Safety of Lasers and Intense Light
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Laser hazards database www.rli.com
No eyewear, wrong eyewear!
Alignment hazard when servicing

Key points for laser safety
Never look into the direct or reflected beam
Wear the correct protective eyewear
Don’t leave the laser or light source running unattended
Comply with safety signs and regulations

Laser Hazards: Eye Dependant on wavelength
Visible or not? Blink reflex
Acute exposure can cause corneal or retinal burns.
Chronic exposure to excessive levels may cause corneal or lenticular opacities (cataracts) or retinal injury.

Response of the Human Eye versus wavelength
The eye focuses visible and near infrared light.
Normal focusing by the eye results in an irradiance amplification of roughly 100,000.
A 1 mW/cm² beam entering the eye will result in a 100 W/cm² exposure at the retina.
This will cause a thermal burn which destroys the retinal tissue. Since retinal tissue does not regenerate, the damage is permanent.

Ocular transparency extends into the bear infrared. Melanin and Hb in retina will absorb visible and near IR light.

MPE (Maximum Permissible Exposure) = the highest laser energy to which the eye or skin can be exposed for a given laser wavelength.

NHZ (Nominal Hazard Zone) = area within which the MPE is equalled or exceeded.

NOHD (Nominal Ocular Hazard Distance) = distance along the laser beam axis beyond which is acceptable for eye exposure.

MPE values vary by wavelength.

Visible light esp. green: Frequency doubled Nd:YAG, DPSS KTP, argon ion lasers
Very high photopic sensitivity so flash blindness and glare are concerns

Near infrared
Nd:YAG, 810-830 Class 4 diode lasers.
Invisible. Strong melanin absorption makes retinal injury likely.
Reflections: Curved surface; Concave vs. Convex. Mirror-like "specular" reflections

All high power lasers can cause skin burns.
At the under five watt level, the heat from the laser beam will cause a flinch reaction before any serious damage occurs. With higher power lasers, a burn can occur despite the flinch reaction. These burns can be quite painful and take a considerable time to heal.

UV light
UVA 280 to 400 nm: increased pigmentation.
UVB: erythema (sunburn)
UVC and UVB: Skin cancer and accelerated skin photo-aging.

Middle IR – cornea absorbs

Regulatory framework
AS4173: Safe use of lasers in health care
AS2211 series: Laser safety
IEC 60825-1

Jurisdictional radiation safety legislation, e.g. Qld, WA
National harmonized radiation safety legislation
Possession licences
Use licences
Facility certification
Coverage for Class 4 lasers
Future: Intense lights such as IPLs – above certain parameters
Impacts upon cosmetic medicine, Hair removal, Skin rejuvenation

Hazard analysis
Primary hazard: Intense light
Laser or IPL
Direct or viewed through an instrument
Focused or defocussed
Reflected off surfaces
Acute vs chronic effects
Eye and skin issues

Secondary hazards Device related/Direct
Electrical risks
Stray pump radiation
Laser medium hazards (dyes, compressed gases)

**Application related/Indirect**

- Fire/ignition
- Plume

**Procedural risks**

Flash Lamps: Stray radiation

**Secondary Hazards**

**Electrical**: Most lasers except diode lasers utilize high voltages that can be lethal.

**Fire**: High voltage circuits or flash lamps may cause ignition. Flammable materials may be ignited by direct beams or specular reflections from high power continuous wave (CW) infrared lasers.

**Chemical hazards**: Dyes, solvents, gases

**Electrical safety**

The use of high voltages is perhaps the most dangerous part of servicing, repairing, or working with lasers. While laser radiation can cause instant blindness, high voltages can cause instant death! Adequate safeguards and safety practices include:

- Insulation around exposed parts operating at high potentials;
- Interlocks on panels

**Fire risks**: especially IR Lasers

Fire starting capability

- All Class 4 lasers are considered to be a fire hazard

**Flammable**: endotracheal tubes, surgical drapes, (dry) gauze, plastics, alcoholic solutions;

**Clothing**

Fire prevention: Fire extinguisher (dry powder recommended).

Use wet gauze as a beam stop.

Be aware of special risks in operating theatre environments such as anaesthetic tubes

**Basic Checklist**

1. Check warning sign in place.
2. Get key.
4. Check mains electrical lead and foot switch lead for damage.
5. Check laser for any damage, especially to the delivery system.
6. Close window blinds if needed.
7. Attach handpiece.
8. Check protective glasses are in place

Before **powering the laser on**.

10. Check aiming beam.

**Servicing**

To ensure operation at it's optimum level, laser systems normally have preventive maintenance performed at regular (6 or 12 month intervals). During preventive maintenance the laser field service engineer will:

- Replace consumables such as HEPA filters or deionizing cartridges.
- Verify, system calibration and adjust as necessary.
- Inspect optics, clean, align as necessary.
- Perform an all system test, and recommend repairs as necessary.

**Practical points for safety**

- All windows, doorways, open portals, etc., of an enclosed facility should be covered or restricted to reduce any escaping laser beams below appropriate ocular MPE level.
- Disable lasers and intense lights when not in use (remove the key)
- Spectators and persons unnecessary to the procedure should be kept away.

**Equipment certification**

IEC 60825-1 is applicable in Europe and the USA. It is recognized in Japan, Australia, Canada and other countries. It is now very much the worldwide laser safety standard for laser manufacturers.

**Australia**

Therapeutics Goods Administration (TGA):

Lasers (other than Class I) require TGA registration when used in patient care

**Europe**

As part of the process of CE marking, all laser (and LED) products sold in Europe must be certified to EN (IEC) 60825-1.

**USA**

FDA Center for Devices and Radiological Health

Lasers require FDA registration (not LEDs)

The regulation controlling laser products is 21 CFR 1040.10

Since 2001, FDA has accepted IEC classification and labelling. Manufacturers selling their products in the USA have the choice
of using classification and labelling to IEC 60825-1 or 21 CFR 1040.10. In both cases the products must be registered with the FDA.

Classification labels
All lasers including class I except if laser is Class 1 even when all housings have been stripped away.

Class I laser
No known biological hazard.
The light is shielded from any possible viewing by a person and the laser system is interlocked to prevent the laser from being on when exposed. Hence the device produces no known biological hazard.
*e.g. CD/DVD players, laser printers, enclosed laser welders*
CD, DVD, Blue Ray etc
Role of Enclosures
Issues with Window glass: Glass windows will not provide any significant protection for the majority of visible and near infrared laser types (e.g. argon ion, KTP, Nd:YAG, diode). However, glass does provide high attenuation at mid-far infrared wavelengths, especially beyond 5 microns.
Glass may shatter if subjected to excessive heating from a concentrated beam.

Class 2 laser
Visible light
Power up to 1 milliwatt.
Blink reflex will limit ocular damage (0.25 seconds)
Eye damage could occur for greater times or if viewed through an optical instrument
No known skin exposure hazard and no fire hazard.
*e.g. small laser pointer*
NB Parallel beam from a laser pointer gives a very high retinal irradiance

Class 3R laser (previously termed 3A)
Power output between 1 milliwatt and 5 milliwatts.
These lasers can produce spot blindness under the right conditions and other possible eye injuries.
No known skin hazard or fire hazards exist.

Class 3B laser
Power output from 5 milliwatts to 500 milliwatts (0.5 watts).
Definite eye hazard
Skin may be burned at the higher levels of power output.
*e.g. Low level laser unit used to promote wound healing*

Class 4 lasers
Power output >0.5 watts.
Visible OR invisible
Cause eye damage.
Cause materials to burn on contact as well as skin and clothing to burn.
The reflected beam should be considered as dangerous as the primary beam.

Laser protective eyewear
Polycarbonate, or Glass
Australian Standard AS2211
European PPE Directive under standard EN 207

Major suppliers
Uvex
Glendale (Zeiss)
Lasermet
Coherent
LaserVision
www.lasermet.com
www.uvex-safety.com
www.glendale-laser.com

Polycarbonate
- Extremely lightweight
- More comfortable to wear than heavier glass filter eyewear, however, comfort is also very dependent on the frame style.
- Less expensive
- May not be available in sufficiently high L number (OD).
- Generally have a lower Visible Light Transmission (VLT) than glass
- Will break if accidentally sat upon.

Glass
- Offers higher protection levels than polycarbonate filters for the same laser. Often the L numbers are greater by 2 or 3 for the D marking (CW or average power density rating), which means that it can withstand 100 or 1000 times as much power density.
- Higher Visible Light Transmission (VLT) gives higher visibility
- More robust and less likely to break than polycarbonate eyewear if accidentally sat upon.
- More expensive
- Heavier

Labelling of eyewear
Modern laser eyewear is normally certified to European Standard EN 207 "Personal eye-protection. Filters and eye-protectors against laser radiation (laser eye-protectors)".

For the USA, Optical Density is usually the only protective information required.
EN 207 takes account of both the Optical Density and the damage threshold of the eyewear. EN 207 breaks down the L number according to three wavelength ranges, 180-315 nm, 315-1400 nm and 1400-1,000,000 nm

OD means optical density – the higher the OD (remembering that it is a LOG scale in base 10), the greater the protection.
OD 4 means 1 part in 10,000 is transmitted
OD 5 means 1 part in 100,000 is transmitted
OD 6 means 1 part in a million is transmitted
e.g. For a 10 Watt laser with a 1 square centimeter beam (power density 10 W/cm²), the transmitted power density should be 0.0001 W/cm² (or 0.1 milliwatt per square centimeter).

For pulsed lasers the eyewear must have both the correct I, R or M specification (depending on the pulse length) and the correct D specification, to ensure that it is suitable for the laser.
The D, I, R and M refer to CW or different pulse lengths as follows:
D = Continuous Wave (CW)
I = Pulsed with pulse length > 100 ns, 'Long Pulse'
R = Pulsed with pulse length > 1 ns and < 100 ns, 'Q-switched'
M = Pulsed with pulse length < 1 ns, 'Femtosecond'

Note that pulsed dental lasers such as Erbiums would all be >50 μsec ("long pulse"), and thus the "I" parameter is relevant, rather than R or M.

Example
Eyewear sold with an Nd:YAG laser was marked as follows:
DI 750 - 1200 L5
R 750 - 1200 L6
M 750 - 1200 L4

This means that over the wavelength range 750 - 1200 nm (which includes the Nd:YAG wavelength of 1064 nm),

The maximum power or energy densities which these glasses would withstand are
(D) CW  1 MW/m² L5
(I) Long Pulse 500 J/m² L5
(R) Q Switched 5 kJ/m² R L6
(M) Femtosecond 1.5 J/m² L4

Wavelength specific eyewear for patients
Universal Opaque eyewear for patients

Protective eyewear for guardians and accompanying persons in the NOHD

Laser hazard sign
Laser hazard: starburst symbol

Warning light

Class 4 laser systems MUST have:
- key switch,
- emergency off switch
- cover removal switches (interlocks),
- emission indicators,
- mechanical shutters,
- warning labels affixed to the laser.

In Qld (and WA), Class IV lasers require licences for possession and use in patient care as well as an approved Radiation Safety Protection Plan (RSPP).
One key on the ring

Warning triangles: All lasers above Class 1
Aperture labels: e.g. Class 3R, 3B, and 4 lasers

Product information labels: All lasers exceeding Class 1

Emission indicator
Warning signs on housings
Protective housing labels
On all panels or connections which when removed, opened or displaced will give access to radiation in excess of Class 1.

Interlocked housing labels
An all interlocked panels which when opened will give access to radiation in excess of Class 1 when the interlock is overridden.

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