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LASER SAFETY

Institut Fresnel

Outline

- Useful notions for LASER safety
- Beam-related hazards
- Preventing risks / protections
- The lab's LASERs
- Associated risks
- In case of an accident : what to do ?
- The people in charge of preventing accidents
- Practical advice and statistics

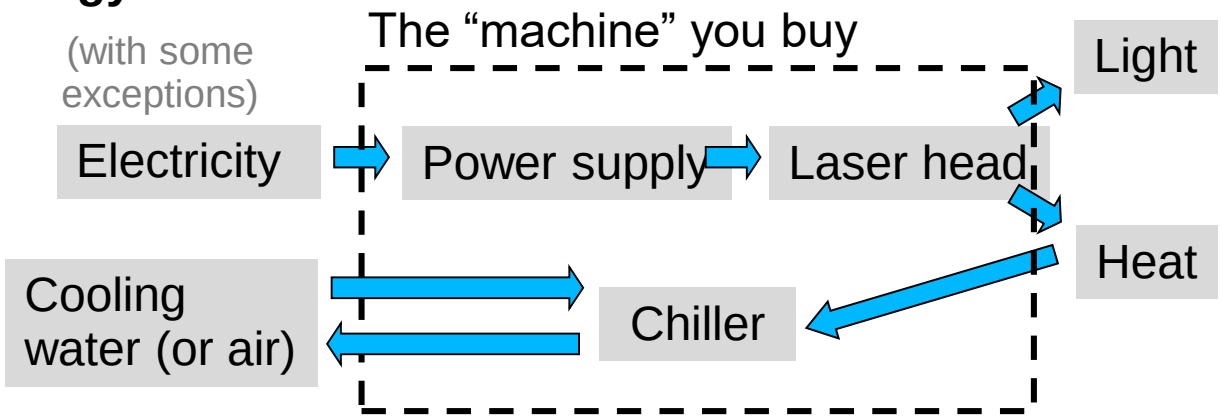
Useful notions in LASER safety

- Recognizing a laser
- LASER beam characteristics
- Mode of operation (pulsed/continuous ‘cw’)
- Limit Exposure Value / Maximal Allowed Exposure
- Eye-Safety Distance
- Classes of risks

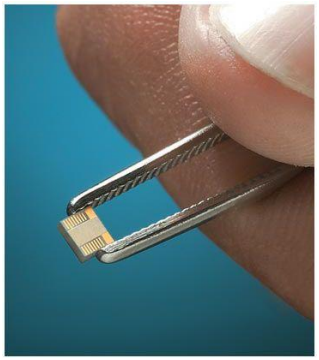
Recognizing a laser

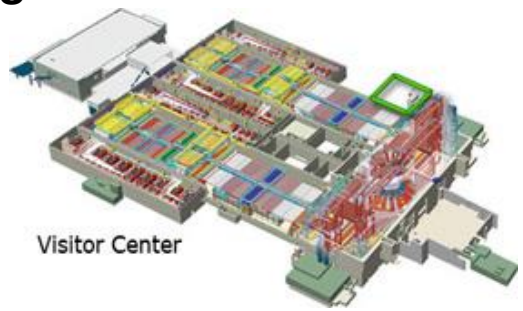
The LASER, a very special “lamp”

Energy fluxes



Small and large lasers – representing a tremendous diversity





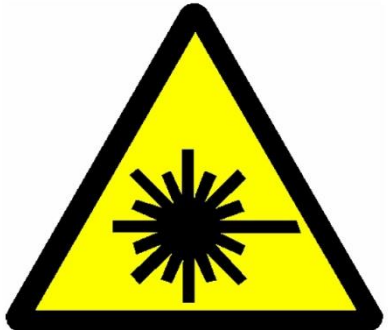
NIF (USA)
Create the conditions of the sun on earth

A large diversity of lasers exists.

Large /Small; Emitting invisible and/or visible light

So … how to recognize them?

By this sign:



It has to be *on the laser head* and *close to the openings* from which the light emerges,
But also on the doors of rooms containing dangerous lasers.

Light emitted by lasers can be dangerous …
- We will see in which conditions and how to protect yourself -

… But this is not the only danger related to work with lasers
- We will briefly speak about this too -

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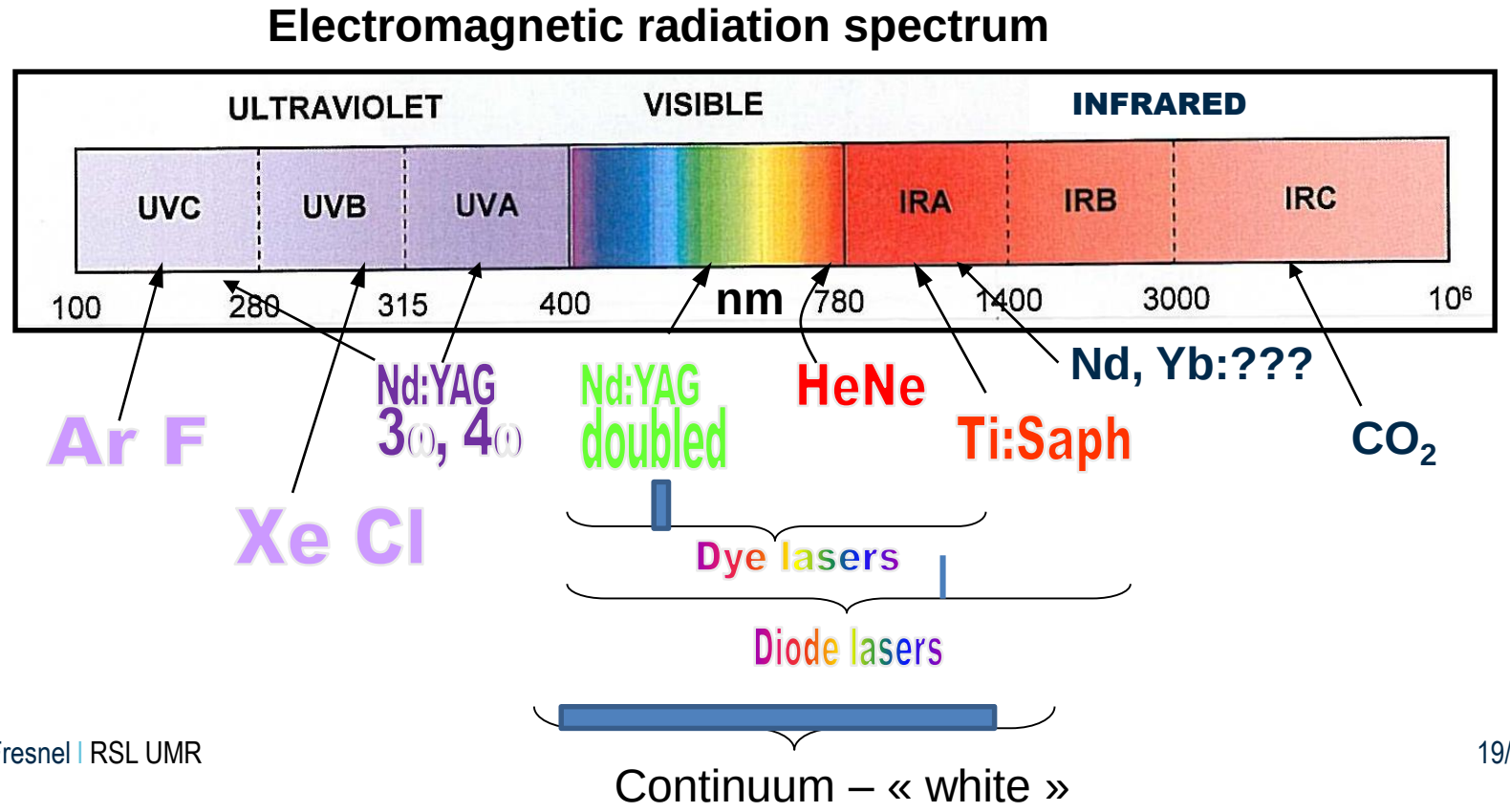
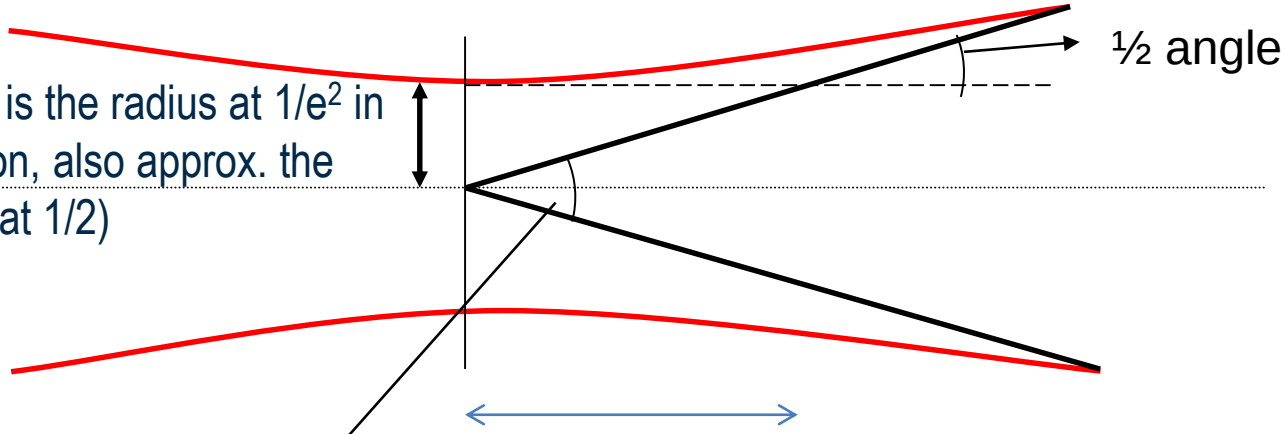
LASER beam characteristics

- **Wavelength**



LASER beam characteristics

- **Beam geometry / divergence**



LASER beam characteristics

- **Power** (W) for continuous wave lasers
- **Energy** (J) for pulsed lasers (energy per pulse)
  - Pulse duration (s) / Peak power (W)
  - Repetition rate (Hz) / number of pulses
- **Beam dimensions (waist)** (m)
  - Beam divergence (rad) / Rayleigh length (m)
- **Illumination** (W/m^2)

Mode of operation

Continuous wave (average power in W)

Pulsed (Energy (J) / Average power (W), Peak power (W))

- Q-switching
- Cavity dumping
- Mode-locking
- Gain switching

This has a consequence on the choice of Individual or Collective Protections (goggles,…)

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Limit Exposure Value (work legislation) / Maximal Allowed Exposure (norm)

Limit Exposure value (« VLE » in french) :

The limit exposure value to artificial optical radiation, based directly on proven effects on health and biological considerations. Respecting them guaranties the worker exposed to artificial optical radiation source will be protected against all health hazards currently known.

Nothing is said about the time of exposure.

Limit Exposure Value (work legislation) / Maximal Allowed Exposure (norm)

Maximal Allowed exposure (« EMP » in french) :

The level of laser radiation to which people can be exposed under normal circumstances without suffering bad consequences.

The “EMP” levels represent the maximal level at which the eye or the skin can be exposed without suffering a damage, immediately after or a long time after exposure.

Limit Exposure Value (work legislation) / Maximal Allowed Exposure (norm)

- The concepts are basically identical
- The legal texts are different
- There exist legal thresholds for:
  - The skin
  - The eye

Eye-safety distance (« DNRO » in french)

The distance from the laser output aperture at which the illumination or the energetic exposure is equal to the Maximal Allowed Exposure (« EMP ») on the cornea .

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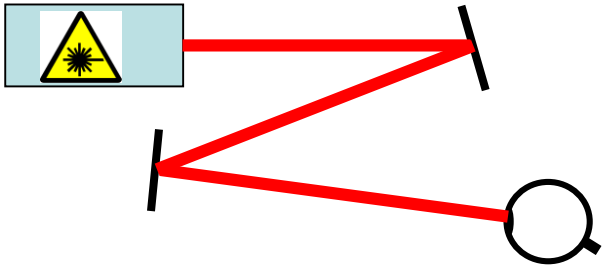
Types of “exposures” to LASER light

Direct exposure

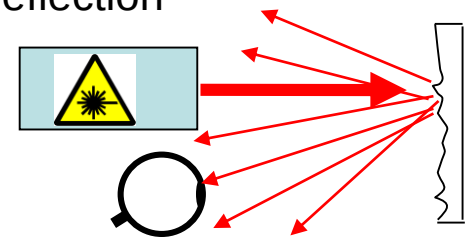
Looking in the beam

Looking across an optical instrument (lens etc.)

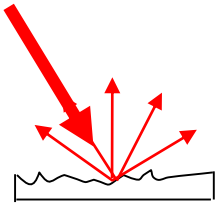
Exposure to specular reflection



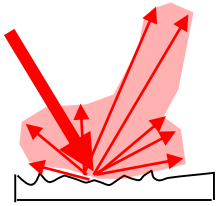
Diffuse reflection



Perfect diffusor



Non-uniform diffusor



Classification, see norm EN60825-A1 from 2006

Classes : (only describing the beam-related risk)

Class 1 : Hazard-free laser device, including when seen directly over a long period of time, even when using a optical observation device (lens,…).

Class 1M : No LAZER hazard, including when seen directly over a long period of time (with naked eye).

HOWEVER, when using an observation optics (lens,…) the exposure can be higher than the « EMP » safety threshold.

Classification, see norm EN60825-A1 from 2006

Classes : *(only describing the beam-related risk)*

Class 2 : 400-700nm

Safe for temporary (<0.25s) exposures. Including with observation optics.

Class 2M :

Safe for temporary (<0.25s) exposures.

Possibility of eye-damage when using observation optics.

Classification, see norm EN60825-A1 from 2006

Classes : *(only describing the beam-related risk)*

Class 3R : When the beam is seen directly, the exposure is unsafe (higher than the « EMP »).

Class 3B : When D<DNRO (minimal safety distance), whatever the duration of exposure, the LASER is dangerous. The diffusion-like reflexions are normally safe.

Classification, see norm EN60825-A1 from 2006

Classes : *(only describing the beam-related risk)*

Class 4 :

Direct observation is dangerous

Skin exposure is dangerous

Diffusive reflexion is dangerous

Fire-hazard

image : Dominique Lamiable

« Old » classification, see EN 60825 from 1994

Class 1 : Safe under any reasonnable condition of use.

Classe 2 :

400-700 nm

The eye is normally protected by the blinking reflex.

« Old » classification, see EN 60825 from 1994

Class 3A :

Safe when seen with a naked eye

400-700 nm = blinking reflex are sufficient

The risk is not higher than that of class 1 for other wavelengths.

Obervation with an optical device is dangerous.

Class 3B :

Direct observation is dangerous

Diffusive reflexion is normally safe.

« Old » classification, see EN 60825 from 1994

Class 4 :

Direct observation is dangerous

Skin exposure is dangerous

Diffusive reflexion is dangerous

Fire-hazard

Classes summary

Without danger

Possibly dangerous

Certainly dangerous

Classes	1	1M	1C	2	2M	3R	3B	4
Eye: vision with an optical instrument								
Eye: direct beam and specular reflexion								
Eye: diffuse reflexions								
Skin								
Fire								

Attention !! A machine of class 1 may contain inside a laser of class 4 !

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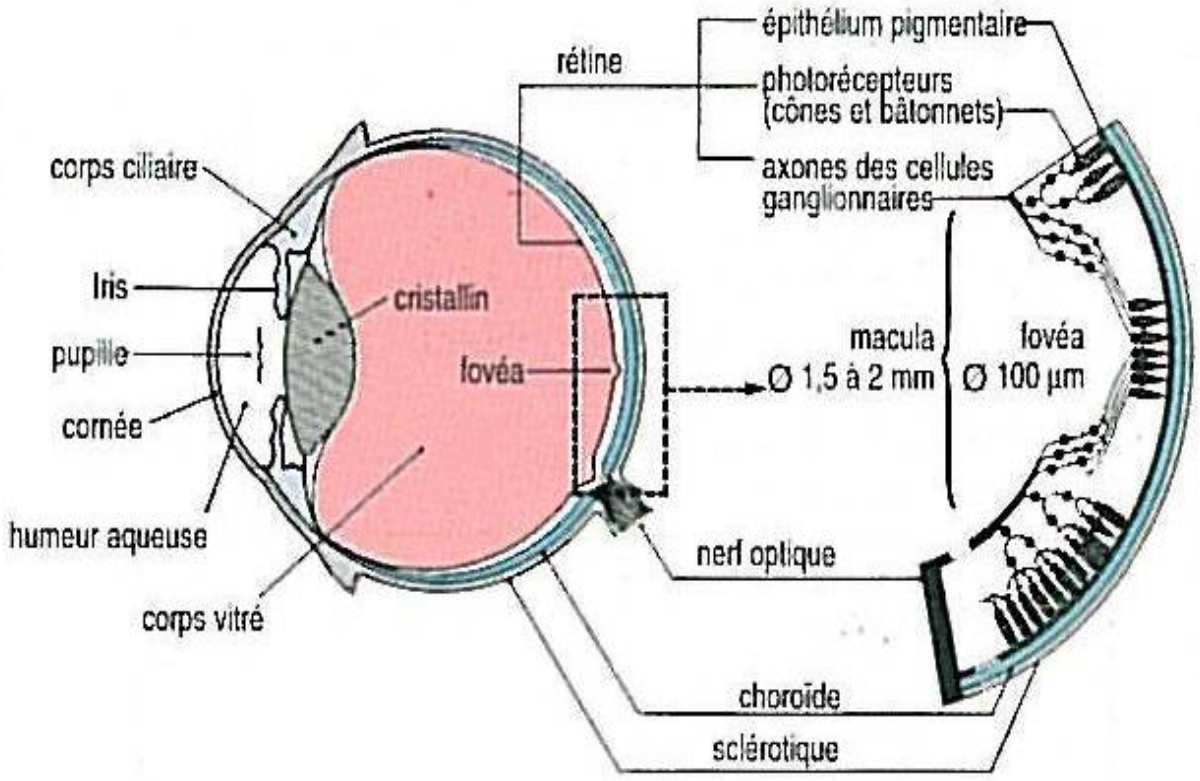
Beam-related hazards

- Thermal effect : it burns !
- Photochemical effect (UV, long exposure times): chemical reactions induced by irradiation. Production of toxic, or even lethal compounds, DNA errors,…
- photoablation (UV, short pulses): chemical links are destroyed, ejection of fragments.
- Electromecanical effects (short pulses): ionisation and release with shockwave.

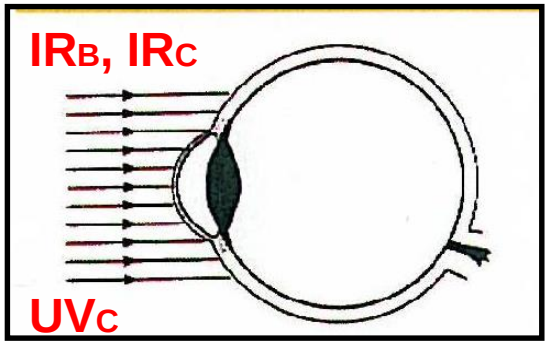
Beam-related hazards

- Eye-hazards :

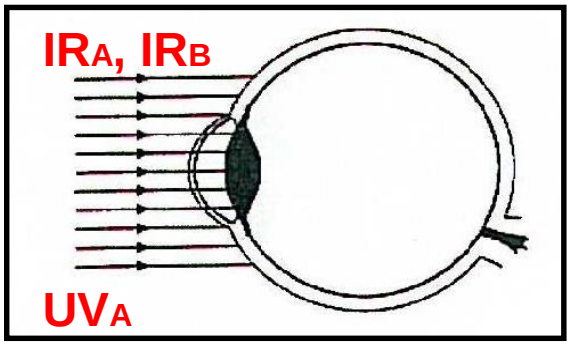


Beam-related hazards

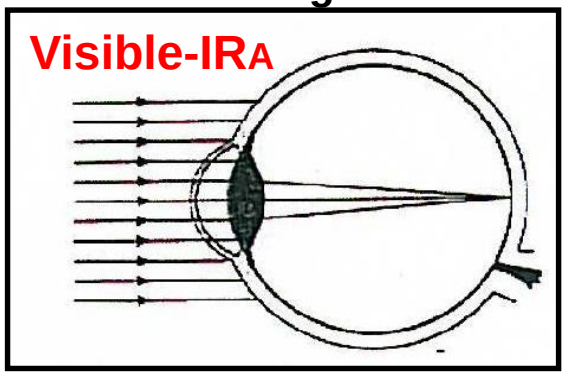
Photokeratitis and cornea burns



Cataract



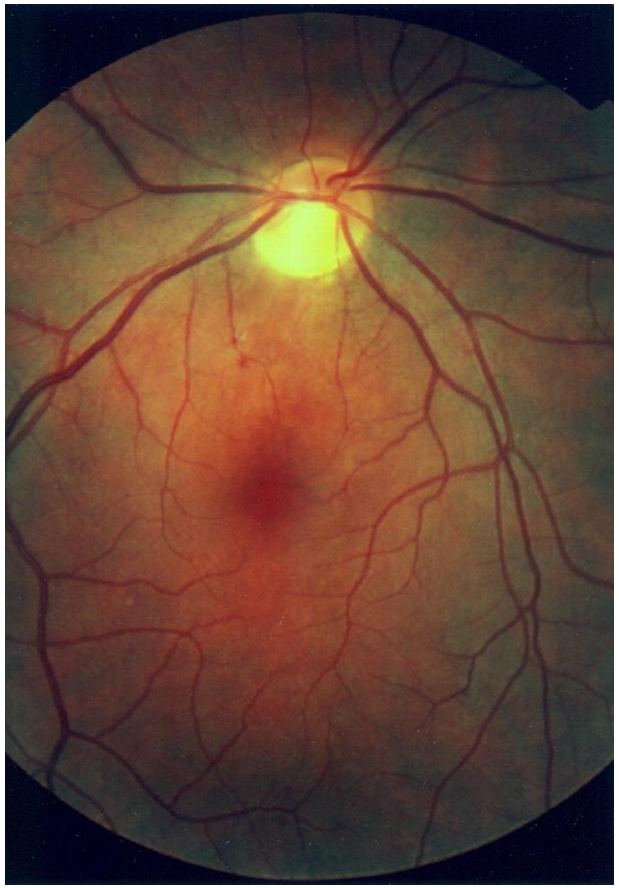
Retina burns and damages



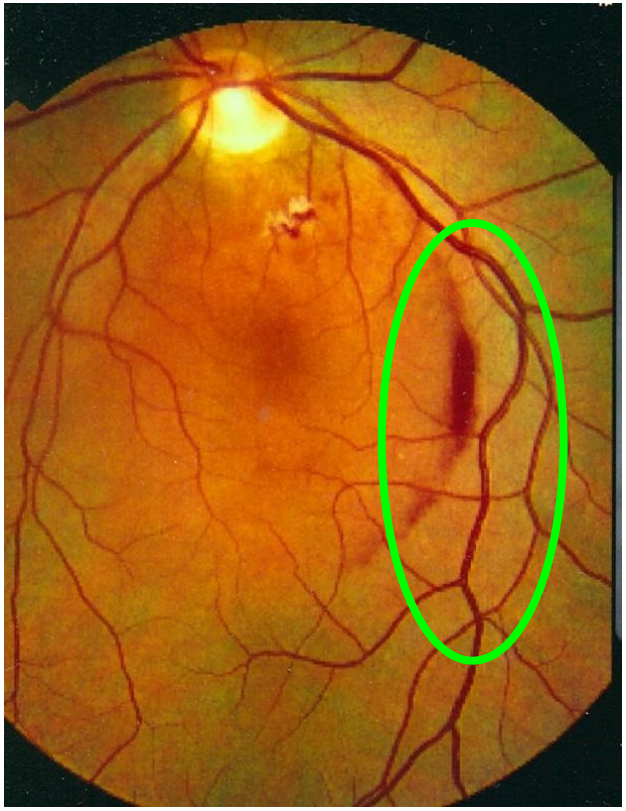
A damage to the retina in the macula region from a few mW laser can produce partial or complete loss of sight

Gain (in term of illumination) of the eye can reach 5.10^5

Beam-related hazards



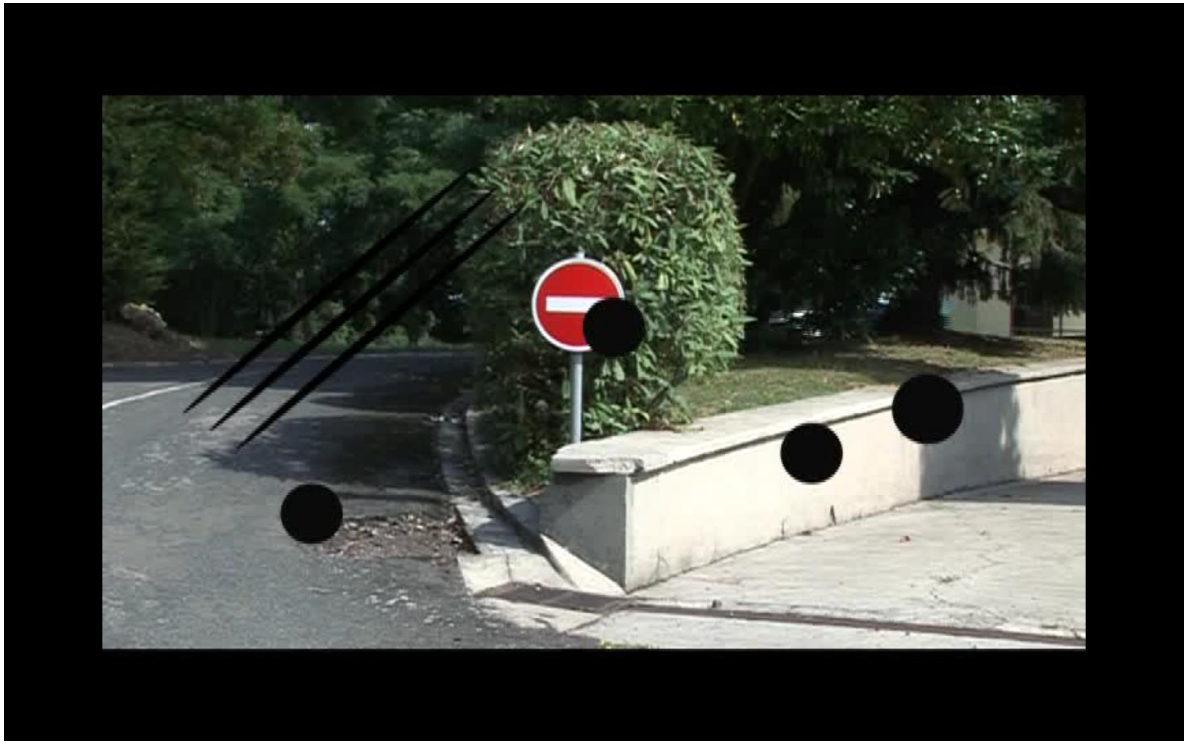
Healthy eye



Damaged eye

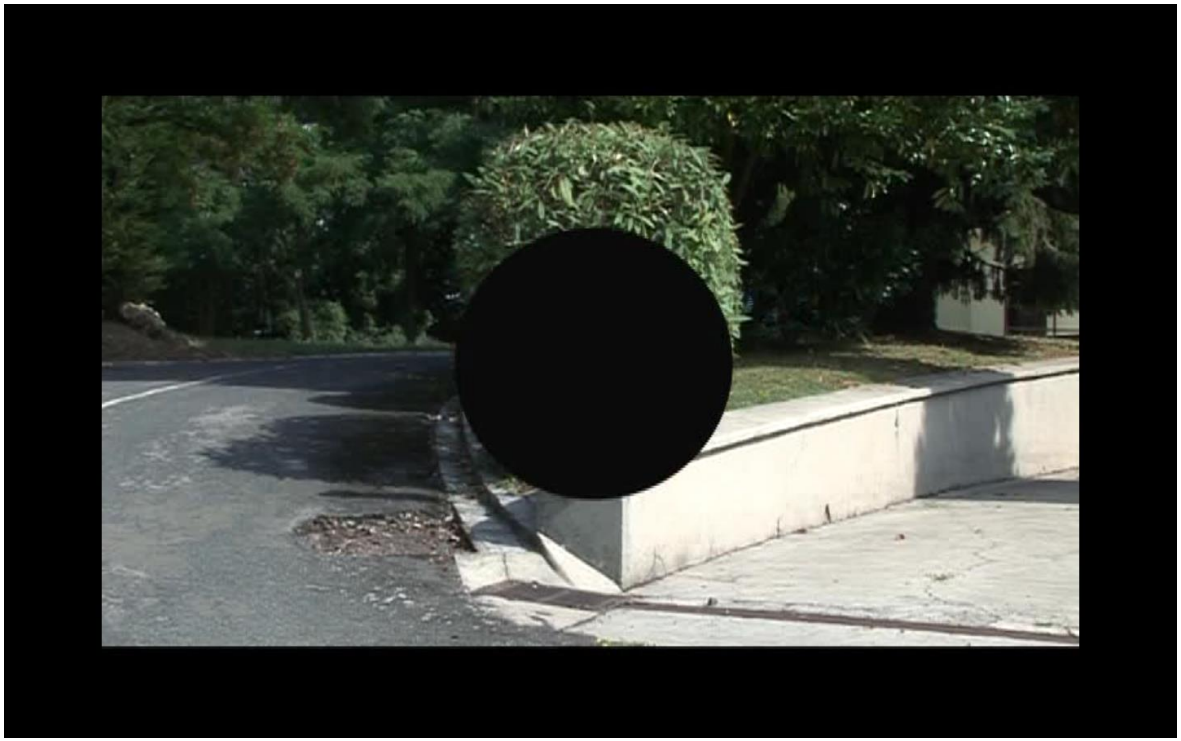
Beam-related hazards

- **Impact on the eye**



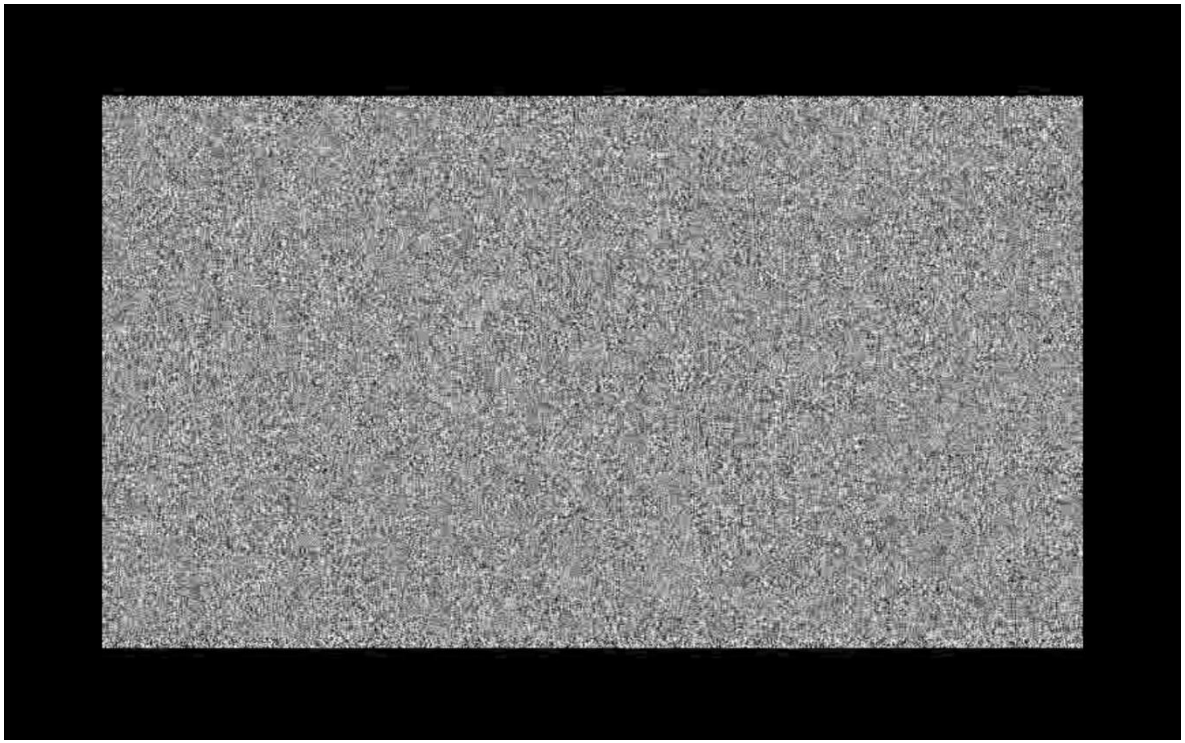
Beam-related hazards

- **Impact on the macula**



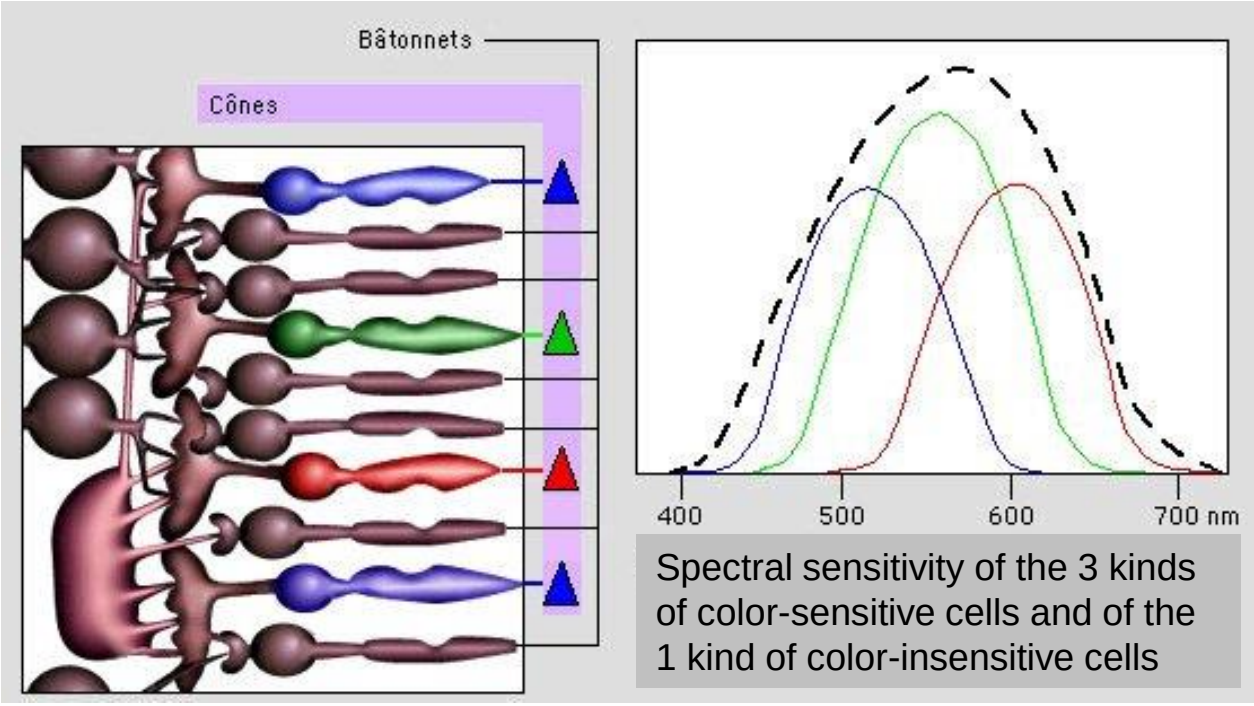
Beam-related hazards

- **Impact on the optical nerve**



Beam-related hazards

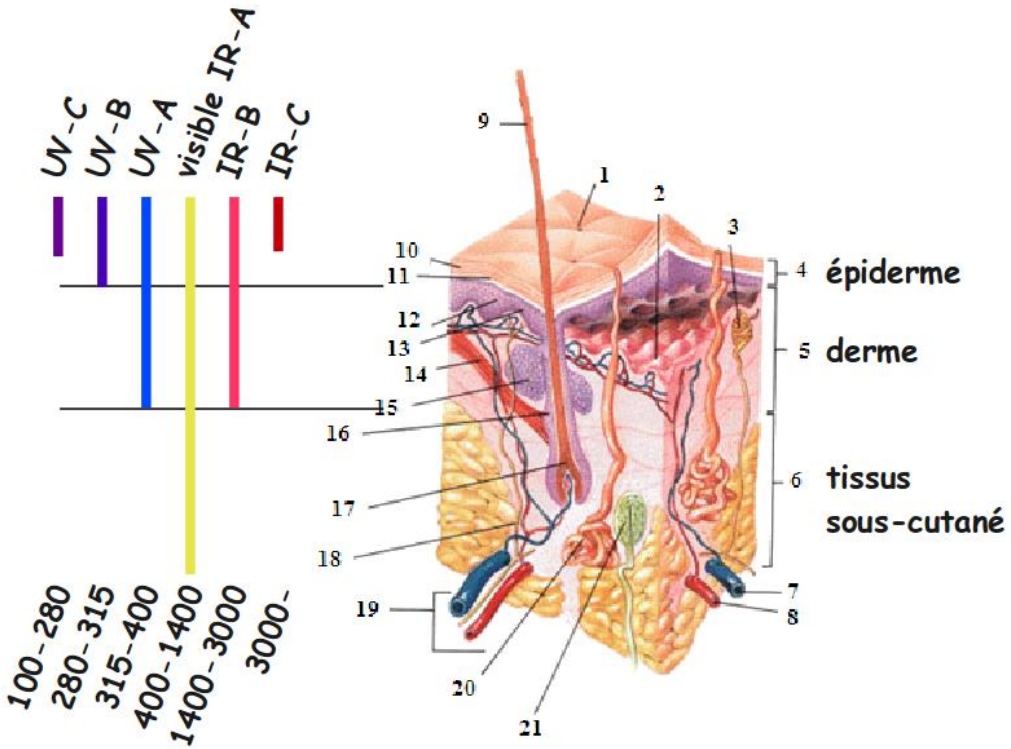
- **Eye sensitivity:** the eye is most sensitive to green light !



Spectral sensitivity of the 3 kinds of color-sensitive cells and of the 1 kind of color-insensitive cells

Beam-related hazards

- **Skin hazard:**



Laser beams (IIIB et IV) can induce burns (UV_A, Visible, IR) and erythemas ($UV_{B,C}$) on the skin

Beam-related hazards

- **Fire**

Check for sink, fire extinguisher, …

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Preventive measures

Similar to the general principles of any preventive measure :

- Substitution / optimization
- Room design
- Experiment design
- Installing and using collective and, if need be, individual protections
- Formation / information of the staff

Substitution / optimization

- Do you really need a LASER ?
- Use the « weakest » possible laser, according to the experiment's requirement
- Prefer visible LASERs when possible

Room design

- Lighting of the room (to decreas the size of the pupil),
- Double-door entrance,
- Barriers inbetween experiments inside the same room,
- Show a map of the room (help people moving and objects handling),
- Interlock,
- (Color coded) indication lights
- Low-reflexion cover on floor and walls,
- Room safety instruction labels,
- …

Design of the experiment

- Covers / tubes around beams / blinds,
- Turn-on procedure,
- Direction of laser beam,
- Alignement procedure,
- Full control of the optical path,
- Tightening the optical elements,
- Beam visualization procedure,
- Positions of the commanding knobs,
- Beam block after beam use (don’t let it run everywhere…),
- Maintainance (cleaning,…) and tuning procedures,
- …

Training / information of staff

- Welcome procedure
- Laser safety habilitation procedure for the laboratory
- Laser Safety Officer
- General Safety officer
- Work station instructions

Individual Protection

- Laser goggles :
  - for protection (LB)
  - for alignment (RB)

Protects against ACCIDENTAL and SHORT exposure

(legal **trial time**: 5s for a continuous wave laser, 50 pulses for a pulsed laser)

Laser goggles (LB)

Accidental exposure to a laser beam whose wavelength is between 180 nm and 1000 µm (NF EN 207)

The duration of exposure varies with wavelength and cw/pulsed operation.

illumination after goggle < « EMP »

To check whether goggles and laser match, please contact the RSL.

Laser goggles (RB)

Accidental exposure to a laser beam whose wavelength is between 400 nm and 700 nm (NF EN 208)

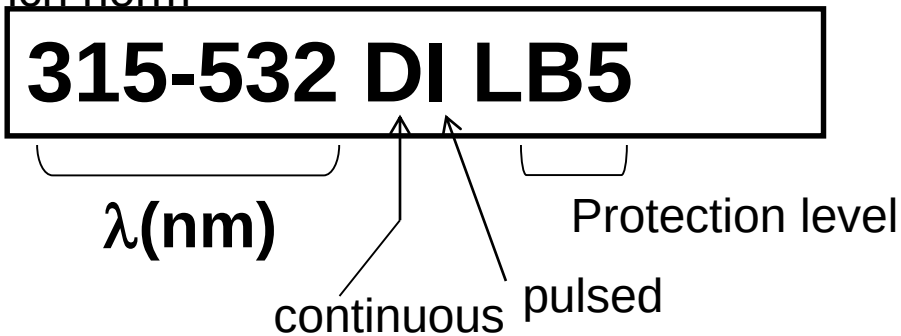
Reduction of exposure to something equivalent to class 2

Maximum duration of the accidental exposure is 0.25s

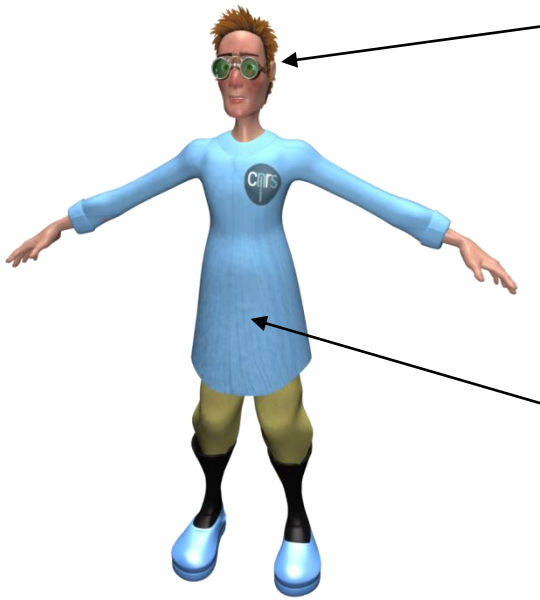
Attention, these glasses are very specific, if you have some keep them to the setup you bought them for

Labeling

λ : wavelength
D : Continuous wave laser
I , R : pulsed laser (ms, μs, ns)
M : Mode-locked pulsed laser (ps, fs)
LBn : level of protection (L1->L10 the more attenuation)
(RB for alignment goggles)
CE : European certification label
EN207, EN208 French norm



Work outfit



NO jewels

possible reflections on surfaces

(rings, watches, wristband, pendant, necklace…)

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The LASERs in the laboratory

- *The LASERs & the workstations instructions….*

There are at least 40 class 4 lasers at Fresnel….

Simply do not enter a lab that you don't know without a person that works there regularly.

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Associated risks

- Electric hazard
- Fire hazard (see beam-related risks)
- Gaz-related hazard
- Chemical hazard
- Cryogenic hazard

Electric hazard

HV power supply of the laser

Electric certification

What to do in case of a power breakdown (*see unit*)

Maintainance of the LASER (flash lamps,…)

Gaz hazard

Which gaz

Inert / toxic / flammable

Pressure

Plumbing / checkout

Gaz bottles / tanks

Weights / size / checkout at delivery / handling / stocking

Chemical hazard

Solvent for the dye

Dye

Cleaning solvent

Optical material composition (ZnSe, KrS_5 for IR)

Cryogenic hazard

Frost-burns

Anoxia (lack of oxygen in the air)

Individual protection equipment for cryofluids trasfers (gloves, goggles, face protection,…)

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What to do in case of an accident

- *To be adapted for each laboratory…*
- *Contact* First-Aid Trained *persons*

Translated from Amu laser safety presentation

- **Skin :**
  - **15min under water (moderate temp)**
- **Eye :**
  - **Close both eyes**
  - **Put sterile cover on both eyes**
  - **Possibly put several layers to avoid light entering..**
  - **Lay down but keep the head higher than the body**
- **Call 15 or 112 :**
  - **Tell them which par of the body is damaged**
  - **Indicate laser class, energy, wavelength**
  - **Ask whether you can hang up**

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The people in charge of preventing accidents

- The worker
- The director of the Laboratory
- The person in charge of the experiment
- The General Safety Officer
- The Laser Safety Officer
- The First-Aid Trained workers
- The medical doctors in charge of preventing accidents
- The engineer in charge of preventing accidents

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Some statistics

Over 28 LASER accidents reported in CNRS research units:

- 27 **didn't wear laser goggles**,
- 16 **non-direct** refexion/ **loss** of beam (reflective vizualization card, mounting post for optics…),
- 4 falls / movements of an un-tightened optical element,
- 3 **insertions** of optical elements in the laser beam while laser was on.

Ideas for best practice

- Lock the door for all non qualified personnel
- Indicate on the door when le laser is on
  (tape a paper on the door handle.)
- Let the right protection glasses outside the lab
  (or in the double-door entrance)
- Communicate clearly before entering the lab
  (laser on? No / YES green…)
- Remove any shining objects (rings, necklaces, watch)
- Bloc reflections of the beam by adapted obstacles
- If possible keep the laser horizontal

Ideas for best practice

- Do not put your eyes at beam height
(optical table height = height of eyes if sitting on a standard chair)
- Avoid reflecting objects facing the setup
(computer screens)
- If possible do not put any instruments below the optical table
- Block the beam when entering or removing an optical component, a mounting, a screwdriver…
- Screw/fix all elements to secure against bad movements
- Align with minimum beam power
- Pay attention to reflections from visualization cards, thermal paper (use with slight angle towards the table)

Remember

We only have 2 trials
(refuse to hire people with only one working eye)

We have to comply to legal regulations
(fill in the FICHE INDIVIDUELLE D'EXPOSITION)

Buy protection glasses and beam blocks

Make a safe lab conception
(doors, windows, wavelengths, diffuse light… I have check lists for this)

Train yourself to use safe working procedures
(be aware when you were lucky)

Thanks for your attention