University of Massachusetts Amherst
Environmental Health & Safety

Laser Safety Manual

1.0 Introduction

The light produced by a laser has a unique combination of spatial coherence (all waves in ‘step’ or in ‘phase’); being monochromatic and at a high level of collimation (low beam divergence). Some lasers can only be operated in a pulsed mode to produce short bursts of coherent radiation. Other types of lasers can be made to produce a continuous output and are known as continuous wave (CW) lasers. Harm from laser radiation results from the absorption of energy from a beam by biological tissue. The narrow, almost parallel beam of coherent monochromatic laser light means that, in the absence of absorbers, the power delivered by the beam does not diminish significantly with distance. In addition, if such a beam is focused by a lens down to a spot, the power intensity is significantly increased. Because of the ability of the eye to focus visible radiation (and some near IR) onto the retina, and the irreversible nature of the injury that may result, the eye is recognised as the critical organ for damage by lasers.

High safety standards are essential when using lasers. The nature of the precautions needed may vary considerably depending on the type and power output of laser in use. This procedure sets out responsibilities and precautions that are relevant to all laser work.

2.0 Scope

This instructions in this manual must be applied to all laser use undertaken by University staff and students, whether at University owned or administered locations on or off campus.

3.0 Purpose

This manual has been produced to ensure there is a consistent and comprehensive approach to laser risk assessment and subsequent use of lasers.

4.0 Definitions

<u>Laser</u> *(Light amplification by the stimulated emission of radiation.)*
Any device that can be made to produce or amplify electromagnetic radiation in the wavelength range of 180nm to 1mm primarily by the process of controlled stimulated emission.

<u>Maximum Permissible Exposure (MPE)</u>
It is important to understand what levels of laser radiation are considered safe and MPEs represent the maximum level to which the eye or skin can be exposed without suffering short or long term damage. MPE values are set below known hazard levels and are based on the best available information. Detailed information on MPEs and tables of values can be found in ANSI Z136.1-2000. MPE’s will also be detailed in the risk assessment.

<u>Accessible Emission Limit (AEL)</u>
The maximum level of laser radiation that the laser can emit. The classification of a laser is determined by its AEL.

<u>Laser Classes</u>
The classification system applies to all laser products. There are 7 classes of laser, these are 1 (safest), 1M, 2, 2M, 3R, 3B and 4 (most hazardous). Class 1 and 1M lasers are engineered controls that make use of a person’s aversion reflex to bright

light as the primary safety feature. This does not mean that staring into a Class 1 or 1M beam is safe. See Appendix 1 for a summary of the laser classification scheme. Remember, that removing manufactured safeguards, safety systems, covers or other devices can change the manufacturer's classification of a device that uses a laser.

5.0 Regulatory Requirements

There is no legislation specific to laser use. The safe use of lasers is administered by state and federal regulatory agencies according to the consensus provisions stated the "Standard for the Safe Use of Lasers, ANSI Z136.1-2000", which is published by the American National Standards Institute (ANSI). The manufacture and registration of lasers is regulated by the U.S. Food and Drug Administration (FDA). These require employers to ensure, so far as is reasonably practicable, the health, safety and welfare of employees or any other person who may be affected by their acts or omissions in the manufacture, use or ownership of lasers. The relevant aspects of the general duties under the standard include the requirements to:

- Provide and maintain safe equipment;
- Provide safety systems that work properly;
- Provide information, instruction and training;
- Provide a safe working environment.

Best practices are currently considered those that are in compliance with the requirements of ANSI, the FDA and the Massachusetts Department of Health Radiation Control Program (MRCP), which registers lasers facilities and laser light shows in the Commonwealth of Massachusetts.

6.0 Hazards

Essentially, the hazards associated with laser use can be divided into two distinct groups. These are Beam Hazards and Non-Beam Hazards.

6.1 Beam hazards

When laser radiation is incident upon the body, some of the radiation is absorbed by the body tissues. If the radiant exposure is high enough, this can cause injury. The parts of the body the most at risk of injury from laser radiation are the eyes and the skin. The amount of radiation absorbed will depend on wavelength, tissue type, power of the beam, size of the irradiated area and the duration of exposure. The collimated beam of a laser and its high irradiance can result in large amounts of energy being transmitted to very small areas of the eye and skin. Damage to the body is produced by several mechanisms and interactions which include:

- Thermal effects
- Acoustic transients
- Photochemical effects
- Chronic exposure

The eye is the most vulnerable to laser radiation and injuries occur at much lower power levels than for the skin. This is because the human eye is designed to transmit, focus and detect light. Due to the nature of laser radiation, if a beam entering the eye were to completely fill a fully dilated pupil, the resulting increase in radiant energy falling on the retina compared to that on the front of the eye may be as high as a factor of 500,000. This is known as the 'optical gain'. Exposure to these extremely high levels of energy can cause permanent damage to the eye. Structures of the eye are effected differently, depending on the wavelength of the laser beam. Some wavelengths may be entirely absorbed at the surface of the eye causing damage to the cornea. Other wavelengths will leave the cornea unharmed but will cause permanent damage to the macula. All activities that may result in direct intrabeam viewing (especially beam alignment work), or exposure to a specular or diffuse reflection, must be identified and suitable control measures implemented to prevent injury.

6.2 Non Beam Hazards.
These generally fall into the following sub-categories.

- Electrical – from high voltage power supplies.
- Chemical – lasing mediums such as toxic gases/liquids, fume/particulate material generated by the laser process and ozone generation.
- Mechanical – handling heavy work pieces, installation of heavy ancillary equipment such as gas cylinders, moving machinery.
- Fire – Direct and diffuse laser beams from high power class 4 lasers can to ignite certain materials.
- X Rays and Electromagnetic Interference – The interaction of high energy laser radiation with heavy metals can generate X-rays.
- Ultraviolet (UV) – UV light produced during metal cutting will burn the cornea, akin to the damage to the eye caused by “welder’s flash.”

7.0 Procedure

7.1 The Laser Safety Officer (LSO)
The University has appointed a Laser Safety Officer. The contact details of the Current LSO can be found in Appendix 2. The responsibilities of the LSO are detailed in Section 8 of this procedure.

7.2 Training
The Principal Investigator for the laboratory must ensure that University staff and students responsible for setting up and using lasers of class 2M, 3R, 3B or 4 must have received laser safety training provided by the LSO. The Principal Investigator must provide training on the practical use of the laser and its auxiliary devices before allowing a staff member or student to use a laser without direct supervision. Undergraduate and post graduate students who work with lasers under the supervision of an experienced staff member or student must receive a laser safety briefing from the experienced member of the laboratory staff prior to being permitted to use any laser of class 3R, 3B or 4. Records must be kept of all safety training and briefings.

7.3 Risk Assessment
A risk assessment must be carried out in line with ANSI standards University EH&S staff should be consulted. EH&S staff can help perform a risk assessment for each laser operation. In order to be suitable and sufficient, the risk assessment must be carried out by employees of the University who fully understand the hazards associated with the work and have the necessary competence to determine control measures that will reduce the risks to an acceptable level. When performing a risk assessment, consideration must be given to the following areas:

- Laser equipment
- Beam delivery
- The laser process
- The environment
- Those who may be affected

For class 3R, 3B or 4 lasers the MPE and Nominal Ocular Hazard Distance (NOHD) must be calculated and the information included in the risk assessment and the local safety precautions.

7.4 Local Safety Precautions

Following the risk assessment, a set of local safety precautions must be developed and brought to the attention of all persons who will be involved in the use of the laser or who may be affected by its operation. An example set of local safety precautions can be found in Appendix 3.

7.5 Control Measures

Having completed a risk assessment, Principal Investigators must make all users aware of the elements of the laser operation that pose a risk of injury. In dealing with any hazard, users should first consider if they can eliminate the hazard completely (e.g. by using a lower powered laser). If this route is not practicable then users should consider the application of other control measures that will reduce the risks to an acceptable level. In the first instance, the approach to risk reduction should be via engineering controls, then by the application of administrative controls, then finally by the use of personal protective equipment.

7.5.1 Engineering Controls

Features incorporated by the manufacturer/supplier or added by the user to prevent access to hazardous levels of laser radiation. Engineering controls include:

- Beam enclosures
- Beam tubes
- Beam stops
- Protective barriers, guards and panels
- Interlocked access panels etc

7.5.2 Administrative Controls

These may include training requirements, the display of warning signs, local rules, schemes of work (especially for alignment work), written procedures, authorised or restricted access and authorised user lists etc.

A medical emergency form (Appendix 4) must be completed for each laser prior to use and be posted adjacent to the activity.

7.5.3 Personal Protective Equipment.

Protective eyewear should be appropriate for the power and wavelength of the laser used and the wavelength range and optical density must be clearly marked on the equipment. An assessment of the PPE's suitability in providing the appropriate level of protection should be undertaken by the LSO.

7.6 Maintenance

Departmental/School Heads are responsible for ensuring appropriate maintenance is carried out on laser equipment within their area of responsibility. Maintenance of laser equipment must only be undertaken by a competent service engineer. Copies of risk assessments must be provided to the relevant Department Head and LSO prior to maintenance work being undertaken.

7.7 In the Event of an Emergency

In the event of a laser eye injury, medical attention must be sought immediately. Notification to the hospital must be given that a case is on its way. On departure from the University, the casualty must take one of the medical emergency documents specific to the laser being used (See Appendix 4). This will allow medical personnel to make an appropriate diagnosis based on the correct information. Medical emergency forms must be completed for all lasers and posted with the local rules to ensure easy access to the information in the event of an emergency.

All accidents, no matter how minor, must be reported to the LSO. Any accident involving the injury to a person, be it eye injury, laser burn, electrical or other injury, must be report to University Health Services as well as the LSO.

8.0 Summary of Responsibilities

Laser Safety Officer

- Establish and maintain laser safety procedures/local rules.
- Provide training to members of staff in the safe use of lasers.
- Audit laser safety.
- Assist users with laser risk assessments.
- Ensure prescribed control measures are implemented and are effective.
- Investigate incidents and accidents.
- Post the laboratory doors with the proper laser warning signs.
- Recommend or approve personal protective equipment.

Principal Investigator

- Ensure risk assessments are undertaken for all laser use within their laboratory.
- Ensure that all laser users attend EH&S laser safety training
- Provide practical training in the laboratory on the safe use of all components of the laser.
- Ensure that the proper laser warning signs is affixed at all entry ways and within the laboratory. (**Note:** The LSO must be contacted before a laser warning sign is posted on a door or within a laboratory. ANSI standard Z136.1-2000 has specific wording that must appear on laser warning signs.)
- Ensure that no there are no uncontrolled reflections or refractions.
- Ensure that the types of beam dumps, safety curtains or barriers will not catch fire while absorbing the laser energy of interest.

Academic staff

- To observe the local rules and schemes of work.
- Leave no laser experiments running unattended.

Appendix 1

Laser Classification Scheme

Class	Basis for classification	Signage
Class 1 SAFE Visible/non visible	Lasers which are safe under reasonably foreseeable conditions of operation. Generally a product that contains a higher laser class system but access to the beam is controlled by engineering means.	**CLASS 1 LASER PRODUCT**
Class 1M SAFE WITHOUT VIEWING AIDS 302.5 to 4000nm	Protection for the eyes is normally provided by the natural aversion response, including the blink reflex, which takes approximately 0.25 seconds. Beams are either highly divergent or collimated but with a large diameter. May be hazardous if optics are used within the beam.	**CLASS 1 LASER PRODUCT**
Class 2 LOW POWER Visible only	For CW lasers, protection of the eyes is normally afforded by the natural aversion response, including the blink reflex, which takes approximately 0.25 seconds. (These lasers are not intrinsically safe) AEL = 1mW for a CW laser.	**LASER RADIATION DO NOT STARE INTO BEAM CLASS 2 LASER PRODUCT**
Class 2M SAFE WITHOUT VIEWING AIDS Visible only	Safe under reasonably foreseeable conditions of operation. Beams are either highly divergent or collimated but with a large diameter. May be hazardous if optics are used within the beam.	**LASER RADIATION DO NOT STARE INTO BEAM CLASS 2 LASER PRODUCT**
Class 3R LOW/MEDIUM POWER 302.5nm to 1mm	Risk of injury is greater than for the lower classes but not as high as for class 3B. Up to 5 times the AEL for Class 1 or Class 2.	**LASER RADIATION AVOID DIRECT EYE EXPOSURE CLASS 3R LASER PRODUCT**
Class 3B MEDIUM/HIGH POWER Visible/non visible	Direct intrabeam viewing of these devices is always hazardous. Viewing diffuse reflections is normally safe provided the eye is no closer than 13cm from the diffusing surface and the exposure duration is less than 10 seconds AEL = 500mW for CW lasers	**LASER RADIATION AVOID EXPOSURE TO BEAM CLASS 3B LASER PRODUCT**
Class 4 HIGH POWER Visible/non visible	Direct intrabeam viewing is hazardous. Specular and diffuse reflections are hazardous. Eye, skin and fire hazard.	**LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION CLASS 4 LASER PRODUCT**

Appendix 2

Laser Safety Officer - contact details

Name: Vincent Chase

Job Title: Program Head, Radiation Safety Services

Dept: **Environmental Health and Safety**

Tel: 413-545-2682

Email: **vchase@ehs.umass.edu**

Appendix 3

Example set of Local Safety Precautions.

SAFEGUARDS FOR THE USE OF LASERS

Location:
Laser Manufacturer:
Laser Type (HeNe, CO2, Dye, etc):
Primary Wavelength(s) Emitted:
Max. Power: Pulsed ?: Laser Class:
Laser Eyewear Type:
Laser Eyewear O.D.:
Local Contact for Information About This Laser:
Phone Number:

Operational Safety Precautions:

- Ensure all optical components are in the correct position and secured to the optical table.
- Be aware of scattered radiation (diffuse and specular) from optical surfaces and other equipment. **Note:** For certain wavelengths, a surface that is non-reflective to visible light may reflect an invisible laser beam.
- Avoid placing any part of your body in the beam path.
- Remove rings, watches and other reflective items that may result in the generation of errant beams.
- Use the lowest power possible to align the laser beam.
- Use appropriate beam stops to terminate the beam at the end of its useful path length.
- Ensure that beam stops, safety curtains and window coverings are fire rated for the power level and wavelength of the laser beam.
- Confine all beams to the optical table wherever possible.
- Always work with laser beams pointing away from access doors.
- Wherever possible, direct laser beams downwards towards the floor, rather than upwards to eye level.
- Enclose all beam paths wherever possible.
- At all times work with high levels of background illumination.
- Check all guards and interlocks where necessary are in place before work commences.
- Do not leave the laser unattended while switched on.
- Where key controls are used, ensure keys are returned to key cabinet on completion of work or at end of day. Do not leave keys in machines overnight.
- Fill in all log books for laser and key cabinet.
- Keep records within the logbook of alterations to laser system or optical configuration.

Reviewed by PI or Laboratory Supervisor:
Printed Name: ______________________________________ Date: ____________

Signature: ____

Approved by LSO

Signature: ____ Date: ____________

Appendix 4

MEDICAL EMERGENCY

In the event of an accident, take the following information about the laser that caused the injury to hospital with the patient.

LASER TYPE: (Gas/Solid state/Diode)

WAVELENGTH:

PULSE LENGTH:

MAX. OUTPUT POWER:

PULSED or CW:

OTHER RELEVANT INFORMATION:

Appendix 5

UNIVERSITY OF MASSACHUSETTS AMHERST
LASER INFORMATION FORM

I. Laser Possessed By:

Principal Investigator	
Phone	
Department	
System Location (Bldg/Room)	

II. Personnel authorized to use laser system:

Name	Phone #	Email

III. Laser Description

	Laser 1	**Laser 2**	**Laser 3**
Manufacturer			
Model #			
Serial #			
Class(1M,2,2R,3R,3B,4)			
Type (CW, Pulsed)			
Description (ie; He-Ne, Nd: YAG)			
Wavelength(s)			
Maximum Power/Peak Power (Watts or Joules)			
Pulse Duration (repetition rate)			
Emerging Beam Divergence (mrads)			
Emerging Beam Dimensions (mm)			
Use (holography, alignment, etc.)			

For EH&S Use Only
Laser Safety Information

Laser warning sign on door: ____ Yes ____ No Visitor

Type of eyewear: ____ Glasses ____ Goggles Other

Statement on sign: ____ Danger ____ Caution Other ______________________________

Eyewear Manufacturer: ____________________ Color: _____________ OD: _______

Eyewear available? Yes No Service Company: ______:_________________________

Is there a written SOP available? ____ Yes ____ No _____ Hard copy ____ Online

Appendix 5
References:

ANSI Z136.1-2000, *American National Standard for the Safe Use of Lasers.*
MRCP Regulation 105CMR120.000, *Laser System*.
USFDA Radiological Health website – www.fda.gov/cdrh/radhealth
Laser Institute of America website – www.lia.org
UMass EH&S website – www.ehs.umass.edu