

Risk factors:

- ❖ collimated, coherent beam \Rightarrow irradiance big in the focused beam

In danger:

❖ eyes

❖ direct beam

- ✓ eyes should never come on the way of the direct beam

❖ reflections

✓ specular reflection

- large irradiation possible
- may come from an unexpected direction
- glass, metal, etc.
- potentially as dangerous as the direct beam

✓ diffuse reflection

- risk difficult to assess

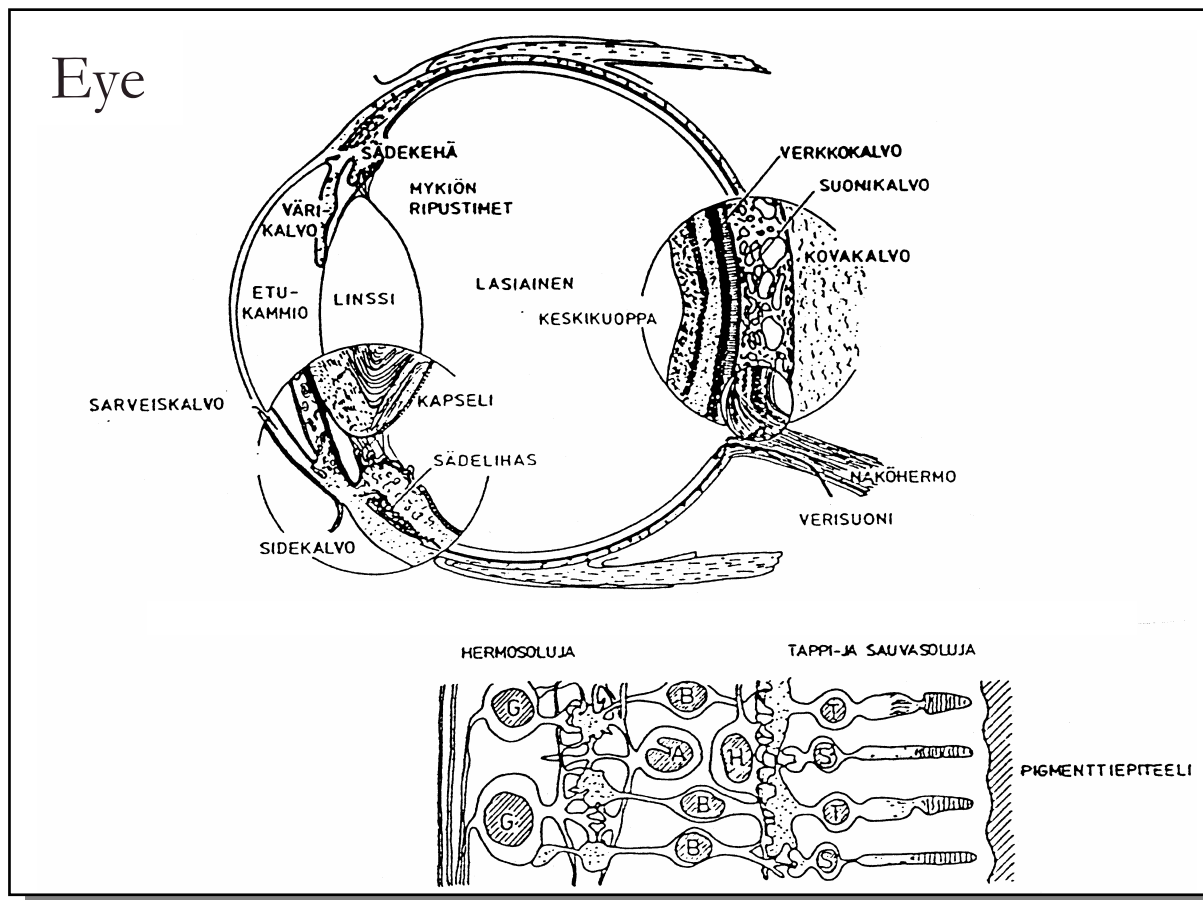
❖ skin (burn)

❖ limit: 1 - 2 kW/m²

❖ especially big industrial lasers

Other risk factors:

- high voltages and large currents
(often causes a larger risk than the radiation)
- poisonous chemicals
- risk for fire, explosion



- Diameter ~ 2.5 cm
- Pupil 2 - 7 mm
- 73 % of the refracting power on the air-cornea interface
- Lens fine tuning (OBS! No blood vessels → risk for thermal damage)
- Vitreous humor; gel containing collagen fibers

Retina

- Network of nerve cells
- Cones (tapit), rods (sauvat)
 - cones: at low light levels > 100 milj. flat spectral response
 - rods: at high light levels in fovea; \varnothing 0.15 mm < 10 milj. 3 types for spectral sensitivity
- Pigment epithelium
 - absorbs most of the radiation

Eye hazards

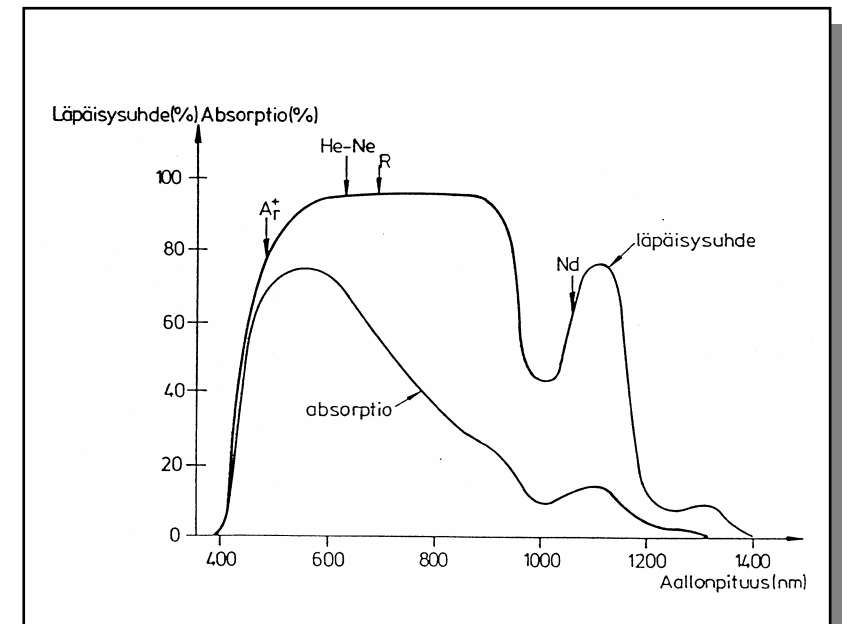
Factors influencing the seriousness of the hazard

pulse

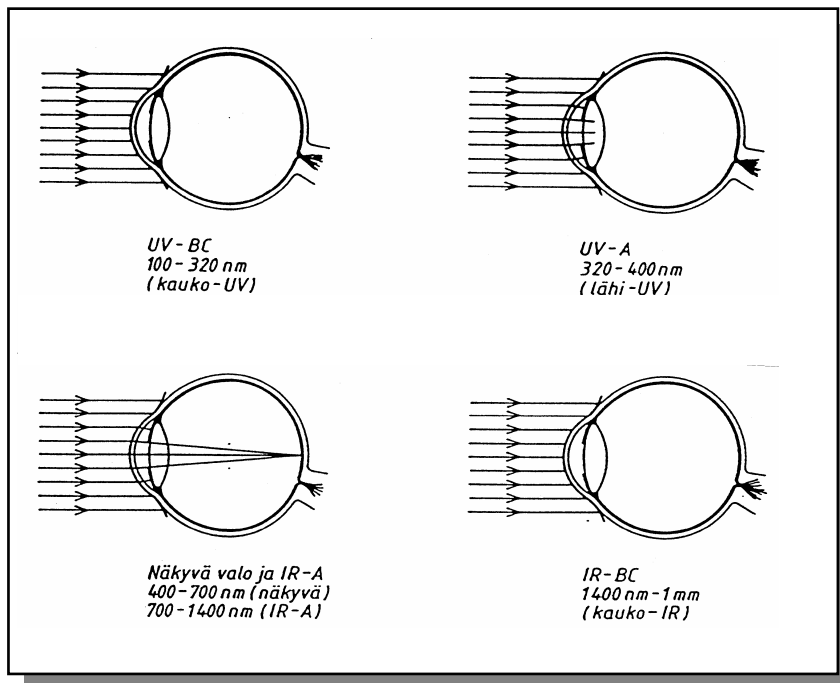
- energy
- length
- repetition rate
- wavelength
- focusing

- Thermal damage
 - protein damages (denaturation)
- Mechanical damages caused by explosive thermal expansion
- Photochemical effects
 - UV ($\lambda < 400$ nm)
 - inflammation of cornea or conjunctiva (e.g. snowblindness)
 - Also 400 - 550 nm (e.g. at solar eclipse)

Transmission of optical radiation from cornea to retina and absorption on the retina of human eye



Penetration and absorption of optical radiation in different parts of the eye

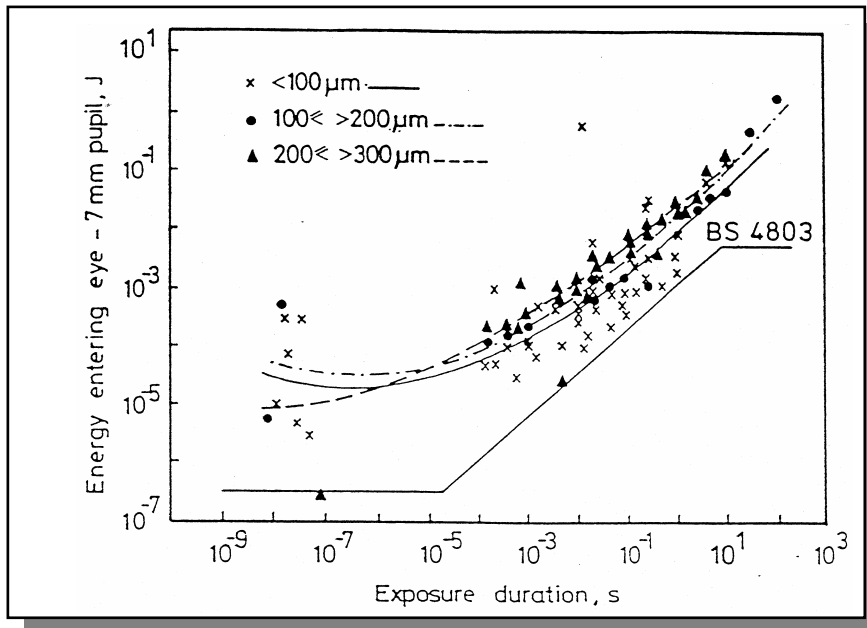


Taulukko 1. Optisen säteilyn tunkeutuminen ja vaikutukset silmän eri osiin

Aallonpituus (nm)	Tunkeutumiskohde	Vaikutusmekanismi kudoksessa
100-280 (UV-C)	sarveiskalvo	fotokemialliset reaktiot
280-320* (UV-B)	sarveiskalvo, linssi	fotokemialliset reaktiot
320*-400 (UV-A)	linssi	fotokemialliset reaktiot, lämpö
400-780 (näkyvä valo)	verkkokalvo	lämpö, lämpölaajenemisilmiöt, fotokemialliset reaktiot
780-1400 (IR-A)	verkkokalvo, linssi	lämpö, lämpölaajenemisilmiöt
1400-3000 (IR-B)	sarveiskalvo	lämpö
3000-1 mm (IR-C)	sarveiskalvo	lämpö

* tai 315

Exposure limits



IR light

700-1400 nm on retina 40% of visible light limit
 (NB. pupil reflex does not work)
 > 1400 nm cornea absorbs ($> 10 \text{ s} : 1000 \text{ W/m}^2$)

UV light

cornea absorbs (epithelium renewed in a week)
 exposure limit $\sim 30 \text{ J/m}^2$
 intensive UV: permanent lens opacity

Visible light (400 - 780 nm)

Max. exposure duration in practice: 0.25 s (pupil reflex)
 Exposure limit: 25 W/m^2 [1 mW (0.25 mJ) through a 7 mm pupil]

Short pulses ($< 10 \mu\text{s}$)

- explosive thermal expansion (“micro explosion”)
 - shock waves, mechanical damage (rupture of retina)
- 1 ns - 18 μs : limit 5 mJ/m^2 (cornea)

International IEC-825 standard (1984):

“Radiation safety of Laser Products, Equipment Classification, Requirements and user’s guide”

Europe:	EN 60-825	1 Exposure limits
Finland:	SFS-IEC 825	2 Safety classification
		3 Protective devices, equipment, and labeling
		4 Safety instructions

Safety classes

Class 1

Not dangerous under any circumstance
Also higher class lasers, when they are sealed
(OBS. interlocks)

Class 2

Low-power, visible light lasers
 $P_{\max} = 1 \text{ mW}$ (25 W/m^2 ; $\varnothing 7 \text{ mm}$)

Class 3A

Visible light, CW; $P_{\max} = 5 \text{ mW}$
Max. intensity 25 W/m^2

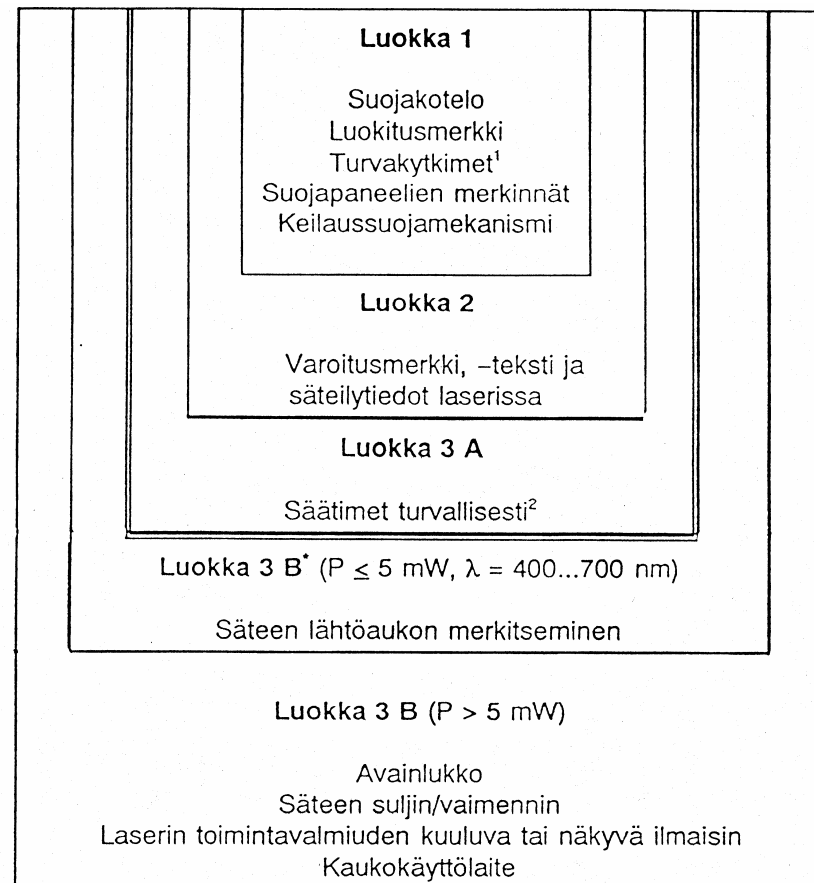
Class 3B

$\lambda > 315 \text{ nm}$, CW; $P_{\max} = 0.5 \text{ W}$
Direct or specular reflection dangerous

Class 4

Lasers more powerful than in Class 3B
Direct or specular reflection on skin causes damage
Eye may be damaged even in diffuse reflection
Beam may cause fire hazard

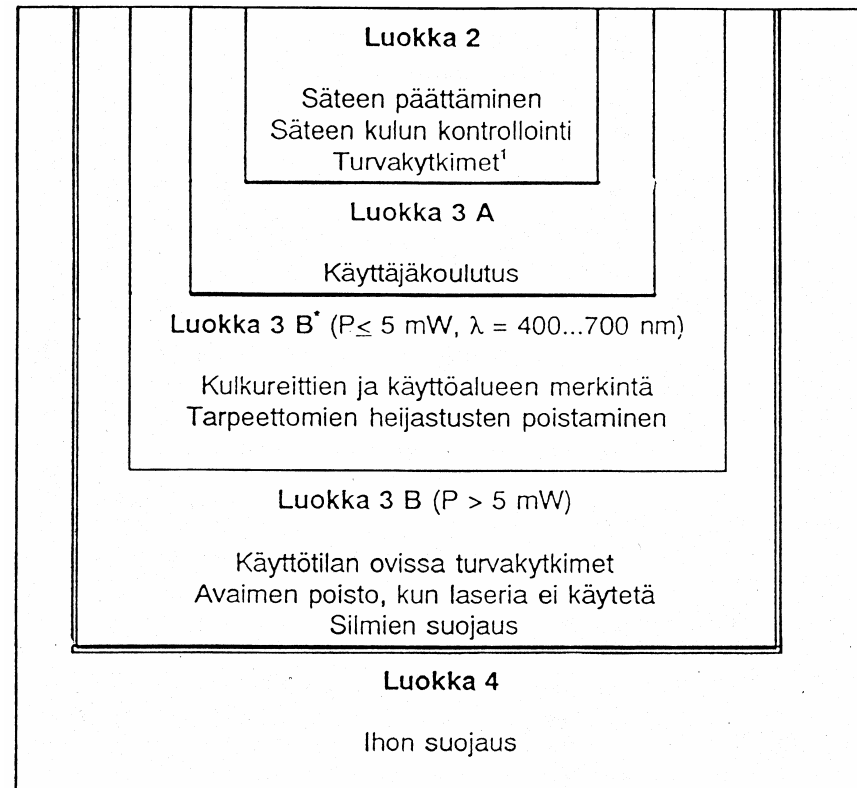
Protective devices and equipment



¹ Jos sisällä suurempitehoinen laser, jonka luokka vähintään 3 B*

² Säädettäessä ei saa altistua yli luokkien 1 tai 2 säteilylle

Laser safety precautions



Lisäksi kaikkia lasereita käytettäessä suositeltavia periaatteita ovat:

- Lasersädettä ei suunnata kohti.
- Lasereita käytetään valvotuissa olosuhteissa.
- Laserit säilytetään asianmukaisesti.
- Laserit ja säteilyn kulkuun vaikuttavat komponentit asennetaan tukevasti.

Security labels

