LASER SAFETY

Presented by PY Wu

Outline

- Classification
- Laser Damage
- Maximum Permissible Exposure (MPE)
- Optical Density (OD)
- Tips


laser Safety

Classification

- **Class I Lasers**
  - Lasers that are not **hazardous** for **continuous viewing**， These consist of low power lasers or higher power embedded lasers. (i.e. laser printers)
  - Class 1 lasers are incapable of causing eye damage and are therefore exempt from any control measures. (typically continuous wave: cw 0.4 mW at visible wavelengths).

Classification

- **Class 2 Visible Lasers** (400 to 700 nm)
  - Lasers emitting **visible** light which because of normal human **aversion responses** (occur within 0.25 seconds) , do not normally present a hazard, but would if viewed directly for extended periods of time, **greater than 1000 seconds** (like many conventional light sources)
  - power < 1mW

Classification

- **Class 3a**：**Medium-power lasers (visible)**
  - Lasers or that normally would not produce a hazard if viewed for only momentary periods with the unaided eye. They may present a hazard if viewed using collecting optics.(fiber optics loupe or telescope).
  - power = 1~5 mW or intensity< 25 W/m^2

Classification

- **Class 3b**
  - Lasers that present an eye and skin hazard if viewed directly. This includes both intrabeam viewing and reflections.
  - Class 3b lasers do not produce a hazardous diffuse reflection except when viewed at close proximity. (cw: 5-500 mW, pulsed: 10 J/cm^2 or the diffuse reflection limit, whichever is lower).

Classification

- **Class 4 Lasers**
  - **High power** lasers capable of causing severe eye with short-duration (<0.25 s) if without protection, i.e. exposures to the direct beam, specular reflection or diffusely reflected beam. Class 4 lasers are also capable of causing severe skin damage and igniting flammable and combustible materials.
    (cw: 500 mW, pulsed: 10 J/cm^2 or the diffuse reflection limit)

Laser Damage

- Electrical Hazards:
  - electric shock
    >> grounded your laser
    >> wear a wrist strap to prevent to prevent static electricity build up on your body

  - fire

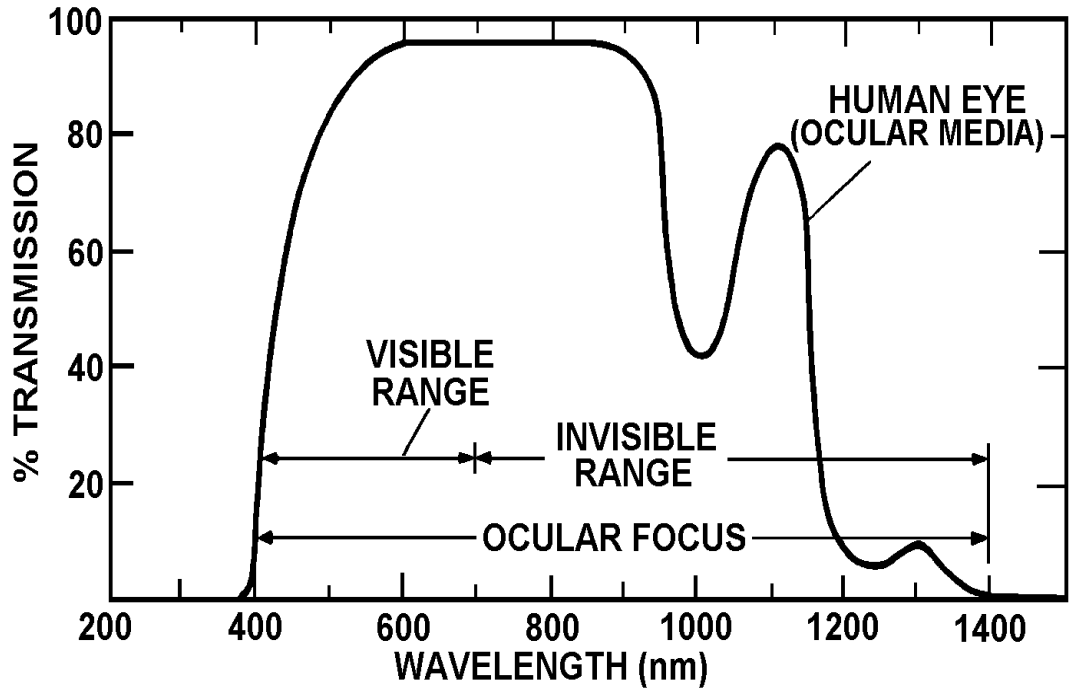
- Chemical Hazards:
  - Laser laboratories contain many hazards,
    ex: chemical dye
  - Laser interactions with certain materials may produce toxic fumes.

Laser Damage

- Miscellaneous Ancillary Hazards
  - Fire hazards: Flammable materials may be ignited by direct beams or specular reflections of high-power laser. Dust explosion should be taken in consideration, too.
  - Hazard form cryogenic coolant or compressed gas
  - **Ionizing Radiation (X rays): high-voltage vacuum tubes, electric discharge lasers** , power supplies over 15 kilovolts
  - Natural calamity: earthquake

Laser Damage

- Optical Radiation Hazards to the Eye
  - Eye injury depends on the wavelength of laser



Laser Damage

- Optical Radiation Hazards to the Eye and skin
  - Injury depends on the wavelength of laser

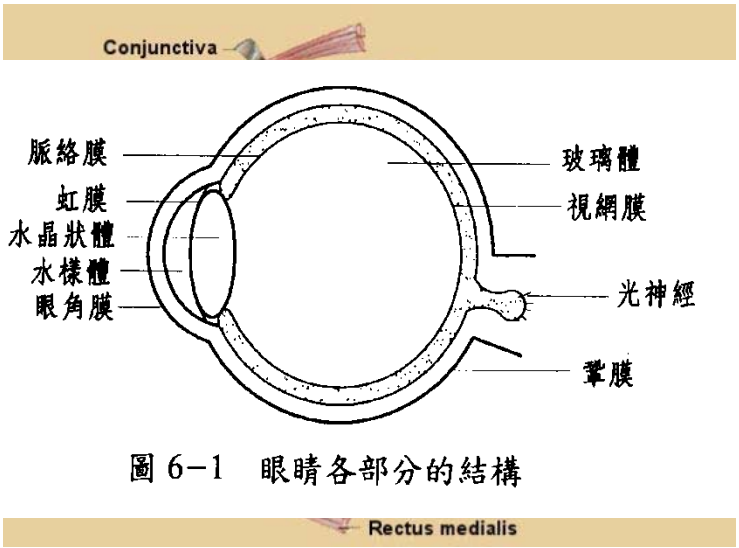
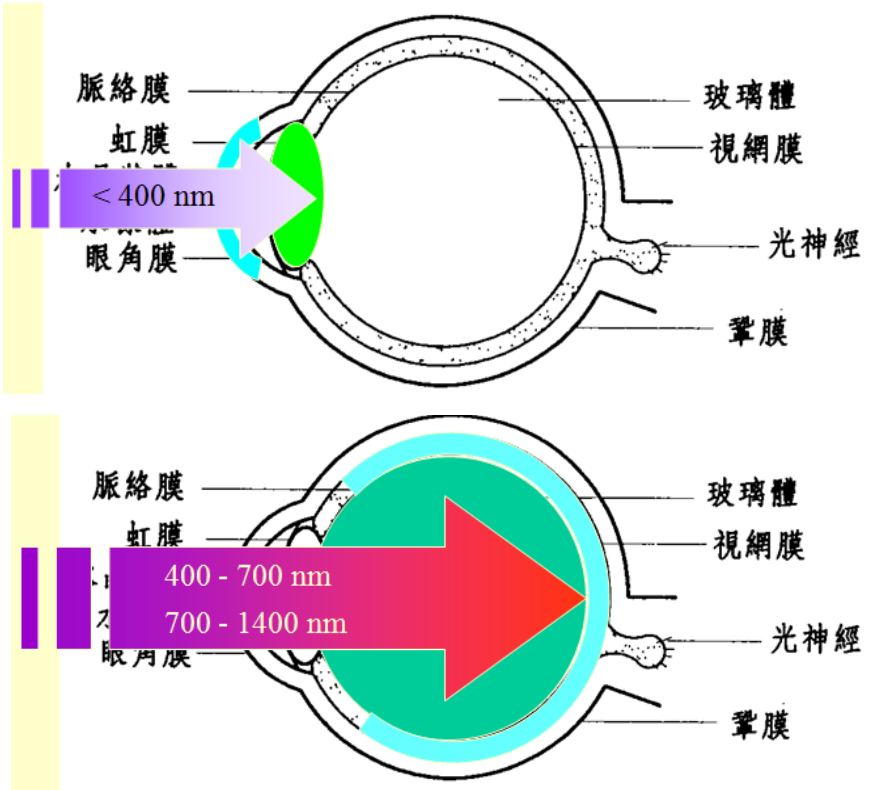


圖 6−1　眼睛各部分的結構



Laser Damage

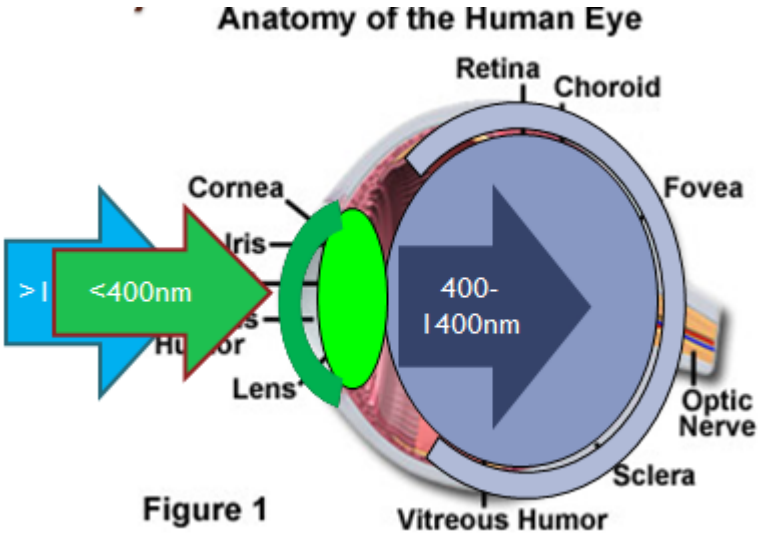
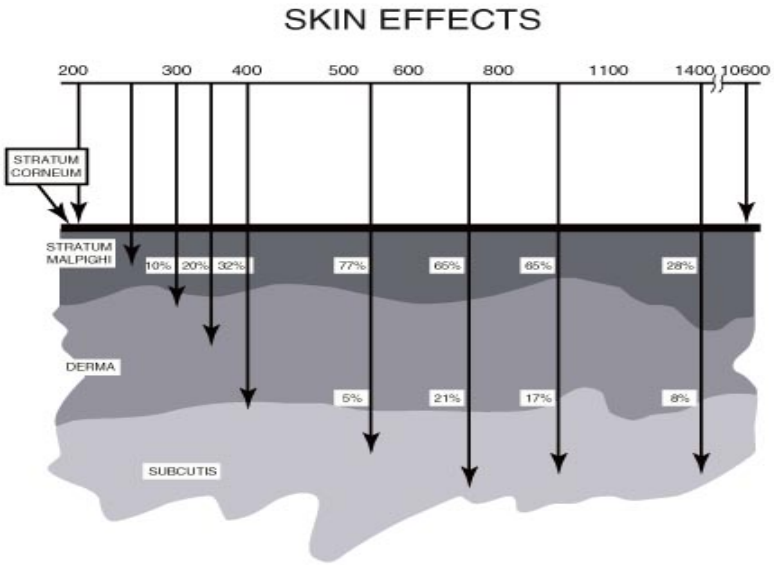


Figure 1

TABLE 1. SPECTRAL REGIONS OF LASER OUTPUTS AND PARTS OF THE EYE MOST SUSCEPTIBLE TO DAMAGE

Spectral Region	Wavelength (nanometers)	Frequency (x 10^{14} Hz)	Eye part susceptible to damage
FAR-MID UV	20–320	150–9.4	Cornea
NEAR UV	320–390	9.4–7.7	Lens, Cornea
VISIBLE	390–750	7.7–4.0	Retina
NEAR IR	750–1400	4.0–2.1	Iris, Retina
NEAR-MID IR	1400–3000	2.3–1.0	Cornea, Retina
MID-FAR IR	3000–500,000	1.0–0.006	Cornea



Laser Damage Mechanisms

- **Electromechanical/ Acoustic Damage**
  - Extremely high power density (109–1,012 W/cm^2) in extremely short pulses (ns) induces dielectric breakdown in tissue
  - This damage is permanent
- **Photoablation**
  - The photodissociation or direct breaking of intramolecular bonds in biopolymers
  - Caused by absorption of incident photons and subsequent release of biological material

Laser Damage Mechanisms

- **Thermal Damage**
  - The conversion of laser energy into heat
- **Photochemical Damage**
  - Light below 400 nm
  - The effect is cumulative over a period of days.

Maximum Permissible Exposure (MPE)

- MPE is the maximum level of laser radiation to which a human can be exposed without adverse biological effects to the eye or skin.
- Calculation of MPE includes:
  - The energy involved in the exposure
  - The area of the exposure
  - The duration of the exposure
  - The wavelength of the laser light

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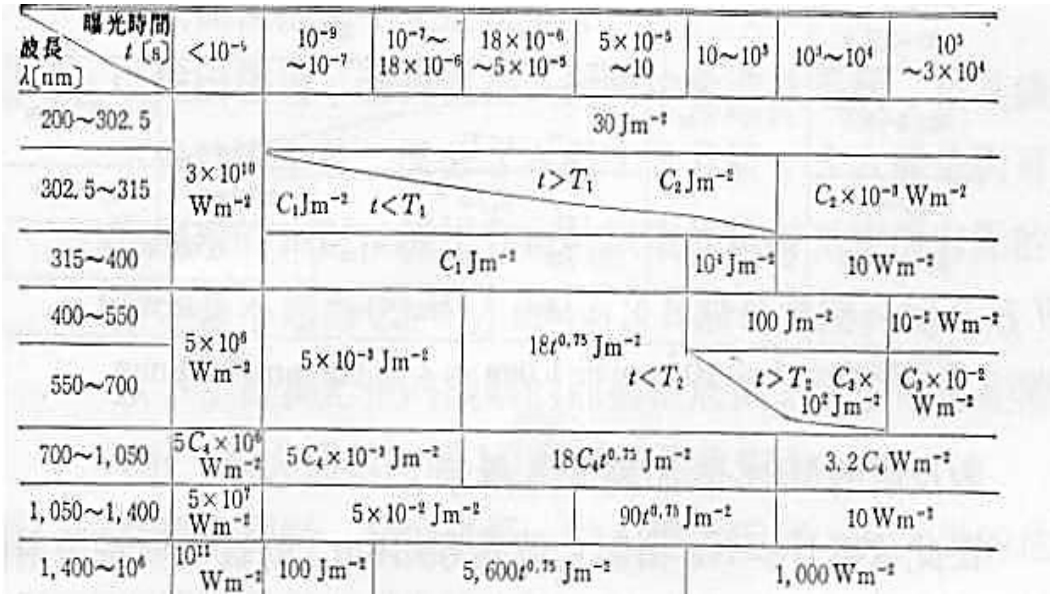

波長 λ[nm] ＼ 曝光時間 t [s]	$<10^{-9}$	10^{-9} ～10^{-7}	10^{-7}～18×10^{-6}	18×10^{-6} ～5×10^{-5}	5×10^{-5} ～10	10～10^{3}	10^{3}～10^{4}	10^{3} ～3×10^{4}
200～302.5	3×10^{10} Wm^{-2}	$30\,Jm^{-2}$						
302.5～315		C_1Jm^{-2} $t<T_1$		$t>T_1$		C_2Jm^{-2}		$C_2\times10^{-3}\,Wm^{-2}$
315～400		$C_1\,Jm^{-2}$				$10^{4}\,Jm^{-2}$		$10\,Wm^{-2}$
400～550	5×10^{6} Wm^{-2}	$5\times10^{-3}\,Jm^{-2}$		$18t^{0.75}\,Jm^{-2}$ $t<T_2$		$100\,Jm^{-2}$		$10^{-2}\,Wm^{-2}$
550～700						$t>T_2$ $C_3\times10^{2}\,Jm^{-2}$		$C_3\times10^{-2}$ Wm^{-2}
700～1,050	$5C_4\times10^{6}$ Wm^{-2}	$5C_4\times10^{-3}\,Jm^{-2}$		$18C_4t^{0.75}\,Jm^{-2}$				$3.2C_4\,Wm^{-2}$
1,050～1,400	5×10^{7} Wm^{-2}	$5\times10^{-2}\,Jm^{-2}$			$90t^{0.75}\,Jm^{-2}$			$10\,Wm^{-2}$
1,400～10^{6}	10^{11} Wm^{-2}	$100\,Jm^{-2}$	$5,600t^{0.75}\,Jm^{-2}$			$1,000\,Wm^{-2}$		

Optical Density (OD)

- OD is the logarithm to the base ten of the reciprocal of the transmittance

$$OD = \log (Ei/Et)$$

- Ei = incident beam irradiance (W/cm^2)
  - → worst case exposure
- Et = transmitted beam irradiance → MPE

Optical Density (OD)

Example:

0.514 um argon laser

d = 7 mm (worst-case pupil size)

P = 5 Watts

$Ei = P/A = 4\ P/\pi d^2 = 12.99\ W/cm^2$

$Et = MPE = 16.7\ W/cm^2$

- $OD = \log (Ei/Et) = 5.9$

Tips: Beam control

- **Purpose:**

  To minimize direct eye exposure

- Precautions

I. **Do not intentionally look directly into the laser beam or at a specular reflection, regardless of its power**

II. **Terminate the beam at the end of its useful path**

Tips: Beam control

III. **Locate the beam path at a point other than eye level**

IV. **Orient the laser so that the beam is not directed toward entry doors or aisles.**

v. **Minimize specular reflections.**

Tips: Beam control

VI. **Mount the laser system on a stable platform to maintain the beam in a fixed position during operation .**

VII. **Confine primary beams and dangerous reflections to the optical table.**

Tips: Beam control

VIII. **Clearly identify beam paths and ensure that they do not cross populated areas or traffic paths.**

IX. **When the beam path is not totally enclosed, locate the laser system so that the beam will be outside the normal eye-level range, which is between 1.2 to 2 meters from the floor.**

Other Tips

- Warning signs :

Post at each entrance to the operating area

"CAUTION - HIGH POWER LASER"

- Wear goggles with proper OD, and never take it off when you are under laser exposure.

Other Tips

- **A log must be maintained showing periods of use, service, maintenance and incidents.**
- **A written record must be kept of each test in the log book.**