Laser Source Size as a Function of Distance

Wesley J Marshall
USACHPPM

Introduction

Maximum permissible exposures (MPEs) for diode lasers or LEDs are based partly on source size. Determining source size is straightforward for bare diodes or from diffuse reflections of laser energy. However, when a lens is used to shape the output power of a laser diode or LED into a beam; the apparent source size changes, complicating the MPE computation. As a further complication, the apparent angular source size decreases with increasing distance from the laser, resulting in a decreasing MPE. Thus, computing a nominal ocular hazard distance (NOHD) for a collimated laser diode or LED beam is more involved than for a collimated solid state or gas laser.

Applicable Standards

Laser MPEs and accessible emission limits (AELs) for laser hazard classification are provided in several different standards. In the U.S., the American National Standards Institute (ANSI) American National Standard for Safe Use of Lasers Z136.1 provides MPEs for the laser user and the Center for Devices and Radiological Health/Food and Drug Administration provides AELs for laser Manufacturers in the Laser Product Performance Standard, 21 CFR 1040. Although these standards cover the use and manufacture of lasers, neither of these standards include LEDs. The International Electrotechnical Commission Standard (IEC) 60825-1 includes MPEs and AELs which apply to both lasers and LEDs. Although this latter document includes guidance for the manufacture and use of LEDs as well as lasers, the International Commission on Non-Ionizing Radiation Protection has issued a statement that surface emitting LEDs are not hazardous for realistic viewing conditions. Both the ANSI RP-27 and the Commission International de l'Eclairage (CIE) draft international standard for the photobiological safety of Lamps 134-3-99 consider LEDs and apply incoherent safety limits.

Computing MPEs

For extended laser sources, the MPE is directly proportional to the apparent angular source for source sizes from 1.5 mrad to 100 mrad. When the extended source is a diffuse reflection from a laser beam striking a Lambertian surface, the size of the extended source is simply the diameter of the laser beam striking the surface. From such a reflection, the angular source size is inversely proportional to the distance from the viewer to the diffuse surface.

When the extended source results from intrabeam viewing of an extended-source laser, the angular source size decreases with distance from the laser, but not as rapidly as it does with diffuse reflections. In fact, when maximum collimation is achieved, the apparent angular source size and the beam divergence are almost the same value for several meters in front of the laser. Of course, the laser exit port limits the apparent angular source size beyond a few meters from the laser.

Small Beam Diameter Lasers

When comparing beam irradiance to the MPE, the irradiance is averaged over the limiting aperture, rather than using the actual computed irradiance based on the beam diameter. With increasing distance from the laser exit port, the average corneal irradiance will not increase so long as the laser beam diameter remains smaller than the limiting aperture (7-mm, simulating pupil size for visible and near infrared lasers). However, in this region of constant average corneal irradiance, the apparent source size will generally decrease as the distance is increased. The smaller angular source size will cause a decrease in MPE as the distance from the laser is increased. Therefore, the computed optical hazard could be greater a few meters in front of the laser exit port than it is at 10 cm. For optically aided viewing, the region of constant average corneal irradiance may extend several meters farther than for unaided viewing.

Conclusions

Computing MPEs at various distances from a laser requires a determination of laser source size at each applicable distance. The computed hazards from a small-beam-diameter, extended-source laser may be greater a few meters from the laser exit port than at 10 cm. Hazards should be computed at the most hazardous distance from the laser and not just at one specified distance. Many extended-source lasers have beam diameters much less than the 5-cm measurement aperture used for magnifying optics, even at a distance of 2 m or more from the laser exit port. Viewing these lasers with magnifying optics may result in increased hazards at distances beyond 2 m due to a reduction in angular source size without a corresponding decrease in computed corneal irradiance.