Laser Safety

Franziska Beer[a], Martin Straßl[b], J. Wernisch[c]

[a] *Assistant Professor, Dental School,Medical University of Vienna, Vienna, Austria.*
[b] *PhD Student, Photonics Institute, Vienna University of Technology, Vienna, Austria.*
[c] *Professor, Institute of Applied and Technical Physics, Technical University of Vienna, Vienna, Austria.*

Summary: This article gives an overview on the safety requirements in laser dentistry and is an excerpt from the chapter "Laser Safety" in the book "Oral Laser Appplications" by Franziska Beer et al, which will be published in June 2005 by Quintessence.

J Oral Laser Applications 2005; 5: 71-79.

The aim of this chapter is to focus on the properties, effects and especially on the dangers of laser and LED radiation and to introduce several protective measures.

Lasers are excellent tools, but they also carry a very high risk of severe injury and damage. Laser radiation mainly endangers the eyes and skin. In particular, the retina, cornea and lens of the eye are highly susceptible. Damage to the retina usually cannot be repaired. Thus, even slight carelessness can lead to lifelong loss of vision.

The second most damage-sensitive organ is the skin, although it is much less vulnerable than the eye and damage only occurs at higher energies.

Hence, these high risks warrant suitable protective measures, with their strict observation being the responsibility of the employer and thus of the management. In the medical profession, it is the duty of the practice owner or the head of department.

Requirements to control and verify correct implementation of the necessary protective measures necessitate comprehensive safety education.

It should be noted once again that the impact of laser radiation on biological tissue not only depends on the radiation properties (eg, wavelength, intensity or irradiation time), but also on the irradiated tissue. Optical and thermal properties determine the absorption, reflection and transmission characteristics of the applied radiation.

One very important factor in this context is the spectral coefficient of absorption, which indicates the fraction of energy absorbed on penetrating a layer of a certain thickness. However, for biological tissues, knowledge of the absorption coefficient alone is not sufficient to describe the behavior of the penetrating radiation, as several additional factors such as scattering and reflection, which are classed under the general term of remission, determine the actual distribution and backscattering properties.

The remission parameters also depend on the wavelength of the applied radiation. Thus, the optical properties of the tissue determine the extent and the form of the coagulation zone.

MAXIMUM PERMISSIBLE EXPOSURE

The maximum permissible exposure (MPE) irradiation values are limits determined in experiments, as for other chemical or physical factors. As the eye and skin have different sensitivity to light irradiation, the MPE values are defined separately for skin and eyes. The physical units used are W/cm^2 and J/cm^2.

The values are generated from animal experiments with consideration of the different anatomical properties and additional safety factors. Thus, damage is reliably prevented if the incoming radiation is below the specified limits.

The MPE values are always specified according to national standards.

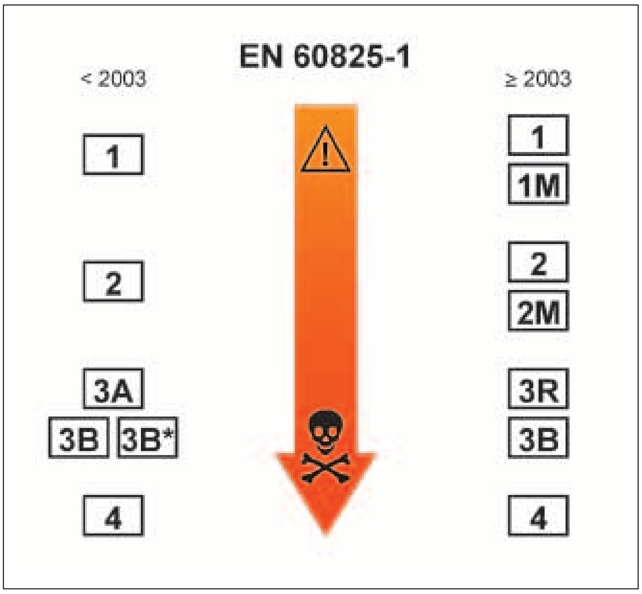

Fig 1 Summary of the six old (valid up until 2003) and the seven new laser classes (valid since 2003) according to European standard EN 60825-1. Classes at the same graph level indicate comparable safety hazards. The danger increases with the number of the laser class.

LASER CLASSES

Laser devices have to be classified by the manufacturer according to their hazard, which allows the user to choose the correct protective measures. The different laser classes are defined in the international laser safety standard IEC 60825-1 and European standard EN 60825-1.

If the user modifies the laser device, an evaluation of the actual hazard has to be carried out and a new classification assigned if necessary.

Laser classification is always carried out by assuming the worst-case hazards:

- The operator uses magnification glasses or other optical devices;
- Minimal distance during measurement;
- Longer exposure time than usual;
- Consideration of foreseeable failures;
- No consideration of the user's actual training (Fig. 1).

Class 1

Safe laser devices.
Condition: below 40 µW in the blue and 400 µW in the red spectral range.
Examples: range finders, CD players.
Protective measures: none
Warnings: **none**
Remark: The new laser safety standards define a new class for laser devices that are safe for the naked eye but involve a safety hazard when using optical instruments, called **Class 1M** (where "M" means "magnifying instruments").
Warning: **"Laser Radiation. Do Not View Directly With Optical Instruments. Class 1M Laser Product."**

Class 2

Class 2 is only defined for visible wavelengths (400–700 nm).
Condition: For cw lasers, the output power has to be below 1 mW (with an assumed diameter of 7 mm for the iris, an average intensity of about 25 W/cm^2 is achieved on the cornea according to the corresponding MPE value).
Examples: laser pointers, targeting lasers.
Protective measures: none
Warnings: **"Laser Radiation. Do Not Stare Into Beam. Class 2 Laser Product."**
Remark: The new laser safety standards define a new class for laser devices that are safe for the naked eye but carry a safety hazard when using optical instruments, called **Class 2M**.
Warning: **"Laser Radiation. Do Not Stare Into Beam Or View Directly With Optical Instruments. Class 2M Laser Product."**

Class 3A (old class)

Remark: In the new laser safety standards, this safety class is replaced by the new Classes 1M and 2M.

Class 3B

Condition: Output power <0.5 W (UV-A to far-IR). The thresholds for UV-B or -C are much lower.
Examples: Lasers for measurement, laser shows and alignment.
Protective measures: safety precautions for the danger zone (boundary, laser protective eyewear), training, laser safety officer (LSO).
Warnings: **"Laser Radiation. Avoid Exposure to Beam. Class 3B Laser Product."**

Special Class 3B* (old classification)

Remark: In the new laser safety standard IEC 60825-1, this class is renamed "Class 3R".

New Class 3R

Conditions: 5x output power of Class 2 in the visible range is not exceeded, maximum 5x output power of class 1 in the invisible range.
Examples: targeting lasers, lasers for measurement, lasers for building sites, etc.
Protective measures: user training, laser safety officer for lasers in the invisible range.
Warnings: **400–1400 nm, "Laser Radiation. Avoid Direct Eye Exposure. Class 3R Laser Product." All other wavelengths, "Laser Radiation. Avoid Exposure To Beam. Class 3R Laser Product."**

Class 4

For output power >0.5 W. Eyes and skin are endangered even for diffuse reflection. Fire hazard for flammable materials in the beam path.
Conditions: Output power >0.5 W.
Examples: Lasers for material processing, lasers for medical therapeutic use.
Protective measures: technical protective measures for the danger zone, laser safety officer, user training, consideration of fire hazards.
Warnings: **"Laser Radiation. Avoid Eye Or Skin Exposure to Direct or Scattered Beam Radiation. Class 4 Laser Product (for Summary see Fig. 2)."**

SECONDARY HAZARDS

Primary hazards are directly caused by the laser beam, such as endangering the skin or eyes as discussed above. Secondary hazards are connected to operation of the laser, but are mainly independent of the radiation characteristics.

Common Hazards

Mechanical Hazards

Mechanical hazards are caused by mechanically moving parts, such as industrial robots, parts operated by them and automatic door locks. Special hazards can be caused by high pressure in tubes and low pressure in the laser cavity.
Tubing: Gas tubes are usually under pressure. Hence, they should be mechanically secured to avoid uncontrolled release in the case of a burst.
Laser resonator: In CO_2 laser cavities, glass tubes are used that operate at very low pressures, carrying a risk of implosion if incorrectly mounted. In addition, during replacement of flashlamps (high-pressure lamps) in solid-state lasers there is an explosion hazard.

Electrical Hazards

The CE mark signifies that the construction of the device is safe. Ex post changes of the device can affect the electrical security.

Each laser device needs a very strong power supply due to its low plug efficiency (eg, an 800-W Nd:YAG laser needs a plug power of 25 kW) requiring adjustment of the fuses and wires for the current supply. Furthermore, in flashlamp pumped laser units, condensers with very high capacity are charged for a long time after the device has been turned off.

If an external water cooling circuit has to be installed, close contact of the water and power lines should be avoided.

Chemical Hazards

Chemical hazards are mostly due to materials used in the laser construction.

- For excimer lasers, toxic fluorine and chloride are used as the laser medium. Thus, the gas containers have to be stored under secure conditions, eg, in gas-proof cupboards with passive air ventilation. All connections of the gas tube system have to be examined carefully. In case of a gas leak, a gas mask should be stored ready to hand. Modern excimer lasers mostly have the gas supply already integrated in their sealed housing.
- Most dyes for dye lasers are toxic or neurotoxic substances. Widely used dyes are rhodamine and coumarine. During dye replacement, the recommendations of the manufacturer must be followed. Contact with skin and inhalation of released vapors must be avoided. Used dyes should be disposed of according to national and local rules and regulations.
- The laser tubes of *Ar+ and Kr+ lasers* contain highly toxic beryllium. Thus, these tubes have to be handled with special care.

	① (t>>)		② (t<<)		③	④
	(magnifier)	(eye)	(magnifier)	(eye)		
1	✓	✓	✓	✓	✓	✓
1M	⚠	✓	⚠	✓	✓	✓
2	⚠	⚠	✓	✓	✓	✓
2M	⚠	⚠	⚠	✓	✓	✓
3R	⚠	⚠	~	~	✓	✓
3B	⚠	⚠	⚠	⚠	~	~
4	⚠	⚠	⚠	⚠	⚠	⚠

Fig 2 Table summarizing the hazards caused by particular laser classes: 1 for permanent irradiation, either for optical instruments (left column) or for the free eye (right column); 2 for short time irradiation for optical instruments or the free eye; 2 for diffuse reflection; and 4 for irradiation of the skin. Legend: green check mark = safe; orange tilde = low risk; warning sign = high hazard.

- Dusts from broken *ZnSe lenses* (transparent material for CO_2 lasers) are toxic. ZnSe dust collection should only be carried out with protective goggles, gloves, protective clothing and a breathing mask. Disposal should be carried out according to national and local rules and regulations.

Thus, opening of laser cavities should not be carried out by the user, but should be left to service personnel or the manufacturer.

Fire Hazards

Flammable materials can cause a fire hazard during the operation of lasers with high output power, mainly due to material in the beam delivery system, in the operation area and the surrounding environment.
Beam delivery system: Potential danger can occur if the beam axis has been changed by alignment work, resulting in the beam directly or indirectly hitting cooling tubes (eg, from guiding mirrors) or the housing of the optical path. Fracture of the optical fibers or wrenching of their connection plugs can lead to the emission of laser radiation.
Operation area: risk objects in this region are:
- cooling tubes or supply devices on the laser head
- objects in the vicinity of the operation site, such as paper rolls and cleaning agents or solvents.

Surrounding environment: Particular fire hazards such as inspection windows and seals of the housing have to be considered. Another critical device, although mostly situated further away, is the filter installation. Fire can occur if the wrong combination of filters and exhaust particles is chosen, eg, aluminum dust and electrostatic filters, which can lead to sparking in the device.

Directly and indirectly reflected laser radiation carries the highest risk, especially in 3D workstations if the beam is accidentally directed horizontally or vertically, and thus propagating freely into the room. For very high-power lasers, even diffuse reflected radiation may represent a fire hazard.

Furthermore, high reflection might occur during treatment of metallic materials such as aluminum, copper and brass or amalgam. Sparking of the processed material can also cause a fire hazard, thus endangering flammable material not even in the operation area, especially synthetics, clothes, wood and alcoholic fluids.

Specific Hazards

Plasma: Laser light generation in gas lasers as well as laser welding leads to a plasma. A physical plasma is a gas mixture containing ions and free electrons. Laser welding and conventional welding both produce a bright welding plasma emitting intense UV and short-wave blue light. This emission is called secondary radiation, representing a risk for retina damage, inflammation of the cornea and even for erythema for long exposure times.
Working processes: If powders are applied, aerosols occur, which have to be exhausted and filtered. Similar to dusts and vapors, the maximum acceptable concentration (MAC) values have to be considered. Unused powder has to be collected using suitable devices (eg, dental laboratories).
Programming: The programs for 3D workstations (robots, multi-axis machines) should ensure that the beam shutters cannot open during positioning of the laser head. For test runs, a working piece has to be mounted. In both cases, free propagation of the laser beam could occur.

***Adjustment tasks:* Most laser accidents reported happen during adjustment tasks.** Usually these tasks have to be performed on the open laser device. As mirrors have to be adjusted during such work, special care should be taken so that:

- The beam is not reflected onto the delivery system
- No parts of the body or tools reach into the optical path
- Only the minimal necessary power is applied.

CO_2 lasers: In particular, HF-excited CO_2 lasers create ozone around the resonator, irritating eyes and airways. Thus, the resonator has to be contained in a sealed housing or suitable ventilation has to be installed.

Vapors and dusts

Usually the emission of vapors and dusts during material processing is reduced compared to other thermal methods. In particular, for laser cutting this can be explained by the much smaller cutting widths. Nevertheless, the emission of gases, vapors and dusts should not be neglected.

The emissions can be divided into:

a) irrespirable dusts and vapors
b) respirable dusts and vapors (aerodynamic diameter <10 µm)
c) gases.

Irrespirable dusts and vapors carry no hazard for the user, but should be avoided to protect the optical devices.

Respirable dusts and vapors carry a high health risk for the user, particularly carcinogenic or toxic substances.

Absorbance of such substances is mainly by respiration. Deposition occurs during inspiration as well as during expiration, with the interior surface of the respiratory tract having an area of 80–100 m^2.

Dust is produced by the separation of solid matter, and vapor by thermal and/or chemical processes. To evaluate health hazards, the effects of the contaminant as well as its concentration, the exposure time and most importantly the size of the particles have to be considered.

Dusts, gases and vapors are distinguished by their effects, which dictate the MAC limits:

a) *Lung-stressing substances:* non-toxic or -carcinogenic fine dusts or vapors showing no reactions but depositing in the lung, thus impeding oxygen exchange.
b) *Toxic substances:* all toxic gases, vapors and dusts showing impact on different organs, implying a risk of acute and chronic diseases.
c) *Carcinogenic substances:* handling requires special care. They are divided into the three subclasses, A1, A2 and B:
   A1: substances definitely categorized as carcinogenic, eg, benzene, nickel.
   A2: substances categorized as carcinogenic only in animal experiments, eg, butadiene, cobalt and its derivatives.
   B: substances suspected of having carcinogenic potential, eg, formaldehyde, pyrolysis products from organic materials (found in dentistry).

Metals

Exposure to emissions caused by the cutting of metals is only of secondary importance in dentistry, but for completeness it is also discussed.

During cutting of stainless steels, chromium and nickel are released. Nickel and all its derivatives are definitely carcinogenic; for chromium, only Cr(VI) has to be considered.

In all studies, the particles released showed a diameter between 0.042 and 0.35 µm, thus requiring the use of filters for sub-µm particles.

Organic Matter

Particle diameters of organic matter emitted are between 0.07 and 0.25 µm, comparable to metals. The diameter tends to decrease for increasing generation of gaseous pyrolysis products.

a) *Concentration of hydrocarbon:* studies show that substances with a high aerosol rate deliver fewer gaseous hydrocarbons. Polymers have very high hydrocarbon emission.
b) *Concentration of carbon monoxide:* processing of polycarbonates cause the highest CO concentration of about 50 mg/m^2. Polyamide causes about 25 mg/m^2.
c) *Carcinogenic substances:*
- polycyclic aromatic hydrocarbons
- benzene
- carbonyl derivatives
- phenol.

PROTECTIVE MEASURES

The protective measures introduced in this chapter follow the international standard IEC 60825-1 and the European standard EN 60825-1. The prescribed measures always describe the minimum safety requirements to be fulfilled.

Although the procedures introduced are highly recommendable in any case, it should be explicitly noted that the national rules and regulations for safe operation of a laser device differ from country to country.

Laser Protective Eyewear

Standard EN 207 (following on from the DIN) encompasses a safety concept that not only involves attenuating the laser radiation to MPE values, but also requires that the filter material used can withstand the specified laser power. For example, normal glasses give no protection against CO_2 radiation, as is often wrongly believed. In fact, glass absorbs the radiation, and due to the instantaneous heating it would splinter immediately, also endangering the eye mechanically.

The filter transmittance $\Delta(\lambda)$ only has to reduce the specified wavelength to the MPE value, without strong suppression of the other wavelengths, to ensure comfortable working conditions.

The resistance of a filter to laser radiation is analyzed by examining if the optical density persists at least for 10 seconds, as this should be enough time to leave the danger zone. For pulsed lasers the condition is to withstand 100 pulses. By passing the test, laser goggles not only have an optical density of eg, 5, but also protective grade 5.

Laser goggles are not designed for permanent staring into the direct beam, but only for accidental irradiation.

For high protective grades, it is not usually the optical density that causes problems for the manufacturer, but resistance to high intensities. Hence, protective grade 5 means that the optical density is at least 5 and that the filter withstands the maximum intensity this filter may be exposed to.

Furthermore, EN 207 requires that:

- The filter must transmit at least 20% of the visible radiation, otherwise the manufacturer has to inform the authorities about it in written form.
- The filter may not lose its protective grade, even for longer UV irradiation.
- The filter has to retain its protective effect at higher temperatures (55°C) and high humidity.
- The wavelength and protective grade must be identified on the goggles.
- The instructions for use (in the language of the country it is distributed in) have to contain all the relevant specifications of the goggles.

Labeling

EN 207 requires the following scheme for labeling laser goggles:

DIR	operation mode
1064	wavelength in nm
L6A	protective grade
RH	manufacturer's mark
DIN	testing standard

Operation modes (simplified): These letters are from the German standard and have to be verified for specific languages:

M	mode-coupled lasers	pulse durations $<10^{-9}$ s
R	Q-switched lasers	pulse durations from 10^{-9} to 10^{-7} s
I	pulsed lasers	pulse durations from 10^{-7} to 5×10^{-4} s
D	cw lasers	pulse durations >0.1 s (315–1400 nm, >0.5 ms)

All operation modes tested have to be noted. In any case, each pair of goggles has to be tested for a cw laser. If no operation mode is shown at all, the goggles can be used for cw lasers.

Wavelength: Written in nm, indication of a range is possible (eg, 600–800).

Warning: **The wavelengths 1064 (Nd:YAG) and 10600 (CO_2) can easily be mistaken. Goggles only for CO_2 radiation do not protect against Nd:YAG radiation.**

Protective Grade: Defined as discussed above.

According to the wavelength and operation mode, different protective grades can be indicated:

- *eg, for different ranges of wavelengths:*
- 570–620 L5A RH DIN
- >620–900 L4A RH DIN

- *eg, for different operation modes:*
- D 1060 nm L5A CZ DIN
- IR 1060 nm L3A CZ DIN

The required protective grade for a certain laser unit has to be specified in its handbook. In case of doubt, a higher protective grade is the better choice.

Many goggles also carry the CE mark. Requirements for the CE mark are not as strict in several aspects as testing according to EN or DIN 207. For example, for a CE certificate only a prototype must be tested, whereas for testing according to EN/DIN 207 standards, continuous random tests must be carried out during manufacture.

Notes for Practical Use

Protection of the Eyes: If a free propagating laser beam is operated, protective eyewear should be worn at all times, even when using optical instruments such as microscopes during laser application.

For practical use of laser goggles, it should be checked if they are suitable for the operational wavelength. The necessary protective grade, eg, L3 or L5, can be calculated. For practical use, goggles with the highest protective grade should be purchased. Furthermore, the operation modes allowed should be checked.

It should be ensured that the goggles transmit sufficient visible light, except at the laser wavelength. Hence, no broadband filtering systems absorbing many wavelengths, and thus transmitting almost no visible light, should be purchased.

A strong decrease in transparency reduces safety during work and increases the risk of accidents, especially due to reduced visibility of illuminated warning signs, controls etc. Thus, clear sight of controls has to be assured during use of protective eyewear.

Before EACH use, the goggles should be carefully checked. Scratches, cracks or discolorations reduce safety. Defective goggles should never be used.

Another important point is comfort during use: goggles with glass filters are heavy, and such goggles are often more uncomfortable to wear than spectacles or wraps. The latter are also usually suitable for spectacle-wearers. A new development involves systems in which reflection layers are sputtered onto plastics, thus allowing high protective grades at low weight.

Windows

The LSO has to consider the estimated irradiation time for windows and shields using risk management principles. Windows have to withstand the expected irradiation time.

Usually, normal glass provides sufficient protection for wavelengths over 4 µm. Lasers with shorter wavelengths (eg, Nd:YAG) can be transmitted into neighboring rooms. For these wavelengths, windows and shields have to be covered with absorbing materials.

In this context, it should also be ensured that the beam axis does not hit windows and doors. Furthermore, the beam should not be at eye-level (110–172 cm) if possible, which is sometimes difficult to achieve.

Reflecting Surfaces

Reflecting surfaces not only reflect laser radiation, but in some cases can even focus it. Thus, the LSO has to make sure that reflecting surfaces are avoided in the working region.

In dentistry, special care has to be taken regarding the use of matte-finished instruments and suitable covering of reflecting surfaces in the mouth (metallic fillings, etc.).

Organizational Protective Measures

Nomination of a Laser Safety Officer (LSO)

The LSO has the duty of training employees and also has to set the access rules for the laser zone.

If only laser devices of Class 1, 1M, 2, 2M or 3R (visible) are operated, no LSO is necessary [Class 3R (invisible) requires an LSO]. Nevertheless, it is highly recommendable that a member of staff is trained in the very simple safety aspects for these laser classes.

Technical Protective Measures

Construction Protective Measures

All surfaces in rooms where lasers of Class 3B and 4 are operated should have a matte and diffuse reflecting finish to avoid specular reflection. For CO_2 lasers the roughness should be more than 40 µm; for Nd:YAG lasers the roughness should be more than 4 µm in depth. Special care has to be taken for enameled surfaces on a metallic base (eg, office equipment), as simple lacquers cannot withstand laser radiation.

Materials containing SiO_2 (ceramics, tiles, plaster) have a reflection band at roughly 9 µm. Common glass surfaces reflect about 8% of the incoming radiation, increasing to almost 100% at grazing incidence. Special care has to be taken in such cases, as these reflections are specular.

Walls in the operation zone should be constructed of bricks, limestone or concrete. Solid masonry is recommended to block the penetration of laser radiation in the case of failure until it has been recognized and stopped.

Protection Measures in Laser Devices

The user can verify that the laser device meets the required technical protective measures by checking if it has the relevant approved safety marks. Furthermore, a manufacturer is only allowed to place a CE mark on his device if, within the scope of risk management, he has assessed and analyzed all foreseeable hazards for normal operation and in the case of damage, and has demonstrably implemented the requisite protective measures for protection of the user and other persons in the endangered zone. In this context, the user should know that for some assessed hazards it is sufficient to inform the user to behave according to the operating instructions, as in some cases technical protective measures cannot help (eg, delivery of ionizing radiation after severe damage of the device due to handling malpractices). Hence, the behavior required by the operating instructions should always be followed. Otherwise, full liability for damage to persons or equipment is due to the operator of the device.

For lasers of Class 2–4, safety interlocks are required to ensure that unintended radiating is always prevented. This is especially required for electromagnetic switches, etc. used as triggers.

A construction measure to mitigate against unwanted redirection of the beam involves defined guidance through protective housings or optical guiding components. Foreseeable failures such as spring fracture or loosening of mounting parts may not lead to critical failure of the whole construction.

Another protective measure pertaining to an apparatus involves electrical interlock switches on manipulation flaps and doors, as well as the key-lock.

For starting the laser by a key-lock, a warning sign for radiation emission has to be implemented.

STANDARDS AND LEGAL RULES

Again it has to be stated that the standards and legal rules are slightly different for each country. Thus, the Austrian rules and standards are discussed here as an example (all the authors of this chapter are from Austria). The actual regulations for each country should be requested from the national professional organizations.

Laser Safety Officer

According to ÖNORM ÖVE EN 60828-1 and ON Rule ONR 1960825-8, a laser safety officer has to be nominated by the responsible operator if a Class 3B, 3R invisible range or Class 4 laser is operated in an institution. The LSO has to attend special training. In Austria, the content and duration of the training are regulated by ÖNORM S 1100.

Responsibilities and duties of the LSO

The main task of the LSO is to support and advise the responsible operator concerning protective measures and safe operation of the laser device.

The specific tasks of the LSO are:

a) Performance of hazard analysis in rooms where the laser is operated, comprising definition of the danger zone. This should be carried out according to risk management principles.
b) Advising the responsible operator and supervisors of the laser areas regarding safety aspects, purchase and starting of laser devices and arrangements concerning occupational medicine.
c) Choice of personal protection equipment.
d) Cooperating in laser safety education for employees working with laser devices or in the laser control areas concerning hazards and protective measures.
e) Cooperating in examination and official acceptance of laser devices according to national rules and regulations. Assuring that maintenance and service of the devices are only carried out by qualified personnel.
f) Scheduled checks on observation of the prescribed protection measures, eg, wearing of personal protection equipment, installation of protective screens and warning signs, standardized methods and procedures for adjustment tasks.
g) Informing the responsible operator and supervisors of the laser areas of defects in and failure of laser devices.
h) Investigation of all accidents and incidents in which lasers were involved and forwarding of all relevant information on preventive actions to all persons involved, including the safety officer.

Additional tasks can involve:

a) Decisions on technical and operational protective measures.
b) Advising employees working with lasers or supervising them.
c) Stopping the use of lasers if necessary.
d) Contacting authorities and keeping in touch with them.

It should be noted here that the responsibilities of the LSO are only so-called expert responsibilities. Thus, management is never and in no case excused from its duty of care and responsibility for the safety of employees. As long as the owner of a dental office is himself trained as an LSO, there is no doubt about his singular responsibility for the safety of his employees. However, as soon as another person is nominated and trained as the LSO, as often happens, for instance in clinical departments, this person is only responsible in cases in which the LSO duties were not carried out properly, for example choice of insufficient protective clothing (including eyewear), no annual training of personnel, no information on construction measures required (coating of windows, interlock switches, etc.), no scheduled control of rules for safekeeping of keys, etc.

However, as the LSO usually has no authority to issue directives against the management or head of the department, he is not responsible for protective measures that were not carried out, eg, no installation of interlocks switches, purchase of poor-grade personnel protective equipment (eg, for economic reasons) if he can prove in any way that he had asked for sufficient measures.

Legal Framework

Standards usually have no legal basis, but are rules for technical requirements. However, standards can be explicitly cited in rules and regulations, and are then authoritative.

Recommendations for users published by standardization organizations have no legal basis, as the behavior of users cannot be standardized. Thus, they are treated as rules or recommendations.

At present there is no law in Austria regulating laser safety for the user, except for laser pointers (BGBl. II Nr. 321/1999) and laser weapons (BGBl I Nr. 4/1998), but there are several laws for general occupational safety.

Remark: In Germany, the rule for accident prevention BGV B2 (former VBG 93) of the German employer's liability insurance association is used. This direction is based on EN 60825-1 and prescribes several mandatory rules for the user.

ACKNOWLEDGMENT

The present chapter is broadly based on the paper "Lasersicherheit in Industrie und Technik", 2003, by Dr. Georg Vees, Austrian Research Center, Seibersdorf.

Contact address: Dr. Dr. Franziska Beer, Dental School, University of Vienna, Währingerstrasse 25 a. A-1090 Vienna. Austria. Fax: 0043-1-427767059. e-mail: franziska.beer@esola.at