Laser Safety
Australian Standards

Laser Classification

There are three important Australian standards applicable to lasers: AS/NZS 2211.1:2004: Safety of laser products, AS 2397: Safe use of lasers in the building and construction industry and AS/NZS 4173: Guide to the safe use of lasers in health care. These divide lasers into 7 classes which correlate to their hazard potential. The classes are: 1, 1M, 2, 2M, 3R, 3B, and 4. Class 1 being the least hazardous and Class 4 the most hazardous. Details of the classification system and emission limits for each class are given in the main standard (AS/NZS 2211.1).
### The Laser Classification System

<table>
<thead>
<tr>
<th>Approx. Power Limits for CW Visible Wave-lengths Only</th>
<th>Class 1</th>
<th>Class 1M</th>
<th>Class 2</th>
<th>Class 2M</th>
<th>Class 3R</th>
<th>Class 3B</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>220µW to 0.4µW</td>
<td>Class 1</td>
<td>Safe with no viewing aids</td>
<td>Safe with (0.25 s.) blink reflex including viewing aids</td>
<td>Safe with (0.25 s.) blink reflex no viewing aids</td>
<td>Hazardous if the eye is exposed directly, but diffuse reflections are not harmful. Generally safe for skin</td>
<td>Unsafe for eyes Unsafe for skin</td>
<td></td>
</tr>
<tr>
<td>0.5mW</td>
<td>Class 1M</td>
<td>Safe with no viewing aids</td>
<td>Safe with (0.25 s.) blink reflex including viewing aids</td>
<td>Safe with (0.25 s.) blink reflex no viewing aids</td>
<td>Hazardous if the eye is exposed directly, but diffuse reflections are not harmful. Generally safe for skin</td>
<td>Unsafe for eyes Unsafe for skin</td>
<td></td>
</tr>
<tr>
<td>1mW</td>
<td>Class 2</td>
<td>Safe with (0.25 s.) blink reflex including viewing aids</td>
<td>Safe with (0.25 s.) blink reflex including viewing aids</td>
<td>Safe with (0.25 s.) blink reflex no viewing aids</td>
<td>Hazardous if the eye is exposed directly, but diffuse reflections are not harmful. Generally safe for skin</td>
<td>Unsafe for eyes Unsafe for skin</td>
<td></td>
</tr>
<tr>
<td>0.5W</td>
<td>Class 2M</td>
<td>Safe with (0.25 s.) blink reflex no viewing aids</td>
<td>Safe with (0.25 s.) blink reflex including viewing aids</td>
<td>Safe with (0.25 s.) blink reflex no viewing aids</td>
<td>Hazardous if the eye is exposed directly, but diffuse reflections are not harmful. Generally safe for skin</td>
<td>Unsafe for eyes Unsafe for skin</td>
<td></td>
</tr>
<tr>
<td>5mW</td>
<td>Class 3R</td>
<td>Safe with (0.25 s.) blink reflex no viewing aids</td>
<td>Safe with (0.25 s.) blink reflex including viewing aids</td>
<td>Safe with (0.25 s.) blink reflex no viewing aids</td>
<td>Hazardous if the eye is exposed directly, but diffuse reflections are not harmful. Generally safe for skin</td>
<td>Unsafe for eyes Unsafe for skin</td>
<td></td>
</tr>
<tr>
<td>0.5W</td>
<td>Class 3B</td>
<td>Hazardous if the eye is exposed directly, but diffuse reflections are not harmful. Generally safe for skin</td>
<td>Hazardous if the eye is exposed directly, but diffuse reflections are not harmful. Generally safe for skin</td>
<td>Hazardous if the eye is exposed directly, but diffuse reflections are not harmful. Generally safe for skin</td>
<td>Hazardous if the eye is exposed directly, but diffuse reflections are not harmful. Generally safe for skin</td>
<td>Unsafe for eyes Unsafe for skin</td>
<td></td>
</tr>
<tr>
<td>0.5W</td>
<td>Class 4</td>
<td>Unsafe for eyes Unsafe for skin</td>
<td>Unsafe for eyes Unsafe for skin</td>
<td>Unsafe for eyes Unsafe for skin</td>
<td>Unsafe for eyes Unsafe for skin</td>
<td>Unsafe for eyes Unsafe for skin</td>
<td></td>
</tr>
</tbody>
</table>
The eye

- **Cornea** is curved front surface of eye: Does most of the focusing
- **Iris** opens to control light intensity reaching retina
- **Lens** is adjustable by the ciliary muscle to focus near or far objects to the retina
- **Retina** contains sensory cells
  - **Rods** are more common on the edge of the retina. Are more sensitive to low intensity light, respond to motion
  - **Cones** are colour sensitive. 3 types, are present closer to centre of retina (fovea, best visual activity)
Why Lasers Are Hazardous

2 Main Factors.

- **Collimation Effects**: More light can be introduced into the eyes compared to other light sources.
- **Spot Size Effects**: Radiation in the 400 – 1400nm region is brought to a sharp focus on the retina. This can increase the radiant exposure (irradiance) by approx 100,000 times.

Spatial coherence!
To Determine the Laser Hazard

6 main factors need to be taken Consideration.

- Wavelength
- CW or Pulsed Operation
- Power or Pulse Energy
- Repetition Rate (PRF)
- Beam Diameter & Profile
- Beam Divergence
Laser Effects on Eyes and Skin

<table>
<thead>
<tr>
<th>CIE ID</th>
<th>uv-C</th>
<th>uv-B</th>
<th>uv-A</th>
<th>Visible</th>
<th>IR-A</th>
<th>IR-B</th>
<th>IR-C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>230</td>
<td>315</td>
<td>400</td>
<td>760</td>
<td>1400</td>
<td>3000</td>
</tr>
</tbody>
</table>

**Adverse Effects**
- Photokernatitis
- Cataract
- Erythema
- Retinal Burns
- Corneal Burns
- Cataracts
- Color vision
- Night vision
- Degradation

**Skin Penetration Of Radiation (Depth)**

**Wavelength range** | **pathological effect**
--- | ---
180–315 nm (UV-B, UV-C) | photokeratitis (inflammation of the cornea, equivalent to sunburn)
315–400 nm (UV-A) | photochemical cataract (clouding of the eye lens)
400–780 nm (visible) | photochemical damage to the retina, retinal burn
780–1400 nm (near-IR) | cataract, retinal burn
1.4–3.0μm (IR) | aqueous flare (protein in the aqueous humour), cataract, corneal burn
3.0 μm–1 mm | corneal burn
Maximum Permissible Exposure - cw

![Graph showing MPE (W/cm²) vs Exposure time (s) for different wavelengths. ](image)

- Cornea
Maximum Permissible Exposure - pulsed

Pulse duration

- 2.9-10 μm
- 355 nm
- 266 nm
- 1064 nm
- 800 nm
- 400-700 nm

MPE (J/cm²)

1e-12, 1e-10, 1e-08, 1e-06, 1e-04, 0.01, 1
Lasers Safety Precautions

Class 1 & 1M Lasers:
- No Precautions

Class 2 & 2M Lasers:
- No Staring

Class 3R Lasers:
- No Staring
- No Magnifiers

(Also old Class 3A lasers)
Lasers Safety Precautions

Class 3B &
Class 4 Lasers:

- Avoid Exposure
- Controlled Area
- Use Beam Stops
- Diffuse Reflections Hazardous
- Use Eye Protection
- Interlocks Required
- Chemical / Electrical hazards
Optical – Laser Labs

- A labyrinth style entryway into labs, giving a safe area to put on safety equipment (PPE).
- A storage rack for laser safety eyewear (labeled with wavelengths etc).
Choose the right safety glasses for your laser!

**e.g. OD 7:**

Transmission = $10^{-7}$
European norm (DIN EN 207)

<table>
<thead>
<tr>
<th>Schutzstufe</th>
<th>Maximaler spektraler Transmissionsgrad bei den Laserwellenlängen</th>
<th>Maximale Leistungs- (E) und/oder Energiedichte (H) im Wellenlängenbereich</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale</td>
<td>Maximum spectral transmittance for laser wavelength</td>
<td>Maximum power (E) and energy (H) density in the wavelength range</td>
</tr>
<tr>
<td>number</td>
<td></td>
<td>For test condition / Impulsdauer in s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Impulsdauer in s</td>
</tr>
<tr>
<td>L1</td>
<td>$10^{-1}$</td>
<td>E_D W/m²: 0,01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H_{IL, R} J/m²: 3 \cdot 10^{2}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E_M W/m²: 3 \cdot 10^{11}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D &gt; 3 \cdot 10^4</td>
</tr>
<tr>
<td>L2</td>
<td>$10^{-2}$</td>
<td>I_R 10^{-9} bis 3 \cdot 10^{4}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M &lt; 10^{-9}</td>
</tr>
<tr>
<td>L3</td>
<td>$10^{-3}$</td>
<td>M &lt; 10^{-9}</td>
</tr>
<tr>
<td>L4</td>
<td>$10^{-4}$</td>
<td>D &lt; 5 \cdot 10^{4}</td>
</tr>
<tr>
<td>L5</td>
<td>$10^{-5}$</td>
<td>I_R 10^{-9} bis 5 \cdot 10^{4}</td>
</tr>
<tr>
<td>L6</td>
<td>$10^{-6}$</td>
<td>M &lt; 10^{-9}</td>
</tr>
<tr>
<td>L7</td>
<td>$10^{-7}$</td>
<td>D &gt; 0,1</td>
</tr>
<tr>
<td>L8</td>
<td>$10^{-8}$</td>
<td>I_R 10^{-9} bis 0,1</td>
</tr>
<tr>
<td>L9</td>
<td>$10^{-9}$</td>
<td>M &lt; 10^{-9}</td>
</tr>
<tr>
<td>L10</td>
<td>$10^{-10}$</td>
<td>E_D W/m²: 10^{2}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H_{IL, R} J/m²: 1,5 \cdot 10^{3}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E_M W/m²: 10^{3}</td>
</tr>
</tbody>
</table>

For test condition / Impulsdauer in s:
Optical – Research Lasers

- Research Lasers
- Multiple wavelengths – selection of laser eyewear
- No aperture Stickers
Other Lab Hazards - Combinations

- High Voltages and Water – Electric shock.