Laser Safety Precautions and Hazards

A class 1 laser is incapable of causing an injury during normal use. Lasers can be class 1 because they are very low power or because the beam is fully enclosed. The operators of class 1 lasers do not need to take any precautions to protect themselves from laser hazards. The class 1 limits for visible lasers under the ANSI Standard vary with laser wavelength. Visible lasers with wavelengths longer than 500nm have a class 1 limit of 0.4 mW. The class 1 limit for visible lasers with wavelengths shorter than 450nm is 40 mW. Power limitations have been increased from earlier versions because we now know that they had been set lower than necessary for safety. The CDRH class 1 limit is 0.4 microwatts for the entire visible spectrum. The power limits have not yet been changed since it took effect in 1976. Class 1 limits under the IEC 60825-1 Standard agree with the ANSI Standard for the visible and near infrared, but they may be slightly different in the UV or far IR.

Class 2 lasers must be visible. The natural aversion response to bright light will cause a person to blink before a class 2 laser can produce an eye injury. The average for a human aversion response to bright light is 190 ms. The maximum aversion time is always less than 0.25 seconds. The only protection you need from a class 2 laser is to know not to overcome the aversion response and stare directly into the beam. This has been done, and people have burned their retinas doing it.

Class 3R lasers are “Marginally Unsafe.” This means that the aversion response is not adequate protection for a direct exposure of the eye to the laser beam, but the actual hazard level is low, and minimum precautions will result in safe use. The CDRH Standard (FLPPS) allows only visible lasers in class 3R. The CW power is limited to 5 mW. If the laser has a small beam so that more than 1 mW can enter the pupil of the eye, it carries a DANGER label. If the beam is expanded to be large enough that only 1 mW can pass through the pupil, the laser carries a CAUTION label. The ANSI Standard has the same limits for visible class 3R lasers. It also allows invisible lasers in this class. An invisible laser with 1 to 5 times the class 1 limit is a class 3R invisible laser under the ANSI Standard. The only precautions required for safe use of a class 3R laser are that the laser user must recognize the level of hazard and avoid direct eye exposure.

Class 3B lasers are hazardous for direct eye exposure to the laser beam, but diffuse reflections are not usually hazardous (unless the laser is near the class limit and the diffuse reflection is viewed from a close distance). The maximum average power for a CW or repetitive pulse class 3B laser is 0.5 W. The maximum pulse energy for a single pulse class 3B laser in the visible and near IR varies with the wavelength. For visible lasers the maximum pulse energy is 30 mJ. It increases to 150 mJ per pulse in the wavelength range of 1050-1400nm. For the ultraviolet and the far IR the limit is 125 mJ. Class 3B lasers operating near the upper power or energy limit of the class may produce minor skin hazards. However, this is not usually a real concern. Most class 3B lasers do not produce diffuse reflection hazards. However, single pulse visible or near IR class 3B lasers with ultrashort pulses can produce diffuse reflection hazards of more than a meter. Your laser safety officer will perform a hazard analysis.

Class 4 lasers are powerful enough that even the diffuse reflection is a hazard. The lower power limit for CW and repetitive pulsed class 4 lasers is an average power of 0.5 W. The lower limit for single pulse

class 4 lasers varies from 0.03 J for visible wavelengths to 0.15 J for some near infrared wavelengths. Class 4 lasers require the application of the most stringent control measures.

Class 1M and class 2M lasers are class 1 and class 2 lasers when viewed with the unaided eye. If these lasers are viewed with magnifying or collecting optics, more light enters the eye and the hazard is greater. These lasers can be viewed safely using optical instruments only if appropriate laser safety eyewear or filters are used.

Both ANSI Z136.1-2007 and IEC 60825-1 use M classifications. However, the detailed definitions of the M classes are different in the two standards. Both standards use the same two general measurement conditions, but the measurement distances and apertures are different. This means that a laser may fall into different classes under the two standards. No matter what class of laser you are working with, always follow the safety rules to protect others and yourself.

MPE or Maximum Permissible Exposure is the highest irradiance level a beam can reach before damage is possible to the eye or skin of a person. MPE values used in our lab and the laser industry come from the CDRH and ANSI Z136.1 Standard for the safe use of lasers. Basically what the ANSI standard is telling us is to wear the proper protective equipment at all times when you are around hazardous conditions.

We can use information from our laser and the ANSI Z136.1 standard to find the MPE for eye and skin. You need to know first the wavelength, or wavelengths, of light your laser is emitting. Next, you should determine the exposure duration of the situation, is it a short burst, or will you be staring at diffuse reflection for 8 hours. Here is an example of a common laser pointer used in classrooms and cat toys. You see the maximum value that cannot be exceeded is 2½ milli-watts per square centimeter. If your pointer emits 2mW is it safe? No way! That is 2mW in a smaller area than one square centimeter. Your beam will be less than ¼ of a square cm. That makes your irradiance over 8mW/square cm.; 2.5 times greater than the MPE. No, it is not safe to point one at a person, or a cat.

Now that we determined what the MPE is of our laser, another factor is the NHZ or how far can we be from the beam and be at a safe viewing distance. Nominal Hazard Zone will tell you at exactly what distance away you will be in a safe zone. There are several factors that play into the determination of NHZ, including laser output, and other working parameters.

Depending on the application and the environment the laser is used, there are a few types of NHZ. If you are inside the NHZ area, you are in a zone where there is potential for the beam to cause damage, mostly to the eye. Most often the NHZ is not clearly marked when the laser is operated. NHZ-IB or intrabeam is basically how far away from the laser do you need to beam to look back directly into the laser beam. Why would you ever do this? Anyway the equation includes beam divergence, aperture diameter, MPE, and laser power.

The safest reflection is a diffuse reflection like light incident on a rough painted wall. Still, you can be close enough to a bright laser diffuse reflection to be in trouble. So it is possible for a technician to calculate the NHZ to insure all personnel are safe. The same goes for what is called “lens on laser” NHZ. When a lens is involved the spreading of the raw beam changes the safe viewing distance. Regardless of which application you have, wear your laser safety goggles!

When it comes to picking the right laser safety eyewear, you should remember a few things about how light transmits and absorbs. Transmission is the ratio of output over input. This could be any measurable quantity like power, irradiance, or energy. It is a ratio so transmission is unit-less. As photons pass through a material, some will be absorbed by the atoms or molecules in the material. This energy is lost to the transmitted beam, but converted to another form of energy, like heat. A term called Absorption Coefficient is a constant for each material and wavelength, and it indicates how much light could be absorbed over a certain distance or thickness of a material. Absorption of light by a material happens exponentially over the thickness or distance the light travels. Think of it as removing a percentage of light over a given distance. You lose the same percentage each increment, you just have much less each time to take from. An exponential change ideally never reaches zero.

Here transmission is found by knowing the absorption coefficient and the thickness of material the light has to travel through. We can also solve the equation for absorption coefficient if we know the transmission and thickness of the lens. Don't forget most all of our parameters we use in optics are wavelength dependent. If you find the absorption coefficient of a material at a certain wavelength, it is NOT the same at other wavelengths.

All laser safety eyewear must be clearly marked on the lens or somewhere on the frame. The optical density of the eyewear should exceed the OD calculated in your hazard evaluation. OD, or here D, is found using the MPE and the laser intensity. The eyewear or filter in this case should block out more than enough light to take the transmitted light well below the MPE that is safe for viewing. Remember, laser eyewear is not intended for intrabeam viewing. There is no reason EVER that you should stare down the bore of any laser system. Laser eyewear OD or other filters are generally sold in ODs of whole numbers, like above. OD is exponential so it is easy to remember how much light each will cut out. Just take the OD and tack on that many zeros to a 1 and you'll have the amount of attenuation of that filter. For instance, an OD 6 cuts out one million times the incident value of light. That is 1000 times darker than welder's goggles! Here is an example of finding the OD of an industrial 40W Nd: YAG laser. An OD of 4.3 means you should buy OD 5 or better laser eyewear. Again remember, the eyewear is rated for diffuse reflection viewing only! Never intrabeam viewing. A CAUTION label means that a laser is visible and that it cannot deliver more than 1 mW through the pupil of the eye. Only the aversion response is needed for protection. A DANGER label means that the laser is a class 4, a class 3B, or a class 3R that has a small beam that can deliver more than 1 mW through a 7mm pupil. The class of the laser is stated in the lower right corner of the class warning label.

Laser products are always labeled according to the requirements of the federal standard. This means that many low power IR diodes that have danger labels stating they are class 3B actually produce no hazard and may be treated as class 1 lasers under the ANSI Standard. Examples of this include diodes with wavelengths of 1.55 microns used in fiber optic communications systems. A 1 mW diode is labeled as class 3B under the federal standard, but it is not really a hazard and can be treated as a class 1 under the ANSI Standard. In fact, the ANSI class 1 limit is 9.6 mW. It is important that workers understand the actual hazard associated with the lasers they are using.

The power levels stated on class warning labels are often greater than the laser can actually produce. The correct values may be found in the printed product information. Just remember to use the correct signage whenever using laser systems. People have the right to know when they walk into a room what the level of potential hazard is. Well I guess first they should be able to read the signs, and take the time to look up and notice them. After that, they are to just wear their safety glasses at all times. It's very simple.

Most people injured by laser exposures had no laser safety training. In most cases, the errors that led to the injury were simple mistakes that could have been avoided easily with a basic knowledge of laser safety. Most laser accidents occurred when beam alignment was performed without adequate safety precautions. Beam alignment should always be performed in accordance with documented alignment procedures that have been approved by a trained Laser Safety Officer. Many accidents in research laboratories occurred because stray reflections were not controlled. All stray reflections should be located and blocked as near to their source as possible. The laboratory should be checked routinely for new stray reflections.

The appropriate use of laser safety eyewear is a fundamental component of real laser safety. Most people injured by laser exposures had eyewear available but were not wearing it at the time of the exposure. Standard Operating Procedures are required for any circumstance in which a worker may be exposed to a hazardous laser beam. Almost all injuries occurred when such procedures had not been prepared or were not followed. In many cases the hazards from exposure to laser light are controlled so well that the greatest risk to workers is from a non-beam hazard associated with laser use.

The most serious hazard associated with lasers is the electrical hazard from the laser power source. Several fatalities have occurred because of this hazard. The most common hazard to workers from industrial laser use is laser generated air contaminants (LGACs). This is followed closely by mechanical hazards from materials handling equipment. Other hazards include radiation from laser processes, light from laser optical pumping lamps, and chemical hazards in laser research environments.