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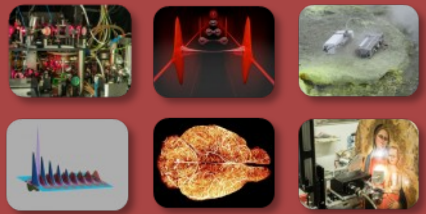

ALLIES of LIGHT

Briefly on Laser Safety

Daniele Palla

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Summary

➔**Laser and Laser Classes**

➔**Biological Laser Effects**

➔**Protective Equipments**

Laser and Laser Classes

Definitions (from the safety regulations point of view):

- **Optical Radiation**: EM radiation with **$100\text{ nm}<\lambda<1\text{ mm}$**. We can further divide into UV (**$100\text{ nm}<\lambda<400\text{ nm}$),** Visible (**$380\text{ nm}<\lambda<780\text{ mm}$)** and IR (**$780\text{ nm}<\lambda<1\text{ mm}$)**. To specify a narrower wavelength range, sub-definitions such as UVA, UVB, UVC, IRA, IRB and IRC are also used..

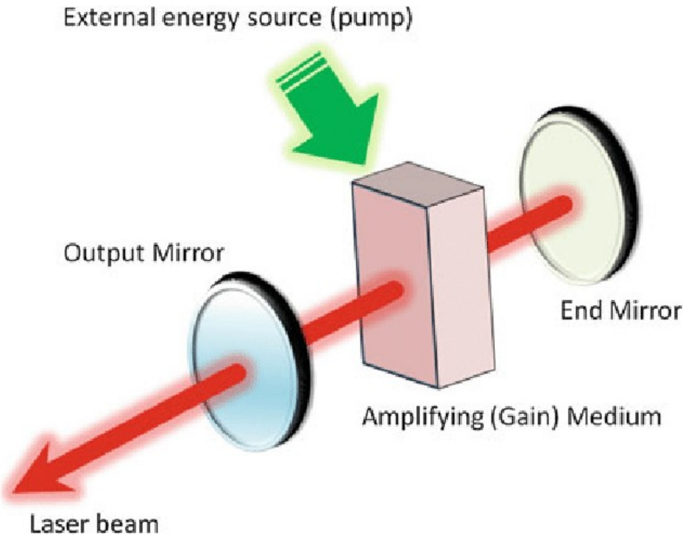
- **Laser**: Any device that can be made to produce or amplify electromagnetic radiation in the optical wavelength range, especially by the process of controlled stimulated emission

- **Laser Radiation**: Optical radiation produced by a laser

- **Non-Coherent Radiation**: Any optical radiation other than laser radiation

Laser and Laser Classes

A laser consists of a **system that supplies energy** (lamps, electrical discharge, chemical reaction, another laser), a **system that transforms this energy into optical radiation** (active medium) and a system that "manages" this optical radiation (cavities, modulators, mirrors, ...). In general, **laser safety concerns not only the output** beam but the entire laser, including the "related risks" of pumping, leaks, high voltage or heat.

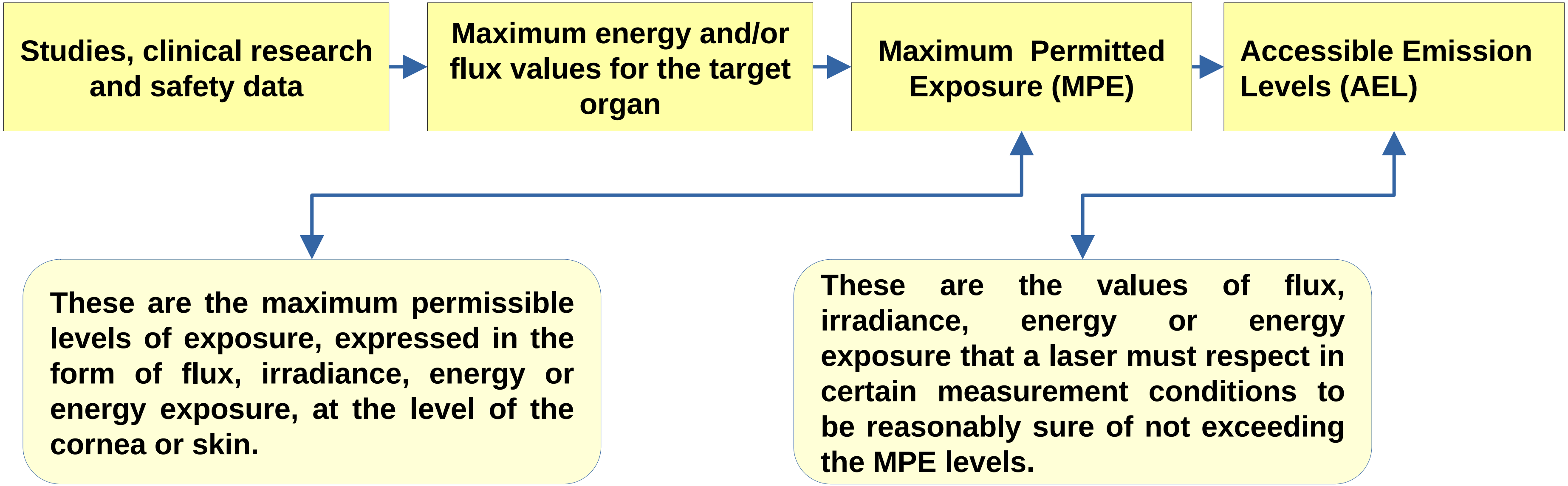


Main Quantities Associated to Laser Radiation:

- Radiometric Quantities: **Energy** (J), **Radiant Flux** (W), **Radiant Exposure** (J/m^2), **Irradiance** (W/m^2) and **Wavelength** (nm)
- Geometrical Quantities: A light source is defined by its geometry, that is, by the structure it has, and by its mode of emission. Mainly, a source can be: **point-like**, **extended**, **continuous**, **pulsed** etc.

Laser and Laser Classes

Fundamental Safety Diagram



Laser and Laser Classes

Depending on the AEL (Accessible Emission Level), laser safety classes are established. Each laser system (including any optics that modify the beam) must be assigned to a safety class. Laser classes do not identify the risk but, above all, the **type of risk**. There are 8 laser classes: **1**, **1M**, **1C**, **2**, **2M**, **3R**, **3B** and **4**.

AEL evaluation parameters

- **Beam diameter:** For wavelengths reaching the retina (400-1400 nm), the diameter of the beam is limited by the size of the pupil, i.e. a diameter of 7 mm.

- **Wavelength:** Different wavelengths have different target organs. The most dangerous wavelengths are between 800 and 1400 nm, because the radiation reaches the retina, but since it is invisible there can be no palpebral reflex

- **Beam divergence and Acceptance angle:** Less divergent beam means having a smaller virtual object. A smaller object, real or virtual, leads to a smaller spot size on the retina, and is therefore potentially more dangerous.

- **Power:** At fixed parameters laser classes scales with power.

- **Exposure time (time base)** The time base indicates the maximum time that an observer's eye points at the beam or the skin is exposed to the radiation. Therefore, the exposure time t considered for safety purposes is limited by the time base

Laser and Laser Classes

Table 8 – Accessible emission limits for Class 3B laser products [a]

Wavelength λ nm	Emission duration t s		
	<10^{-9}	10^{-9} to 0,25	0,25 to 3×10^4
180 to 302,5	$3,8 \times 10^5$ W	$3,8 \times 10^{-4}$ J	$1,5 \times 10^{-3}$ W
302,5 to 315	$1,25 \times 10^4$ C_2 W	$1,25 \times 10^{-5}$ C_2 J	5×10^{-5} C_2 W
315 to 400	$1,25 \times 10^8$ W	0,125 J	0,5 W
400 to 700	3×10^7 W	0,03 J for t < 0,06 s 0,5 W for $t \geq$ 0,06 s	0,5 W
700 to 1 050	3×10^7 C_4 W	0,03 C_4 J for t < 0,06 C_4 s 0,5 W for $t \geq$ 0,06 C_4 s	0,5 W
1 050 to 1 400	$1,5 \times 10^8$ W	0,15 J	0,5 W
1 400 to 10^6	$1,25 \times 10^8$ W	0,125 J	0,5 W

[a] For correction factors and units, see Table 9.

Laser and Laser Classes

- **Class 1** lasers are **non-hazardous under all conditions of use**. They can be used in places open to the public without supervision or special measures. **Class 1M** is characterized by **302.5 nm<λ<4000 nm**, and is not dangerous if its beam is not observed with optical instruments. **Class 1C** lasers are class 1 lasers whose intended use is in contact with the target. This class is essentially limited to medical lasers.

- **Class 2** lasers are **non-hazardous thanks to the palpebral reflex**, and therefore this class is reserved for lasers that emit only in the visible range (400-700 nm). **Class 2M** lasers are like Class 2 lasers, but their beam must not be observed using optical instruments.

- **Class 3R** lasers are lasers that exceed safety limits, but whose risk of actually causing **eye damage in the event of accidental viewing is quite low**. **Class 3B** lasers are lasers that exceed safety limits to a greater extent than class 3R lasers. They are actually **dangerous if the beam is accidentally viewed**, i.e. there is a significant probability that they could cause eye damage. **Diffuse reflections or skin exposure are not dangerous**.

- **Cass 4** lasers **<u>are dangerous in all conditions of use</u>**, even for the skin and for diffuse reflection. Furthermore, their use involves risks of a non-optical nature (for example, fire risk). Class 4 is a **residual class**, that is, it includes lasers that do not fall into the other classes.

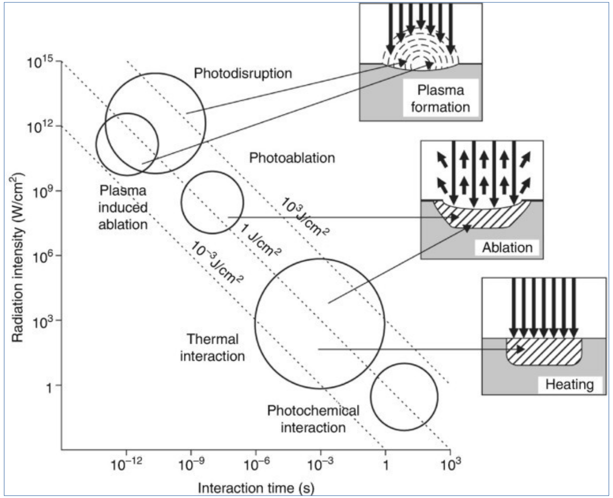
Biological laser Effects

Three main damaging mechanisms are distinguished deriving from the interaction between laser radiation and biological tissues. These are dependent on the **characteristics of the biological material**, the type of **wavelength** and the way in which it is released (**power**, **duration** of exposure, **size** of the impact area).

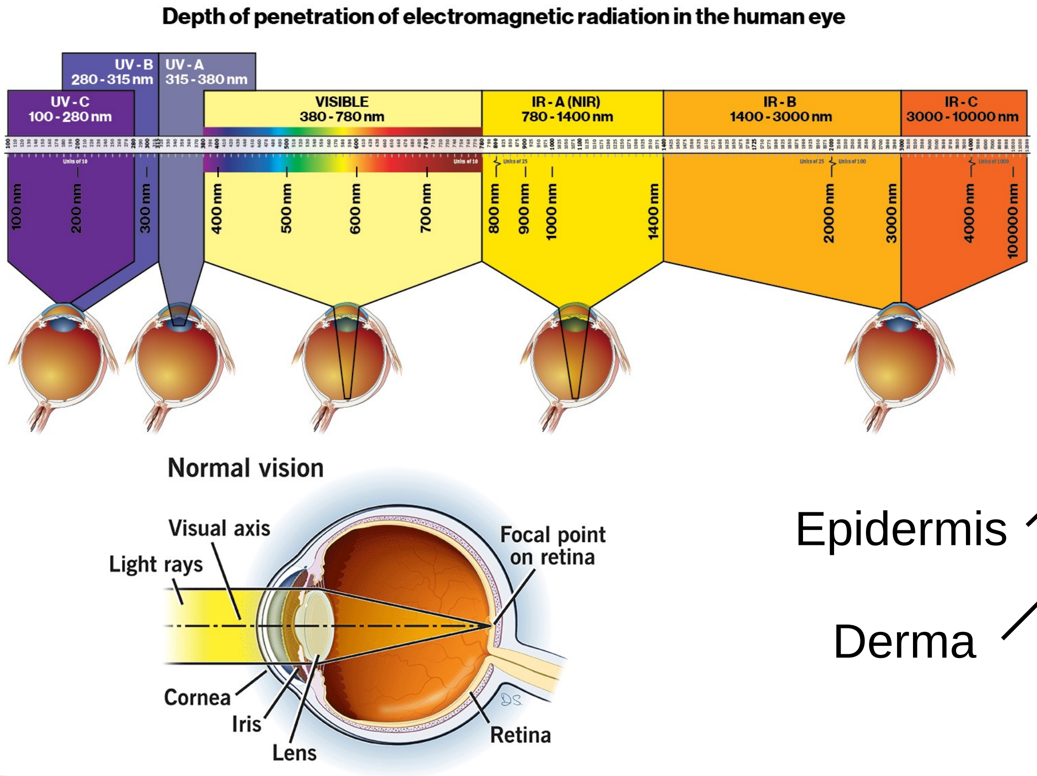
- **THERMAL EFFECT** or photocoagulative effect occurs with radiation with wavelengths in the visible, from **450 nm** to the near infrared **1064 nm**, and with exposure times ranging from **0.1 sec to 1-5 sec**. This process depends on the presence of **photoabsorbent** substances (first of all melanin) that must be present in the affected tissue

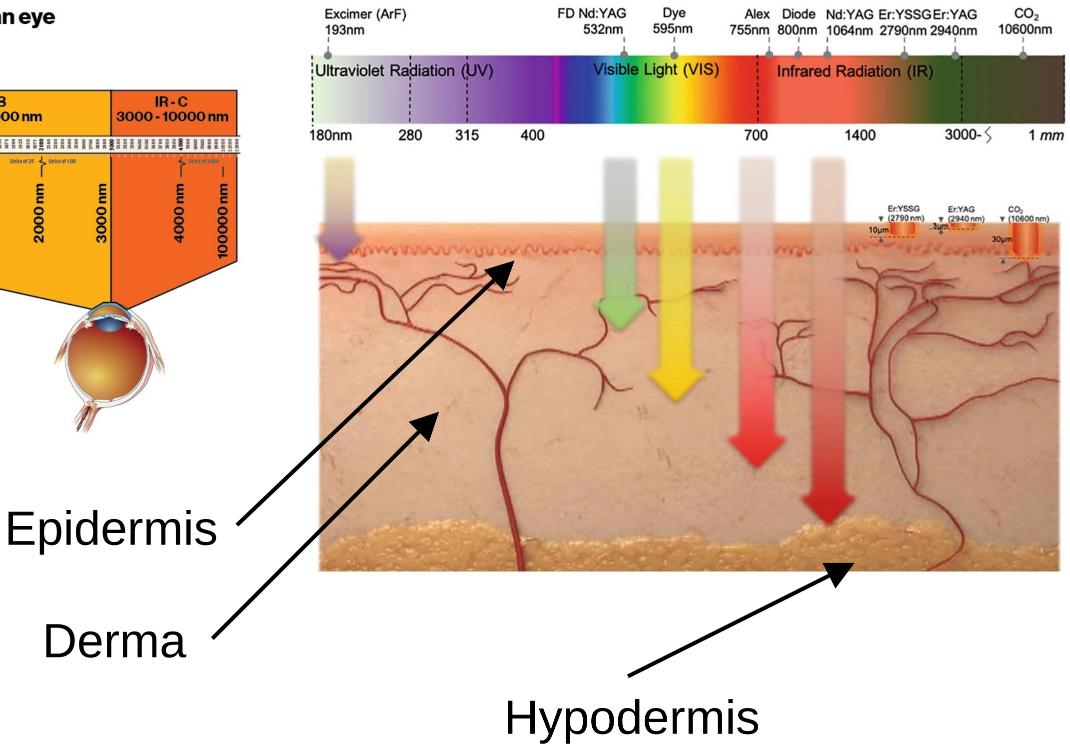
- **PHOTOCHEMICAL EFFECT** is a selective absorption which occurs with very long exposures **10 sec**. - **1-2 hours** and low power density. A photochemical effect (**photoablation**) also occurs with very short exposures and high power density when the single incident photons have enough energy to **break the molecular bonds** and expel fragments of molecules from the affected tissue at high speed. This effect is prevalent only for wavelengths lower than 400 nm (ultraviolet) or in the infrared

- **PHOTOMECHANICAL EFFECT** **Not dependent** on any photo-absorbing substance, is observed with ultra-rapid exposures (in the order of **pico** or **nano seconds**)



Biological laser Effects

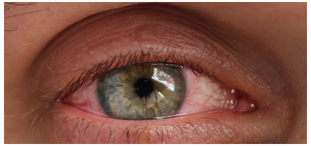




Biological laser Effects

λ (nm)	Eye	Skin
100–280 (**UVC**)	Photokeratitis, Photoconjunctivitis	Erythema, Skin cancer, Accelerated process of skin ageing
280–315 (**UVB**)	Photokeratitis, Photoconjunctivitis	Erythema, Skin cancer, Accelerated process of skin ageing
315–400 (**UVA**)	Photochemical cataracts	Photosensitivity reaction, Accelerated process of skin ageing
400–780 (**Visible**)	Photochemical and thermal injury to the retina	Photosensitivity reaction, Skin burn
780–1400 (**IRA**)	Cataracts and Retinal burn	Skin burn
1400–3000 (**IRB**)	Cataracts and corneal burn	Skin burn
3000–10^6 (**IRC**)	Corneal burn	Skin burn

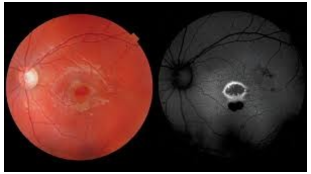
Photokeratitis



Photoconjunctivitis

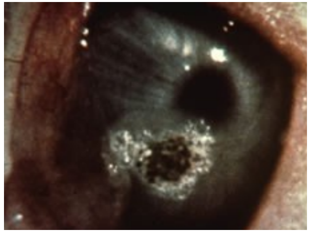
Erythema

Cataracts



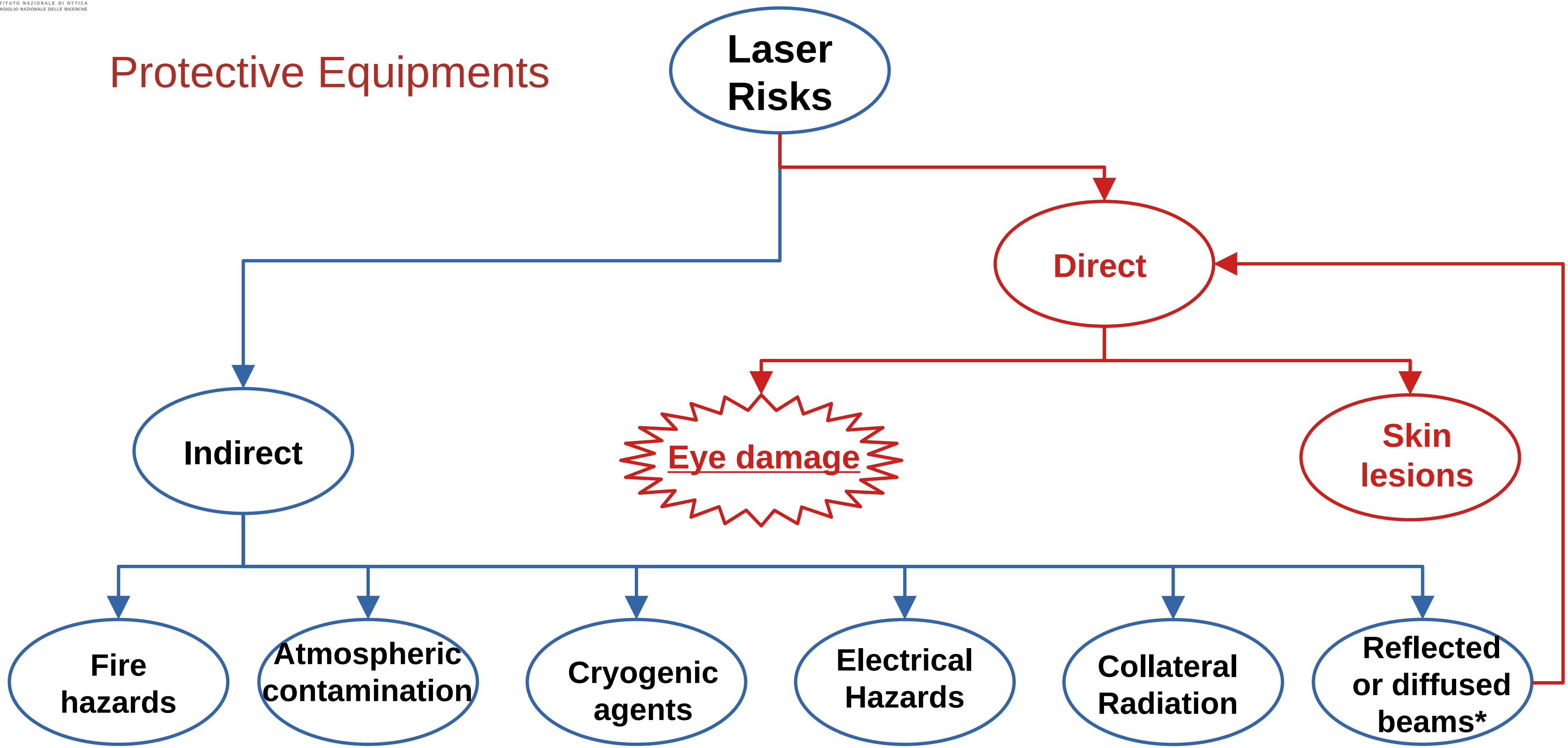
Retinal burn

Skin burn



Corneal burn

Protective Equipments



*Workbench components/portions, improper accessories, watches and jewelry

Protective Equipments

- **Definition:** **PPE** (Personal Protective Equipment) means any equipment intended to be worn and kept by the worker for the purpose of protecting him against one or more risks likely to threaten his safety or health during work, as well as any complement or accessory intended for this purpose.

- **Obbligations:** **PPE** **must be used** when risks cannot be avoided or sufficiently reduced by technical prevention measures, collective protection measures, work reorganisation measures, methods or procedures.

- **When:** In case of possible exceeding of the maximum permitted exposition **MPE**, protective glasses appropriately chosen for the source used must be worn. The PPE must be identified by the person in charge together with the Laser Safety Technician (**LST**).

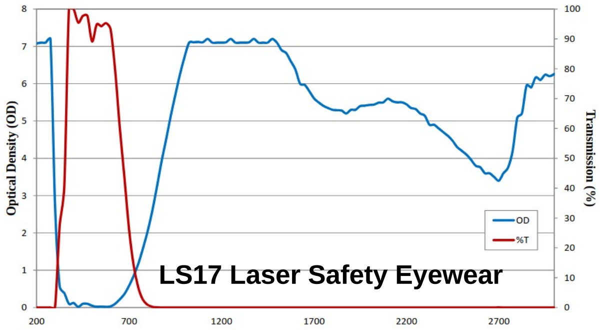
- **LST:** The Laser Safety Technician must take into consideration all aspects of the environment, the work activity, the equipment used, the personnel employed in order to suggest a series of measures aimed at reducing the risk. **It is up to the LST to decide which measures to adopt** (and take responsibility for them).

- **Examples of PPE:** The most important personal protective equipment are **GOGGLES** (for use or alignment), **lab coat**, **visor** and **gloves**.

Protective Equipments

- The European standard UNI **EN 207**:2017 applies to eye protectors used to **protect against accidental exposure to laser radiation** in the spectral range from 180 nm to 1000 µm

- The glasses defined by the **EN 208**:2010 standard are characterised by a **small attenuation in the visible spectral range**, they transmit a residual radiation of class 2 in order to be able to make adjustments.



D 620-700 LB5 + IR 700-1100 LB6 X

D: continuous **> 0.25 s**

I: Pulsed **> 1 µs–0.25 s**

R: Giant (Q-switch) **> 1 ns–1 µs**

M: Modelocked **< 1 ns**

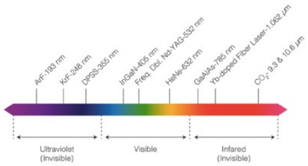
Wavelength range

Attenuation factor LBx (OD>x)

Identification or certification mark

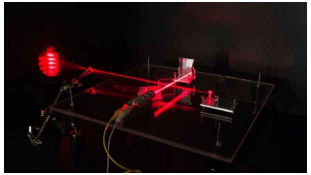
$$OD = \log_{10}\left(P_{inc}(\lambda)/P_{out}(\lambda)\right)$$

Most important Recommendations!

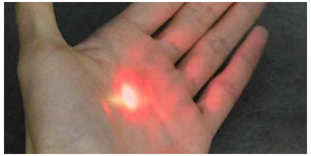


- Always be aware of the **class of laser you are using and its wavelength(s)**!

- Always **wear goggles** and **check** if they are the right ones!



- If you work on a laser line try to keep the **beam horizontal** at a height of **90-120 cm** from the ground. Don't lower your face to the laser!



- Remember that class 4 lasers can also **burn your skin**; wear a lab coat and gloves if you think you may interfere with the beam.

- Do not wear **rings, jewellery, or watches**. Keep your smartphone away from the beam.

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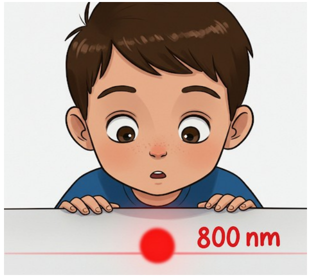
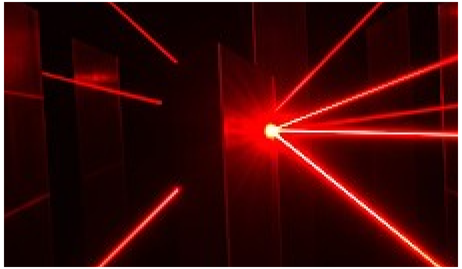
Further Recommendations!

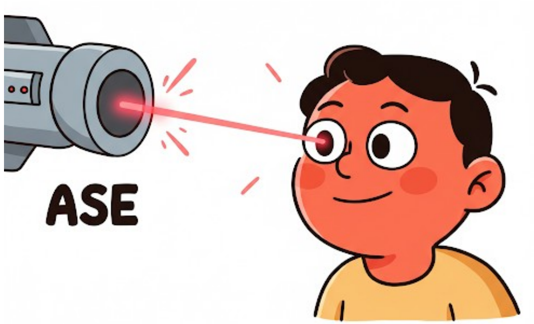
- You will work with a **class 4 laser beam at 800 nm**. The weak visual sensation easily leads to the belief that one can remove the glasses and observe directly the beam, leading to the opening of the pupil. This is the one of the most dangerous situation!

- Any secondary free beams (reflections and transmissions) must be properly **damped**.

- You may think that it is possible to observe the laser line when the laser is not operating. In certain conditions, ASE (Amplified Spontaneous Emission) may be present. This can be **extremely dangerous** in a class 4 laser.







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