ESH 120 LASER SAFETY CHALLENGE EXAM HANDOUTS:

1. **ESH Manual Chapter 6.2, Laser Safety (8/15/02)**

2. **ESH120 Slides and Charts**

ESH 120 LASER SAFETY CHALLENGE EXAM HANDOUTS:

1. **ESH Manual Chapter 6.2, Laser Safety (8/15/02)**

6.2 LASER SAFETY

6.2.1 PURPOSE

The purpose of this section is to establish requirements for the safe use of lasers at ANL-E.

6.2.2 SCOPE

All lasers used at ANL-E, whether purchased, borrowed, fabricated, or brought in for use by others, are governed by the provisions of this section.

Table 6.2-1 lists the most important safety requirements for laser operation at ANL-E.

If you have any content questions, please call the point of contact, B. Murdoch, EQO-IH, at 2-4905.

6.2.3 RESPONSIBILITIES

Division directors and department heads (DD/DH) must:

- Approve new or modified class 3a, 3b, or 4 laser installations and usage after considering the documented advice of the laser safety officer (LSO) or deputy LSO regarding the adequacy of those installations;

- Approve a standard operating procedure (SOP), after considering the documented advice of the LSO or deputy LSO, for each class 3b or class 4 laser installation or each laser controlled area (LCA) containing such laser installations;

- Appoint a laser control area supervisor for each LCA;

- Ensure that all authorized laser users of class 3b and class 4 lasers receive a laser-specific medical eye examination approved by ANL-E Medical Department prior to any laser use, following any accidental exposure where an eye injury is suspected, or when an authorized user is not expected to perform further work with lasers at ANL-E;

- Ensure that LCA supervisors and laser users receive and remain current in all required ESH laser safety training (see subsection 6.2.6).

The divisional ESH coordinator must:

- Review each class 3a, 3b, or 4 laser installation;
- Assess organizational conformance with the requirements of this section;
- Review and approve SOPs; and
- Coordinate laser safety activities with LSO/deputy LSO.

Project managers and technical representatives must ensure that subcontractors bringing lasers on site for use comply with the requirements of this section.

LCA supervisors must:

- Advise the LSO or deputy LSO of plans to acquire, borrow, fabricate, or relocate a class 3 or class 4 laser, or modify an existing class 3a, 3b, or 4 laser installation;
- Request LSO or deputy LSO review and inspection of new or modified class 3a, 3b, or 4 laser installation and use;
- Prepare and maintain current an SOP for each class 3b or class 4 laser installation, or each laser controlled area containing such laser installations, under their supervision;
- Post each LCA with the most recently completed laser safety checklist and with ANL-E laser safety signs provided by the LSO;
- Ensure that all authorized laser users complete ANL-E laser safety training prior to any use of class 3a, 3b, or class 4 lasers, and receive any necessary facility-specific training prior to any laser use, including reading and understanding the applicable SOP;
- Maintain control of laser operation within the LCA either administratively or by controlling keys;
- Ensure that all required engineering controls are in place and operational;
- Ensure that interlocks and automatic warning devices are tested quarterly and the tests documented in accordance with the requirements in subsection 6.2.5.2;
- Maintain awareness of and observe activities of personnel within the LCA, stopping or correcting any unsafe acts;

- Coordinate activities of laser service and repair contractors, including review of job safety analyses and oversight of worker activities;

- Ensure that all personal protective equipment, including laser safety eyewear, is available in the LCA, stored properly, and in good condition;

- Perform and document an annual inspection of all laser safety eyewear;

- Ensure that all class 3a, 3b, and 4 lasers in the custody of the LCA supervisor have been identified to the LSO for entry into the sitewide laser inventory database;

- Inform the LSO or deputy LSO

  - Of any significant layout changes or changes in laser operations or procedures that may have an impact on authorized laser user safety,

  - When class 3a, 3b, or class 4 lasers are moved into or out of the LCA or changes in use status, including when such lasers are surplused,

  - When authorized laser users are added to or removed from the list of approved LCA users.

Authorized laser users must operate lasers in a manner consistent with the requirements of this section and any specific operating procedures.

Personnel entering an LCA must meet the qualifications, controls, and responsibilities appropriate to their activity category as described in Appendix C.

The director of Environment, Safety and Health/Quality Assurance Oversight (EQO) must appoint a site LSO. An associate Laboratory director/chief operations officer (ALD/COO) may appoint a deputy laser safety officer (deputy LSO) to serve his or her organization. In such a case, the ALD/COO must notify in writing the Laboratory director and the site LSO of the appointment.

The site laser safety officer (LSO) or deputy LSO must:

- Review and inspect upon request new or modified class 3a, 3b, class 4 laser installations in order to advise the DD/DH regarding the adequacy of the installations;

- Provide guidance upon request on the preparation of SOPs;

- Review SOPs upon request in order to advise DD/DH regarding the adequacy of the SOPs;
- Provide safety postings for LCAs (LSO only);
- Conduct periodic safety reviews of all existing class 3a, 3b, and class 4 laser installations (LSO only) and assist, if requested, in the conduct of the reviews (deputy LSO only);
- Provide, upon request, eyewear and hazard zone computations and specifications;
- Ensure that ANL-E laser safety training meets required standards of content (LSO only);
- Maintain a sitewide inventory of all class 3a, class 3b, and class 4 lasers (LSO only); and
- Serve as a member, upon request, of any laser safety committee on site.

The Medical Department must arrange for or approve special eye examinations for all authorized laser users of class 3b or class 4 lasers.

The Procurement Department must obtain review, from the LSO only, prior to placing a purchase order for a class 3a, 3b, or class 4 laser.

6.2.4 PERIODIC ACTIONS AND DELIVERABLES

Quarterly: LCA supervisors must ensure that interlocks and automatic warning devices are tested in accordance with the requirements of subsection 6.2.5.2.

Annually: LCA supervisors must perform and document an inspection of all laser safety eyewear used within the LCA.

6.2.5 REQUIREMENTS

6.2.5.1 General

Appendix A provides a glossary of terms.

Appendix B describes hazards associated with laser use.

This section is intended to ensure that all lasers at ANL-E are operated in accordance with the technical and programmatic requirements of the American National Standard for the Safe Use of Lasers, ANSI Z136.1 (current version). In case of any disagreement between this section and ANSI Z136.1, the ANSI Z136.1 standard will prevail.

There are no specific controls required for use of a class 1 laser.

Any use of a class 2 laser that requires staring into the beam or its specular reflection must be evaluated by the LSO or deputy LSO.

Only class 2 laser pointers are approved for presentation purposes at ANL-E. Class 3a or higher laser pointers must not be used outside a laser controlled area.

Public demonstrations of class 3a, 3b, or class 4 lasers must have prior review by the laser safety officer or deputy LSO and approval of the DD/DH.

6.2.5.2 Laser Installation Requirements

Primary safety requirements for each class of laser are summarized in Table 6.2-1.

The laser beam path and target area should be totally enclosed. If total enclosure is not possible, as much of the beam path as possible should be enclosed or shielded from workers.

Beam stops should be used to terminate beams and to contain specular reflections.

Class 3b and class 4 laser installations with totally enclosed beam paths (Class 1 enclosure; see Appendix A – Glossary) must:

- Prevent the escape of laser radiation exceeding the maximum permissible exposure, and

Table 6.2-1 Primary Safety Requirements for Installations with Exposed Laser Beams

	Class 2	Class 3a	Class 3b	Class 4
No intentional staring into beam or specular reflections	LSO or deputy LSO evaluate and advise	X	X	X
No unshielded eye level or vertical beams		LSO or deputy LSO evaluate and advise	X	X
Area posted	LSO or deputy LSO may advise	X	X	X
Indicator of invisible beam "ON"		X	X	X
Laser safety training	LSO or deputy LSO may advise	X	X	X
Eye protection	only for direct beam viewing	LSO or deputy LSO evaluate and advise	X	X
Careful control of spectators		X	X	X
Laser controlled area		recommended	X	X
Interlocked LCA entry			if operated unattended	X
SOP document			X	X
Eye examination			X	X
Shield diffuse reflections				X
Laser safety review		X	X	X

X indicates requirement

- Prevent entry into the enclosure by the use of engineering controls or by automatically cutting off the laser beam upon enclosure entry.

Class 3b and class 4 lasers that are not installed in class 1 enclosures must:

- Be operated only in an LCA,
- Confine any unenclosed or unshielded laser beams to a horizontal plane well above or below normal viewing height, and
- Totally enclose or shield vertical beams from the direct view of workers.

Invisible beam class 3a, 3b, and 4 laser systems must incorporate an automatic warning light or other device to indicate presence of a beam. Warning devices must be either audible or visible through laser safety eyewear and must be located so that persons will hear or see the warning at any location in the LCA. Audible warning devices may include distinctive sounds produced by some pulsed lasers.

All new or modified class 3a, 3b, and 4 laser installations must be reviewed and inspected by the laser safety officer or deputy laser safety officer prior to initial start-up. The findings of this review must be documented to the DD/DH through use of the ANL-E laser safety checklist. It is recommended that LSO/deputy LSO consultation be sought early in the planning stage to minimize delays in start-up or prior to actual movement of a class 3a, 3b, or 4 laser intended for relocation or a loan.

All new or modified class 3a, 3b, and class 4 installations must be approved by the DD/DH prior to initial start-up and after considering the advice provided from the review of the installations by the LSO or deputy LSO.

Figure 6.2-1 provides an overview of the process used to authorize laser installations.

Interlocks and automated warning devices must be tested quarterly, as a unit as well as in their component parts; test results must be documented and maintained. If a malfunction is found during testing or use, it must be corrected immediately, or equivalent temporary controls must be substituted.

6.2.5.3 Laser Controlled Areas

A laser controlled area (LCA) restricts access to and use of an area with administrative and engineering controls. Controlled access is recommended for class 3a laser operations and is required for class 3b and class 4 laser operations where an open beam path can exist.

An LCA must include the following features:

- Prevention of escape of any laser radiation level exceeding maximum permissible exposure levels;
- Prevention of unexpected or unauthorized entry into the LCA by engineering controls or, alternatively, by interrupting the laser beam automatically upon such entry; and
- Prohibition of work that is not directly associated with use of the laser when a laser is operating.

An LCA must be fully interlocked when any unattended Class 3b or class 4 lasers are being operated within it.

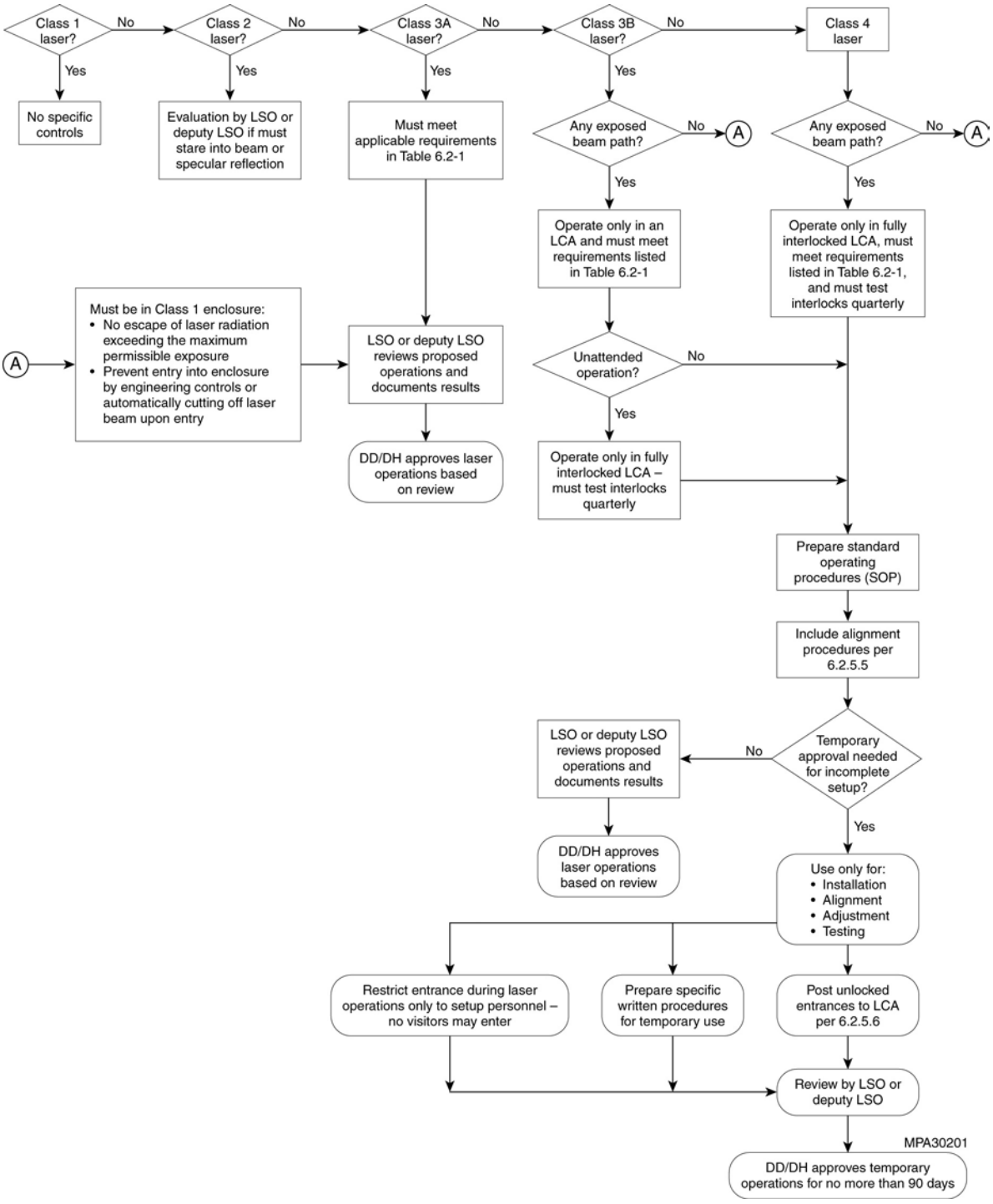


Figure 6.2-1 Laser Operational Requirements

A copy of a completed ANL-E laser safety checklist (see Attachment A – form ANL-609), signed by the LSO or deputy LSO, must be posted in each LCA. The LSO provides all signage for LCAs and ensures that the signs conform to the requirements of ANSI Z136.1.

Laser safety eyewear must be worn at all times by all persons in an LCA when engineering or administrative controls are inadequate to eliminate potential exposures in excess of the applicable MPE.

Laser safety eyewear must be inspected annually by each LCA supervisor for pitting, crazing, cracking, discoloration, mechanical integrity, and light leaks. Eyewear in suspicious condition must be tested for acceptability or discarded. Results of the eyewear inspection must be documented and maintained. Laser safety eyewear must not be relied upon as the primary means of personnel protection unless feasible engineering controls are inadequate to prevent hazardous exposures.

Personnel may need to enter an LCA for a variety of reasons. Appendix C provides categories for personnel entering an LCA and describes the qualifications, hazard controls, and responsibilities appropriate to each category. All personnel entering an LCA must follow the controls appropriate to their category.

6.2.5.4 Standard Operating Procedures

A standard operating procedures document (SOP) must be prepared for each class 3b or class 4 laser installation; normally only one SOP must be prepared for an entire LCA, with operating procedures that address for each class 3b and class 4 laser in the LCA. A sample SOP (ANL-610) is attached (see subsection 6.2.10).

All SOPs must be approved by the DD/DH after considering the advice provided from the LSO or deputy LSO review of the SOPs and prior to use of the SOPs.

All SOPs must include the following information:

- Name of LCA supervisor
- Names of all authorized laser users and scientific collaborators (see Appendix C)
- Detailed descriptions of all lasers
- Hazard analysis

- Hazard controls description
- LCA entry controls
- Protective eyewear description and use for each laser
- Alignment hazards and controls (see subsection 6.2.5.5)
- Beam enclosure
- Justification for any unenclosed beam paths
- Interlock testing procedure

6.2.5.5 Beam Alignment Procedures Design Requirements

Alignment procedures must be designed to minimize the possibility of accidental specular or diffuse reflection toward a worker's eye or skin of a laser beam with power level exceeding maximum permissible exposure. Special shields, guards, or other engineering controls may be necessary. Alternative viewing methods may be required to achieve a satisfactory level of safety.

Special care must be taken for class 4 lasers when manipulating reflective objects near the laser path. Wristwatches and jewelry are prohibited while working near the beam, and shiny tools must never be used. With class 4 lasers, authorized laser users must be certain to shield even diffusely reflecting surfaces from view.

For alignment of a class 3a, 3b, or class 4 laser system, the following requirements apply (also see Figure 6.2-2):

1. If at all possible, a class 2 laser should be used to align the optical system.

2. If condition 1 above cannot be met, and if the laser emits only visible continuous wave radiation, then the laser output should be reduced to less than 1 milliwatt.

3. If neither condition 1 nor condition 2 above can be met, then the use of remote sensing devices (e.g., video or position-sensing instruments) must be given serious consideration. Alternate viewing devices must be used for UV and infra-red wavelengths.

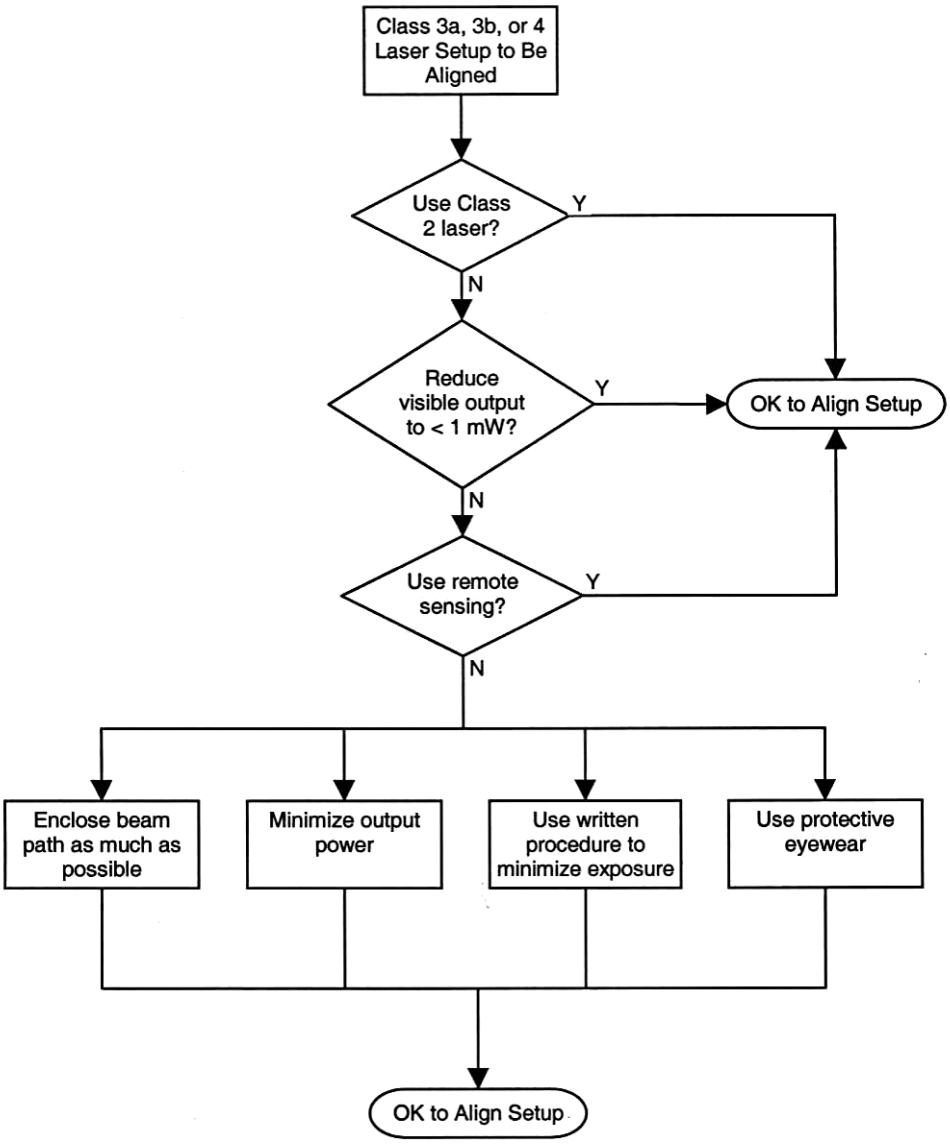


Figure 6.2-2 Class 3 & 4 Laser Alignment Safety Protocol

4. If none of the safety controls in 1-3 above can be implemented, then the alignment must be performed with **all** of the following safety controls in place:

   a. The beam path and target area must be enclosed as much as possible while still allowing the alignment to be performed; and

   b. Laser output power must be reduced to the practical minimum; and

c. An alignment procedure must be developed and documented in the SOP that minimizes the possibility of direct beam or specular reflection exposure to the authorized laser user; and

d. When feasible, protective eyewear should be worn during alignment of beams with visible wavelengths, with an optical density at least sufficient to protect against a diffuse reflection under the following standard conditions: 20 minutes viewing at a distance of 50 cm from a surface with a reflectivity of 60%. Computed optical density must be designed to reduce such a reflection to a value below the MPE for eye exposure. The LSO or deputy LSO can provide the computation of optical density to meet this requirement; and

e. Fully protective eyewear (with optical density sufficient to protect against a direct beam exposure) must be worn at all times for invisible wavelengths (<400 nm or >700 nm), whenever radiation levels exceeding MPE levels may be present.

Departures from requirement 4d may be technically sensible, depending on particular geometry and other physical constraints, and can be developed in collaboration with the LSO or deputy LSO. For example, it may be safer to work with eyewear and slightly higher beam power output for visibility than to work at minimum power with no eyewear. Protection against the specified standard diffuse reflection through a balance of eyewear and beam power must be achieved where possible.

The process of developing alignment hazard controls must be documented in the SOP, including a specific acknowledgment and explanation of implementation for each of steps 1 through 4e, above.

6.2.5.6 Temporary Approvals

Temporary approvals may be issued for the setups of Class 3b and Class 4 laser installations. During installation, alignment, and testing of a new laser configuration, it may not be possible to have in place all the hazard controls normally required for routine operation. Temporary operational approval may be given with the following restrictions:

- Laser beams must be operated only as necessary for the purposes of installation, optical alignment and adjustment, and testing – not for routine research operations or data acquisition;

- Written procedures must be developed and approved, describing in general the setup procedures and safety precautions to be followed. The procedures may be brief and

informal in style, but must be reviewed by the LSO or deputy LSO, and approved by the LCA supervisor, divisional ESH coordinator, and DD/DH;

- All unlocked entrances to the LCA must be posted with the standard "Notice – Laser Repair Area" sign specified by ANSI Z136.1 and supplied by the LSO only. The signs must be placed conspicuously on yellow ropes or tape hung across the unlocked entrances during laser operation;

- Only those persons directly needed to perform laser setup operations may enter the LCA during laser operation; and

- Only authorized laser users may enter the LCA during laser operation under a temporary approval.

Temporary setup approvals must be written to expire within a time period not to exceed 90 days from the date of approval authorization. DD/DH must approve temporary setups.

6.2.5.7 Laser Use Authorization

Figure 6.2-3 provides an overview of the requirements to use lasers at ANL-E.

Only an authorized laser user may operate a class 3a, 3b, or 4 laser or work in direct proximity to the laser beam. This includes adjusting and aligning the laser and related optical components, inserting or observing targets or samples inserted into the beam, as well as observing such activities from close proximity. Personnel entering a class 3b or class 4 LCA who are not authorized users must follow the requirements given in Appendix C appropriate to their category.

A laser-specific medical eye examination approved by ANL-E Medical Department is required of authorized laser users of class 3b and class 4 lasers prior to any laser use, following

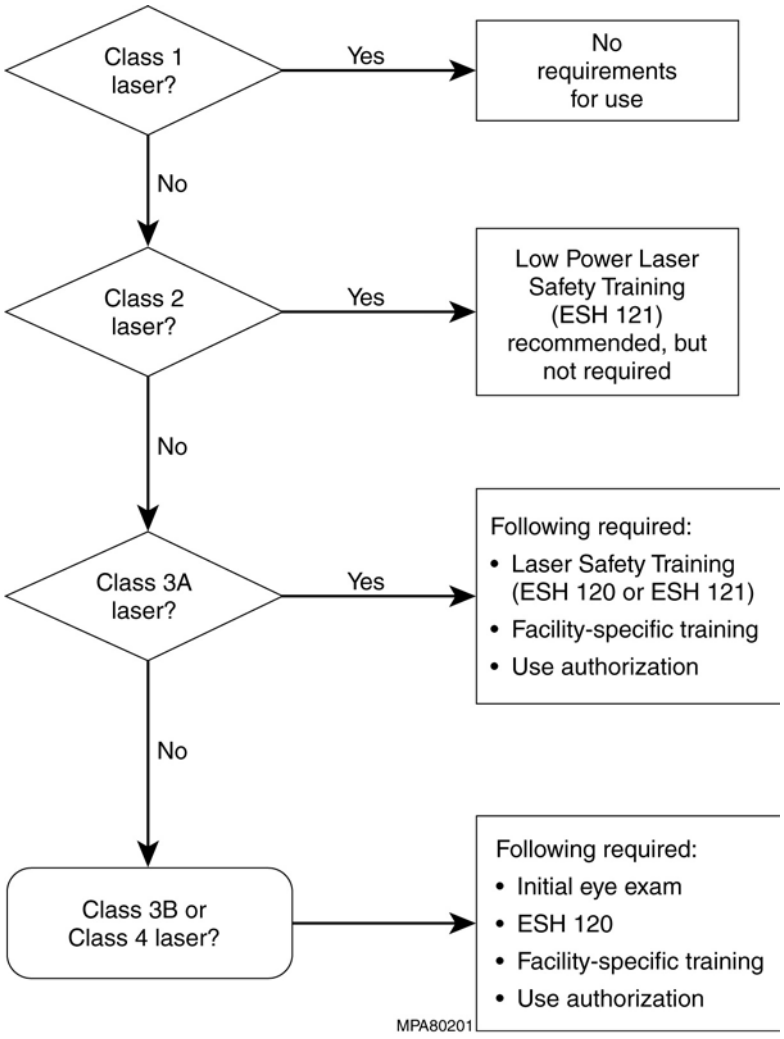


Figure 6.2-3 Laser User Requirements

any accidental exposure where an eye injury is suspected, and as part of the termination process from the Laboratory or further laser work at ANL-E.

6.2.6 TRAINING AND QUALIFICATIONS

LCA supervisors and authorized laser users of class 3b and class 4 laser installations must have completed the ANL-E laser safety training course, ESH 120, Laser Safety Training, and all required facility-specific training prior to appointment as an LCA supervisor or authorization to perform laser activities. Refresher training (every 2 years for ESH 120 and as required for facility-specific training) must be completed for continued use. If laser activities are to be performed using only class 3a lasers, an alternate ANL-E laser safety training course, ESH 121, Low Power Laser Safety Training, may be substituted for course ESH 120. There is no refresher training required for course ESH 121. Facility-specific training and use authorization are required prior to use of class 3a lasers.

Users of class 2 lasers should complete site laser safety training course ESH 121.

Persons who may need to enter an LCA for a variety of reasons and who have not had ANL-E laser safety training or eye examinations, under certain conditions may enter the LCA or participate in experiments involving class 3b or class 4 lasers. See Appendix C for further details regarding the required training, qualifications, and safety precautions for various categories of personnel who may need to enter an LCA.

The site laser safety officer and deputy laser safety officer must be qualified and knowledgeable in those aspects of laser safety specified in ANSI Z136.1 (most recent edition), paragraph D6.2. The LSO and deputy LSO must have completed at a minimum a formal 40-hour laser safety officer training course as provided by the Laser Institute of America, Rockwell Laser Industries, or an equivalent vendor. Continuing education in laser safety should be pursued by periodic attendance at workshops and through completion of advanced laser safety officer courses.

6.2.7 LASER SAFETY COMMITTEES

Divisions owning or using lasers may form local laser safety committees if warranted by the magnitude of the potential hazard of laser operations. Membership should include authorized laser users, division safety representatives, the LSO, and deputy LSO. A local committee should establish division safety practices and standards above and beyond site-wide requirements and maintain among authorized laser users awareness of requirements and safe practices.

6.2.8 REFERENCES

"A Guide for the Control of Laser Hazards," American Conference of Governmental Industrial Hygienists, Akron, OH, latest edition.

"The Safe Use of Lasers," American National Standards Institute, ANSI Z136.1, New York, NY, latest edition.

"Safety with Lasers and Other Optical Sources," Sliney, D. and M. Wolbarsht, Plenum Press, NY, 1980.

"Worker Protection Management for DOE Federal and Contractor Employees," DOE Order 440.1A, March 27, 1998.

6.2.9 APPENDICES

Appendix A – Glossary

Appendix B – Hazards Associated with Laser Use

Appendix C – Laser Personnel Categories

6.2.10 ATTACHMENTS

ANL-609, ANL-E Laser Safety Checklist

ANL-610, Standard Operating Procedure for Laser Controlled Area Format

APPENDIX A

GLOSSARY

accessible radiation – laser radiation to which it is possible for the human eye or skin to be exposed in normal use.

administrative controls – specific operating procedures, personnel access restrictions, and warning signs for the safe operation of lasers and laser systems.

alignment – small adjustment of optical components which have been previously placed and attached. Does not include re-configuration of an optical path by insertion or removal of optical components.

authorized laser user – a person who operates a class 3b or class 4 laser or works in direct proximity to the laser beam; includes those who adjust and align the laser and related optical components, insert or observe targets or samples inserted into the beam, as well as those who observe such activities from close proximity.

class 1 laser – (per ANSI Z136.1) a laser that, due to low emission or installation, cannot produce accessible laser radiation levels in excess of the class 1 Accessible Emission Limit (AEL) for the maximum possible exposure duration as listed in ANSI Z136.1.

class 1 laser enclosure – (per ANSI Z136.1) an enclosure, in which a class 3a, 3b, or class 4 laser is operated, that prevents the escape of any laser radiation exceeding MPE values for eye and skin, and employs access and engineering controls to prevent accidental exposure as a result of opening panels, hatches, or doors.

class 2 laser – (per ANSI Z136.1) a continuous wave (CW) or continuously pulsed visible light laser that could cause injury to the retina of the eye upon more than very brief exposure to the direct beam or certain specular reflections. Class 2 laser output cannot exceed 1×10^{-3} watts (1 milliwatt) total power.

class 3 laser – (per ANSI Z136.1) a pulsed or CW, visible or invisible beam laser that produces sufficient power or energy to cause retinal or other injury to the eye from even momentary exposure to the direct beam or specular reflections. Diffuse reflections of class 3 laser beams are not hazardous unless the beam is focused. Class 3 laser output cannot exceed 0.5 watts for periods >0.25 seconds or 0.125 joule for periods <0.25 seconds. A class 3a laser produces accessible radiation that is between 1 and 5 times the class 1 emission limit for invisible beams,

or between 1 and 5 times the class 2 emission limit for visible beams. All other class 3 lasers are class 3b.

class 4 laser – (per ANSI Z136.1) a pulsed or CW, visible or invisible beam laser that produces sufficient power or energy to cause retinal or other injury to the eye from the briefest of exposures to the direct or specularly reflected beam, and diffuse reflections of which can be hazardous. Class 4 lasers are skin burn hazards and fire hazards. Class 4 laser output exceeds 0.5 watts for periods >0.25 seconds and 0.125 joule for periods <0.25 seconds.

diffuse reflection – change in the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or medium.

deputy laser safety officer (deputy LSO) – a person qualified to recognize and evaluate laser hazards, appointed by an ALD or the COO to review and advise on laser installations in organizations reporting to the ALD or COO. Has fewer responsibilities than the laser safety officer.

engineering controls – enclosures, beam stops, shutters, interlocks, and automated warning devices for the safe operation of lasers and laser systems.

laser – a device that produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels. An acronym for Light Amplification by Stimulated Emission of Radiation.

laser controlled area (LCA) – an area containing class 3a, class 3b, or class 4 laser operations to which access and use is restricted through administrative or engineering controls, and which is designed to prevent escape of hazardous laser radiation.

laser safety officer (LSO) – a person qualified to recognize and evaluate laser hazards, appointed by EQO to review and advise on laser installations at ANL-E, and carry out other related duties.

laser service personnel – person(s) employed by a recognized laser manufacturer or service contractor who may enter an LCA for the sole purpose of installing or servicing laser equipment.

LCA supervisor – a person appointed by a DD/DH who has primary responsibility for the safety of laser operations within a specific LCA. The position is not necessarily the same as the line supervisor of the authorized laser users of the LCA.

maximum permissible exposure (MPE) – the maximum level of laser radiation that will not result in adverse biological changes in the eye or skin, as specified in ANSI Z136.1.

scientific collaborator – a person who is not an authorized laser user, but may have a need to work in proximity to the laser beam while participating in experimental work.

spectator – an individual who observes or watches a laser or laser system in operation, and who may lack appropriate safety training or medical screening.

specular reflection – a mirror-like reflection.

visitor – a person who is not an authorized laser user or scientific collaborator, and has no official need to view the laser in actual operation when entering the LCA.

APPENDIX B

HAZARDS ASSOCIATED WITH LASER USE

Most lasers are capable of causing eye injury to anyone who looks directly into the beam or specular reflection. Even diffuse reflections of a high-power laser beam can produce permanent eye damage. High-power laser beams can burn exposed skin, ignite flammable materials, and vaporize materials, possibly releasing hazardous fumes, vapors, or gases. The equipment and optical apparatus required to produce the lasing action and control and direct the laser beam may introduce additional hazards. These hazards may include high voltage, high pressure, cryogenics, noise, radiation, and toxic fluids.

All lasers sold in the U.S. since 1976 must have a label affixed to them by the manufacturer that describes their hazard class.

Class 1 lasers cannot cause an eye injury under any condition of exposure to the beam, so no controls are required.

Class 2 lasers can cause retinal injury as a result of prolonged exposure to the direct or specularly reflected beam; however, a pain aversion response offers protection from accidental exposure injury, so controls normally are not required. Class 2 alignment lasers, most laser pointers, and bar code scanners are examples of common class 2 laser uses that do not require controls.

Class 3 lasers (both Class 3a and Class 3b) can cause eye injury from brief viewing of the direct beam or its specular reflection, and the pain aversion response cannot be relied upon for protection from injury. Class 3 lasers normally will not produce hazardous diffuse reflections, and they normally are not skin burn hazards or fire hazards. See Section 6.2.5 for specific requirements for class 3a, 3b, or class 4 lasers. Class 3a laser pointers are prohibited for use in lectures or open demonstrations and are normally approved for use only in controlled laboratory applications.

Class 4 lasers can cause eye injury from the briefest of exposures to the direct or specularly reflected beam. Class 4 lasers can produce hazardous diffuse reflections. Class 4 lasers are skin burn hazards and fire hazards. See Section 6.2.5 for specific requirements for class 3 or class 4 lasers.

Class 4 lasers can ignite flammable materials and cause painful skin burns. Class 4 lasers can also vaporize targets or beam stops, creating an inhalation hazard. Local exhaust

ventilation should be used to remove hazardous vapors (see Section 7.11, Ventilation and Air Cleaning).

Electric shock and burns that result from input power or capacitor discharge can cause serious injury or death. Appropriate electrical safety practices as prescribed in Section 7.1, Control of Hazardous Energy and Lockout/Tagout, and Section 9.1, Electrical Safety, must be employed when working with or near high voltage laser circuits with exposed terminals in excess of 50 volts. This includes obtaining a form ANL-211, Hot Work Permit (Electrical), when necessary, and employing a CPR-trained safety watch when the permit so stipulates.

Laser dyes and solvents may be hazardous by inhalation, ingestion, or skin absorption. Consult an industrial hygienist with chemical safety expertise to determine proper handling procedures.

Other non-beam hazards that may be encountered in laser operations include:

- Ignition of flammable or combustible materials in the beam path;
- Toxic or caustic gas releases;
- High-pressure gas systems;
- Potential x-ray exposure;
- Intense UV light exposures; and
- Hazardous noise levels.

APPENDIX C

LASER PERSONNEL CATEGORIES

Workers entering a posted Laser Controlled Area (LCA) are classified into one of the following categories, depending upon qualifications and work duties:

- Authorized laser user
- Scientific collaborator
- Spectator
- Visitor
- Laser service personnel

An authorized laser user is a person who will work directly with, or in close proximity to, the beam path of class 3b or class 4 lasers. This includes those who operate and adjust the laser, adjust optical components in the beam path, perform alignments, and place samples in the beam.

- *Qualifications*: Completion of ESH120 laser safety training, ANL-E medical examination for laser users and any required LCA-specific training. Approval by the LCA supervisor as indicated on the required Standard Operating Procedures (SOP) document.
- *Safety restrictions*: Fully qualified to perform procedures specified by the SOP and approved by the LCA supervisor. Must obtain permission from the LCA supervisor before operating a laser system.
- *Responsibilities*: Must operate lasers in a manner consistent with the requirements of this section and any specific operating procedures. May be required to escort and observe laser service personnel, issuing stop work request if warranted.

A scientific collaborator is a person who may participate in a laser experiment in a limited way, such as inserting and removing samples, but who does not operate, align, or adjust the laser system. The actions and safety of a scientific collaborator while within the LCA are the direct responsibility of the LCA supervisor.

- *Qualifications*: Depending on the nature of the participation, and upon specific approval by the LCA supervisor, may be offered the opportunity to take the ESH 120 laser safety course.

- *Safety restrictions*: Will not be permitted to control any laser beam in any fashion, including the insertion or adjustment of optical elements. Must not handle or manipulate any laser in the LCA. Must be accompanied and supervised at all times in the LCA by an authorized laser user. Must not be present in the LCA while a laser or beam alignment is being performed. Must be wearing fully protective laser eyewear (optical density sufficient to protect against accidental full beam exposure) at all times while inside the LCA, unless lasers have been locked out and the LCA supervisor has given permission to remove the protective eyewear.

- *Responsibilities*: Must work specifically under the direction of the LCA supervisor.

A spectator is a person who has an official need to observe a laser system in operation, but is not an authorized laser user or scientific collaborator, and may lack appropriate safety training and medical screening.

- *Qualifications*: Approval by the LCA supervisor and accompaniment by an authorized laser user.

- *Safety restrictions*: Will not operate any laboratory equipment, including laser system components. Must wear fully protective laser eyewear at all times inside the LCA unless all lasers have been locked out and the LCA supervisor has given permission to remove the protective eyewear. Must be positioned so as to be fully shielded from any direct line-of-sight view of any portion of unshielded beam. Must observe from viewing positions directed by the LCA supervisor. All beam enclosure devices must be fully in place while the spectator is present. No alignments will be performed in the presence of the spectator.

- *Responsibilities*: The spectator must follow the direction of the LCA supervisor, including the wearing of protective equipment and positioning for viewing. Any safety concerns the spectator may have should be communicated immediately to the LCA supervisor. The LCA supervisor is responsible for the actions and safety of a spectator while within the LCA.

A visitor is a person who enters an LCA with no official need to observe the laser in operation. This visitor classification would apply to all individuals who are touring or inspecting laboratories, performing building maintenance, or carrying out custodial tasks.

- *Qualifications*: Permission of the LCA supervisor, higher level line supervisor, divisional ES&H coordinator, or DD/DH. Notification of entry to the LCA supervisor.

- *Safety restrictions*: The laser circuitry must be disabled at all times when a visitor is present, so that the beam may not be turned on easily.

- *Responsibilities*: The visitor and the person giving entry permission must be certain that the LCA supervisor has been notified and that the laser systems have been disabled before any entry. The person giving entry permission is responsible for the actions and safety of a visitor while within the LCA.

Laser service personnel are technicians or engineers from recognized laser manufacturers or service companies who install, service, or repair laser systems. Normally on site for less than one week at a time.

- *Qualifications*: Employees of recognized laser firms. Must have completed the appropriate ESH contractor service orientation.

- *Safety restrictions*: For class 3B and 4 lasers, the vendor must have submitted in advance a high risk job contractor job safety analysis (JSA form) which has been approved as required. Service personnel must be accompanied at all times in the LCA by an authorized laser user.

- *Responsibilities*: Must observe all safety precautions in the SOP and as directed by LCA supervisor. Must respond immediately to stop work request by an ANL-E employee. The ANL-E escort is responsible for the actions and safety of laser service personnel within the LCA.

ANL-E LASER SAFETY CHECKLIST

Inspection date: _____

LCA location: Bldg ._____ Room _____
LCA Supervisor: _____ Division _____
IHID #s: _____
Highest Laser Classification: _____

Entry Control Type

- ☐ Non-defeatable door interlocks
- ☐ Defeatable door interlock/s
- ☐ Administrative controls only

OK?	Item	Comments
☐	**SOP DOCUMENT CONTENTS**	
☐	LCA Supvisor identified	
☐	Authorized Personnel identified	
☐	Laser descriptions correct	
☐	Hazard Analysis Section	
☐	Modes (alignment, normal) described	
☐	Controls Section	
☐	Entry controls	
☐	Eyewear	
☐	Specific to each laser	
☐	Minimum O.D.s	
☐	Chart (multiple laser types)	
☐	Alignment mode precautions	
☐	Beam enclosure	
☐	Power control (unauthorized operation)	
☐	Op & alignment procedures	
☐	Interlock testing–proced & schedule	
☐	Eyewear inspection	
☐	Justifications for any variations	
☐	Signature approvals	
☐	Posted at entry	
☐	**INVENTORY**	
☐	IHID tags	
☐	ANL inventory data correct	

(To page 2)

ANL-609 (6-01)

LASER SAFETY CHECKLIST Page 2

Bldg ._____ Room _____

OK?	Item	Comments
☐	SAFETY FEATURES	
☐	Interlocks	
☐	In place	
☐	Test log	
☐	Warning Lights (not required for non-defeatable interlocks)	
☐	LCA enclosure	
☐	Eyewear	
☐	Condition	
☐	Adequate numbers	
☐	Meets min. OD/wavelength reqmts.	
☐	Inspection log	
☐	Beam path enclosures	
☐	Exceptions (if applicable)	
☐	Panic button (Class 4) w/sign	
☐	"ON" indicator inside LCA	
☐	Grounding strap (dye lasers)	
☐	Vent hood setup (dye mixing)	
☐	Satellite Accumulation Area	
☐	PERSONNEL	
☐	Laser Safety Training current	
☐	Baseline eye exams	
☐	Electrical Safety (as appropriate)	
☐	CPR (as appropriate)	

OTHER/COMMENTS:

ALL REQUIREMENTS SATISFIED FOR LASER OPERATION?

☐ YES ☐ YES–For temporary use not to exceed 90 days (see comments above) ☐ NO

COMPLETED BY:

_____ _____

☐ ANL-E Laser Safety Officer ☐ Deputy Laser Safety Officer Date

Other (please specifiy): _____ Expires _____

Argonne National Laboratory

Name of Division

Standard Operating Procedures For

(*Location of LCA, indicate bldg. & room*)

Laser Controlled Area

ver #. (*Indicate version number*)

(*Current Date of Version*)

Prepared by:

LCA Supervisor:

NAME OF LCA SUPERVISOR

Name Printed Signature Date

Reviewed by:

ANL-E Laser Safety Officer or Deputy Laser Safety Officer:

NAME OF LASER SAFETY OFFICER

Name Printed Signature Date

Recommend approval ☐ Yes ☐ No ☐ Conditional

ESH/QA Coordinator:

NAME OF ESH/QA COORDINATOR

Name Printed Signature Date

Approved by:

Division Director:

NAME OF DIVISION DIRECTOR

Name Printed Signature Date

ANL-610 (6-01)

INTRODUCTION

Indicate in a paragraph the physical location of this LCA; include the building, room, etc. Provide a brief description of the overall mode of operation of this LCA, indicating the total number of active lasers. If diagrams or floor plans are available for this LCA, the descriptions should be noted here, and included as Appendix A at the end of this document.

LCA SUPERVISOR

Indicate the LCA supervisor, including their badge number and how to contact him/her (i.e., phone extension and email address if available).

AUTHORIZED USERS

While an important part of your SOP, this list of all Authorized Users, including their badge number, should appear as Appendix C of this document and users should sign the document to verify that they have read and understand the Standard Operating Procedure for the LCA. Appendix C can be updated as frequently as needed.

SCIENTIFIC COLLABORATORS & SPECTATORS

Define what a Scientific Collaborator is and under what conditions will they be allowed in your LCA. A collaborator is a scientific or technical visitor who handles some other (non-laser) part of the experiment. Define under which circumstances they are allowed in and what they will do, what eyewear they must have etc.

Define what a spectator is and under what conditions will they be allowed in your LCA. A spectator is a visitor who does not participate in the experiment. Define circumstances under which they are allowed in and what they will do. Typically, they will be allowed in only if lasers are off or all beams are enclosed.

NORMAL LASER OPERATION

Indicate the General Setup of your LCA. This should provide a detailed description of what the essential system consists of; how it is set-up on the tables; how the output is directed; where the optical components are located; how the beam is terminated; where the emergency stop is located, if applicable; how and where the beam is enclosed, or unenclosed; and the height of the beam. Unenclosed beams have to be fully justified by the needs or nature of the experiment.

List each laser in use in your LCA: 1) Indicate the Industrial Hygiene Identification Number (IHID); 2) Indicate the ANL Property #; 3) Indicate the serial number; 4) Indicate the class of the laser; 5) Indicate the type of eyewear appropriate for that laser. For each laser, provide a brief paragraph describing the essential technical specifications, such as wavelength(s), power,

Standard Operating Procedure for
(Location, bldg./room)
LCA Supervisor: (Name)

Ver. #
Date: 6/1/2001
Page 3 of 6

repetition rate, beam shape and dimensions, divergence, O.D. of eyewear needed for protection from a direct hit. An example follows:

Example:
Lambda Physik COMPex 102 Excimer Laser

IHID	Property #	Serial #	Class	Eyewear
02346	P065553	9512E4280	4	O.D. 7

This laser is capable of pulsed operation up to 20 Hz and can emit a variety of UV wavelengths that depend on the excimer gas, as listed below:

Gas:	F_2	ArF	KrF	XeCl	ZeF
Wavelength (nm):	157	193	248	308	351
Pulse energy (mJ):	10	200	350	200	150

The laser is currently optimized for fluorine operation, and thus its use with XeCl is not recommended at this time. The main purpose of this laser is to photodissociate the sample molecular beam, although it can be used to pump one of the dye lasers (IHID# 1234 and #44443 above).

EYEWEAR SECTION

This section contains the calculation or specification for the calculation of O.D. for eyewear appropriate to your operating conditions. If several types of eyewear are normally used in the LCA, indicate the different types and the laser for which they are needed. If there is a simple solution for eyewear (such as eyewear X is always worn when laser Y is on) list it here. However, if it is complex consider providing the information in a table or graph form, (as Appendix B to this document) indicating the types of eyewear appropriate to the lasers used in this LCA. The supervisor should consider posting such a graph or chart in the lab. Also, indicate spectator and collaborator eyewear here, if different than that of the operator.

Note that eyewear shall be physically inspected at least annually for damage or deterioration. Indicate your testing procedure including intervals and your procedures for logging of this practice.

ALIGNMENT HAZARD CONTROL

Indicate the General Setup for the alignment procedure of your LCA. Describe internal (manufacturer procedures can be deferred to the respective laser manuals) and external alignments of the beams separately. If possible, break down this information according to each laser.

Describe in adequate detail alignment procedures, listing the changes in set-up that may occur. Provide a detailed description of changes that are made to shielding, housing etc., to access the beam, how is alignment done, and what is monitored/viewed to optimize alignment etc.

Standard Operating Procedure for
(Location, bldg./room)
LCA Supervisor: (Name)

Ver. #
Date: 6/1/2001
Page 4 of 6

Indicate what type of eyewear is used if different than normal, and give a calculation supporting a lower O.D. Include spectator and collaborator policy during this procedure here.

Indicate all other non-routine work here.

Example:
Laser 02346 - Lambda Physik COMPex 102 Excimer Laser This laser is factory aligned and generally does not require any addition internal adjustments. Routine minor adjustments are to be performed at the lowest power feasible and in complete accord with the manufacturer's maintenance manual.

LASER HAZARD CONTROL

1. *Door Interlocks:* Describe in detail all interlock systems used to control entry to the LCA. Indicate your testing procedure, including intervals, and how you document this practice. Note that interlocks must be tested at least quarterly for proper operation.

2. *Window/Door Covers:* Describe all covers and materials used for control. Indicate your testing procedure including intervals and your procedures for logging of this practice.

3. *Warning Signs:* Describe all signs posted, especially at the entrance for control. Indicate your testing procedure including intervals and your procedures for logging of this practice.

4. *Unauthorized Operation (Class 4):* Describe the methods used in the LCA to prevent unauthorized operation (e.g., lab is locked when nobody is in, and/or laser keys removed, etc.)

5. *Invisible Laser Beam "ON" Indicator:* Describe methods used in the LCA to indicate that invisible beams are on.

6. *Emergency Cut-off Switch (Class 4)*: Describe the panic switch operation and location in the LCA.

Provide some general discussion regarding the type of activities that are permitted when the laser is on under normal conditions. Discuss proper training, adequate care, and laboratory practices. Include the additional use of computers and monitors and the positioning and/or shielding of these items. Note in this area the additional hazard controls used for chemicals, high voltage, hot plates, glassware, cryogenic fluids, and other equipment.

CONTROL OF ADDITIONAL LCA HAZARDS

Indicate other possible hazards associated with the lasers in your LCA.

Standard Operating Procedure for
(Location, bldg./room)
LCA Supervisor: (Name)

Ver. #
Date: 6/1/2001

Example:
Some of the lasers listed above pose additional hazards over and above those associate with the laser light output. These include:

Laser 02346 - Lambda Physik COMPex 102 Excimer Laser The high voltage circuitry associated with this laser is contained within the laser cabinet, and cannot be accessed except by removing the cover (as performed during maintenance and repair). An interlock switch on the cabinet prevents the high voltage circuits from charging when the cover is opened, except when this switch is deliberately defeated.

Compressed gases are used to generate the lasting medium for this laser. Compressed He, Ne , Ar, Kr, Xe, 5% Hcl - 1% H_2 in He, and other necessary gases or mixture are contained either in full-size or reduced-size standard high pressure tanks fitted with appropriate regulators. Typically, the tanks are located in the dedicated space along the east wall. At all time the tanks are rigidly secured using standard straps and/or chains. When appropriate form the safety viewpoint, the smaller size cylinders can be located in the adjacent hood. All corrosive gases are fed into the laser inlet using tubing made of compatible materials. In particular, tubing used for mixtures containing elevated concentrations of F2 has to be properly passivated prior to routine use.

ASSOCIATED CHEMICAL HAZARD CONTROL

List chemicals used in this LCA include a list MSDS numbers, or attach MSDS's to the end of the document (not required to attach MSDS sheets). If you prefer, provide the chemical list section from your Project Review Document as an Appendix. Indicate in this section if there is a registered Satellite Waste Accumulation Area in the LCA and where it is located. Discuss any site-specific chemical hazards for this LCA in this section.

CONTROL OF EMERGENCIES & ABNORMAL SITUATIONS

Describe some of the general emergencies (fire, explosion, personal injury, etc.,) that are possible with the site-specific hazards in the laboratory. This section provides some guidance for other extraordinary situations that may require immediate action in order to avoid the possibility of personal injury or equipment damage.

In any emergency or unusual situation, the main rule of thumb is to act conservatively, and protect personnel and equipment as much as possible. Action can be taken only if it is safe to do so. If a situation is out of your control, get help by dialing 911.

APPENDIX A

FLOOR PLAN DIAGRAM

If diagrams or floor plans are available for this LCA, the descriptions should be noted and included.

Standard Operating Procedure for
(Location, bldg./room)
LCA Supervisor: (Name)

Ver. #
Date: 6/1/2001
Page 6 of 6

APPENDIX B

EYEWEAR SECTION

Shall contain the calculation of O.D. for eyewear; include a chart or graph indicating the types of eyewear appropriate to the lasers used in this LCA.

APPENDIX C

AUTHORIZED USERS

List all Authorized Users, including badge numbers. Users should sign the document to verify that they have read and understand the Standard Operating Procedure for the LCA.

NAME (printed)	**BADGE**	**SIGNATURE**

ESH 120 LASER SAFETY CHALLENGE EXAM HANDOUTS:

2. ESH120 Slides and Charts

LASER SAFETY

ESH-120

Bruce Murdoch, Laser Safety Officer
EQO – Industrial Hygiene
Building 200 / L158
2-4905

Ralph Hinterman, Dpty. Laser Safety Officer
EQO - Industrial Hygiene & Safety
Building 200 / C102
2-7853

Rev. 08/02

Course Preview

- Accident Cases
- Laser Basics
- Reflections
- Bioeffects -- Eye and Skin
- ANSI Standard Exposure Limits
- Ultrafast Pulsed Lasers
- VIDEO - 20 min
- FDA/CRDH Laser Classifications
- Hazard Controls
- Non-Beam Hazards
- Important Rules and Procedures
- Responsibilities
- Personnel Classifications
- QUIZ

Who Works with Lasers?

- Research Personnel
- Trades
  - Surveying
  - Construction
  - Welding and cutting
- Photographers

Who Needs Laser Safety Training?

- Everyone who works with Class 3 or 4 Lasers
- Supervisors of Class 3 or 4 laser users
- Division Safety /ES&H Coordinators

1996 Incident Summaries

Accident summaries from the Rockwell Laser Industries Laser Accident Database. Selecting a highlighted entry will provide a detailed summary of the incident.

1996 - *A listing of 16 laser incidents*

RLI No.	Site of Incident	Laser Type	Accident Subject
313	University Physics Lab (CA)	Diode	Researcher
	Brief eye exposure of diode laser gave afterimage		
312	University Research Lab (A)	Ti-Sapphire	Research Scientist
	Off-axis beam causes macular burn in left eye		
311	National Lab (CA)	HeNe	Security Employee
	Guard views HeNe beam reflection gets afterimage		
309	University (IN)	CO2	Plexiglas Enclosure
	Fire damage to laser and sample enclosure box		
307	University (MI)	Ti-Sapphire	Graduate Student
	Mirror backscatter causes hemmorrage & blindspot		
305	Hospital (PA)	Doub. Nd:YAG	Patient
	First-degree burn of mouth from fiber sheath fire		
304	High School Classroom (WI)	Diode (pointer)	High School Teacher
	Teacher gets 10 day afterimage from laser pointer		
303	High School Rally (WI)	Diode (pointer)	Cheerleader
	Vision loss from laser pointer exposure		
286	University (CA)	Argon	Researcher
	Vision blank-spots after "target area" viewing		
285	National Lab. (IL)	Nd:YAG	Technician
	Electrical shock from fans even when unit off		
283	University (CA)	HeNe	Student
	Photophobia in right eye after beam misalignment		
282	Manufacturing Plant (CO)	Diode	Technician
	Technician received eye exposure from diode laser		
281	Industrial Plant (AZ)	Nd:YAG	Plant worker
	Worker received severe hand burn		
280	University (RI)	Nd:YAG	Graduate student
	Picosecond laser beam caused retinal injury		
278	Medical Facility (MI)	Pulsed Dye	Laser Technician
	Serviceman gets eye laser exposure when misfires		
274	University (MA)	Ti-Sapphire	Lab Technician
	Permanent macular burn with one pulse from laser		

1996 Laser Accident Case Studies

#307: Backscatter from mirror causes hemorrhage and foveal blindspot.

A 26 year old male Student aligning optics in a university chemistry research lab using a "chirped pulse" Titanium-Sapphire laser operating at 815 nm with 1.2 mJ pulse energy at 1 KHz. Each pulse was about 200 picoseconds. The laser beam backscattered off REAR SIDE of mirror (about 1% of total) caused a foveal retinal lesion with hemorrhage and blind spot in central vision. A retinal eye exam was done and confirmed the laser damage. The available laser protective eyewear was not worn.

#280: Graduate student receives macular lesion from picoseond laser.

Picosecond Nd:YAG pulsed laser operating at 1064 nm was on a laser optics table. Beam directed from one table to another across an isle. The beam went onto the second table, where it was directed onto a liquid sample holder. Here, apparently, the beam was bigger than the liquid sample holder the edges of the beam went pass the sample bottle - then off that table into the room area where a Strip Chart Recorder (SCR) was located.

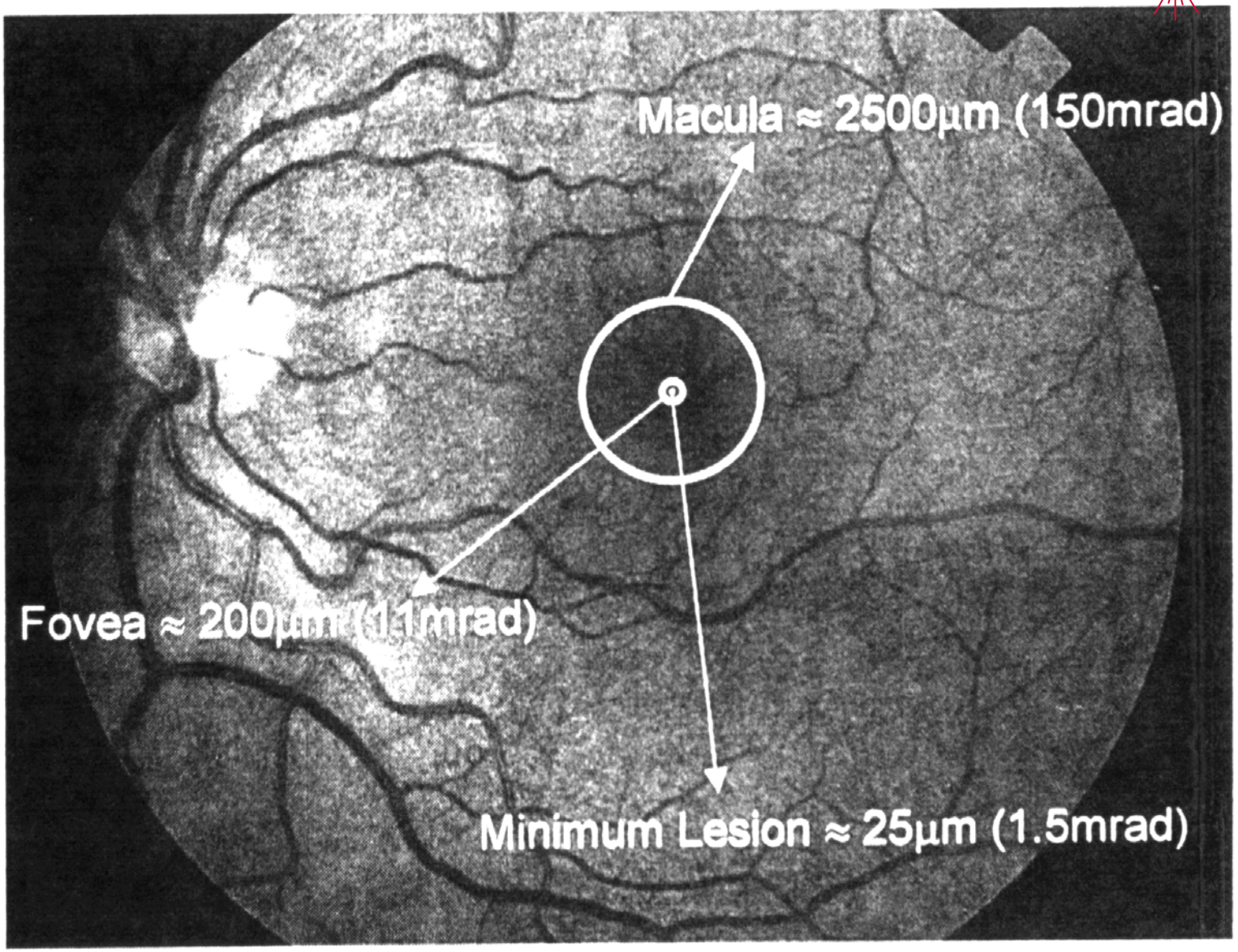
A graduate student working on the experiment looked at the SCR and it was here that the student received the beam into the eye. It was estimated that he received about 10% of the beam into the eye. The student reportedly a "heard a popping sound" which was followed by a white spot in the vision center. The professor took the student to an eye doctor for a retinal exam which confirmed the burn exposure. The student did not experience shock. The beam caused a retinal burn. The student now complains that his "eyes get tired" while reading.

#274: Technician receives retinal burn with a single Ti-Sapphire laser pulse.

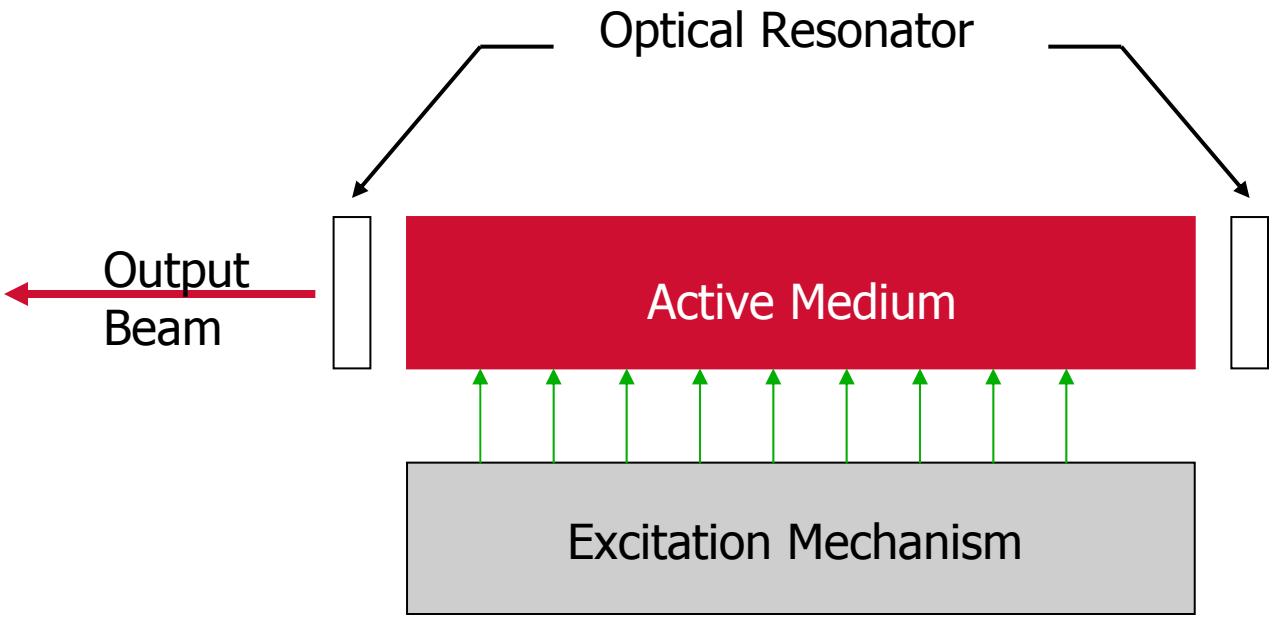
Laser lab technician was working without laser protective eyewear. He was exposed to a single 7 ns pulse at a pulse energy of 10-50 μJ. In the setup, the beam was directed onto a metal "test slide" from the power meter manufacturer. This was used to test whether the beam would harm the power meter. The slide was accidentally tilted so-as-to reflect the beam into technician's eye (assume about ~4% reflection). At time of exposure the person perceived a bright flash that persisted (with eyes closed) as if he had looked at the sun. There was no pain nor did the person go into shock. There was eyewear was available but not for the 806 nm wavelength in use.

Back to 1996 Incident Summaries

« LaserNet Homepage


Macula ≈ 2500µm (150mrad)
Fovea ≈ 200µm (11mrad)
Minimum Lesion ≈ 25µm (1.5mrad)

LASER Components

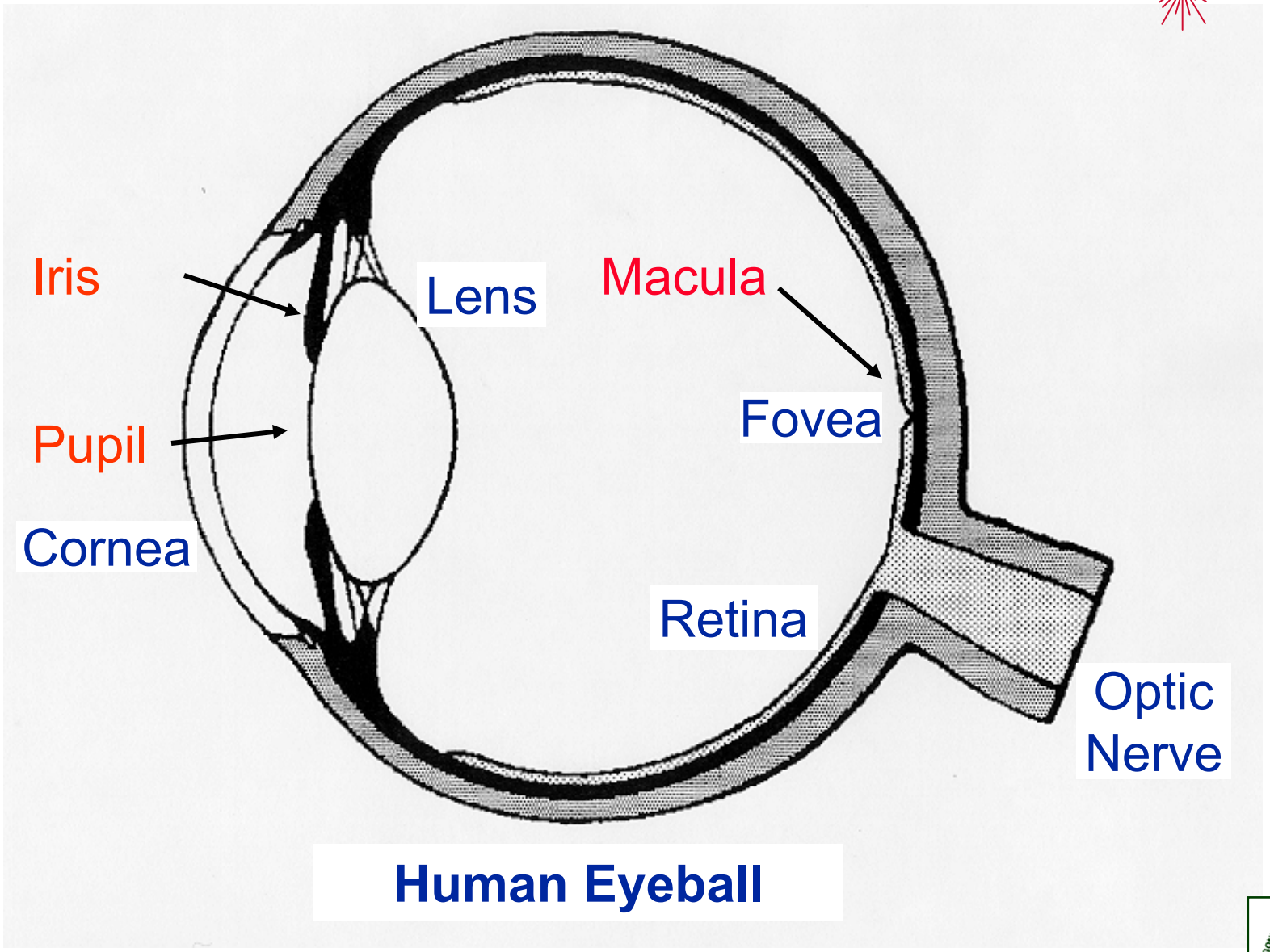


Light
Amplification by
Stimulated
Emission of
Radiation

Reflections

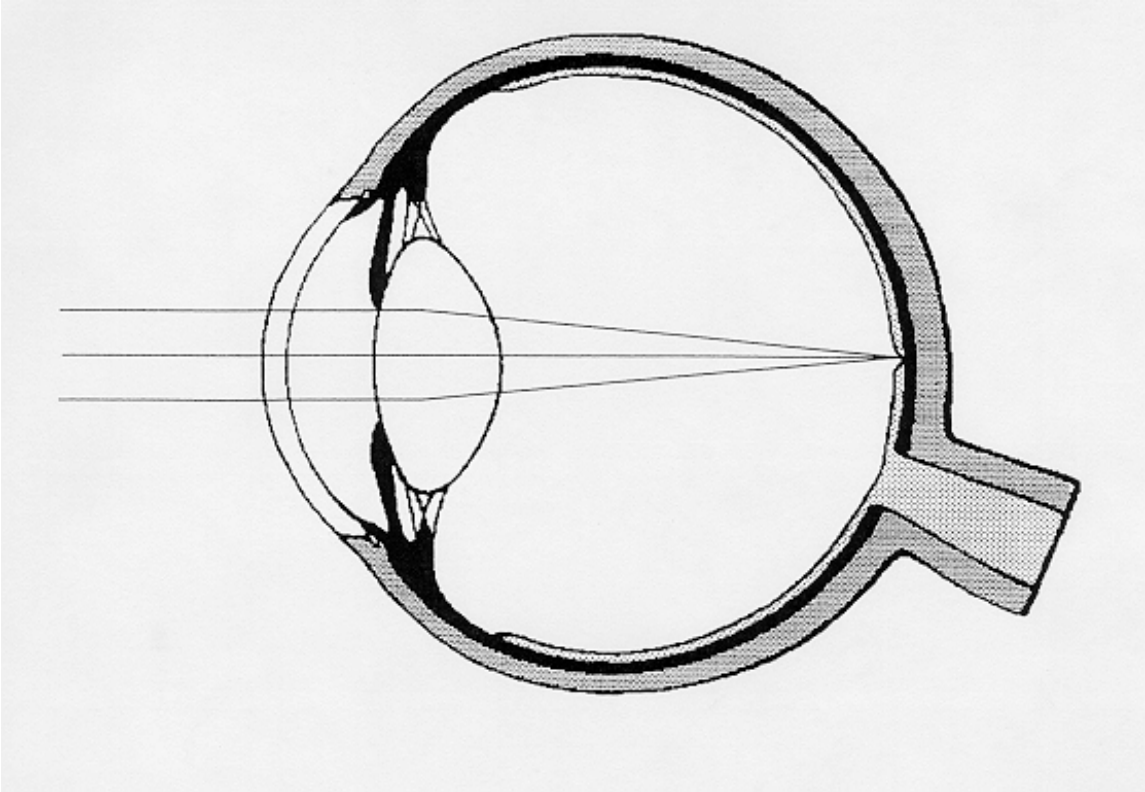
- Specular
  - Mirror-like
  - Glass surfaces reflect 4% or more, up to 100%
  - Lenses, cells, windows
  - Shiny tools
  - Watch crystals
  - Jewelry
  - Even dull surfaces can be specular in the IR

- Diffuse
  - Illumination of dull surfaces
  - Beam stops
  - Heat-resistant screens
  - Even shiny surfaces can be diffuse in UV



Human Eyeball

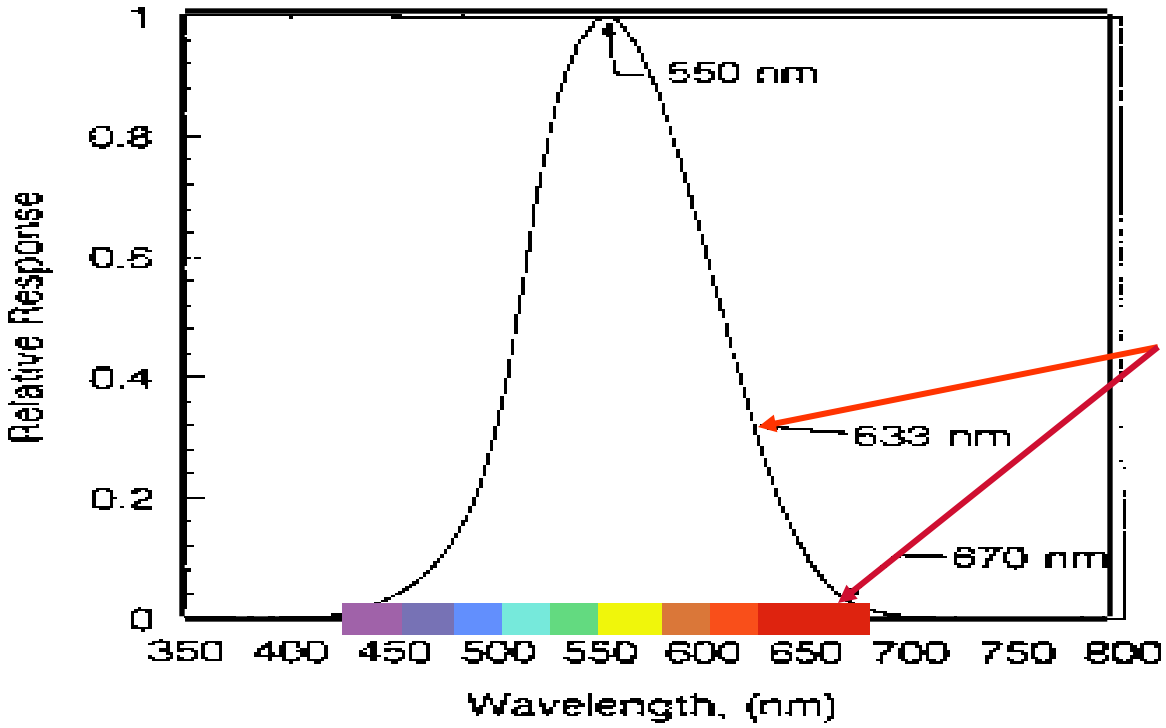
Retinal Irradiance



Retinal irradiance for a 1 mW laser beam entering the eye:
Entire beam focussed to a spot 20 um diameter, producing I_r=300 W/cm^2

For the noonday sun, I_r=10 W/ cm^2

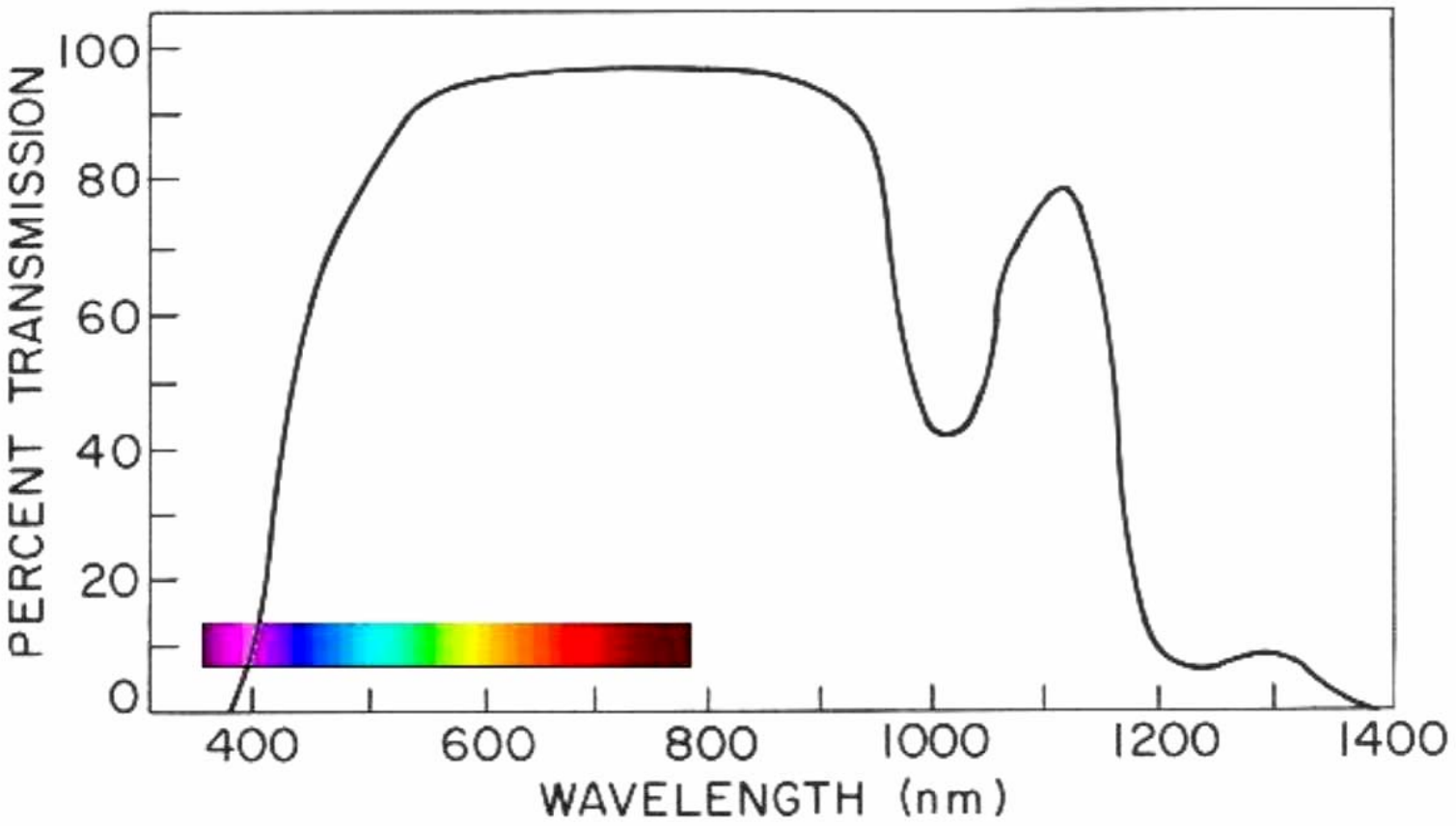
The eye's response to the visible spectrum



Laser pointers

FIGURE 1. CIE photopic (daylight color vision) relative spectral sensitivity function V_λ. Note the significant difference in visibility of the He–Ne versus the 670 nm diode laser.

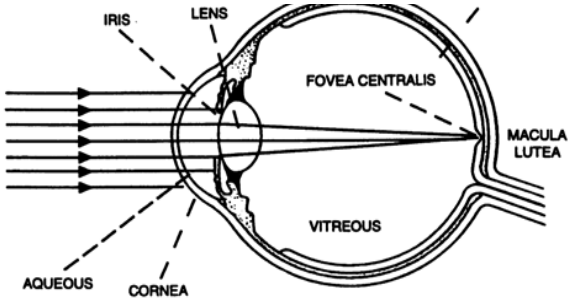
How much light reaches the retina?



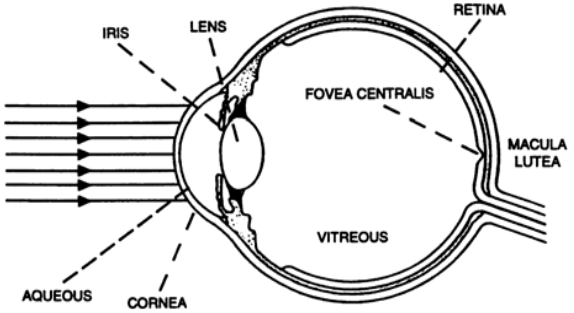
TRANSMISSION OF THE OCULAR MEDIA

OCCULAR ABSORPTION SITE vs WAVELENGTH

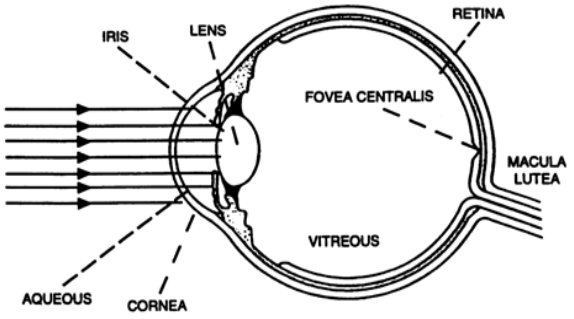
Visible and
Near-Infrared
(400 - 1400 nm)
Radiation



Mid-Infrared and
Far-Infrared
(1400 nm - 1mm)
and
Far-Ultraviolet
(180 nm - 315 nm)
Radiation

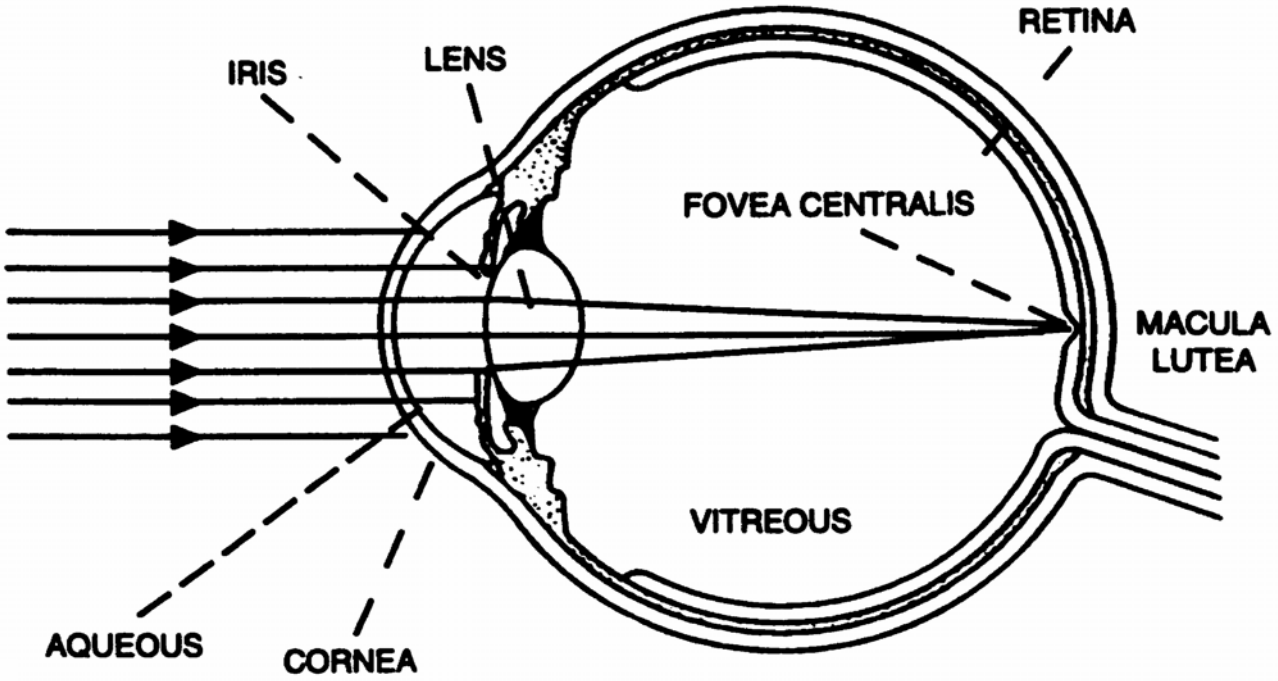


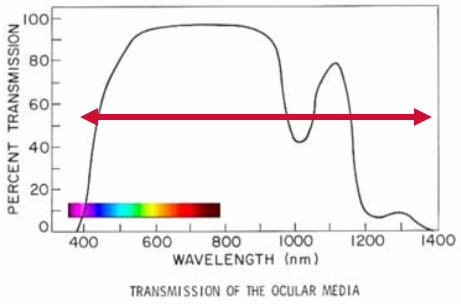
Near-Ultraviolet
(315 - 390 nm)
Radiation



Ocular Absorption Site vs Wavelength

Visible and Near-Infrared (400 - 1400 nm) Radiation



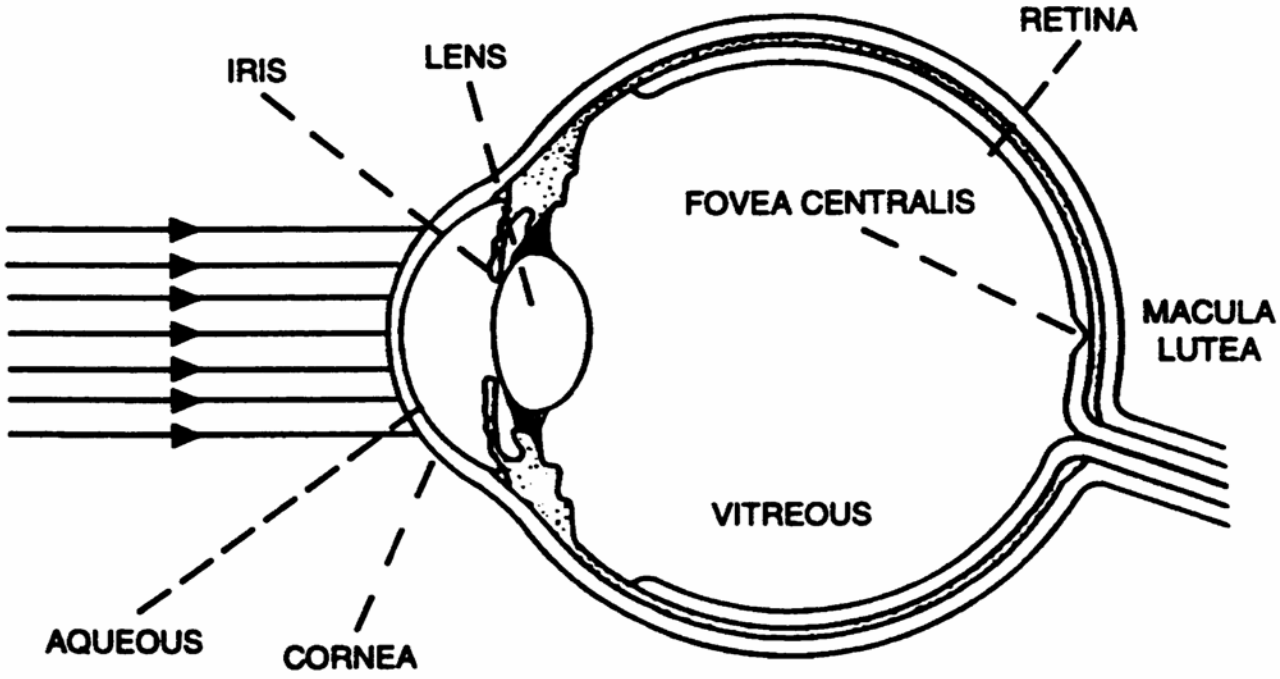


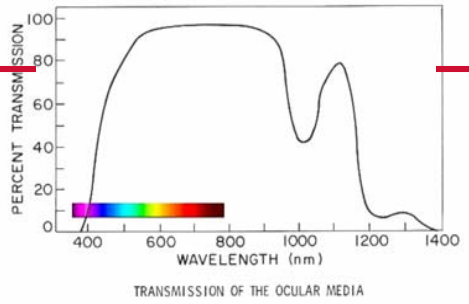
TRANSMISSION OF THE OCULAR MEDIA

rajah

Ocular Absorption Site vs Wavelength

Mid-Infrared and
Far-Infrared
(1400 nm - 1mm)
and
Far-Ultraviolet
(180 nm - 315 nm)
Radiation



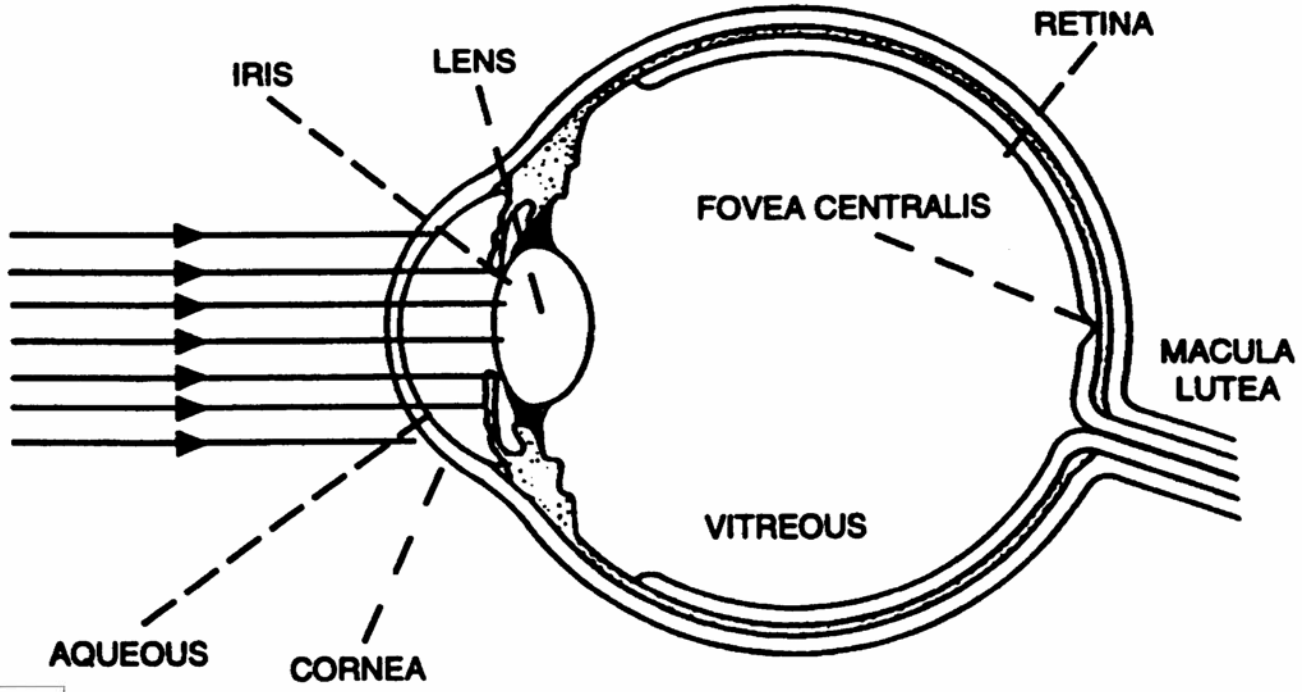


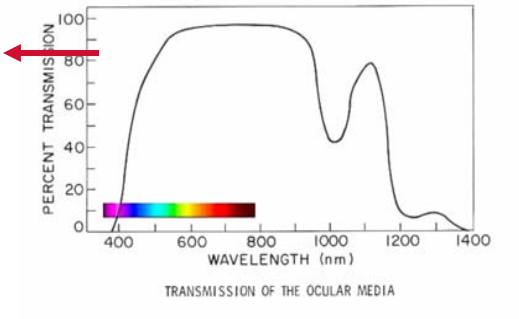
TRANSMISSION OF THE OCULAR MEDIA

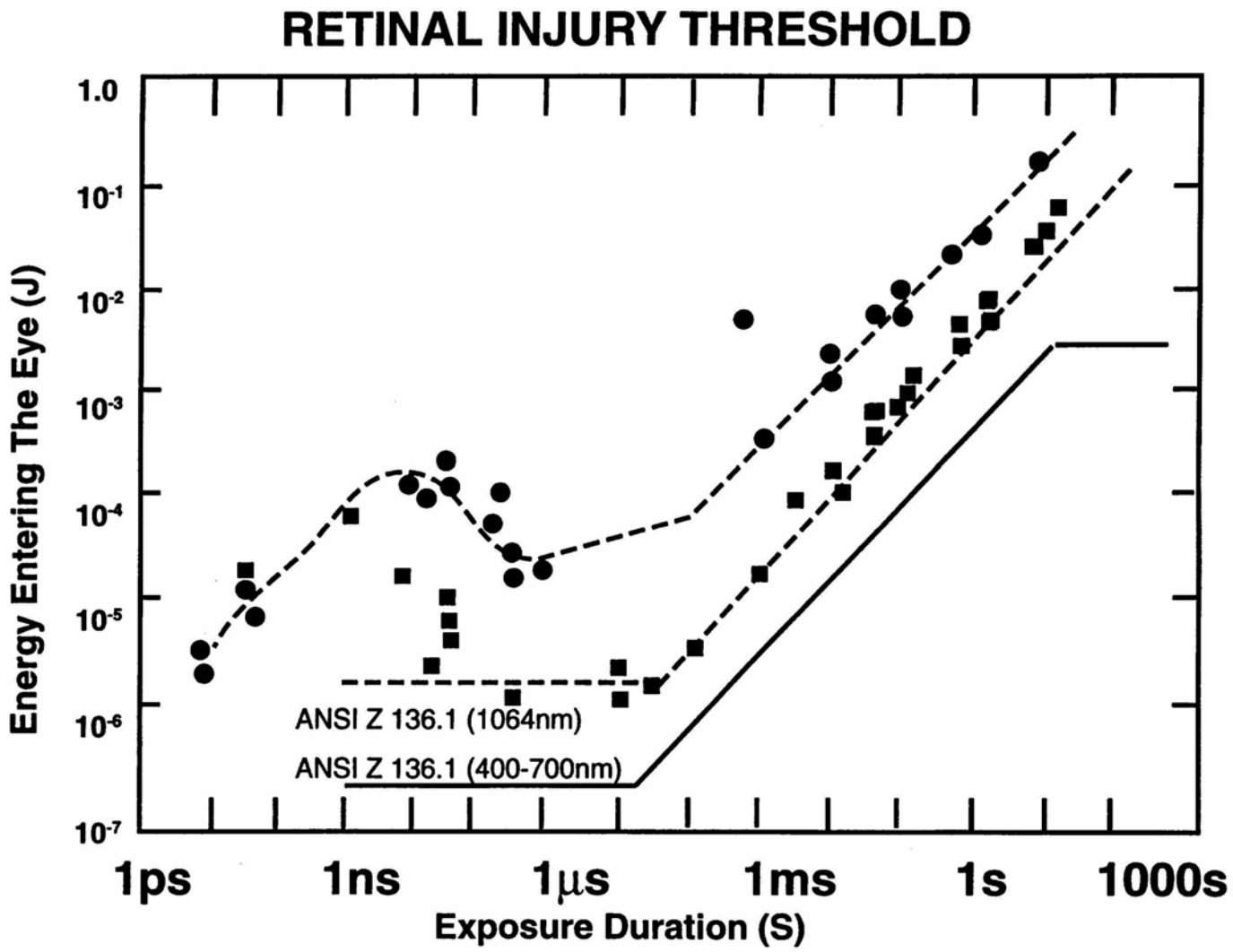
rajah

Ocular Absorption Site vs Wavelength

Near-Ultraviolet
(315 - 390 nm)
Radiation



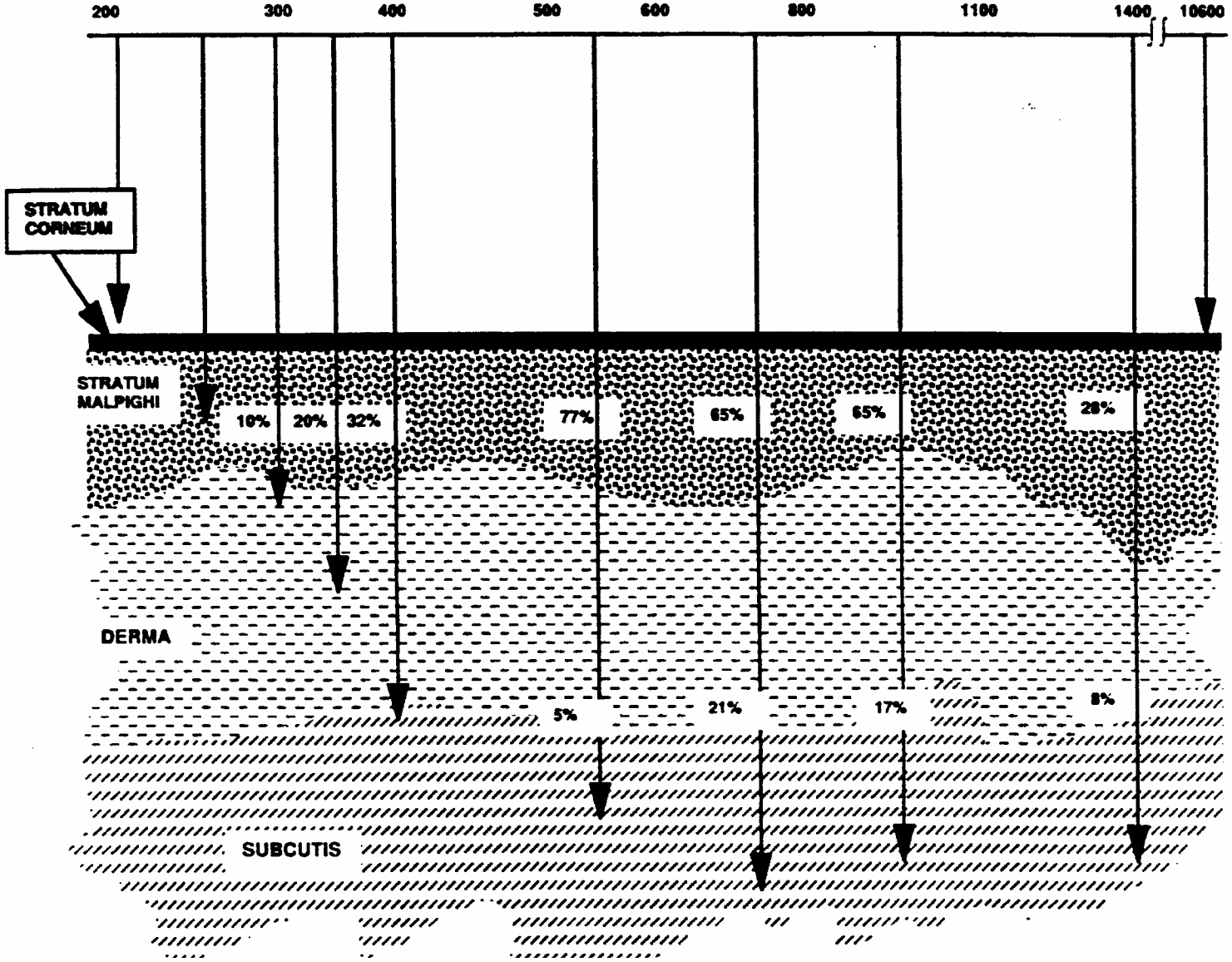




Ultra-Fast Pulsed Lasers

- Pulse widths < 1 nanosecond (10^{-9} sec)
- Bioeffects are enhanced.
- Eyewear dye filters less effective
- Do not trust OD ratings on eyewear!

Skin Effects



rajah

Rules for Exposed Laser Beams

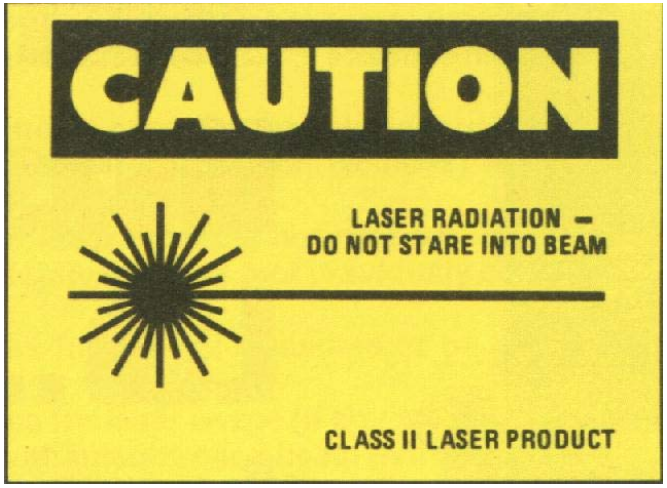
Chapter 6-2

	Class 2	Class 3a	Class 3b	Class 4
No intentional viewing	xxx	xxx	xxx	xxx
No eye level or vertical beams		xxx	xxx	xxx
Posting area		xxx	xxx	xxx
Indicator of invisible beam		xxx	xxx	xxx
Laser safety training		xxx	xxx	xxx
Wear eye protection			xxx	xxx
Careful control of spectators			xxx	xxx
Laser controlled area			xxx	xxx
Interlocked LCA			unattended	xxx
Standard Operating Procedures			xxx	xxx
Eye examination			xxx	xxx
Shield diffuse reflections-UV		xxx	xxx	xxx
Shield diffuse reflections-visible				xxx

Class 1 Laser

- Normally used as components of other devices
- Limits are complex (depend on wavelength), but generally <1 microwatt
- Cannot cause eye injury under any condition of exposure
- No controls necessary

Class 2 Laser



- Laser pointers, alignment lasers, bar code scanners
- >Class 1 but ≤ 1 milliwatt
- Eye injury possible, but pain aversion response will protect from accidental exposure. Accidental eye injury is not possible!
- Laser safety training required only if beam is to be viewed.
- Controls required only if beam is intended to be viewed
- Visible, continuous wave (CW) only

Class 3a Laser

- Surveying, construction, research, instrumentation

- Invisible beam: 1-5X Class 1 limit
  Visible beam: 1-5X Class 2 limit (5 mW max)

- Pain aversion response may not protect against accidental exposure to direct or specularly reflected beams within 15 m, or when viewed with optical instruments.

- Controls and requirements:
  - LSO review, Division approval for all uses and changes
  - No use as laser pointers
  - Public demonstrations require LSO review, Division approval
  - Beam path control
  - Warning of invisible beam
  - Posting
  - Laser safety training

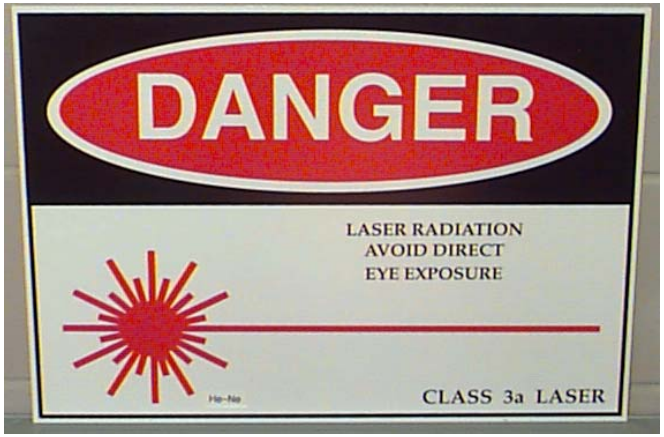
ANSI 3a Laser sub-classifications

Class 3a LOW IRRADIANCE
< 2.5 mW/cm^2

"CAUTION" label
Should not be viewed with optical instruments.
Slight chance of eye injury

Class 3a HIGH IRRADIANCE
≥ 2.5 mW/cm^2

"Danger" label
Can cause accidental eye injury.
Eye protection may be required.



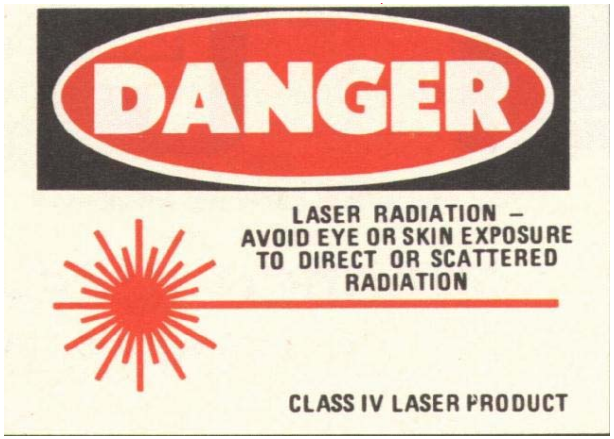
Class 3b Laser

- Research
- CW: > Class 3a but ≤ 0.5 W
- Pulsed: >Class 1 but < 0.125 J @ <0.25 sec

- Eye damage almost certain to occur from direct beam or specular reflection, but diffuse reflections will not be hazardous. No skin burn or fire hazard unless focused.

- Controls and requirements in addition to all for Class 3a
  - Laser controlled Area (LCA)
  - LCA interlocked for unattended operation
  - Standard Operating Procedures (SOP)
  - Protective eye wear whenever possible
  - Eye examination for all users

Class 4 Laser



- Research, laser welding, laser weapons
- >Class 3b
- Eye damage will occur from direct beam and most specular reflections, diffuse reflections may be hazardous, can produce skin burns, fire hazard
- Controls & requirements in addition to Class 3b:
  - Interlocked LCA
  - Panic button (E-stop)
  - Shield diffuse reflections
  - No combustible materials in beam path

Hazard Control Priorities

1, *SUBSTITUTION* - **Less hazardous equipment / process**

2. *ENGINEERING CONTROLS* - **Shields, interlocks,..**

3. *ADMINISTRATIVE CONTROLS* - **Rules, procedures,..**

4. *PERSONAL PROTECTIVE EQUIPMENT* – **Eyewear, …**

Engineering Controls

- Beam enclosures, shields
- Interlocks
- Shutters
- Automatic beam warning
- Video monitoring
- No exposed eye-level (standing or sitting) or vertical beams

Administrative controls

- Authorization to use
- Standard Operating Procedures
- Interlock checks

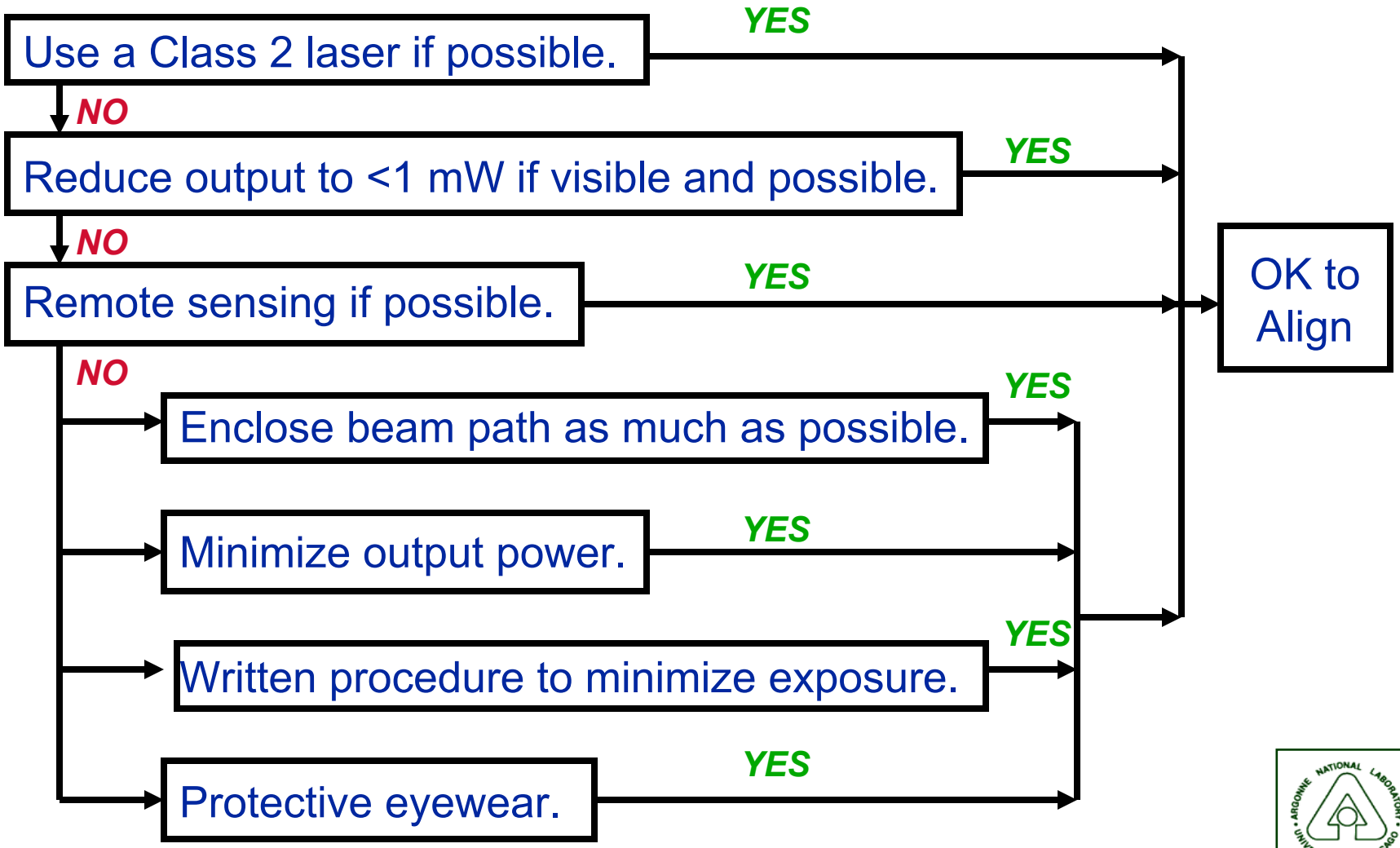
Laser Controlled Areas (LCA)

- Required features include:
  - No escape path for laser radiation
  - Engineered entry control (interlock/auto-warning)
  - Operated by authorized operator
  - Authorized personnel only
  - No work except directly related to laser

Some Important Safety Requirements for Class 3 & 4 Lasers and ANL

1. Beam path should be totally enclosed or shielded from workers.
2. Vertical beams MUST be totally enclosed.
3. Eye-level beams MUST be totally enclosed.
4. Follow alignment safety protocol (part of SOP).
5. Lasers must be reviewed by LSO and approved by Division before beam activation.

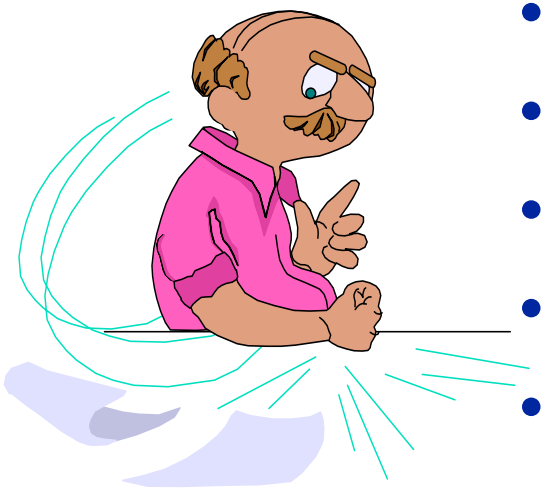
Class 3 & 4 Laser Alignment Safety Protocol



You MUST obtain LSO review And Division approval

- Prior to any use of a new Class 3 or 4 laser
- Prior to moving, loaning or borrowing a Class 3 or 4 laser
- When new users are added to an existing Class 3 or 4 laser
- When a Class 3 or 4 laser installation is modified in any way that may affect its safety
- Whenever a Class 3 or 4 laser is transferred, decommissioned, excessed or destroyed

LCA Supervisor Responsibilities



- Worker Safety
- Safe Practices
- Engineering Controls
- PPE
- Procedures
- Laser registration with LSO
- Notifying LSO for reviews
- Obtain Division Approval
- On-the-Job Training

Personnel Entering an LCA

- Authorized laser user
- Scientific collaborator
- Spectator
- Visitor
- Laser service personnel

Authorized Laser User

- Laser Safety Training, Eye Exam
- Fully qualified for specific LCA
- Approved by LCA Supervisor, named in SOP
- Follow SOP

Training Requirements Authorized Laser Users

ESH121 Low-Power Laser Safety (Classroom)

- Class 2 (recommended)
- Class 3a
- No retraining rqmt

- ESH120 Laser Safety

- Class 3a (option, no retraining rqmt)
- Class 3b/4
- 2-year retraining time
- WWW option for retraining/special

Scientific Collaborator

- May participate in research project
- Directly supervised by LCA Supervisor
- May not operate laser/adjust optics/align
- Must be escorted/use full eyewear
- Laser safety training/eye exam NOT required

Spectator

- Has official need to observe laser operation
- Not a research participant
- Must be escorted by authorized user
- Not present during alignments
- All controls in place
- Laser safety training/eye exam NOT required

Visitor

- Tours, maintenance, etc
- Has no need to be present during laser operation
- Lasers must be disabled
- LCA Supervisor must be aware of entry

Laser Service Contractors Must:

- Submit “High-Risk Job Safety Analysis Form (JSA)
- Attend CSO Training (unless exempted)
- Be escorted by ANL Laser User unless they have had:
  - Laser safety training
  - Eye exams
- Obtain LSO review of planned work and PPE
- Obtain Division approval of planned work
- Comply with stop work requests

Personnel Entering an LCA

- Authorized laser user
- Scientific collaborator
- Spectator
- Visitor
- Laser service personnel

Cardiopulmonary Resuscitation Training (CPR)

- All laser users exposed to high voltage
  - Required by ANSI Z136.1
  - High voltage >50 V
  - Does not include normal handling of power cords, switches, etc.
- Annual retraining required
- User or supervisor arranges with ANL Fire Department 2-6136

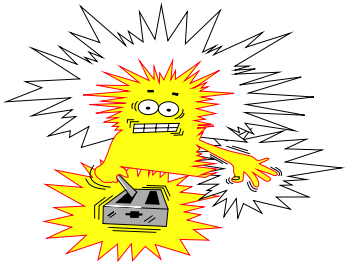
Laser Protective Eyewear

- Not a substitute for engineering controls!
- Not a substitute for administrative controls!
- Back-up protection in case things go wrong
- Not intended for prolonged viewing
- OD rating = Log_{10} (Attenuation)
- OD and wavelength ratings must be correct
- LSO will recommend specific choices

Eye Examinations

- Every Class 3b and 4 laser user
  - Prior to laser work
  - Immediately following an accident
  - Immediately following cessation of laser work
  - Immediately prior to termination
- User or supervisor arranges with Medical
- Advanced preparation for temporary personnel
  - May take days
  - Can delay work

Non-Beam Hazards



- Electrical shock
- Laser generated air contaminants
- Collateral & plasma radiation
- Fire & explosion (Class 4 lasers)
- Compressed Gases
- Laser dyes
- Robotics-associated mechanical hazards
- Noise
- Waste disposal
- Confined space
- Ergonomics

- **Laser Dyes and Solvents**

- Exposure effects generally unknown. Some known to be toxic or carcinogenic (ES&H Manual 4-5).

- Avoid inhalation, or skin/eye contact.
  Always mix dyes in hoods, wear gloves and eye protection (ES&H Manual 12-1); contact ESH- Ind. Hyg. & Safety about chemical gloves.

- Solvents also can be hazardous:
  - DMSO transports solutes through unbroken skin
  - Most are toxic (ES&H Manual 4-3),
  - Many are flammable (ES&H Manual 11-3)
  - Explosive peroxides can form in some organic ethers (ES&H Manual 4-3).

- **Laser Dyes and Solvents** (Concluded)

- Flow of some solvents, notably p-dioxane and hexane, can cause surface static charges on high resistivity plastics such as Teflon. Fires and explosions have resulted.

- Spent solvents and dye solutions require proper disposal (Waste Handling Procedures Manual-Illinois Site).