GROUPE D'ÉTUDES
DE PRÉVENTION

Instructions for use by laboratory personnel

laser safety

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Pôle Maîtrise des Risques
Direction de la Protection et de la Sûreté Nucléaire

A symbol of new technologies, Laser tools are widely used in laboratories, industry and the medical and surgical fields.

While the use of Lasers is often synonymous with performance, being capable of improving working conditions in comparison with conventional methods and machines, their use always requires the user to take human and environmental safety into account starting at the design and installation phase.

This is called integrated safety.

This brochure aims to increase safety awareness among laser users through an understanding of **Laser hazards** and to minimise the risk of these hazards occurring by advising safe working practice.

Several decades of experience in the use of Lasers at research laboratories has demonstrated the importance of a 'collective' orientated approach to laser safety. This requires the appropriate behaviour of trained personnel and consequently laser safety instruction plays a pivotal role in providing a safe working culture.

Lasers are everywhere and, if used within an appropriate safety environment, provide a significant performance advantage with a minimum level of hazard to individuals.

The members of the "Laser safety" working group

Fields of Use of the Principal Lasers

Active Material	Use
Gases Helium – Neon Helium – Cadmium	Work-site use (alignment, plane definition, public works machinery guidance, telemetry, topography); metrology (machine settings, grading, error measurement, interferometry); assembly positioning (electronics); holography; encoded sign recognition; graphic printing.
Ionised gases (krypton, argon)	Telemetry; holography; spectroscopy; ophthalmo-dermatology; research; entertainment.
Carbon dioxide	Cutting various materials (metals, plastics, refractory alloys); soldering metals and plastics; heat treatment; surgery (odontology, ears; nose & throat, etc.).
Nitrogen	Photochemistry; research, graphic printing.
Excimers	Graphic printing; ophthalmology; dermatology.
Metal vapours	Phototherapy.
Solids	Metal vaporisation; resistance adjustment; annealing; ophthalmology.
Yag Doped Yag	Drilling and soldering (clockmaking, micro-mechanisms, electronics; engraving; surgery; research; treatment for tumours; spectrography).
Ruby	Holography for moving objects; telemetry.
	Microsurgery; vaporisation of metal coatings; drilling (diamond, ruby); soldering (fine wires).
optical parametric oscillator (OPO)	Research.
Semi-conductor lasers **Laser diodes**	Fibre telecommunications; compact disks.
	Pulse or phase-comparison telemetry. Automobile manufacturing.
Liquids Dyes	Spectroscopy; materials studies; dermatology.

Essential Features

Active Material	Wavelength in nm	Pulse duration	Energy, power
Gases Helium – Neon Helium – Cadmium	632, 800, 1500 and 3000 543, 594	continuous	0.1 to 100 mW
Ionised gases (krypton, argon)	350 to 800	continuous	0.1 W to 40 kW
Carbon dioxide	10600	continuous	1 W to 45 kW
Nitrogen	337	100 ns	1 mj to 100 mJ
Excimers	190 to 350	10 to 60 ns	1 mj to 500 mJ
Metal vapours	500 to 1500	20 ns	a few mJ
Solids Yag Doped Yag	264, 355, 532 940, 1064, 1320	30 ps to 25 ms and continuous	0.1 mJ to 100 J up to several hundred W
Ruby	694	30 ns to 500 ns	0.1 J to 10 J pulsed
optical parametric oscillator (OPO)	300 – 3000	pulsed	a few mJ to a few hundred mJ
Semi-conductor lasers Laser diodes	620 to 2000	continuous or pulsed	a few mW to a few W
Liquids Dyes	variable 350 to 1000	continuous or pulsed	a few mW to a few W

Laser Classification

Definition of laser categories

Class 1 ▶ No danger

Class 1M ▶ 302.5 nm ≤ wavelength ≤ 4 000 nm
Hazard if laser beam is used with optics

Class 2 ▶ 400 nm ≤ wavelength ≤ 700 nm (visible)
Do not intentionally keep the eye in the axis of the laser beam

Class 2M ▶ 400 nm ≤ wavelength ≤ 700 nm (visible)
Do not intentionally keep the eye in the axis of the laser beam
Do not look into the beam with an optical instrument.

Class 3R ▶ 302.5 nm ≤ wavelength ≤ 10^6 nm
Looking directly at the laser is potentially dangerous

Class 3B ▶ Looking directly at the laser is dangerous
Risk of skin lesions
Diffuse reflection without danger if the distance between the cornea and the screen (D) > 13 cm and if the exposure (t) < 10 s

Class 4 ▶ Eye and skin exposure is dangerous
(direct or diffuse beam)

Summary of the effects of the beam by laser classification

CLASSES	1	1M	2	2M	3R	3B	4
Eye: vision with optical assistance		X	*	X	XX	XX	XX
Eye: direct beam and mirrored reflections			*	*	*, X	XX	XX
Eye: diffuse reflections						+	XX
Skin						X	XX
Fire							O

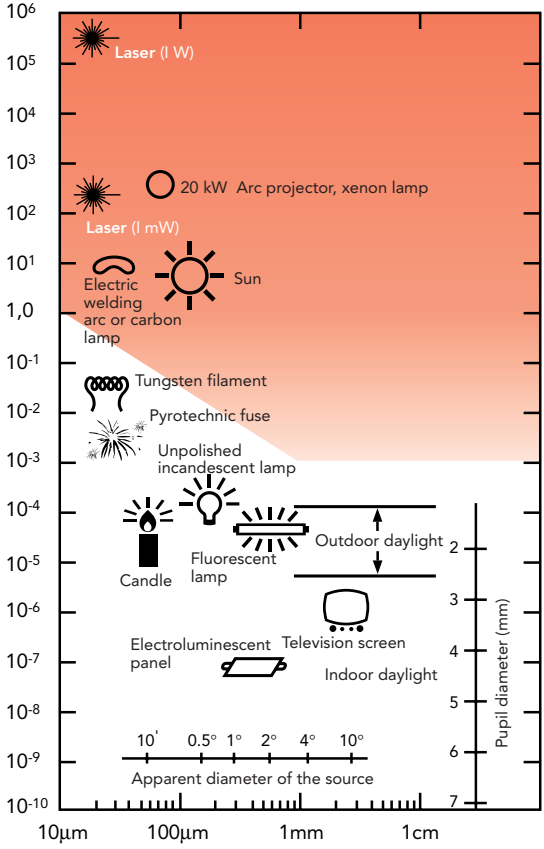
XX is dangerous
X can be dangerous
* no danger with palpebral reflex
O can cause fire
+ dangerous if D < 13 cm and t ≥ 10 seconds

Maximum permissible exposure: M.P.E.

The Maximum permissible exposure level (MPE), is the maximum level of laser radiation to which a person may be exposed without hazardous effects or biological changes in the eye. This value, measured at the cornea, is determined on the basis of the wavelength, the duration and conditions of exposure (see the criteria defined in standards NF EN 60825-1).

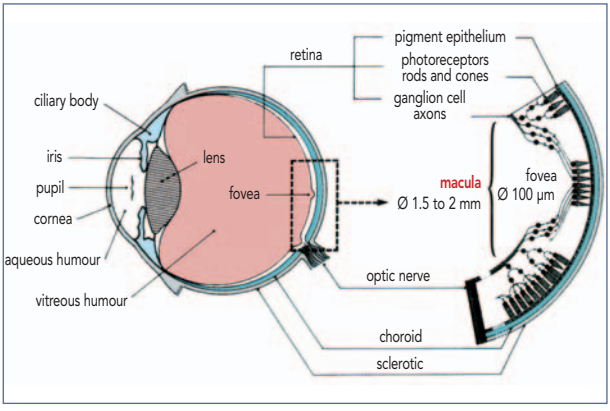
The following table gives the energy lighting on the retina when viewing common luminescent objects:

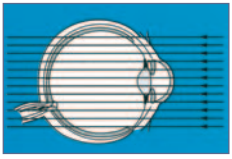
Surface power density received by the retina (Watt/cm²)



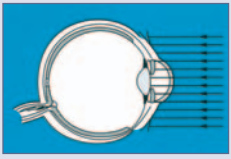
Size of the retina image

General Structure of the Eye

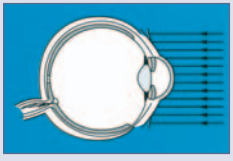




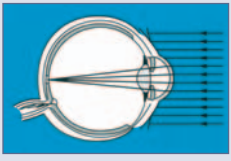
a. Microwaves and ionising radiation



c. Near ultraviolet



b. Far ultraviolet and far infrared



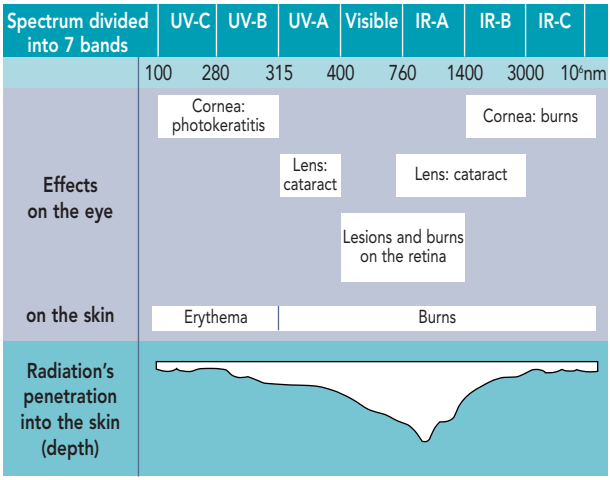
d. Visible and near infrared

Very dangerous: focus on the retina

OPTICAL GAIN OF THE EYE: up to 500 000

Biological effects...

...caused by laser radiation depending on the wavelength (diagram based on information from the C.I.E. – International commission on illumination)



A laser beam with a power of just a few mW hitting the macula zone of the retina can cause partial or total loss of visual acuity.

▼

EYE PROTECTION

Other Hazards

Hazards other than laser beams

ELECTRICAL: Low and High Voltages in the power supplies, capacitors.

CHEMICAL: dyes, solvents, gases, targets, etc.

ACOUSTICS: electric power supplies, discharge from high-power pulse lasers.

FIRE/EXPLOSION: solvents, static electricity.

MECHANICAL: handling, rupture of enclosures.

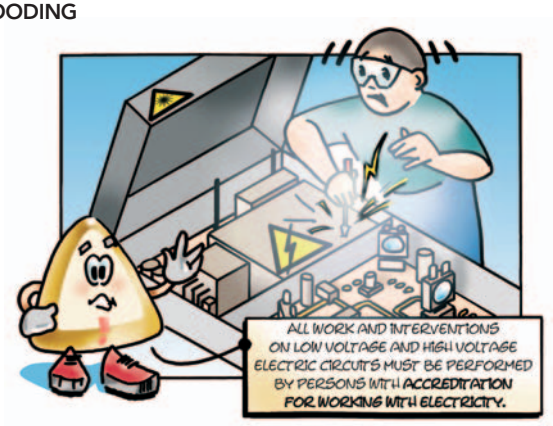
X RAYS: Very High Voltage power supply (>15 kV)

RELATED EMISSIONS: ultraviolet, visible and infrared, Radiation/Material interaction

OZONE: ozone produced by intense UV sources.

CRYOGENICS (burns, anoxia): liquid helium and nitrogen, etc.

FLOODING



Safety Rules

COLLECTIVE PROTECTION: should be stressed.

Ask the Installation Safety Engineer for advice when setting up equipment, laying out the premises, performing **equipment** maintenance, drawing up **recommendations**, etc.
TRAINING: awareness, workstation training and certification.

Premises:

- Laser premises, marked out by an illuminated signal indicating that class 3B lasers (3R for invisible wavelengths) or higher are being used.
- Access to laser premises restricted to authorised personnel wearing suitable eye-protectors.
- Remove, where possible, sources of unwanted reflections. Pay particular attention when using small reflective objects such as metal tweezers, watches, small tools, etc.
- The premises must be well lit (at least 500 lux) to reduce the diameter of the pupil of the eye.

Equipment:

- Confine the beam as much as possible.
- Define the beam path precisely and make sure it remains free of obstacles.
- Never start up a laser if the whole system (laser equipment, optics, target, etc.) is not fully prepared.
- Block the laser beam at source when undertaking any work that does not require the presence of the beam.
- All fibre optics transmitting a laser beam should be considered as a laser source.
- Despite their small volume, "laser diodes" are laser sources and are therefore subject to the same classification and safety rules.

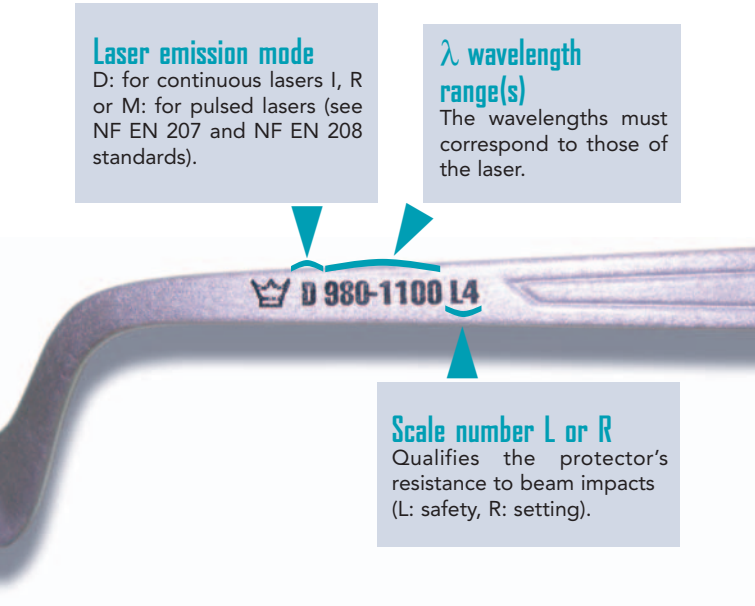
Recommendations:

- Work at low power when adjusting the beam.
- Check the safety systems periodically.
- Medical supervision for users (ophthalmologic examinations).
- Individual protection suited to lasers and to the type of intervention.
- Follow special safety recommendations for the workstation in question (goggles, etc.).

Eye-protectors

Eye-protectors must be worn when the collective protection system is only partial or cannot be applied (adjustment phase, etc.).
Goggles must never be used to replace the collective protection.

The three major parameters for protective goggles are:



These figures **must** be engraved on the frame or on the lenses. Some goggle manufacturers add optical density D or OD (depending on the power or energy of the **laser**).

Whatever the quality of the goggles, it is strictly forbidden to look along the axis of the beam. Always keep eyes well above the level of the optical table.

Goggle production must follow European standard NF EN 207 (safety goggles) and 208 (goggles with settings for visible wavelengths between 400 nm and 700 nm only).

Signs and Labels

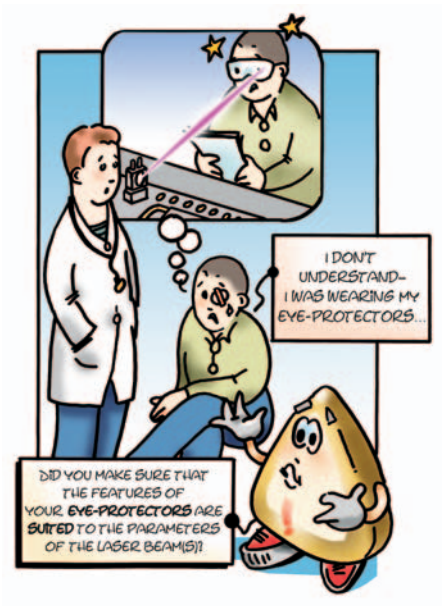
All laser systems above category 1 must bear:

- danger symbol ▶

- an information plaque indicating the laser class and a description of the hazard, in compliance with the applicable standards.
  For example: ▶

All laser premises must display the danger symbol at the entrance: ▶

When this sign is blinking, all movement is regulated. ▶



Bibliography – Documentation

- Radiation Safety with Laser Equipment
  NF EN 60825-1/X standards (X: latest applicable release)
- Goggle production. Individual protection NF EN 207/X
  and NF EN 208/X standards (X: latest applicable release)
- "Sécurité laser" Prevention Guide, CEA – GEP – 2004
- "Lunettes de protection laser" Guide, CEA – GEP – 2001
- http://www-dpsnsecurite.cea.fr:8000/

Contacts

For further information, consult your safety contact and read the Laser Safety guide published by the CEA's Prevention studies group (GEP).
For information concerning the use of lasers or requests for documentation and films, contact the GEP Laser Safety working group at the CEA or the "Direction de la protection et de la sûreté nucléaire".

This document has been produced by the GEP "Laser Safety" working group directed by the "Direction de la protection et de la sûreté nucléaire".

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