TECHNICAL GUIDE FOR LASER SENSORS

DEFINITIONS

Laser is an acronym from "Light Amplification by Stimulated Emission of Radiation."

A laser is a device which radiates coherent light by excitation of electrons in a gas or a solid to a high energy state, and release of this energy in the form of light after amplification by back and forth oscillations.

A laser beam has the following features:
1. Monochromatic
2. Low divergence
3. High energy density
4. Coherent in phase

Types of lasers
Examples of materials which are used to emit laser beams are:
Liquid: Pigment
Gas: He-Ne, Ar and CO₂
Solid: YAG, ruby and glass
Semiconductor: GaAs

IEC/JIS CLASSIFICATION

Even a small laser beam has such a high energy density that it may be harmful to the human skin or eyes. To prevent injuries by laser products, JIS C 6802 (Radiation Safety Standards for Laser Products) was established based on IEC standards. (The U.S. FDA standard also uses a similar classification system for laser products.)

JIS C 6802-2005 classification

<table>
<thead>
<tr>
<th>Class</th>
<th>Model</th>
<th>Basic hazard assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>PBZ series</td>
<td>Intrinsically safe design</td>
</tr>
<tr>
<td>Class 1M</td>
<td>HLA series HLB series</td>
<td>A low-power laser beam (302.5 to 4,000 nm). The laser is safe under specified conditions, including looking directly into the beam. However, looking directly into the beam with optical instruments may be hazardous.</td>
</tr>
<tr>
<td>Class 2</td>
<td></td>
<td>A low-power visible laser beam (400 to 700 nm). Normally the eyes are protected instinctively by the blink reflex.</td>
</tr>
<tr>
<td>Class 2M</td>
<td></td>
<td>A low-power visible laser beam (400 to 700 nm). Normally the eyes are protected instinctively by the blink reflex. However, looking into the beam with optical instruments may be hazardous.</td>
</tr>
<tr>
<td>Class 3R</td>
<td></td>
<td>A visible laser beam (400 to 700 nm) not more than five times as powerful as a Class 2 laser. An invisible laser beam (302.5 nm or higher) not more than five times as powerful as a Class 1 laser. Direct viewing of the beam directly may be hazardous.</td>
</tr>
<tr>
<td>Class 3B</td>
<td></td>
<td>A laser of 0.5 W or less. Directly viewing of the beam is hazardous. Viewing diffuse reflections of a pulsed laser that is not focused is safe under certain conditions.</td>
</tr>
<tr>
<td>Class 4</td>
<td></td>
<td>A high output laser. Even diffuse reflections may be hazardous. The laser can burn the skin or cause a fire.</td>
</tr>
</tbody>
</table>

Note: Azbil’s FDA-compliant products are classified as FDA Class 2 (JIS/IEC Class 1) laser products.

Notice No. 39 by the Ministry of Health, Labour and Welfare in Japan defines safeguards for workers in “Measures for the Prevention of Injury by Laser Beam” for laser products of Class 3A or over. For details, refer to that notice.
Safety precautions required for users of laser products in each laser product class are stated in JIS C 6802 and IEC 60825-1. The following table is only a summary for the sake of convenience. Refer to the original standard for complete requirements.

### Laser Safety

- **Supervisor**: Required if beam is invisible during emission of invisible laser beam.
- **Key**: Removed when laser is not in use. Connected to room or door circuit.
- **Warning Instructions**: Prevention of accidental exposure during use.
- **Remote Interlock Connector**: Not required.
- **Beam Attenuator**: Not required.
- **Laser Emission Indicator**: Not required.
- **Warning Sign**: Gives warning instructions.
- **Beam Path**: Stops the beam at the end of the range.
- **Specular Reflection**: Accidental reflection is avoided.
- **Eye Protection**: Required where technical or administrative measures cannot be taken, and where MPE (maximum permissible exposure) would be exceeded.
- **Protective Clothing**: Required depending on the conditions. Specific instructions are required.
- **Training**: Required for all operators and maintenance personnel.

### Laser Safety Precautions

Safety precautions required for users of laser products in each laser product class are stated in JIS C 6802 and IEC 60825-1. The following table is only a summary for the sake of convenience. Refer to the original standard for complete requirements.

#### User Safety Precautions (Summary) JIS C 6802-1997

<table>
<thead>
<tr>
<th>Class</th>
<th>Model</th>
<th>Basic hazard assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>PBZ series</td>
<td>Intrinsically safe design</td>
</tr>
<tr>
<td>Class 1M</td>
<td>HLA series</td>
<td>A low-power laser beam. The laser is safe under specified conditions, including direct exposure to the beam. However, looking directly into the beam with optical instruments may be hazardous.</td>
</tr>
<tr>
<td>Class 2</td>
<td>HLB series</td>
<td>A low-power visible laser beam (400 to 700 nm). Normally the eyes are protected instinctively by the blink reflex.</td>
</tr>
<tr>
<td>Class 2M</td>
<td></td>
<td>A low-power visible laser beam (400 to 700 nm). Normally the eyes are protected instinctively by the blink reflex. However, looking into the beam with optical instruments may be hazardous.</td>
</tr>
<tr>
<td>Class 3R</td>
<td></td>
<td>A visible laser beam (400 to 700 nm) not more than five times as powerful as a Class 2 laser. An invisible laser beam (302.5 nm or higher) not more than five times as powerful as a Class 1 laser. Direct viewing of the beam directly may be hazardous.</td>
</tr>
<tr>
<td>Class 3B</td>
<td></td>
<td>A laser of 0.5 W or less. Directly viewing of the beam is hazardous. Viewing diffuse reflections of a pulsed laser that is not focused is safe under certain conditions.</td>
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Note: Azbil’s FDA-compliant products are classified as FDA Class 2 (JIS/IEC Class 1) laser products.

For laser products of Class 3A or higher, safeguards for workers are given in “Measures for the Prevention of Injury by Laser Beam” in Notice No. 39 of the Ministry of Health, Labour and Welfare in Japan.

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### User Safety Precautions

- **Laser Safety Supervisor**: Basically not required, but recommended if direct observation of laser beam is required.
- **Remote Interlock Connector**: Not required. Connected to room or door circuit.
- **Control by Means of a Key**: Not required. Key is removed when laser is not in use.
- **Beam Attenuator**: Not required. Prevents accidental exposure during use.
- **Laser Emission Indicator**: Not required. ON during emission of invisible laser beam. ON during laser emission.
- **Warning Sign**: Not required. Gives warning instructions.
- **Beam Path**: Not required. Stops the beam at the end of the range.
- **Specular Reflection**: Not required. Accidental reflection is avoided.
- **Eye Protection**: Not required. Required where technical or administrative measures cannot be taken, and where MPE (maximum permissible exposure) would be exceeded.
- **Protective Clothing**: Not required. Required depending on the conditions. Specific instructions are required.
- **Training**: Not required. Required for all operators and maintenance personnel.

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*1. Applies to Class 1M products that do not meet Requirement 1 in Table 10 (refer to the original standard). Does not apply to Class 1M products that do not meet Requirement 2 in Table 10.

*2. Applies to Class 2M products that do not meet Requirement 1 in Table 10 (refer to the original standard). Does not apply to Class 2M products that do not meet Requirement 2 in Table 10.
FDA CLASSIFICATION

FDA (CDRH)
The Food and Drug Administration (FDA) is a U.S. governmental agency that oversees many smaller organizations. One of these organizations is the Center for Devices and Radiological Health (CDRH), which is responsible for radiological electrical products and medical devices. Products using lasers are controlled by the CDRH. 21 CFR Part 1040.10 provides specific safety standards for laser products. Products that do not comply with these standards cannot be sold in the U.S., nor can they be imported to the U.S. Therefore, manufacturers of laser products are required to file a Product Report with the CDRH demonstrating conformity to Part 1040.10 before selling laser products in or importing laser products to the United States.

FDA 21 CFR Part 1040.10 (CDRH)
FDA laser product classification

<table>
<thead>
<tr>
<th>Class</th>
<th>Laser class valuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>Levels of laser radiation are not considered to be hazardous.</td>
</tr>
<tr>
<td>Class IIa</td>
<td>Lasers emit radiation in the visible wavelength range of 400 to 710 nm. Levels of laser radiation are not considered to be hazardous if viewed for 1000 s or less, but are considered to be a chronic viewing hazard for more than 1000 s.</td>
</tr>
<tr>
<td>Class II</td>
<td>Lasers emit radiation in the visible wavelength range of 400 to 710 nm. Levels of laser radiation are considered to be a chronic viewing hazard. Eye protection is normally afforded by aversion responses, including the blink reflex.</td>
</tr>
<tr>
<td>Class IIIa</td>
<td>Levels of laser radiation are considered to be, depending on the irradiance, either an acute intrabeam viewing hazard or chronic viewing hazard. Levels of laser radiation are considered to be an acute viewing hazard if viewed directly with optical instruments.</td>
</tr>
<tr>
<td>Class IIIb</td>
<td>Levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct radiation.</td>
</tr>
<tr>
<td>Class IV</td>
<td>Levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct and diffuse radiation.</td>
</tr>
</tbody>
</table>

FDA performance requirements according to laser classifications

<table>
<thead>
<tr>
<th>Class</th>
<th>I</th>
<th>II</th>
<th>IIIa</th>
<th>IIIb</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protective housing</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Safety interlock*1</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Remote interlock connector</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Key control</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Location of control</td>
<td>—</td>
<td>—</td>
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<td>—</td>
<td>—</td>
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<tr>
<td>Laser radiation emission indicator</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>—</td>
</tr>
<tr>
<td>Beam attenuator</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Scanning safeguard*2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Manual reset mechanism</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Identification label</td>
<td>—</td>
<td>—</td>
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<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Certification label</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Warning label</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Aperture label</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Protective housing label*3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

*1. A safety interlock is not necessary if the protective housing cannot be detached or moved.
*2. The scanning safeguard is required regardless of class if the product incorporates a laser scanning system.
*3. A label is required on every portion of the protective housing that can be removed or displaced if a laser greater than Class I can be emitted when the portion is moved.
GLOSSARY

**Resolution**
Even when detecting a stationary target, analog output voltage fluctuates slightly due to internal noise. The amount of fluctuation is called resolution; the smaller the fluctuation, the better or higher, the resolution.
Example: 0.1 % FS
The minimum readable measurement is 1/1000 of the measurement range. In digital signal processing, the resolution refers to the minimum reading of the measurement, or the minimum indication unit.

**Linearity**
Analog voltage output from a displacement sensor increases in proportion to the distance. The relationship of analog output voltage to distance is ideally represented by a straight line. However, actual measurements deviate from this line. Linearity is the tolerance range in relation to the ideal line, and is indicated as a percentage of full scale. Measurements obtained by digital signal processing are slightly different from actual displacement. In this case, linearity refers to the ratio of this difference to the measurement range.

**Temperature characteristics**
The analog output voltage changes with ambient temperature. This fluctuation range is called temperature drift and is expressed as the change in the level of analog output for each 1 °C of temperature change.
Example: ±0.1 % FS/°C (FS = full scale = 4 V in this example)
This means that the analog output voltage changes by ±4 mV per degree centigrade.

**Repeatability**
Variation in measurements taken with a sensor mounted in the same environment without changing the detection conditions.

**Moving accuracy**
Measurement variation when the target object is moved a fixed amount from the reference position.

PRECAUTIONS FOR USE

Laser sensors are a commonly used type of non-contact sensor, but to ensure proper and trouble-free operation, it is necessary to bear in mind the unique characteristics of laser sensors. When using laser sensors, please take the following information into consideration.

### Classification of our main laser sensor products

<table>
<thead>
<tr>
<th>Detection type</th>
<th>Application</th>
<th>Judgment type</th>
<th>Output</th>
<th>Applicable model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retroreflective</td>
<td>Target detection</td>
<td>Light level difference</td>
<td>ON/OFF</td>
<td>HLA-C250DN</td>
</tr>
<tr>
<td>Retroreflective</td>
<td>Target detection</td>
<td>Distance</td>
<td>ON/OFF</td>
<td>HLA-D300DN etc.</td>
</tr>
<tr>
<td>Retroreflective</td>
<td>Displacement measurement</td>
<td>Distance</td>
<td>Analog output</td>
<td>HLA-D130A etc.</td>
</tr>
<tr>
<td>Thru-scan</td>
<td>Displacement measurement</td>
<td>Position of shadow</td>
<td>Analog output</td>
<td>Comm. output</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PBZ series</td>
<td></td>
</tr>
</tbody>
</table>

### Optical system of retroreflective laser sensors
The optical system of retroreflective laser sensors and displacement sensors can be roughly divided into the diffuse reflection and specular reflection types. Most Azbil laser sensors are the diffuse reflection type.

**Diffuse reflection type**
The sensor emits a laser beam perpendicular to a target object and receives a scattered reflection of the light components from the target object. This type is not suitable for the detection and measurement of highly reflective (specular) objects.

**Specular reflection type**
The sensor receives a reflection of light components from the target object by specular reflection. This type is suitable for the detection and measurement of metal and other specular objects, but not for long-distance measurement.

### Principle of edge measurement in PBZ series sensors
PBZ sensors make use of Fresnel diffraction and an algorithm called the FDN algorithm. Light is diffracted by the edge of a thin object like a knife or film. The intensity distribution of the diffracted light at the receiver depends on the distance (Z) between the target object and the receiver. This principle is applied to enable high-accuracy measurement of the edge position of target objects.

**What is the FDN algorithm?**

**Fresnel diffraction**
Light is diffracted by the edge of a thin object like a knife or film. The intensity distribution of diffracted light at the receiver depends on the working distance, which is the distance between the target object and the receiver.
PRECAUTIONS FOR USE OF PBZ SENSORS

1 Installation precautions

Installing the sensor head

- Do not use the sensor outdoors.
- Avoid installing the sensor where it will be exposed to strong vibration or shock.
- Avoid using the sensor in an atmosphere of corrosive or flammable gas.
- Avoid using the sensor in a steamy or dusty place.
- Do not expose the sensor to thinner, other organic solvents, water, oil, or grease.
- Install a hood so that the receiving surface of the sensor head is not exposed to light with a wavelength near 670 nm or to sunlight.
- Keep the sensor head emitting and receiving surfaces free from water, oil, fingerprints, and other things that bend light, and also free from dust, dirt and other material that blocks or scatters light.
- If there is foreign matter on the emitting or receiving surface, stop emission of the laser beam and wipe the surface with a soft lint-free cloth.

Installation method

- Install the sensor head so that the emitting and receiving surfaces are parallel to each other. Align their optical axes.

Installing the controller

Installation site

Install the controller according to the instructions below.
- Mount the controller in a panel.
- Do not install the controller in a place subject to high or low temperature or humidity.
- Do not install the controller where gas containing sulfur or other corrosive gases are present.
- Do not install the controller where there is a large amount of dust or oily smoke.
- Install the controller where it is protected from direct sunlight, wind, and rain.

PRECAUTIONS FOR USE OF HLA AND HLB SERIES SENSORS

1 Installation precautions

Target object direction of motion and sensor orientation

Measurement error can be reduced if the same mounting orientation is used, even if the color of the target objects changes greatly.
2 Reflection from surrounding objects

Incorrect measurements or false detection may occur due to light reflected from surrounding objects. Install the sensor away from such objects or in the orientation shown above. To reduce reflection, dull the surface of surrounding objects or paint them to give them a matte surface.

3 Sensing through a narrow gap

Install the sensor so that light is not reflected from an inner wall, etc.

If the target is a rotating object

If the target object has a difference in level

4 Wiring precautions

- Be sure to turn the power off before installation.
- If the wiring for the photoelectric sensor is run through the same conduit as high-voltage or power lines, induction may cause malfunction or damage. Route the wiring in a different conduit or its own conduit.
- When using an off-the-shelf switching regulator, ground the frame ground and the ground terminals. Otherwise, switching noise may cause malfunction.
- If a load, such as a capacitive load or incandescent lamp, is connected which causes an inrush current exceeding the switching capacity, connect a current-limiting resistor between the load and the output terminal. Otherwise, the output short-circuit protection may be activated.

5 Handling precautions

Cautions on installation

- Do not install the sensor where there is strong vibration or shock. Vibration or shock may cause misalignment of the optical axis.
- Install a shielding plate or the like to protect the lens from water and oil. Liquid on the lens may cause malfunction.
- When installing the sensor outdoors, put it in a case so that it is not directly exposed to sunlight and rainwater.
- Since the end of the cable outside the protective structure, be sure not to allow water to enter the cable from the end.

- If the sensor is used in a location where there is strong ambient light, block the light with a hood, or change the installation orientation of the sensor and then check that the sensor functions correctly.
- If the sensor is used in a dusty environment, enclose it in a sealed case and use an air purge to keep the lens free of dust.
- Laser sensors are assembled with high precision. Do not strike an object against a laser sensor. Be especially careful with the lens, as its characteristics will deteriorate if it is scratched or cracked.

Precautions for operation

- It takes about 75 ms (HLA) or 500 ms (HLB) for operation to stabilize after the power is turned on.
- If multiple sensors are used in close proximity to each other, they may not operate reliably. After installation, be sure to check sensor operation sufficiently before use.
- The laser sensor may malfunction if there is a shiny metal surface nearby. Give nearby metal a matte surface by dulling or painting.

Maintenance precautions

- If the lens is dirty, wipe it with a soft, dry, clean cloth. If the lens is very dirty, moisten the cloth with pure alcohol.

Laser beams

- Do not stare into the laser beam. Avoid specular reflection radiation entering the eyes. Never point a laser beam towards someone’s eye.
- Shield the laser beam to prevent radiation from reaching the human body.
- For safety, terminate the beam path by a diffusing or absorbing object with appropriate reflectivity and thermal characteristics.
- A label like that shown is affixed to laser products. Follow the instructions on the label.

- If the warning label on the installed sensor is not visible, affix the included warning label on a visible part of the sensor before use.