TEN YEARS EXPERIENCE WITH A LASER SAFETY CODE

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During the period 1967-1972, we made several studies of the use and need for the control of industrial laser exposures in New York State. These studies indicated rapidly expanding laser usage by generally untrained individuals particularly in the construction industry. At the time both high and low intensity lasers were in field use. Based in part on experience in controlling ionizing radiation exposures a performance type Industrial Standard consistent with national guides such as ACGIH (1) was formulated and distributed for comment. Public Hearings were held throughout the State and a generally satisfactory standard Rule 50, Lasers (2) was promulgated.

Rule 50 separates lasers into three classes - exempt, low and high intensity laser. The division between exempt and low intensity being set at a value which was considered reasonably safe to view without permanent damage - 10 microwatts per cm^2 for CW lasers. The definition of low intensity laser and the demarcation value between low and high intensity laser was more difficult to establish. This was set at 3 watts per cm^2 for CW lasers. Lasers above this value are classified high intensity lasers. The requirement for some controls on high intensity lasers has never been in doubt. There is controversy on the need and extent of controls for low intensity lasers. The performance-type Rule required the registration of all high intensity lasers, certification of all operators of mobile lasers and approval of low intensity lasers. Approval of low intensity lasers was made considerably easier by the promulgation by U. S. Food and Drug Administration of a federal standard covering lasers (3). The intent of approving lasers was to make it easier to control laser exposure by built-in safeguards and also to simplify inspection procedures. A general safety inspector could check the laser for the approval tag and assume that it met the standard if tag was present.

Our experience with regulating ionizing radiation sources led us to believe that mobile lasers - those used outside a permanent installation would require additional controls. The standard therefore required the certification by examination of mobile laser operators. Since control requirements varied greatly between low and high intensity laser, two classes of certification were specified Class A for use of low intensity mobile lasers and Class B for use of high and low intensity lasers.

All firms possessing high intensity lasers must register them and appoint a laser safety officer with appropriate experience who is required to assure that the laser safety standards are adhered to by the firm. One area of controversy arose involving the extent of controls needed for low intensity lasers especially the helium neon lasers in use in the construction industry. The literature on the subject is somewhat ambiguous and it is uncertain that a 5 milliwatt helium neon laser could cause permanent eye damage. On the other hand the potential for projecting the laser beam, even a low intensity beam, is too great and the possibility for causing disturbances in the highway or airways justify the requirement of certification of the laser user.

Lasers in use by New York State Industry

The distribution of high intensity and unapproved low intensity lasers by type of industry is given in Table 1a. The only suprise and change from a similar table, prepared in 1975, is in the lasers used for light shows and advertising displays. This distribution does not indicate, because they are unregistered, the large number of firms in the construction field and industry in general using low intensity, primarily helium-neon, lasers for precision measurements. Most high intensity lasers are used for welding, cutting, scribbing and trimming. While only in its infancy lasers are adaptable to automated processes. Problems have arisen in this application such as the automated sealing of tubes with tritium (4). This has arisen because insufficient development work has been done on the application of very high power densities on the materials involved. Precision work in the electronics industry has been met by using lasers. Table 1b summarizes the type of laser in use. Even for registered firms helium neon lasers are the predominant laser. Part of this arises from the fact that most high intensity lasers must be precision aligned which is done with the HeNe laser. Another type of laser in increasing use is the solid state laser-mainly by the communication industry. To date field measurements of these lasers have indicated that they can be used safely with no hazard to worker. This is due to the relatively large divergence of the laser light both from solid state laser and out the end of the fiber optic cable into which the solid state feeds.

Laser Light Shows

The entertainment and advertising industries have embraced lasers as dramatic adjuncts to their visual effect repetoire. Lasers are used not only for entertainment but their claimed artistic effect. Over the past seven years when this usage has increased, experiments of all types were tried and the Laser Code has permitted a relatively controlled increase in usage. While there are countervailing claims that the use of lasers in this area is too dangerous and inappropriate, even frivolous, use of high technology, Rule 50 does not prohibit this usage if the laser is used within the constrains of the rule. The predominant lasers in use are the argon, krypton and argon-krypton gas lasers. An occasional attempt is made to use the helium-neon laser but without a great deal of success. The helium-cadmium laser is also used on occasion for its deep blue line. We have required the laser light shows to comply with the following main requirements: 1) registration of firm 2) certification of laser operator and 3) maximum power and energy densities restricted in occupied areas to less than 1 microwatt/cm^2 and 1 microjoule/cm^2 in spectral region from 400 to 700 nanometers and no spectral radiation shall be emitted from laser system outside this band.

A recent inspection in a facility using a krypton laser tuned to red line (647.1 nm) had an output of 3.7 watts and with a scanning beam off a stationary mirror ball read 2 microjoules/cm^2. The operator increased the beam scanning frequency to reduce the energy density to 0.7-1 microjoules/cm^2. In practice the mirror ball is turning which reduces the effective power density. Our inspections of laser light show operators has generally found willingness on the part of the operators to comply with Rule 50 requirements.

Incidents

In general the history of the expanding laser use has been accomplished safely but it has not been incident free. Four incidents were reported and all occurred with laser radiation in the infra red band. Three were in a research environment and one was on the production line.

Incident #1 involved a technician with about 2 years laser experience working with the following laser:

Mfg: Coherent Radiation, Model No. 41
Type: CO_2 gas
Power: 325 watts
Use: R & D experiment
Date of Incident: 8-4-75

The technician was involved in sliding test material into beam irradiation area and irradiating material to study laser beam effects. In sliding test item into irradiation position and firing laser he irradiated his left index finger causing a hole in fingernail approximately 1 mm diameter and 2 mm deep. The employee was seen in plant clinic and no lost time was involved. Corrective measures involved additional laser safety training of laser workers.

Incident #2 involved the following laser:

Mfg: GTE-Sylvania Model 971
Type: CO_2 gas
Power: 1200 watts
Use: Automated Welding
Date of Incident: 6-8-81

A maintenance engineer with 1 year laser experience was attempting to remove the laser beam protector tube to monitor output power with station control and shutter control in auto position. The proper procedure for this authorized maintenance function was to place the shutter in "off" position and take the station out of the automatic run position. As the employee removed the tube the laser fired striking the employee in the right thumb. A 0.75 inch diameter burn pattern resulted from the unfocused laser beam. The burn healed uneventfully. Corrective measures included additional training for the maintenance engineers.

Incident #3 involved the following laser:

Mfg: Molectron Model MY34
Type: Neodymium Laser with Methane Cell
Power/Energy: 15 watts/1.5 joules
Wave Length: 1064, 532, 355, 266nm
Date: 10-15-82

Two researchers with several years experience working with lasers were performing stimulated Raman emission experiment. The 532 nm laser beam was focused into a methane cell causing emission at 630 and 460 mm. One researcher was looking into the cell with laser safety goggles to check for gaseous breakdown when he experienced a bright flash. Subsequent reconstruction of incident indicated that cell also radiated at 770 nm and it was this radiation that caused the damage. Measurements indicated the individual received approximately 0.8 millijoules in 10 nsec pulse. Literature (5) indicates that it would require 30 J/cm^2, 1064 nm photons in 15 nsec pulse to cause a 10 μm retinal lesion. Assuming a similar size lesion one can calculate that this individual received an exposure of about 260 J/cm^2 on the retina. This is sufficient to have caused the 3 mm blind spot that researcher described in clinic following incident.

Incident #4 involved the following laser:

Manufacturer: In-house
Type: Neodymium
Wavelength: 1064 mm
Date: 10-26-82

The person was working in lab with 4 other persons. He reported to company dispensary with complaint of irritation of eyes. Examination by opthamologist indicated minor damage to corneas of both eyes attributed by opthamologist to ultraviolet light. The person while working in lab on specified day did not wear laser safety goggles and viewed diffuse laser light. Subsequent investigation showed no exposure in spectral region from 200 to 400 mm. The Nd laser has a shielded Xenon pump lamp. The person indicated he knew of no other possible UV source he might have been exposed to.

In summary these laser incidents involved in 2 cases, Nd laser and in the other 2 cases, CO_2 laser. The recent incident literature also reveals the potency for damage of the infra red radiation, partially I am certain because it is unseen until damage occurs. The second point also common with other recent incidents is the susceptibility for laser injuries of an r and d environment even for experienced workers. Precautions in such situations must include a vigorous in-house program of laser safety instruction of all personnel which should be periodically repeated and independent audits of laboratory precautions to ensure compliance with good laser safety practices.

References:

1. ACGIH Publication "A Guide for Uniform Industrial Hygiene Codes or Regulations for Laser Installations" (1969); Cincinnati, Ohio 45201

2. Official Compilation of Codes, Rules and Regulations of State of New York, Title 12, Part 50, Lasers (1972)

3. Code of Federal Regulations, Title 21, Part 1040 (1976)

4. Bradley, F. J., Schuster, L., Cabasino, L., Tedford, C., Warren, D. and Fitzrandolph, L., Proceedings of 5th Congress of IRPA (1980) Pergamon Press, Oxford

5. Sliney, D. and Wolbarsht, M. "Safety with Lasers and Other Optical Sources" (1980) Plenum Press, New York.

Table 1a. Laser Use by Industry

General Manufacturing	31%
Laser Light Shows	29%
Electrical Machinery and Electronics	21%
Research and Development	8%
Aerospace	6%
Electro Optical & Telecommunications	5%

Table 1b. Type of Laser in Use

HeNe	48.0%
Solid State (GaAs)	20.0%
Nd	10.3%
CO_2	7.4%
Ar	5.5%
Kr	2.7%
Ruby	1.2%
HeCd	1.1%
Ar/Kr	0.5%
Miscellaneous (Dye, Xe, CO, etc.)	3.3%