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Activities involving lasers at PSI

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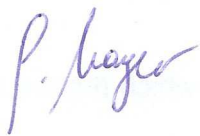
Summary:

This general directive outlines the most important statutory and operational instructions concerning activities which involves lasers at the Paul Scherrer Institute, and governs the relevant responsibilities. It also refers to basic codes of conduct adopted to protect personnel from the hazards presented by lasers.

This directive is structured in line with the various uses of lasers at the Paul Scherrer Institute, and therefore provides each individual with information about his/her responsibility with respect to activities involving lasers at the Institute.

This directive is obligatory for every person working at the Paul Scherrer Institute.

Following the form of wording used in the statutory texts, personal descriptions are often shown in the masculine form only. All descriptions always apply equally to women.

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1. General

The directive on laser safety at PSI is based on the Suva Pro information sheet on lasers (“Achtung Laserstrahl” – “Danger, laser beam”), the EKAS (Swiss Institute of Safety and Security) Guideline No. 6502 on laser radiation (“Laserstrahlung”) and the VDE standard on the safety of laser equipment (DIN EN 60825 and VDE 0837, “Sicherheit von Laser-Einrichtungen”).

2. Laser safety: Definition of laser classes

In 2001, the laser classes have been redefined. The definitions used in this document are based on DIN EN-Norm 60825-1. Therefore the laser Class 3A is omitted.

These definitions of laser classes are only provided for the information of the operator. Commercial laser systems are classified by the manufacturer, whereas systems installed by the operator are classified by that operator in conjunction with the safety officer and the official laser expert.

2.1. Class 1

In Class 1, the accessible laser emission is not hazardous under any conditions that might reasonably be foreseen.

- *The reasonably foreseeable conditions will be maintained if the system is operating as intended.*
- *Under DIN EN 60825-1:2001-11, the accessible emission limit stays the same in the wavelength range 400nm to 1400nm for any time from 100s to 30000s for laser classification. Minor damage or irritations from long term exposure can therefore not be excluded.*

2.2. Class 1M

The accessible laser emission lies within the wavelength range of 302.5nm to 4000nm. The accessible laser emission is not hazardous to the eye, as long as its cross-section is not reduced by optical instruments (magnifying glasses, lenses or telescopes).

- *As long as no focusing instruments are being used to reduce the cross-section of the beam, the level of hazard for laser equipment in Class 1M is comparable to that of laser equipment in Class 1.*
- *If focusing instruments are being used, levels of danger comparable to Class 3R or 3B may arise.*

2.3. Class 2

The accessible laser emission lies within the visible spectrum (400nm to 700nm). It is not hazardous, even to the eye, as long as the exposure time is short (up to 0.25s). Any additional emission components outside the 400nm to 700nm wavelength range meet the requirements for Class 1.

- *For Class 2 lasers there is no danger to the eye from accidental, short-term (i.e. up to 0.25s) exposure to laser radiation . Class 2 laser equipment can therefore be used without any additional protective measures, as long as there will definitely be no requirement to look deliberately into the laser beam for longer than 0.25s, or to look repeatedly into the laser beam or reflected laser beam.*
- *It should not be assumed that eyes will be protected by the blink reflex.*

2.4. Class 2M

The accessible laser emission lies within the visible section of the spectrum (400nm to 700nm). There is no danger to the eye if the exposure time is short (up to 0.25s), as long as the cross-section of the beam is not being reduced by optical instruments (magnifying glasses, lenses or telescopes). Additional emission components outside the 400nm to 700nm wavelength range meet the requirements for Class 1M.

- *As long as no focusing instruments are being used to reduce the cross-section of the beam, the level of hazard of laser equipment in Class 2M is comparable to that of laser equipment in Class 2.*
- *If focusing instruments are being used, levels of danger comparable to Class 3R or 3B may arise.*

2.5. Class 3R

The accessible laser emission lies within the wavelength range of 10⁶nm to 302.5nm and is dangerous to the eyes. The *output power / energy levels* amount to a maximum of five times the permissible emission limit for Class 2 in the 400nm to 700nm wavelength range.

- *Class 3R laser devices are potentially just as dangerous to the eye as Class 3B laser devices.*
- *The risk of eye damage is reduced because the permissible exposure limit (PEL) in the visible wavelength range is restricted to five times the permissible exposure limit for Class 2; in the other wavelength ranges, it is restricted to five times the permissible exposure limit for Class 1.*

2.6. Class 3B

The accessible laser emission is dangerous to the eye. It is also frequently dangerous to the skin. It is dangerous to look directly into the beam of Class 3B lasers. A beam can be viewed safely via a diffuse reflector as long as the following conditions also apply:

- a) The minimum observation distance between screen and cornea must be 13cm;
- b) The maximum observation time is limited to 10s;
- c) It must be impossible for directional emission components to appear and enter the eye.

A beam can only be observed via a diffusing light screen if no directional emission components are generated. Accessible laser emission from Class 3B laser equipment poses a danger to the skin if the maximum permissible exposure values are exceeded.

2.7. Class 4

Accessible laser emission is extremely dangerous to the eye and is also dangerous to the skin. Diffusely scattered radiation can also be dangerous. This laser emission can cause a fire and explosion hazard.

- *Class 4 laser devices are high-performance lasers with output power / energy levels that exceed the permissible radiation for Class 3B.*
- *The laser emission from Class 4 laser devices is so intense that damage must be anticipated to occur as a result of any type of exposure of the eyes or the skin.*
- *When using Class 4 laser devices, sufficient means of control to safeguard against the risk of fire and explosions have to be implemented.*

2.8. Summary of the classes

The different laser classes are summarized with comments in Table 1.

Class	Basic Concept	Comments
1	Radiation emitted by the laser is not dangerous.	No protective equipment necessary.
1M	Safe for the eye when used without optical instruments. Can be dangerous when used with optical instruments.	No protective equipment necessary, unless used with optical instruments.
2	Safe for the eye for exposures shorter than 0.25 sec..	No protective equipment necessary.
2M	Light pervading the eye pupil is equivalent to a laser class 2. Depending on the divergence and widening of the beam, it can be dangerous when used with optical instruments.	No protective equipment necessary, unless used with optical instruments.
3R	Exceeds the MPE-value. Radiation is up to five times higher than the PEL-value for class 1 (or class 2). Risk is lower than class 3B.	Dangerous to the eye, safety goggles recommended.
3B	Equivalent to the former class 3B without 3R. Looking directly into the laser beam is dangerous. Diffuse reflections are classified as not dangerous.	Dangerous to the eye, safety goggles mandatory.
4	Equivalent to the former class 4. Looking directly into the laser beam is dangerous. Exposure to diffuse reflections is equally dangerous. Additional risk of fire and danger to the skin when exposed to laser irradiation.	Personal protective equipment mandatory (safety goggles, lab coat, screening)

Table 1: Laser classes (MPE = maximum permissible exposure, PEL = permissible exposure limit) (table based on the „Handbuch zum Laserschutz“, p 12, Laservision GmbH und Co. KG, Siemensstrasse 6, D-90766 Fürth)

3. Risks associated with activities involving laser radiation

The risks associated with activities involving laser radiation can be divided into direct and indirect risks. Direct risks arise when the beam hits the eye or the skin directly; these are summarized in Table 2 as a function of the wavelength of the laser. Damage may occur to the retina, cornea, lens (clouding of the lens = cataract) or a particularly sensitive section of the retina, the fovea (responsible for color vision and clarity of vision), depending on the wavelength. UV radiation can lead to skin aging and skin cancer.

Table 2: Direct risks associated with laser radiation

CIE BAND	UV-C	UV-B	UV-A	VISIBLE	IR-A	IR-B	IR-C	
wavelength (nm)	100	280	315	400	760	1400	3000	10 ⁶
ADVERSE EFFECTS	PHOTOKERATITIS = Snow blindness		CATARACTS		RETINAL BURNS	CORNEAL BURNS		
	ERYTHEMA = Sunburn		CATARACTS		COLOR VISION NIGHT VISION DEGRADATION			
THERMAL SKIN BURNS								
Laser Light Wavelengths								

Attention must be paid to the indirect risks associated with laser radiation in particular in the case of Class 3B and 4 lasers, which are connected to the following risks:

- *Electrical risks associated with the main power supply of the laser. The most common cause of fatal injuries associated with a laser is contact with the electricity supply system.*
- *Risk associated with fire or explosions: Causes are the flashbulbs in the lasers or irradiation of inflammable objects.*
- *Risks caused by laser dyes: The dyes have varying levels of toxicity or mutagenicity, while solvents may be inflammable or toxic.*
- *Collateral irradiation: This may involve UV, microwave, radio-frequency or X-ray radiation.*
- *Laser-generated particles: These particles may be chemical or biological hazards. If, for example, your experiments could generate any of these particles by laser ablation (structuring, cutting, etc.), please contact the responsible safety officer.*
- *Other risks: These might involve toxic substances (e.g. halogens, CO, beryllium oxide, etc.), pressurized containers, noise or refrigerant.*

4. Controlling the laser risks

Various options are available to safeguard against and control risks arising from lasers, as listed below in order of priority:

1. **Engineering control:** This involves equipment that minimizes or even eliminates the risk as much as possible. The equipment might be installed by the manufacturer or operator of the laser. For example: housing (highly recommended), interlocks (at the laser itself or at the entrance door), key control (laser or control equipment) that only allows authorized personnel to access the laser.
2. **Administrative controls:** These minimize the risks by means of instructions, directives and protocols. Examples are: Operating instructions, restrictions who is permitted to enter the laser zones, labeling, laser safety training.
3. **Individual protection measures:** These should be used in addition to the engineering and administrative controls. Examples are: laser safety glasses, laboratory coats and gloves. All safety glasses must meet the requirements of the European standards (EN 207, EN 208 for laser equipment only, or EN 60825 – but only if no EN 207 safety glasses are available). Operators of femtosecond lasers should note that special requirements apply to these lasers in particular (e.g. not just safety glasses, but also laser safety curtains) taking into account the laser bandwidth and the rapid changes to the protection level caused by the laser radiation. For example, only specified and certified safety glasses should be used in goggles.

5. The duties of laser operators at PSI

5.1. Design

For class 3B and class 4 lasers, the laser must have an interlock for the coupling of safety devices.

5.2. Labeling

Laser equipment involving accessible emissions must be labelled (see Figure 1).

- Laser warning labels must be fitted to all lasers of Class 2 or higher.
- Labels indicating the Class of the laser, with class-specific warning text (from Class 1M upwards)
- Laser data plate
- Type plate

- Additional labels must be fitted near the laser exit points for Class 3B and Class 4 laser equipment, i.e. an additional laser warning label, and a label carrying the following text
 - Laser beam opening, and/or
 - Opening for invisible laser beam, or
 - Avoid irradiation/Exit point for laser beam, or
 - Exit point for invisible laser beam.



Figure 1: Laser labeling plates

Signs from the first row in Fig. 1 have to be placed at the entrance of the laser zone and at the laser itself. Signs from the second row in Fig. 1 are for labeling at the laser only.

- If any sections of the protective housing can be removed or if their positions can be altered, causing more powerful laser radiation than Class 1 to be accessible, these sections must be labeled with the appropriate warning text and the relevant Laser Class.

5.3. Class-specific safety precautions

The operator has the duty to carefully study the operating instructions supplied with the equipment before putting the equipment into use for the first time, and to obey the instructions strictly. The provisions regarding safety at work (Art.82 of the Swiss law governing insurance against injury, the “Bundesgesetz über die Unfallversicherung”, SR 832.20, and Art.3 of the Swiss ordinance on the prevention of accidents and occupational diseases, SR 832.30) require all operators to take all the necessary measures with regard to safety and health protection at work, and to check that they are maintained. The operator must observe the PSI “General directive for activities involving lasers at PSI”.

- Class 1:
 - ☞ None.
- Class 1M:
 - ☞ Special warning/advice to people who are able to use optical instruments.
- Class 2:
 - ☞ Do not look into the beam.
 - ☞ Do not deliberately point the beam at people.
- Class 2M:
 - ☞ Do not look into the beam.
 - ☞ Do not deliberately point the beam at people.
 - ☞ Special warning/advice to people who are able to use optical instruments.
- Class 3R:
 - ☞ Post a safety sign.
 - ☞ Avoid direct irradiation of the eye, i.e. do not let the beam stray to eye level, irrespective of people standing or sitting.
 - ☞ Remove or cover any reflecting objects within the radiation area.
 - ☞ Restrict the beam as much as possible at the end of its intended travel (e.g. install a screen).
 - ☞ Protect out-of-operation lasers from access by unauthorized people
- Class 3B and 4
 - ☞ Lasers of Classes 3B and 4 may only be operated within a restricted laser zone. The operator must ensure that no unauthorized people can be irradiated and the necessary safety precautions have to be taken. Access to the laser zone must be controlled (e.g. with a badge reader).
 - ☞ A warning light must be installed at each entrance point to the laser zone. This light must switch on automatically whenever the laser is in operation.
 - ☞ Safety rule: the person operating the beam release switch must only allow the laser beam to exit if they have made sure that all those present are wearing the correct protective equipment and that no outsiders can find their way into the laser zone by accident.
 - ☞ Emergency stop-switches (power or shutter) are recommended.

5.4. Operating procedure

A written operating procedure for the operation of a laser must be prepared, starting with Class 3R lasers. An example of an operating procedure is given in Appendix 1. This procedure must be posted clearly visible at the entrance of the laser area. The operating procedure must contain the following information:

1. Labeling of the laser
2. Description of hazards
3. Protection measures and rules of conduct
4. Behavior in case of failure or emergency
5. Behavior in the event of an accident
6. Procedure for maintenance
7. Name of the person responsible for the laboratory (including OG-unit)
8. Date and signature of the person responsible for the laboratory or laser setup

In case several lasers are operated in the same room by only one group but not at the same time, only one operating procedure is sufficient. Otherwise, every laser needs its own operating procedure.

5.5. Miscellaneous

All laser systems from class 3R must be checked for safety by the PSI laser expert or his deputy before operation is allowed.

Major changes must be reported and require a new review by the PSI laser expert or his deputy.

Only trained personnel may operate or work with lasers. The training is regulated in Chapter 6. The laser responsible has to ensure that the instructions are in place and followed.

The laser responsible defines, who is eligible to enter the laser operating area. He must ensure, that the people operating the lasers have been instructed as outlined in Chapter 6.

5.5.1. Registration

Laser facilities class 3R or higher must be registered with the safety officer. The form of registration must contain the following information:

1. Description of the device or facility
2. The classification of the laser (Class 4, 3B, 3R).
3. Laser medium
4. The output of the laser, with units
5. Wavelength or wavelength range
6. Operational mode: continuous wave (CW) or pulsed (pulse length)
7. Radiation energy
8. Location (building / room)
9. Name of operator/person responsible and a deputy
10. Organizational unit

The laser owner must complete the registration.

The registration form has to be filled in the intranet using the following link:

<http://sicherheit/Laseranlagen/Forms/AllItems.aspx>

After registration, the supplied registration plates have to be placed clearly visible and accessible at the laser.

PSI does not assume liability for unregistered laser.

5.5.2. Procuring the laser safety equipment

- The control element for coupling of all safety and warning devices can be obtained for PSI-West from the *Section Electrical Systems* (9330), and PSI-East from *Section Electrical Maintenance* (9340).
- Laser warning lights are available via the “*Sicherheitszentrale*” (SIZ).
- For installation and ordering of badge readers, contact the SIZ.
- Suva laser labels can be ordered via the ASI Safety Section.
- Laser safety glasses and laser safety curtains can be ordered from various companies (Laser Vision etc.).
- The operators of the laser facilities are responsible for the costs of the laser safety measures.
- Compliance with the safety measures is compulsory in existing laser facilities. The official laser expert must be consulted about any uncertainties. The operators of the facilities are responsible for implementation of and adherence to the instructions.

6. Training / instruction

The operation of laser facilities at PSI is prohibited without instructions starting with class 1M lasers and it is prohibited without training and instructions starting with class 3R lasers. The responsibility for the control of the laser-training lies with the line managers (for the PSI personnel) or with the PSI supervisor (for external staff).

The laser training at PSI is done in 2 steps:

6.1. Step 1: User-specific instruction

The laser owner has to carry out and to log the user-specific instruction. With this instruction, the specific laboratory conditions and operating procedures for safe laser operation are instructed.

These instructions have to be renewed on an annual basis.

6.2. Step 2: Training

The training provides the basic information of the risks while operating lasers and safe operation procedures when working with lasers. The training is offered twice per year or is carried out by the PSI laser experts if required. The training will be registered. The training is published in the course catalog of the *PSI Training Center*.

This training has to be renewed every three years.

7. Operation of lasers at PSI owned by external users

Lasers from external users, which remain longer than 1 month at PSI, have to be registered (see Chapter 5.5.1).

7.1. Users with their own lasers at a beam line

Users, who wish to bring their own lasers for experiments, must declare this at the proposal submission. In such cases, the experiment can only be carried out at a beam line which is equipped for safe laser operation and warning components according to the class of the laser.

7.2. User with their own lasers not at a beam line

The operation of lasers from users outside PSI is only allowed in areas which are equipped for laser safety equipment and warning components according to the class of the laser. The PSI supervisors ensure that the laser user follows the PSI guidelines for laser safety instructions. The laser safety expert advises on matters of laser safety.

8. PSI laser expert

8.1. Basic principles

- AW-01-07-02e, Safety, Health Protection and Environmental Protection at PSI.
- EKAS Guideline 6508 on consulting occupational physicians and other specialists in safety at work (ASA guideline) [the "Richtlinie über den Bezug von Arbeitsärzten und anderen Spezialisten der Arbeitssicherheit" (ASA-Richtlinie)].

8.2. Areas of activity

- The drafting and application of the regulations for lasers, in collaboration with the safety officer.

8.3. Duties

- Responsibility for the drafting and application of the regulations for lasers at PSI.
- Appointment of a deputy in consultation with the safety officer.
- Appointing a sufficient number of people with partial responsibility for lasers at PSI. Responsibility for maintaining the standard of their training.
- Function as PSI laser expert.

8.4. Competences

The holder of this post is authorized to:

- Issue directives on the use of lasers at PSI, in consultation with the safety officer.
- Prohibit the use of lasers at PSI, in consultation with the safety officer if statutory provisions and/or Suva or EKAS guidelines have not been observed, or if the risk seems too high in his/her opinion. Prohibition in the latter case is permitted without previous consultation with the safety officer if there is any immediate danger.
- Delegate part of his/her responsibility as official laser expert to suitable people with partial responsibility for lasers at PSI, in writing and by agreement with the safety officer.
- Request information about the operation of lasers from all the people dealing with lasers at PSI.
- Communicate independently, verbally and in writing, with the authorities and other external offices, by agreement with the safety officer as long as this does not result in any legal or financial obligations on the part of PSI.

8.5. Line of reporting for specialist subject, official channels

8.5.1. Line of reporting for specialist subject

The holder of this post is responsible to the safety officer with respect to his/her duties as “PSI laser expert”. He or she must report to the safety officer.

8.5.2. Official channels

The “PSI laser expert” has direct chains of command to the line units to fulfill his/her specified duties.

Laser operating procedure

PSI Registration number:	Location:	PSI organizational unit:
Person responsible / Phone:	Deputy / Phone:	

Laser specification

Class:	Medium:	Manufacturer:
Wavelength:	Power:	Type:
Emission / pulse:	Energy:	Serial number:

Dangers for humans and environment



- Laser with class 3R, 3B and 4 are very harmful to eyes and skin!
- The interaction of the laser beam with certain materials can release harmful substances, explosions can be triggered, and fires can start.

Protective measures and rules of conduct



- The laser-protected area cannot be entered without safety goggles when the warning light is on!
- The operating staff must be trained for safe laser operation.
- Upon entering the laser-protected area, appropriate safety goggles must be used, which are certified for the wavelength and power of the used laser!
- When the laser is not needed, the laser should be switched into stand-by mode or turned off, if possible!
- Personnel which are not directly working with the laser, should stay away from the optical devices (largest possible distance)!
- Undesired reflections should be avoided. If possible, tools and instruments with dull surfaces or with black foil wrapping should be used.
- The setup must be surrounded as much as possible with shields, when reflective tools are used.
- The beam should be operated as much as possible in tubes.
- Beam lines that run on table or similar level must be shielded or marked!
- Beam lines that run on eye level, must always be shielded!
- Optical setups must be secured by screws to prevent uncontrolled movements!
- The beam line must be blocked, if it is necessary to come with the eyes to the level of the laser beam.

Behavior in case of danger



- The PSI expert for lasers or safety officer and the person responsible for the laboratory or beam line must be immediately informed.
- Work on equipment or parts with live voltage is only allowed for qualified electricians or service technicians!
- Work on equipment or parts non-carrying live voltage can be done only by qualified personnel!
- **In case of fire: keep calm! Call the fire department on 3333!**
- Warn people! If necessary activate the fire alarm.
- Inform the person who is responsible for the laboratory or beam line.
- Fight the fire with powder, CO₂ or foam fire extinguisher!
- Pay attention to self-protection.

Behavior in the event of accident, first aid



- **Call 3333, which will send medical service, who will determine the next medical steps.**
- Turn off the laser!
- Look after injured person!
- Inform the person who is responsible for the laboratory or beam line, the PSI laser expert and safety officer!
- In the case of eye injuries, consult immediately an eye specialist.
- The system can only be turned on again with a written release by PSI laser expert, his deputy, or the security officer.

Maintenance, care and disposal

- Maintenance can only be performed by qualified persons!
- The safety instructions for maintenance procedures in the documents of the manufacturer must be followed!

Date:	Signature of laser expert:
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