Fachhochschule
Münster University of
Applied Sciences

Laboratory Policy

Fachbereich
Physikalische Technik

Labor für Photonik
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www.photonics-lab.de

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1. Smoking, foods and drinks, especially alcoholic, are forbidden in the laboratory room.

2. Before starting to work, everybody using the laboratory room has know the location of main and emergency electric switches, fire extinguisher and first-aid box.

3. Be careful dealing with laser radiation! Never look directly into a laser beam! In particular take notice of the „*Instruction about eye hazard due to intensive light sources, especially laser light*“. You have to take off wrist watches and jewellery in order to avoid laser reflections.

4. Before a staff member puts a laser into operation, she/he has to make sure that all people in the room carry laser safety glasses with appropriate degree of protection and are informed about laser radiation hazards. Moreover, the door and the protection devices at the windows have to be closed. The laser warning light above the door must be switched on.

5. During laser operation, office work has to be done in other rooms.

6. During operation of laser devices, visitors are only allowed to enter the room after a short instruction. In addition they have to carry laser safety glasses with appropriate degree of protection.

7. If you are setting up electric circuits, the voltage supply must be connected only after all other assembly work is finished. In the case of disassembling, the voltage supply must be disconnected first. The electric leads have to be arranged in a way avoiding disconnection due to unintended motion.

8. Each person performing work at experimental setups is committed to make sure that no electric voltage is applied. Working with connected voltage is forbidden.

9. The emergency shutdown equipment must always be accessible. If emergency shutdown has been released, only scientific personnel are allowed to activate the emergency shutdown equipment again. Emergency exits (doors and windows) generally have to be kept free.

10. In the case of a suspected electric accident, i.e. human body perfusion by an electric current, a physician must be contacted immediately. If necessary, life sustaining measures are to be initiated.

11. In the case of a suspected optical accident, i.e. looking into an intense light source, an ophthalmologist must be contacted immediately (performing fluorescence angiography). Also the supervisor must be informed. Apart from the safety regulations, constituted by GUV-V B2 (as from 2007), are valid for each laboratory user. They can be inspected in the laboratory room.

12. In the case of fire all laboratory users have to leave the building and go to the gathering place (parking area).

13. Instructions for the last one leaving the laboratory room:
    - close windows and doors
    - switch of laser equipment
    - switch off cooling water systems
    - switch off electrical power supplies
    - switch of computers
    - switch off measurement devices
    - close dust covers

14. New optical components shall be labeled by a scientific member of the laboratory (mark with a pencil in the edge area).

15. Optical components are to be handled properly and cleaned before putting back.

16. Components, setups, devices and tools shall be put back to the original place after using.

17. Optical components and setups are allowed to be removed from an experiment only in agreement with the staff member being responsible.

18. In dealing with chemicals for cleaning (acetone, methanol) avoid contact with eyes, skin and clothes as well as extended and repeated exposure. Hence, storage vessels have to be closed immediately after use. Note that these chemical substances are highly flammable and toxic!

Additional rules for students, student assistants and interns:

19. Entering the laboratory rooms (H-18, H-03, H-04, and H-05) is allowed only during the presence of a scientific laboratory member or after express request.

20. The use of devices is allowed only in agreement with a scientific laboratory member. Young people below the age of 16 years (e.g. scholar interns) are not allowed to work with lasers of the laser classes 3R, 3B or 4. Young people aged between

16 and 18 years are only allowed to work with these lasers supervised by a scientific laboratory member.

21. During work with intense light sources, unwanted reflections have to be avoided, especially at the level of people’s eyes when they are sitting or standing. Unwanted reflections can occur at components of your own setup or neighbouring experiments.

22. During experimentation, working is only allowed on the allocated setup. Adjustment of light beams and changes of electric circuits are only allowed if the consequences are clearly reviewed. If unrecoverable disturbances occur, a scientific laboratory member has to be informed immediately. Autonomous opening of closed devices is forbidden.

23. After termination of the work, re-establish the initial state of the experiment and inform the scientific laboratory member.

24. If components or devices are defect or optical elements are contaminated, immediately inform a scientific laboratory member.

Instruction about eye hazard due to intensive light sources, especially laser light

Maximum permissible exposure (MPE) for laser exposure to the eye

The accident prevention regulation concerning laser radiation (GUV-V V2, 2007) provides maximum permissible exposure (MPE) values for laser exposure to the eye. These values are defined for various wavelengths and exposure times of the laser radiation (see table 1 and figure 1). If power density or radiant exposure is below the valid MPE value, permanent eye damage is not expected.

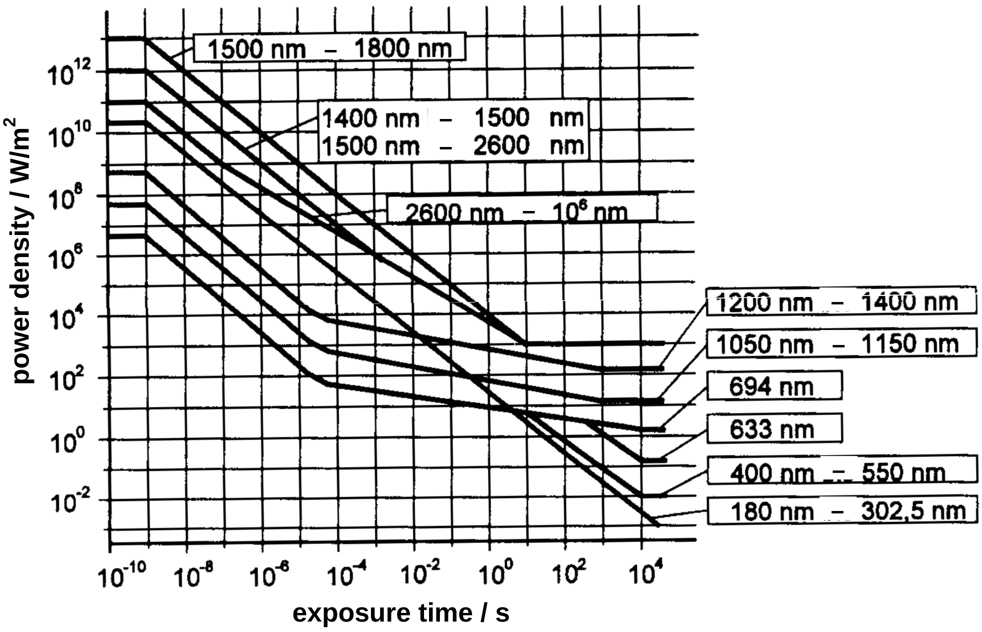

Fig. 1: Maximum permissible exposure (MPE) for laser exposure to the eye (corneal exposure) according to DIN EN 60 825-1 [source: BGV B2 A09, 2003]. Different wavelengths and wavelength intervals are shown.

wavelength range / nm	**power density E**				**radiant exposure H**	
	exposure time / s	W / m²	**exposure time / s**	W / m²	**exposure time / s**	J / m²
180 - 315	≥ 30 000	0,001	$< 10^{-9}$	$3 \cdot 10^{10}$	10^{-9} **to** $3 \cdot 10^{-4}$	30
315 - 1400	$> 5 \cdot 10^{-4}$ **to** 10	10	$< 10^{-9}$	$5 \cdot 10^{6}$	10^{-9} **to** $5 \cdot 10^{-4}$	0,005
1 400 - 10^{6}	> 0,1 **to** 10	1 000	10^{-9}	10^{11}	10^{-9} **to** 0,1	100

Tab. 1: Simplified MPE values for laser exposure to the eye (corneal exposure) [source: BGV B2 A09, 2003]

Example: In case of accidental looking (duration t with $0.05s < t < 1s$) into the beam of a Helium-Neon-laser (wavelength λ = 632.8 nm), the maximum permissible exposure (MPE) value for laser exposure (corneal exposure) is **10 W/m² = 10^{-3} W/cm².**

If laser irradiation exceeds the MPE, permanent and irreparable damage of the retina or the cornea can be induced! Extra hazardous are invisible laser radiation in the UV and IR spectrum (blink reflex is not being induced) and working in the dark (eye pupil is widened).

Laser power density on the retina

For estimating eye hazard, we assume an eye length of 24 mm and a pupil diameter of 7 mm (in the dark).

In case of a collimated incident light beam, the light is focused onto the retina due to the combined lensing effect of the curved cornea and the internal eye lens. For diffraction limited radiation, the size of the focus is determined by diffraction at the eye pupil. Hence, for the same power density at the cornea, laser radiation leads to essential higher power density on the retina than incoherent light. According to diffraction theory, we calculate the radius R of the diffraction-limited Airy disk:

$R = 1.22\,(f\,\lambda)/\,(nD)$

- λ: wavelength (= 632.8 nm for a He-Ne laser)
- f: focal length of the eye lens composed of cornea and internal lens (f=b=24 mm for collimated light)
- D: pupil diameter determining the diffraction limit (D=7 mm)
- n: index of refraction inside the eye (n = 1.4)

The irradiated surface area on the retina amounts to $A = \pi R^2 = 1.1 \cdot 10^{-7}$ cm² (Airy disk). Assuming a laser power of P = 1 mW, the resulting power density on the retina is E = P/A = **$9 \cdot 10^3$ W/cm²**.

Compare: In case of looking directly into the sun, the resulting power density on the retina is about **100 W/cm²**! The calculated laser power density exceeds this value by a factor of 90!

This comparison with only 1 mW of laser power illustrates the high danger potential of directly looking into a laser beam. Therefore, in order to prevent from eye damage one always has to follow this general principle:

Never look directly into a light source!

During work with lasers, additional threats are present due to by light reflections. In general, the light intensity is weakened by reflections. The fractional intensity after reflection on a glass surface is typically about 4% for normal incidence (water: about 2%). But, in case of a large angle of incidence, the fractional intensity can be much higher! Especially for intense light sources (e.g. lasers) even reflected light can cause retinal damage. Reflections at glass-air boundaries occur at all optical elements (e.g. lenses, filters, windows etc.). For that reason we have a second general principle:

Never look directly into light reflections!

Working with lasers, you always have to care for blocking unwanted reflected radiation in order to avoid hazards at your own work place as well as the surrounding working area. If you feel blinded, turn away your head immediately!

Additional threats from lasers devices:

Danger of fire and explosion
Toxic solvents
Flammable plastics
Toxic laser media (halogens, dyes, solvents)
Toxic substances set free during laser treatment (metal vapour, plastic vapour)
Electric hazards due to high voltage and potential leakage of cooling water

Laser classes

Lasers are classified by wavelength and maximum output power into four classes with appropriate subclasses. A laser is called “safe” if the maximum permissible exposure (see above) is not exceeded. Except for class 2 and 2M, the maximum permissible exposure values are calculated for 100 s and 30 000 s exposure time. The classification refers to the accessible laser radiation outside the device. This means that the laser power inside the laser device might be higher and the beam geometry might be different. So if the laser device is opened, the assignment of a higher laser class might be necessary.

New laser classes

Class 1: A class 1 laser is safe under all conditions of normal use. This means the maximum permissible exposure cannot be exceeded when viewing a laser beam with the naked eye or with the aid of optics (e.g. lenses, telescopes, magnifying glasses or microscopes).

Class 1M: The laser is safe for all conditions of normal use, except when the light passes through optics (e.g. lenses, telescopes, magnifying glasses or microscopes). The wavelength of the accessible laser radiation is in the range of 302.5 nm to 4000 nm.

Class 2: The laser is safe for exposure times of no more than 0.25 s (according to the blink reflex which is expected to limit the exposure time to about 0.25 s). The wavelength of the accessible laser radiation is in the range of 400 nm to 700 nm. Because often the blink reflex is not induced, one should turn away the head immediately in case of exposure to the eye.

Class 2M: The laser fulfils the safety conditions of class 2, except when the light passes through optics (e.g. lenses, telescopes, magnifying glasses or microscopes). In this case the laser is not safe.

Class 3R: If the eye is exposed directly by a class 3R laser, the maximum permissible exposure can be exceeded. The wavelength of the accessible laser radiation is in the range of 302.5 nm to 10^6 nm. The limit for accessible laser power equals 5 times the limit of class 2 lasers in the visible wavelength range (400 nm - 700 nm) and 5 times the limit of class 1 lasers for other wavelengths.

Class 3B: The accessible laser radiation is hazardous for the eye. Even scattered light might induce permanent retinal damage, especially in case of short distances. Also direct exposure of skin can be harmful. The limit for accessible laser power is 500 mW for visible, continuous wave laser radiation.

Class 4: The accessible laser radiation is very hazardous for the eye and hazardous for the skin. Even scattered light is potentially hazardous for the eye and skin. These lasers may ignite burnable materials, and thus represent risk of fire and explosion.

Old laser classes (valid until 1997, still in use in the USA)

Class 1: This class is equal to the new laser class 1. The laser is safe under all conditions of normal use.

Class 2: This class is equal to the new laser class 2. The laser is safe for exposure times of no more than 0.25 s. The wavelength of the accessible laser radiation is in the range of 400 nm to 700 nm.

Class 3 A: The accessible laser radiation can exceed the maximum permissible exposure if the light passes through optics (e.g. lenses, telescopes, magnifying glasses or microscopes). Without optics, visible lasers (400 nm - 700 nm) are safe in case of maximum exposure times of 0.25 s. Lasers of other wavelengths are safe even for long-term exposure.

Class 3 B: All lasers not assigned to one of the other classes. The accessible laser radiation is hazardous for the eye. Even scattered light might induce permanent retinal damage, especially in case of short distances. Also direct exposure of skin can be harmful. The limit for accessible laser power is 500 mW for visible, continuous wave laser radiation.

Class 4: This class is equal to the new laser class 4. The accessible laser radiation is very hazardous for the eye and hazardous for the skin. Even scattered light is potentially hazardous for the eye and skin. These lasers may ignite burnable materials, and thus represent risk of fire and explosion.

In the Photonics Laboratory several class 4 lasers are operated! Thereby even laser light scattered at surfaces which appear dark (e.g. on power meters or beam dumps) can induce permanent eye damage!

Laser safety glasses

If laser radiation exceeds the maximum permissible exposure (MPE), one has to wear appropriate laser safety glasses. This is the case for laser class 3R (new classes) or 3A (old classes) and higher classes. Laser safety glasses have to be chosen in such a way that the maximum permissible exposure is not exceeded for all present laser wavelengths (see tables 2 and 3). The label of laser safety glasses follows DIN 58215 and DIN EN 207. The label of safety glasses for laser alignment follows DIN EN 208; these glasses are only available for visible radiation.
Laser safety glasses are labeled according to the following scheme:

„Laser working mode - Wavelength range - Protection level - Safety norm“

Laser working mode:	Continuous wave (D) Pulsed mode (I) Giant pulsed mode (R) Mode locked (M)
Wavelength range:	The protection wavelength range is given in Nanometers
Protection level:	Declaration of the attenuation given in decadic logarithm scale. Therefore “L2“ corresponds to an intensity attenuation of factor 100 within the given wavelength range.
Safety norm:	Declaration of the safety norm which underlies the labeling (e. g. „RH DIN S“)
Example:	D 690-1070 nm L7 RH DIN S IR 690-1040 nm L7 RH DIN S IR 1040-1070 nm L8 RH DIN S (…)

Laser safety glasses withstand a direct irradiation from an intensive laser beam only for a short time. They are designed in way that melting of the protective coating or the spectacle frame is signalized by a hissing sound.

protection level	maximum fractional transmission within the laser wavelength range	maximum irradiation E or radiant exposure H in the wavelength range 180 nm to 315 nm			> 315 nm to 1400 nm			> 1400 nm to 1000 μm		
		for laser working mode / laser pulse duration (seconds)								
		D $\geq 3\cdot10^{4}$	I, R 10^{-9} to $3\cdot10^{4}$	M $<10^{-9}$	D $>5\cdot10^{-4}$	I, R 10^{-9} to $5\cdot10^{-4}$	M $<10^{-9}$	D $>0{,}1$	I, R 10^{-9} to 0,1	M $<10^{-9}$
		E W/m²	*H* J/m²	*E* W/m²	*E* W/m²	*H* J/m²	*E* W/m²	*E* W/m²	*H* J/m²	*E* W/m²
L 1	10^{-1}	0,01	$3\cdot10^{2}$	$3\cdot10^{11}$	10^{2}	0,05	$5\cdot10^{7}$	10^{4}	10^{3}	10^{12}
L 2	10^{-2}	0,1	$3\cdot10^{3}$	$3\cdot10^{12}$	10^{3}	0,5	$5\cdot10^{8}$	10^{5}	10^{4}	10^{13}
L 3	10^{-3}	1	$3\cdot10^{4}$	$3\cdot10^{13}$	10^{4}	5	$5\cdot10^{9}$	10^{6}	10^{5}	10^{14}
L 4	10^{-4}	10	$3\cdot10^{5}$	$3\cdot10^{14}$	10^{5}	50	$5\cdot10^{10}$	10^{7}	10^{6}	10^{15}
L 5	10^{-5}	10^{2}	$3\cdot10^{6}$	$3\cdot10^{15}$	10^{6}	$5\cdot10^{2}$	$5\cdot10^{11}$	10^{8}	10^{7}	10^{16}
L 6	10^{-6}	10^{3}	$3\cdot10^{7}$	$3\cdot10^{16}$	10^{7}	$5\cdot10^{3}$	$5\cdot10^{12}$	10^{9}	10^{8}	10^{17}
L 7	10^{-7}	10^{4}	$3\cdot10^{8}$	$3\cdot10^{17}$	10^{8}	$5\cdot10^{4}$	$5\cdot10^{13}$	10^{10}	10^{9}	10^{18}
L 8	10^{-8}	10^{5}	$3\cdot10^{9}$	$3\cdot10^{18}$	10^{9}	$5\cdot10^{5}$	$5\cdot14^{14}$	10^{11}	10^{10}	10^{19}
L 9	10^{-9}	10^{6}	$3\cdot10^{10}$	$3\cdot10^{19}$	10^{10}	$5\cdot10^{6}$	$5\cdot10^{15}$	10^{12}	10^{11}	10^{20}
L 10	10^{-10}	10^{7}	$3\cdot10^{11}$	$3\cdot10^{20}$	10^{11}	$5\cdot10^{7}$	$5\cdot10^{16}$	10^{13}	10^{12}	10^{21}

Tab. 2: Protection levels and assignment of laser safety glasses or filters [source: BGV B2 A09, 2003]

Which laser safety glasses to choose?

Laser	wave-length (nm)	Required protection level without focusing	Laser safety glasses (number is noticed on the glasses): light green filter (1)	white frame, green filter (2)	white frame, brown filter (3)	white frame, light green filter (4)	green glasses (5)	brown glasses (6)	for disk laser (ID 860-862) (7)	(7+)	orange glasses (8)	orange glasses (9)	(9+)
Diode laser	445	L5	Red	Red	Red	Red	Red	Red	Red	Red	Green	Green	Green
Nd:YAG, SHG cw, E<1W/mm²	532	L5!	Red	Red	Green	Red	Red	Red	Red	Red	Green	Green	Green
HeNe (P=10 mW)	633	R2*	Red	Green	Red	Red	Red	Red	Red	Red	Red	Red	Red
Diode bar (FAC)	808	L6	Red	Green	Yellow	Red	Red	Yellow	Red	Green	Red	Red	Yellow
Vectormark, Pump diodes alone	808	L7	Red	Red	Red	Red	Red	Yellow	Red	Yellow	Red	Red	Red
Diode laser	830	L4	Red	Green	Red	Red	Green	Green	Red	Green	Red	Green	Green
Diode bar (FAC)	880	L6	Red	Green	Red	Red	Yellow	Yellow	Red	Green	Red	Yellow	Yellow
Disk laser (Trumpf)	1030	L7	Red	Red	Red	Red	Yellow	Yellow	Green	Green	Red	Yellow	Yellow
Diode laser	1050	L4	Red	Green	Red	Red	Green	Green	Green	Green	Red	Green	Green
CTSL	1064	L7	Green	Red	Yellow	Green	Yellow	Yellow	Green	Green	Red	Yellow	Yellow
MISER	1064	L6	Green	Green	Yellow	Green	Yellow	Yellow	Green	Green	Red	Yellow	Yellow
Microchip laser (IMPEX)	1064	L5	Green	Green	Green	Green	Green	Green	Green	Green	Red	Green	Green
Vektormark, DPSSL (Haas/Trumpf)	1064	L8	Green	Red	Red	Green	Yellow	Red	Red	Yellow	Red	Red	Red
Lamp pumped rod laser (Haas)	1064	L8	Green	Red	Red	Green	Yellow	Red	Red	Yellow	Red	Red	Red

* safety glasses for laser alignment (attenuation down to <1 mW, laser class 2); glasses do NOT hold protection level L4.

Colours:
- Red: Laser safety glasses do NOT hold the required protection level.
- Yellow: Laser safety glasses do NOT hold the required protection level, but the optical density of the filter is sufficient (the protection level is defined by the optical density and the durability of filter and frame against long-lasting irradiation).
- Green: Laser safety glasses hold the required protection level.

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Tab. 3: Lasers and laser safety glasses in the Photonics Laboratory