HAZARD CONTROL MEASURES FOR LASERS

David H. Sliney
Laser Microwave Division, US Army Environmental Hygiene Agency
Aberdeen Proving Ground, MD 21010-5422 USA

INTRODUCTION

Considerable attention has been paid to the establishment of exposure limits (EL's) for laser radiation [1,2,3], but it has been generally not well recognized that EL's are infrequently measured in actual hazard evaluations of laser installations. Inasmuch as many laser beam irradiances are at least a thousand-fold higher than applicable EL's, a very careful measurement is seldom needed [4]. A movement of a measuring instrument a few mm from the beam axis may result in completely missing the beam. Recognition of these difficulties led to an approach in laser safety that departs from the methods followed in evaluating and controlling ionizing radiation sources.

It was recognized in the 1960's that regardless of detailed measurements certain similar types of lasers repeatedly required the same hazard control measures regardless of the specific application and environmental setting [5]. This recognition led to the development of the laser hazard classification scheme now almost universally applied throughout the world. Despite some small differences in national standards, the basic concepts embodied in the hazard classes (i.e., Classes 1, 2, 3A, 3B and 4) are the same as in Standard 825 of the International Electrotechnical Commission [6].

LASER HAZARD CLASSIFICATION

Lasers fall into one of four general hazard classes. The basic concept is that a laser's potential hazard is defined by wavelength and output power/energy. A Class 1 laser product is not hazardous--either by virtue of an extremely low-powered output (e.g., some low-powered injection diode lasers) or from the use of an enclosure.

A Class 2 laser product is limited to a laser which emits visible light between 400 nm (violet) and 700 nm (red) and is sufficiently bright (up to 1 mW power) to evoke an aversion response to bright light (i.e., blink reflex with eye and head movement). The hazard of looking into a beam ("intrabeam viewing") of a Class 2 laser is similar to that of staring at a welding arc or looking into a slide projector beam. Forced staring into such bright lights for minutes to hours can result in a photochemically initiated retinal injury (equivalent to eclipse blindness). The output power of a Class 2 laser must be less than 1.0 mW--a level which equates to the permissible occupational exposure limit of 2.5 mW/cm^2 over a 7-mm diameter pupil for a 0.25-s exposure (the aversion, or blink-reflex exposure time). One should consider Class 1 lasers "safe" and Class 2 lasers "safe for all practical purposes," since Class 2 lasers pose only a theoretical hazard.

Class 3 and 4 laser products are potentially dangerous. Class 3 lasers can injure the eye upon direct intra-beam viewing. Class 3 is divided into 3A and 3B; Class 3A is a transitional class which includes lasers that pose a hazard only under certain worst-case conditions. A Class 3A laser product is generally a 1 to 5 mW visible laser (most commonly a He-Ne, 632.8-nm laser). In all countries except the USA, Class 3A lasers are limited in output irradiance to the EL for $\frac{1}{4}$ s (i.e., 2.5 mW/cm^2) [6-8]. Class 3 laser products are hazardous to the eye from intrabeam exposure--even for brief exposures less than 0.25 s. Class 4 laser products, like Class 3, have a warning label with the familiar starburst logo representing laser radiation (Figure 1); and unlike Class 3 lasers, they may pose a significant fire hazard or skin burn hazard, and pulsed lasers may pose a beam reflection hazard even from diffuse surfaces. The hazard classification is marked on the safety label by the manufacturer (since 1976) and the classification scheme is complicated. However, for the visible lasers used by Itek, those less than 1.0 mW output power are Class 2; those with an output power of 1.0 to 500 mW are Class 3; and those with an output power exceeding 0.5 W are Class 4. Any continuous-wave (CW) lasers in the infrared or UV are Class 4 if their output power exceeds 0.5 W average. Hence, most CO-2 lasers in the infrared are Class 4. Most excimer lasers which emit in the UV, and many argon lasers are Class 4 since their average output power normally exceeds 0.5 W, or the output radiant exposure exceeds a given limit. Visible and near-infrared lasers (400-1400 nm) may cause retinal injury; whereas, far-infrared and UV lasers may injure the cornea or lens.

HAZARD CONTROL MEASURES FOR THE USER

For Class 2 lasers, one need only caution the uninitiated not to stare into the light source, and treat it with caution as one would a bright movie projector or spotlight. For Class 3 lasers, persons should be instructed to wear laser eye protectors or enclose the beam or use baffles to preclude direct intrabeam exposure to the primary beam or specular reflections. Class 2 laser power levels should be used for alignment where feasible, and intrabeam exposure must be prevented if Class 3 lasers must be used for alignment unless the beam has been expanded to reduce the beam irradiance below 2.5 mW/cm^2. Laser eye protectors are particularly important for Class 3 pulsed lasers and for invisible (IR or UV) laser beams.

For Class 4 lasers, the requirements for Class 3 should be followed, and in addition eye protectors must be worn if any open beam is accessible. Most laser eye injuries have occurred from reflected beams from Class 4 lasers. The greatest "offender" has been the Neodymium:YAG Q-switched laser systems. Entryway door interlocks may be required for Class 4 laser laboratories to protect persons entering during laser operation unless the beam is well baffled or enclosed to greatly reduce the Nominal Hazard Area (or Zone). The skin should not be exposed to Class 4 laser beams. Entryway doors should have a standard warning symbol (Figure 1) and sign indicating the hazard and appropriate precaution to take (e.g., "Do Not Enter When Red Light is On, "Knock

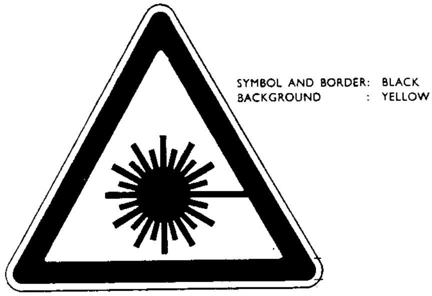

FIGURE 1. Laser Radiation Warning Symbol [6]. Detailed precautionary guidance and hazard classification is found in panel below the triangle.

---

before Entering," etc.). A warning symbol without meaningful instructions for the reader is useless. For Class 3B and 4 laser systems emitting between 300 and 4,000 nm (where glass transmits) windows should be non-existant or covered with a light-tight, opaque screen. In this regard, many plastic "opaque" curtains actually transmit near-infrared (e.g., 1064 nm) wavelengths.

SYSTEM SAFETY HAZARD CONTROL MEASURES

Most countries have regulations for laser manufacturers which mandate certain system safety features depending upon hazard classification. These generally follow the IEC standard 825 [6]. For example, in the USA, a manufacturer of any commercial laser product must comply with provisions of Title 21, Code of Federal Regulations, Part 1040, Performance Standard for Laser Products [8]. The manufacturer must certify that his laser product meets these requirements, and must file documents which detail this certification with the Center for Devices and Radiological Health (CDRH) of the Food and Drug Administration (FDA), Rockville, MD.

The laser system safety features required by such performance standards which are applicable to most commercially constructed research and industrial Class 3b and 4 lasers are: (1) an interlocked or secured protective housing, (2) a remote connector which can be used to interlock an entrance door, (3) a key operated switch, (3) an emission indicator, such as a pilot light, (4) a beam attenuator, e.g., a mechanical shutter, (5) specified warning labels, (6) protective viewing optics (i.e., by a filter or shutter system), and (7) operator controls located to limit the chance for exposure. In addition to these general requirements, all medical laser products must also comply with three other requirements: (1) a means to measure the output within ±20 %, (2) a measurement calibration schedule, and (3) a "laser aperture" label. In some instances, a self-monitoring fixed laser output is considered to fulfill the first medical requirement. In the USA, manufacturers can obtain variances from the above standards if alternate and effective controls are provided. A few controls (e.g., the protective housing), are also required for laser products assigned to lower classes.

It is important that each person working with a Class 3B or 4 laser product understand that the system safety controls are only helpful if used, and cannot be relied upon alone without other user control measure. Airborne contaminants must be evaluated [9]. Controls (e.g., filters in viewing optics) must be checked to be in place after servicing. Use of the key switch can prevent unauthorized use of the device by untutored persons. Since hazardous reflections and high voltages are accessible within the protective housing, the interlocked or screw-fastened enclosure should not be tampered with except by a well trained serviceman.

MEDICAL SURVEILLANCE

Medical Surveillance is not a control measure. At one time, many regulations required that all employees working with lasers have pre-placement and periodic eye examinations. However, today some examinations remain only for legal reasons [10]. But, if an accidental over-exposure to laser radiation occurs, it is critically important that an examination be performed within 1 - 2 days following the accident or suspected accident [10].

REFERENCES

1. International Radiation Protection Association, Guidelines on limits of exposure to laser radiation of wavelengths between 180 nm and 1 mm, Health Phys., 49(2): 341-359, 1985.
2. Sliney, D. H., and Freasier, B.C., The evaluation of optical radiation hazards, Appl. Optics, 12(1): 1-24, 1973.
3. Sliney, D. H., Wolbarsht, M. L., Safety with Lasers and Other Optical Sources, A Comprehensive Handbook. New York: Plenum Publishing Corp. 1980.
4. Sliney, D. H., Radiometry and laser safety standards, Health Phys., in press 1988.
5. Sliney, D. H., and Palmisano, W. A., "The Evaluation of Laser Hazards, Amer Industr Hyg Assn J, 29(5):325-431, 1968.
6. International Electrotechnical Commission (IEC), Radiation Safety of Laser Products, Equipment Classification, and User's Guide, Publication WS-802, Geneva, IEC, 1984.
7. American National Standards Institute, Safe Use of Lasers. Standard Z-136.1, New York: ANSI, 1430 Broadway, 1986.
8. Center for Devices and Radiological Health, Federal Performance Standards for Laser Products, Food and Drugs. Title 21, Code of Federal Regulations, Section 1040. Rockville, 1985.
9. Sliney, D. H., Vorpahl, K. W., and Winburn, D. C., "Environmental Health Hazards of High Powered Infrared Laser Devices," Arch. Environ. Health, 30(4):174-179, 1975.
10. Pitts, W. G., and Sliney, D. H., (Eds.), Proceedings, Symposium on Medical (Ophthalmic) Surveillance of Personnel Potentially Exposed to Laser Radiation, 8-9 September 1982, US Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD, undated [available from National Technical Information Service, Springfield, VA].