LASER SAFETY TRAINING

UNIVERSITY OF ARKANSAS
Office of Environmental Health and Safety
LASER SAFETY PROGRAM

COORDINATED THROUGH THE

OFFICE OF ENVIRONMENTAL HEALTH AND SAFETY (EH&S)

PROGRAM ELEMENTS ENFORCEABLE THROUGH

OSHA GENERAL DUTY CLAUSE
OSHA LAB STANDARD
OSHA SUBSTANCE SPECIFIC STANDARDS
Introduction

Lasers are present in many different areas and used in many different applications.

Following the procedures presented in this training module will help prevent harm to you and your co-workers.
TRAINING OVERVIEW

PART 1
GENERAL LASER SAFETY

PART 2
CLASS 3B AND CLASS 4 LASER SYSTEMS
POTENTIAL FOR MORE SERIOUS HAZARDS
PART ONE
LASER TRAINING FOR ALL LASERS
LASER IDENTIFICATION
AND CLASSIFICATION
WHAT IS A LASER?

Laser - light amplification by stimulated emission of radiation.

Laser light is a non-ionizing form of radiation.

May be:

- UV (100-400NM)
- Visible (400-700NM)
- Infrared (700NM to 1MM)
Laser Basics

MONOCHROMATIC – SINGLE WAVELENGTH

COHERENT – WAVES ALL IN SAME PHASE

DIRECTIONAL – VERY LOW DIVERGENCE

OPTICALLY INTENSE –
EVEN WHEN PROPAGATED OVER LONG DISTANCES
COMPONENTS OF A LASER

- LASING MEDIA (GAS, SOLID, LIQUID, SEMICONDUCTOR)
- EXCITATION MECHANISM (POWER SUPPLY, FLASHLAMP, LASER)
- TOTAL REFLECTOR OR FEEDBACK MECHANISM (MIRROR OR GRATING)
- LASER OUTPUT (PARTIALLY REFLECTING MIRROR)
DO YOU KNOW WHAT CLASS LASER YOU HAVE?
LASER CLASSES

ALL MANUFACTURERS REQUIRED TO IDENTIFY LASER CLASS OF ALL SYSTEMS

LASERS STATING “CAUTION” ARE LOWER CLASS

“DANGER” INDICATES A HIGHER CLASS (IIIB OR IV)

OLDER LASERS OR SYSTEMS THAT HAVE BEEN MODIFIED MUST BE CLASSIFIED BY EH&S
ELEMENTS USED IN CLASSIFICATION

LASING MEDIA
- GAS (CO\textsubscript{2}, ARGON ION, EXCIMER)
- SOLID (NEODYMIUM YAG, TITANIUM SAPPHIRE)
- SEMICONDUCTOR (GALLIUM-ARSENIDE)
- DYE

MODE OF OPERATION
- CONTINUOUS WAVE (CW)
- PULSED (<0.25 SEC.)
- Q-SWITCHED

WAVELENGTH - DEPENDENT UPON LASING MEDIA USED
- ULTRAVIOLET (180-400 NM)
- VISIBLE (400-700 NM)
- IR REGION (700 NM-1MM)
THE FOLLOWING CHART ILLUSTRATES THE WAVELENGTHS ASSOCIATED WITH VARIOUS TYPES OF LASER SYSTEMS.
<table>
<thead>
<tr>
<th>LASER TYPE</th>
<th>WAVELENGTH (Nanometers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon Fluoride</td>
<td>193</td>
</tr>
<tr>
<td>Xenon Chloride</td>
<td>308 and 459</td>
</tr>
<tr>
<td>Xenon Fluoride</td>
<td>353 and 459</td>
</tr>
<tr>
<td>Helium Cadmium</td>
<td>325 - 442</td>
</tr>
<tr>
<td>Rhodamine 6G</td>
<td>450 - 650</td>
</tr>
<tr>
<td>Copper Vapor</td>
<td>511 and 578</td>
</tr>
<tr>
<td>Argon</td>
<td>457 - 528 (514.5 and 488 most used)</td>
</tr>
<tr>
<td>Frequency doubled Nd:YAG</td>
<td>532</td>
</tr>
<tr>
<td>Helium Neon</td>
<td>543, 594, 612, and 632.8</td>
</tr>
<tr>
<td>Krypton</td>
<td>337.5 - 799.3 (647.1 - 676.4 most used)</td>
</tr>
<tr>
<td>Ruby</td>
<td>694.3</td>
</tr>
<tr>
<td>Laser Diodes</td>
<td>630 - 950</td>
</tr>
<tr>
<td>Ti:Sapphire</td>
<td>690 - 960</td>
</tr>
<tr>
<td>Alexandrite</td>
<td>720 - 780</td>
</tr>
<tr>
<td>Nd:YAG</td>
<td>1064</td>
</tr>
<tr>
<td>Hydrogen Fluoride</td>
<td>2600 - 3000</td>
</tr>
<tr>
<td>Erbium:Glass</td>
<td>1540</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>5000 - 6000</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>10600</td>
</tr>
</tbody>
</table>
LASER CLASSIFICATIONS

CLASS 1

INCAPABLE OF PRODUCING DAMAGING RADIATION LEVELS DURING OPERATION

EXEMPT FROM CONTROL MEASURES

LOW POWER LASERS OR HIGH POWER EMBEDDED LASERS (E.G. LASER PRINTERS, CD PLAYERS)
LASER CLASSIFICATIONS

CLASS 1M (M = MAGNIFICATION)

INCAPABLE OF PRODUCING DAMAGING RADIATION LEVELS DURING OPERATION UNLESS THE BEAM IS VIEWED WITH AN OPTICAL INSTRUMENT; e.g., EYE LOUPE OR TELESCOPE

EXEMPT FROM CONTROL MEASURES OTHER THAN TO PREVENT POTENTIALLY HAZARDOUS OPTICAL INSTRUMENT VIEWING
Lasers in the visible range (400-700 nm) are classified as Class 2 lasers. Protection is the eye aversion response. Power levels up to 1 MW are common, for example, in barcode scanners.
LASER CLASSIFICATIONS

CLASS 2M - POWER LEVELS UP TO 1MW

LASERS IN THE VISIBLE RANGE (400-700NM)

PROTECTION IS THE EYE AVERSION RESPONSE

0.25 SECONDS REQUIRED TO BLINK OR AVERT EYES

HAZARDOUS WHEN VIEWED WITH OPTICAL AID
LASER CLASSIFICATIONS

CLASS 3R (FORMERLY 3A) (R=REDUCED REQUIREMENTS)

POTENTIALLY HAZARDOUS UNDER SOME DIRECT AND SPECULAR REFLECTIONS

EYE MUST BE FOCUSED AND STABLE

LOW POSSIBILITY OF INJURY

DOES NOT POSE DIFFUSE-REFLECTION HAZARD

POWER LEVELS 1MW-5MW

LASER POINTERS
LASER CLASSIFICATIONS

CLASS 3B

OPERATE BETWEEN 5 MW AND 500 MW

NORMALLY NOT A FIRE OR DIFFUSE VIEWING HAZARD

HAZARDOUS UNDER DIRECT AND SPECULAR REFLECTION VIEWING

THERAPEUTIC MEDICINE, RESEARCH
LASER CLASSIFICATIONS

CLASS 4

POWER LEVELS > 500 MW

HAZARDOUS TO EYE AND SKIN FROM DIRECT VIEWING, SPECULAR AND DIFFUSE REFLECTIONS

FIRE HAZARD

MAY PRODUCE LASER GENERATED AIR CONTAMINANTS (LGAC)

MAY PRODUCE HAZARDOUS PLASMA RADIATION

SURGICAL LASERS, CUTTING AND WELDING LASERS
LASER INVENTORY

IDENTIFY ALL LASERS AND LASER USERS ON CAMPUS

COLLECT AND MAINTAIN INFORMATION (TYPE, NUMBER, CLASS, POWER, ETC.)

ENSURE PROPER APPLICATION OF SAFETY PROTOCOL APPROPRIATE TO EACH CLASSIFICATION

THE INVENTORY FORM IS LOCATED UNDER THE RADIATION SAFETY SECTION OF THE EH&S WEBPAGE

DO WE HAVE YOUR LASER INFORMATION?
LASER INSPECTIONS

INSPECTED BY EH&S AND THE PRINCIPAL INVESTIGATOR

EVERY TWO YEARS FOR CLASS 1, 1M, 2, 2M AND 3R LASERS

ANNUAL INSPECTIONS FOR CLASS 3B AND 4 LASER SYSTEMS
LASER HAZARDS
THERE ARE SPECIFICATIONS DEFINING A “SAFE” EXPOSURE.

MINIMIZE EXPOSURES AS MUCH AS POSSIBLE, EVEN IN THE “SAFE RANGE”.

SAFETY

LASER
MAXIMUM PERMISSIBLE EXPOSURE (MPE)

THE “SAFE” EXPOSURE IS DEFINED TO BE BELOW THE MPE LEVEL

MPE DEPENDS ON POWER, WAVELENGTH, EXPOSURE PERIOD, AND OTHER LASER-SPECIFIC FACTORS

EH&S DETERMINES MPE LEVELS
LASER HAZARDS

HAZARDS ASSOCIATED WITH LASER SYSTEMS

COMPRESSED GASSES

PHYSICAL

ELECTRICAL

RADIATION

CHEMICALS
LASER RADIATION HAZARDS

MORE HAZARDOUS TO EYES AND SKIN THAN REGULAR LIGHT
SINGLE WAVELENGTH
DIRECTIONAL AND COHERENT ENERGY.

CRITICAL FACTORS
WAVELENGTH (NEAR IR MORE HAZARDOUS THAN VISIBLE-LIGHT)
FOCUS ON RETINA
LACK OF EYE AVERSION RESPONSE
ENERGY OF THE BEAM
DURATION OF EXPOSURE
PULSATION LASER VS CONTINUOUS WAVE

(PULSATION LASER HAS HIGHER PEAK POWER THAN AVERAGE OUTPUT POWER OF CONTINUOUS WAVE (CW) LASER)
EFFECT OF WAVELENGTH ON LOCATION OF DAMAGE

Microwaves and Gamma Rays
Near Ultraviolet

Far Ultraviolet and Far Infrared
Visible and Near Infrared
# SUMMARY OF LASER BIOLOGICAL EFFECTS ON EYES

<table>
<thead>
<tr>
<th>Photobiological Spectral Domain</th>
<th>Eye</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet C (200 nm - 280 nm)</td>
<td>Photokeratitis</td>
</tr>
<tr>
<td>Ultraviolet B (280 nm - 315 nm)</td>
<td>Photokeratitis</td>
</tr>
<tr>
<td>Ultraviolet A (315 nm - 400 nm)</td>
<td>Photochemical cataract</td>
</tr>
<tr>
<td>Visible (400 nm - 780 nm)</td>
<td>Photochemical and thermal retinal injury</td>
</tr>
<tr>
<td>Infrared A (780 nm - 1400 nm)</td>
<td>Cataract and retinal burn</td>
</tr>
<tr>
<td>Infrared B (1.4mm - 3.0 mm)</td>
<td>Corneal burn, aqueous flare, cataract</td>
</tr>
<tr>
<td>Infrared C (3.0 mm - 1000 mm)</td>
<td>Corneal burn only</td>
</tr>
</tbody>
</table>
## SUMMARY OF LASER BIOLOGICAL EFFECTS ON SKIN

<table>
<thead>
<tr>
<th>Photobiological Spectral Domain</th>
<th>Skin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet C (200 nm - 280 nm)</td>
<td>Erythema (sunburn), skin cancer, accelerating skin aging</td>
</tr>
<tr>
<td>Ultraviolet B (280 nm - 315 nm)</td>
<td>Increased pigmentation</td>
</tr>
<tr>
<td>Ultraviolet A (315 nm - 400 nm)</td>
<td>Pigment darkening, Skin burn</td>
</tr>
<tr>
<td>Visible (400 nm - 780 nm)</td>
<td>Pigment darkening, Photosensitive reactions, Skin burn</td>
</tr>
<tr>
<td>Infrared A (780 nm - 1400 nm)</td>
<td>Skin burn</td>
</tr>
<tr>
<td>Infrared B (1.4mm - 3.0 mm)</td>
<td>Skin burn</td>
</tr>
<tr>
<td>Infrared C (3.0 mm - 1000 mm)</td>
<td>Skin burn</td>
</tr>
</tbody>
</table>
CHEMICAL HAZARDS

POSSIBLE SPILLS AND LEAKS

LASER DYES

FLAMMABLE SOLVENTS

NON-POLAR SOLVENTS
TYPES OF LASER DYE HAZARDS

SOLVENTS USED FOR DYE LASERS MAY POSE BOTH CHEMICAL AND PHYSICAL HEALTH HAZARDS.

TYPES OF LASER DYE HAZARDS

CONCENTRATED POWDER

TYPE OF SOLVENT USED (EX: DMSO)

MANY ARE KNOWN OR SUSPECTED CARCINOGENS, TOXINS, AND MUTAGENS
HAZARDS ASSOCIATED WITH COMPRESSED GASES

- **HIGH PRESSURE**
- **UNSECURED CYLINDERS**
- **VENTILATION**
- **INCOMPATIBILITIES**
- **CHEMICAL PROPERTIES (TOXIC, CORROSIVE, FLAMMABLE, ETC.)**
HAZARDOUS GASES ARE OFTEN EXHAUSTED FROM GAS LASERS (I.E. EXCIMER LASERS), REQUIRING PROPER VENTILATION.

LASER ABLATION TARGETS CAN PRODUCE HAZARDOUS FUMES OR VAPORS AND REQUIRE PROPER VENTILATION.
NON-BEAM RADIATION IS INCOHERENT RADIATION THAT IS NOT THE SAME WAVELENGTH AS THE LASER

GENERATED BY THE OPERATION OF THE LASER OR LASER SYSTEM COMPONENTS

LASERS WITH VOLTAGES >15 KV, CAN GENERATE X-RAYS

OPTICAL RADIATION IS PRODUCED FROM PUMP SOURCES SUCH AS FLASH LAMPS, ELECTRICAL DISCHARGES, ETC.

SOME LASER SYSTEMS CAN ALSO PRODUCE RF RADIATION.
ELECTRICAL HAZARDS

- HIGH VOLTAGE AND CURRENT
- CAPACITORS
LASER HAZARD CONTROL
HAZARD ANALYSIS

EH&S AND THE PI WILL EVALUATE HAZARDS:

- EYE AND SKIN EXPOSURE
- ELECTRIC SHOCK POTENTIAL
- CHEMICAL EXPOSURE
- FIRE HAZARD
HAZARD CONTROL

ADMINISTRATIVE CONTROLS

ENGINEERING CONTROLS

PROTECTIVE EQUIPMENT
ADMINISTRATIVE CONTROLS

REQUIRED WARNING SIGNS AND LABELS

USE MINIMUM POWER ENERGY REQUIRED FOR PROJECT

REQUIRE WRITTEN STANDARD OPERATING PROCEDURES\(^1\)

EDUCATION AND TRAINING

SERVICE ONLY BY AUTHORIZED PERSONNEL

DESIGNATION OF NOMINAL HAZARD ZONES\(^2\)

\(^1\) Mandatory for Class 3B & 4; encouraged for all

\(^2\) For Class 3B & 4 only
FOR CLASS 1 LASERS:

NO WARNING SIGN IS NEEDED.

FOR CLASS 2 LASERS:

POST WARNING AT ENTRANCE TO OPERATING AREA.

“CAUTION - LASER RADIATION - DO NOT STARE INTO BEAM”.

WARNING SIGNS

CAUTION

LASER RADIATION
DO NOT STARE INTO BEAM

DIODE LASER
1 mW MAX OUTPUT at 635-670 nm
CLASS II LASER PRODUCT
FOR CLASS 3R LASERS:

POST WARNING AT ENTRANCE TO OPERATING AREA

“CAUTION! LASER RADIATION - DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS”
FOR CLASS 3B LASERS:
POST WARNING AT ENTRANCE TO OPERATING AREA.

“DANGER - LASER RADIATION AVOID DIRECT EXPOSURE TO BEAM”.
FOR CLASS 4 LASERS:
POST WARNING AT ENTRANCE TO OPERATING AREA.

“DANGER - LASER RADIATION - AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION”
LASERS THAT HAVE BEEN MODIFIED MUST BE LABELED ACCORDINGLY.

MODIFIED LASERS MUST BE CLASSIFIED BY EH&S; AND EH&S MUST APPROVE ALL MODIFICATIONS.
Engineering Controls

GENERAL CONTROLS:
MASTER KEY
INTERLOCKS

CONSIDER REMOTE FIRING OF UNIT

REMOVE UNNECESSARY OBJECTS FROM VICINITY OF LASER

SECURELY MOUNT THE LASER TO MAINTAIN THE BEAM IN A FIXED POSITION AND LIMIT BEAM TRAVERSE DURING ADJUSTMENTS
ENGINEERING CONTROLS

BEAM CONTROLS:

- REDUCE OUTPUT WITH SHUTTERS AND ATTENUATORS
- TERMINATE LONGER BEAMS WITH BEAM STOPS
- KEEP BEAM PATH AWAY FROM EYE LEVEL
- USE CURTAINS TO CONTROL SPECULAR REFLECTIONS
- ENCLOSE ANY BEAM PATH THAT EXITS FROM A CONTROLLED AREA, WHERE THE IRRADIANCE EXCEEDS THE MPE.
- ENSURE THAT BEAM PATHS DO NOT CROSS POPULATED AREAS OR TRAFFIC PATHS
- CONFINE BEAMS AND REFLECTIONS TO THE OPTICAL TABLE; BEAM TERMINATORS FOR WAVELENGTHS OVER 710NM SHOULD BE OF FIRE RESISTANT MATERIALS (CLASS 3B AND 4).
ENGINEERING CONTROLS

VIEWING AND ALIGNMENT CONTROLS

USE DIFFUSE REFLECTIVE SCREENS OR REMOTE VIEWING SYSTEMS DURING ALIGNMENT IF POSSIBLE
PERSONAL PROTECTIVE EQUIPMENT

- EYE PROTECTION
- PROTECTIVE GLOVES
- FACE SHIELDS
- PROTECTIVE APRONS
PROTECTIVE EQUIPMENT

EYEWEAR SELECTION DEPENDS ON:

- WAVELENGTH
- OPTICAL DENSITY
- COMFORT
- FIELD OF VIEW
- EFFECT ON COLOR VISION
- POWER/PULSE OF RADIATION

CONSULT WITH EH&Q FOR SELECTION DETERMINATION—
EYEWEAR IS VERY SPECIFIC TO A LASER AND IS TYPICALLY
NOT INTERCHANGEABLE BETWEEN SYSTEMS.
EYEWEAR EXAMPLES
CHEMICAL HAZARDS

TREAT DYSES ACCORDING TO (M)SDS, HANDLING AND DISPOSING OF THEM AS HAZARDOUS CHEMICALS WHERE APPROPRIATE.

MINIMIZE STORAGE OF CHEMICALS AND FLAMMABLE MATERIALS NEAR LASER SYSTEMS.

EVALUATE POTENTIAL HAZARDS FROM HAZARDOUS GASES, SUCH AS FLUORINE.

EVALUATE POTENTIAL HAZARDS FROM INTERACTION OF THE BEAM WITH TARGET MATERIALS.

*PLEASE CONTACT EH&S FOR ASSISTANCE WITH THESE DETERMINATIONS.
CLEARLY MARK ALL SYSTEM SHUT-OFFS.

ALL ELECTRICAL INSTALLATION, OPERATION AND MAINTENANCE MUST CONFORM TO NATIONAL ELECTRIC CODE (CONTACT EH&S FOR INFORMATION).
IN THE EVENT OF INJURY DUE TO LASER EXPOSURE:

- DIAL 911

- CONTACT EH&S AT 575-5448 TO REPORT THE INCIDENT
COMMON CAUSES OF ACCIDENTS

- Altering beam path by adding optical components
- Reflective objects into beam path (i.e. jewelry and watches)
- Improper termination of beam
- Bypassing interlocks (particularly during alignment procedures)
- Accidental firing of lasers
PART TWO

LASER TRAINING FOR USERS OF CLASS 3B AND 4 LASER SYSTEMS
SPECIAL PRECAUTIONS REQUIRED

- WRITTEN STANDARD OPERATING PROCEDURES
- SPECIAL CONTROLS AND PROTECTIVE EQUIPMENT
STANDARD OPERATING PROCEDURES

- REQUIRED FOR CLASS 3B AND CLASS 4 LASER SYSTEMS
- OPERATION, INCLUDING ANY UNATTENDED OPERATION
- USE OF SAFETY EQUIPMENT AND SAFEGUARDS
- MAINTENANCE, SET-UP AND CALIBRATION

THE SOPS MUST REMAIN ACCESSIBLE IN THE WORK AREA TO ALL USERS!
EXPLOSION HAZARDS

- FLASH LAMPS
- CAPACITORS
- SOLVENTS
- COMPRESSED GASES
- LASER TARGETS OR OPTICAL COMPONENTS CAN SHATTER FROM HIGH INTENSITY BEAMS
FIRE HAZARDS

- ELECTRICAL CIRCUITS
- IMPROPER BEAM ENCLOSURE
- IGNITION OF GASES/VAPORS
- FLAMMABLE SOLVENTS
- ELECTRICAL ARC
- CLASS 4 BEAM

ENSURE THAT FLAMMABLE AND COMBUSTIBLE MATERIALS ARE STORED AWAY FROM BEAM PATHS.
Nominal Hazard Zone

BASED ON HAZARD ANALYSIS

AREA INSIDE WHICH MAXIMUM PERMISSIBLE EXPOSURE (MPE) MAY BE EXCEEDED

AUTHORIZED PERSONNEL ONLY

APPLICABLE TO CLASS 3B AND 4
LASER CONFOCAL MICROSCOPY

UNDERSTAND BEAM PATH AND POTENTIAL FOR HUMAN EXPOSURE

BEAM INTERACTION ON PATH TO INTENDED TARGET

UPWARDLY DIRECTED BEAMS?

COMPUTER MONITORS POTENTIALLY IN LINE WITH THE BEAM
CONFOCAL MICROSCOPE
LASER CONFOCAL MICROSCOPY

IS BEAM AT EYE LEVEL WITH RESPECT TO OPERATOR’S POSITION AT ANY TIME?

ARE ANY OBJECTS/ITEMS IN PATH OF THE BEAM THAT MAY CAUSE SCATTER?

ARE FILTERS OR A BEAM STOP PRESENT TO PREVENT VIEWING LASER LIGHT THROUGH THE EYEPieces?

IS PROTECTIVE EYEWEAR NEEDED AND IS IT AVAILABLE?

IS LASER USED WITH LIGHTS ON, OFF OR DIMMED?
FOR MORE INFORMATION SEE APPLICABLE STANDARDS

ANSI Z136.1-SAFE USE OF LASERS (2014)

ANSI Z136.5-SAFE USE OF LASERS IN EDUCATIONAL INSTITUTIONS (2009)

ANSI Z136.6-SAFE USE OF LASERS OUTDOORS (2005)

ANSI/NFPA 70 NATIONAL ELECTRIC CODE (1996)