LASER SAFETY

Ing. Jan Remsa, Ph.D.

Motto: "The Safety Rulebook was written in blood."

TRAINING CONTENT

- Lecture
  - Legal and other regulations
  - Basic laser concepts and principles
  - Laser classification and designation
  - Effects on humans
  - Accidents

- Test 17 questions – 15 required to pass
  - Multiple correct answers possible.

LEGISLATION

- Act 267/2015 Sb.
  - Act amending Act No. 258/2000 Coll., on the protection of public health and amending certain related acts, as amended, and other related acts
  - § 35, 36 Non-ionising radiation
- Government regulation 291/2015 Sb.
  - Government Regulation on health protection against non-ionising radiation
- Decrees
  - 432/2003 Coll. - Decree laying down conditions for categorisation of work, limit values for biological exposure test indicators, conditions for collection of biological material for biological exposure tests and reporting requirements for work with asbestos and biological agents (All those working with classes 3B and 4 fall into risk category 3)
  - 180/2015 Coll. - on jobs and workplaces prohibited for pregnant employees

ACT NO. 258/2000 COLL. ON THE PROTECTION OF PUBLIC HEALTH

- § 35 **Non-ionising radiation**
- (2) A person who uses or operates machinery or equipment which is a source of non-ionising radiation, including lasers (hereinafter referred to as a 'source of non-ionising radiation') shall
  - (a) take technical and organisational measures to ensure that the exposures of natural persons do not exceed the maximum permissible levels of non-ionising radiation within the limits laid down in the implementing legislation,
  - (b) in detecting and assessing the exposure of natural persons and the level of non-ionising radiation, to proceed in the manner laid down in the implementing legislation,
  - (c) before commencing the use or operation of a stationary source of non-ionising radiation from an electronic communications network in a residential development, to prepare documentation demonstrating compliance with the maximum permissible levels of non-ionising radiation in terms of potential exposure of natural persons by calculation or measurement, and to submit this documentation to the competent authority for the protection of public health,
  - (d) in cases provided for in the implementing legislation, to mark with a warning the places (areas, zones) in which the exposure of persons to non-ionising radiation may exceed the maximum permissible values.
- (3) If a defect occurs in a source of non-ionising radiation which could lead to exposure of natural persons exceeding the maximum permissible values, the person referred to in paragraph 2 shall immediately stop its operation. This shall be without prejudice to his obligations under special legislation.

LAWS

- Act 262/2006 Coll. (Labour Code)
  - Reference is made, inter alia, to standards "in so far as they regulate matters relating to the protection of life and health"
  - **Every employee is obliged to take care, to the best of his/her ability, for his/her own safety, health and the safety and health of persons who are directly affected by his/her actions or omissions at work.**
- Technical standards – they create minimum (either it meets the standard, or I have to prove that my measure is better)
- NEW – NV č. 390/2021 on more detailed conditions for the provision of personal protective equipment, washing, cleaning and disinfecting equipment

LASER IN TERMS OF GOVERNMENT REGULATION 291/2015 COLL.

- For the purposes of this regulation
  - (a) non-ionising radiation static electric and magnetic and time-varying electric, magnetic and electromagnetic fields and electromagnetic radiation from artificial sources with frequencies from 0 Hz to 1,7-1015 Hz,
  - b) electromagnetic radiation from artificial sources in the frequency range from 3×10^{11} Hz do $1,7\times10^{15}$ Hz corresponding to wavelengths from **180 nm do 1 mm,**
    so LASER and MASER together
  - (c) coherent radiation is optical radiation produced by stimulated emission where its phase and frequency are clearly defined; radiation emitted by a laser is coherent radiation,
  - (d) incoherent radiation optical radiation which is produced by spontaneous emission of radiation,
  - (e) laser, any device which can be adapted to produce or amplify electromagnetic radiation in the wavelength range of optical radiation by a process of controlled stimulated emission,

STANDARDS

- ČSN EN 60825 Safety of laser products
  - Standard is valid for laser device safety that emits radiation in wavelength range from 180 nm to 1 mm.
- ČSN EN 60825-1 Equipment classification and requirements
- ČSN EN 60825-4 Laser guards
- ČSN EN 207 Personal eye-protection equipment. Filters and eye-protectors against laser radiation (laser eye-protectors)
  - Safety goggles for lasers
- Other standards ČSN and IEC

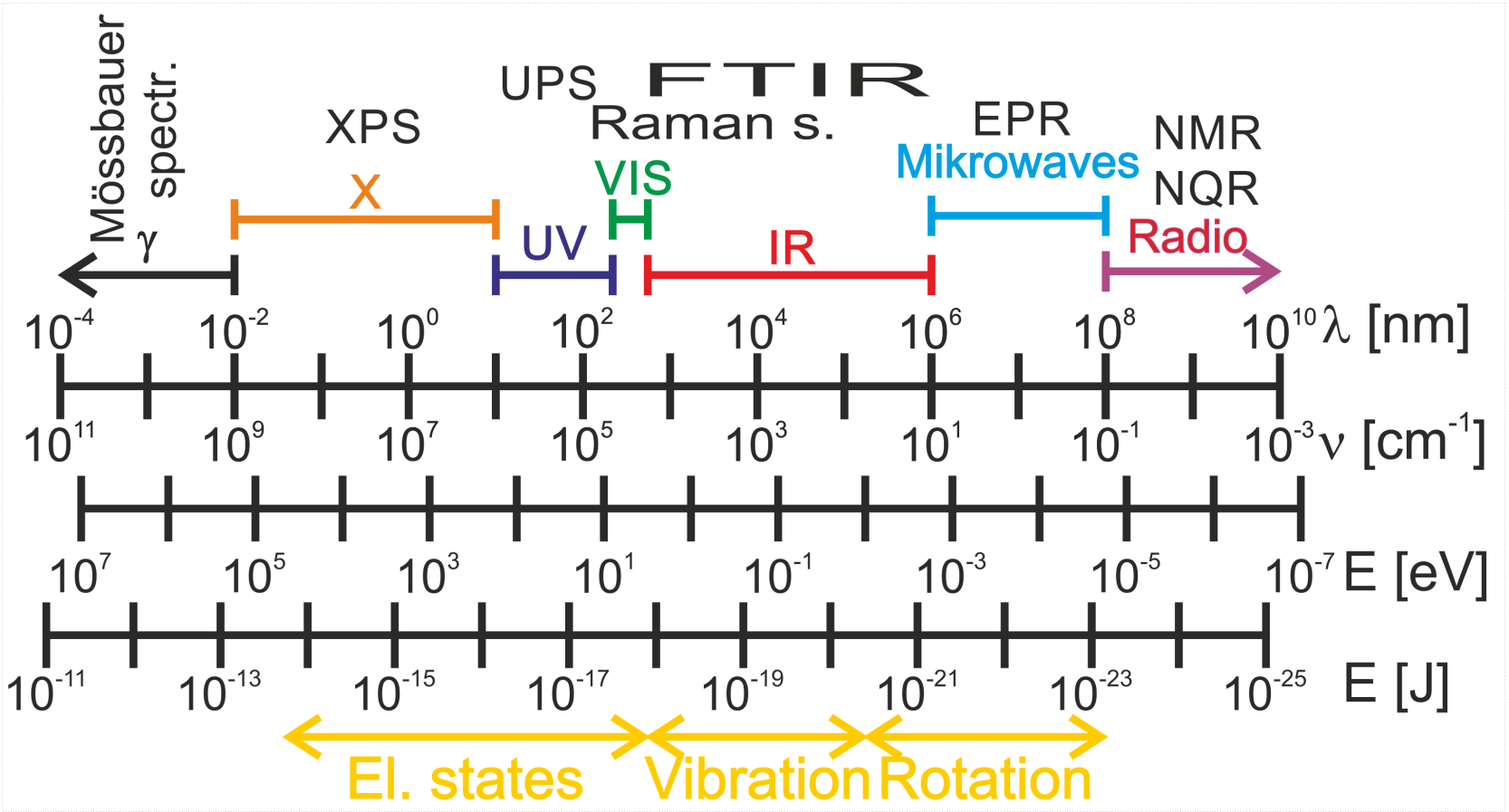
STANDARDS – NOTE 1

- ČSN EN 60825-1:2014 / amendment A11:2021
  - For consumers (mostly)
  - European change only
  - Reduced limit (AEL) for the cornea in the region 1250 - 1400 nm (water absorption)
  - Requirement for the device to be in the lowest possible class.

STANDARDS – NOTE 2

- CSN EN 50689: Safety of laser products - special requirements for laser products (V. 2022)
  - Laser product definition
  - Definition of laser pointer
  - A laser product advertised and intended as a handheld laser either for entertainment purposes or for pointing at objects and/or places
  - Maximum power of 1 mW
  - Class 2 maximum
  - Attention: levelling devices and distance measuring devices are not!

ELECTROMAGNETIC RADIATION



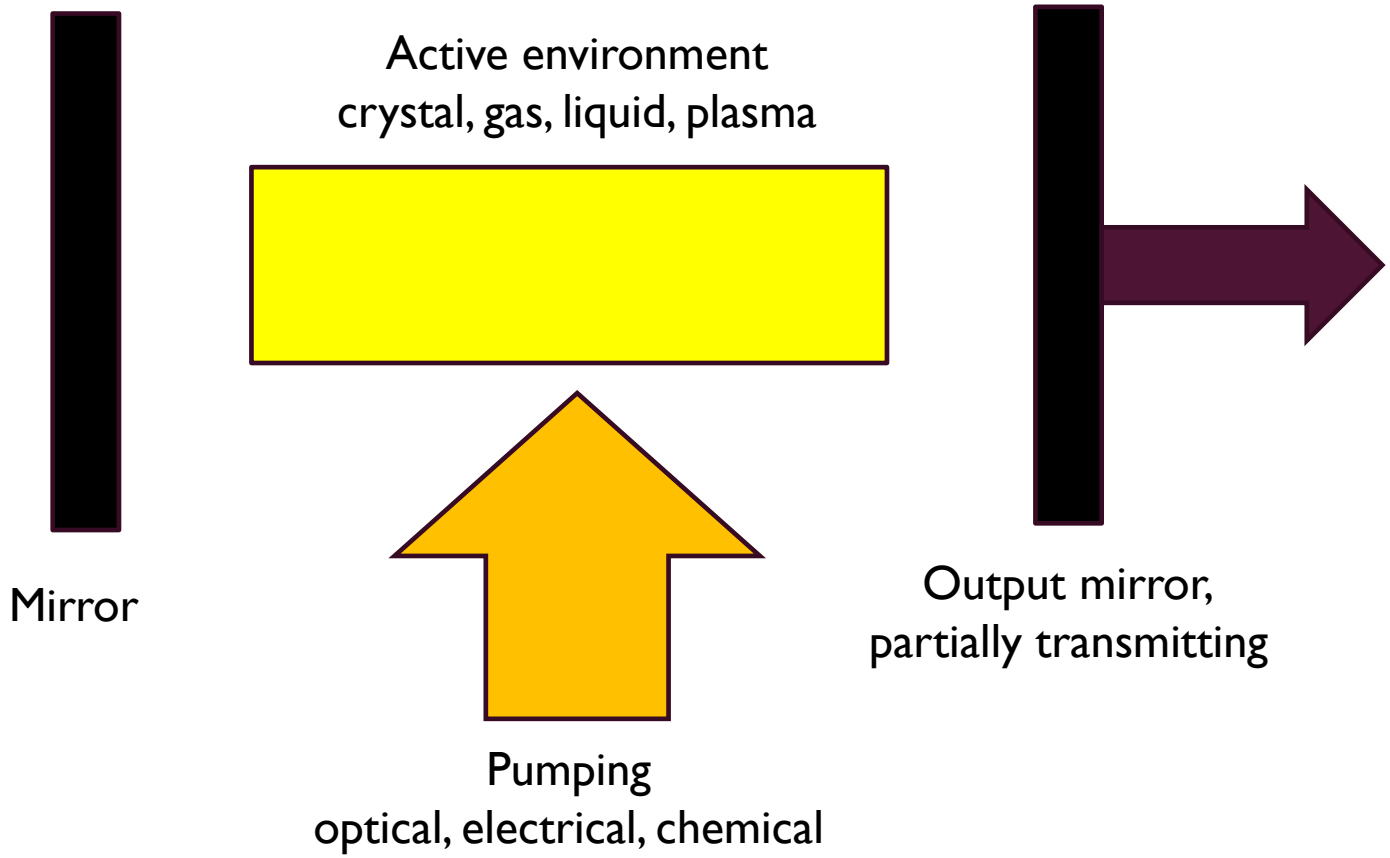
ELECTROMAGNETIC RADIATION

Spectral region	Wavelength (nm)
UV-C	180 – 280
UV-B	280 – 320
UV-A	320 – 400
Visible	400 – 700 (380 nm and 760 nm)
IR-A	700 – 1 400
IR-B	1 400 – 3 000
IR-C	3 000 – 1 000 000

Caution, it may vary in stadards, legislation and physical definitions.

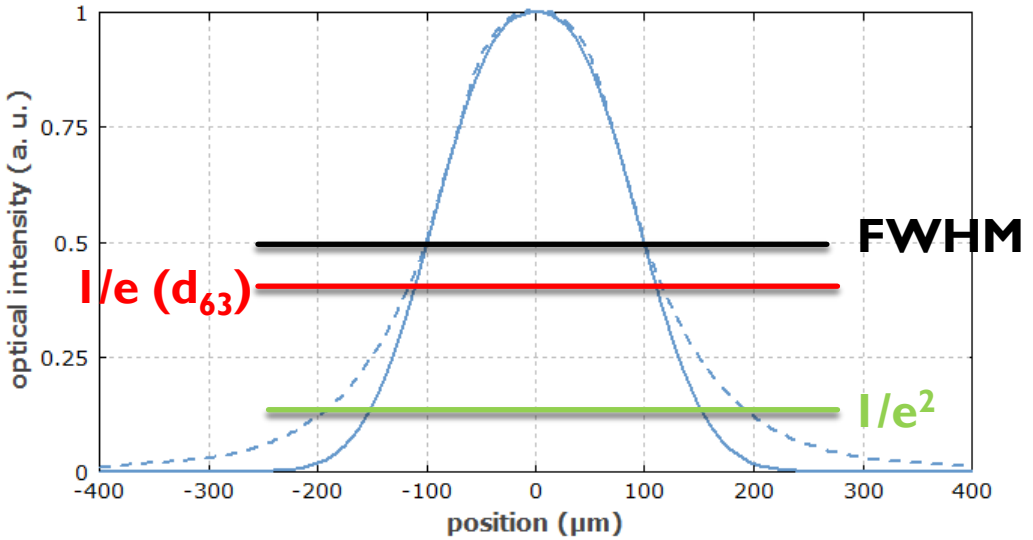
LASER BASICS

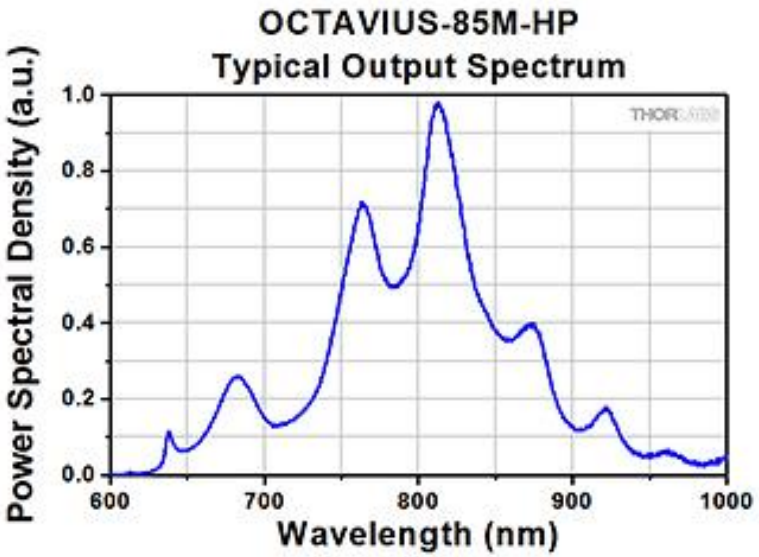
- Light Amplification by Stimulated Emission of Radiation

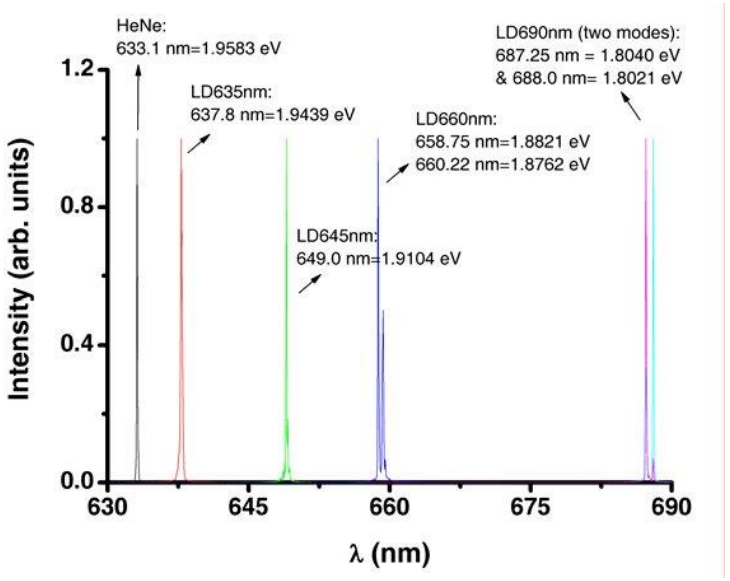


LASER BASICS

- Laser radiation is:
  - Monochromatic (there are exceptions for short pulse lasers, Ti:SAPPHIRE)
  - Directional (low divergence), focuses well
  - Coherent (temporally and spatially)
- Beam diameter
  - Caution! Standards use 1/e (d_{63})
  - There are different:

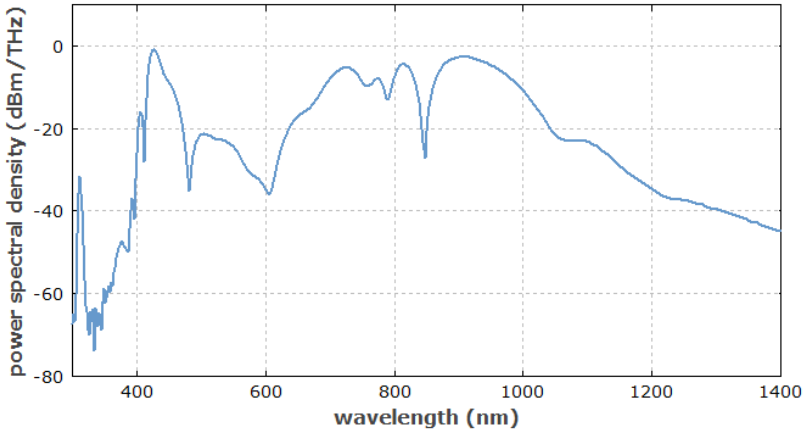






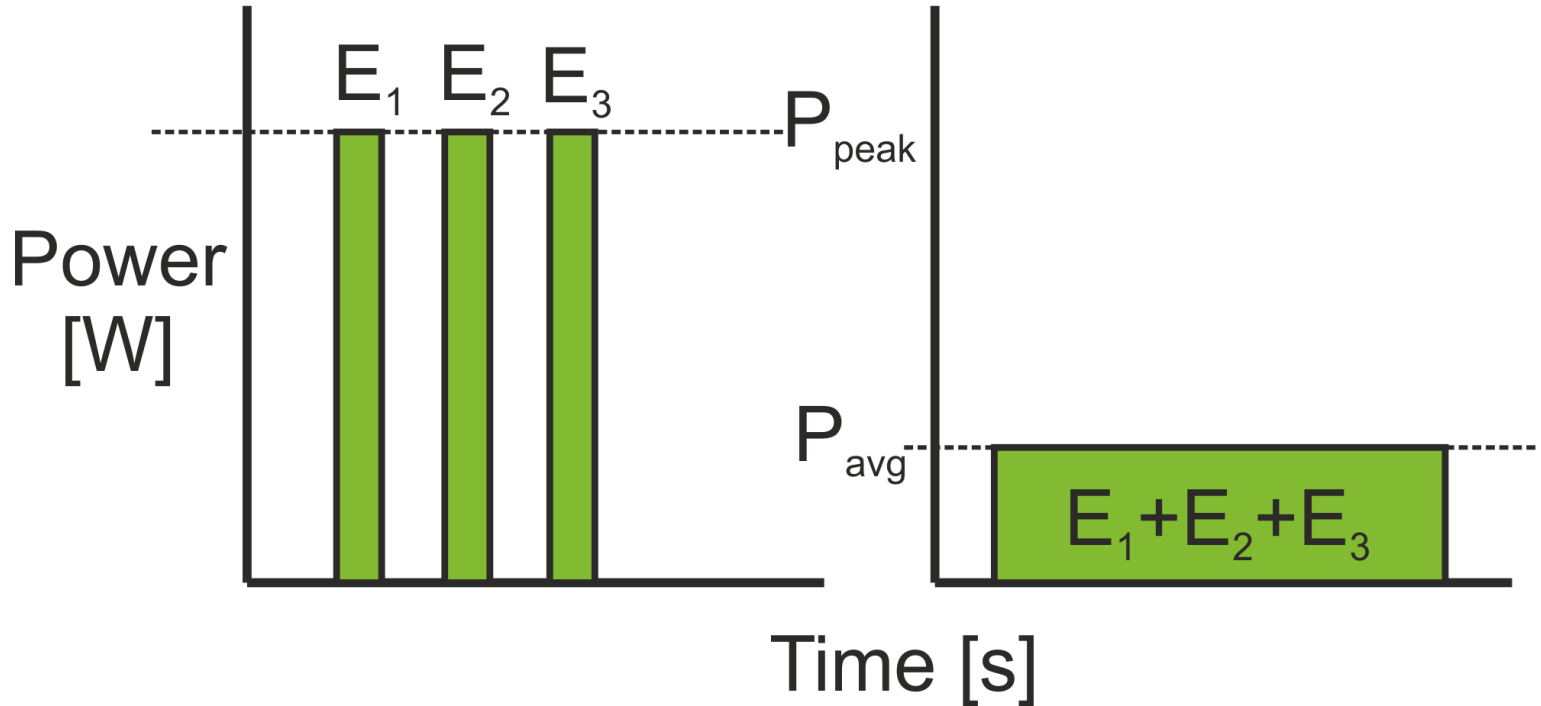
„MONOCHROMATISM“

- He-Ne
- Ti:SAF
- Supercontinuum (low temporal coherence)



LASER BASICS

- $Peak\ power = \frac{Energy\ in\ pulse}{Pulse\ length}$
- $Average\ power = \frac{Total\ energy}{Irradiation\ time} = frequency \cdot E$



LASER PARAMETERS

- Energy in pulse / Power
- Wavelength
- Pulse length
- Repetition frequency or continuous mode (CW)
- Beam diameter
- Divergence

CLASSES OF LASERS

- EN 60825-1:2014
- Accessible emission limit: AEL
  - The maximum accessible emission that is allowed within a class
- Depends on:
  - Wavelength
  - Output power
  - Divergence
  - Exposure time
- Marking and security requirement
- **The manufacturer or his representatives are responsible for the classification.**

MAXIMUM ACCESSIBLE EMISSION - EXAMPLE

MPE for skin was determined by cornea

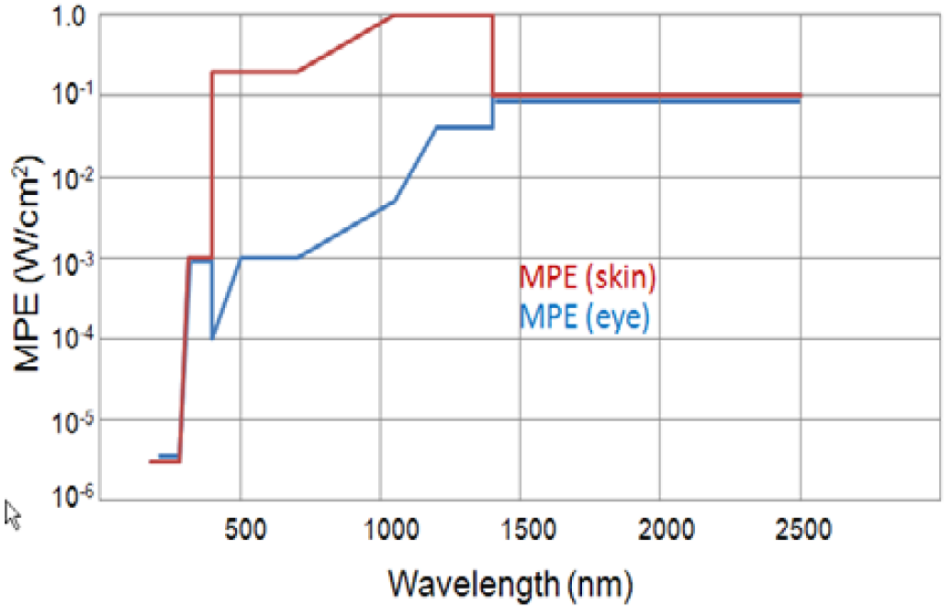


Figure 1: MPEs for eye and skin for 1000s exposure, using Tables 5a and 7 in ANSI Z136.1-2007. The MPEs are the same outside of the retinal hazard region, 400-1400nm (red and blue lines have small artificial offsets in the UV and mid-IR in the figure).

Jeff Corbett , Michael Woods UV LASER RADIATION: SKIN HAZARDS AND SKIN PROTECTION CONTROLS 1 (2013)

CLASSES OF LASERS

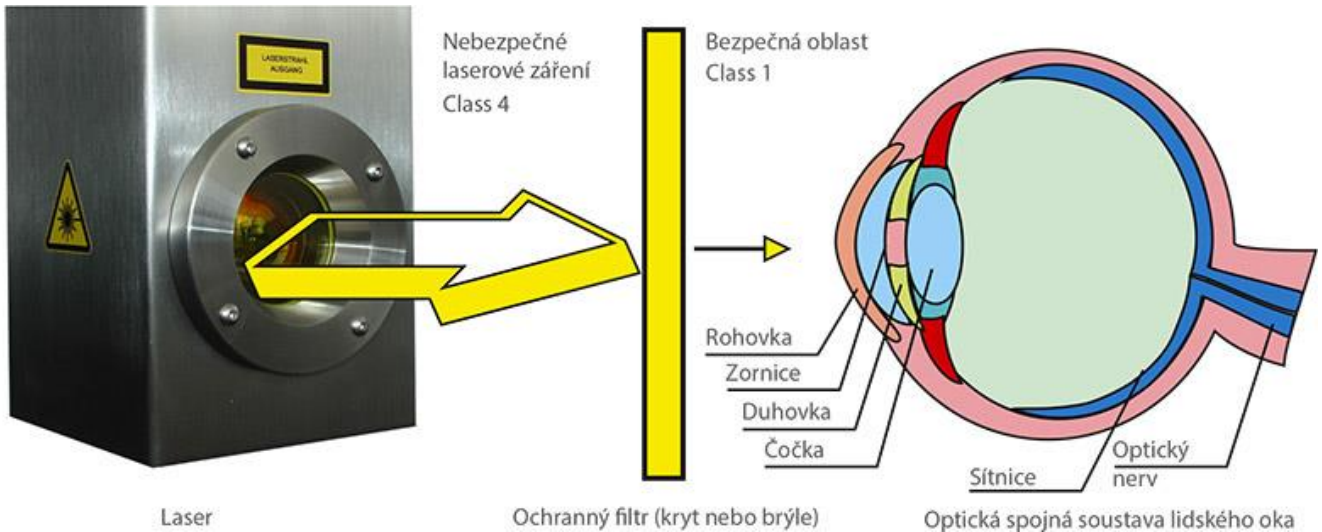
Mandatory training

Class	1 1M 1C	2 2M	3R	3B	4
Wavelength range	180 nm - 1 mm 1M: 302,5 – 4 µm	400-700 nm	180 nm - 1 mm	180 nm - 1 mm	180 nm - 1 mm
Maximum accessible power	<0,4 mW @ 632 nm	< 1 mW	< 5 mW	< 500 mW	No limit
Risks	Safe for naked eye	Safe for the naked eye for < 0,25 s	Dangerous to eye	Dangerous to eye	Dangerous for eye and skin Direct and indirect reflection
Protection	-	Wink	Prevent direct view into the beam	Compulsory safety goggles	Compulsory safety goggles

Does not cause permanent damage

CLASS 1 LASER

- Safe for eye
- **<u>Two ways to achieve this!</u>**
  - 1) Accessible exposure limit < maximum permissible exposure
  - 2) An encapsulated device that cannot be opened without tool and shuts off when the cover is opened (safety system / Interlock).
- Beware of power sum of whole laser system e.g., laser pointer with second harmonic



SUBCLASSES „M“ A „C“

- 1M and 2M (Magnifying)
  - Safe for naked eye
  - With optical aids they can reach up to **3B!!!!** (Telescope / Magnifier hazard)
  - Dioptric glasses are not considered an optical aid
- 1C (Contact)
  - Device for direct application of laser radiation to the skin or internal tissues
  - Medical, therapeutic or cosmetic procedures
  - Radiation may be at level for Class 3R, 3B or 4, eye exposure is prevented by one or more technical means.
  - The level of skin irradiation depends on the application; therefore, this aspect is regulated in the parent standards. This class has been introduced because these devices currently exist on the market and the measures normally specified for laser device classes 3B and 4 are inadequate.

CLASS 4 LASERS – THE MOST DANGEROUS

- May cause dangerous diffuse reflection
- Must be equipped with:
  - Operation signalling (light / acoustic)
  - Security device reliably preventing it from being started by and unauthorized person
  - A secure area to prevent unauthorized persons from entering
  - The beam path needs to be covered and terminated with an absorption target so that the eyes of persons could not be hit by diffuse reflected radiation.
- For solid state lasers and lasers with small M^2, beware of back reflections!

OVERVIEW OF MANUFACTURER REQUIREMENTS

	1	1M	2	2M	3R	3B	4
Classification	■	■	■	■	■	■	■
Instruction manual	■	■	■	■	■	■	■
Label with output parameters		■	■	■	■	■	■
Safety case		■	■	■	■	■	■
Safe control box placement					■	■	■
Aperture label					■	■	■
Laser radiation warning					UV+IR	■	■
Key control						■	■
Remote interlock connector						■	■
Beam attenuator						■	■
Manual restart							■

CLASSIFICATION PROCESS IS COMPLEX

Tabulka 4 – Limity přístupné emise pro laserová zařízení třídy 1 a 1M a $C_6 = 1$ [a, b]

Vlnová délka λ nm	Doba trvání vyzařování *t* s										
	10^{-13} až 10^{-11}	10^{-11} až 10^{-9}	10^{-9} až 10^{-7}	10^{-7} až $1{,}8 \times 10^{-5}$	$1{,}8 \times 10^{-5}$ až 5×10^{-5}	5×10^{-5} až 1×10^{-3}	1×10^{-3} až 0,35	0,35 až 10	10 až 10^{2}	10^{2} až 10^{3}	10^{3} až 3×10^{4}
180 až 302,5	3×10^{10} W·m^{-2}		30 J·m–2								
302,5 až 315	$2{,}4 \times 10^{4}$ W		Tepelné nebezpečí ($t \le T_1$) $7{,}9 \times 10^{-7}$ C_1 J					Fotochemické nebezpečí $7{,}9 \times 10^{-7}$ C_2 J ($t > T_1$)	$7{,}9 \times 10^{-7}$ C_2 J		
315 až 400			$7{,}9 \times 10^{-7}$ C_1 J						$7{,}9 \times 10^{-3}$ J		$7{,}9 \times 10^{-6}$ W
400 až 450	$5{,}8 \times 10^{-9}$ J	$1{,}0\ t^{0,75}$ J	2×10^{-7} J	$7 \times 10^{-4}\ t^{0,75}$ J					$3{,}9 \times 10^{-3}$ J	$3{,}9 \times 10^{-5}$ C W	
450 až 500									$3{,}9 \times 10^{-3}$ C_3 J a [c] $3{,}9 \times 10^{-4}$ W		
500 až 700									$3{,}9 \times 10^{-4}$ W		
700 až 1 050	$5{,}8 \times 10^{-9}$ C_4 J	$1{,}0\ t^{0,75}$ C_4 J	2×10^{-7} C_4 J	$7 \times 10^{-4}\ t^{0,75}$ C_4 J					$3{,}9 \times 10^{-4}$ C_4 C_7 W		
1 050 až 1 400	$5{,}8 \times 10^{-8}$ C_7 J	$10{,}4\ t^{0,75}$ C_7 J	2×10^{-6} C_7 J		$3{,}5 \times 10^{-3}\ t^{0,75}$ C_7 J						
1 400 až 1 500	8×10^{5} W		8×10^{-4} J				$4{,}4 \times 10^{-3}\ t^{0,25}$ J	$10^{-2}\ t$ J	$1{,}0 \times 10^{-2}$ W		
1 500 až 1 800	8×10^{6} W		8×10^{-3} J					$1{,}8 \times 10^{-2}\ t^{0,75}$ J			
1 800 až 2 600	8×10^{5} W		8×10^{-4} J				$4{,}4 \times 10^{-3}\ t^{0,25}$ J	$10^{-2}\ t$ J			
2 600 až 4 000	8×10^{4} W		8×10^{-5} J	$4{,}4 \times 10^{-3}\ t^{0,25}$ J							
4 000 až 10^{6}	10^{11} W·m^{-2}		100 J·m^{-2}	$5\,600\ t^{0,25}$ J·m^{-2}					1 000 W·m^{-2}		

POZNÁMKA Laserová zařízení, která vyhovují požadavkům pro zařazení do třídy 1 díky splnění měřicích podmínek 1 a 2, mohou být nebezpečná při použití s optickými přístroji s větším než sedminásobným zvětšením nebo s průměrem objektivu větším, než je uvedeno v tabulce 11.

[a] Hodnoty korekčních činitelů a jednotky jsou uvedeny v tabulce 10.

[b] Hodnoty AEL pro doby trvání vyzařování kratší než 10^{-13} s se rovnají hodnotám AEL pro odpovídající výkon nebo intenzitu ozáření a dobu 10^{-13} s.

[c] Na rozsah vlnových délek od 450 nm do 500 nm se vztahují dvojí limity a vyzařování nesmí překročit ani jeden z nich pro příslušnou třídu.

Tabulka 7 – Limity přístupné emise pro laserová zařízení třídy 3R a $C_6 = 1$ [a, b, c]

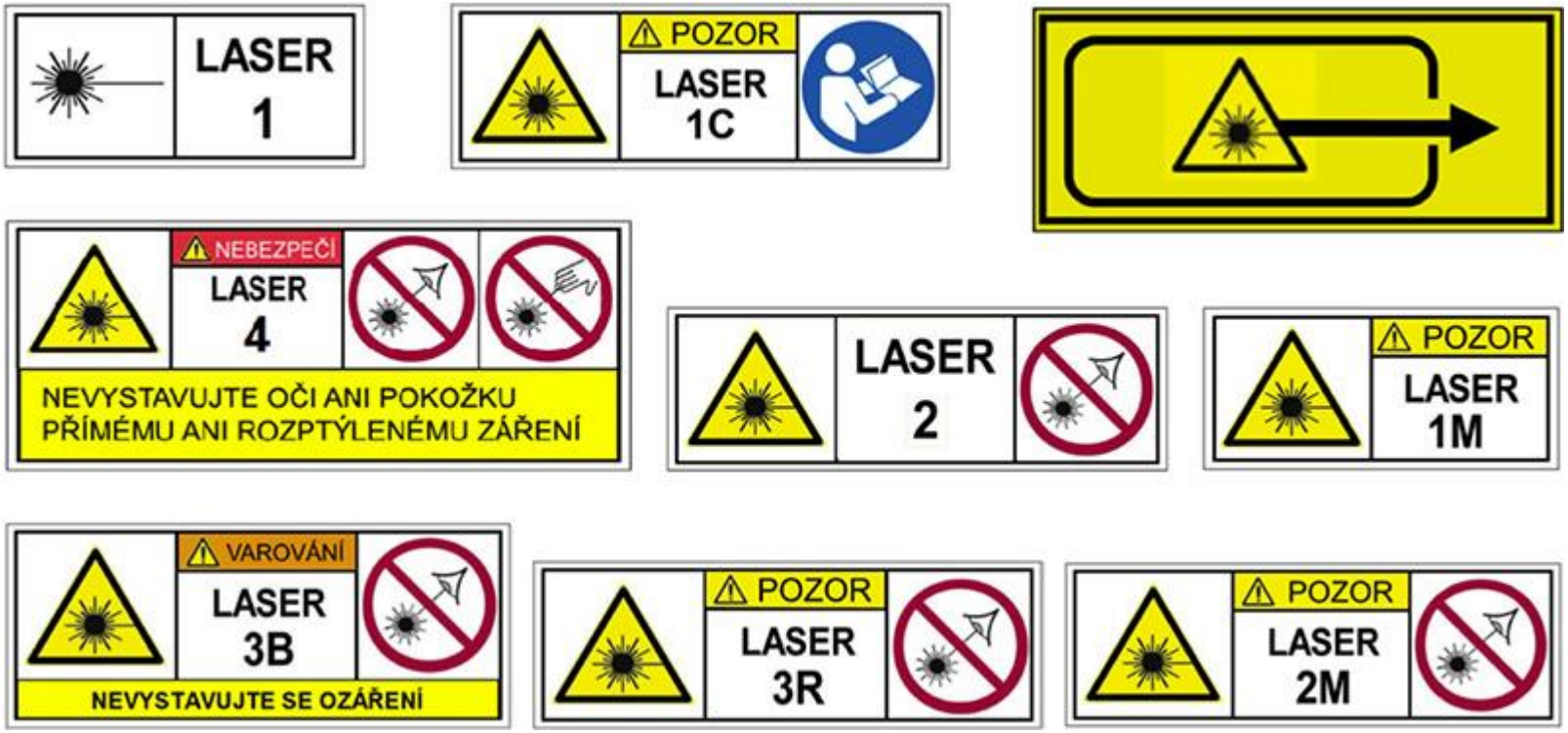
Vlnová délka λ nm	Doba trvání vyzařování *t* s									
	10^{-13} až 10^{-11}	10^{-11} až 10^{-9}	10^{-9} až 10^{-7}	10^{-7} až $1{,}8 \times 10^{-5}$	$1{,}8 \times 10^{-5}$ až 5×10^{-5}	5×10^{-5} až 1×10^{-3}	1×10^{-3} až 0,35	0,35 až 10	10 až 10^{3}	10^{3} až 3×10^{4}
180 až 302,5	$1{,}5 \times 10^{11}$ W·m^{-2}		150 J·m^{-2}							
302,5 až 315	$1{,}2 \times 10^{5}$ W		Tepelné nebezpečí $4 \times 10^{-6}\ C_1$ J ($t \le T_1$)[c]					Fotochemické nebezpečí $4{,}0 \times 10^{-6}\ C_2$ J ($t > T_1$)[c]	$4{,}0 \times 10^{-6}\ C_2$ J	
315 až 400			$4{,}0 \times 10^{-6}\ C_1$ J						$4{,}0 \times 10^{-2}$ J	$4{,}0 \times 10^{-5}$ W
400 až 700	$2{,}9 \times 10^{-8}$ J	$5{,}0\ t^{0{,}75}$ J	1×10^{-6} J	($t < 0{,}25$ s) $3{,}5 \times 10^{-3}\ t^{0{,}75}$ J			$5{,}0 \times 10^{-3}$ W ($t \ge 0{,}25$ s)	$5{,}0 \times 10^{-3}$ W		
700 až 1 050	$2{,}9 \times 10^{-8}\ C_4$ J	$5{,}0\ t^{0{,}75}\ C_4$ J	$1 \times 10^{-6}\ C_4$ J	$3{,}5 \times 10^{-3}\ t^{0{,}75}\ C_4$ J					$2{,}0 \times 10^{-3}\ C_4\ C_7$ W	
1 050 až 1 400	$2{,}9 \times 10^{-7}\ C_7$ J	$52\ t^{0{,}75}\ C_7$ J	$1 \times 10^{-5}\ C_7$ J		$1{,}8 \times 10^{-2}\ t^{0{,}75}\ C_7$ J					
1 400 až 1 500	4×10^{6} W		4×10^{-3} J			$2{,}2 \times 10^{-2}\ t^{0{,}25}$ J	$5 \times 10^{-2}\ t$ J		$5{,}0 \times 10^{-2}$ W	
1 500 až 1 800	4×10^{7} W		4×10^{-2} J				$9 \times 10^{-2}\ t^{0{,}75}$ J			
1 800 až 2 600	4×10^{6} W		4×10^{-3} J			$2{,}2 \times 10^{-2}\ t^{0{,}25}$ J	$5 \times 10^{-2}\ t$ J			
2 600 až 4 000	4×10^{5} W		4×10^{-4} J	$2{,}2 \times 10^{-2}\ t^{0{,}25}$ J						
4 000 až 10^{6}	5×10^{11} W·m^{-2}		500 J·m^{-2}	$2{,}8 \times 10^{4}\ t^{0{,}25}$ J·m^{-2}					5 000 W·m^{-2}	

[a] Hodnoty korekčních činitelů a jednotky jsou uvedeny v tabulce 10.

[b] Hodnoty AEL pro doby trvání vyzařování kratší než 10^{-13} s jsou stanoveny jako hodnoty AEL odpovídající ekvivalentnímu výkonu nebo intenzitě ozařování při 10^{-13} s.

[c] Pro opakovaně pulzní UV lasery by neměl být překročen žádný limit.

LABELLING OF LASER CLASSES



The highest risk rule apply!

SIGNS AT THE ENTRANCE

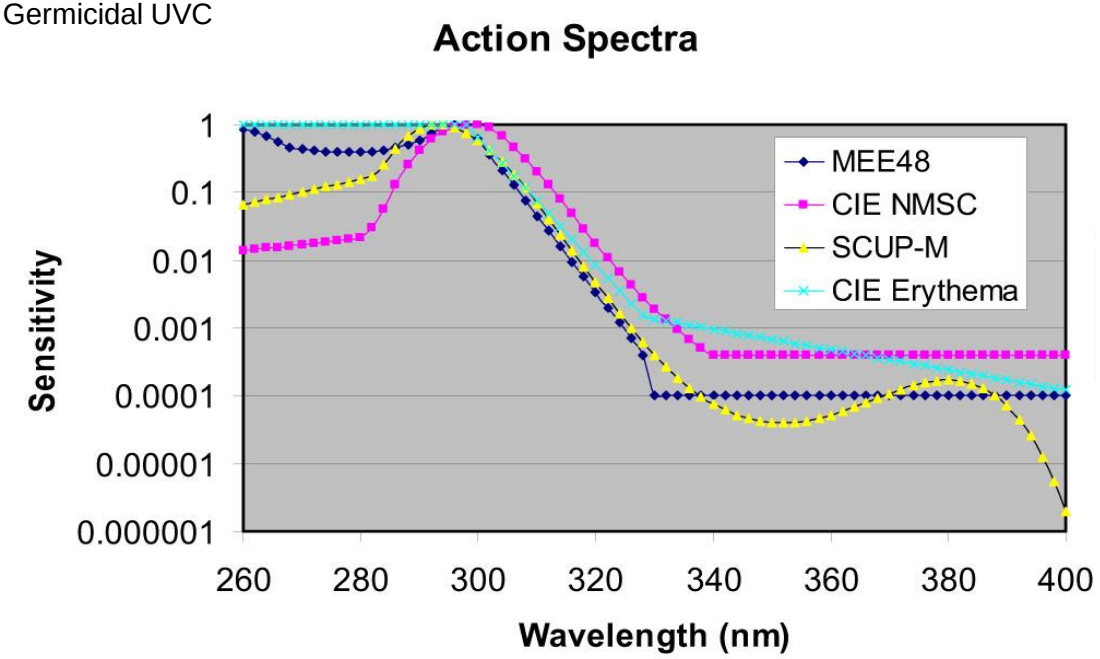
Government regulation č. 375/2017 sb.

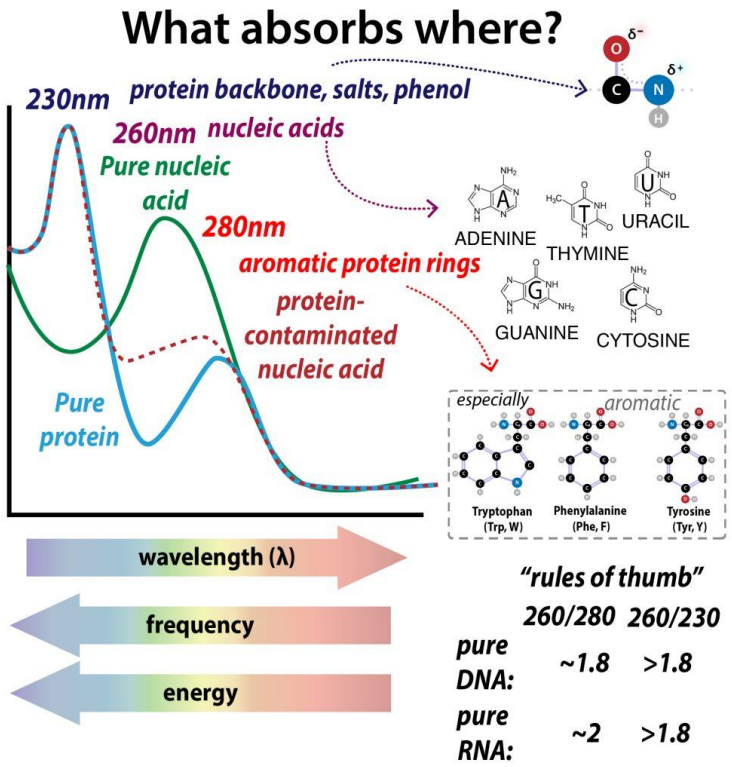
EFFECTS ON HUMANS

- Absorption by the tissues which the radiation hits
- The eyes are the most sensitive (an optical system!), skin is also sensitive
  - From publications: above 2,5 mW/cm^2 permanent damage occurs
- Depends on
  - Tissue
  - Wavelength
  - Intensity
  - Size of irradiated tissue
- Types
  - Photochemical – two meanings:
    - Photon energy > binding energy
    - Short high intensity pulses
  - Thermal (pulses longer than 10 μs)
  - Non-linear (photoablation, photoacoustic damage)

EFFECTS ON HUMANS

Origins and Evolution of Photocarcinogenesis Action Spectra, Including Germicidal UVC

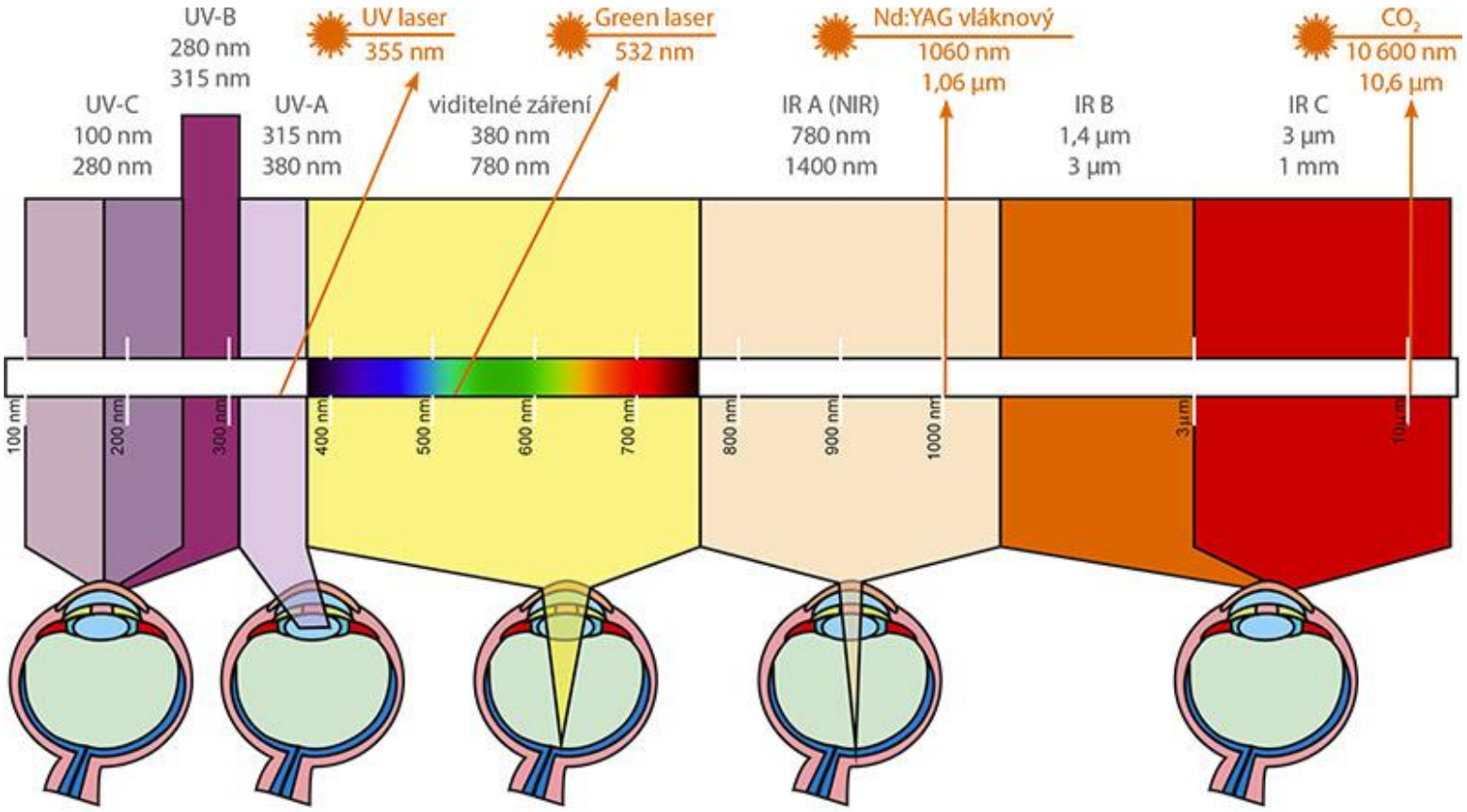




Photochem & Photobiology, Volume: 97, Issue: 3, Pages: 477-484, First published: 22 December 2020, DOI: (10.1111/php.13371)

Courtesy of bumbling biochemist

OKO



Zobrazení prostupu elektromagnetického záření do lidského oka a jeho absorpce. Laser je neionizující záření, které je možné mít ve spektru od ultrafialového do infračerveného, působení laserového paprsku může zapříčinit poškození zraku a újmu na zdraví!

https://www.lt.cz/e-learning/laser/bezpecnost-laseru-tridy-1-az-4 Leonardo Technology

EFFECTS ON HUMANS

Spectral region	Eye	Skin
Ultraviolet C (180 nm to 280 nm)	Cornea inflamation	Accelerated skin aging, Increased pigmentation (tanning)
Ultraviolet B (280 nm to 315 nm)		
Ultraviolet A (315 nm to 400 nm)	Photochemical cataracts	Darkening of pigment, Photosensitive reaction, Skin burn
Visible (400 nm to 780 nm)	Photochemical and thermal damage to retina	
Infrared A (780 nm to 1400 nm)	Cataracts, retinal burn	Skin burn
Infrared B (1,4 um to 3 um)	Corneal clouding, cataract corneal burn	
Infrared C (3 um to 1 um)	Cornea burn	

HEALTH PROTECTION

- Personal protective equipment (PPE)
  - Eyes – Goggles
  - Skin – Clothing / lab coat, gloves, face shield
- Technical measures

LASER SAFETY GOGGLES

- Goggles must be manufactured to EN 207 or EN 208 and have CE mark
- **Mandatory for class 3B and 4 lasers!**
- Goggles must protect against the laser beams **currently in use**
- Room must be sufficiently illuminated – **risk of collision** (tripping)
- Attention to legibility in used goggles (coloured markings)
- Goggles should fit well (shape, weight)
- Goggles should not fog up
- Check goggles before each use (scratches and other damage)

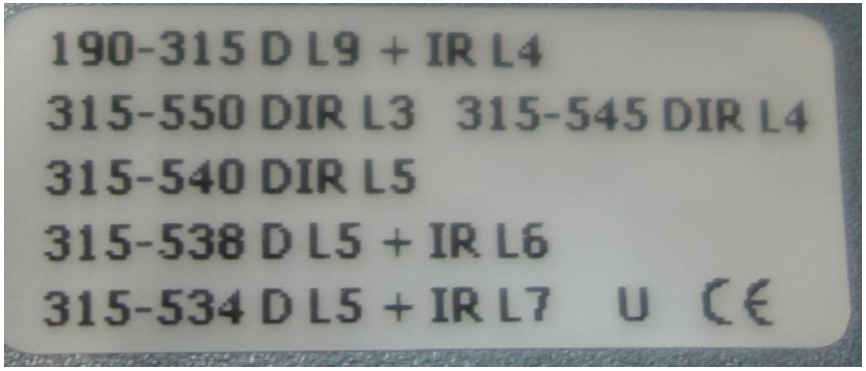
LASER SAFETY GOGGLES

- Protect against accidental laser beam strikes
- Filter and frame must provide protection for **at least 5 s, but never less than 50 pulses**
- Required parameters
  - Laser wavelength
  - Pulse length
  - Laser power / energy in pulse
  - Beam diameter
- Note: Beware of reflective filters in goggles!

LASER SAFETY GOGGLES

- D continuous laser, pules longer than 0,25 s
- I pulse length μs to 0,25 s
- R Q-switched laser, pulse length ns to μs
- M Mode locked laser, pulse length less than ns

New way of classification is underway – googles characterized by OD



LASER SAFETY GOGGLES

- EN 208 – Personal eye-protection equipment – eye-protection equipment for adjustment work on lasers and laser systems
- Only for 400 to 700 nm, cw or longer than ns pulses
- Protects only against accidental direct hit by laser beam for 0,25 s

TECHNICAL MEASURES

- Elements in or around the laser equipment
  - Protective „access barrier “ and protective curtains
    - ČSN EN 12254:2010 Blocking equipment for workplaces with laser equipment
    - AB Numbers
  - Laser protection windows or cameras
  - Beam attenuators
  - Beam stops
  - Safety systems – e.g. Disconnecting the laser when entering the room

TRAINING

- When you start work
  - When changing job classification/type of work
  - When a new technology or change in process is introduced
- The frequency of training is not specified by specific legislation
- The employer is obliged to determine the content and frequency of training, the method of verifying the knowledge of employees and the maintenance of documentation of the training carried out. If the nature of the risk and its severity so require, the training must be repeated periodically (paragraph 3 of §103 ZP 262/2006 Coll.).
- By class
  - Class 1, 2, 3R - not required
  - Class 1M, 2M – recommended
  - **Class 3B, 4 - required**

RISK EVALUATION

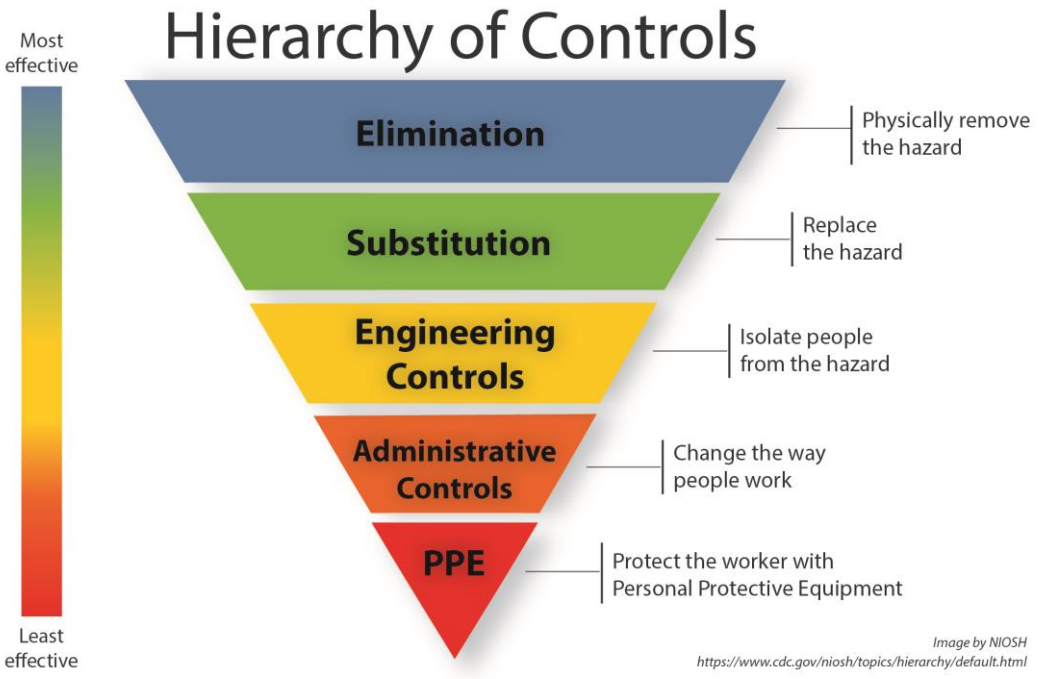
- Always
  - New equipment
  - Change the configuration of an existing device or process
  - Removing a device
- Attend:
  - Teamwork
  - Whoever owns the device or process
  - Whoever performs the work
- If possible, in simple and clear terms
- SOLID 21 - new laboratories
- The local safety regulation in the FZU is the "Interní Metodika"

RISK EVALUATION

- Take into account all life stages of the laser equipment
  - Installation, operation, maintenance, service, disposal of equipment
  - Predictable failures and misuse
- Hazards associated with laser
  - λ, E/P, τ, HV, gases, chemicals, noise, mechanical hazards
- Environment
  - Laser location - laboratory, production hall
  - Condition of the area
  - Level of access - restricted (there is a ball on the door), out of public, out of hours
- Beam distribution
  - Open beam path, fiber, elements in the beam path, focusing optics, alignment...
- Process
  - Material processing, fumes, scattering on target, manual handling...
- People
  - Employees, contractors, visitors, children...

RISK EVALUATION - PROCEDURE

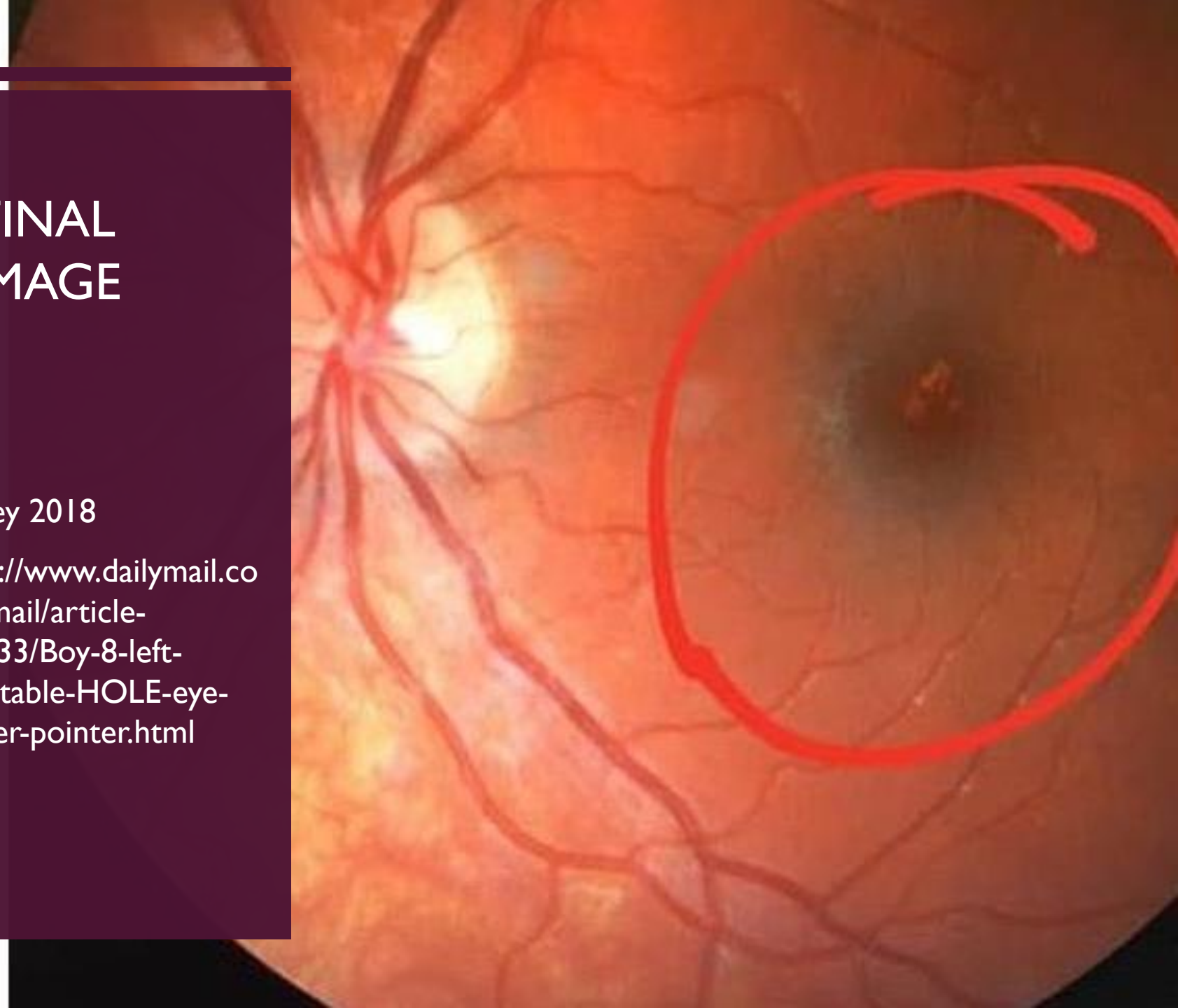
- Task specification - collection of complete and up-to-date information
- Hazard identification
- Risk assessment - determining the severity of the hazard impact and the likelihood



ACCIDENTS AND NEAR-MISSES

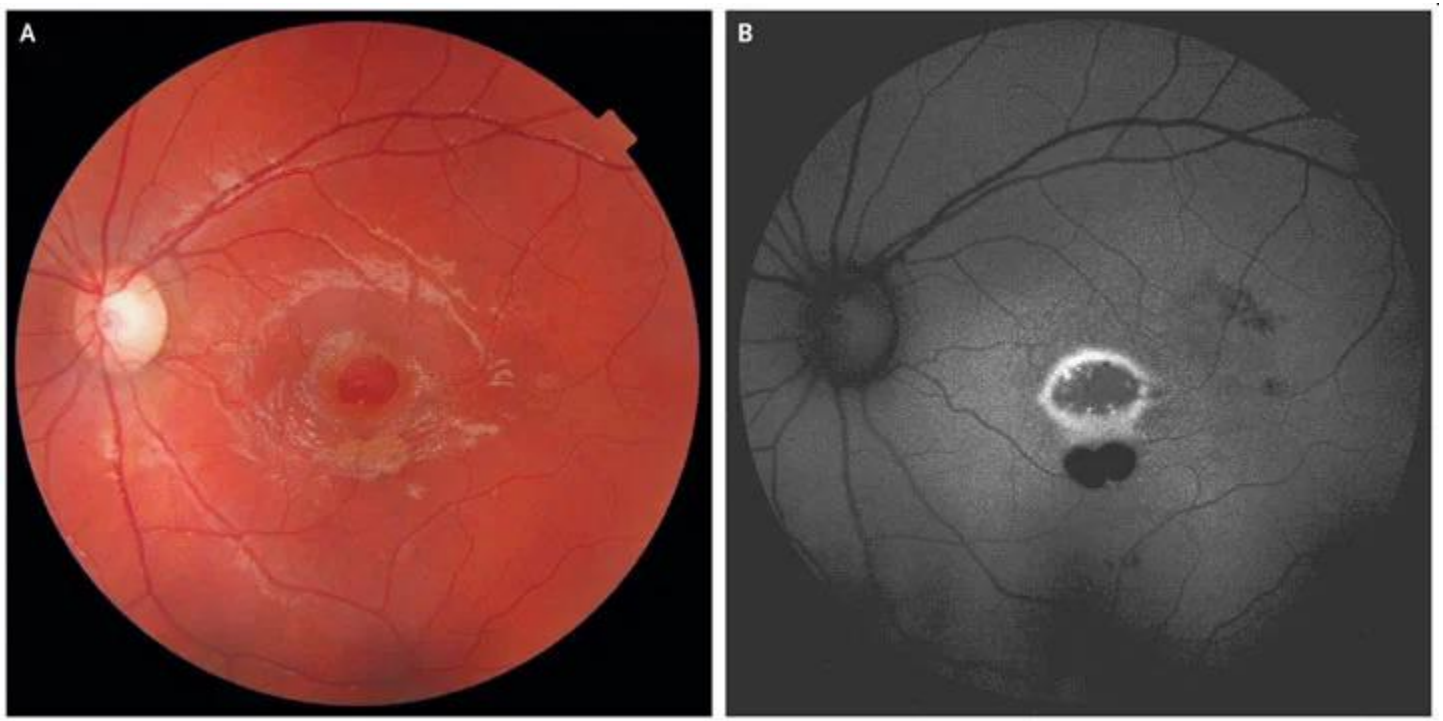
- An accident at work is defined as damage to health or death caused to an employee, independently of his/her will, by short-term, sudden and violent action of external influences or his/her own physical strength in the performance of work tasks or in direct connection with it (262/2006 Coll.)
- Most accident during system setup.
- Examples:
  - Laser pointer damage to the retina
  - Laboratory accident
  - Poorly adjusted cosmetic lasers

RETINAL DAMAGE



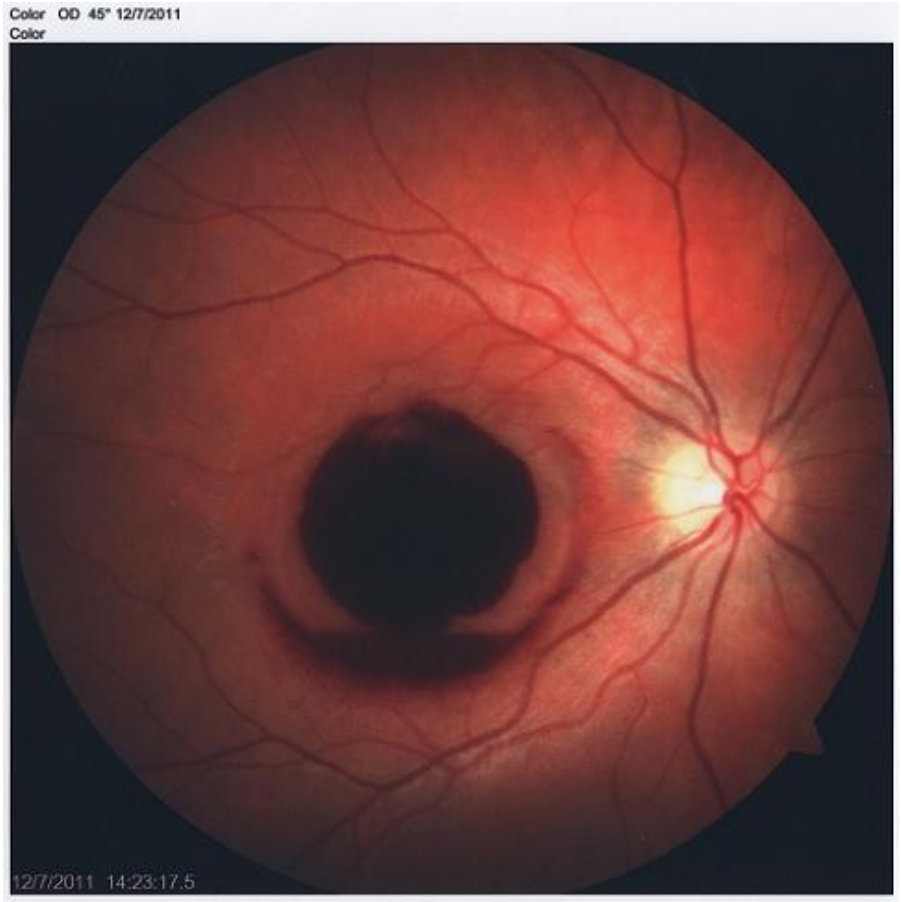
- Turkey 2018
- https://www.dailymail.co.uk/femail/article-7480933/Boy-8-left-untreatable-HOLE-eye-hit-laser-pointer.html

RETINAL DAMAGE



Macular Hole from a Laser Pointer – Androudi and Papageorgiou/NEJM 2018
A nine-year-old boy had impaired vision in his left eye after looking into the beam of a laser pointer. Fundoscopy and optical coherence tomography revealed a full-thickness macular hole.

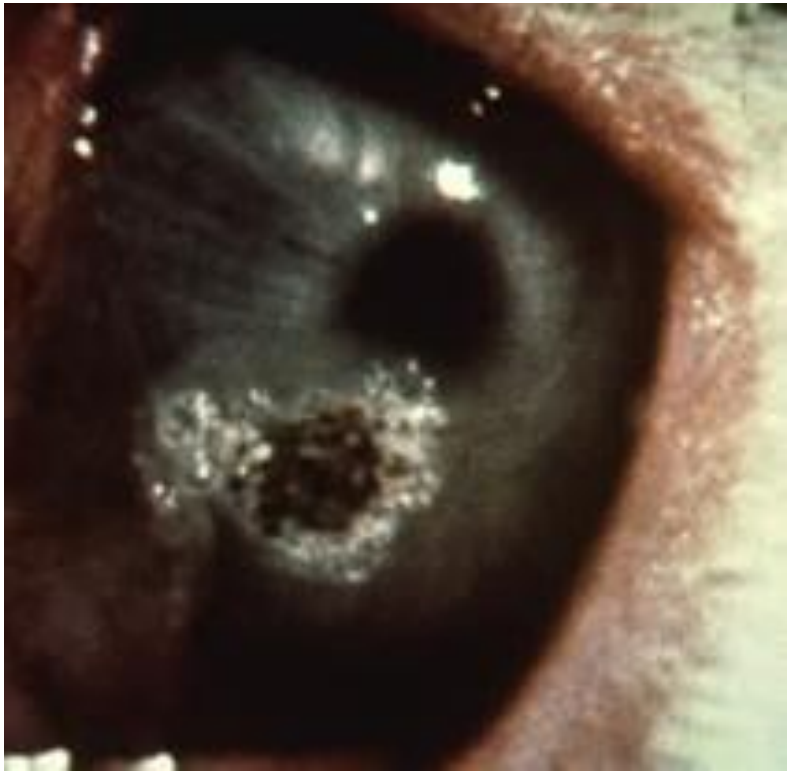
RETINAL DAMAGE



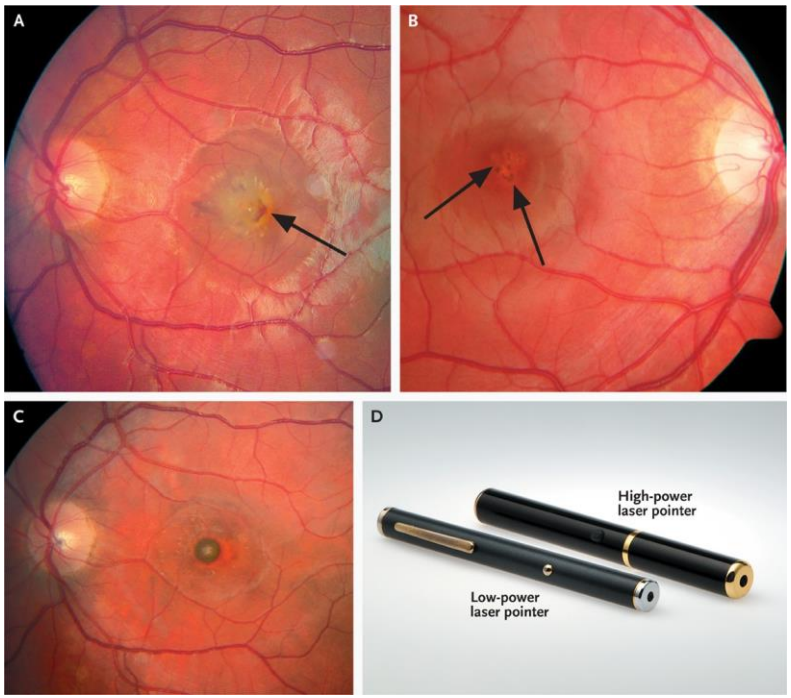
Laser pointer safety 2011

- 1 W, time < 1 s; @ 445 nm
- Laser on unstable surface
- Eye hit during fall of the laser

CORNEAL PHOTOABLATION



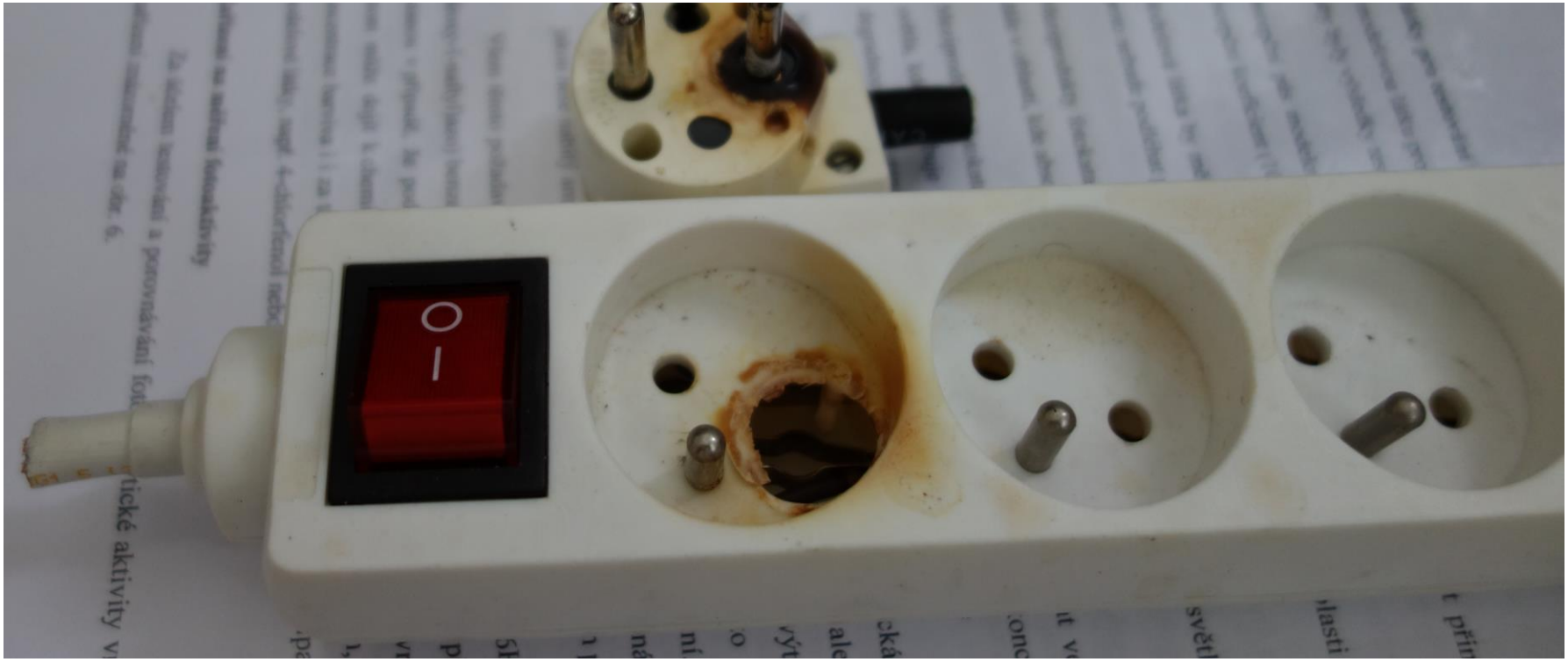
- Typical for excimers
- Photo of rabbit‘s eye (Berkley)
- https://ehs.lbl.gov/resource/documents/radiation-protection/laser-safety/laser-bio-effects/



- „Laser pointer“ 150 mW
- Reflection from mirror
- 15-year-old boy
- https://www.nejm.org/doi/full/10.1056/nejmc1005818

SKIN

Image courtesy of Maria Natale via The Post



MISTAKES HAPPEN

LEARN FROM THEM!

SAFETY CULTURE IS IMPORTANT

MOST COMMON CAUSES FOR ACCIDENTS

- Insufficient training
- Failure to follow correct working procedures **(Bathtub curve)**
- Poorly adjusted optics (Beware of reflections)
- Laser safety goggles were not used or were inappropriate
- Watching laser-generated plasma
- Instrument malfunction
- Ungrounded workplace
- Improper handling of high voltage
- Inhalation of laser-generated particles
- Intentional exposure of a person without PPE (laser pointers, laser show)

OTHER OBLIGATIONS AND REMARKS

- Medical examination – **mental and physical fitness**
  - **As of 1 January 2023, Amendment to Decree No. 79/2013 Coll. - cat. 1 and 2 option at the employer's discretion (FZU will not order), the employee may request**
  - Input/output still mandatory
- Ocular exam is only recommended for 3R, 3B, 4, – e.g. employee benefit (personal department will send you, but you can refuse, no penalties).
- **In the event of an accident**
  - Turn off the device
  - Provide first aid
  - If necessary, call emergency services (usually the ambulance or fire brigade)
  - Specification of the procedure in a particular laboratory is given by the **emergency regulation.**
- **If health protection cannot be ensured, the laser cannot be operated.**

OTHER RISKS

- High voltage
- Fire
- Explosion
- Vacuum
- Noise
- Chemicals – chemical lasers, ozone generation
- Gaseous vapors – respiratory damage
- Mechanical risks (cable routing, water hoses)
- Strong magnetic field (pacemaker)
- Ionizing radiation

QUESTIONS AND TEST

Institute of Physics - Section 5 Division of High Power Lasers – HiLASE Centre makes webinars and meeting on safe use of high-power lasers – I highly recommend.