Laser Safety

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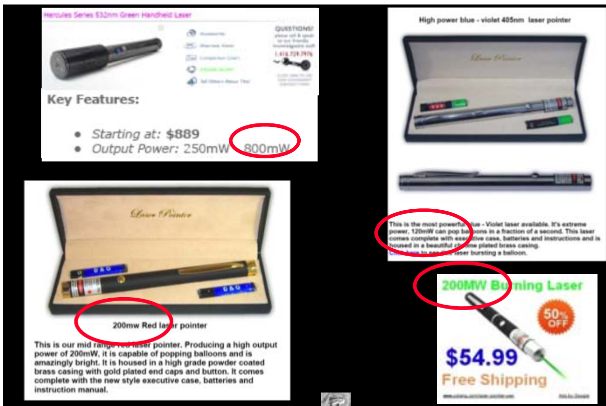
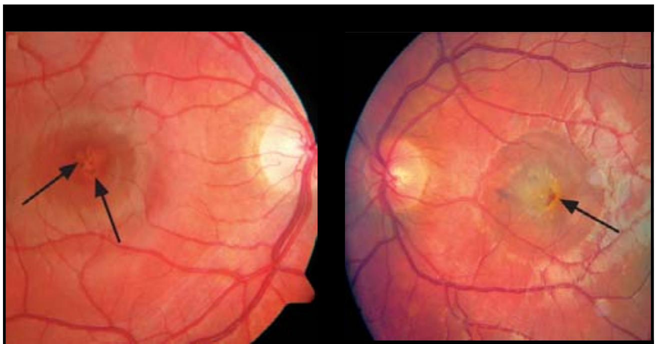
Available at
http://www2.neuro.uu.se/ophthalmology/Downloads/Miami/LaserSafetyMiamiPresentation.pdf

Laser eye damage Risk groups

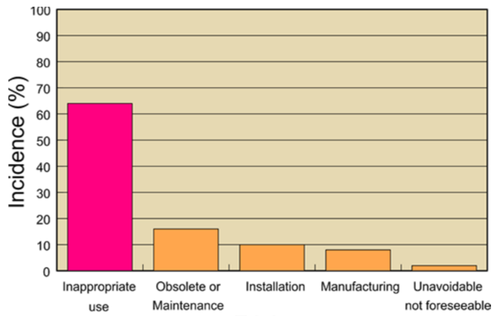
- Scientists
- Military staff
- Vehicles





Wyrsch et al. 2010

Relative incidence of laser eye damage



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Laser Safety

- Risk evaluation
- Safety measures
- Surveillance program

Risk evaluation

- Standards/Guidelines
- Laser Hazard Classification
- Radiometric risk evaluation

US Laser standards

- Non-governmental
- Governmental

Non-governmental US guidelines

- American Conference of Governmental Industrial Hygienists (ACGIH)

  Rational: Define generally agreed upon limits for safe exposure of the eye, Threshold limit values (TLVs)

  Issuing (no inforcement): ACGIH

Non-governmental US guidelines

- American National Standards Institute (ANSI) (Committe Z 136: hazard evaluation for lasers)

  Based on the ACGIH eye hazard function for low intensity beams and specifically considers high intensity short pulses of light energy. Conforms to the ICNIRP laser standard

  Rational: Develop a standard for hazard evaluation of lasers

  Issuing (no inforcement): ANSI

Governmental US standards

- Protect the worker
  Occupational exposure standards

  Recognizes ANSI recommendation for hazard classification

  Rational: Protect the worker

  Issuing, enforcement: United States Government, Dept. of Labour by
  Occupational Safety and Health Administration (OSHA)

Governmental US standards

- Protection the environment
  Environment exposure standards

  Recognizes ANSI recommendation for laser hazard classification

  Rational: Protect the environment

  Issuing, enforcement: United States Government, Environmental Protection Agency (EPA)

Governmental US standards

- Protect the public
  Product performance standards

  Recognizes ANSI recommendation for laser hazard classification

  Rational: Protect the individual

  Issuing, enforcement: Bureau of Radiological Health (BRH) of Federal Drug Administration (FDA)

International standards/guidelines

- Comission International d'Eclairage (CIE)
  Rational: Define radiological terms and references (standard sensitivity of the eye, standard color vision observer…)
  Issuing (no enforcement): CIE

- International Committee on Non-Ionizing Radiation Protection (ICNIRP)
  Standard corresponds to the ACGIH eye hazard function for broad band sources and the ANSI laser standard
  Rational: Protect the individual
  Issuing (no enforcement): ICNIRP

- International Electrotechnical Committee (IEC)
  Rational: Make equipment safe
  Issuing (no enforcement): Industry

- International Standards Organisation (ISO)
  Rational: Facilitate international collaboration
  Issuing (no enforcement): ISO

Other standards

- Specific national standards for almost every country

  Standards are usually based on the ICNIRP Guidelines

  Rational: Protect the individual

  Issuing, enforcement: National radiation protection institute

Laser Safety

Risk classification

- Class I-IV(V)

Laser Safety

Class I

- Can be stared into without any eye hazard for 8 hrs

  < 40 μW for blue
  < 400 μW for other wavelengths
  collimated within 6 mm diameter

Laser Safety

Class IM
(Large beam diameter)

- Can be stared into without any eye hazard, but may be dangerous if observed with magnifier

Same power limits as Class I within a 6 mm measurement aperture

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Laser Safety

Class II

- Visible
- Aversion reflex (10-20 s) protects from damage

<1 mW collimated within 6 mm diameter

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Laser Safety

Class IIM
(Wide field beam)

- Visible
- Aversion reflex (10-20 s) protects from damage (Power < 1mW within 6 mm)
- Dangerous if exposure with magnifier

Same power limits as Class II within a 6 mm measurement aperture

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Laser Safety

Class III

1-500 mW collimated within 6 mm diameter

- Class IIIR
  Visible, potentially dangerous for intentional intrabeam viewing but accidental exposure (faster than blink reflex<0.25 s) does not cause damage. Power < 5 mW
- Class IIIa
  Non-visible lasers that allow accidental exposure (faster than blink reflex<0.25 s). Power < 5 mW
- Class IIIb
  Visible and IR, all direct exposure dangerous. Power 5-500 mW

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Class IV

>500 mW

- Diffuse reflexes can be dangerous

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Class V

- Completely safe because enclosure protects completely

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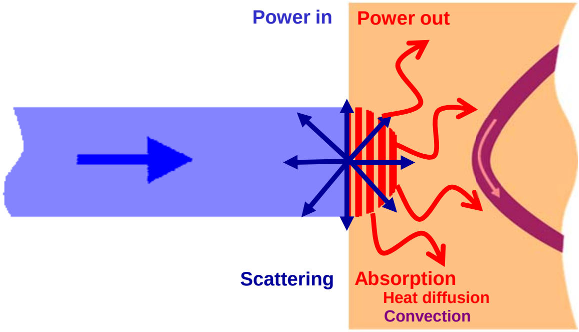
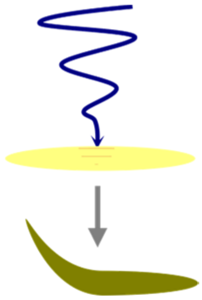


Photochemical Damage



Mechanisms for photobiological damage caused by photochemical reaction

- Direct damage to biomolecule
- Photosensitization
- Photoallergic reaction

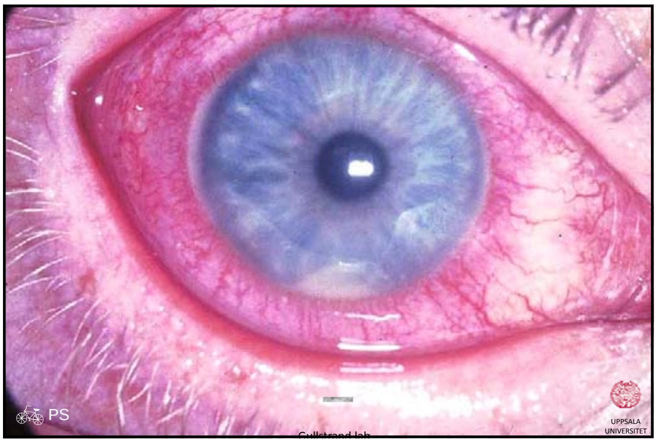
Laser – Eye damage

Photochemical – direct damage Keratitis

- E.g. Krypton-ion

  (CW) 350.7, 356.4 nm

  0.7 kJ/m^2 (5.8 W/m^2, 120 s)



Laser – Eye damage

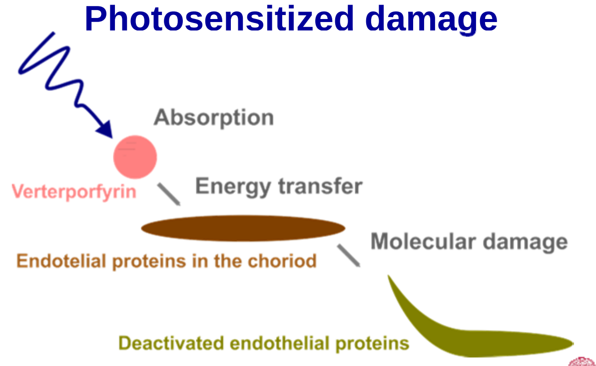
Photochemical – photosensitization Vessel destruction

- E.g. HeNe

  (CW) 632.8 nm

  300 kJ/m^2 (500 W/m^2, 10 min.)

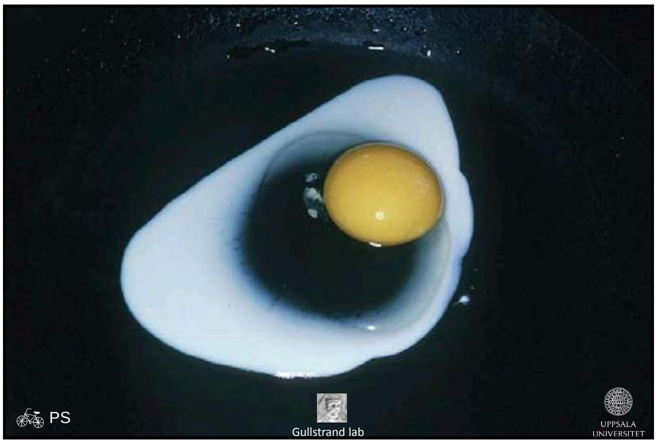
Photosensitized damage

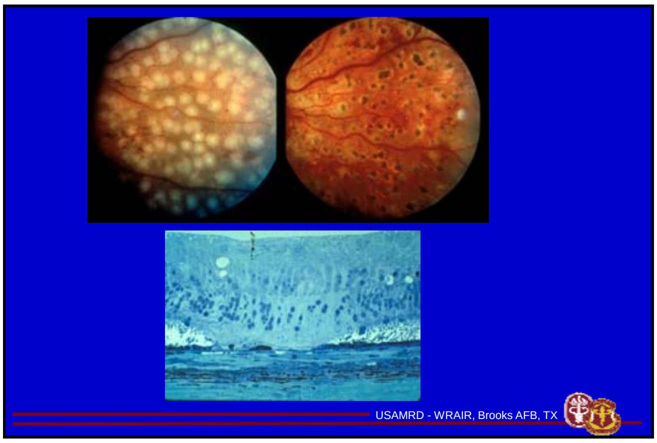


Laser – Eye damage

Thermal- Photocoagulation
Retinal treatment

- E.g. Argon green (514.5 nm)
  Spot size: 100 μm
  Power on the eye: 0.2 W
  Retinal irradiance: 2 kW/m^2
  Pulse duration: 0.1 s
  Radiant exposure: 0.2 kJ/m^2

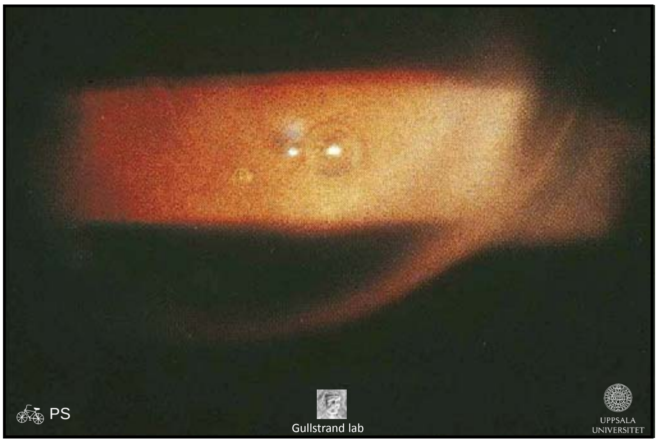




Laser – Eye damage

Thermal- Photovaporization
Drilling holes in the iris

- E.g. Argon green (514.5 nm)
  Spot size: 100 μm
  Power on the eye: 0.6 W
  Iris irradiance: 6 kW/m^2
  Pulse duration: 0.1 s
  Radiant exposure: 0.6 kJ/m^2



Laser – Eye damage

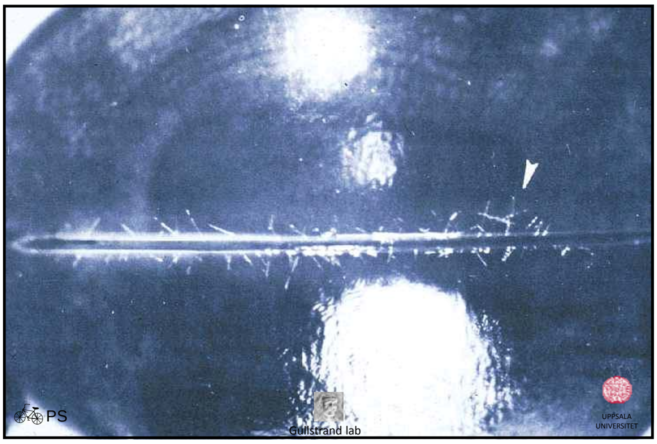
Thermal- Carbonization
Evaporation of wharts

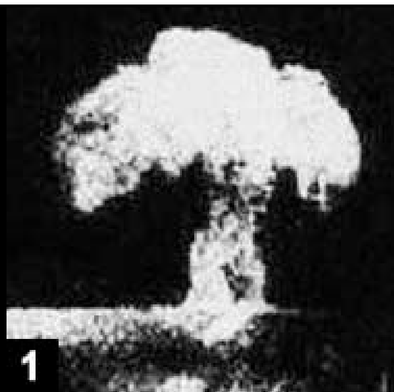
- **E.g. CO_2 (10.6 μm)**
  Spot size: 1 mm^2 (Diam. 0.6 mm)
  Power on the skin: 100 W
  Irradiance on the skin: 1x10^8 W/m^2
  Pulse duration (CW): 1 s
  Radiant exposure: 1x 10^8 J/m^2

Laser – Eye damage

Photoablation

- **E.g. ArF (193 nm)**
  Spot size: 1 cm^2 (Diam. 0.6 cm)
  Beam power: 3 x10^8 W
  Irradiance: 5 x10^{10} W/m^2
  Pulse duration: 15 ns
  Radiant exposure: 7.5 x10^2 kJ/m^2
  1 puls = 0.1 μm ablation along the beam





Laser – Eye damage

Photodisruption

- **E.g. Nd:Yag (1064 nm)**

  Spot size: 1 μm^2 (Diam. 0.6 μm)

  Power: 2.8 $x10^{13}$

  Irradiance: 5 $x10^{19}$ W/m^2

  Pulse duration: 10 ns

  Pulse dose: 5 $x10^{11}$ J/m^2)

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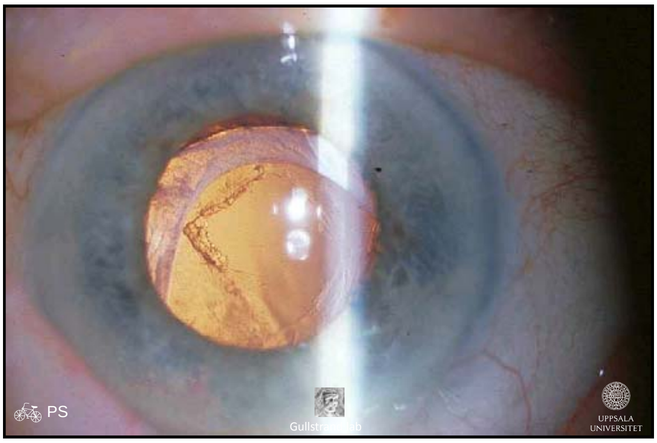
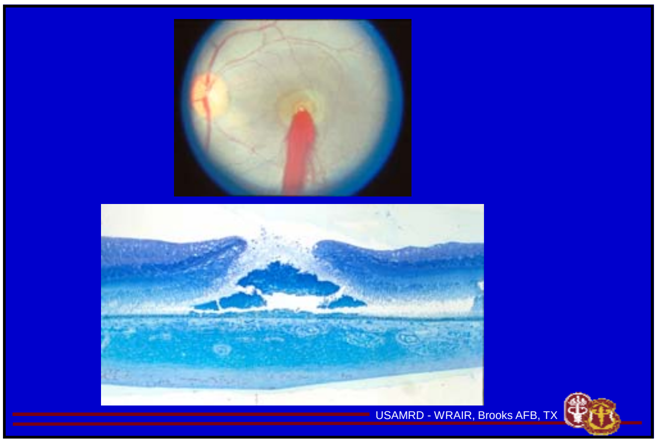
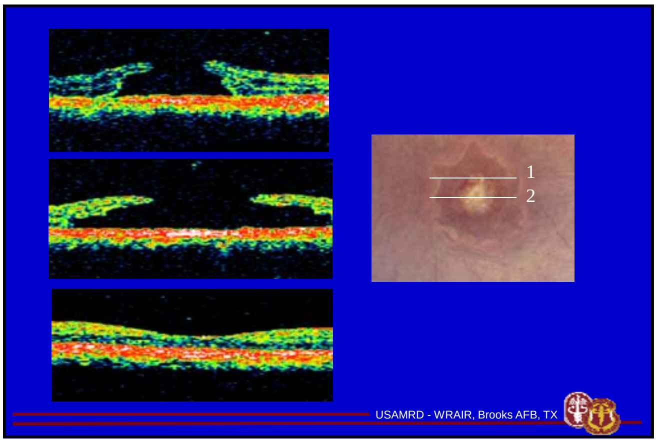
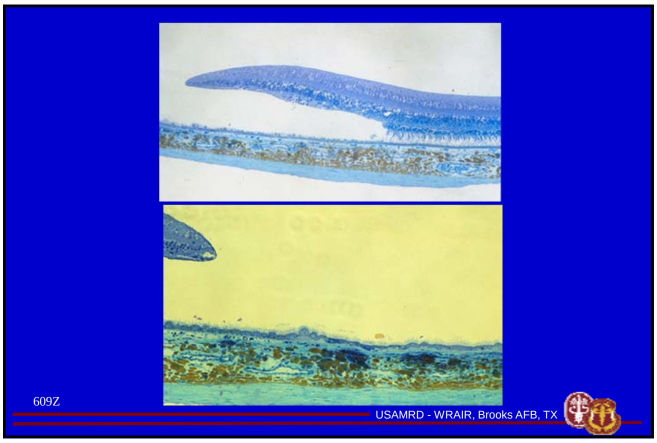
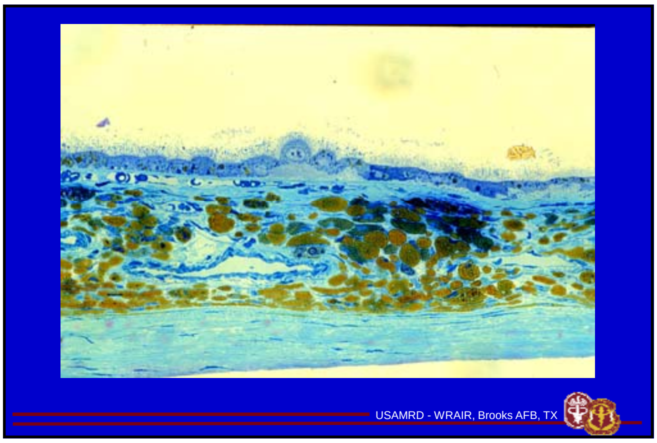
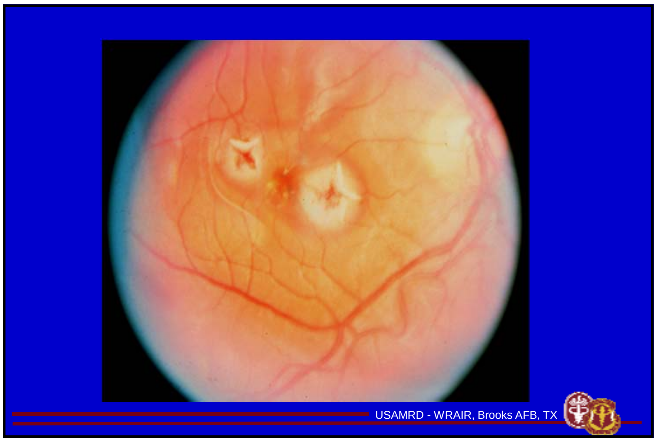




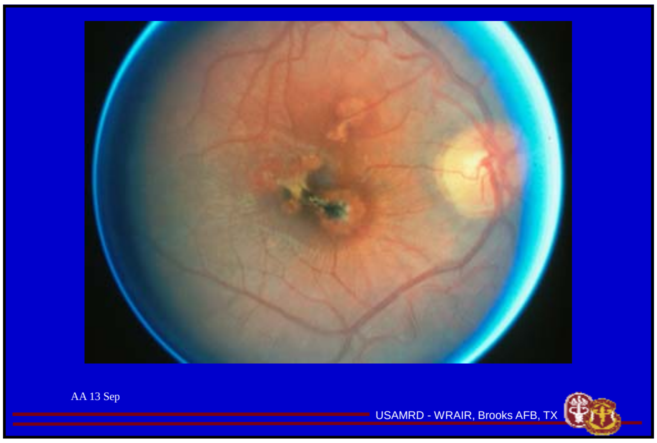





USAMRD - WRAIR, Brooks AFB, TX


USAMRD - WRAIR, Brooks AFB, TX


AA 4 Aug
USAMRD - WRAIR, Brooks AFB, TX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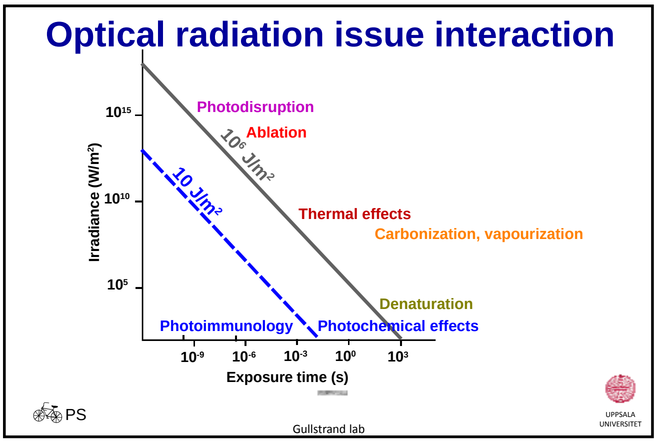
USAMRD - WRAIR, Brooks AFB, TX


AA 25 Sep
USAMRD - WRAIR, Brooks AFB, TX


Optical radiation issue interaction
Irradiance (W/m²)
10¹⁵
10¹⁰
10⁵
Photodisruption
Ablation
10⁶ J/m²
10 J/m²
Thermal effects
Carbonization, vapourization
Denaturation
Photoimmunology
Photochemical effects
10⁻⁹
10⁻⁶
10⁻³
10⁰
10³
Exposure time (s)
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Treshold dose

The least dose that evokes a defined damage

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Defined damage

- **Reversible**
- **Irreversible**

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Action spectrum

Threshold dose as a function of wavelength

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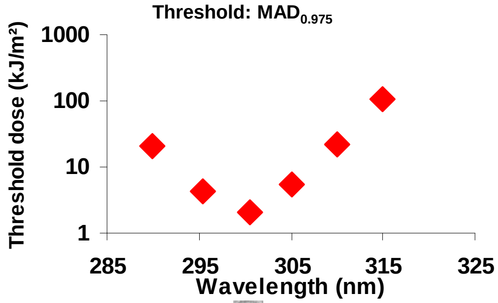
Action spectrum UVR-cataract

Albino SD rat, 6 weeks, 1 week latency

Threshold: $MAD_{0.975}$



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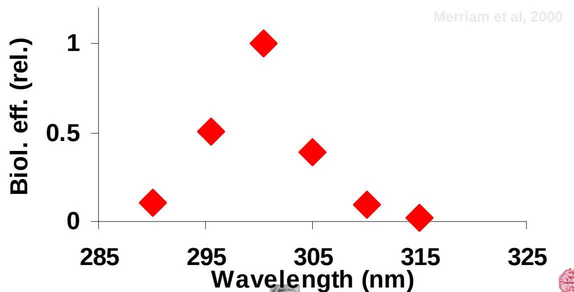
UVR cataract, relative spectral biologial efficiency

UVR-induced cataract, rat, in vivo

Albino SD rat, 6 weeks old 1 week latency, Treshold definition: MAD 0.975



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Maximum Permissible Exposure

MPE

- **Radiant exposure (J/cm²) if $power_{in}$< $power_{out}$**
- **Irradiance (W/cm²) if $power_{in}$> $power_{out}$**
- **Joule (J/cm²)/Watt (W/cm²) if $power_{in}$>> $power_{out}$**

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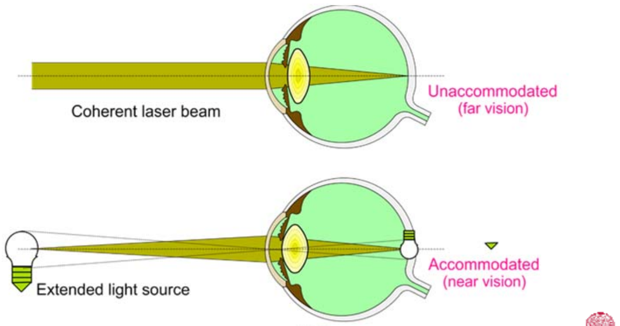
Bioeffects of lasers depend on

- Energy
- Duration of pulse
- Location on the retina
- Size of spot on retina
- Wavelength

Laser hazard - distance



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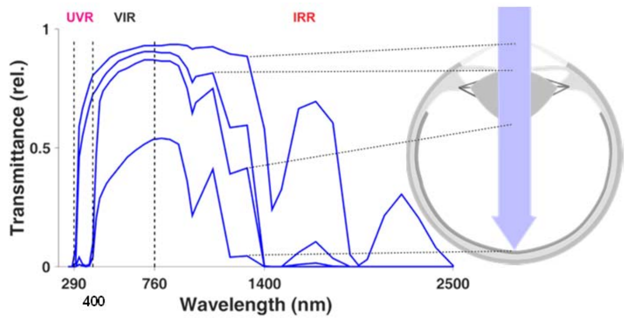

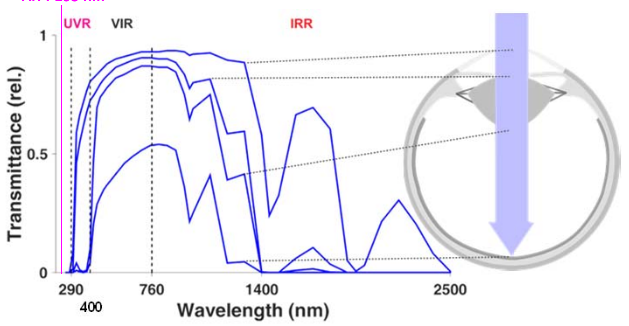

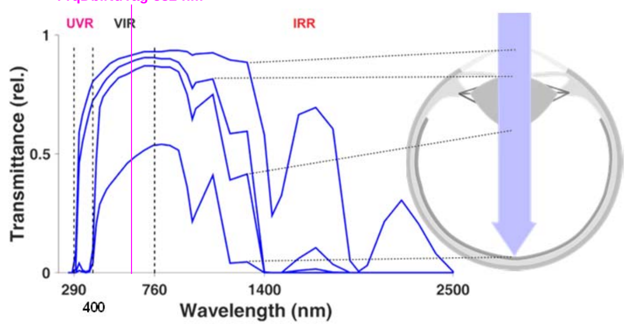

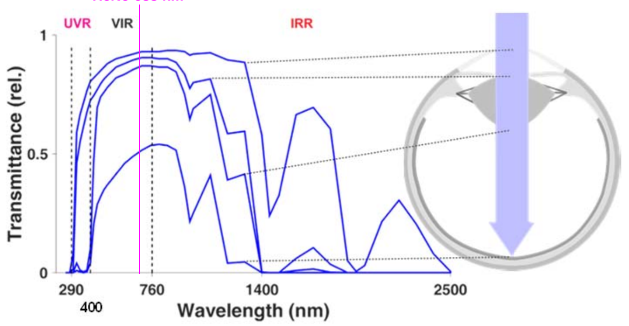

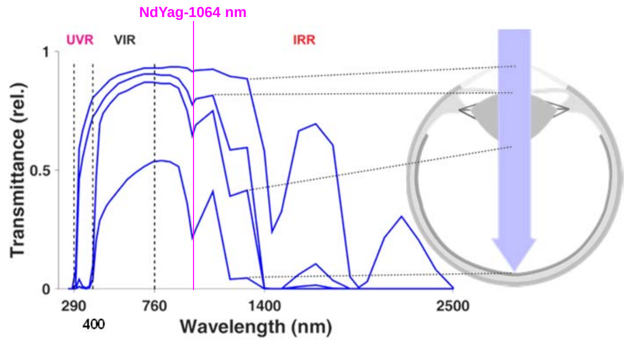

Safety measures

- Laser safety officer
- Labelling
- Filter goggles

Laser safety – proper labelling

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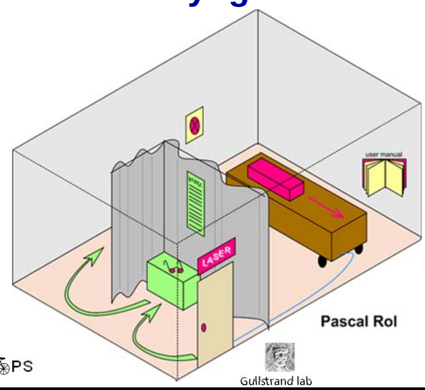
Laser safety- geometrical design



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Laser safety goggles

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Surveillance program

- Pre-job ophthalmic examination?
- During job ophthalmic examination?
- Post-job ophthalmic examination?

If accident may have occured

- Make an emergency visit to ophthalmic care unit
- Ask the ophthalmologist to contact

  Dr David Sliney (david.sliney@att.net)

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