CONTROL AND USE OF LASERS IN N.Y.S. INDUSTRY

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Introduction

General

Since the important and historic paper of Solon, Aronson & Gould[1] pinpointed the potential for eye damage from lasers, it has been recognized that the eye is the critical body organ for laser radiation exposure in the visible and near-infrared. Experimental data by Ham, and others have confirmed the early predictions of eye damage and that eye exposure especially to the retina is a limiting factor in working around lasers[2]. Damage of the retina is usually irreversible and since the eye is crucial for an individual's well-being extreme care is indicated to ensure that such damage does not occur. An additional inducement for care in laser radiation exposure is the fact that maximum permissible exposure values are based on acute damage as evidenced by standardized objective tests on experimental animals. Little human data and fortunately no epidemiological data are available to confirm the suggested maximum permissible exposure limits. Very little data is available as a result of long term exposures at sub-acute levels of laser radiation and none to date have been incorporated except through safety factors into maximum permissible exposure limits.

Laser radiation that is not amplified by the optics of the eye causes surface damage either to the cornea or skin. Sufficient biological data is available to set corneal maximum permissible exposure limits for infrared radiation in the wave length range above 1400 nm and skin maximum permissible exposure limits in the visible and infrared wave length range above 400 nm. Insufficient data is available to set corneal or skin maximum permissible exposure limits in the laser UV region. Most of the skin damage data is based on short term exposures and little information is available on what might result from long term exposures.

To ensure that the benefits of laser radiation will be reaped with little human eye or skin damage New York State has promulgated Industrial Code Rule 50, Lasers, to regulate the industrial use of lasers in the State. The Code Rule is generally a performance-type Code but some specification type regulations for certain types of lasers and certain laser working conditions are incorporated.

The Code Rule separates lasers into three categories based on their emission characteristics. These are exempt, low intensity and high intensity lasers. There is an additional classification of the low and high intensity categories into fixed and mobile lasers. The rest of this paper expands on the control measures specified in Industrial Code Rule 50 and the industrial use of lasers in the State.

Control of Lasers

Exempt Lasers

There are two conditions which make a laser exempt from the provisions of Code Rule 50. Exemption #1 covers storage, shipment or sale of inoperable lasers. Exemption #2 covers the case of lasers which by reason of their design and construction cannot emit radiation that exceeds 1×10^{-7} J/cm^2 or 1×10^{-5} W/cm^2 when measured at 10 centimeters from the exterior surface of the laser.

Low Intensity Lasers

Approvals. Low intensity lasers have an emission level which exceeds the above values for exempt lasers but do not exceed 1×10^{-1} J/cm^2 for 1 nsec to 1 μsec pulse, 1 J/cm^2 for 1 μsec to 0.1 sec pulse and 3 W/cm^2 for CW or repetitively pulsed lasers. The values are approximately set at the values where skin burns for visible and infrared electromagnetic radiation start to become a factor in control measures. Low intensity lasers other than those in research and development status will need Board of Standards and Appeals approval prior to distribution and use but with approval the laser installation will not need to register.

Mobile Lasers. Code Rule 50 places special requirements on mobile lasers - lasers used outside fixed installations. Such lasers have additional potential for causing injury to the laser worker and the general public and also have a high nuisance potential if not properly controlled. Because of these factors the Code requires that individuals using mobile lasers must be certified by the Industrial Commissioner. To assist him in implementing this provision the commissioner has appointed a Laser Examining Board whose functions are (a) examination of applicants and their experience and make recommendations thereon, (b) holding of hearings on denials, (c) holding of hearings on suspension or revocation of certificate, and (d) reporting findings and recommendations to the commissioner. There are two categories of certificates of competence. Class A certificate of competence for operators of low intensity mobile lasers and Class B certificate of competence for operators of high and low intensity mobile lasers.

High Intensity Lasers

Fixed Laser Installation and Mobile Laser. All such installations and mobile laser operations utilizing high intensity lasers must register with the commissioner and designate a laser safety officer. In addition prior notification is required for all field work with mobile high intensity lasers. In case of fixed installation a laser radiation area must be designated and posted with the standard laser hazard symbol. Special precautions that may be necessary are (a) remote viewing apparatus, (b) special termination materials for high intensity beams, (c) interlocks on equipment and doors to laser radiation areas, and (d) "fail safe" electronic circuity wherever it is warranted. Because of its importance in determining the extent of the outdoor laser radiation area a survey is required of the output power or energy density of high intensity mobile lasers.

Each laser shall be safeguarded against unauthorized use and no person shall dispose of a high intensity laser except by making it permanently inoperative or by transferring to another person authorized to receive it.

Each person who possesses a laser shall report (a) any theft or loss of intact laser, (b) any injury to individual resulting from operation of laser or associated equipment.

Personal Protection. It is obvious that persons using lasers must be adequately instructed in the safe use of the laser. One must never look directly into a laser beam above the maximum permissible exposure limits without adequate eye protection. Code Rule 50 recommends the use of approved safety eyewear by those individuals who may be exposed to laser radiation above the maximum permissible exposure limits. Minimum standards for such eyewear are (a) adequate optical density to reduce laser radiation to safe levels, (b) designed and tested to insure that eyewear retains its protective properties during use, (c) legibly labeled with the optical density of the lens and wave length at which it was measured. In the case of a high intensity laser protective eyewear should not be relied on as the primary protective barrier between an individual and the laser beam. Protective eyewear should be primarily for accidental exposures and the laser application should be designed to ensure that the probability of eye exposure is minimal. Reliance on protective eyewear is a poor substitute for adequate control measures such as enclosures or remote viewing equipment. Furthermore in today's laser world protective eyewear can be very tricky because of the large number of potential laser wavelengths which one may encounter.

Associated Hazards. At least 2 deaths from electrical shock have been reported in the literature around lasers. The electrical hazard is especially great in research and development work and therefore all laser equipment must be designed, constructed, installed and maintained so as to minimize the possibility of electrical hazards.

With high intensity laser beams adequate protection must be provided for air contamination arising from vaporized target materials, toxic gases, vapors and fumes. Two areas of special concern are vaporized fire brick which may contain beryllium, and UV laser beams and UV pumping lamps emitting radiation in the wavelength range from 185-210 nm which will produce ozone from oxygen in the atmosphere.

Besides adequate radiation shielding an explosion shield around the resonating laser cavity is recommended where explosions of the lasing medium are possible.

Every laser and laser installation must be designed, installed, operated and maintained to eliminate or reduce any fire hazard.

The only ionizing radiation hazard associated with lasers at present is in the high voltage power supplies and only gross ignorance or carelessness will lead to exposure from this source in this day and age. X-ray or neutron radiation hazard associated with the laser beam or its target interaction lie in the future.

Future

Scanning Laser Beams. Lasers operating in the scanning mode have assumed commercial importance within the last 3 years. Code Rule 50 stipulates that the laser exposure values can be determined while the beam is in the scanning mode. Exposures therefore are equivalent to a repetitively pulsed laser beam. While it appears logical that the human eye will respond to such exposures in a manner similar to a pulsed laser, no experimental evidence is available on such laser beam exposures to ensure that these are appropriate maximum permissible exposure limits. Further experimental data is needed in this area.

UV and Subnanosecond Laser Pulses. Additional biological data is also urgently needed in the UV region so that maximum permissible limits can be established for corneal and skin exposure.

Pulse width is also a factor in the biological response and data is needed to establish maximum permissible limits for subnanosec laser pulses.

Use of Lasers

Construction Industry (SIC #15, 16, 17)

The largest number of individuals potentially exposed to laser radiation are in the construction industry which has approximately 51% of the registrants. The main application is a rather prosaic one involving the establishment of a reference line or plane. Basic surveying tools used by the construction industry have changed little since ancient Egyptian times until the advent of the laser. Stakes, rods and tapes have served for engineering works from Stonehenge to the Empire State building. But now the laser has revolutionized surveying. It can provide a reference line or plane at any desirable angle. In addition distance measurement can be accomplished in seconds with a high degree of accuracy.

In the construction industry the laser is used to (a) provide line and grade in laying of pipe, mainly storm and sewer pipe, (b) provide line and grade in heavy construction projects, such as, tunneling, erection of dams and dredging, (c) provide horizontal plane for installation of floors and ceilings and (d) distance measurement.

All of the lasers which we have encountered in this application are low intensity HeNe lasers. From a sample of 114 lasers the average reported power density was 27 mW/cm^2 with a range from 3 to 160 mW/cm^2. This classification has 12% of the lasers and 41% of the laser workers. (See Figure 1.)

Instrument, Photographic and Electro-Optical Industries (SIC #38)

This industrial classification has 19% of the registrants but 47% of the lasers and 32% of the laser workers. Lasers are incorporated in instruments, such as, surveying instruments for use by the construction industry as described above. They are used in the holographic studies. High intensity lasers are used in the manufacture of balance wheels and scribing.

General Manufacturing including Computers (SIC #35)

There are 5% of the laser registrants in this industrial classification with 17% of the lasers and 10% of the laser workers. High intensity lasers, such as, CO_2, Nd (YAG or glass) and ruby lasers, are used for drilling, welding, melting, burning and micro machining. Low intensity lasers are used for precision measurements, alignment and as a light source.

Research and Development (SIC #73)

This service category has 3% of the registrations, 11% of the lasers and 5% of the laser workers. The main laser and application are the HeNe low intensity lasers used for alignment.

Aerospace Industry (SIC #37)

This classification has 2% of the registrations, 8% of the lasers and 5% of the laser workers. High intensity CO_2, Nd (YAG or glass) and ruby lasers are used for scribing, drilling and metal cutting mainly titanium alloy. Low intensity HeNe lasers are used for alignment of various airplane components onto the airframe.

Electrical Machinery and Electronics (SIC #36)

There are 10% of the registrations, 3% of the lasers and 4% of the laser workers in this industrial classification. High intensity Nd laser is used for resistor trimming, CO_2 laser for glass cutting and contact cleaner and ruby laser for drilling diamond dies. Low intensity HeNe lasers are used for alignment and smoke detection.

Miscellaneous Industries

Finally the remaining registrants fall in various industrial classifications, including jewelry, pharmaceutical and mining. The number of registrants is 10% of the total number of registrants, 2% of the lasers and 3% of the laser workers. High intensity Nd lasers are used by the jewelry industry for diamond drilling to improve their quality. High intensity ruby lasers are used in biological research by pharmaceutical industry. HeNe lasers are used by mining industry for grade and alignment and by surveyors for geodetic distance measurements. A high intensity argon laser is used in research on determination of air and water contaminants.

Recommendations

With several national standard setting bodies establishing maximum permissible exposure limits for laser radiation, many of them different in one way or another, the time is appropriate for an international body (possibly this Association) to take the initiative in formulating Basic Laser Radiation Exposure Guidelines. Expanding interchange of men and goods make it desirable that such guidelines be established to ensure maximum protection of the working population as well as the general public.

References

[1] Solon, L. R., R. Aronson & G. Gould, Physiological implications of laser beams, Science 134, 1506–1508 (1961).

[2] Ham, W. T., Jr., R. C. Williams, H. A. Mueller, R. S. Ruffin, F. H. Schmidt, A. M. Clarke, J. J. Vos & W. J. Geeraets, Ocular effects of laser radiation, Acta Ophthalmologica 43, 390–409 (1965).

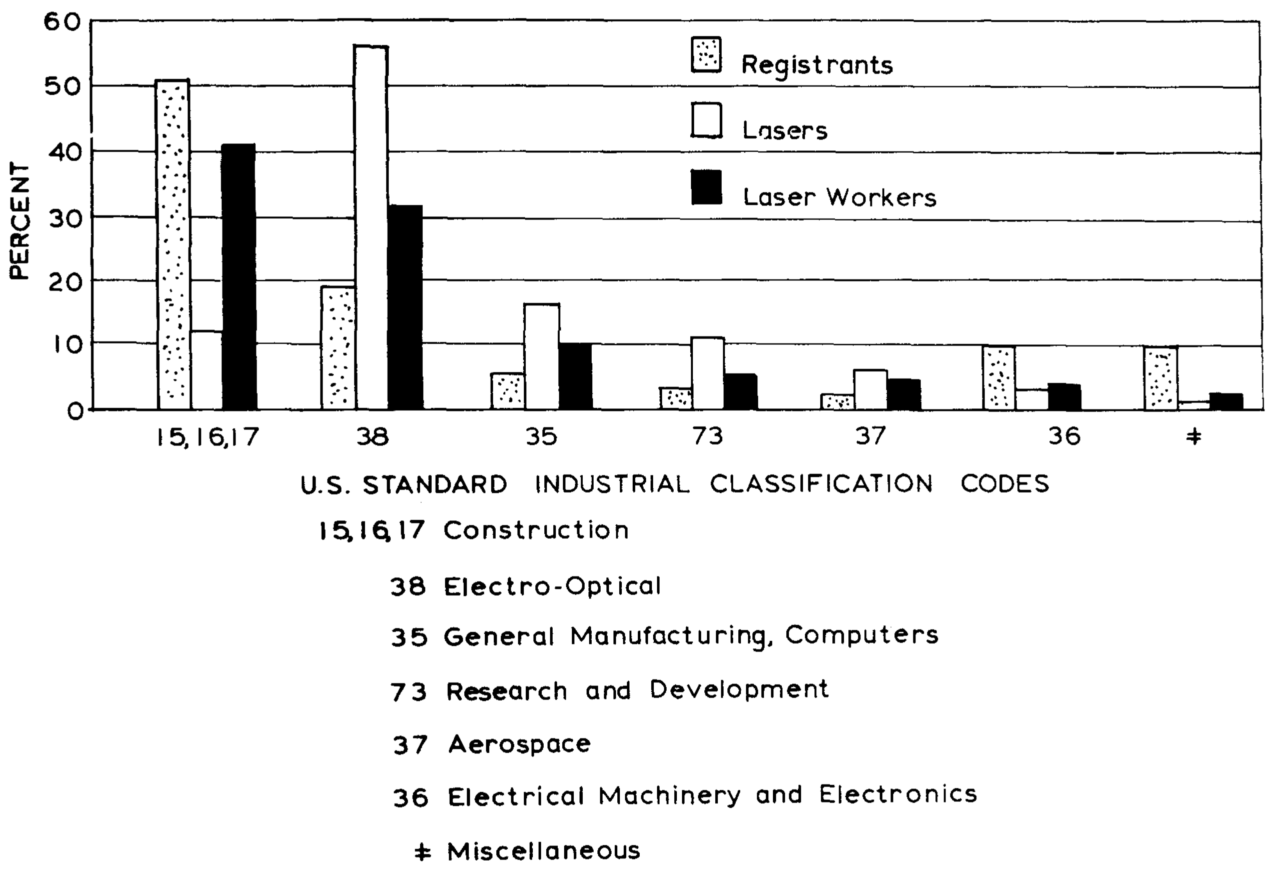

Figure 1- Registration, Laser and Laser Worker Percentages in Selected U.S. Standard Industrial Classifications as of January 1973