Complementary directive to the LEX 1.5.1: Control of laser risks

1 Introduction

A laser is a source of monochromatic and highly collimated light; as such, its energy can be easily focused into a micron-size spot, causing severe damage to health and property. Lasers are grouped in four classes according to the damage their radiation can induce, from class 1 (harmless) to class 4 (harmful to the eye and skin and able to cause a fire). See Appendix 1: Summary of laser classes. Damage to the eye can occur not only from direct viewing of the laser beam, but also when the laser beam is specularly reflected (class 3B and 4 lasers) or scattered from a surface (class 4 lasers).
This directive is based on the norm SN EN 60825-1:2014 "*Safety of laser products – Part 1: Equipment classification and requirements*" and the SUVA information sheet on lasers "*Caution: laser beam*" 66049.e:2016. It applies to **all lasers belonging to class 3B and 4** that emit radiation in the wavelength range from 180 nm to 1 mm at the Ecole Polytéchnique Fédérale de Lausanne.
Specific recommendations concern the following lasers:

- Embedded laser products;
- Class 3R lasers;
- Class 1M and 2M lasers used with optical instruments.

These are listed in Appendix 2: Special cases.

All dispensations from this directive must be approved by the DSE – Occupational Health and Safety (DSE-OHS)[1].

[1] E-mail address: ohs-pr@epfl.ch

2 Classification

Lasers must be marked clearly according to their classification:

- Commercial laser systems are classified and marked by the manufacturer.
- Lasers made in-house or modified laser systems must be classified by the researcher responsible for the setup, with the support of the DSE-OHS[2].

3 Laser registration

The DSE-OHS owns a database of existing lasers at EPFL and safety audits are done regularly. Instalation of **new** lasers belonging to class 3B or 4 must be announced[2] to DSE-OHS to ensure that all the requirements of the present directive are satisfied.

4 Safety measures

Safety measures vary according to the specific laser used, the experimental configuration (see Appendix 3, *Figure 1*, and *Figure 2* for some examples), and the degree of training of the users. They comprise technical measures (e.g., interlocks, beam confinement), organizational measures (e.g., training, access restriction), and personal protective measures (e.g., laser safety goggles and skin protection). The safety of all personnel entering the laser hazard area[3] must be ensured at all time.

4.1 Safety measures provided by school infrastructure

a. Access to the lab is restricted to authorized personnel only, using an access control system. The doors of the laboratories must be automatically closing ones.
b. A doorbell must be installed near the door so that visitors can ask permission to enter.
c. An illuminated laser warning sign with a LED-based blinking white light must be installed above the door (see Appendix 4: Laser warning sign). Preferably the light is automatically activated as soon as the laser is on. Otherwise, it must be manually activated before turning the laser on.
d. The entrance must have an "airlock" configuration (SAS, see Appendix 3, Figure 4a for an example), with at least a laser-proof protection curtain preventing direct laser radiation from reaching the door.
e. If any window is present in the laboratory, it must also be protected with a laser-proof protection curtain to avoid stray laser beam outside the laboratory.
f. Installation of emergency stop switch is recommended. It should be situated in the "SAS" (see point c. and Appendix 3, Figure 4a) or close to the entry.

[2] Open a request for safety support at: go.epfl.ch/support-ohs

[3] The laser hazard area is defined as the "area in which the exposure of the eye and/or the skin exceeds the respective maximum permissible exposure values (MPE)". The MPE is a "level of laser radiation to which, under normal circumstances, person may be exposed without suffering adverse effects" (SN EN 60825-1:2014).
Considering the size of EPFL laboratories, the laser hazard area corresponds to the entire laboratory with open beam configuration.

4.2 Safety measures organized by the research group

4.2.1 Technical measures

a. All optical elements and shields must be fixed to the optical table (see Appendix 3, Figure 3a)
b. Beam stops (blocks, traps) must be used as terminal pieces of laser optical systems. The heat dissipation system of the beam stops must be compatible with the laser output power.
c. The beam must run parallel to the plane of the optical table, and screens compatible with the beam power and wavelength must be used to confine it to the area of the table (see Appendix 3, Figure 1, and Figure 2 for some examples).
d. The beam plane must be at a level lower than the eye level of a person in a sitting or standing position. Lab furniture must be selected accordingly (see Appendix 3, Figure 3b).
e. If a vertical beam path is necessary, the beam must be fully enclosed with screens compatible with its power and wavelength.
f. If there is more than one laser, confinement of each beam individually is recommended.

4.2.2 Organizational measures

a. Access to the laser hazard area is granted after passing the Phase 1 training (see Appendix 5: Training for more details).
b. Visitors and personnel who have not passed the Phase 1 training are allowed to enter only under the supervision of a trained user.
c. All curtains (entrance doors and windows) must be closed before switching on the laser.
d. Watches and jewelry must be removed (put in a pocket or out of the hazard area) before working with lasers to avoid undesired reflections. Use only tools and instruments with dull surfaces.
e. The beam path must be free of flammable objects.

4.2.3 Personal protective measures

a. Laser protective eyewear must be worn by all personnel present in the laser hazard area[3] depending on the laser used. Additionally, the following organizational measures regarding laser protective eyewear apply:
   - Certified goggles (EN 207 or EN 208) must be available in each laboratory appropriate to the laser wavelength and power used, and in sufficient number for the occupancy of the laboratory.
   - There must be a dedicated shelf or box for laser protective goggles at the entrance of the laboratory.
   - When more than one laser is present in the lab, laser protective googles must be labeled with the name of the laser they are used for (see Appendix 3, *Figure 4*b).
   - The group is responsible for purchasing[4] and maintaining goggles.
   - To verify if goggles already in use are suitable for a specific laser system, contact the DSE-OHS[2].
b. Direct beam exposure must always be avoided, even when wearing eye protection.

[4] Protective eyewear suitable for the laser system used must be purchased from the laser goggles supplier. The expense is the responsibility of the research group.

c. For some laser installations covering wide wavelength ranges, there are no filters/ safety glasses suitable for the whole range. In this case, it is necessary to choose the most convenient glasses and to adapt the working procedures. For help, contact[2] DSE-OHS. Only personnel duly trained for this situation (e.g., senior staff, laser service technicians) are authorized to perform the needed tasks and are allowed to be present in the lab.
d. When working with UV lasers, where scattered reflections cannot be well shielded, contact[2] DSE-OHS for advice on appropriate skin protection.

5 Behavior to adopt in case of accident

a. Call 115 (021 693 3000 from a mobile)
b. Turn the laser off (the fastest way is to press the emergency stop button if there is one).
c. Sit the injured person (do not lie). Place a dry and sterile gauze on both eyes.
d. Note the characteristics of the laser (wavelength and power) so they can be given to the first aid staff.
e. First aid staff will take the injured person to the ophthalmic hospital.
f. Announce the incident or near miss[5] (used exclusively for an analysis, safety improvement, and lessons learning.)

[5] Link is available at: go.epfl.ch/lab-safety

Appendix 1: Summary of laser classes

Table 1 Laser classes based on the SUVA 66049.f and SN EN 60825- 1.

Class	Explanation	Personal equipment
1	Radiation emitted by the laser is not hazardous.	No protective equipment is necessary.
1M	Safe for the eye when used without optical instruments. It can be hazardous when used with optical instruments. Wavelength range between 302.5 nm and 4000 nm	No protective equipment is necessary. When used with optical instruments, safety goggles are recommended.
1C	Radiation emitted by the laser can correspond to class 3R, 3B or 4 but the beam is focused only on the target and protection measures ensure that the radiation does not exceed the values for class 1. Usually these are employed for the medical/cosmetic treatment of skin and tissues.	No protective equipment is necessary.
2	Safe for the eye for exposures shorter than 0.25 s. This class exists only in the visible range (wavelength between 400 nm and 700 nm).	No protective equipment is necessary.
2M	Depending on the divergence and widening of the beam, it can be hazardous when used with optical instruments. The wavelength range is between 400 nm and 700 nm.	No protective equipment is necessary. When used with optical instruments, safety goggles are recommended.
3R	Radiation emitted by the laser can correspond to up to five times the emission limit for Class 1 (invisible radiation) or Class 2 (visible radiation) lasers. Safe as long as direct beam viewing is prevented.	Safety goggles are mandatory if laser is in the non-visible range.
3B	Looking directly into the laser beam and specular reflection is harmful. Hazardous to the skin. Diffuse reflections are classified as not hazardous.	Safety goggles are mandatory.
4	Looking directly into the laser beam and specular reflections is harmful. Exposure to diffuse reflections is also harmful for the eyes. Hazardous to the skin. It can provoke fire.	Safety goggles and long sleeves are mandatory.

Appendix 2: Special cases

Embedded laser product

According to the norm SN EN 60825-1:2014, an embedded laser product is defined as "a laser product which, because of engineering features limiting the accessible emission, is of a class lower than the inherent capability of the laser incorporated".
If the embedded laser system belongs to a class lower than 3B, this directive is not applicable even if the laser incorporated in the embedded laser products belongs to a class equal to or higher than class 3B.

Class 3R

Personnel working with lasers belonging to class 3R in the invisible range (180 nm - 400 nm and 700 nm – 1 mm) must contact the DSE-OHS[2] for instructions.

Class 1M and 2M used with optical instrument

For these lasers, optical instruments or optical experiments can lead to an increased hazard.
Two typical cases are:
A laser beam passing through a system containing an optical microscope with an eyepiece. The person looking into this eyepiece is then exposed to the laser beam.
A laser beam being focused on a small (diffraction-limited) spot, where its power density can cause a fire hazard.
The researcher must take care either to avoid such configurations or to take measures to ensure safety. As an example, in the first case, removing the eyepiece and using a video camera can reduce the risk.

Appendix 3

Illustration of technical and organizational safety measures

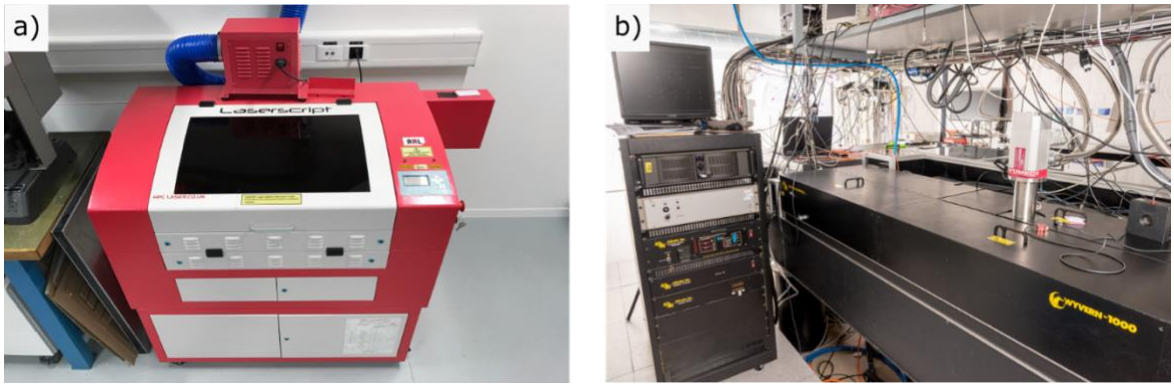

Figure 1 a) Embedded laser product with interlock; b) home-made closed setup without interlock.

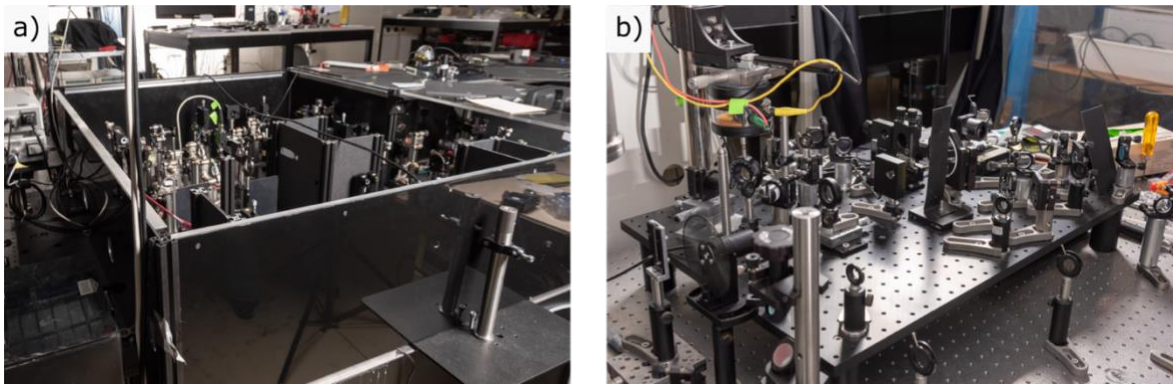

Figure 2 a) Partially closed experimental set-up; b) open experimental setup.

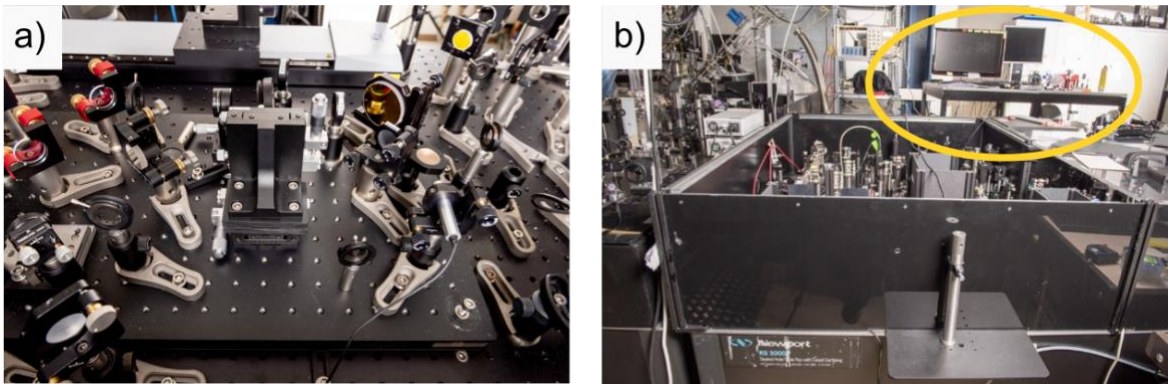

Figure 3 a) optical elements fixed to the optical table; b) lab furniture chosen as to avoid having the beam plane at the eye level of a person in a sitting or standing position.

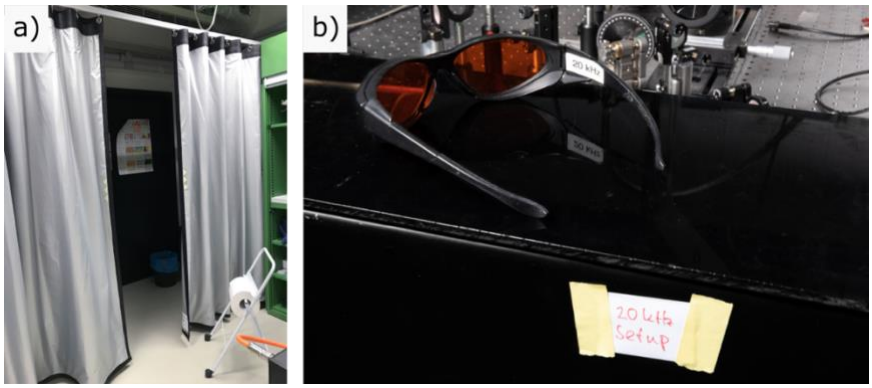

Figure 4 a) Airlock configuration (SAS); b) Correctly labeled laser safety goggles.

Appendix 4: Laser warning sign

Figure 5 Laser warning panel. White background, red letters and ISO 7010 warning sign.

Appendix 5: Training

To work with lasers class 3B and 4, a user must complete the Phase 1 training beforehand. This training consists of **two distinct** mandatory parts:

- **Equipment-specific training** organized by the group.
- **General laser safety training** organized by the DSE-OHS.

Equipment-specific training:
The laboratory head is responsible for organizing the equipment-specific training, usually given by senior staff. Users must be instructed about the laser setup they will use and the safety measures specific to the laboratory. The group must keep written evidence of the given trainings.

General laser safety training:
This can **either** be in a **classroom** or **online**. Either way, the training is followed by a test whose success requires a score ≥ 80 %.
The content of the classroom laser safety training is similar but more comprehensive than the content of the online training. Therefore, the user should **prefer the classroom training** if it is not scheduled too far away from his/ her activity start date.

The classroom training calendar and link to the Online training are available on the **Laser hazard/User training** section of the DSE-OHS website[6].

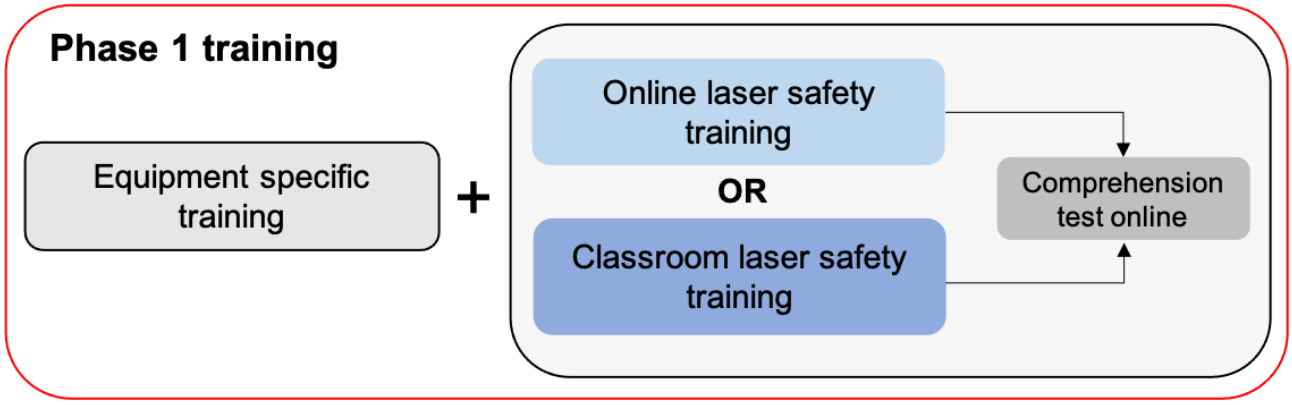

Figure 6: Schematic diagram of the Phase 1 training.

[6] Available at: go.epfl.ch/laser-hazards