angle is zero. (See Figure 13 on page 22.)

A wide working angle range is useful for two reasons. The first is to allow two scans to be done at different points on the wafer edge. This is often done for redundancy and to give the ability to detect wafer tilt as an indicator of a misplaced wafer.

The second need for a wide working angle range is for use with flatted wafers. The wafer scanning strategy must take into account the fact that the flat may be at any orientation, so that even with the worst-case flat position, the wafer edge is still within the recommended working angle of the sensor. For the EX-73QS two scans are needed to guarantee that in at least one scan the flat will be within the recommended working angle.

Figure 13 - Wafer Mapping Sensor Geometry (top view)



The sensor optics are tilted upward three degrees with respect to the plane of the sensor. This is to avoid reflections from structure that might be present on the top surface of wafers, and to avoid reflections from the back of FOUPs, in the case of 300 mm wafers. To maintain this advantage, you should orient the sensor within ±0.5 degrees of the same plane as the target wafer. This means that the wafer and the sensor need to be parallel to within ±0.5 degrees.

If the sensor is mounted on a wafer handling robot, the sensor working angle should not be confused with the robot arm angle, or the "theta motion" of the robot arm. While it is possible to convert from robot theta motion to sensor working angle, the conversion depends on working distance, wafer diameter, and robot arm extension. The exact calculation is presented in the following paragraphs. In addition, Table E and Table F on page 25 present typical setups from which approximations can be derived.

For each mapping setup, you should calculate the working angle of the sensor to verify that the sensor is being used in the proper range to achieve the recommended sensing performance.

As shown in Figure 13 on page 22, the following values are defined:

ϕ = **Working angle.** The angle between the sensor axis and a line drawn between the wafer center and the focal point.

θ = **Robot Arm Angle.** The angle at the robot axis between the line to the sensor and the line to the wafer center. When $\theta = 0$, the sensor is pointed directly at the center of the wafer.

γ = **Wafer Angle.** The angle at the wafer center between the line to the focal point and the line to robot center.

ψ = **Carrier-Robot Angle.** The angle of the carrier axis with respect to the line between the wafer center and the robot axis.

η = **Carrier-Sensor Angle.** The angle of the carrier axis with respect to the line between the wafer center and the focal point. The carrier-sensor angle is the sum of the wafer angle and the carrier-robot angle. The carrier-sensor angle is the negative of the wafer angle when the robot axis is on the FOUP axis.

W_D = **Working Distance.** The distance along the sensor axis from the wafer edge to the center of the front of the sensor.

R = **Robot Axis Distance.** Distance from sensor face to robot axis for $\theta = 0$. This is the distance from the center front face of the sensor to the robot arm's center of rotation.

W_R = **Wafer radius.** This is ½ the diameter of the wafer (i.e. 150 mm for a 300 mm wafer).

L = The distance from the robot center (rotation axis) to the wafer center.

ΔR = **Radial Offset.** The radial offset of the robot for a given angle θ needed to maintain W_D.

Often when the sensor is mounted on a robot, the sensor must be positioned using robot rotational and radial coordinates, corresponding to robot arm angle and R. The following equations are useful for finding θ and R or ΔR.

We first define the following constant, Q:

$$Q \equiv \frac{W_R}{L} \equiv \frac{W_R}{W_R + W_D + R}$$

To calculate the working angle ϕ, first calculate γ for a given robot angle θ:

$$\gamma = \sin^{-1}\left(\frac{\sin\theta}{Q}\left[\cos\theta - \sqrt{Q^2 - \sin^2\theta}\right]\right)$$

The working angle, ϕ, is then calculated from γ and θ.

$$\phi = \theta + \gamma$$

When the robot angle, θ, is changed, you must also change the robot arm extension, R, to maintain the sensor working distance, W_D. This is calculated as ΔR.

$$\Delta R = \left(\frac{W_R \sin\gamma}{\sin\theta}\right) - (R + W_D)$$

Table E and Table F on page 25 show the calculated working angles for a sensor at typical setup values. Use the tables to get a rough estimate of the relationship for the various setup parameters. For both tables:

- Robot axis distance (R) = 250 mm
- Wafer Diameter = 300 mm

Table E - EX-43QS Example Setup Parameters

Working Distance (W_D) = 38.1 mm			
Robot θ (deg)	**Wafer γ (deg)**	**Working Angle ϕ (deg)**	**R (mm)**
0	0.0	0.0	0.000
0.5	1.0	1.5	0.032
1	1.9	2.9	0.128
1.5	2.9	4.4	0.289
2	3.9	5.9	0.514
2.5	4.8	7.3	0.805
3	5.8	8.8	1.162
3.5	6.8	10.3	1.586
4	7.8	11.8	2.079
4.5	8.7	13.2	2.641
5	9.7	14.7	3.274

Table F - EX-73QS Example Setup Parameters

Working Distance (W_D) = 55.9 mm			
Robot θ (deg)	**Wafer γ (deg)**	**Working Angle ϕ (deg)**	**R (mm)**
0	0.0	0.0	0.000
0.25	0.5	0.8	0.009
0.5	1.0	1.5	0.035
0.75	1.5	2.3	0.080
1	2.0	3.0	0.142
1.25	2.6	3.8	0.222
1.5	3.1	4.6	0.319
1.75	3.6	5.3	0.435
2.0	4.1	6.1	0.568
2.25	4.6	6.9	0.720
2.5	5.1	7.6	0.890

7.5 Distance

The distance from the wafer to the sensor should be set at the *optimum detecting distance*, as specified in Table A on page 3. While EX-QS sensors will perform satisfactorily anywhere within their specified maximum detecting range, you can achieve the best performance by operating them at the specified optimum detecting distance.

CyberOptics Semiconductor strongly recommends that the EX-QS sensors be used only within the specified *maximum detecting range* (see Table A on page 3). Sensor optics and geometry are carefully matched to the specified distance, so that the sensor will respond to wafers throughout (and beyond) the range of variations in wafer parameters. Outside the specified range, sensor response to wafers is degraded, and the sensor will not respond correctly to the full possible range of wafer parameters. At other distances the sensor will not respond correctly to all wafers even though it responds correctly to a test wafer.

7.6 Offset and Multiple Scans

EX-QS sensors can operate pointed either to the wafer center (on-axis) or off-axis. The EX-43QS sensor will detect all standard SEMI flatted and notched wafers when scanning on-axis.

However, two scans separated by ½ to 1 inch (each scan ¼ to ½ inch to each side of on-axis) are recommended for robust detection and to allow for misalignment in setup. When using two scans, the scanning algorithm should allow for, and correctly detect, a wafer that is seen on only one of the two scans. For working angle information, see Section 7.4 on page 21.

The EX-73QS sensor can detect flatted wafers by using multiple scans. For further information on offsets and multiple scans, contact CyberOptics Semiconductor Technical Support (see page ii) for the working angle specifications to calculate the number and positions of scans required.

7.7 Algorithms

The EX-QS wafer mapping sensor is a component in a complete wafer mapping system, and the algorithms used for wafer mapping have a great effect on the robustness of wafer detection. This is particularly true in detecting cross-slotted or ultra-thin wafers and wafers with a wide dynamic range of wafer coatings. To assure optimal wafer maps when writing wafer mapping algorithms or adjusting wafer mapping algorithm parameters, consider the following:

- Ensure that the sensor is properly aligned and calibrated to the wafers in the Z-axis. Algorithms often compare the measured wafer position to a predetermined position range and use that comparison to predict a cross-slot error.
- Check the robot speed and calculate whether the minimum on-time of the sensor will affect the measured positions of the wafers. This is usually only a factor with robots or loaders traveling at speeds in excess of five inches per second.
- Make sure that the robot is following the proper path. Ensure that the distance, offset, and alignment are correct when the robot is running.
- Verify that the configurable algorithm parameters are set for an optimum map. For example, if initial test scans on correctly positioned wafers detect false cross-slots, check the error threshold parameter. Verify that enough space is designated for the positioning of a normal wafer.
- Verify that the algorithm has dropout filtering implemented. For more information on dropout filtering, refer to CyberOptics Semiconductor's “Dropout Filter Technote,” available from CyberOptics Technical Support (see page ii).

The design of algorithms that are intended to detect cross-slotted wafers must consider the geometry of wafer slots and scan position. With a single scan, only the detected position can be used, and scanning near the side of the carrier may not provide sufficient positional differentiation for reliable cross-slot detection. In such cases, scanning should be done within about the center 1/3 of the carrier width. For more information, contact CyberOptics Semiconductor Technical Support (see page ii).

8.0 Cleaning and Maintenance

If EX-QS sensors are kept in a clean environment no maintenance is required. Sensor performance can be degraded by human contact to the lens, or by dust and debris. Keep the sensor in its plastic bag until you are ready to install it.

Warning:

- Any contact with the lenses could result in severely degraded optics performance.
- Do not attempt to clean the laser lens.
- If you have any questions, please contact CyberOptics Semiconductor Technical Support (see page ii).

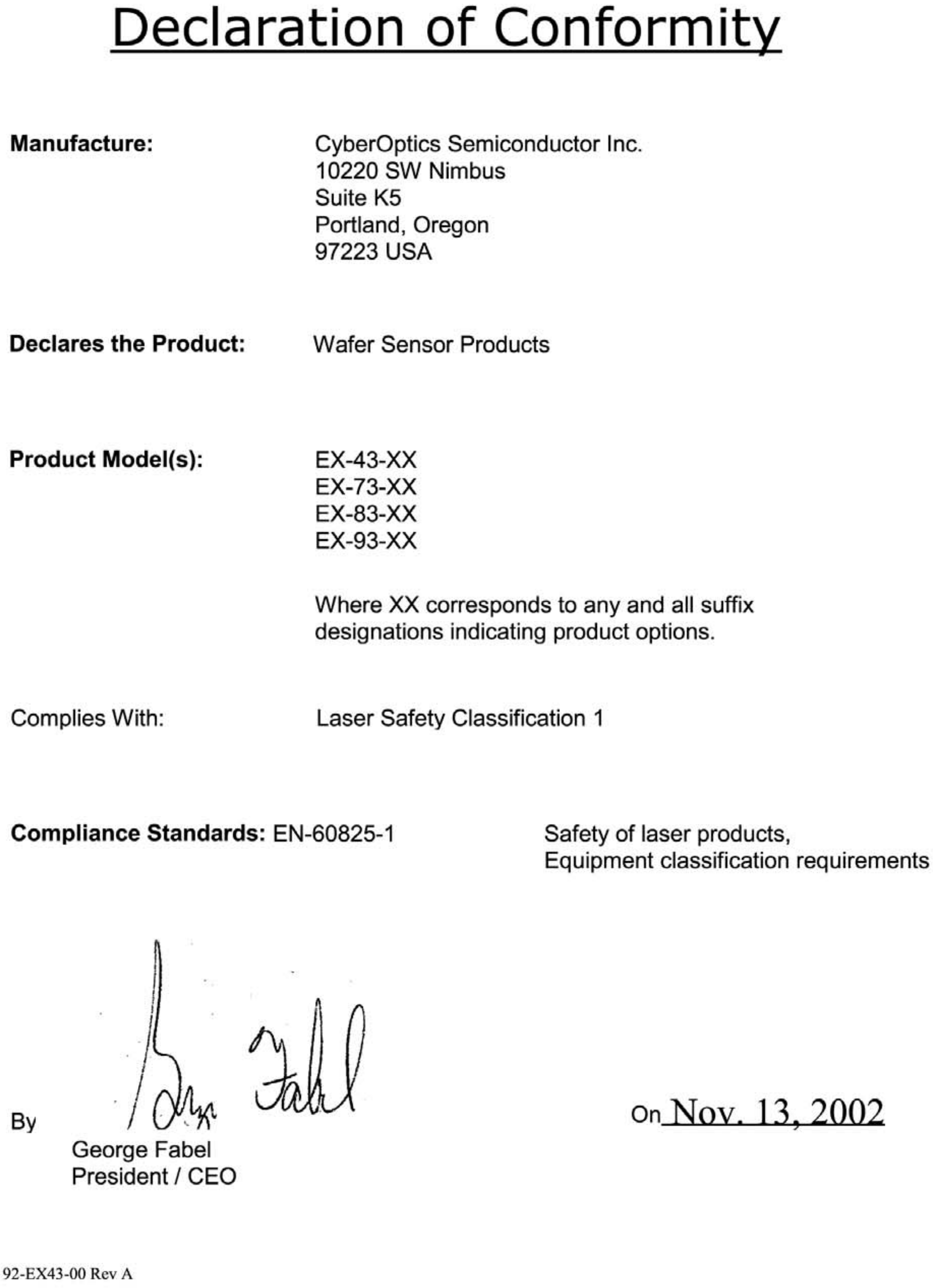
9.0 Troubleshooting

Symptom	Possible Cause	Possible Solution
Laser ON indicator (Red LED) does not turn on.	The power to sensor is not connected.	Check the power source and connections on the power lines.
	Sensor is in remote ON mode without remote enable control.	Check the Enable switch (see Figure 5 on page 10 and Section 5.2.3 on page 12) to make sure it is in the proper position for your application.
	Component failure.	If the above troubleshooting steps do not resolve the problem, contact CyberOptics Semiconductor Technical Support (see page ii) for further assistance and possible return merchandise authorization (RMA).
OUT Signal indicator (Green LED) is always on or always off.	The Detection Mode Switch (Light On/Dark On) is in the incorrect position.	Change the Detection Mode switch (see Figure 5 on page 10 and Section 5.2.2 on page 12) to the correct position.
	Component failure.	If the above troubleshooting step does not resolve the problem, contact CyberOptics Semiconductor Technical Support (see page ii) for further assistance and possible return merchandise authorization (RMA).

Symptom	Possible Cause	Possible Solution
False “cross-slot” events or abnormally thick wafer measurements.	Robot may be improperly taught.	Reteach robot for proper Z, Radius, and Theta position (see Section 7.4 on page 21).
	Software algorithm on the robot or load port may be creating the cross slot.	Map the first wafer position (bottom wafer) according to SEMI.
	The error threshold value in the mapping algorithm is set too small.	Increase the threshold (the area that represents a normally positioned wafer within a FOUP or cassette).
	Interrupts or dropouts might be occurring.	Verify that Dropout filtering is present in software. For details, refer to the technote “Dropouts and Algorithm Filters” available from Technical Support (see page ii).
	Ultra-thin wafer may be sagging so front edge of wafer is lower than expected.	Set up software to accommodate sagging wafers.
	Gain is set too high.	Verify the gain setting (see Section 5.2.1 on page 11) is correct. Contact Technical Support (see page ii) before changing the gain setting from the factory default.
	Software parameters may be conflicting.	Obtain a dump of “raw” sensor data and contact CyberOptics Semiconductor Technical Support (see page ii) for further assistance.
	Contaminated lens.	Contact CyberOptics Semiconductor Technical Support (see page ii).

Symptom	**Possible Cause**	**Possible Solution**
Sensor does not detect some wafers.	Wafers have non-standard characteristics that cause them to have low reflectivity.	Contact CyberOptics Semiconductor Technical Support (see page ii) for proper gain adjustment.
	Robot might be improperly taught.	Reteach robot for proper Z, Radius and Theta position.
	Software might not be properly configured.	Correct software setup.
	The standoff distance or working angle are outside the range specified for the sensor.	Check for the correct standoff distance and working angle. Table A on page 3 lists the *optimum detecting distance*, *maximum detecting range*, and *working angle range* for the sensors.
Not detecting real cross-slot events.	Software thresholds are not properly set.	Correctly set software thresholds.
	Robot not properly taught.	Reteach robot for proper Z, Radius, and θ position (Section 7.4 on page 21).
Occasional or sporadic occurrence of unknown mapping errors or obvious erratic sensor behavior.	Intermittent disconnect in the wiring to the sensor.	Check and repair, as necessary, wiring or connectors (see Section 5.3 on page 13).
	Faulty ground wire causing sensor and robot case to act as signal return.	Repair ground wire or connector (see Section 5.3 on page 13).

10.0 Compliance Documentation



Declaration of Conformity

Manufacture:

CyberOptics Semiconductor Inc.
10220 SW Nimbus
Suite K5
Portland, Oregon
97223 USA

Declares the Product: Wafer Sensor Products

Product Model(s):

EX-43-XX
EX-73-XX
EX-83-XX
EX-93-XX

Where XX corresponds to any and all suffix designations indicating product options.

Complies With: Laser Safety Classification 1

Compliance Standards: EN-60825-1 Safety of laser products, Equipment classification requirements

By

George Fabel
President / CEO

On Nov. 13, 2002

92-EX43-00 Rev A

SEMI™ Standards

RELATED INFORMATION 9
LASER CHECKLIST

NOTE: This related information is not an official part of SEMI S2 and was derived from practical application by task force members. This related information was approved for publication by vote of the responsible committee on October 21, 1999.

Laser Manufacturer:	CyberOptics Semiconductor
Model #:	EX-43, EX-73, EX-83, EX-93
Serial #:	
Laser Hazard Classification: (During Operation)	
1. Classification Number (e.g. 1, 2, 3a, 3b, 4):	Class 1 (all models)
2. Classification Standard(s) (e.g. FDA/CDRH, IEC, JIS, etc.):	FDA/CDRH (EX-43, EX-73 Accession #0120569-00: EX-83, EX-93 Accession #0120569-01)

NOTE R9-1: If any laser contained in the equipment is Class 2, 3a, 3b or 4 laser system or product, the vendor should make available upon request a hazard evaluation to include the following information for each laser in the equipment (where applicable):

Laser Parameters	
1. Laser medium type (HcNe, Nd:YAG, CO_2, Argon, Excimer, GaAs, etc.):	AlGaAs
NOTE: For Excimer lasers, specify gases:	
2. Wavelength(s) in nanometers (nm):	850nm
3. Continuous Wave	
A. Peak Power in Watts (W):	0.0012W (max)
B. Available Power in Watts (W):	0.0012W (max)
C. Irradiance in Watts/square centimeter (W/cm^2):	Not directly applicable
4. Pulse Characteristics	
A. Duration of Pulse in Seconds (s):	63 microseconds
B. Energy per Pulses in Joules (J):	0.075 microJoules (max)
C. Frequency of Pulses (Pulse Repetition Frequency) in Hertz (Hz):	8kHz
D. Average Power in Watts (W):	0.00060W (max)
E. Radiant Exposure in Joules/square centimeter (J/cm^2):	Not applicable
F. Q-Switch controlled pulses:	No
5. Beam Parameters	
A. Emerging beam diameter in millimeters (mm):	6 x 4.5mm
B. Expanded beam diameter in millimeters (mm):	Not applicable - beam expands continuously
C. Beam divergence in milliradians (mr):	EX-43 105mr (horiz) x 118 (vert) EX-73 178mr (horix) x 80mr (vert) EX-83 118mr (horiz) x 59mr (vert) EX-93 140mr(horiz) x 39mr (vert)
D. Collecting optics type:	None
E. Focal length in millimeters (mm):	EX-43 - 38.1mm, EX-73 - 55.9mm, EX-83 - 76.2mm, EX-93 - 114.3mm

Revised 7/7/2003