European Laser Safety: Laser Emitters and Flight Safety

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European Laser Safety: Laser Emitters and Flight Safety

• Classes of lasers.
• Laser bioeffects and hazards.
• Laser hazard evaluation.
  • Maximum Permissible Exposure (MPE).
  • Nominal Ocular Hazard Distance (NOHD).
• Lasers and flight safety.
Classes of Lasers

• Class 1: No risk to eyes.

• Class 2: No risk to eyes for short time exposure.

• Class 3: Medium to high risk to eyes, low risk to skin.

• Class 4: High risk to eyes and skin.
Class 4 lasers

- Appoint a Laser Safety Officer (person responsible).
- Undertake a risk assessment.
- Ensure that users act responsibility, and are adequately aware and appropriately trained.
- Establish a system of key security.
- Use in an interlock-protected enclosed controlled area.
- Use an interlock connector and beam attenuator as necessary.
- Keep open beam paths to a minimum, using guards, screens, etc.
- Use appropriate eye protection.
- Follow the manufacturer’s instructions.
- Develop and use adequate procedural control measures.

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Biological tissue damage mechanism

• Photochemical damage: occurs when the energy of an incoming photon is high enough to break existing chemical bonds within individual molecules (cataracts, macular degeneration…).

• Thermal damage: when organic molecule absorbs a photon, this additionally new energy drives the molecule into several types of unstable excited states. The heat can damage surrounding proteins and other tissues (retinal lesions much larger than expected).

• Acoustico-mechanical damage: occurs as a consequence of high energy, short-duration exposures. Ultra-fast elevations of tissue temperature generate bubbles in the tissue. Aera affected 220 times larger than the thermal damage.
Maximum Permissible Exposure (MPE)

• MPE represents the maximum level to which a person can safely be exposed without incurring biological damage.

• MPE values are determined from biological studies:
  • the skin: 1 J/cm²
  • the eyes: 50 µJ/cm²
### MPE table

<table>
<thead>
<tr>
<th>Exposure time t in s</th>
<th>10^{-13} to 10^{-11}</th>
<th>10^{-11} to 10^{-9}</th>
<th>10^{-9} to 10^{-7}</th>
<th>10^{-7} to 10^{-5}</th>
<th>10^{-5} to 10^{-3}</th>
<th>10^{-3} to 10^{-1}</th>
<th>10^{-1} to 10^{1}</th>
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- \( C_3 \) J m\(^{-2} \)
- \( C_3 \) W m\(^{-2} \)
- mrad

Retinal photochemical hazard:
- \( \gamma_p = 11 \) mrad
- \( \gamma_p = 1,1 \times 10^2 \) mrad
- \( \gamma_p = 110 \) mrad

Retinal thermal hazard:
- \( \alpha \leq 1,5 \) mrad: \( 10 \) W m\(^{-2} \)
- \( \alpha > 1,5 \) mrad: \( 18 \) C\(_4\) C\(_7\) T\(_2\) \( \times 10^{-2} \) W m\(^{-2} \)

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MPE: 50mJ, 100ps, single pulse

- ANSI Z136.1-2000 (Table 5a):
  - 100ps: \( \text{MPE} = 2.7 \ t^{0.75} \ J / \text{cm}^2 \)

- \( \text{MPE}_{100\text{ps}} = 2.7 \ (100 \times 10^{-12})^{0.75} = 0.1 \ \mu J / \text{cm}^2 \)
Nominal Ocular Hazard Distance

• NOHD is the distance, line of sight, from the emitting source beyond which an eye-safe laser hazard exists.

\[
NOHD = \frac{1}{\theta} \sqrt{\frac{4Q}{\pi \cdot MPE} - d^2} \quad \text{cm}
\]

- \( Q = \) Pulse energy in Joule \( 0.06 \) J at 532 nm
- \( \theta = \) Beam Divergence in radian \( 1 \) arcsec
- \( d = \) Output beam diameter in cm \( 154 \) cm

• NOHD = 1 800 km
Protected flight zones

Elevation

Laser-beam sensitive flight zone
100 $\mu$W/cm$^2$

Laser-beam critical flight zone
5 $\mu$W/cm$^2$

Laser-beam free flight zone
50 nW/cm$^2$

To be determined by local aerodrome operations

Aerodrome reference point
AGL is based on published aerodrome elevation
Air Space restrictions

- Laser beam free flight zone (LFFZ): \( 50\text{nW/cm}^2 \)
- Laser beam critical flight zone (LCFZ): \( 5\mu\text{W/cm}^2 \)
- Laser beam sensitive flight zone (LSFZ): \( 100\mu\text{W/cm}^2 \)
- Normal flight zone (NFZ): equal or less than MPE
Laser beam bioeffects and air operations

- Distraction: natural reaction is to look at it.
- Glare: temporary disruptions in visual acquisition.
- Flash-blindness: interference effect that persists after the light is terminated.
- After-images: light dark or colored spots following the exposure.
- Scotomas: after-effect which is either temporary or permanent.
- Retinal burns: significant and permanent damage.
- Retinal haemorrhages: blood vessel disrupted somewhere in the eye.
- Globe rupture: tear in the tissue.
- Other: mechanical trauma to the cornea and conjunctiva.
Manuals, and Standards

- NF EN 60825: Security of laser products, Association Française de Normalisation (AFNOR), European Norm.
- Laser Safety: Roy Henderson (Bioptica, Cambridge, UK) and Karl Schulmeister (ARC Seibersdorf Research, Austria).

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Safety

• **Active safety:**
  – Radars.
  – ADSB transponder: Commercial flights.
  – FLARM transponder: Private flights.
  – Infrared camera: Hot objects.
  – Visible camera: Recognition of objects.

• **Passive safety:**
  – Free aircraft zone in a cone at the vertical of the station.
Conclusion

• If in the past you had the excuse not to, or would not want to, know the risks that you should incur or you should make to someone (even for birds!), it is no longer the case!

• So use all your skills and ingenuity to avoid hazards.

• With one eye, it will be difficult for you to appreciate distances…