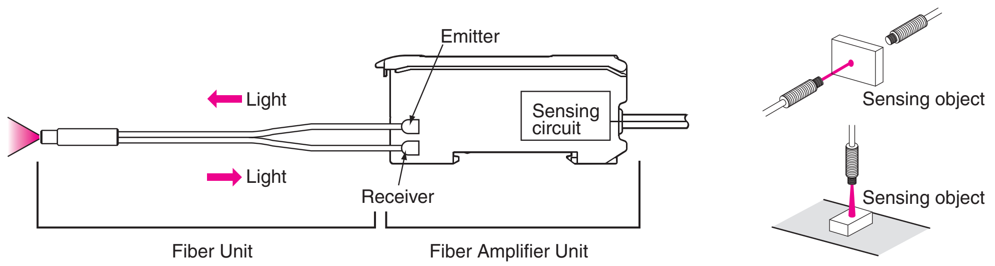
Technical Explanation for Fiber Sensors

CSM_FiberSensor_TG_E_1_3

Introduction

What Is a Fiber Sensor?

A Fiber Sensor is a type of Photoelectric Sensor that enables detection of objects in narrow locations by transmitting light from a Fiber Amplifier Unit with a Fiber Unit.



Features

1. Detection in Narrow Locations
The small sensing section and flexible Fiber Unit cable enable a Fiber Sensor to detect objects in narrow locations.

2. Superior Environmental Resistance
The sensing section of a Fiber Unit has no electric circuits. This makes it highly reliable even under severe environmental conditions, such as temperature, vibration, shock, water, and electrical noise conditions.

3. Easy Installation
The Fiber Unit can be installed close to the sensing object. This allows you to freely select where to install the Fiber Amplifier Unit.

4. Virtually No Sensing Object Restrictions
These Sensors operate on the principle that an object interrupts or reflects light, so they are not limited like Proximity Sensors to detecting metal objects. This means they can be used to detect virtually any object, including glass, plastic, wood, and liquid.

5. Fast Response Time
The response time is extremely fast because light travels at high speed and the Sensor performs no mechanical operations because all circuits are comprised of electronic components.

6. Non-contact Sensing
There is little chance of damaging sensing objects or Sensors because objects can be detected without physical contact. This ensures years of Sensor service.

7. Color Identification
The rate at which an object reflects or absorbs light depends on both the wavelength of the emitted light and the color of the object.
This property can be used to detect colors.

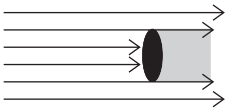
8. Easy Adjustment
Positioning the beam on an object is simple with models that emit visible light because the beam is visible.

Operating Principles

(1) Properties of Light

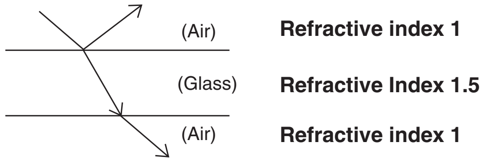
Rectilinear Propagation

When light travels through air or water, it always travels in a straight line.



Refraction

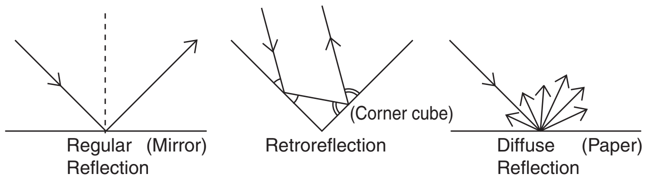
Refraction is the phenomenon of light being deflected as it passes obliquely through the boundary between two media with different refractive indices.



Reflection

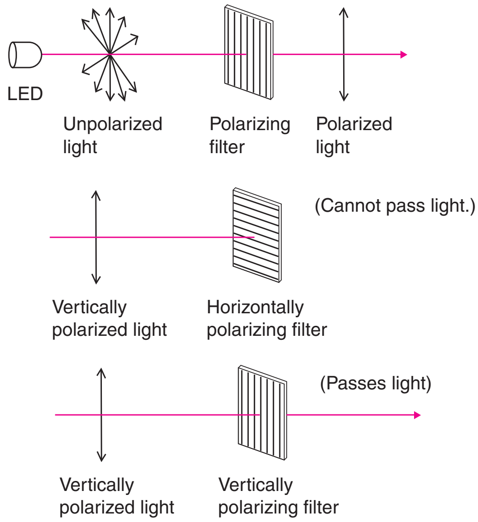
(Regular Reflection, Retroreflection, Diffuse Reflection)

A flat surface, such as glass or a mirror, reflects light at an angle equal to the incident angle of the light. This kind of reflection is called regular reflection. A corner cube takes advantage of this principle by arranging three flat surfaces perpendicular to each other. Light emitted toward a corner cube repeatedly propagates regular reflections and the reflected light ultimately moves straight back toward the emitted light. This is referred to as retroreflection.
Most retroreflectors are comprised of corner cubes that measure several square millimeters and are arranged in a precise configuration.
Matte surfaces, such as white paper, reflect light in all directions. This scattering of light is called diffuse reflection. This principle is the sensing method used by Diffuse-reflective Sensors.



Polarization of Light

Light can be represented as a wave that oscillates horizontally and vertically. Fiber Sensors almost always use LEDs as the light source. The light emitted from LEDs oscillates in the vertical and horizontal directions and is referred to as unpolarized light. There are optical filters that constrain the oscillations of unpolarized light to just one direction. These are known as polarizing filters. Light from an LED that passes through a polarizing filter oscillates in only one direction and is referred to as polarized light (or more precisely, linear polarized light). Polarized light oscillating in one direction (say the vertical direction) cannot pass through a polarizing filter that constrains oscillations to a perpendicular direction (e.g., the horizontal direction). The MSR function on Retro-reflective Sensors (see page 11) operates on this principle.

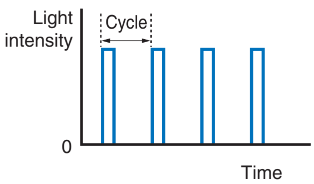


(2) Light Sources

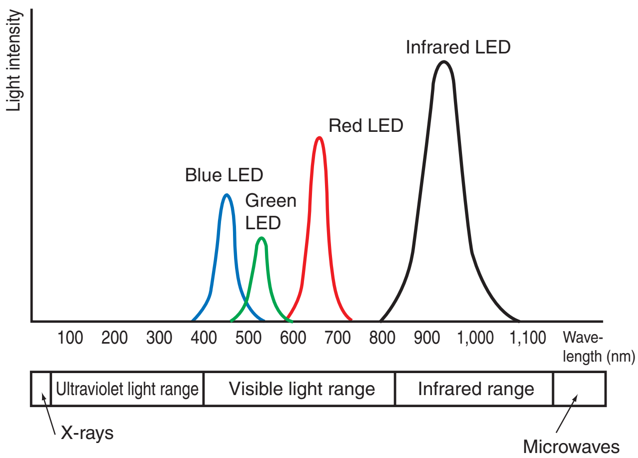
Light Generation

<u>Pulse Modulated light</u>

The majority of Photoelectric Sensors use pulse modulated light that basically emits light repeatedly at fixed intervals.



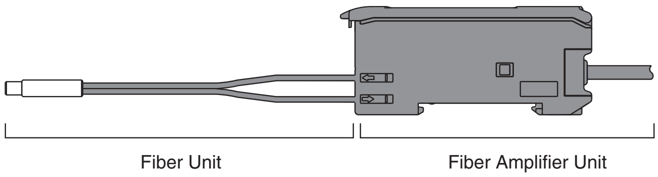
Light Source Color and Type



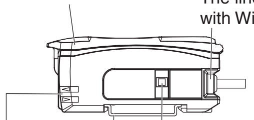
(3) Structure and Principles

Structure

The Fiber Unit has no electrical components whatsoever, so it provides superior resistance to noise and other environmental influences.

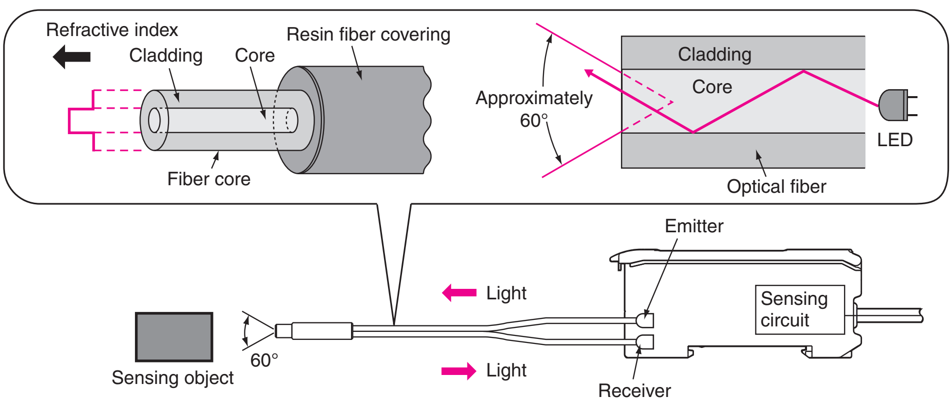


Nomenclature (E.g., E3NX-FA21/-FA51)



Detection Principles

Optical fiber is comprised of a central core with a high refractive index surrounded by cladding with a low refractive index. When light enters the core, repetitive total internal reflection at the boundary of the less refractive cladding guides the light down the optical fiber. The angle of the light traveling through the optical fiber increases to about 60° by the time the light exits the fiber and strikes a sensing object.



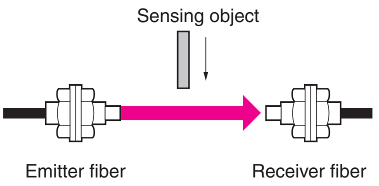
Classification

(1) Classification by Sensing Method

1. Through-beam Sensors

Sensing Method

The emitter and receiver fibers are installed facing each other so that the light from the emitter enters the receiver.
When a sensing object passing between the emitter and receiver fibers interrupts the emitted light, it reduces the amount of light that enters the receiver. This reduction in light intensity is used to detect an object.



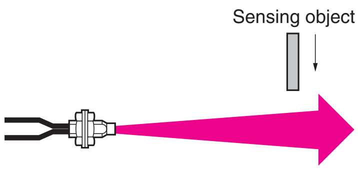
Features

- Stable operation and long sensing distances ranging from several centimeters to several tens of meters.
- Sensing position unaffected by changes in the sensing object path.
- Operation not greatly affected by sensing object gloss, color, or inclination.

2. Reflective Sensors

Sensing Method

The emitter and receiver fibers are installed in the same housing and light normally does not return to the receiver.
When light from the emitter strikes the sensing object, the object reflects the light and it enters the receiver where the intensity of light is increased. This increase in light intensity is used to detect the object.



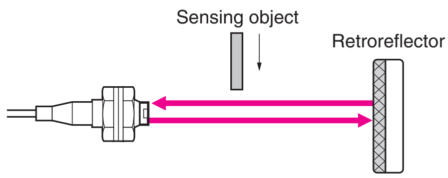
Features

- Sensing distance ranging from several centimeters to several meters.
- Easy mounting adjustment.
- The intensity of reflected light and operating stability vary with the conditions (e.g., color and smoothness) on the surface of the sensing object.

3. Retro-reflective Sensors

Sensing Method

The emitter and receiver fibers are installed in the same housing and light from the emitter is normally reflected back to the receiver by a Reflector installed on the opposite side.
When the sensing object interrupts the light, it reduces the amount of light received. This reduction in light intensity is used to detect the object.



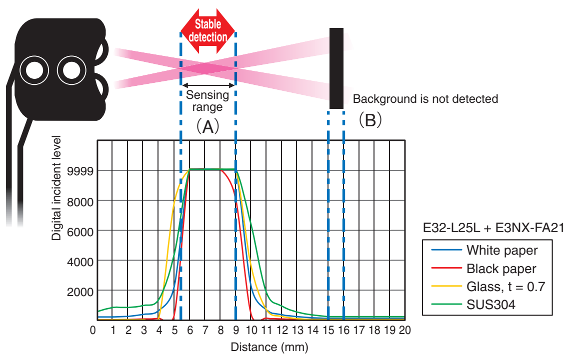
Features

- Sensing distance ranges from several centimeters to several meters.
- Simple wiring and optical axis adjustment (labor saving).
- Operation not greatly affected by the color or angle of sensing objects.
- Light passes through the sensing object twice, making these Sensors suitable for sensing transparent objects.
- Sensing objects with a mirrored finish may not be detected because the amount of light reflected back to the receiver from such shiny surfaces makes it appear as though no sensing object is present. This problem can be overcome using the MSR function.

4. Limited-reflective Sensors

Detection Method

In the same way as for Reflective Sensors, Limited-reflective Sensors receive light reflected from the sensing object to detect it. The emitter and receiver are installed to receive only regular-reflection light, so only objects that are a specific distance (area where light emission and reception overlap) from the Sensor can be detected. In the figure below, the sensing object at (A) can be detected while the object at (B) cannot.



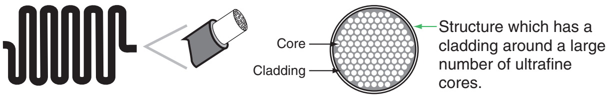
Features

- Small differences in height can be detected.
- The distance from the Sensor can be limited to detect only objects in a specific area.
- Operation is not greatly affected by sensing object colors.
- Operation is greatly affected by the glossiness or inclination of the sensing object.

(2) Types of Fiber Cables

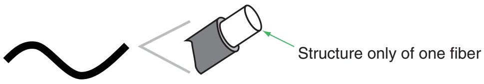
• Flexible Fibers

The flexible fiber has a small bending radius for easy routing without easily breaking.
It is easy to use because the cable can be bent without significantly reducing light intensity.



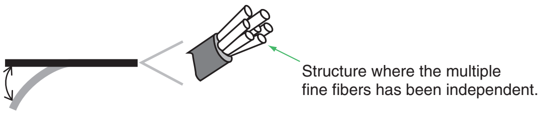
• Standard Fibers

This fiber have a large bending radius compared with bend-resistant or flexible fiber.
Use this fiber where the bending radius is large, or on non-moving parts.



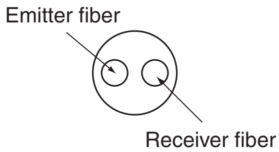
• Break-resistant Fibers

This fiber is resistant to repeated bends for use on moving parts.



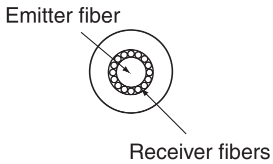
• Standard Reflective Fiber Units

This structure is standard for most Reflective Fiber Units. The receiver fiber is located next to the emitter fiber as shown below.



• Coaxial Reflective Fiber Units

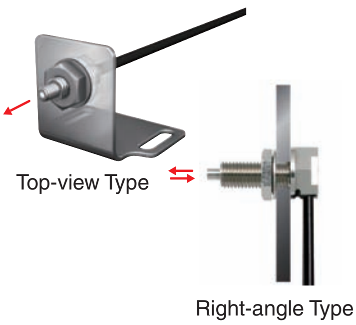
These Fiber Units offer better detection of small objects at close distances (of 2 mm or less) than Standard Reflective Fiber Units. They also detect glossy surfaces more reliably than Standard Reflective Fiber Units, even if the surface is tilted. The receiver fibers are arranged around the emitter fiber as shown below.



(3) Types of Fiber Units

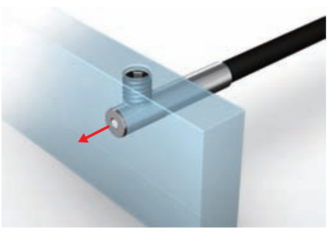
1. Standard Installation

Threaded Models



Standard screw-type installation.
The Fiber Units is mounted into a drilled hole and secured with nuts.

Cylindrical Models



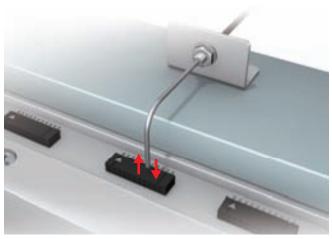
Ideal for installation in narrow spaces.
The Fiber Unit is secured with a set screw.

2. Saving Space

Flat Models

Mount directly in limited spaces without using special mounting brackets.

Sleeve Models (Close-range Detection)



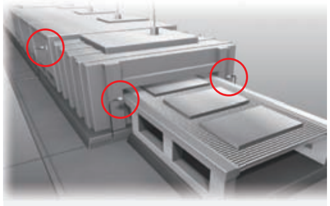
Suitable for close-range detection.
Ideal for detecting minute objects in areas with limited space.

3. Beam Improvements

Small-Spot, Reflective (Minute Object Detection)

Small-spot to accurately detect small objects.

High-power Beam (Long-distance Installation, Dust-resistant)



Suitable for detection on large equipment, of large objects, and in environments with airborne particles

Narrow View (Detection Across Clearance)

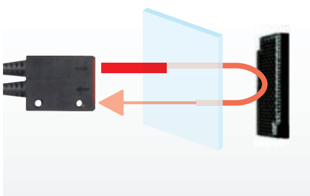
The fine beam prevents false detection of light that is reflected off surrounding objects.

Detection without Background Interference

These Fiber Units detect only objects in the sensing range. Objects in the background that are located beyond a certain point are not detected.

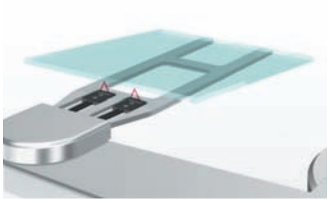
4. Transparent Object Detection

Retro-reflective



Detect transparent objects reliably because the beam passes through the object twice, resulting in greater light interruption.

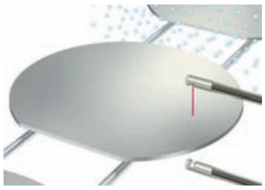
Limited-reflective (Glass Detection)



The limited-reflective optical system provides stable detection of specular reflective glass.

5. Environmental Immunity

Chemical-resistant, Oil-resistant

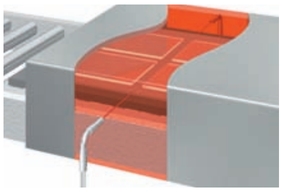


Made from materials that are resistant to various oils and chemicals.

Bending-resistant, Disconnection-resistant

Resistant to repeated bending on moving parts and breaking from snagging or shock.

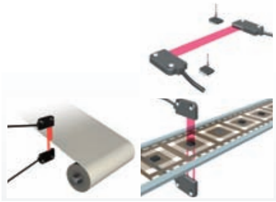
Heat-resistant



Can be used in high-temperature environments at up to 400°C.

6. Special Applications

Area Beam (Area Detection)



Detect across areas for meandering materials or falling workpieces whose position vary.

Liquid-level Detection

Detect only liquid when being mounted on tubes or in liquid.

Vacuum-resistant

Can be used under high vacuums of up to 10^{-5} Pa.

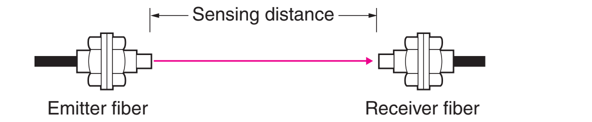
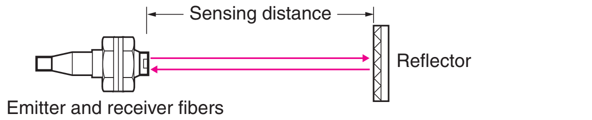
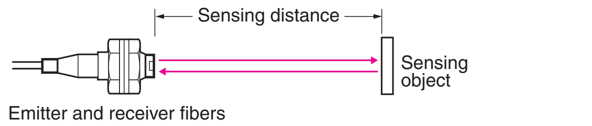
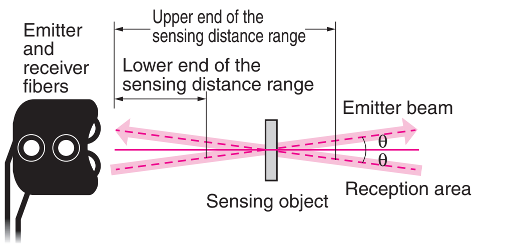
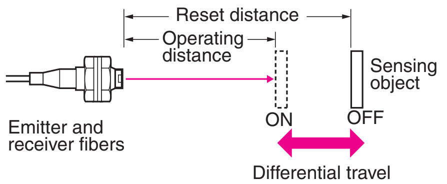
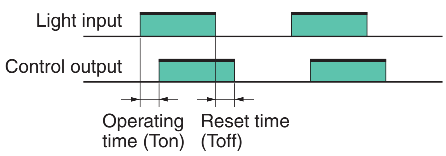
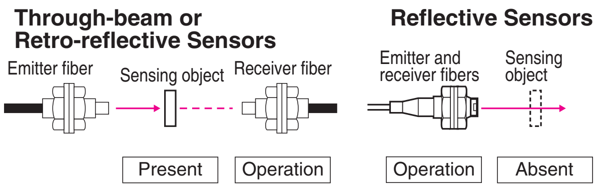
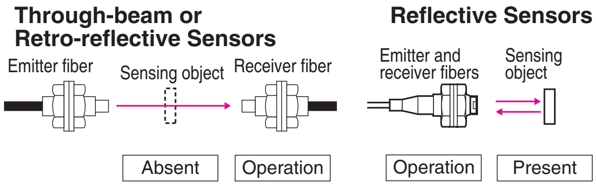
FPD, Semiconductors, and Solar Cells

Designed specifically to reliably detect glass substrates and wafers.

(4) Types of Fiber Amplifier Units

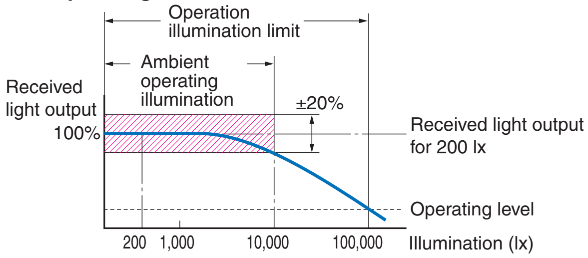
For information on the types of Fiber Amplifier Units and Communications Unit, refer to the product pages on your OMRON website.

Explanation of Terms

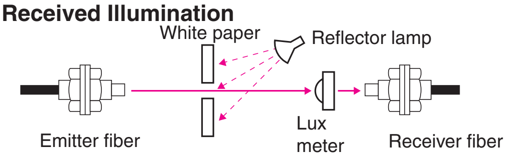
Item		Explanatory diagram	Meaning
Sensing distance	Through-beam Sensors		The maximum sensing distance that can be set with stability for Through-beam and Retro-reflective Sensors, taking into account product deviations and temperature fluctuations. Actual distances under standard conditions will be longer than the rated sensing distances for both types of Sensor.
	Retro-reflective Sensors		
	Reflective Sensors		The maximum sensing distance that can be set with stability for the Reflective Sensors, taking into account product deviations and temperature fluctuations, using the standard sensing object (white paper). Actual distances under standard conditions will be longer than the rated sensing distance.
	Limited-reflective Sensors		As shown in the diagram at left, the optical system for the Limited-reflective Sensors is designed so that the emitter axis and the receiver axis intersect at the surface of the detected object at an angle θ. With this optical system, the distance range in which regular-reflective light from the object can be detected consistently is the sensing distance. As such, the sensing distance can range from 10 to 35 mm depending on the upper and lower limits. (See page 4.)
Differential travel			Reflective Sensors The difference between the operating distance and the reset distance. Generally expressed in catalogs as a percentage of the rated sensing distance.
Response time			The delay time from when the light input turns ON or OFF until the control output operates or resets. In general for Photoelectric Sensors, the operating time (Ton) ≈ reset time (Toff).
Dark-ON operation			The "Dark-ON" operating mode is when a Through-beam Sensor produces an output when the light entering the Receiver is interrupted or decreases.
Light-ON operation			The "Light-ON" operating mode is when a Reflective Sensor produces an output when the light entering the receiver increases.

<table>
<tr><th>Item</th><th>Explanatory diagram</th><th>Meaning</th></tr>
<tr><td>Ambient operating illumination</td><td>

Difference between Ambient Operating Illumination and Operating Illumination Limit

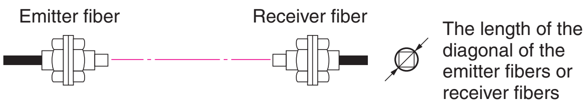


Received Illumination

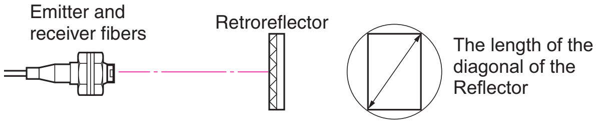


</td><td>The ambient operating illumination is expressed in terms of the receiver surface illuminance and is defined as the illuminance when there is a ±20% change with respect to the value at a light reception output of 200 lx. This is not sufficient to cause malfunction at the operating illuminance limit.</td></tr>
<tr><td>Standard sensing object</td><td>

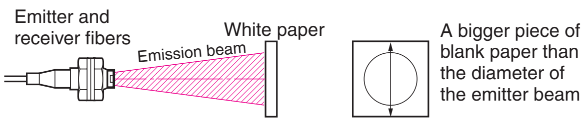
Through-beam Sensors



Retro-reflective Sensors



Reflective Sensors

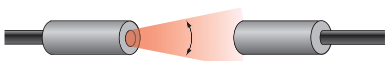


</td><td>The standard sensing object for both Through-beam Sensors and Retro-reflective Sensors is an opaque rod with a diameter larger than the length of a diagonal line of the optical system. In general, the diameter of the standard sensing object is the length of the diagonal line of the emitter/receiver fibers for Through-beam Sensors, and the length of a diagonal line of the Reflector for Retro-reflective Sensors.

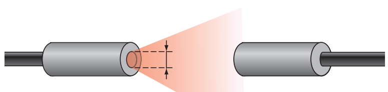
Size of Standard Sensing Object Using Reflector

<table>
<tr><th>Reflector models</th><th>Diagonal line of optical system</th><th>Sensing object</th></tr>
<tr><td>E39-R1/R1S/R1K</td><td>72.2 mm</td><td>75-mm dia.</td></tr>
<tr><td>E39-R2</td><td>100.58 mm</td><td>105-mm dia.</td></tr>
<tr><td>E39-R3</td><td>41.44 mm</td><td>45-mm dia.</td></tr>
<tr><td>E39-R4</td><td>26.77 mm</td><td>30-mm dia.</td></tr>
<tr><td>E39-R6</td><td>56.57 mm</td><td>60-mm dia.</td></tr>
<tr><td>E39-R9</td><td>43.7 mm</td><td>45-mm dia.</td></tr>
<tr><td>E39-R10</td><td>66.47 mm</td><td>70-mm dia.</td></tr>
<tr><td>E39-RS1</td><td>36.4 mm</td><td>40-mm dia.</td></tr>
<tr><td>E39-RS2</td><td>53.15 mm</td><td>55-mm dia.</td></tr>
<tr><td>E39-RS3</td><td>106.3 mm</td><td>110-mm dia.</td></tr>
<tr><td>E39-R37</td><td>13.4 mm</td><td>15-mm dia.</td></tr>
</table>

For Reflective Sensors, the standard sensing object is a sheet of white paper larger than the diameter of the emitted beam.</td></tr>
<tr><td>Aperture angle</td><td>

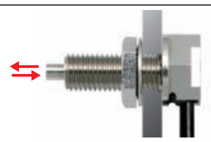


Aperture angle</td><td>The aperture angle is the angle at which the emitter beam spreads out.</td></tr>
<tr><td>Optical axis diameter</td><td>

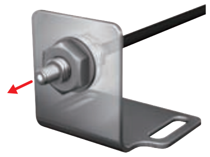
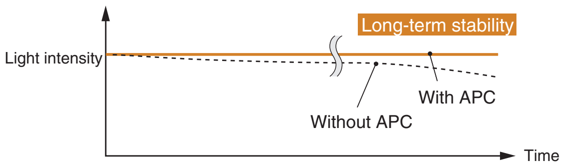
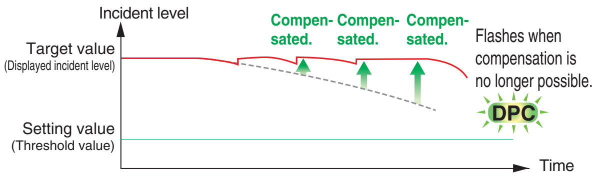
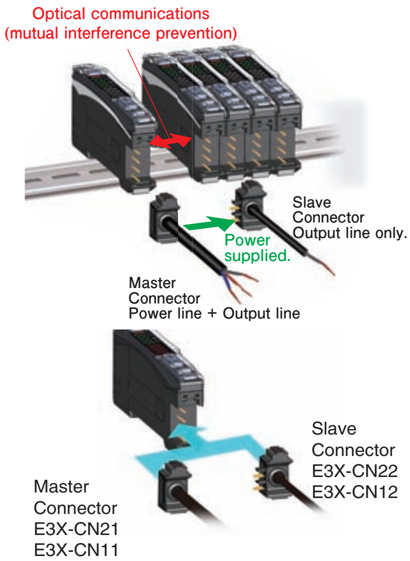


Optical axis diameter</td><td>The optical axis diameter is the beam size that the Through-beam Fiber Unit uses for detection.
If you are detecting objects larger than the optical axis diameter, you can expect stable detection performance because the object will block all of the beams of light that are used for detection.
The incident level may fluctuate, however, if the workpiece passes the beam at high speed.
In this case, it is best to select a Fiber Unit with a smaller optical axis diameter, or change the response time of the Fiber Amplifier Unit to High-speed mode or to Super-high-speed mode setting.</td></tr>
<tr><td>LENS in
Fiber Units with Build-in-Lenses</td><td>

</td><td>These Fiber Units have built-in lenses.
They feature high-power beams.
You don’t have to worry about the lens falling off and getting lost.</td></tr>
<tr><td>Right-angle Type/ Hex-shaped Models</td><td>



Right-angle Type/Hex-shaped Models</td><td>These Fiber Units have the fiber and the optical axis at a 90° angle to each other. The Right-angle type prevents snagging on the cable because the cable runs along the mounting surface. This type saves space in the depth compared with a Top-view type. The nut is attached to the Fiber Unit to reduce installation work.</td></tr>
</table>

Item	Explanatory diagram	Meaning
Top-view Type	 Top-view Type	The optical axis is along the center (vertical direction) of the Sensor. For different optical axis positions, there are also Side-view and Flat-view types.
APC		APC is an acronym for auto power control. This function maintains a constant light intensity by continuously monitoring the emitter LED in the Fiber Amplifier Unit and raising the internal electric power when deterioration of the LED reduces the light level. Applications that detect subtle differences particularly need this function to prevent changes in the light emission level, which can cause malfunctions. With OMRON Fiber Sensors, APC is always ON.
DPC		DPC is an acronym for dynamic power control. This function automatically compensates the displayed incident level when Smart Tuning is executed. This function can reduce malfunctions and differences in performance due to changes over time and environmental factors.
Mutual interference prevention		This function prevents mutual interference among Fiber Amplifier Units by mounting them side by side. OMRON achieves this by using infrared communications through the small windows on the sides of Fiber Amplifier Units to shift the timing of emitted pulses.
Wire-saving Connectors		Reduced wiring can be achieved by connecting Fiber Amplifier Units with Wire-saving Connectors. At OMRON, Fiber Amplifier Units are not divided into masters and slaves. Instead, their connector cables are divided into Master Connectors and Slave Connectors.

Further Information

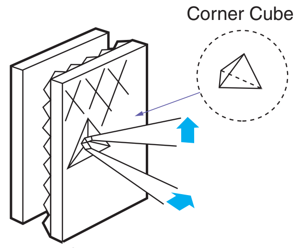
Application and Data

(1) MSR (Mirror Surface Rejection) Function

[Principles]

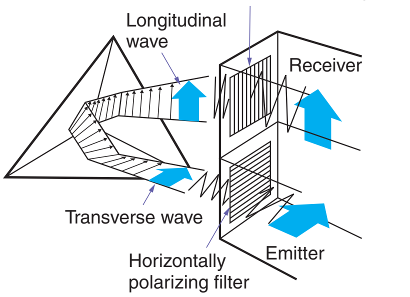
This function and structure uses the characteristics of the Retroreflector and the polarizing filters built into the Retro-reflective Sensors to receive only the light reflected from the Retroreflector.

- The waveform of the light transmitted through a polarizing filter in the emitter changes to polarization in a horizontal orientation.
- The orientation of the light reflected from the triangular pyramids of the Retroreflector changes from horizontal to vertical.
- This reflected light passes through a polarizing filter in the receiver to arrive at the receiver.



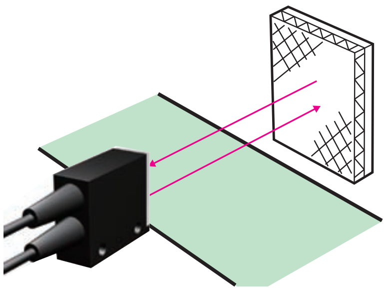
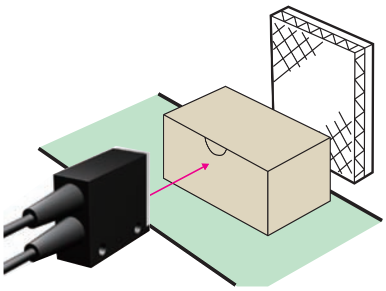
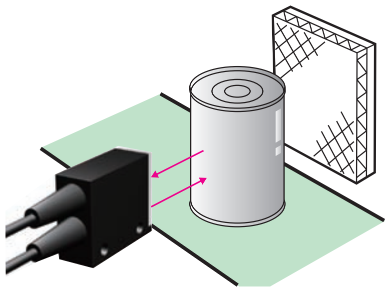
[Purpose]

This method enables stable detection of objects with a mirror-like surface.
Light reflected from these types of objects cannot pass through the polarizing filter on the receiver because the orientation of polarization is kept horizontal.



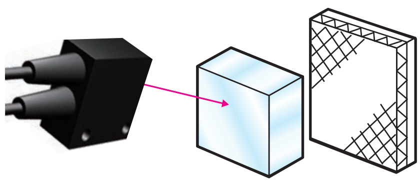
[Examples]

A sensing object with a rough, matte surface (example (2)) can be detected even without the MSR function. If the sensing object has a smooth, glossy surface on the other hand (example (3)), it cannot be detected with any kind of consistency without the MSR function.

(1) No Object	**(2) Non-glossy Object**	**(3) Object with a Smooth, Glossy Surface (Example: battery, can, etc.)**
The light from the emitter hits the Reflector and returns to the receiver.	Light from the emitter is intercepted by the object, does not reach the Reflector, and thus does not return to the receiver.	Light from the emitter is reflected by the object and returns to the receiver.
		

[Caution]

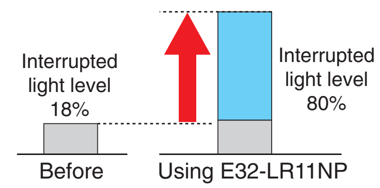
Stable operation is often impossible when detecting objects with high gloss or objects covered with glossy film. If this occurs, install the Sensor so that it is at an angle off perpendicular to the sensing object.



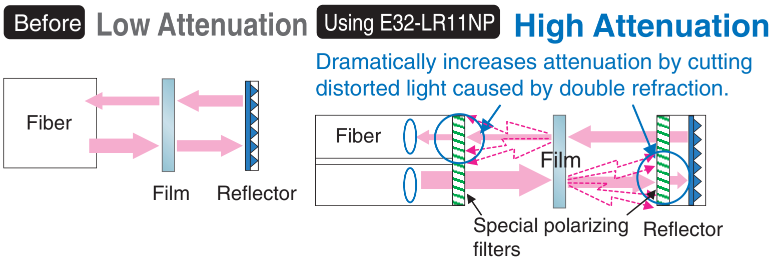
(2) Technology for Detecting Transparent Objects Exhibiting Birefringence

P-opaquing (Polarization-opaquing)

Conventional methods for detecting transparent objects depend on refraction due to the shape of the sensing objects or on the attenuation of light intensity caused by surface reflection. However, it is difficult to attain a sufficient level of excess gain with these methods. P-opaquing uses the birefringent (double refraction) property of transparent objects to dramatically increase the level of excess gain. The polarization component that is disturbed by the sensing object as they pass along the line is cut by a special and unique OMRON polarization filter. This greatly lowers the intensity of the light received to provide stable detection with simple sensitivity adjustment. "P-opaquing" is a word that was coined to refer to the process of applying polarization in order to opaque transparent objects that exhibit the property of birefringence.



* Installation distance: 200 mm, Sensing object: Multilayered polyolefin film, Sensing object position: Middle



- Excellent detection performance with transparent films. (E32-LR11NP + E39-RP1)
  The specially designed filter eliminates undesirable light, which allows significantly more light to be interrupted for stable detection of films.

(3) Influence of Fiber Cable Length

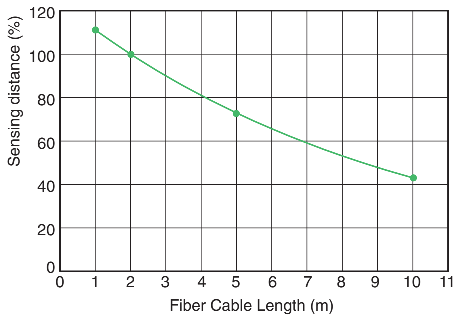
The sensing distance listed in the Fiber Units specifications are based on the fiber cable lengths found in the suffix of the model number.

The sensing distance will change if the fiber cable is cut or extended.

The following graph shows the percentage change of the various fiber cable length, where 100% is the sensing distance for a fiber cable with a length of 2 m.

Use this as a guideline for installation distances.

Keep in mind that extending the cable with a fiber connector will result in even shorter sensing distances than the value given in the graph.

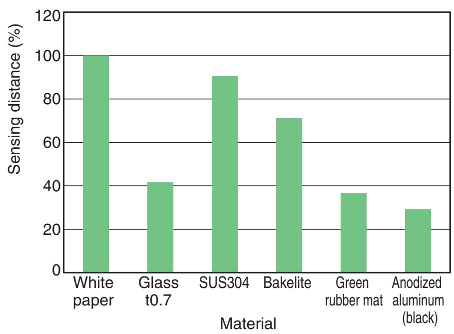


* The 100% value is for a fiber cable with a length of 2 m (same for Through-beam and Reflective Models).

(4) Reflective Models: Sensing Distance Ratios by Workpiece Materials

The following graph shows the percentage change of the various workpieces, where 100% is the sensing distance for white paper, the standard sensing object.

Refer to the value of the material that looks like your workpiece.

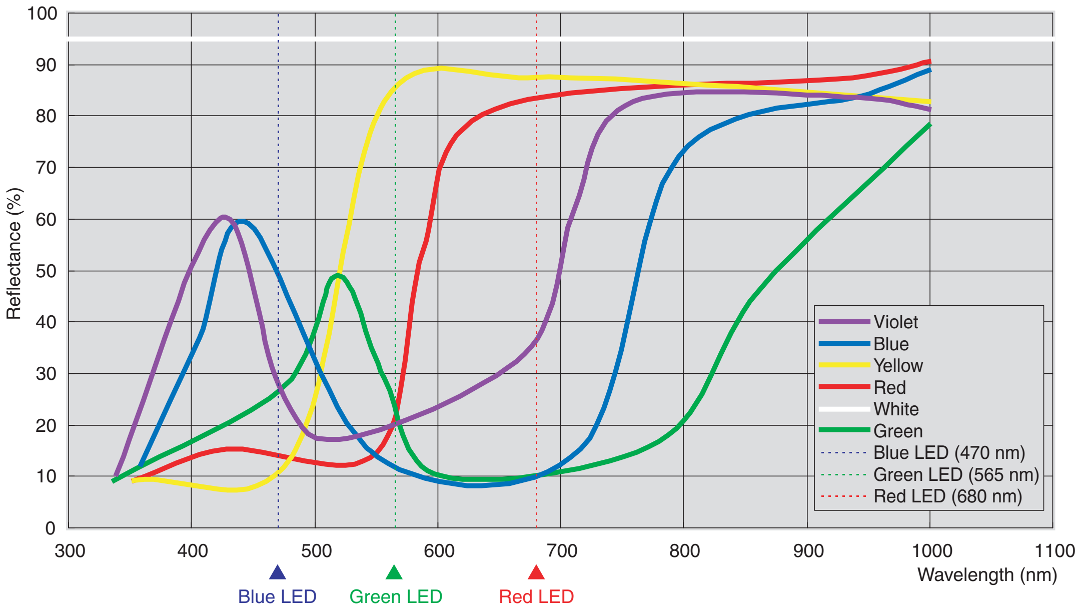


* White paper is 100%.

(5) Surface Color and Light Source Reflectance

Surface Color Reflectance

Reflectance of Various Colors at Different Wavelengths of Light



Identifiable Color Marks

Sensor Light Color : Blue

	White	Red	Yellow	Green	Blue	Violet	Black
White		5	5	3		3	8
Red	5				3	2	
Yellow	5			2	4	2	
Green	3		2		2		3
Blue		3	4	2			6
Violet	3	2	2				4
Black	8			3	6	4	

Sensor Light Color : Green

	White	Red	Yellow	Green	Blue	Violet	Black
White		8			3	5	10
Red	8		5	5	3		
Yellow		5				3	6
Green		5				3	6
Blue	3	3					4
Violet	5		3	3			3
Black	10		6	6	4	3	

Sensor Light Color : Red

	White	Red	Yellow	Green	Blue	Violet	Black
White				5	6	3	9
Red				4	4	2	7
Yellow				5	5	3	8
Green	5	4	5			2	
Blue	6	4	5			2	
Violet	3	2	3	2	2		4
Black	9	7	8			4	

The numbers express the degree of margin (percentage of received light for typical examples).
Models with an white light source support all combinations.

Sensor light color	Product classification	Model
Red light source ●	Fiber Sensors	E3NX-FA
		E3X-HD
		E3X-SD
		E3X-NA
		E3X-MDA
Blue light source ●	Fiber Sensors	E3X-DAB-S
Green light source ●	Fiber Sensors	E3X-DAG-S
White light source ●●●	Fiber Sensors	E3NX-CA

(6) FAQs

Category	Question	Answer
Fiber Units	Are there any differences between the Fiber Units that are used for emitter and receiver?	With Through-beam Fiber Units, there is no difference between emitter fibers and receiver fibers. With Reflective Fiber Units, the emitter fibers and receiver fibers are different on Coaxial Reflective Models. Emitter fiber cables have identification marks. Refer to the individual dimensions diagrams of Fiber Units for details.
	What size must the hole be to mount a Threaded or Cylindrical Fiber Unit?	Refer to the recommended mounting hole dimensions given in the catalog.
	Are Fiber Cables available in different lengths?	Some models are available with either 5-m or 10-m cable. Ask your OMRON representative for details.
	Are these Fiber Units CE certified?	Fiber Units do not have any electrical components and therefore are exempt from CE certification.
	What the Fiber Units with built-in lenses?	These highly recommended Fiber Units have built-in lenses that achieve stable detection with high-power beams.
Fiber Amplifier Units	Can the E3X-HD Series be linked with Fiber Amplifier Units from other series?	The E3X-HD Series can be connected with the E3X-DA-S and MDA Series.
	Can the E3NX-FA Series or E3X-HD Series be operated from a Mobile Console?	Mobile consoles cannot be used with either the E3NX-FA Series or the E3X-HD Series.
	Can Sensor Communications Units be used with models from the E3NX-FA Series or E3X-HD Series?	If you use E3NX-FA0 Amplifier Units, you can use the E3NW-ECT(EtherCAT), E3NW-CRT(CompoNet) or E3NW-CCL (CC-Link). If you use E3X-HD0 Amplifier Units, you can use the E3X-CRT (CompoNet) or E3X-ECT (EtherCAT).

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