The UCONN Laser Line

UCONN Laser Safety Newsletter

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Laser safety is the game

UCONN EH&S

Fire Safety Regarding Beam Containment

Never use ignitable materials such as posterboard, cardboard, or wood for beam containment when operating high power (> 1 Watt) visible or infrared lasers. This includes materials for beam barriers, beam stops and beam enclosures particularly when the containment material can be exposed to an irradiance of 10 Watts/cm^2 or greater. The best material to use for high power beam containment is metal painted jet black. Ideally, the metal should be roughed with steel wool prior to painting in order to texture the surface to absorb and diffuse laser beams.
The "Cadillac" of laser barrier materials is Ever-Guard® supplied by Kentek. It is lightweight metal painted jet black and dimpled throughout to diffuse laser beams; it can handle 1200 Watts/cm^2 for several minutes with no melting: [Note: a recent visit from the Kentek salesperson indicated that UCONN is entitled to a 30% discount.]

http://www.kenteklaserstore.com/ever-guard-barriers_309.aspx

Ultraviolet beams (λ < 380 nm) do not present the risk of fires since they interact with materials photochemically rather than thermally. Metal beam containment is not needed for UV beams.

Emergency Procedures

1. Turn off the laser involved in the accident immediately and unplug it. Post a sign ("Do Not Use!") on the laser to ensure it is not used again until it can be determined that it is safe.
2. Keep the injured person calm. If an eye injury is suspected, keep the person in an upright position.
3. ***Make sure the injured person receives immediate medical treatment if the injury is serious—injured persons need to be seen by a medical doctor as soon as possible.***
4. Arrange for transportation of the seriously injured person to a medical facility, the victim might be in shock or have impaired vision so self-transportation is contra-indicated.
5. If the injury is life threatening (electrocution), ***call 911 immediately***. Perform CPR if no pulse, or breathing detected in the victim.
6. Minor skin injuries can often be treated by rendering First Aid in the laboratory.
7. Call the UCONN Laser Safety Officer, Martin Graham, at (860) 486-1108. If the Principal Investigator responsible for the laser involved is not present at the time of the injury, he/she must also be notified as soon as possible.

All laser accidents at the University of Connecticut, no matter how minimal, shall require an accident report. If individuals suspect they have received a laser exposure, they should first seek immediate medical attention. Any incident involving an alleged or suspected laser radiation overexposure will be reported to the LSO. Whenever an alleged or suspected overexposure to laser radiation occurs, the following steps will be taken:

ULTRAFAST PULSE RATED PROTECTIVE EYEWEAR

Some laser safety eyewear vendors are now inserting disclaimers into their advertising and on their websites regarding doubts about whether their standard protective eyewear is capable of adequately absorbing femtosecond-pulse radiation emitted by Ti:Sapphire regenerative amplifiers and other ultrafast lasers *(normally mode-locked lasers)* with pulse durations of less than one nanosecond. For example, Rockwell Laser Institute (RLI) currently includes the following disclaimer on its website: *"Note that some filters may exhibit saturated absorption when exposed to femtosecond laser pulses and may not afford adequate laser eyewear protection for those laser types."* It therefore appears that even though eyewear has sufficient optical density (OD) as determined using LAZAN©, the computer program most frequently employed by laser eyewear vendors and laser safety professionals *(the pulse duration is an input parameter in that calculation)*, **the eyewear might not be able to adequately protect against a direct hit by a high-power ultrafast-pulse laser beam.**

The standard eyewear OD specification will likely work well for diffusely-scattered ultrafast-pulse laser radiation and for greatly reduced power beams such as those ideally used during beam alignments.

Saturated absorption is not a problem when operating nanosecond-pulse Q-switched Nd:YAG lasers; it becomes a concern when the pulse duration is considerably less than one nanosecond -- on the order of picoseconds and faster. It is also not a problem for continuous wave lasers. But since ultrafast lasers are becoming more commonplace these days, including uses in research, industrial and medical/dental applications, sufficient care needs to be exercised to avoid eyewear failure and subsequent eye injuries.

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EN 207, CE Marking and Laser Protective Eyewear

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All products sold in the European Union must be CE marked where a relevant European Directive exists. To sell non-CE marked products is illegal. For laser safety eyewear this means showing conformity to the laser protection requirements of the Personal Protective Equipment (PPE) Directive. While in theory manufacturers can use their own standard to show conformance with the directive, as long as they can show that their standard is sufficiently rigorous, in practice the eyewear is always tested and certified to EN 207[1] (or EN 208[2] for alignment eyewear). Such testing must be carried out by a government approved laboratory - self certification is not allowed for these standards. Consequently since 1997, when the EN 207 became a harmonized European Standard, all laser protective eyewear sold legally in Europe has been certified to EN 207 or EN 208.

Despite being around for 8 years EN 207 is still often not well understood. Consequently we are writing a brief explanation here to help users of laser safety eyewear.

Optical Density Specification

Prior to EN 207 laser protective goggles were usually specified by their Optical Density (OD) and this is still a widely used method especially in the USA (where Optical Density is usually the only protective information available for the eyewear). The OD of eyewear is the log of the attenuation factor at a given wavelength. Thus, eyewear which attenuates Nd:YAG laser radiation by a factor of 1,000,000 has an OD of 6 at 1064 nm. The method for specifying eyewear using optical density involves working out the maximum accessible emission from the laser and dividing it by the Maximum Permissible Exposure (MPE)[3] for the laser radiation. The log of this number is the minimum required OD for the eyewear.

Limitations of Optical Density Specification

The problems with this approach are graphically illustrated if we consider a high power CO2 laser emitting at 10600 nm, and some polycarbonate eyewear having an OD > 6 at the same wavelength. The Class 1 Accessible Emission Limit for this wavelength is 10 mW and this power is therefore safe under all exposure conditions. We might therefore expect that the eyewear will protect us against 1,000,000 x 10 mW = 10 kW from the CO2 laser. However, if we place the eyewear in a CO2 laser beam of even a few hundred watts we find that it is very quickly destroyed and offers little protection (even a 20 W beam will cause immediate burning of the eyewear).

Damage Threshold

So we see that Optical Density alone does not take account of the damage threshold of the material which is used to protect us from the laser radiation - i.e. the power or energy density (W/m2 or J/m2) which the eyewear will withstand. EN 207 was written to address this problem and takes account of both the Optical Density and the damage threshold of the eyewear.

EN 207 Markings Explained

After testing to EN 207 the laser protective eyewear is awarded various markings which are printed on the eyewear and specify the maximum power and energy densities which the eyewear can protect against at different wavelengths. For instance eyewear may be marked as follows:

DI 750 - 1200 L5
R 750 - 1200 L6
M 750 - 1200 L4

This means that over the wavelength range 750 - 1200 nm the eyewear has the following ratings:

D L5 I L5 R L6 M L4

The D, I, R and M refer to CW or different pulse lengths as follows:

D - Continuous Wave (CW)
I - Pulsed with pulse length > 100 ns, 'Long Pulse'
R - Pulsed with pulse length > 1 ns and < 100 ns, 'Q-switched'
M - Pulsed with pulse length < 1 ns, 'Femtosecond'[4]

The 'L numbers' (L5, L6, L4 etc) refer to the maximum power or energy density which the eyewear is specified for. The actual values must be looked up from Table

B1 in EN 207. For the eyewear markings given above, the values are:

CW - 1 MW/m2 D L5
Long Pulse - 500 J/m2 I L5
Q Switched - 5 kJ/m2 R L6
Femtosecond- 1.5 J/m2 M L4

An increase in the L number by 1, will increase the power and energy density values by one order of magnitude. Note however, that EN 207 breaks down the L number table into three wavelength ranges, 180 - 315 nm, 315 - 1400 nm and 1400 - 1,000,000 nm. The relationship between the L numbers and power / energy densities shown above holds only for the 315 -1400 nm wavelength region. For other wavelengths refer to EN 207.

L Numbers and Optical Density

As well as being able to withstand the power of the laser beam without being destroyed, the filter must also be able to attenuate the laser beam in order to protect. During the EN 207 testing, in order for a filter to be given an L rating, the filter must have an Optical Density in excess of the L number, at the specified wavelength. Therefore, in the example shown above, we can deduce that the eyewear has an OD > 6 across the wavelength range 750 - 1200 nm (because it has an R L6 rating across this wavelength range). However, we do not need to worry about calculating the MPEs and accessible emission, because this has already been taken account of in the maximum power / energy densities specified for each L number.

Specifying Eyewear Using EN 207

To specify appropriate L numbers for your laser, do the following:

i. Determine the minimum laser beam diameter to which a person might be exposed under reasonably foreseeable circumstances
ii. Calculate the cross-sectional area of the beam at this point
iii. Calculate the average power density at this point by dividing the average power of the laser by the beam area.
iv. Look up the required L number from Table B1 in EN 207. Precede this number with a D.

Additionally for pulsed lasers:

v. Calculate the energy density by dividing the energy per pulse by the beam area.
vi. Look up the required L number from Table B1 in EN 207. Precede this with an I for long pulse, R for Q-switched and M for femtosecond lasers.

Thus a 532 nm laser emitting 1 mJ, 7 ns pulses at at 10 kHz, and having a minimum accessible beam diameter of 2 mm would require eyewear with the following minimum specification:

D 532 L6 (corresponding to 10 MW/m2)

R 532 L5 (corresponding to 500 J/m2)

Note that for pulsed lasers the eyewear must have both the correct I, R or M specification (depending on the pulse length) and the correct D specification, to ensure that it is suitable for the laser.

Two methods of obtaining the L number specification are to use the LaserSafe PC™ software, or to ask the advice of Laser Safety.

NB: This article is intended to help laser users, gain a better understanding of EN 207. It is not intended as an exhaustive study of the subject. For more information refer to the Standard.