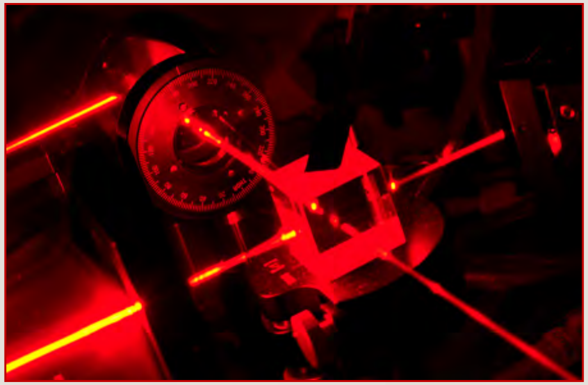
Principles of Laser Safety



and the uOttawa Laser Safety Program

September 20, 2016

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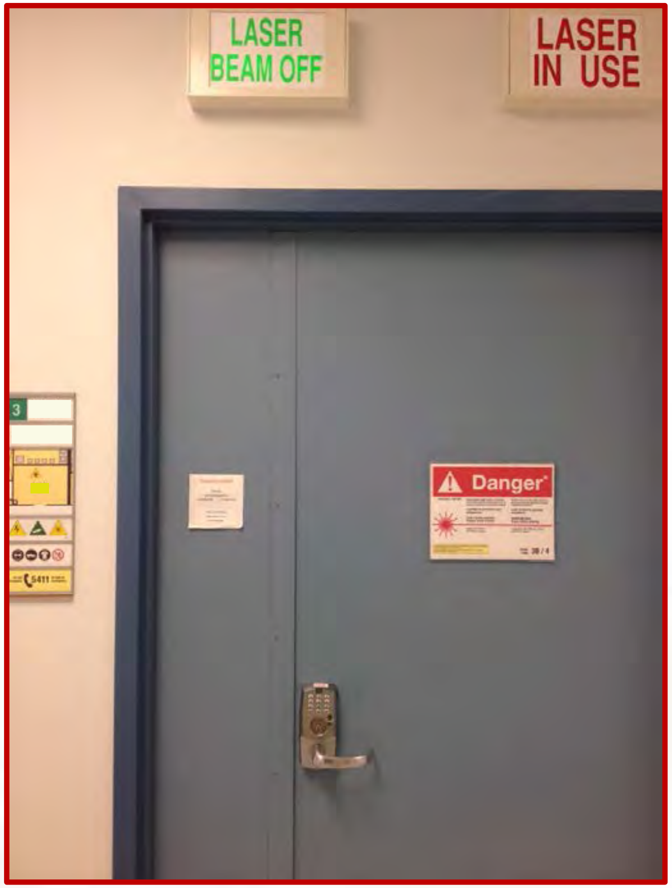
What is Laser Safety?



- Signs?
- Permits?
- Warning lights?
- Goggles?

- What do you ask yourself before entering?

What is Laser Safety?

The person most likely to care about your safety is <u>you</u>

Do I need to be here right now?

Do I understand the safety measures?

Where do I go if I have questions?

Is there a better way to do that?

Safety Starts Here

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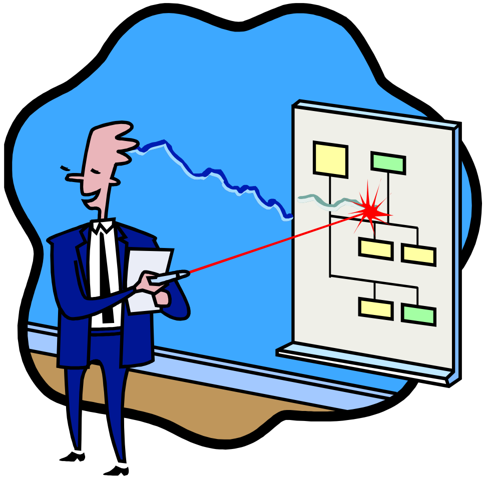
Responsibility

The ultimate responsibility in the safe use of lasers in any environment falls completely ***on the user***.

YOU are responsible to ensure all hazards are contained.



YOU are responsible to ensure beams do not pose a hazard to others.

YOU are responsible to ensure your actions do not harm others.

Learning Objectives

1. Identify laser components, properties and classifications
2. Understand how an eye images light
3. Recognize how lasers injure the eye and skin
4. Develop engineering & administrative laser controls
5. Follow the uOttawa Laser Safety Program and ANSI Z136.1
6. Familiarize yourself with non-beam hazards
7. Evaluate laser eyewear needs

Lasers

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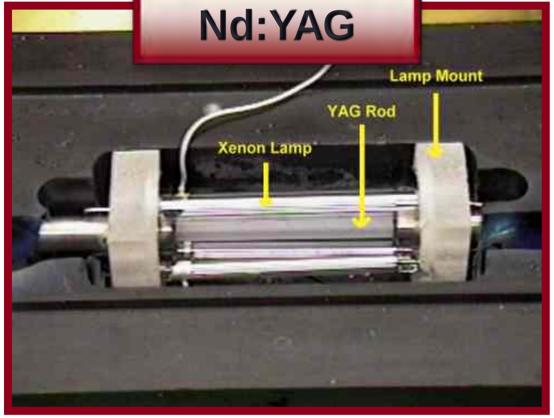
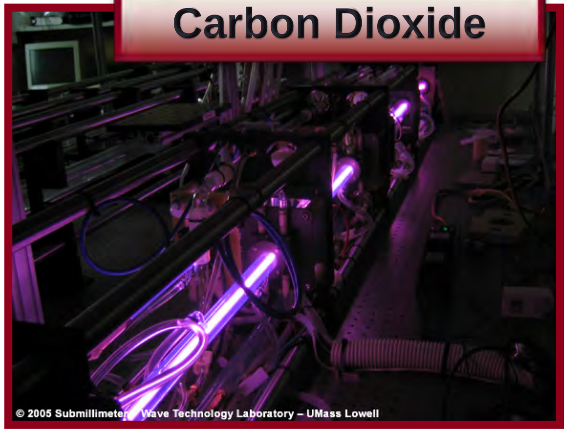
Common Types of Lasers

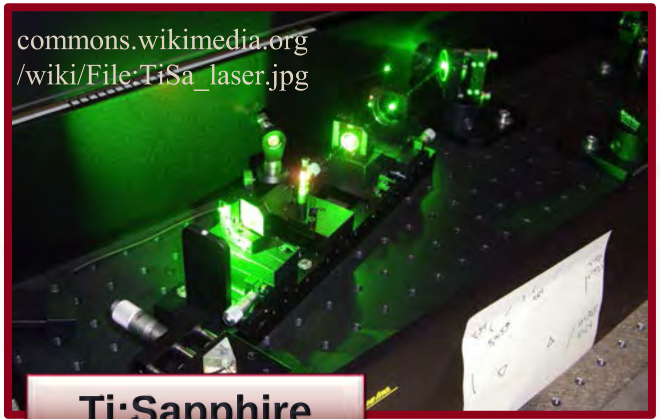
HeNe

Nd:YAG



Carbon Dioxide





Ti:Sapphire

Diode/Semiconductor

Fibre *

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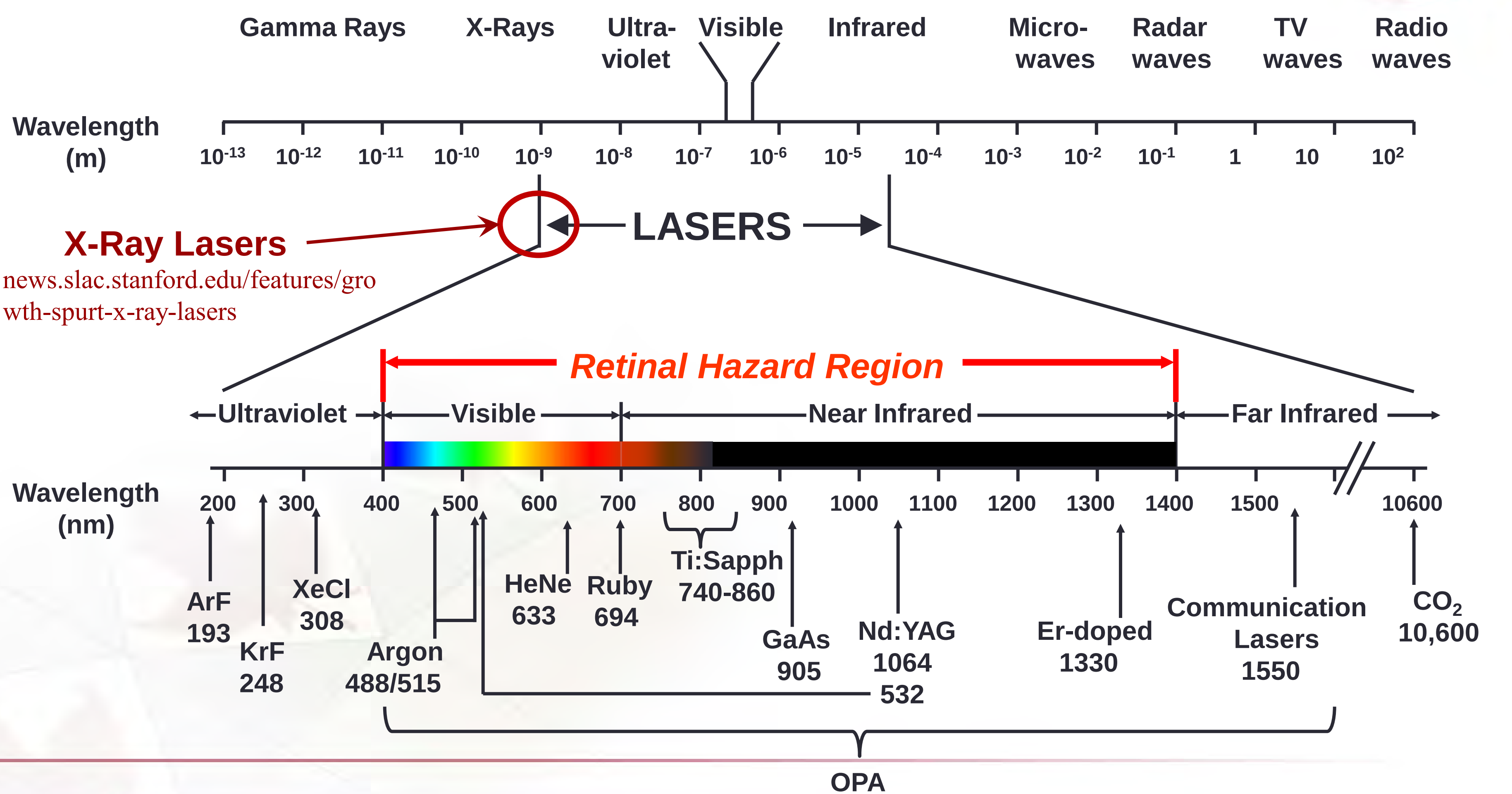
* "Supercontinuum in a microstructured optical fiber" by I, Blinking Spirit. Licensed under CC BY-SA 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Supercontinuum_in_a_microstructured_optical_fiber.PNG# /media/File:Supercontinuum_in_a_microstructured_optical_fiber.PNG

The Electromagnetic Spectrum



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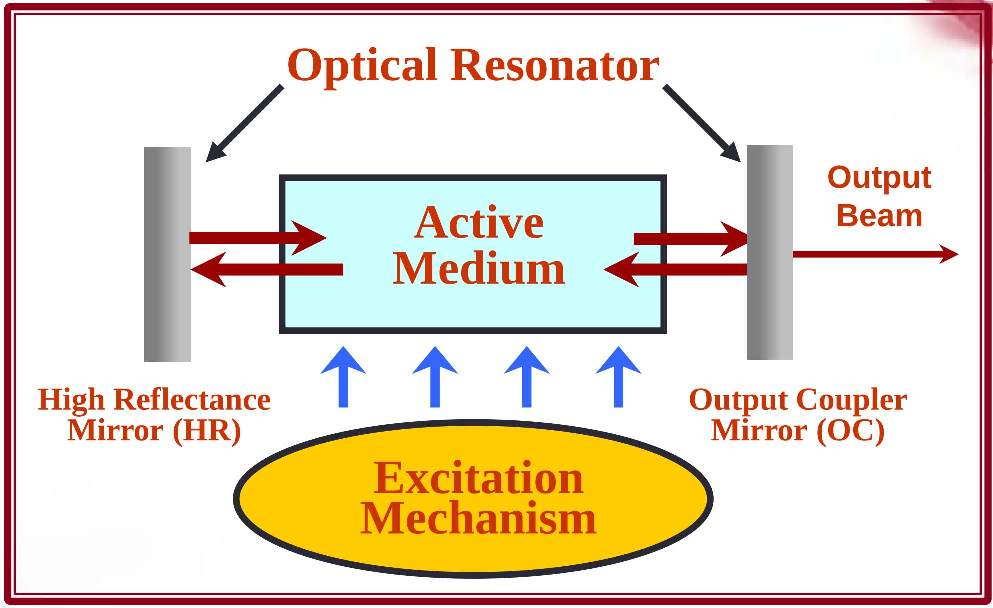
Main components of a Laser

EXCITATION MECHANISM
Optical
Electrical
Chemical

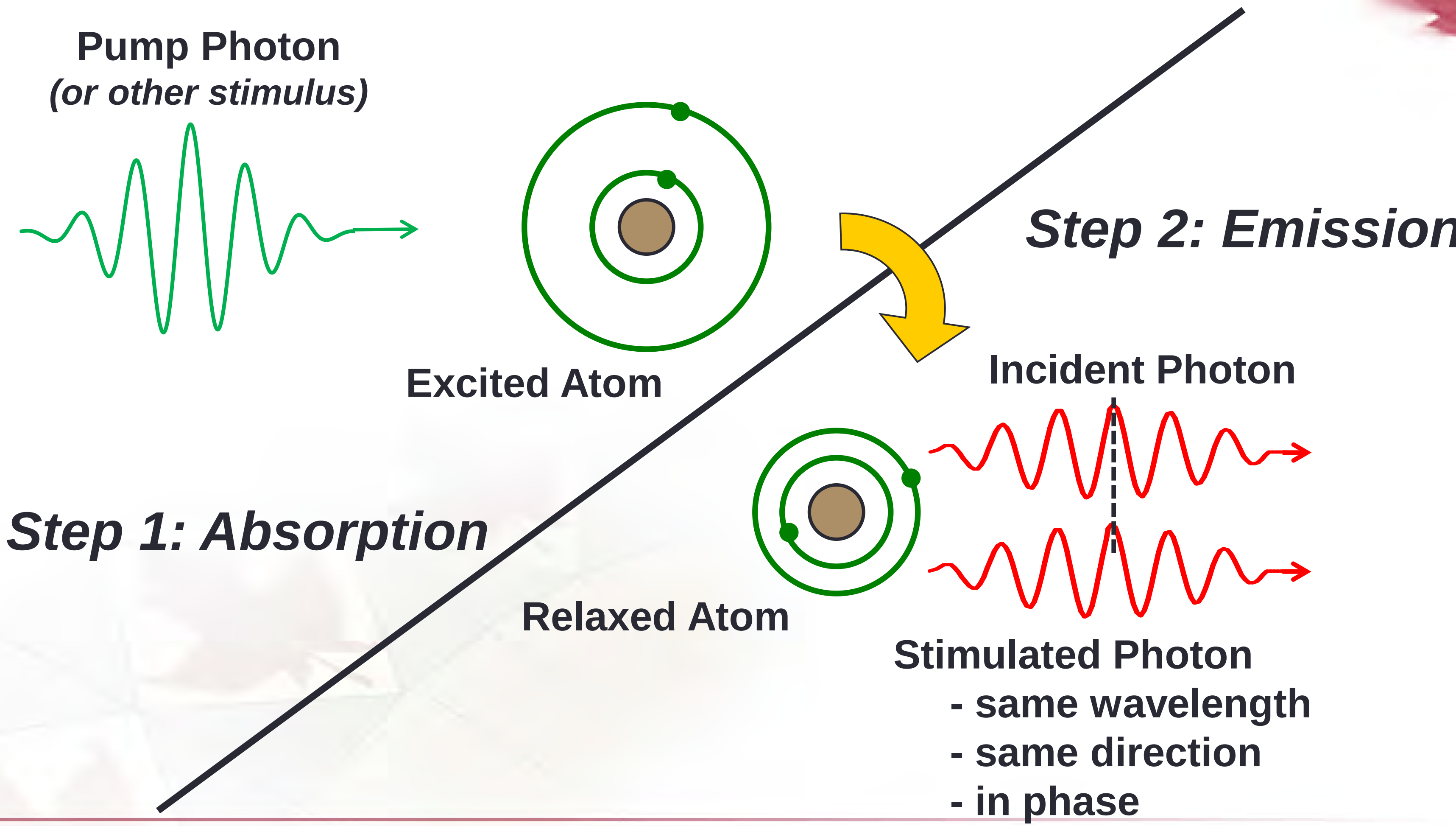
ACTIVE MEDIUM
Solid (Crystal, Diode)
Liquid (Dye)
Gas

OPTICAL RESONATOR
HR Mirror and
Output Coupler



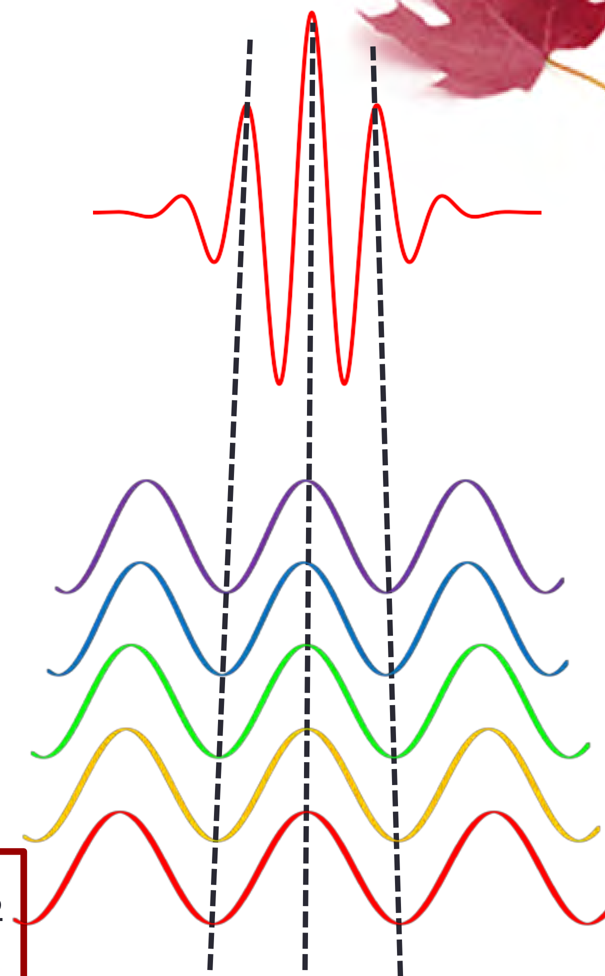
Excitation Mechanism (Pump)	Excites atoms to higher energy state.
Active Medium (Gain, Amplifier)	Contains atoms that emit light by stimulated emission.
Optical Resonator	Reflects laser beam through the active medium for amplification.

What is Stimulated Emission?



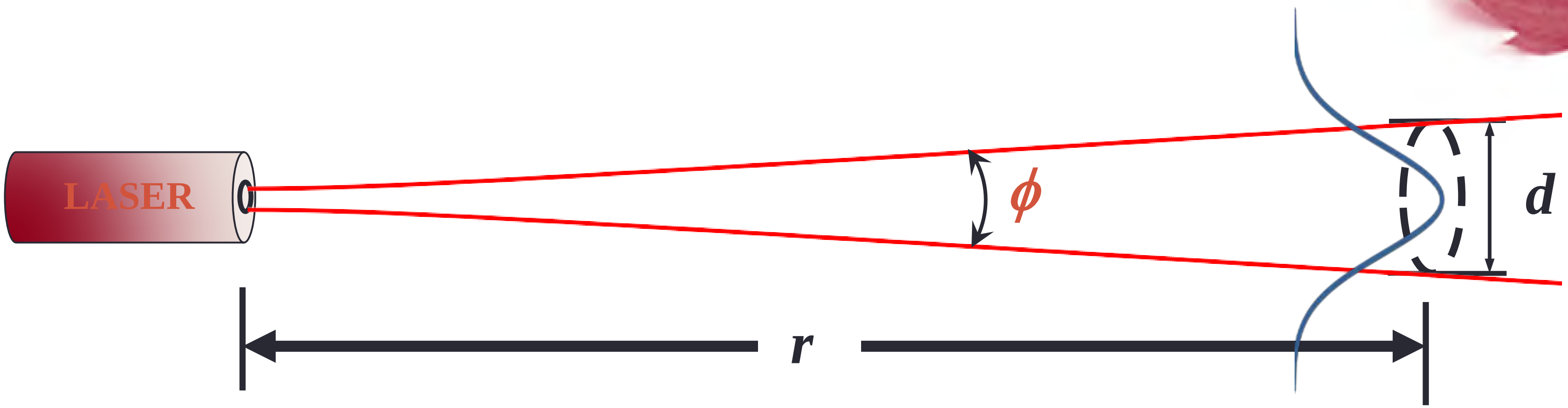
Characteristics of a Laser Beam (Coherence)

- Low divergence
  - highly directional
  - small focal spot
- High Brightness
  - High power density
  - Short pulses
- Monochromatic
  - narrow spectrum a better term



This combination makes laser light <u>focus</u> 100 times better than ordinary light

Beam Divergence



<u>Far-field measurement</u>:

<u>ex</u>: 1 foot diameter beam (d) on a wall 1000 feet away (r), divergence angle (ϕ) is:

$$\phi = \frac{d}{r} \quad \textbf{(Eq.1)}$$

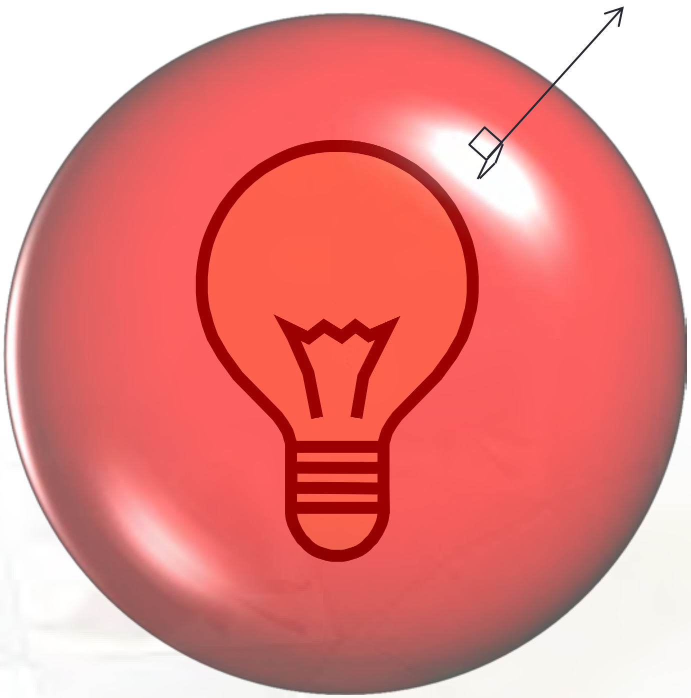
$$\phi = \frac{1\text{ ft}}{1000\text{ ft}}$$

= 0.001 radian

= 1 mrad

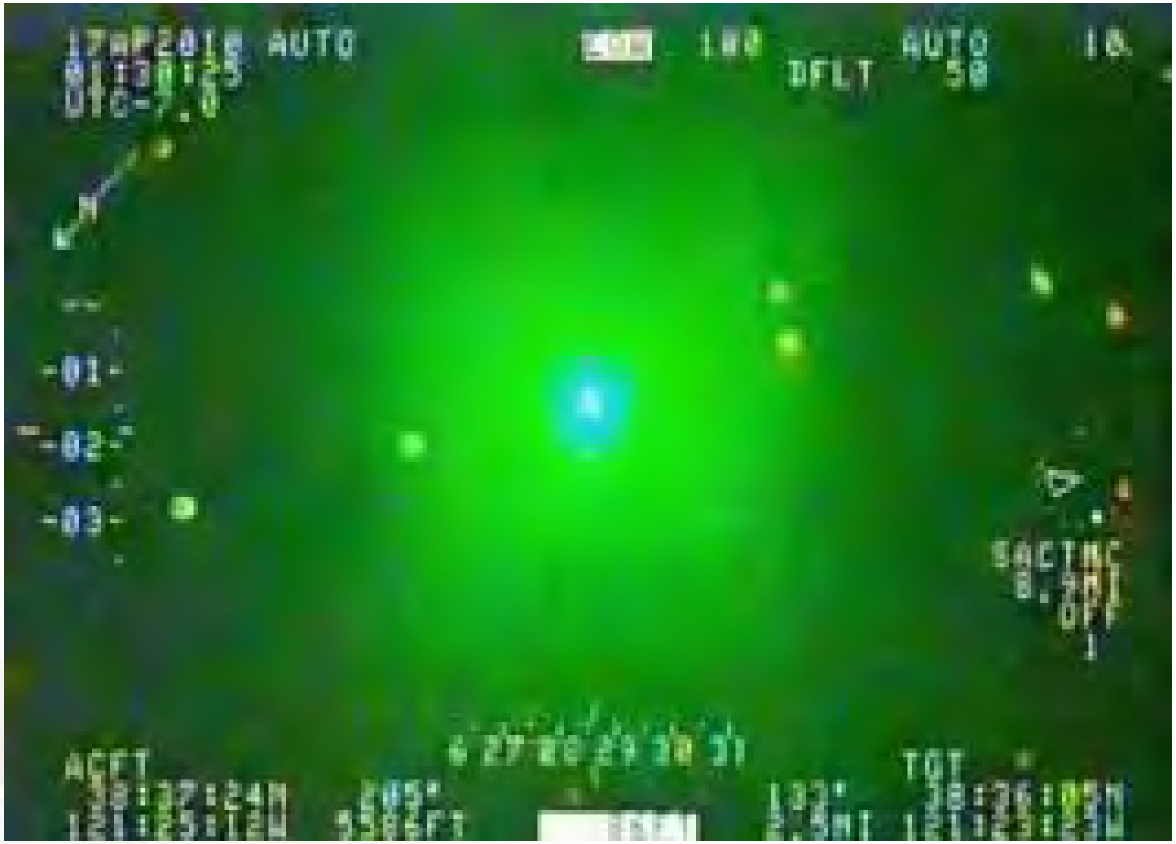
Beam Divergence

Incoherent source:



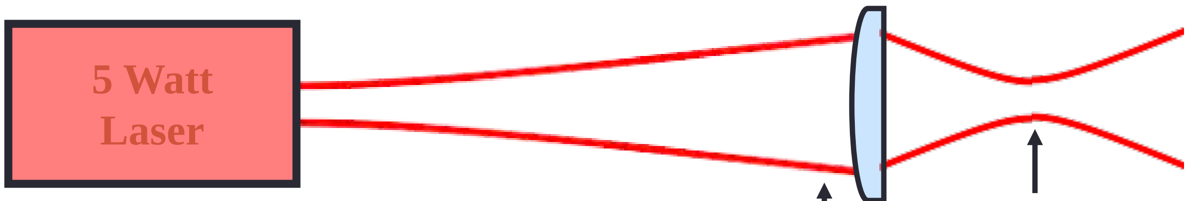
- Sphere: 4π steradians
- Power spread over large area
- Drops as r^2 with distance

Why a laser pointer is a borderline ocular hazard



http://www.geek.com/geek-cetera/pointing-a-laser-at-a-police-helicopter-is-a-very-bad-idea-1430893/

Beam Intensity



$$\text{Irradiance} = \frac{\text{Power}}{\text{Area}} \quad \text{(Eq.2)}$$

IRRADIANCE AT LENS:

$$E_1 = \frac{5\ \text{W}}{\pi(0.5\ \text{cm})^2}$$

$$E_1 = 6.4\ \frac{\text{W}}{\text{cm}^2}$$

IRRADIANCE AT FOCAL SPOT:

$$E_2 = 64\ \frac{\text{kW}}{\text{cm}^2}$$

The diameter is reduced by a factor of 100;
The irradiance is increased by a factor of 10,000

Sun Intensity

- Sun emits 3.826×10^{26} W into 4π steradians
- Verify with Stefan-Boltzmann Law:

$T = 5770$ K

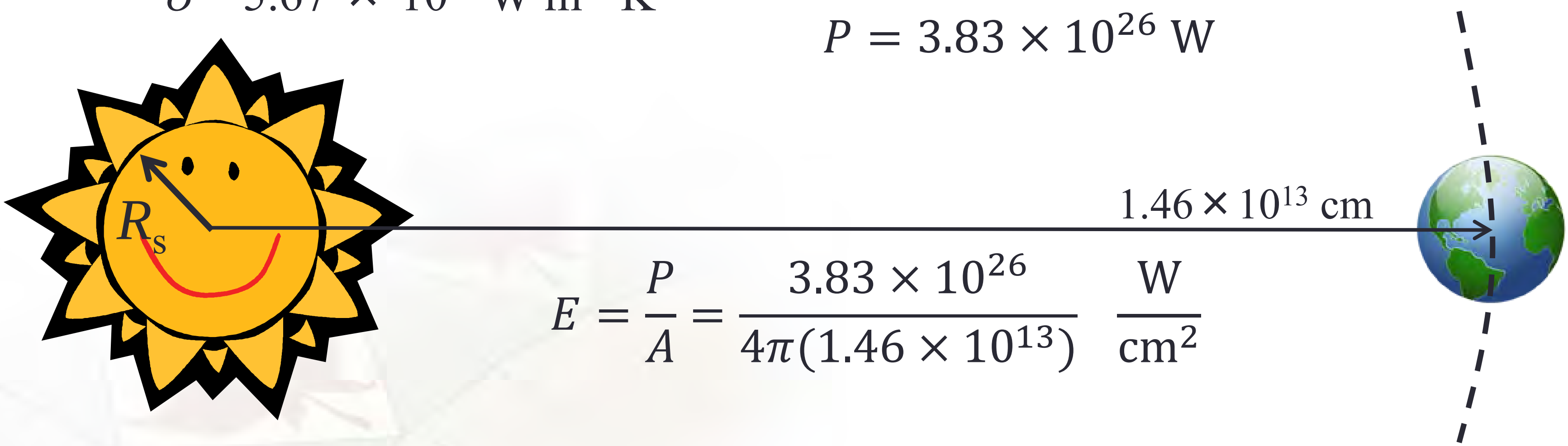
$R_s = 6.96 \times 10^8$ m

$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}

$$P = \epsilon\sigma A T^4$$

$$P = (1)(5.67)4\pi(6.96)^2(5770)^4 \times 10^8$$

$$P = 3.83 \times 10^{26}\ \text{W}$$



$$E = \frac{P}{A} = \frac{3.83 \times 10^{26}}{4\pi(1.46 \times 10^{13})}\ \frac{\text{W}}{\text{cm}^2}$$

$$E = 0.143\ \text{W/cm}^2$$

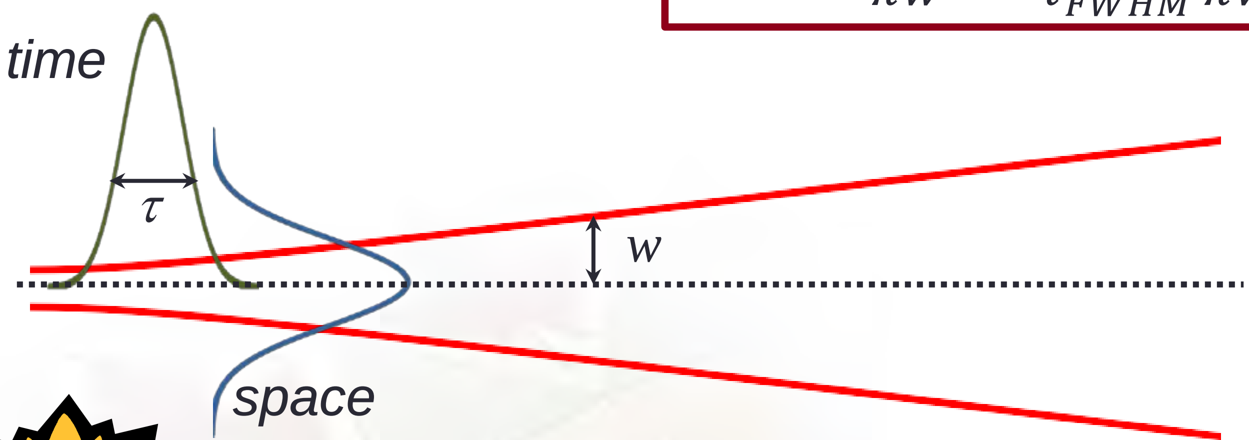
http://nssdc.gsfc.nasa.gov/planetary/factsheet/sunfact.html

Beam Intensity

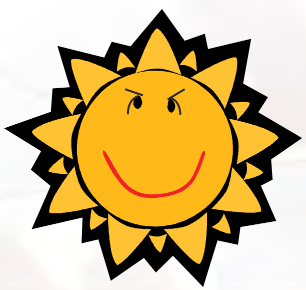
- Ti:S oscillator beam: 2 mm diameter (e^{-1}), 20 nJ pulse energy, and a 30 fs pulse width (FWHM)
  - The irradiance is:

$$E_{avg} = \frac{P}{\pi w^2} = \frac{Q}{\tau_{FWHM}} \frac{1}{\pi w^2}$$

(Eq.2 again)



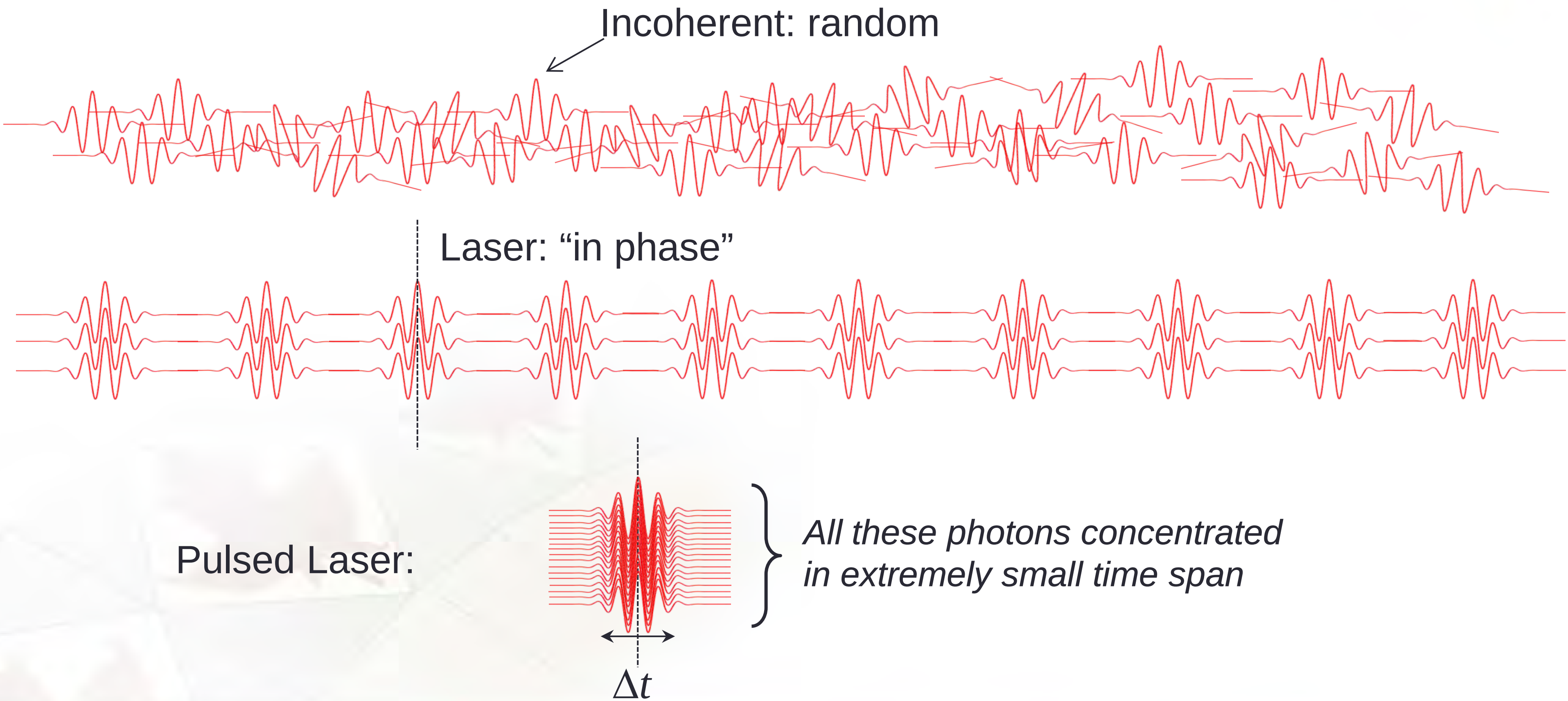
$$E = 21 \frac{\mathrm{MW}}{\mathrm{cm}^2}$$



<u>**Note**</u>: this laser operates at 80 MHz; in 0.25 s you would take in 20 million of these pulses!!

Incoherent vs. Laser Sources

The "microscopic" view



Classification of Lasers

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Laser Classifications of Lasers

- Hazards
  - Increase with laser intensity
  - Classification system categorizes increasing hazard

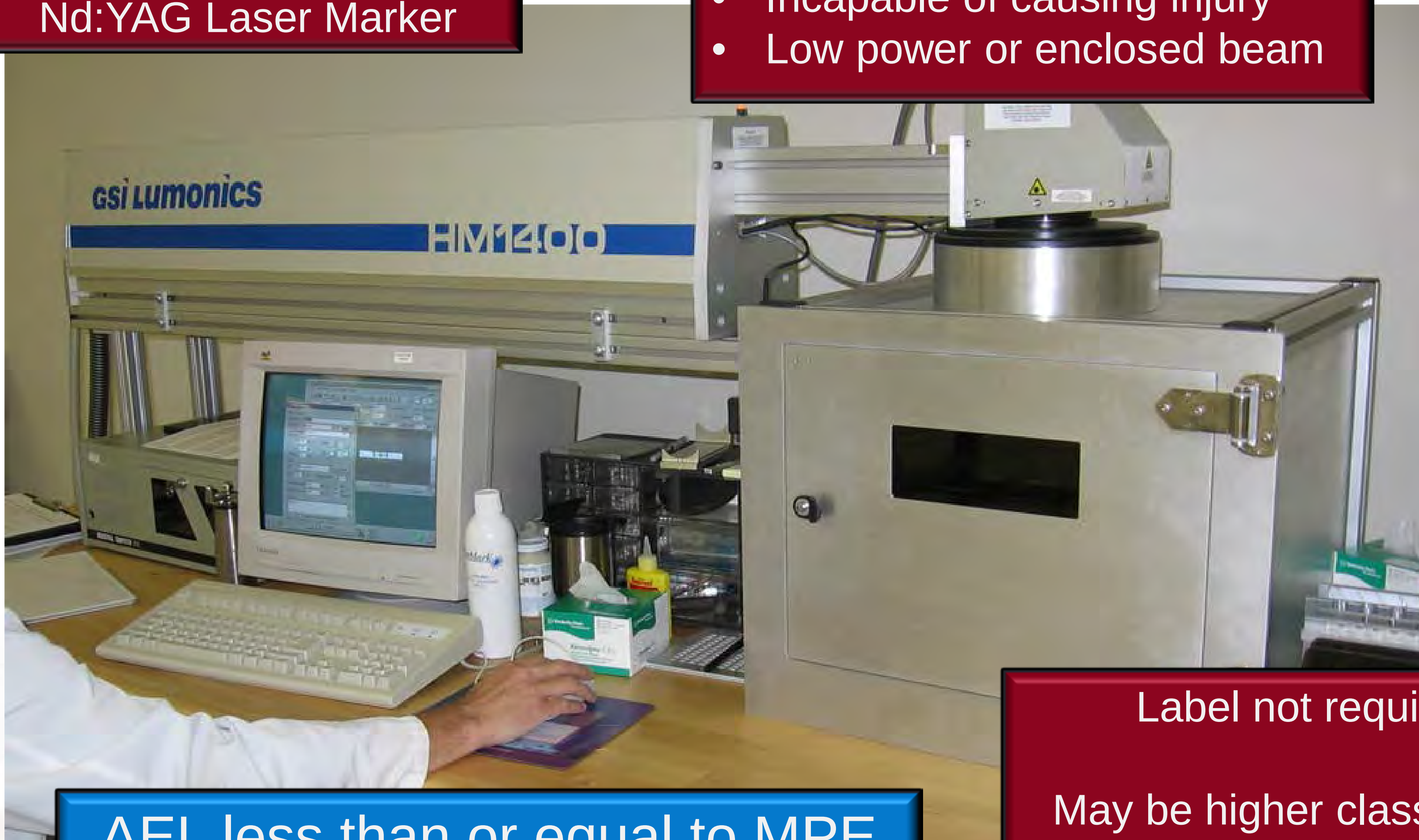
- Classification
  - Based on **accessible level** of laser radiation during **normal operation**

- Classification made by manufacturer

Class 1

Nd:YAG Laser Marker

- Safe during normal use
- Incapable of causing injury
- Low power or enclosed beam



Label not required

May be higher class during maintenance or service

AEL less than or equal to MPE

Class 2

- Staring into beam is an eye hazard
- Eye protected by aversion response
- **Visible lasers only (400 – 700 nm)**
- CW maximum power 1 mW

Label not required

May be higher class during maintenance or service

AEL less than or equal to MPE for visible lasers and ¼ sec exposure

Class 1M and 2M

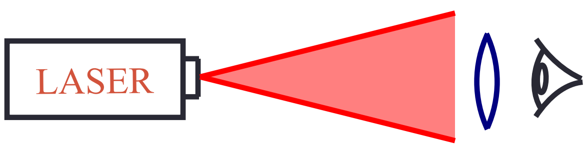
M is for magnification

A class 1M laser is class 1 unless magnifying optics are used.

A class 2M laser is class 2 unless magnifying optics are used.

M classes usually apply to expanded or diverging beams.

Condition 1
Expanded Beam



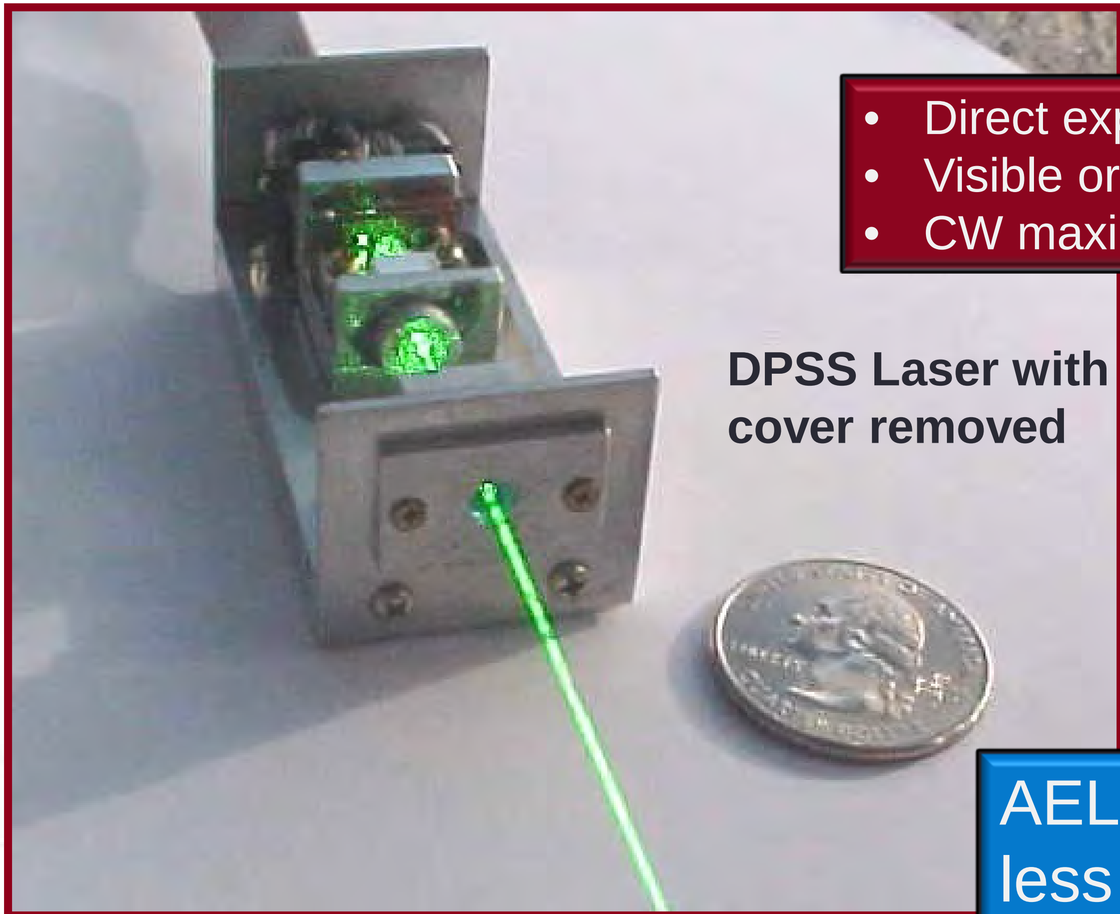
Condition 2
Diverging Beam

Class 3R (Formerly IIIa)

- Aversion response not adequate eye protection
- CDRH includes visible lasers only
- ANSI includes invisible lasers
- CW max power (visible) 5 mW

1 to 5X AEL Class 1 (invisible)
< 5X AEL Class 2 (visible)

Class 3B



DPSS Laser with cover removed

- Direct exposure to beam is eye hazard
- Visible or invisible
- CW maximum power 500 mW

AEL exceeds Class 3R but less than 500 mW (CW)

Class 4

- Exposure to direct beam & scattered light is eye and skin hazard
- Visible or invisible
- CW power above 500 mW
- Fire hazard

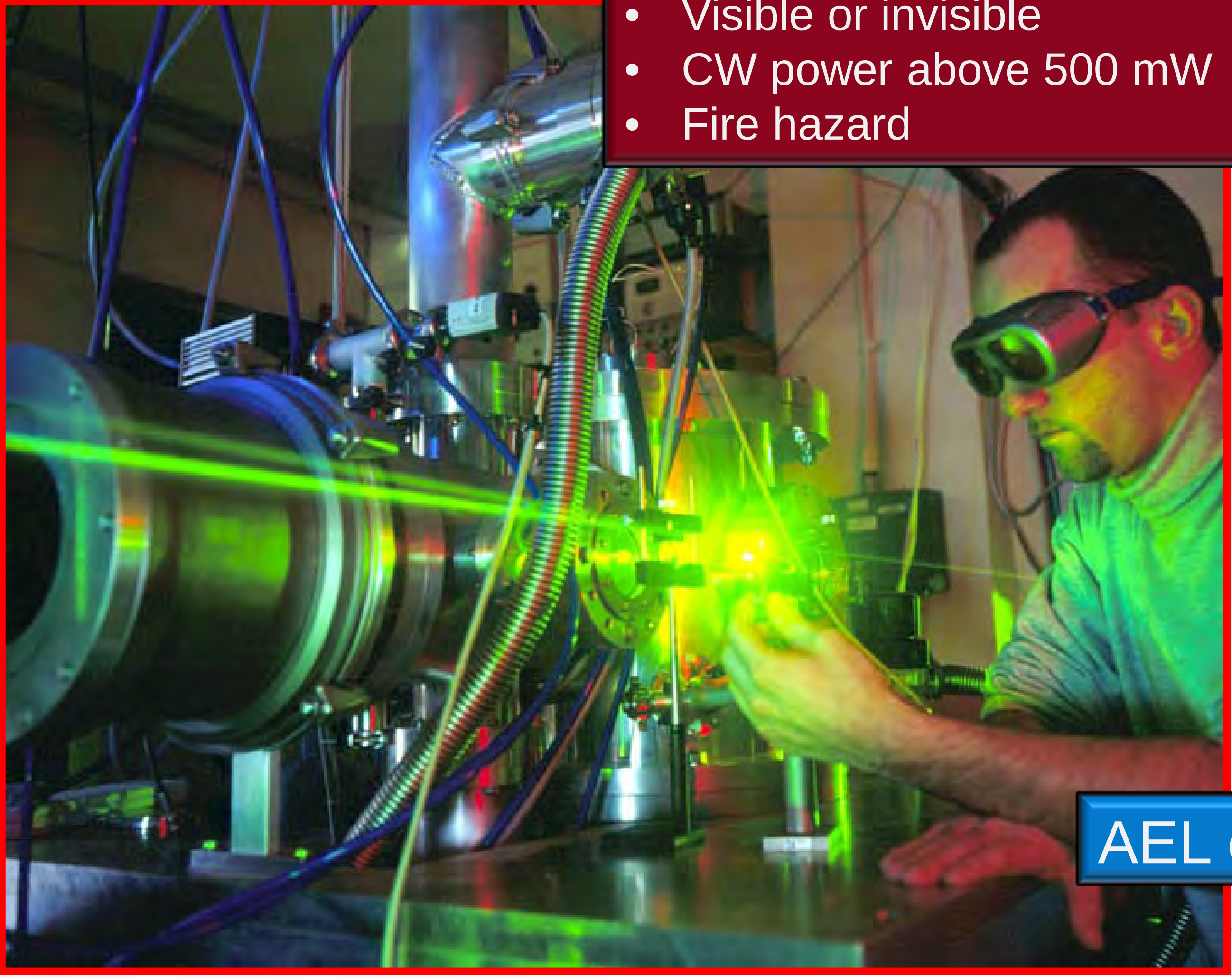


Photo: Keith Hunt - www.keithhunt.co.uk
Copyright: University of Sussex, Brighton (UK)

AEL exceeds Class 3B

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Laser-Professionals.com

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Laser Classifications

1	**Incapable of causing injury during normal operation**
1M	**Incapable of causing injury during normal operation unless collecting optics are used**
2	**Visible lasers incapable of causing injury *in 0.25 s*.**
2M	**Visible lasers incapable of causing injury *in 0.25 s* unless collecting optics are used**
3R	**Marginally unsafe for intrabeam viewing; up to 5 times the Class 2 limit for visible lasers or the Class 1 limit for invisible lasers**
3B	**Eye hazard for intrabeam viewing, usually not an eye hazard for diffuse viewing**
4	**Eye and skin hazard for both direct and scattered exposure**

Laser Classification Language

1	No signage needed. May have Class 3B or 4 language on protective housings if embedded.
1M	No signage
2	CAUTION : Do Not Stare Into Beam
2M	CAUTION : Do Not Stare Into Beam or View Directly with Optical Instruments
3R	WARNING : Avoid Direct Eye Exposure to Beam
3B	WARNING : Avoid Direct Eye Exposure to Beam
4	WARNING / DANGER : Avoid Eye and Skin Exposure to Direct or Scattered Radiation

Optics and the Eye

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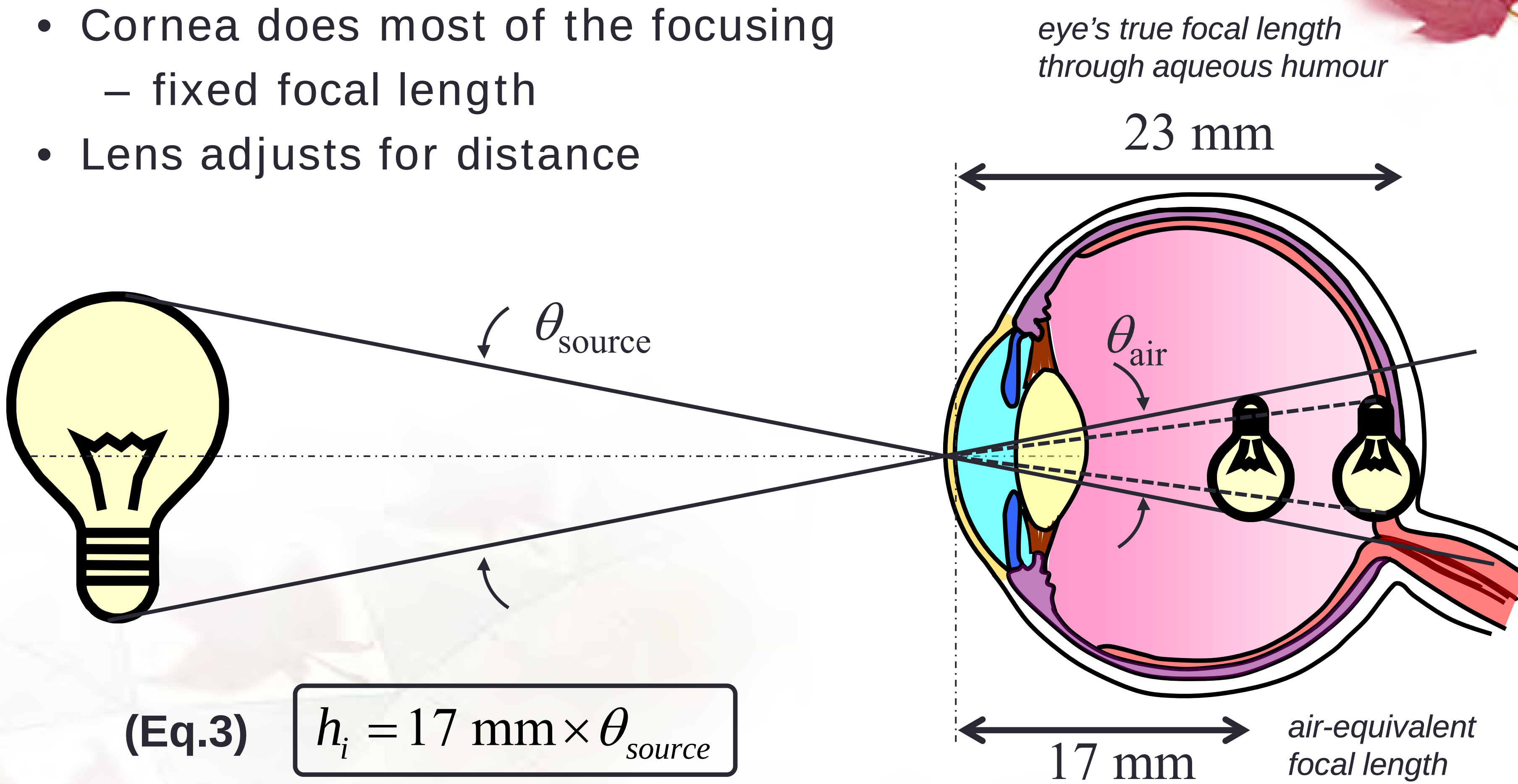
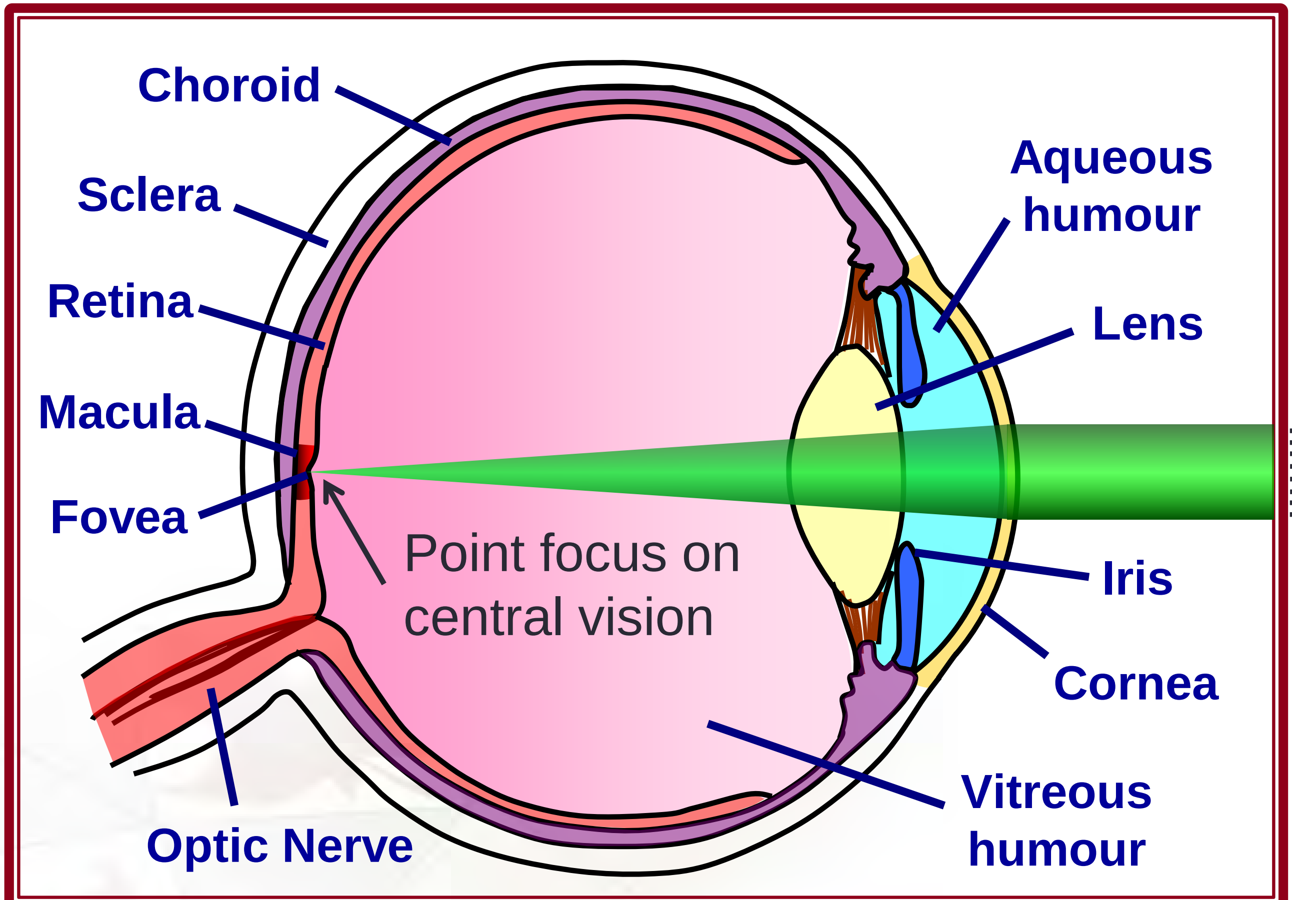
Optics: Focusing in the Eye

- Cornea does most of the focusing
  - fixed focal length
- Lens adjusts for distance



(Eq.3) $$h_i = 17\ \text{mm} \times \theta_{source}$$

Optics: Focusing in the Eye



Parallel rays

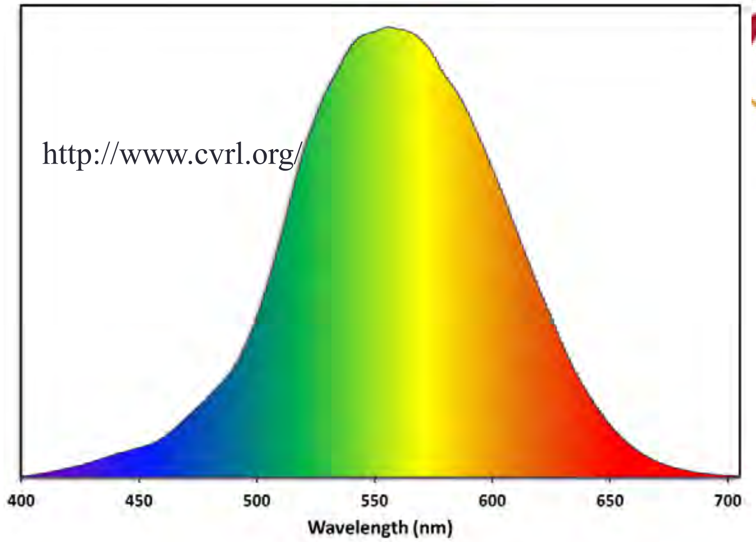
θ < 1.5 mrad is a point source for the eye

Optics: Focusing in the Eye

θ < 1.5 mrad is a point source for the eye

Incoherent Light vs. Laser: Power

- Light bulb power (60 W) is Electrical not Optical
  - Laser rated in optical power
  - Tungsten bulb: 16 lumens/W



- Lumen??
  - Eye's response to visible light
  - 683 lumens is 1 W of optical power

Wavelength	Response
475 nm	0.1535
515 nm	0.6206
556 nm	0.999
570 nm	0.9733
630 nm	0.298
680 nm	0.0181

- 60 W tungsten filament bulb about 1.4 W (optical)
  - 2 % conversion efficiency

Example: How much light enters the eye

Standing 50 cm from a 6 cm tall 60 W light bulb and a 1 mW laser pointer with a 2 mm beam diameter.

1. How much light enters your eye?

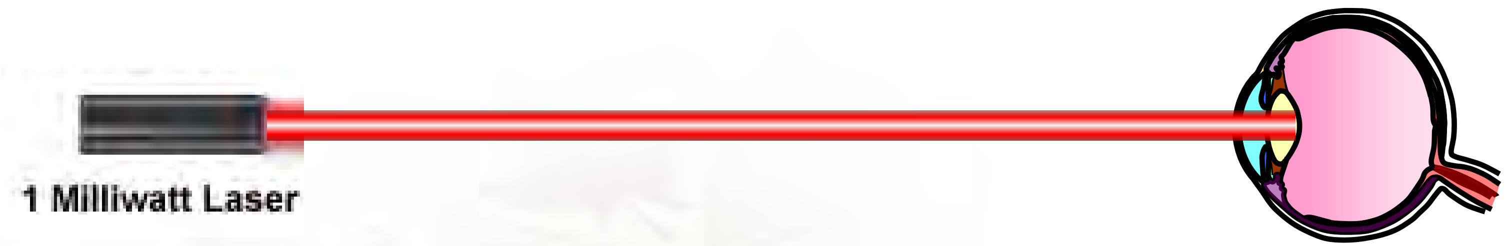
$$\frac{1.4\ \text{W}}{4\pi\ \text{sr}} = 0.11\ \text{W}/\text{sr}$$

3.3 μW enters eye (2×10^{-4} %)

Example: How much light enters the eye

Standing 50 cm from a 6 cm tall 60 W light bulb and a 1 mW laser pointer with a 2 mm beam diameter.

1. How much light enters your eye?



1 mW enters your eye (100 %)
300X more power

Example: Light concentration

Standing 50 cm from a 6 cm tall 60 W light bulb and a 1 mW laser pointer with a 2 mm beam diameter.

2. How concentrated is the light on the retina?

Bulb is a 2 mm image
(assume circular diameter)

$$E = \frac{3.1\ \mu\text{W}}{\pi(0.1\ \text{cm})^2} = 0.1\ \text{mW}/\text{cm}^2$$

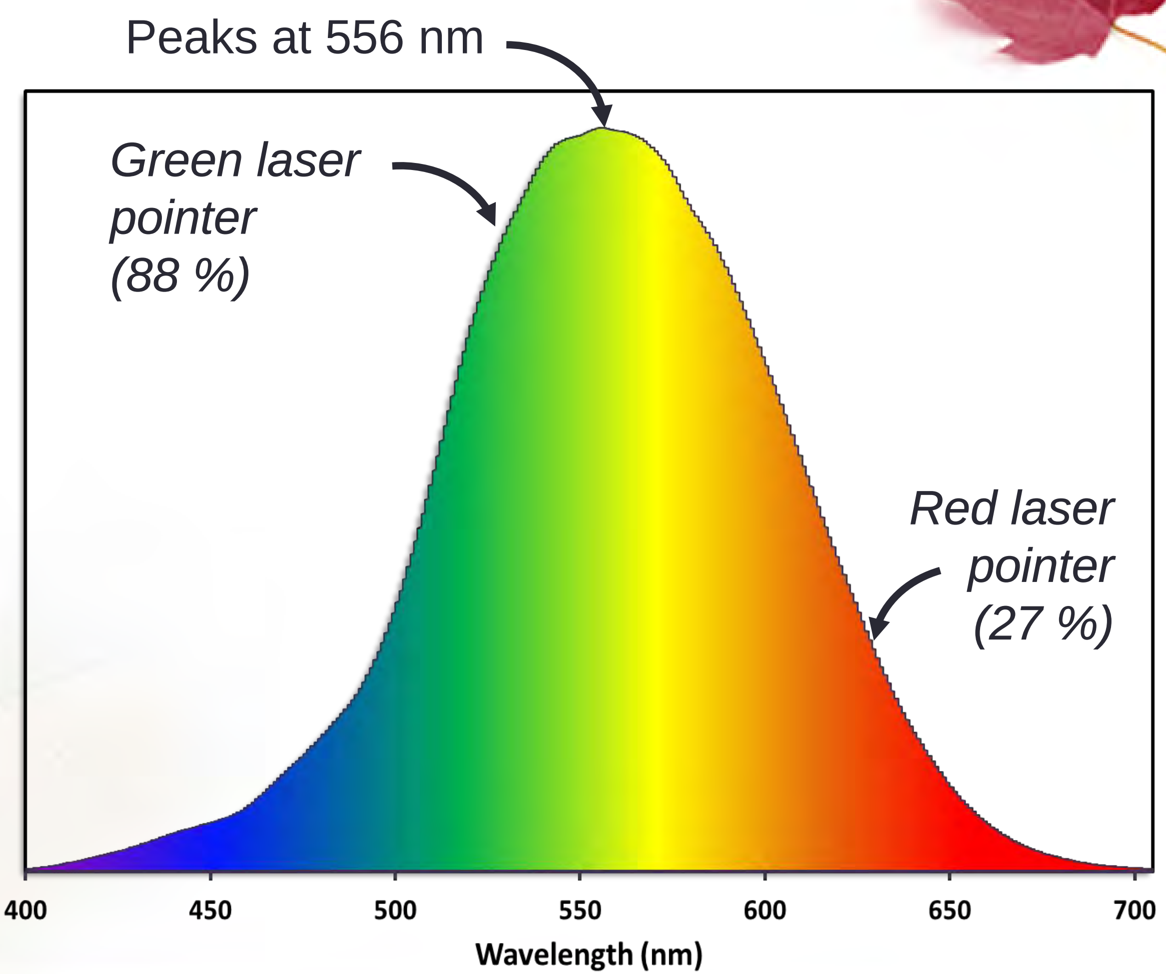
Laser focuses to 10 µm spot
(conservative guess)

$$E = \frac{1\ \text{mW}}{\pi\left(5\times10^{-4}\ \text{cm}\right)^2} = 1.3\ \text{kW}/\text{cm}^2$$

Laser pointer power density is a
million times higher on your retina

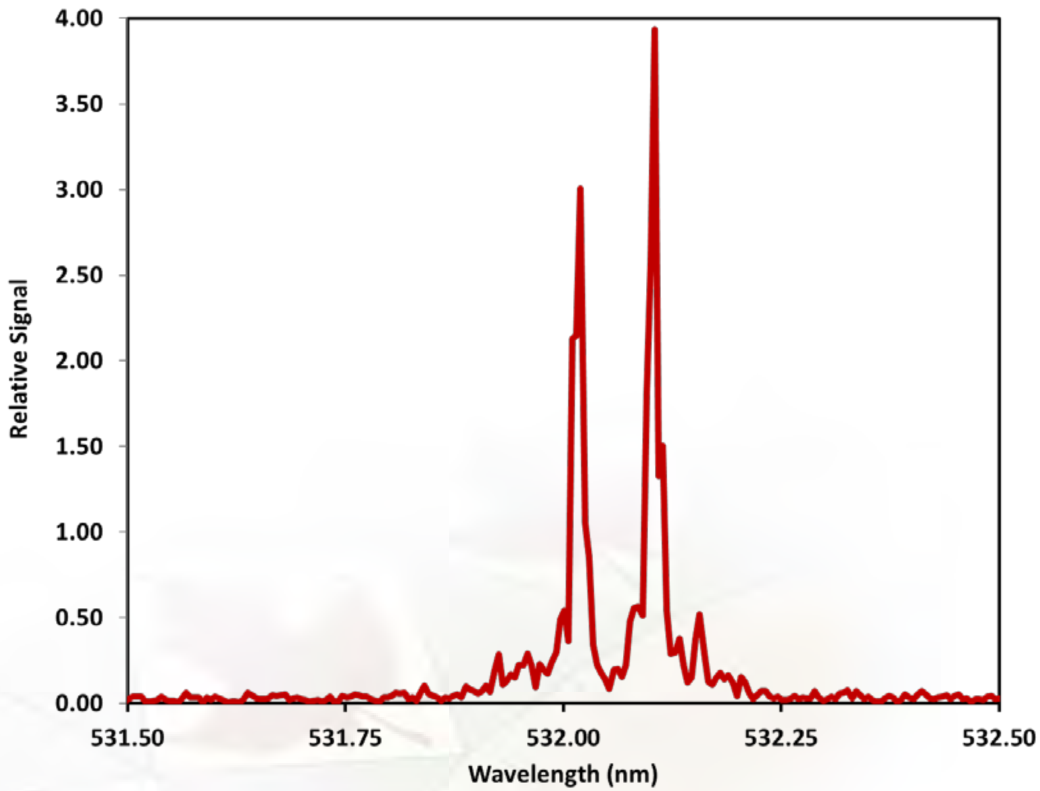
Eye: Colour Response

- Response to different wavelengths
- Green pointers do not need to be **5x** more powerful!



http://www.cvrl.org/cvrlfunctions.htm
(2 deg. Luminous efficiency function)

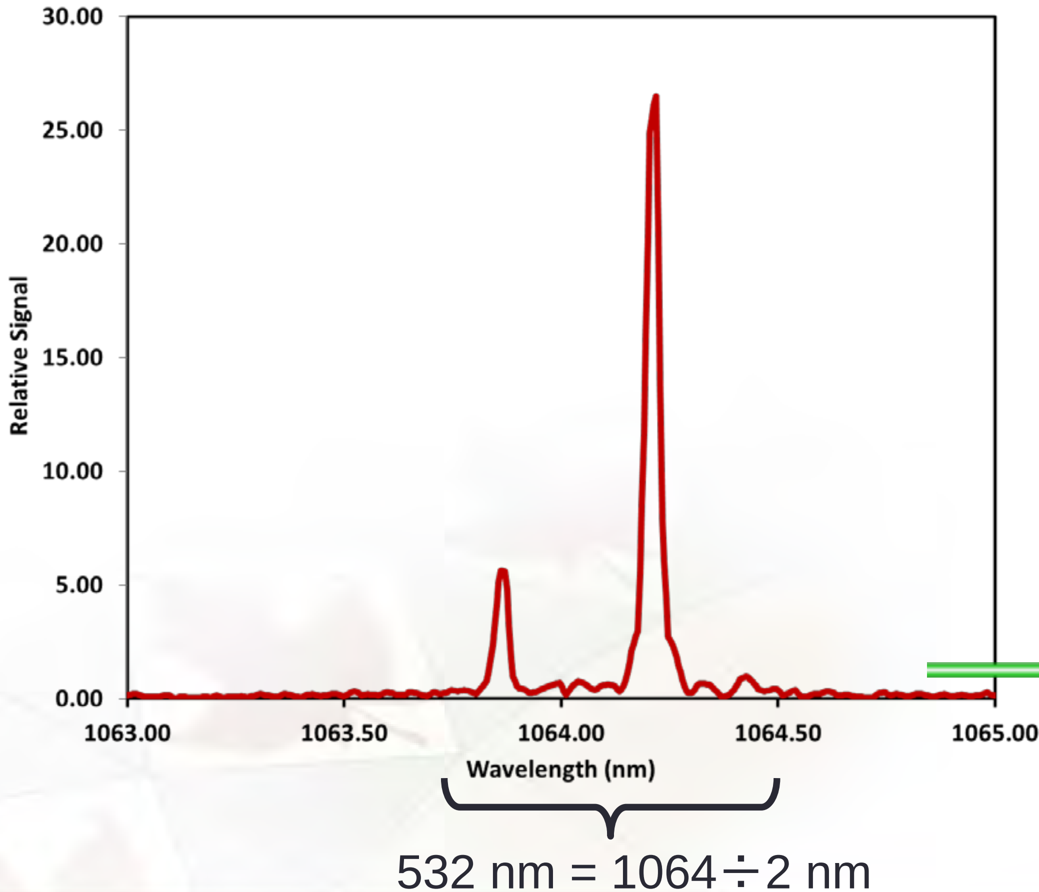
But how well do you know your laser pointer?



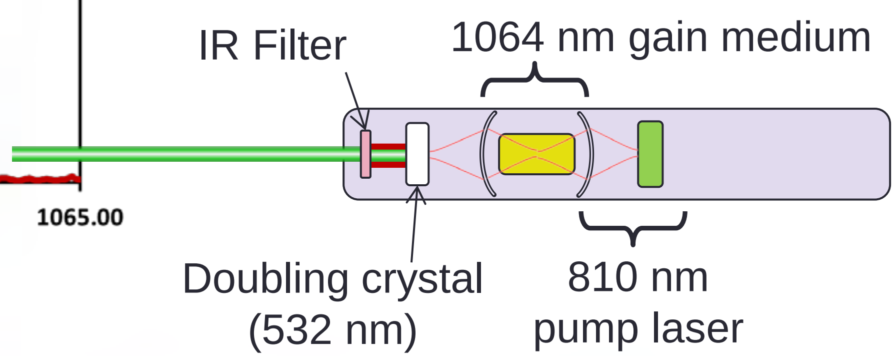
- Green colour
  - but how?
- Power < 5 mW
  - okay, but…kind of bright..?
  - red laser pointers are only 1 mW and they work fine…

see recent FDA video: www.youtube.com/watch?v=FPPnFg_ujJI

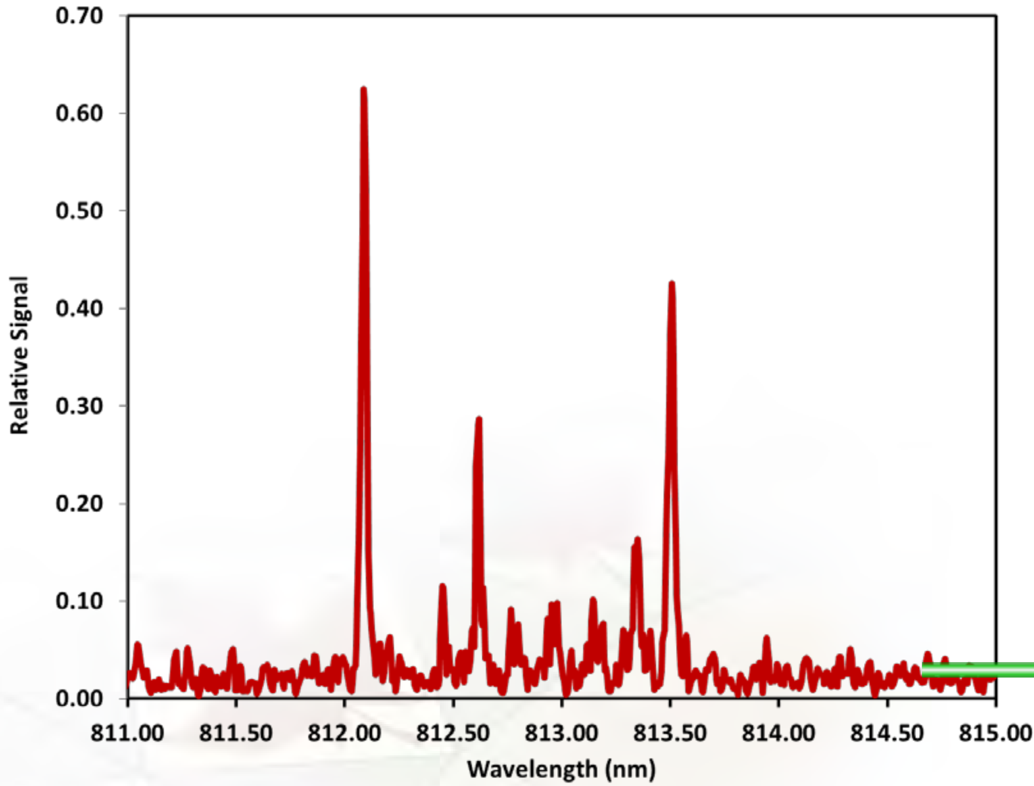
But how well do you know your laser pointer?



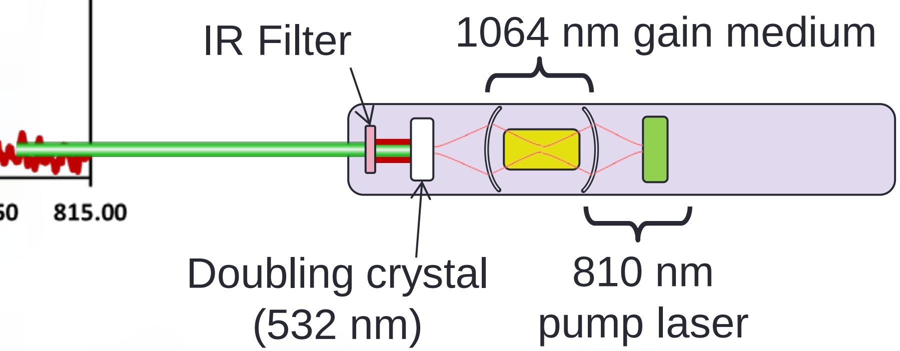
- Green colour
  - second harmonic generation
- **The IR is 7x brighter!**



But how well do you know your laser pointer?



- Green colour
  - second harmonic generation
- **The pump light leaks through, also**



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Laser Injuries

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Risk

Probability of laser injury: Product of probability of laser exposure and amount exposure exceeds the injury threshold

$$P(\text{Laser Injury}) = \underline{P(\text{Exposure})} \times \text{Impact}$$

Need countable instances, but can enumerate:

Causes of Exposure	Improvement Strategies
Uncontrolled beams	Horizontal, below waist, clamped optics, covered beams, dumped
Misfire	Beam blocks, redundant controls (microscopes)
Behaviours	SOPs, Respect Risks

(Also apply to non-beam hazards)

Risk

Probability of laser injury: Product of probability of laser exposure and amount exposure exceeds the injury threshold

$$P(\text{Laser Injury}) = P(\text{Exposure}) \times \underline{\text{Impact}}$$

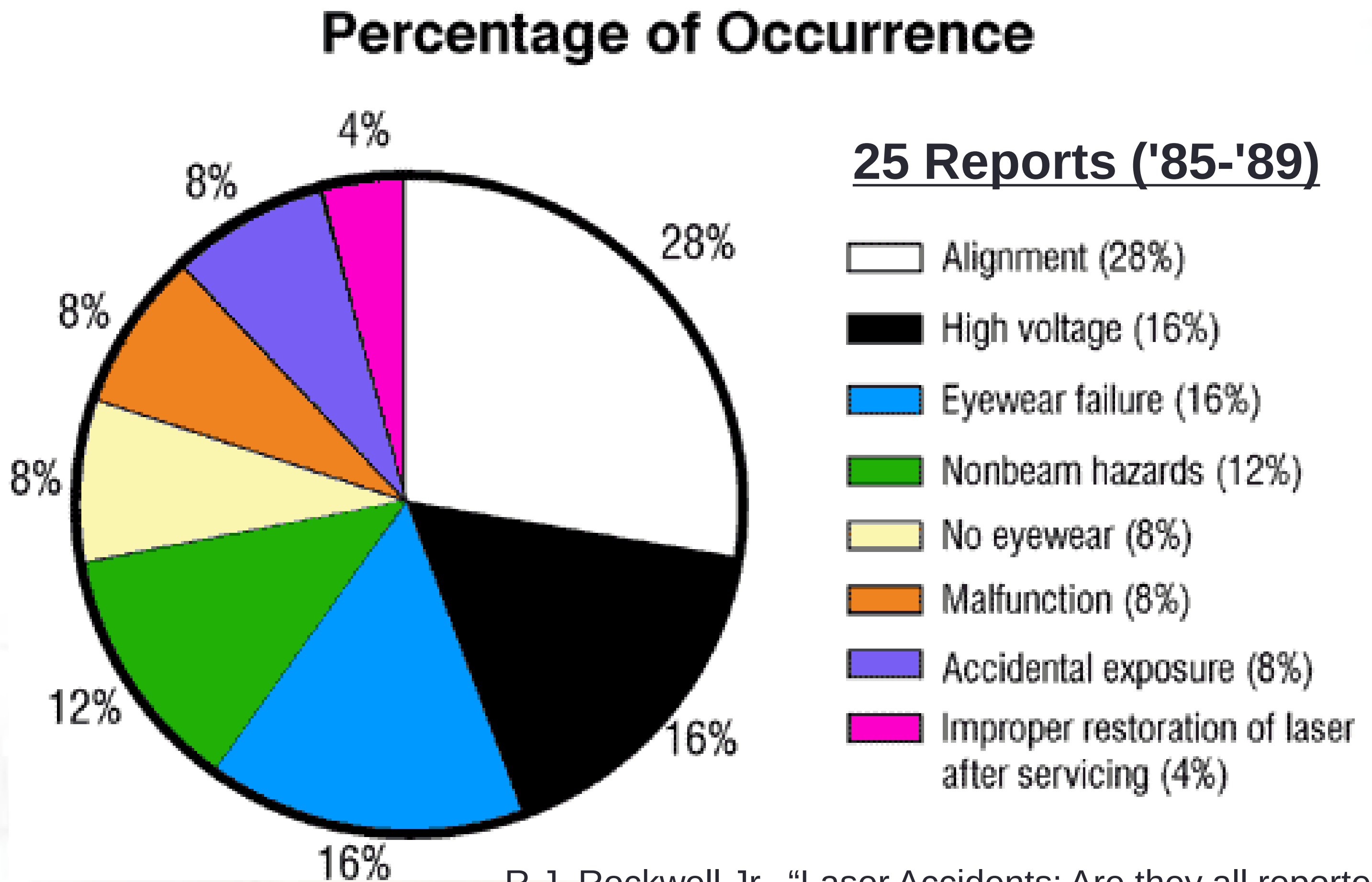
Need countable instances, but can enumerate:

Exceed Injury Limit	Improvement Strategies
Excessive power level	Reduce power during alignment, use other lasers
Improper PPE	Wear goggles, wear lab coat, evaluate goggle need

(Also apply to skin hazards)

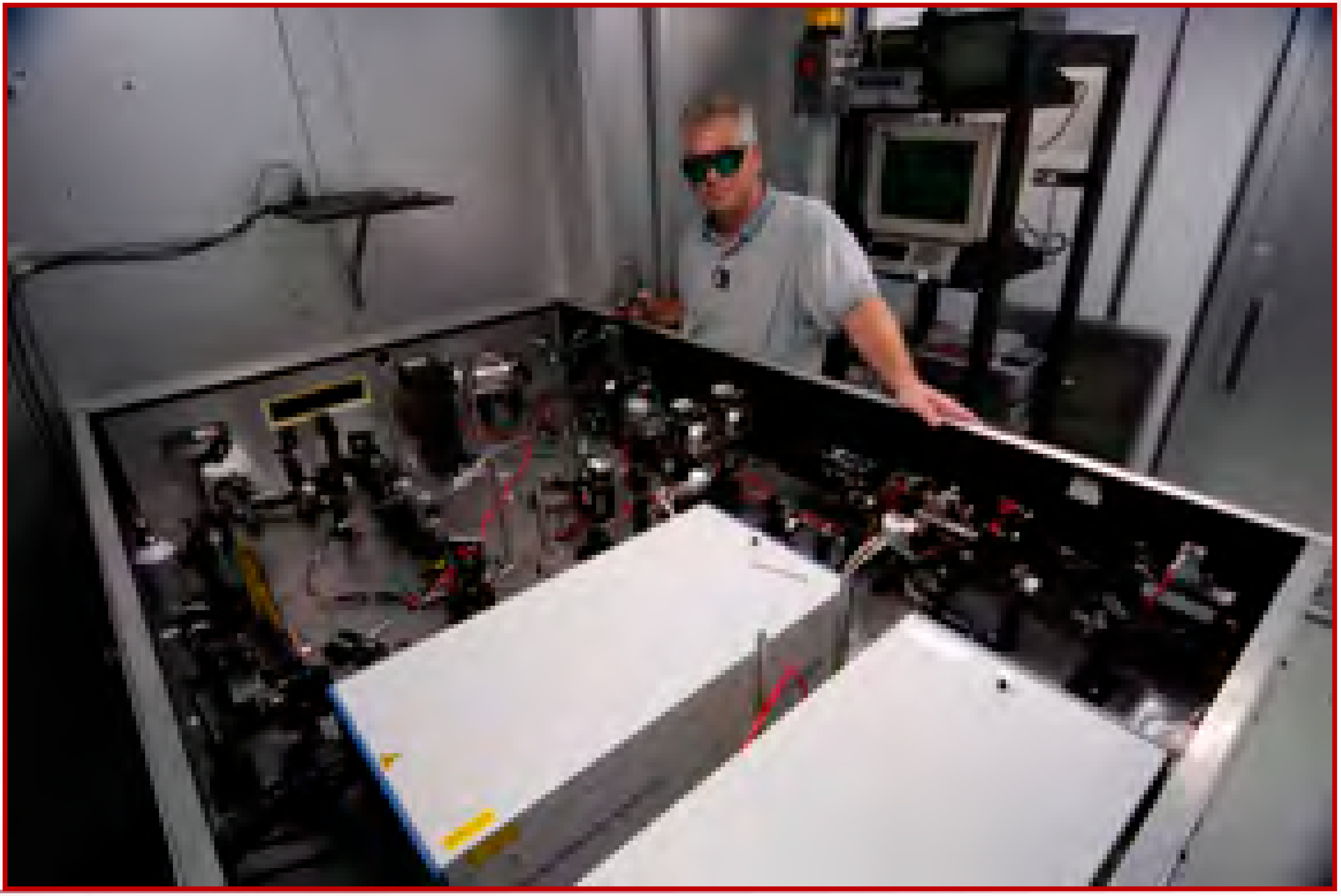
You likely have a higher tolerance for your voluntary use of research-grade lasers as compared to general public who walks by the lab door

Causes of Laser Accidents



R.J. Rockwell Jr., “Laser Accidents: Are they all reported and what can be learned from them”, *J. Laser Appl*., vol. 1, p. 53 (1989)

Eye Injury



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Eye Injury

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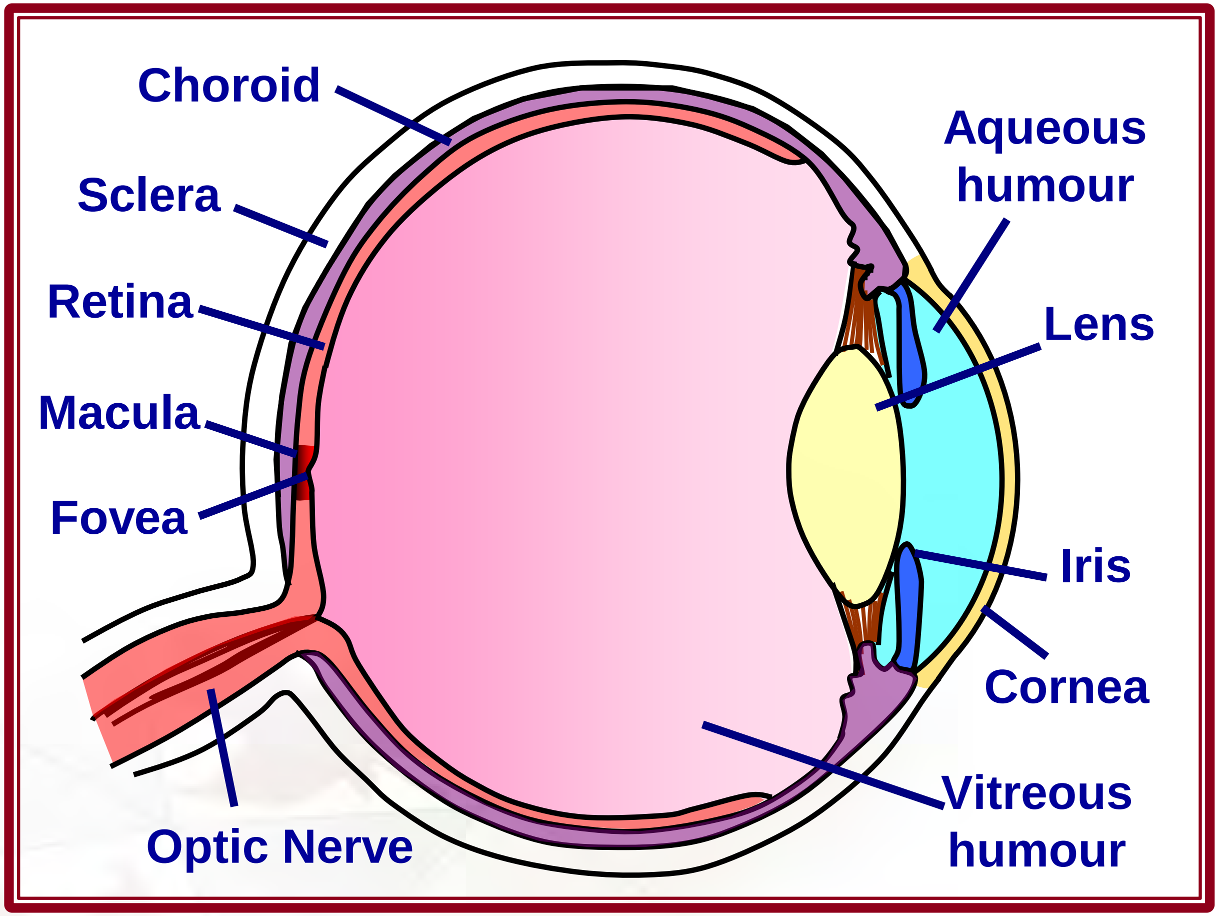
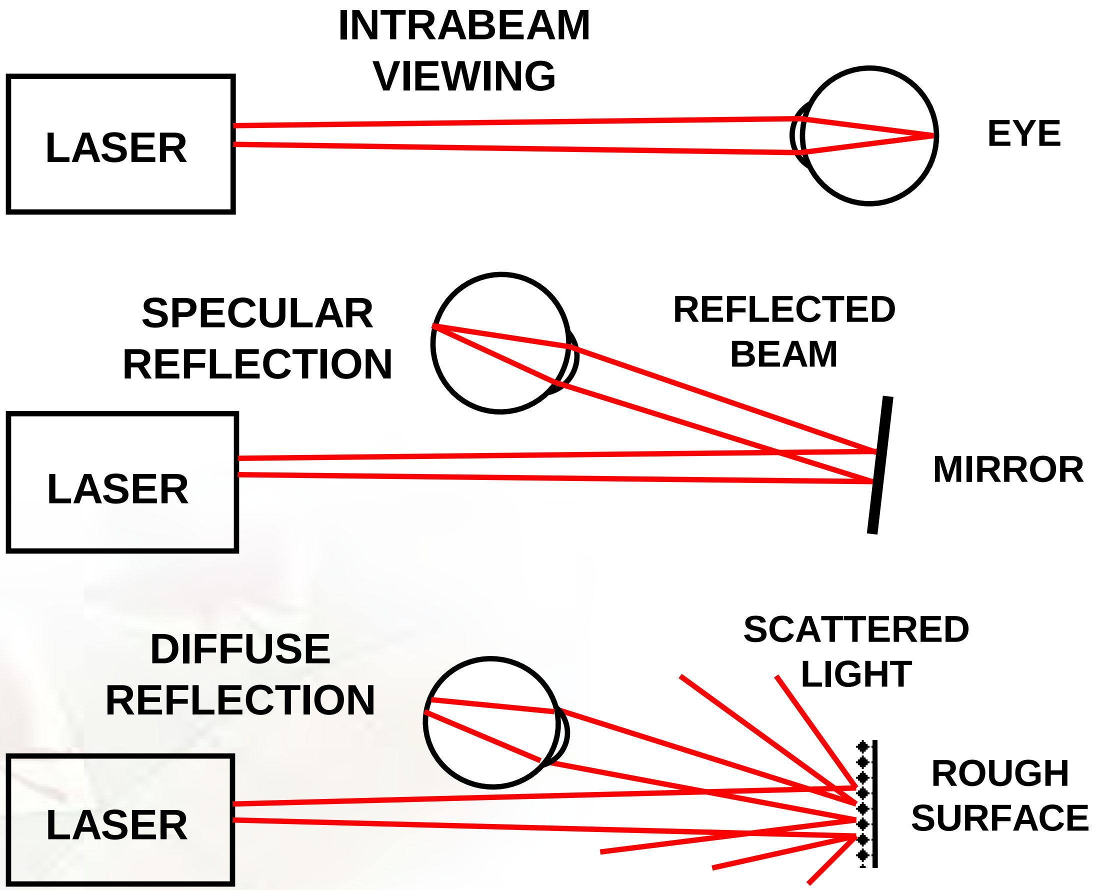
The Human Eye



<u>Laser Safety</u>

- ¼ second blink rate
- 7 mm dark-adapted iris diameter
- 10 s fixed gaze limit (saccadic movement)
  - factor in blue-light/UV dose

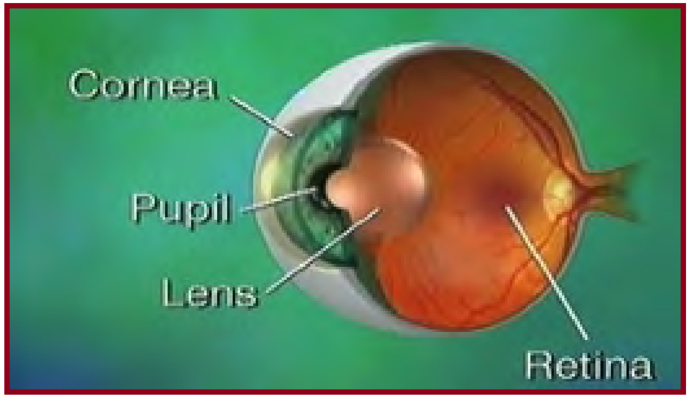
Types of Laser Eye Exposure



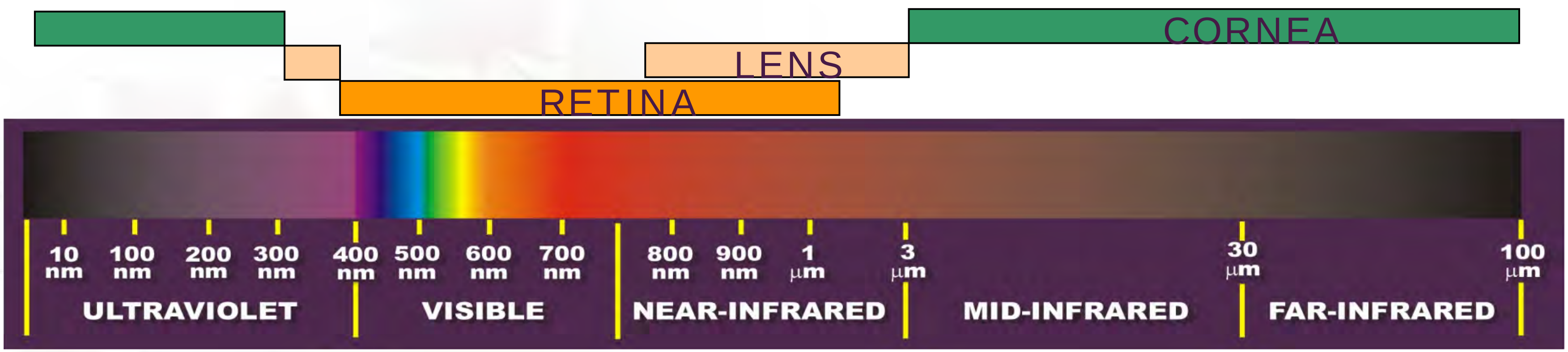
Wavelength Dependent Effects

- 3 vulnerable ocular structures (absorbs at different wavelengths):

Cornea:	UV, mid-IR & far-IR	(burns, opacity)
Lens:	near-UV & near-IR	(cataracts)
Retina:	visible & near-IR	(burns, lesions)



- **Retina** is most vulnerable
  - absorbs at common laser wavelengths
  - light 100,000 × more intense than at cornea



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Lasers harm eyes because:

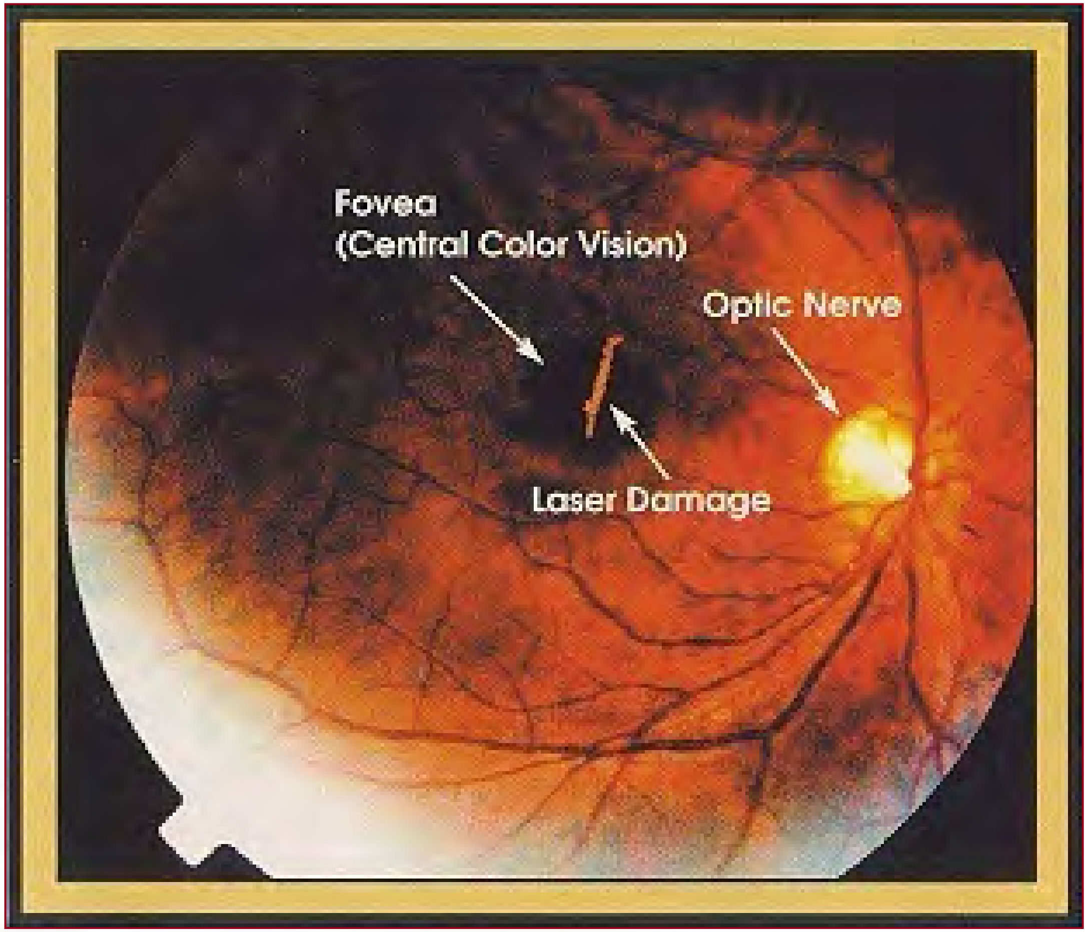
- Focused to nearly a spot by the eye
  - Retina and macula (fovea)
  - increases laser power density by 100,000
  - 1 mW/cm^2 becomes 100 W/cm^2

- Focuses visible and infrared radiation
  - you can’t see infrared
- A 0.5 mJ pulse can cause permanent retinal damage
  - **blindness** if central vision affected
  - Retina can repair some damage

Example: Retinal Injury

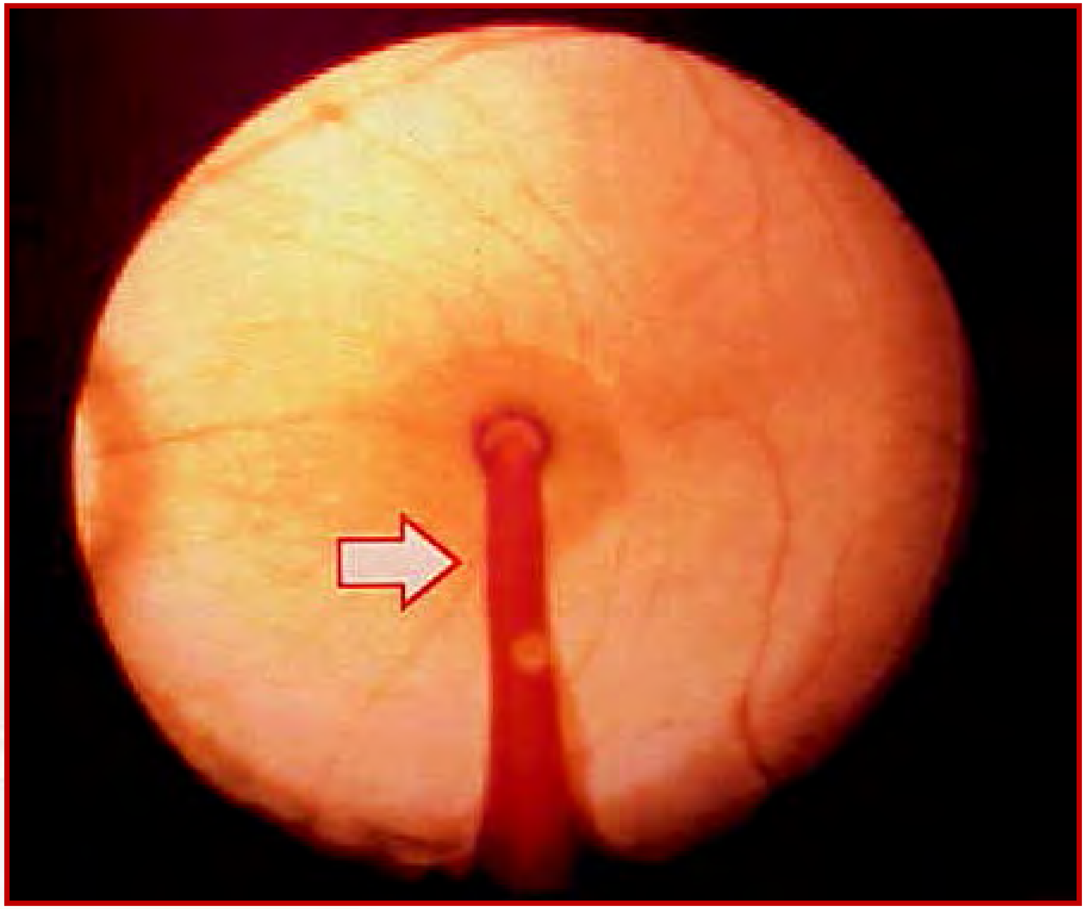
- Several hours aligning low-power 532 nm Nd:YAG through a dye laser
  - Not wearing goggles to see beam
- A 10 ns, 20 nJ pulse focused onto fovea
  - Green flash: no pain
  - Not immediately aware of eye damage
- Noticed blind spot like a camera flash in right eye after returning to desk
  - 5.00 pm Friday: didn't report incident
  - Saturday afternoon: knew a problem existed

Example: Retinal Injury



Ph.D. student,
Ti:S compressor

Example: Retinal Injury



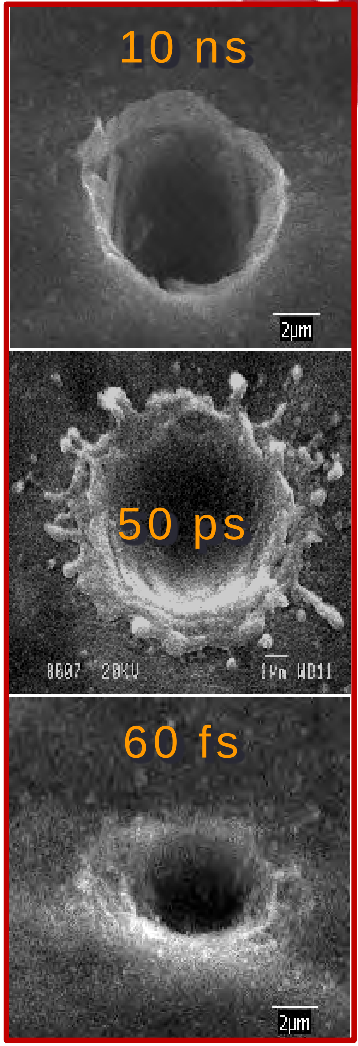
Example:
Multiple Pulse Retinal Injury

- Partial reflection of 10 ns, 6 mJ Nd:YAG
  - no goggles
- Beam struck eye
  - Distinct popping sound
  - Laser-induced explosion at back of eyeball
- Vision obscured by blood streams in vitreous humour
  - Viewing through fishbowl with mix of glycerine, blood and black pepper
- Most immediate response is horror then going into shock

Example:
Multiple Pulse Retinal Injury

Pulsed Laser-Matter Interaction

- Damage mechanism varies with pulse duration
- continuous beam - 50 ns
  - charring/blistering of tissue
- 50 ns - 1 ps
  - shock wave formation and tissue liquification
  - tissue ejected into vitreous humour (floaters
- 1 ps - 1 fs
  - multiphoton ionization of tissue
  - ejection of individual nuclei/small clusters



Summary on Retinal Injury

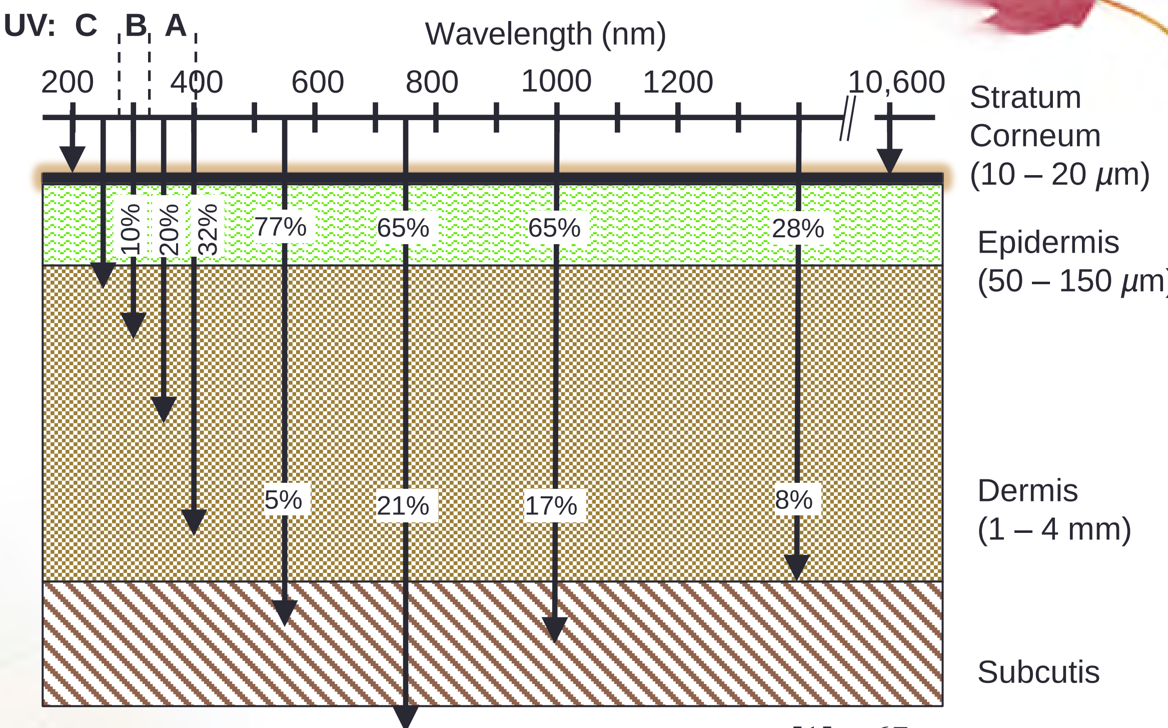
- Retinal Injuries (blindness) are **<u>permanent</u>**
- Retina contains:
  - Fovea
    - central colour vision
    - depth perception in 3° cone
    - enables reading, driving, etc.
  - Optic Nerve
    - central nerve bundle of an eye
    - damage can lead to total loss of vision
  - Blood Vessels
    - rupture leads to blood in vitreous humour

<u>Conclusion:</u>

A single retinal lesion can lead to severe visual impairment!

Laser Radiation as a Skin Hazard

- Thermal Injury (burn)
- Erythema (sun burn)
- Epidermis: melanin inactivates free radicals made at UV
- Accelerated ageing and pigmentation



[1] p.67

Some people may be more at risk of photosensitive reactions from genetics or induced by medicines

Example: Skin Irradiation

- XeCl (308 nm) excimer laser
- Laser enclosure opened to look for an electrical short inside the laser chamber
- Struck in neck by several 15 mJ pulses
  - did not feel anything until hours later
  - four burns appears on his neck
  - Took three weeks to heal
- Wore eye protection
  - eyes were unaffected

www.uottawa.ca/services/ehss/EMR.html

ACGIH TLV for UV Exposure Limits

Example: Skin Irradiation

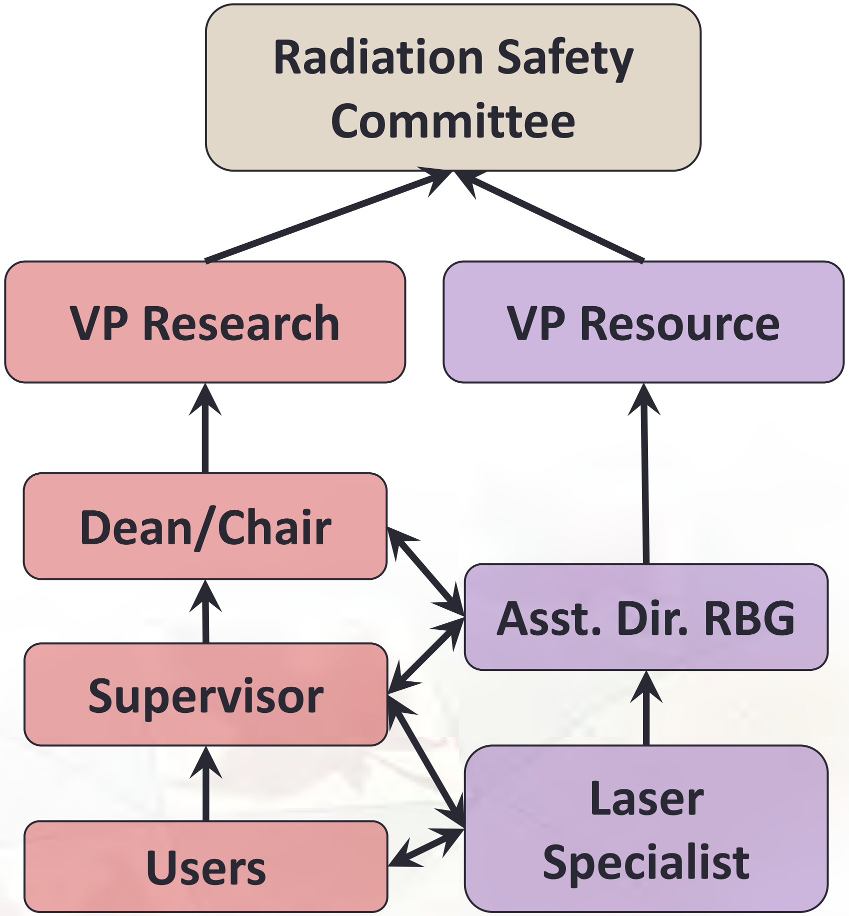
BREAK

uOttawa Laser Safety Program

uOttawa

Office of Risk Management
Laser Compliance Specialist ext.2000

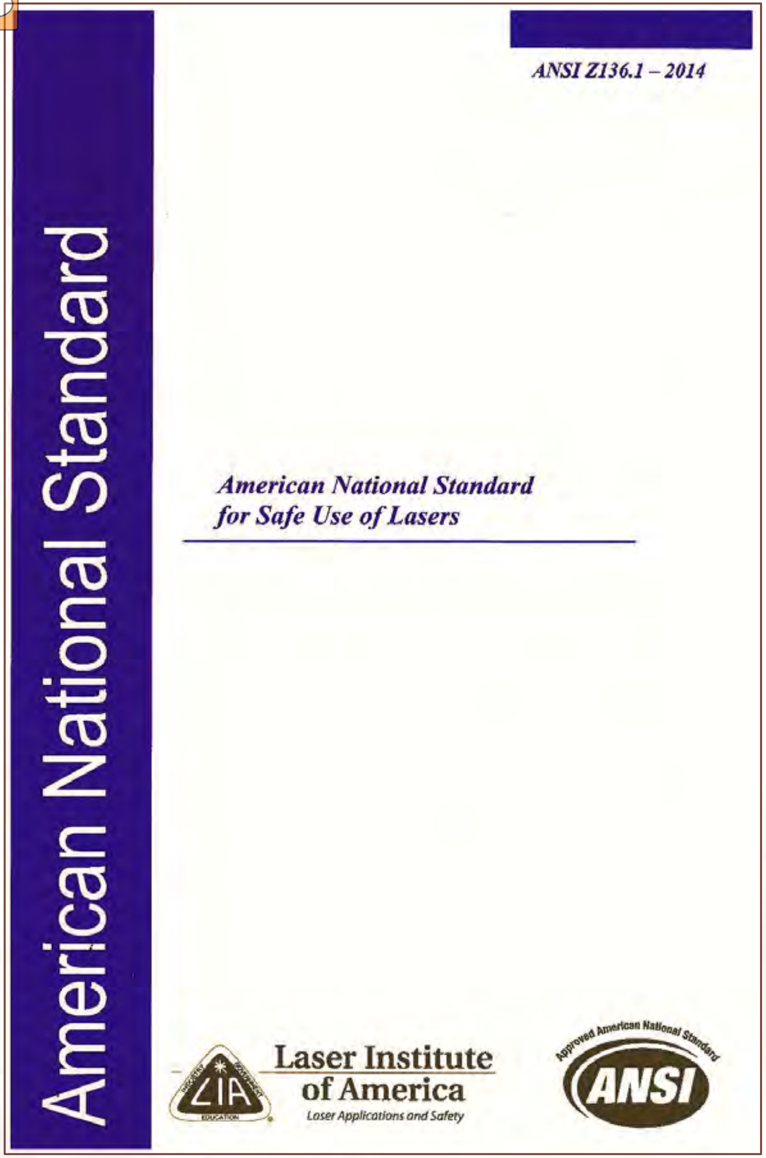
Laser Safety Program at uOttawa



- Individuals
- Office of Risk Management/ RadBio Safety Group
  - Assistance/Guidance
  - Permits
  - Education and Training
  - Inspections/Accidents/ Incidents Follow-up
- Department/Faculty
  - Ensure lasers used in accordance with our standards

Who makes the laser rules?

- The following regulatory bodies:
  - Ontario Ministry of Labour (MOL) and the Occupational Safety and Health Administration (OSHA) recognizes the American National Standard for Safe Use of Lasers (ANSI Z136.1) as part of our General Duties and Due Diligence
    (www.labour.gov.on.ca/english/hs/topics/radiation.php)
  - also in Canada OHS Regulation (SOR/86-304 (10.26(*l*))
  - US Federal Laser Product Performance Standard (FLPPS) of the Center for Devices and Radiological Health (CDRH)
  - International Electrotechnical Commission (IEC 60825-1)
  - Canadian Standards Association (CSA-Z386): Health Care Facilities



- Defines classification of lasers by accessible energy
- Defines LSO roles (App.A)
  - Expected level of previous expertise
- Defines laser safety program structure (App.A)
  - Track lasers
  - Train users
- Control of Laser Areas by classification

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Office of Risk Management

About · Programs · Specific Activities · Training · Resources · Health an

orm.uottawa.ca/programs/laser-safety

Laser Safety

Laser technology has dramatically evolved since its conception in 1917, to the development of the first laser in 1960; and now to its expanding applications. Currently, lasers are used in such diverse areas as: research, telecommunication, industry, medicine, entertainment and commercial products. The risk associated with laser use varies from minimal to potentially significant depending upon the characteristics of the laser and the design of the laser system.

The University of Ottawa has mandated the Radiation Safety Committee and the Office of Risk Management to ensure the appropriate measures are in place to address any potential risk. The Laser Safety Program is managed by the Assistant Director, Radiation and Biosafety (Lois Sowden-Plunkett), and the Laser and Non-ionizing Radiation Compliance Specialist (Sean Kirkwood). It is designed to assist in minimizing the associated risk of laser use.

This web page has been designed as an educational tool and to provided direction to users as to the University's standards and those found in industry.

Researcher's Corner

- Laser Permit Form
- Laser User Form
- Training Requirements
- Presentation
- Moving/Shutting Down Lab

Laser Safety Eyewear

- How to choose the right one?

Specific Topics

- Biological Effects
- Control Measures
- Classification of Lasers
- Femtosecond Laser Technology Safety Aspects
- Hazard Evaluation
- Laser Pointers
- Laser SOP Template
- Laser signs and Labelling
- Laser Plumes
- LEDs vs Laser Diodes

External Links

- Quebec Photonic Network
- Agile All-Photonic Networks
- Canadian Photonics Industry Consortium (PhotonsCanada)
- Canadian Centre for Occupational Health and Safety

Regulatory

- Ontario Ministry of Labour
- Radiation Emitting Devices Act (R.S.C. 1985, c. R-1)

Free Software

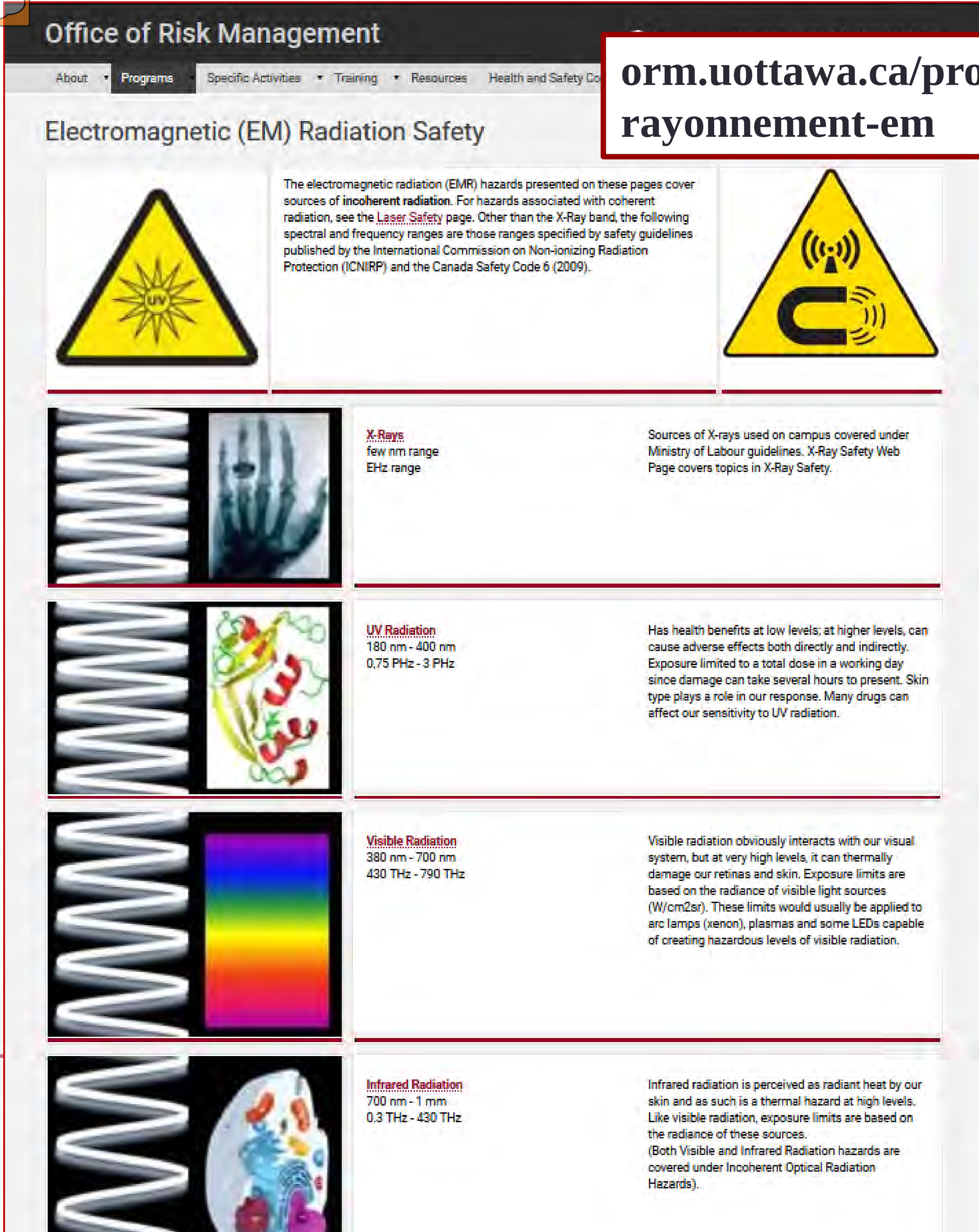
- EasyHAZ (Kentek)

Associations

- IEEE Photonics Society
- International Laser Display Association
- Laser Institute of America
- Canadian Radiation Protection Association (CRPA)
- International Radiation Protection Assocation (IRPA)

- Updated Winter 2015

- Bookmark it
- Refer to it
- Bilingual


Office of Risk Management

About | Programs | Specific Activities | Training | Resources | Health and Safety Co

Electromagnetic (EM) Radiation Safety

The electromagnetic radiation (EMR) hazards presented on these pages cover sources of **incoherent radiation**. For hazards associated with coherent radiation, see the Laser Safety page. Other than the X-Ray band, the following spectral and frequency ranges are those ranges specified by safety guidelines published by the International Commission on Non-ionizing Radiation Protection (ICNIRP) and the Canada Safety Code 6 (2009).

	X-Rays few nm range EHz range	Sources of X-rays used on campus covered under Ministry of Labour guidelines. X-Ray Safety Web Page covers topics in X-Ray Safety.
	UV Radiation 180 nm - 400 nm 0.75 PHz - 3 PHz	Has health benefits at low levels; at higher levels, can cause adverse effects both directly and indirectly. Exposure limited to a total dose in a working day since damage can take several hours to present. Skin type plays a role in our response. Many drugs can affect our sensitivity to UV radiation.
	Visible Radiation 380 nm - 700 nm 430 THz - 790 THz	Visible radiation obviously interacts with our visual system, but at very high levels, it can thermally damage our retinas and skin. Exposure limits are based on the radiance of visible light sources (W/cm2sr). These limits would usually be applied to arc lamps (xenon), plasmas and some LEDs capable of creating hazardous levels of visible radiation.
	Infrared Radiation 700 nm - 1 mm 0.3 THz - 430 THz	Infrared radiation is perceived as radiant heat by our skin and as such is a thermal hazard at high levels. Like visible radiation, exposure limits are based on the radiance of these sources. (Both Visible and Infrared Radiation hazards are covered under Incoherent Optical Radiation Hazards).

orm.uottawa.ca/programmes/securite-de-rayonnement-em

- Lasers are electromagnetic waves (radiation)
  - EMR
  - hazards are wavelength dependent
  - more info here

- Bookmark it
- Refer to it
- Bilingual

CONTROL OF LASER HAZARDS

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Laser Compliance Specialist ext.2000

How do we reduce risk?

Laser Control Measures: <u>shall</u> be devised to reduce the possibility of exposure of the eye and skin to hazardous levels of laser radiation – ANSI Sec. 4.1.

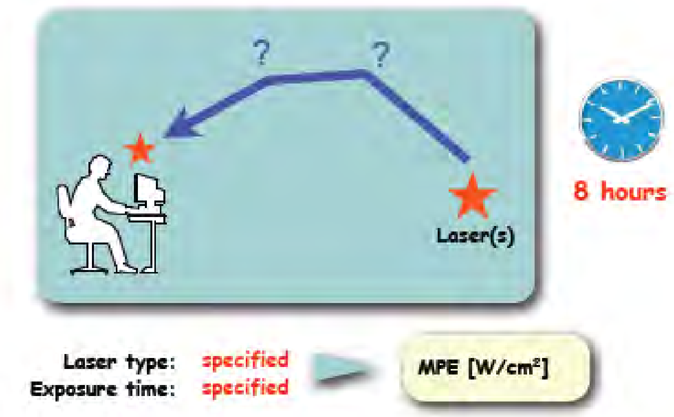
- Engineering Controls (Beam hazard control)
  - barriers/curtains, warning device, beam blocks, protective housing (with interlocks), key control
- Administrative and Procedural Controls
  - SOPs, training, appropriate signage, laser registration (permit)
- Protective Equipment
  - eyewear, lab coats

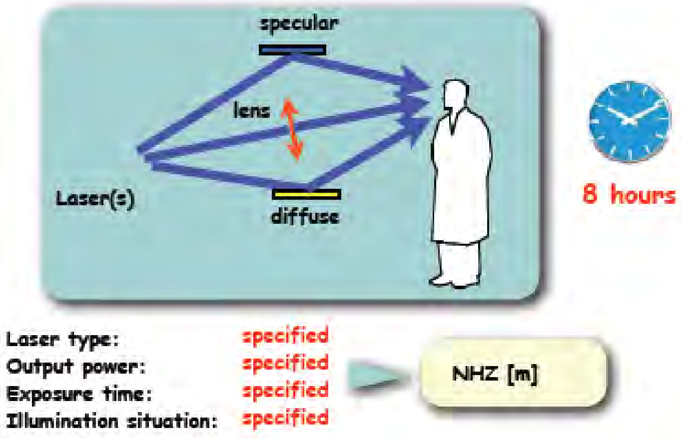
Laser Hazard Evaluation

MPE – Maximum permissible exposure
Laser radiation level up to which a person may be exposed without hazardous effects

NHZ – Nominal Hazard Zone
Where direct, reflected or scattered radiation during normal operation exceeds MPE

LCA – Laser Controlled Area
Where beams are deliberately contained to limit the NHZ





Individual Responsibility

- Ensure you are an authorized user
- Have your name on the uOttawa laser permit
- Follow appropriate training
- Take reasonable precautions to ensure your safety and that of others
- Performed laser tasks in a manner that minimizes radiation exposure
- Do not initiate or participate in any activity that may endanger the health or safety of anyone

The person operating the laser always has the primary responsibility for all hazards associated with laser use

PRIORITY #1
Engineering Controls

CONTROL OF LASER HAZARDS

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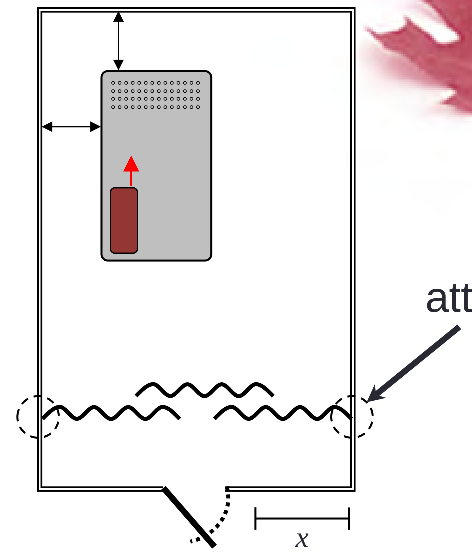
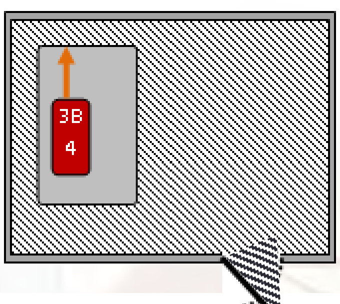
Laser Compliance Specialist ext.2000

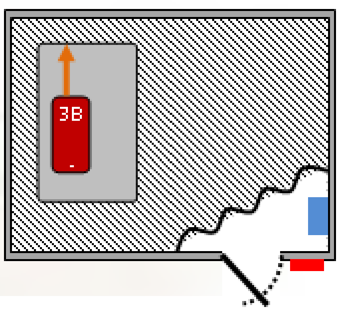
Indoor Laser Controlled Area

Shields public from inadvertent exposure to laser radiation and associated non-beam hazards

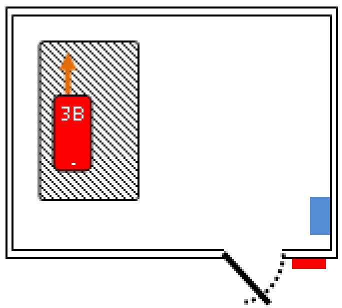




Not compliant: A room without shield to public

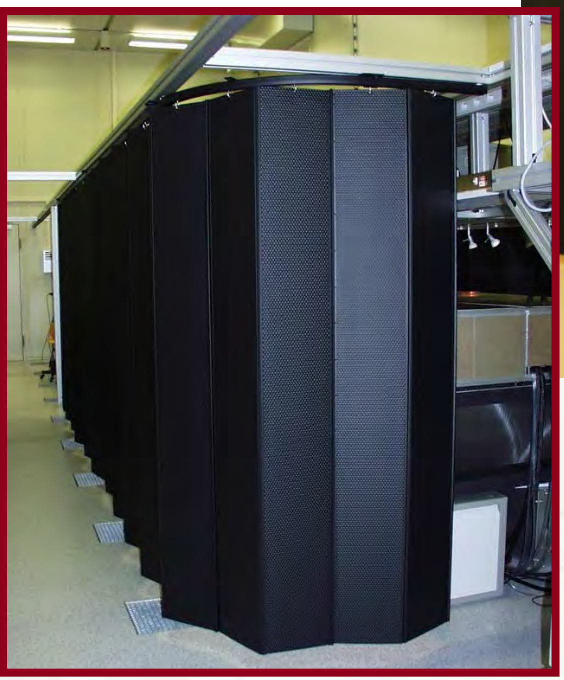


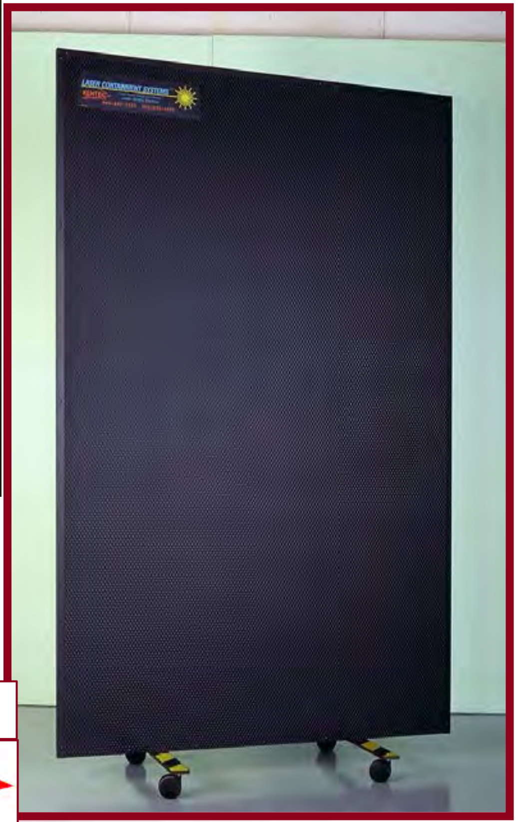
Compliant: protects public, PPE, warning lights



Best: Compliant, and reduces hazard to users

Curtains and Barriers (Room)





Photos courtesy of

KENTEK

"Laser People Helping Laser People"

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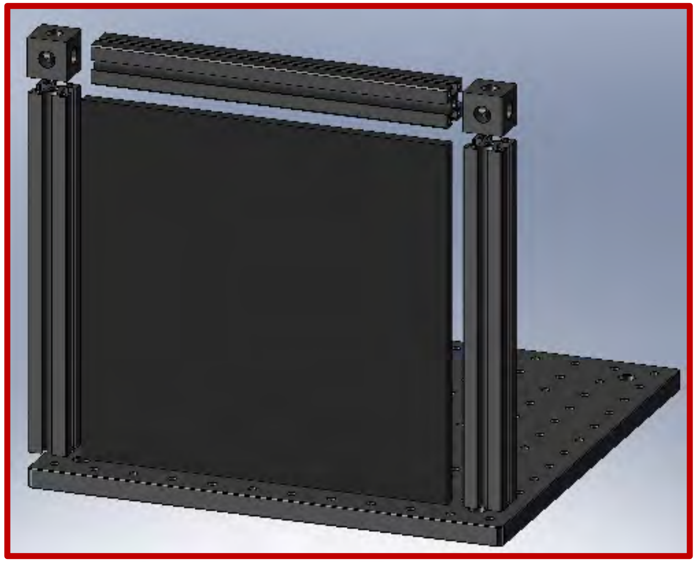
Laser Compliance Specialist ext.2000

Enclosures and Controls

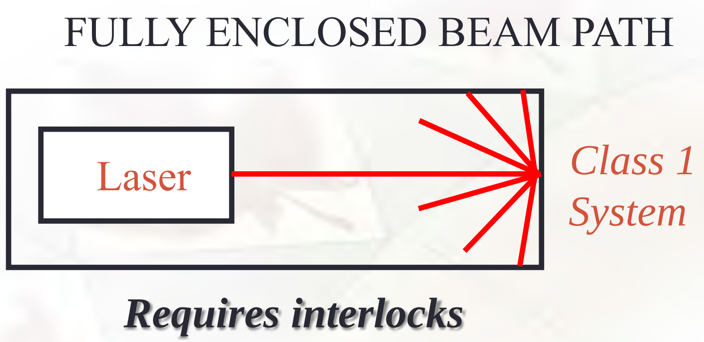
- Protective Housing (if has interlocks)
  - curtains/barriers or enclosure otherwise

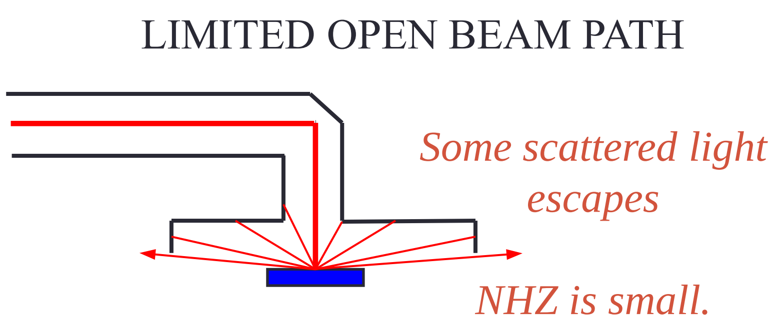
- Key control (with master switch)
- Laser area warning signs
- Activated warning system (illuminated or audible)

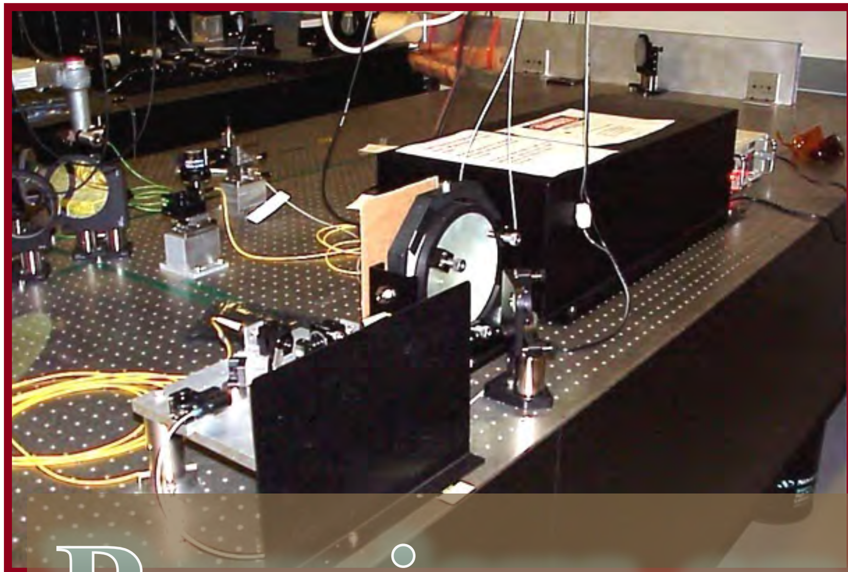


ANSI Enclosure Definitions

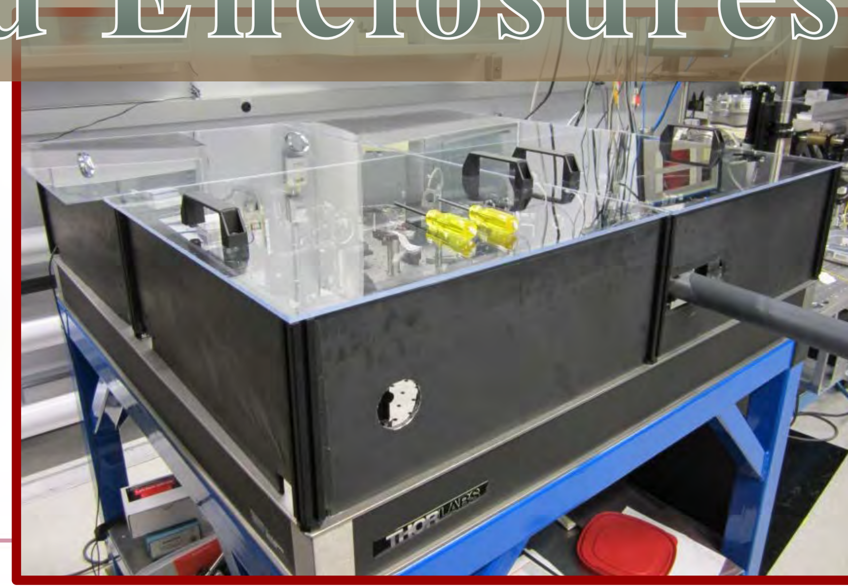
Protective Housing	Enclosure
- Interlocked or tool entry enclosure	- No interlocks
- Required for Class 3B and 4 lasers	- Considered barrier or curtain
- Embedded lasers (Class 1 designation)	- Removable panels labeled with laser classification language
- Fail-safe interlocks ideal	







Barriers and Enclosures



PRIORITY #2

Administrative and Procedural Controls

Control of Laser Hazards

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Office of Risk Management
Laser Compliance Specialist ext.2000

Administrative and Procedural Controls

- Education and Training
  - User tracking
  - Spectators/Visitor rules
- Standard Operating Procedures (SOPs)
  - Laser Tracking and Permitting
  - Laser On/Off, Alignment, Training
- Signage

Laser Training and uOttawa Safety

- Class 3B and Class 4 lasers have highest hazard
  - User training required (practical and theoretical)
  - Danger signs and other control measures
  - User tracking

- Training
  - This class is a theoretical baseline for all users
  - Practical training covers in-lab issues (very important)
  - Refresher Training every 4 years

Laser Permits And User Tracking

Your supervisor (permit holder)

Lab supervisor

Open Class 3B / 4 Laser Info

PERMIS POUR APPAREILS ÉMETTEURS LASER

LASER EMITTING DEVICE PERMIT

N° DE PERMIS / PERMIT #
L13-ORM-0225

NOM / NAME	DR. JOHN SMITH	BUREAU / OFFICE	ARC 123 — N° DE TÉL / TEL # 2000
POSTE / POSITION	PROFESSOR	COURRIEL / E-MAIL	laser.safety@uottawa.ca
FACULTÉ / FACULTY	SCIENCE	DÉPARTEMENT / DEPARTMENT	PHYSICS
CONTACT DE LABO / LAB DELEGATE	Jim Knowitall	N° DE TÉL. LABO / LAB TEL. #	2599
COURRIEL DE CONTACT / DELEGATE E-MAIL	askme@uottawa.ca	N° DE TÉL. DE CONTACT / DELEGATE TEL. #	2001
ENTRÉE EN VIGUEUR / EFFECTIVE DATE	January 25, 2016	DATE D'EXPIRATION / EXPIRY DATE	February 28, 2020

SECTION 1: ÉQUIPEMENT LASERS OUVERTS ET PARAMÈTRES D'USAGE / OPEN LASER SYSTEMS AND OPERATING PARAMETERS

(AFFICHES ET DISPOSITIFS D'AVERTISSEMENT POUR LASER NÉCESSAIRES) (APPROPRIATE LASER WARNING SIGNS AND DEVICES ARE REQUIRED)

CLASSE / CLASS	FABRICANT / MANUFACTURER	N° DU MODÈLE/DE SÉRIE / MODEL/SERIAL #	DESCRIPTION DU LASER / LASER DESCRIPTION	LONGUEUR D'ONDE / WAVELENGTH	SORTIE MAX / MAX OUTPUT	FRÉQUENCE / REP. RATE	PIÈCE / ROOM

NOTES DU PERMIS / PERMIT NOTES

Year-DEPT-MMDD issued

Expiry Date

- Refresher
- Inspections
- Record review

uOttawa

LASER USER REGISTRATION FORM

(Une version française est disponible)

LASER RADIATION

☐ New ☐ Amendment Received: ____

Return to: *Laser Compliance Specialist*
Office of Risk Management
1 Nicholas Street, Suite 840
Ottawa, ON K1N 7B7
Phone: (613) 562-5800 x2000 Fax: (613) 789-5711

Laser User Information:

Surname: ____ First Name: ____ Employee / Student No.: ____

Faculty: ____ Department: ____ Position: ____

Telephone: ____ Lab. tel. #: ____ Fax #: ____

Building: ____ Room # ____ E-Mail: ____

Supervisor (Permit Holder) Information:

Surname: ____ First Name: ____ Phone or Extension: ____

Position: ____ E-Mail: ____

Lab Supervisor: Surname: ____ First Name: ____

SECTION 1: INFORMATION ON LASERS YOU WILL BE USING

When do you expect to start working with lasers? ☐ Already Started ☐ Now ☐ 0-3 Months ☐ 3-6 Months ☐ > 6 Months ☐ Never

Lab Building: ____ Room#: ____ Permit #: ____ Laser ID on Permit: ____

Laser class: ____ Wavelengths: ____ ☐ Open Beam ☐ Embedded Beam

SECTION 2: RISK MITIGATION

Please describe your experimental techniques, strategies and procedures that you will use to mitigate the risk to yourself and others during your use of the laser listed above. Take this opportunity to think and consider all possible hazards (beam and non-beam) introduced by your proposed use of the laser.

Is this a new or existing experimental setup? ○ New ○ Existing

Will other lasers be operating at the same time as your laser? ○ Yes ○ No

Will you be working alone/ with others/supervision? ____

What protective equipment or products will you use? (include any details) ____

What hazards does your experiment introduce? (Consider both beam and non-beam hazards) ____

Briefly describe or provide the Standard Operation Procedures (SOPs) you will require and follow in your use of this laser — Location

OFFICE OF RISK MANAGEMENT
LASER COMPLIANCE SPECIALIST, EXT. 2000

English Version 2.1/20130313/SEK

Your information

Your supervisor (permit holder)

Lab supervisor

Laser Info

Are you thinking ahead? (reactive/proactive)
Do you know what you need to protect yourself and others?
Do you know what will happen?

Office of Risk Management
Laser Compliance Specialist ext.2000

- Interim training
- Previous training
- This training

<u>In-Lab Training</u>

What have you been taught by the lab supervisor?

- Optics handling
- Beam handling
- Hazardous material
- Emergencies
- Laser Maintenance

  -- I want to know who is manipulating/servicing Class 4 lasers

Brief, descriptive
Most important

uOttawa

SECTION 3: TRAINING AND EXPERIENCE

Visit the University of Ottawa Laser Safety Website (http://www.uottawa.ca/services/ehss/laserintro.htm) and follow the link to Interim Training. There you will find additional requirements to follow before attending the next training session.

Have you attend the University of Ottawa Laser Safety Course? ☐ Yes ☐ No

Will you attend the University of Ottawa Laser Safety Course? ☐ Yes ☐ No

Date of Training: ____________

Describe the types of laser systems you have used in the past and the number of years experience with each laser.

Describe the type of training that you have received	Date received	Institution (if uOttawa: state instructor's name and years of experience)

SECTION 4: PRACTICAL TRAINING

Fill in the details of your in-lab training in the following boxes. This table is to be completed by the new user.

Actions *(examples)*	**Describe how these actions are being addressed in your lab** *(if not applicable, type N/A)*
Optics Handling *(cleaning, mounting, blocks)*	
Beam Handling *(safe viewing, blocking with curtains/curbs, appropriate materials)*	
Laser Media/Solvents *(handling gases, liquid dyes, solvents; MSDS)*	
Emergencies: *(what to do for fires, leaks, evacuations)*	
Nonbeam Hazards *(electrical, LGAC, lab maintenance, substrates)*	
Laser Maintenance *(SOP, training by whom, strategies)*	

Trainer Name: ____________ Signature: ____________

SECTION 5: DECLARATION AND SIGNATURE

I hereby declare that I have been informed of the risks associated with the laser/laser system mentioned herein. I agree to abide by all the conditions associated with the permit under which I will be working. I have met all the interim training requirements (if applicable).

Signature: ____________ Date: ____________

Lab Supervisor's Signature: ____________ Laser Compliance Specialist Initials: ☐

OFFICE OF RISK MANAGEMENT
LASER COMPLIANCE SPECIALIST, EXT. 2000

English Version 2.1/20130313/SEK

☐ New
☐ Amendment
☐ Renewal
☐ Transfer

uOttawa

Received:

Permit Application for a Laser Emitting Device

(Une version française est disponible)

Return to: *Laser Compliance Specialist, Office of Risk Management, 1 Nicholas Street, Suite 840, Ottawa, ON K1N 7B7, Phone: (613) 562-5800 x2000, Fax: (613) 789-5711*

OFFICE USE ONLY

Approved/Denied ______ Date ______ Initials ______

Principal Investigator:

Surname: ______ First Name: ______ Position: ______

Faculty: ______ Department: ______ Building: ______ Room # ______

E-Mail: ______ Phone or Ext.: ______ Fax #: ______

SECTION 1: LASER EQUIPMENT

	Manufacturer	Model No.	Serial No.	Building/Room #	Laser Type	Laser Class
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

SECTION 2: LASER OPERATING PARAMETERS

	Mode (CW/Pulsed)	Wavelength (nm)	Avg. Power (W)	Beam Dia. (FWHM mm)	Divergence (mrad)	Pulse Energy* (J)	Pulse Width* (FWHM)	Rep. Rate* (Hz)
1.								
2.								
3.								
4.								

pg. 1

Permit holder

Laser information

- Identify the laser uniquely
- Laser parameters to assess hazard and PPE

SOPs

- Laser Turn On/Off/Emergency Procedure
- Beam handling/Alignment Procedure
  - How do you steer from optic to optic?
  - How do you visualize it (cards/viewers)?
- Training Procedure
  - Routine in-lab training (User Form)
  - Steps to achieve authorization
- Hazardous material
  - MSDS location, handling, disposing, cleaning spills
  - Optical fibres

SOPs Can Include:

Description of laser

- Type and wavelength; intended application & location
- Average power, energy per pulse, pulse duration, rep. rate

Why? In case procedure is specific to laser

Non-Beam Hazards

- Electrical hazards, LGAC, other
- ***Spill control***

Control Measures – List for each hazard:

- Eyewear requirement; wavelength and OD
- Description of controlled area and entry controls
- Reference to equipment manual

Suggested SOP Format

Standard Operating Procedures

Manufacturer	*Maker*	Model	*YLS*	Serial	
Type	*Fibre laser*	Class	*4*	Max Power	*5 W*
Location	*CBY B123*				
Emergency Contact	*Type name and telephone # of Sublicensee for this instrument here*				

Write a statement that operation of this system is restricted to authorized and trained users as indicated on the permit (permit location written here).

Training Protocol

For new users of the system, list the steps an authorized and fully trained individual must communicate and demonstrate to fully inform the new user of all protocols and hazards associated with this system.

1. Verify that the new user has attended the 3 hour Principles of Laser Safety course provided by the Office of Risk Management (ORM) at the University of Ottawa. This requirement can be fulfilled by reviewing the permit for this system, seeing a copy of the certificate provided by ORM upon successful completion of the course, or in writing by the Laser Compliance Specialist that the training was completed.
2. Ensure that a new user registration form has been completed and sent to ORM.
3. Provide these SOPs to the user and indicate all areas where they can be accessed including written and electronic formats.
4. Communicate who is currently authorized to use the system, the lab designate if not the principal investigator on the permit, and who to contact in case of an emergency including where the contact information can be located.

Table summarizing laser details

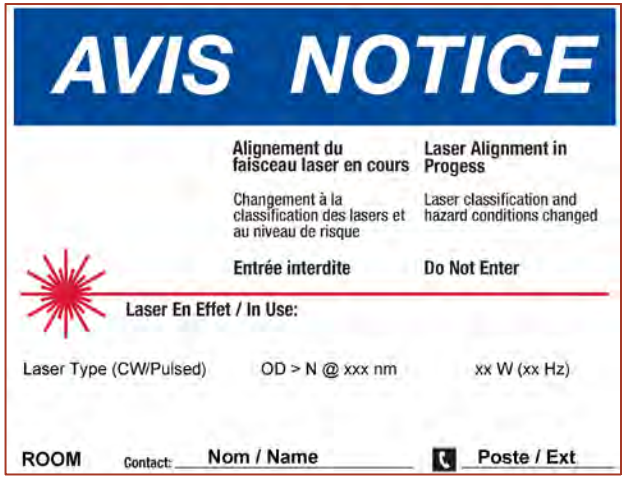
Step by step protocols: (training, on/off procedures, alignment, experimental, emergency)

This example I wrote for a lab in Word (nothing fancy). Send to me for verification and guidance.

Guidelines for Class 3B and 4 Laser Alignment

Getting started

- Post ***Notice*** signs during alignment where lasers are **normally Class 1 or enclosed**
- Alignments done by those who have received laser safety training
- Exclude unnecessary personnel during alignment
- Wear protective eyewear for existing wavelengths



Guidelines for Class 3B and 4 Laser Alignment

During alignment

- Use **<u>physical beam block</u>** to block high-power beam at their source if not needed
  - *electronic shutters are dangerous*
- Use *low-power visible lasers* to simulate high-power laser path or use lowest possible power setting
- Place beam blocks behind optics to terminate beams
  - might miss mirrors during alignment
- Locate and block stray reflections properly before proceeding to next optical component (beam blocks)
  - ex: blocks versus beam dumps for high-power beams

Class 3B / 4 Warning Devices *(Illuminated)*

2 Way

3 Way

ATTENTION
CAUTION

Classe **2M**	Class **2M**
Laser activé	**Laser In Use**
Ne pas fixer le faisceau avec les yeux ni l'observer directement avec des instruments optiques	Do not stare into beam or view directly with optical instruments

Laser Type (Wavelength) xx mW maximum

ROOM Contact: Nom / Name ______ Poste / Ext ______

AVERTISSEMENT
WARNING

Classe 4

Région contrôlée laser

Rayonnement laser visible et invisible

Éviter toute exposition des yeux ou de la peau à un rayonnement direct ou diffusé

Lunettes de protection laser obligatoires

Accès autorisé seulement
Frapper avant d'entrer

Class 4

Laser Controlled Area

Visible and invisible laser radiation

Avoid eye and skin exposure to direct or scattered radiation

Laser protective eyewear mandatory

Authorized Access Only
Knock before entering

Laser Type (CW/Pulsed) OD > Integer @ XXX nm xx mW

2014 Bilingual Version

Most Class 3B and 4 Lasers

ROOM **Contact:** Nom / Name ______ Poste / Ext ______

DANGER

Classe 4	Class 4
Région contrôlée laser	**Laser Controlled Area**
Rayonnement laser visible et invisible	Visible and invisible laser radiation
Éviter toute exposition des yeux ou de la peau à un rayonnement direct ou diffusé	Avoid eye and skin exposure to direct or scattered radiation
Lunettes de protection laser obligatoires	Laser protective eyewear mandatory
Accès autorisé seulement **Frapper avant d'entrer**	**Authorized Access Only** **Knock before entering**

Laser (CW/Pulsed): OD > Integer @ XXX nm X J or W (Rep Rate)

2014 Bilingual Version

Highest hazard lasers (kW or non-traditional alignments)

ROOM **Contact:** ______________ ☎ ______________

AVIS NOTICE

Usually laser alignments

(changed conditions behind door)

Alignement du faisceau laser en cours

Laser Alignment in Progess

Changement à la classification des lasers et au niveau de risque

Laser classification and hazard conditions changed

Entrée interdite

Do Not Enter

Laser En Effet / In Use:

Laser Type (CW/Pulsed) OD > N @ xxx nm xx W (xx Hz)

ROOM **Contact:** **Nom / Name** **Poste / Ext**

International Laser Warning Labels on Devices

Symbol and Border: Black
Background: Yellow

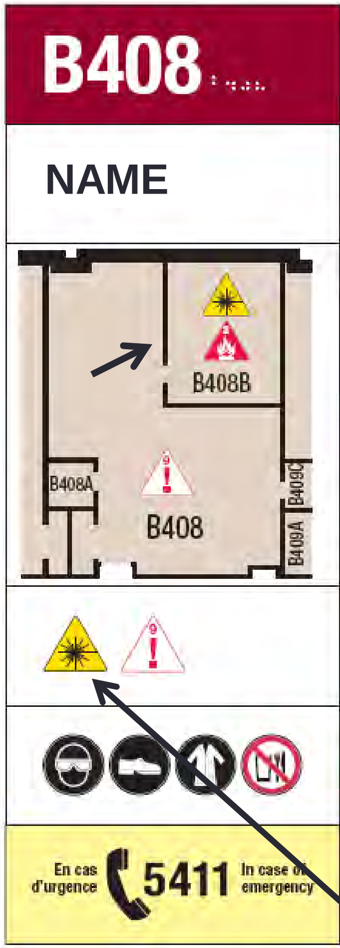
Placement: Output aperture

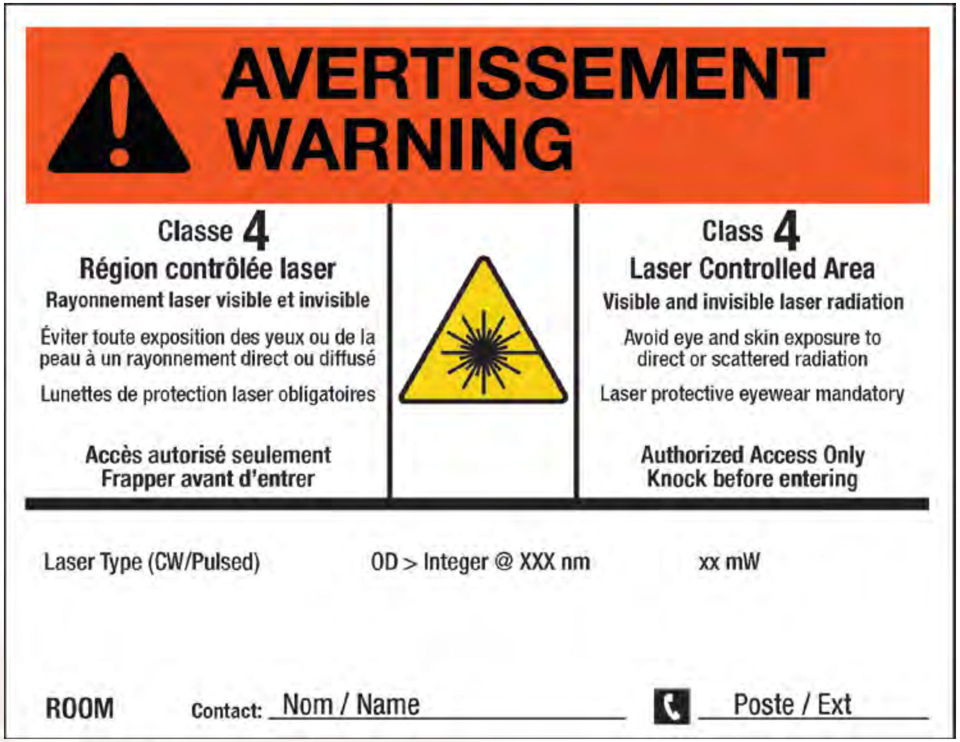
Legend and Border: Black
Background: Yellow

CAUTION : Class II, some IIIa
DANGER : Class IIIb and IV

uOttawa Class 3B / 4 Entryway

Highest Hazard





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PRIORITY #3

Personal Protective Equipment

CONTROL OF LASER HAZARDS

Laser Safety Eyewear

H. Eye and Face Protection

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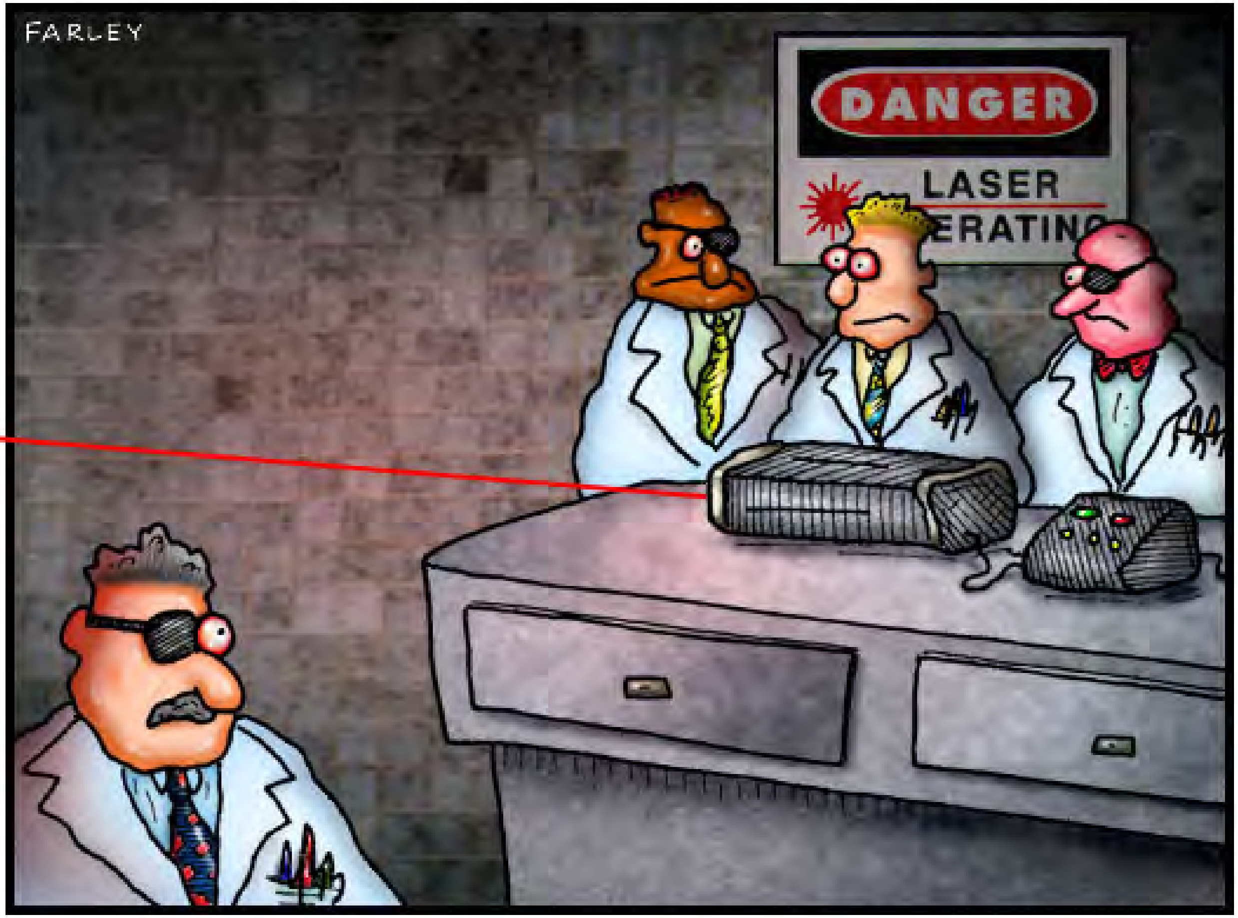
DOCTOR FUN

26 June 97



Peer pressure in the laser lab

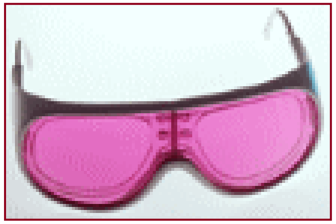
Example: Laser Safety Eyewear Failure

An inexperienced graduate student lost 50% of his vision after sighting the reflecting beam of a Nd:YAG laser while wearing ordinary safety goggles as eye protection.

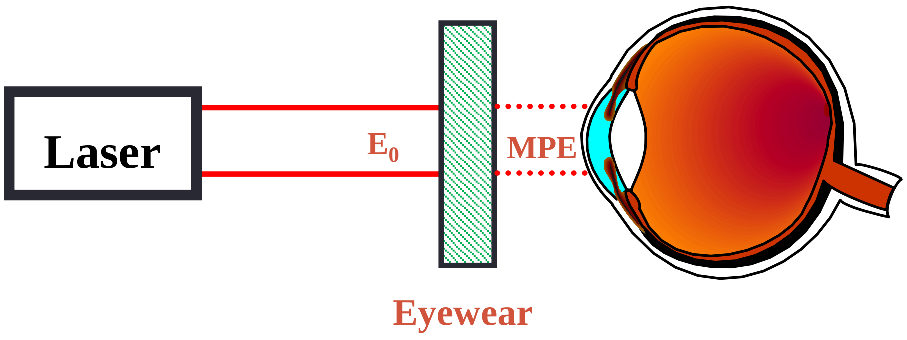
A more experienced student gave him the goggles

Laser Safety Eyewear: Which One?

- Determine laser wavelengths in use
- Choose OD to remain below exposure limit at each λ
- Avoid unnecessarily large ODs
  - ***Look at VLT (visible light tx)***
- Comfort
- Prescription eyewear



Optical Density of Laser Safety Eyewear



Area used in calculation: area of limiting aperture, provides a worst case OD based on the assumption that the entire beam enters the eye.

Worst situation ?

When the largest beam enters the eye, because it produces the smallest spot on the retina

(Eq.4)

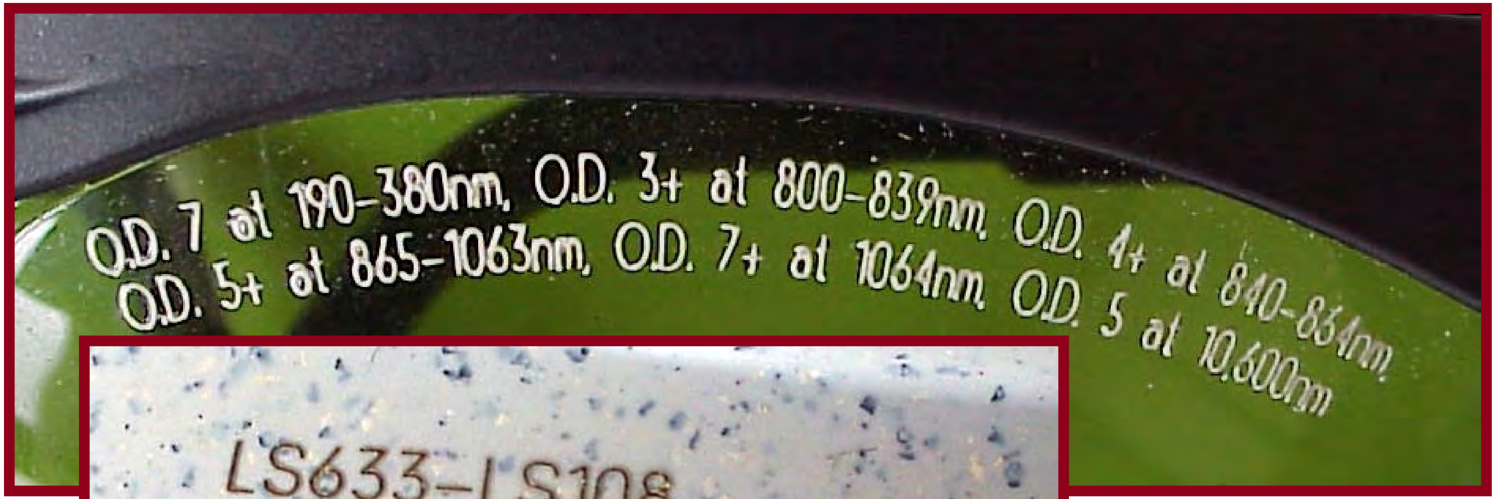
$$OD = \log_{10} \frac{E}{MPE{:}E}$$

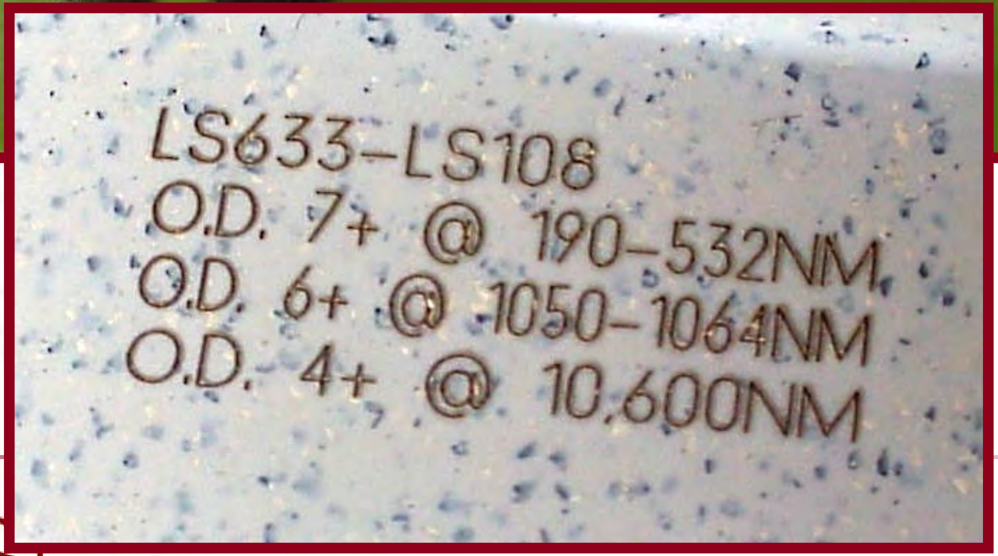
$$OD = \log_{10} \frac{H}{MPE{:}H}$$

OD	% Transmission
0	100%
1	10%
2	1%
3	0.1%
4	0.01%
5	0.001%
6	0.0001%

Laser Safety Eyewear: Labels

- All eyewear must be labeled with wavelength and optical density





Without visible OD information, the goggles should *NOT* be used

Evaluation of Laser Eyewear and NHZ

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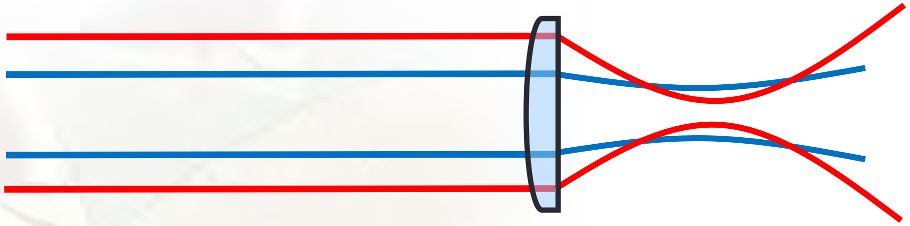
Laser Eyewear Analysis

- Basics : Assume MPE given (W/cm^2 or J/cm^2)
- Given : Laser power (Φ) in Watts (W)
  - or laser pulse energy (Q) in Joules (J)
- Beams are usually smaller than dark-adapted eye
  - dark-adapted eye diameter is worst-case (tighter focus)
  - MPE referenced to lens-input



Laser Eyewear Analysis

$E = \frac{\Phi}{\pi w^2}$ **W/cm²** or $H = \frac{Q}{\pi w^2}$ **J/cm²** *Eq. 2, slide 15*

- w is usually dark-adapted pupil radius (0.35 cm)
  - when beam smaller than pupil
  - Area (πw^2) is 0.385 cm^2

$\text{OD} = \log_{10} \frac{E}{\text{MPE:}E}$ or $\text{OD} = \log_{10} \frac{H}{\text{MPE:}H}$ *Eq. 4, slide 100*

- CW exposure time is usually blink rate
  - ¼ s visible, 10 s infrared, 100 s UV
- Pulsed laser is usually pulse width

Laser Eyewear Analysis

Continuous-Wave (CW)

use Watt

405 nm ← visible; ¼ second

80 mW

1 mm ← less than 7 mm

$$OD = \log_{10} \frac{208\ \mathrm{mW/cm^2}}{2.54\ \mathrm{mW/cm^2}}$$

1.91 (2+)

Pulsed

use Joule

800 nm ← invisible & IR; 10 seconds

400 mW

1 kHz

100 fs

1 mm ← less than 7 mm

$$OD = \log_{10} \frac{1.04\ \mathrm{mJ/cm^2}}{100\ \mathrm{nJ/cm^2}}$$

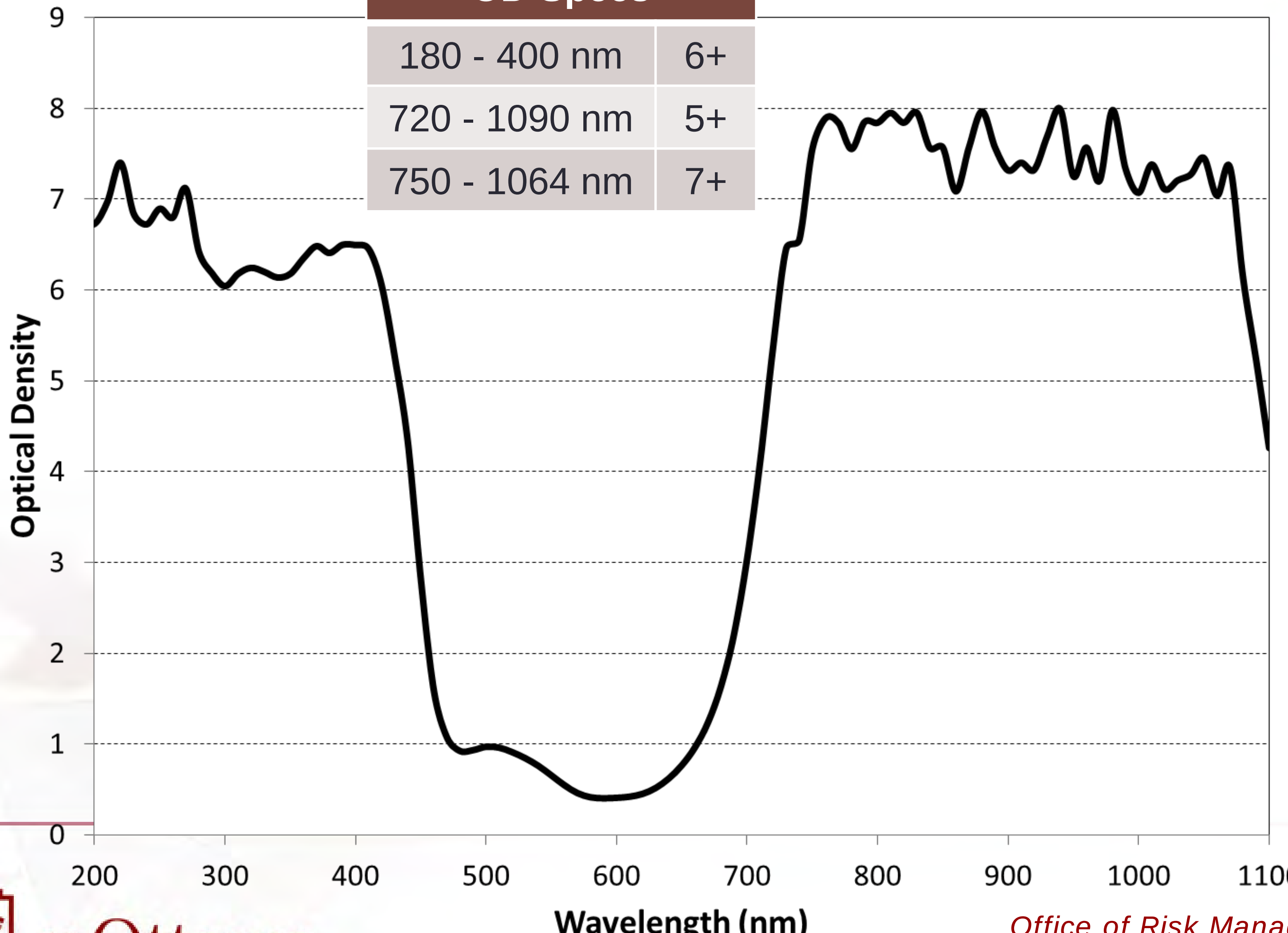
4.02 (5+)

Laser Safety Eyewear Quick Reference (400 – 1400 nm)

Q-switched (1 ns – 10 ms)	Non Q-switched (0.4 ms – 10 ms)	CW (1/4 – 10 s)	OD
Max Output Energy (mJ)	Max Output Energy (mJ)	Max Output Power (W)	
100	1000	1000	6
10	100	100	5
1	10	10	4
0.1	1	1	3
0.01	0.1	0.1	2
0.001	0.01	0.01	1

Laser Eyewear Analysis

OD Specs	
180 - 400 nm	6+
720 - 1090 nm	5+
750 - 1064 nm	7+



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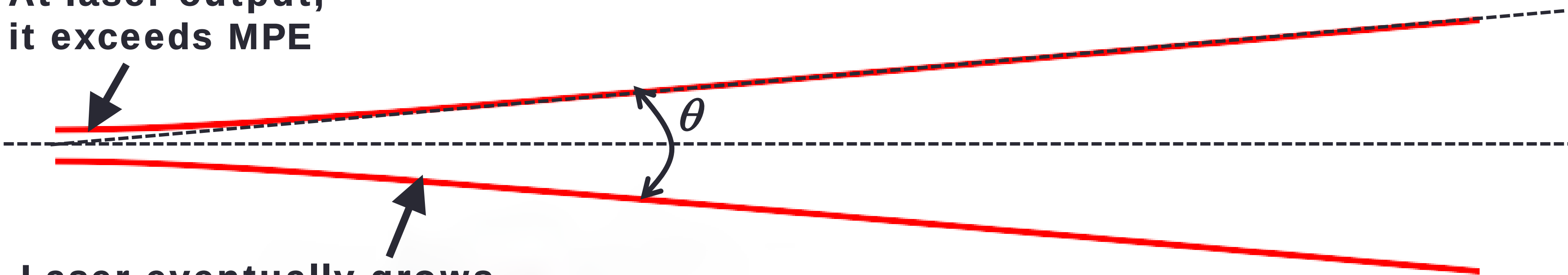
Nominal Hazard Zone

- The distance the laser must travel until its radiant exposure or irradiance drops below MPE

At laser output, it exceeds MPE



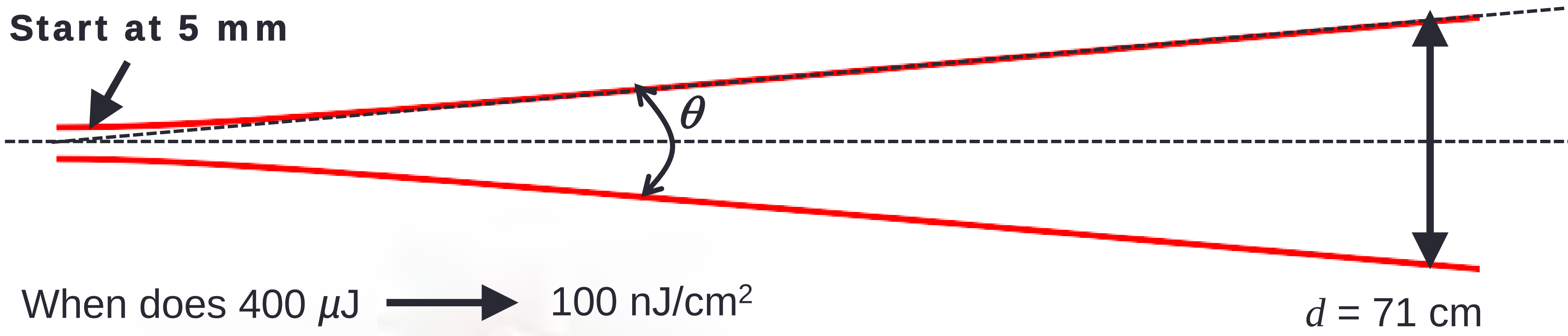
Laser eventually grows by its divergence angle
(make sure you use full angle)

ex: θ **= 0.1 mrad** **grows linearly 0.1 mm in diameter for every 1 m of travel**

(good estimate for the far-field)

Nominal Hazard Zone

- The distance the laser must travel until its radiant exposure or irradiance drops below MPE



When does 400 μJ → 100 nJ/cm^2

d = 71 cm

θ = 0.21 mrad → D = 4.8 km → **Not contained in a room**
Reason for curtains & barriers

NON-BEAM HAZARDS

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Non-beam Hazards (NBH)

- Electrical
- Fire
- Chemical
- Laser-generated air contaminants (LGACs)
- Collateral and plasma radiation
- Explosion
- Noise
- Human Factors
- Fibre splicing

NBH: Electrical Hazards

- High voltage & current supplies
  - Experiments may use these sources too
  - Current limiting essential
- RF power supplies in some gas lasers
- Watch for improper grounding or shielding
- Failure to follow standard electrical safety procedures during maintenance and service:
  - Electrical shock
  - Burns
  - Blistering
  - Electrocution

NBH: Electrical Hazards

- Electrical equipment covered by Ontario Regulation 438/07

- Must have Certification or Field Evaluation marks

Certification Body	Marking		
Canadian Standards Association (CSA)	SP		C SP US
Curtis Strauss			
FM Approvals	FM APPROVED		
IAPMO	IAPMO	UPC	UEPC
Intertek Testing Services	ETL / entela	c ETL us	
Labtest Certification (LC)	c LC	c LC us	
Met Laboratories (MET)	c MET		
Nemko	Nemko		
NSF International	NSF		
OMNI Environmental Services Inc	O-T-L		
Quality Auditing Institute	QAI		
QPS	c PS		
TUV America	TÜV		
TUV Rheinland			
Underwriters' Laboratories of Canada (ULC	ULC		
Underwriters Laboratories Inc.	c UL		c UL us

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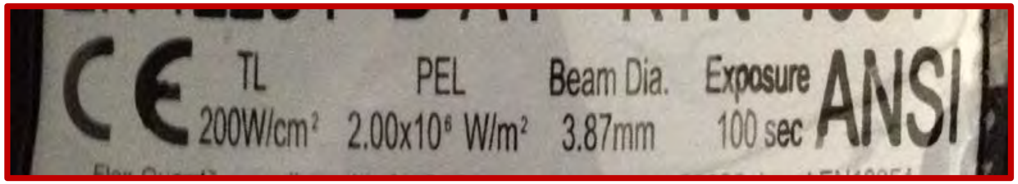
Example: Electrical Hazards

- Graduate student wiped condensate from CO_2 laser tube and received a 17 kV shock, suffered cardiac arrest and 2^{nd} degree burns
- Repair technician fatally electrocuted working alone on CO_2 laser with interlocks defeated
- Serviceman electrocuted adjusting the power supply of copper vapour laser
- Senior scientist working alone electrocuted replacing high-voltage regulator in a laser power supply

Fire Hazards

- Class 4 Lasers:
  - Material beam enclosures
  - Barriers and stops
  - Wiring
  - potentially flammable if exposed to high beam irradiance for more than a few seconds



- Flammable solvents:
  - In enclosed area without adequate dilution or exhaust ventilation
  - pose fire or explosion hazard in presence of ignition source

Example: Fire Hazards

- Student used plain paper to check excimer beam accidentally place it in focal spot
  - Paper ignited
  - Triggered laboratory smoke alarm
  - No injury or fire occurred, but building was evacuated and fire crews arrived

Chemical Hazards

- Laser Dyes (and solvents):
  - toxic, carcinogenic, mutagenic, corrosive or flammable
  - Minimize exposure during solution preparation (see MSDS)
- Far-IR optical materials (windows and lenses) source of potentially hazardous levels of airborne contaminants:
  - CaTe, ZnTe burn in oxygen when beam irradiance exceeded
- Cryogenic fluids (liquid nitrogen, helium and hydrogen)
  - Skin and eye contact causes frostbite
- Compressed gases
  - Chlorine gas corrosive; He, Ar, N_2 asphyxiates; H is flammable
  - Unsecured cylinders

LGAC and Collateral Radiation

- Laser Ablation:
  - Materials may be carcinogenic or be harmful (tissue, ionic compounds like arsenic)
  - Sparks create plasma and X-rays
  - Plasma radiation emits UV

- High-intensity lasers can generate ozone when tightly focused
  - An irritant that can lead to chronic lung problems

LGAC and Collateral Radiation

- X-rays can be generated from high voltage (over 15 kV) power supply tubes
  - May cause tissue damage, leukemia or other cancers; permanent genetic effects

www.uottawa.ca/services/ehss/x-ray-safety-prgm.html

- UV and visible radiation from laser discharge tubes and pumping lamps
  - The levels produced may exceed the MPE and cause skin and eye damage

www.uottawa.ca/services/ehss/EMR.html

NBH: Explosion Hazards

- High pressure arc lamps or filament lamps can fail during operation
  - should be enclosed in a housing that withstands the maximum explosive force
- Targets and optics may shatter if heat cannot be dissipated quickly
  - Provide adequate mechanical shielding when exposing brittle materials to high intensity lasers
  - Vacuum windows can shatter

NBH: Noise

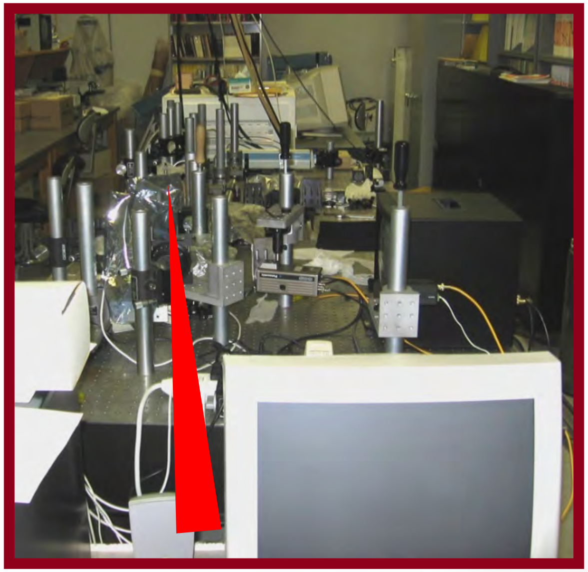
- Pumps for vacuum chambers can emit high frequency noises
  - Turbomolecular pumps can be very noising approaching end-of-life
  - Scroll pumps often best used in a separate room

- Excimer lasers emit a clacking sound with each pulse

NBH: Human Factors

- Lack of knowledge or understanding of equipment
- Lack of awareness of potentially hazardous conditions
- Underestimation of the risk
- Inappropriate attitude to safety – risk taking
- Conflict between safety and performance criteria
  - Poor safety leadership on the part of management
  - Poor communication on safety issues
- Lapses of attention and mistaken actions

NBH: Computers in Labs



Direct view of a laser experimental setup from computer area increases risk of eye exposure to direct or reflected beams.

NBH: Fibre Splicing

http://www.thefoa.org/tech/ref/safety/safe.html

- Shards invisible when next to water
- Shards can travel in bloodstream to heart
  - Cause secondary infections

- Goggles must be worn
- Waste must go in puncture-proof container
  - Tape the lid closed
- Use a black surface

10 Golden Rules of Laser Safety

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Golden Rule #1

Wear laser safety eyewear

Ensure that you are using the appropriate one.

Remember laser radiation can be invisible, so just because you don't see anything does not mean that there is nothing !

Golden Rule #2

Do not look into the laser beam

Don't look down specular reflections.

Don't stare at diffuse reflections.

Golden Rule #3

Keep room lights on brightly, if possible

The brighter the ambient lighting, the smaller the eye's pupil will become and the chance of a laser beam entering the eye will be lessen

Golden Rule #4

Remove personal jewellery

When entering a laser lab, remove anything which may pose a reflection hazard.

This is to protect you and your co-workers

Golden Rule #5

Locate and terminate all stray laser beams

Make sure that all stray beams are terminated with a matt, diffusing beam dump which is capable of handling the power of the laser beam

Golden Rule #6

Clamp all optical components securely

This helps your experiment from becoming misaligned and reduces the chances of a component moving and sweeping a laser beam over you.

Golden Rule #7

Keep beams horizontal

Horizontal beams are easier to work with and are predictable. Avoid vertical and skew beams if possible. Change beam height if necessary and be careful when aligning it

Golden Rule #8

Don't bend down below beam height

If you drop something, block the laser before picking up the object up.

If you can't stop the beam, kick the object out of the way so you don't trip over.

Golden Rule #9

Remember, optical components reflect, transmit and absorb light

Often a transmitting component will also reflect light. This can lead to stray beams. Beware that optical components may change their characteristics when used with high power lasers.

Golden Rule #10

Don't forget non-optical hazards

Don't trip over, electrocute yourself, spill solvents, burn yourself on liquid nitrogen, ...

Laser Safety Program at uOttawa

- Contact me when new lasers are purchased
  - Preferably at grant writing stage
  - Discuss safety protocols
  - Help with hazard analysis
- Contact me when new users arrive
  - In-lab training documented
  - ***Interim training performed***
  - ***This course mandatory***
- Contact me with any questions about lasers
  - 14 years research experience in high-energy laser physics
  - Built and maintained many types of laser systems

Reporting Accidents

- Known or suspected eye injury should obtain IMMEDIATE medical attention. Time of treatment can often change the outcome and reduce long terms effects

- Call the emergency line 5411

- Call our office 5892 or the LSO at 2000

- Remember our websites

  web30.uottawa.ca/v3/riskmgmtfrm/aioreport.aspx?lang=en

  www.uottawa.ca/services/ehss/index.htm

Before using Class 3B or 4 Lasers at uOttawa

- Make sure you know:
  - What are lasers hazards
  - How to identify lasers hazards in your work area
  - How to work safely with lasers
  - How to work safely around others

- **Be Proactive not Reactive to laser hazards**


Big Scary Laser
Do not look into beam
with remaining eye


OMG LASERS!
PEW! PEW!

Before you leave…
Please remember

References

[1] R. Henderson, K. Schulmeister, "Laser Safety," IoP Publishing, 2004. TA 1677.H46

[2] http://www.microscopyu.com/articles/fluorescence/lasersafety.html

Recently Reported Laser News

Date	Category	Link
July 16, 2015	Airplane events - pilots with blurred vision	Good Morning America (Video)
Aug. 27, 2015	Non-Lethal Ocular Disruptor for crowd control	Yahoo News
Aug. 27, 2015	Compact Laser Weapons System (2 kW)	Boeing (Video)
Nov. 13, 2013	Spanish woman loses 60% vision from toy laser bought in China (0.5 to 6 W)	La Vanguardia (Original) La VanGuardia (Translated)
Mar. 28, 2014	FBI looking for suspects in laser incident with Delta	CBS