LED safety and the evolution of international standards

For the purposes of LED safety analysis, newer standards use lamp-based rather than laser-based criteria. However, with continued improvements in LED performance, safety standards for LED are still evolving, according to Neil Haigh and Geoff Archenhold.

As everyone working in the LED industry is aware, LEDs are getting brighter and brighter. People are also aware that many of today's LEDs are so uncomfortably bright that even a momentary glimpse of the source can leave a strong after-image on the retina that persists for several minutes in many cases. A strong after-image is never a good thing and yet there seems to be little awareness of the actual eye hazards posed by LEDs: are they safe to view, or not? If so, for how long? Does LED safety need to be formally assessed and measured? If so how should this be done? Furthermore, how should an LED product be labelled for the purposes of eye safety?

These are all important questions, and some answers can be found in the work of national and international optical radiation safety committees in tackling the LED safety issue. Foundation work in LED safety was put in place as long ago as 2001. Subsequently, however, a sideline debate has dominated matters concerning whether or not an LED is to be treated as either a "lamp" or a "laser" source. With this debate now concluded in favour of a lamp-based safety analysis, 2008 should be the year when clear guidelines are issued to answer all of the above questions.

Measuring optical radiation safety

Whilst a thorough discussion of the measurement methods used for LED safety assessment is beyond the scope of this article, the basic principle is quite straightforward: a light collection aperture coupled to an optical detector is placed in the beam at a given distance, and the level of optical radiation is recorded. The collection aperture is typically 7 mm in diameter with the measurement distance ranging from 100 mm to 200 mm depending on the standard, to mimic naked eye viewing of the source. An additional field stop is also placed over the source to create a well defined field of view as required for a radiance measurement.

The term "apparent source" is often used to denote that any primary and secondary optics placed in front of an LED can serve to alter both the observed size of the source, and its apparent location as perceived by the observer. The impact of the apparent source can be to modify the safe exposure limit and required measurement distance.

Broadband optical radiation safety

Any standardisation work on LED safety must first take into account known safe limits of human exposure to optical radiation for the various bands of the ultraviolet, visible and infrared regions of the spectrum. Historically, baseline exposure limit data has been published by two international, not-for-profit organizations, namely the International Commission on Non-Ionising Radiation Protection (ICNIRP) and the American Conference of Governmental Industrial Hygienists (ACGIH). The various laser and lamp safety standards that currently exist have very likely based their limits on elements of the ICNIRP and ACGIH data, and ultimately the same situation will be true for LED safety.

Figure 1. Construction of an insulated metal substrate (IMS) for enhanced thermal management.

Laser safety & IEC

At the international level, laser safety standardisation work has centred on the work of the International Electrotechnical Commission (IEC), which publishes product- and application-based standards for electronic and electrical products. For laser safety, the main IEC product safety standard is the landmark document IEC 60825-1 published in various incarnations over the last few decades. IEC also publishes a range of applications-based laser safety standards covering for example the medical, industrial and optical fibre communication fields.

The main laser safety product standard IEC 60825-1 undergoes constant review by the IEC laser safety committee, with updates and revisions reflecting technology advances and increasing expertise; it can be considered to be an extremely advanced optical radiation safety standard (albeit difficult to follow in places).

The 2001 edition of the standard IEC 60825-1:2001 explicitly and unambiguously included LED sources within its scope. This was not necessarily the outcome of some controversial decision, as is often protrayed; instead it was simply a reflection that by the year 2001, the methodology within the standard was advanced enough to include an analysis of LED and LED array sources should they be needed. It didn't really matter whether or not the output of an LED was even akin to that of a laser - a safety analysis could be performed if need be.

LEDs & lamp safety

The decision by the IEC committee to remove LEDs from the scope of the IEC 60825-1: 2007 laser safety standard was in fact an acknowledgement of an existing standard CIE S 009: 2002, which addresses the photobiological safety of lamps and lamp systems, including LED sources if needed. This standard was prepared by the International Commission on Illumination (CIE), an independent organisation devoted to the worldwide dissemination of knowledge and information pertaining to the science of light and lighting. Note that the CIE standard is itself drawn extensively from the work of the Illuminating Engineering Society of North America (IESNA), which publishes several standards in the field.

The safe exposure limits in the CIE lamp safety standard are, like those in the IEC laser safety standard, based upon the underpinning ICNIRP safety data and guidelines. Also, the measurement methods in CIE S 009: 2002 are similar in format to those contained in the IEC laser safety standard.

Unfortunately, the CIE standard does not provide detailed information on how to assess an arrayed source, nor does it include the hazards posed by aided optical viewing, and there is also no information on product safety labelling requirements. Also, the exposure measurement is undertaken at a fixed distance of 200mm from the (apparent) source location and this approach may not be universally applicable to the evaluation of LED and LED array sources. However, the standard does provide clear delineation of the various ocular hazard bands and its methodology is directly applicable to broadband sources (such as white HB-LEDs), which would require a very complex assessment via the laser safety product standard.

IEC 62471:2006

To accommodate the removal of LED sources from IEC 60825-1, the IEC published in 2006 a lamp and LED standard (IEC 62471:2006) that was harmonised with (and indeed directly based upon) the CIE S 009: 2002 lamp safety standard. This relatively new IEC standard is already undergoing revision to better reflect the needs of LED source hazard assessment and labelling, and the updated version is forecast for release in 2008.

While there is no specific information on labelling requirements, the lamp safety standard does contain its own risk classification scheme for potentially hazardous lamps namely: Exempt; Low Risk; Moderate Risk & High Risk which follows a similar reasoning to the IEC laser product classification. In the author's opinion, it would be better to have one harmonised (risk-based) classification scheme for the hazards posed by laser, lamp and LED sources rather than the two schemes which now exist.

For the purposes of international trade of LED products, manufacturers and vendors of LED products should consider IEC 62471:2006 to be the currently applicable product standard for LED safety. This is notwithstanding any specific national regulatory requirements or directives which refer to an alternative standard or assessment method such as the IEC 60825-1:2001 laser (and LED) safety standard. Also, as noted above, caution needs to be advised at this stage that a fixed assessment distance of 200mm may not be sufficient to fully ascertain the maximum optical radiation hazard posed by the source. Consideration might also need to be given to the effect of aided viewing (e.g. magnifiers, telescopes) upon the hazard assessment.

European Union

Within the European Union, there is a clearly established process by which safety standards are prepared and adopted. For electrical and electronics goods such as lasers and LED light sources, responsibility for standards ratification lies with the European Committee for Electrotechnical Standardisation (CENELEC). Once CENELEC issues a European normative standard, then member states will usually adopt that standard adding a national prefix (e.g. BS for the UK, DIN for German etc.) as they do so.

At the present time, the relevant EU normative safety standard for the trade of laser and LED products is EN 60825-1:2001. It should be noted that this standard is still based on the corresponding IEC laser safety standard IEC 60825-1:2001 which includes LEDs within its scope. It cannot be assumed that CENELEC will necessarily follow the recent changes implemented at IEC, and it may be some time (e.g. mid 2008 at the earliest) before the EU standard is revised and updated (presumably, to remove LEDs from its scope).

Furthermore, there are certain EU product regulatory requirements such as CE marking. Another consideration is compliance with the Low Voltage Directive (LVD) and General Product Safety Directive (GPSD), both of which specifically stipulate the use of standard EN 60825:1. Accordingly, LEDs are encompassed by these product safety-based requirements and regulations.

In addition to any work on laser and LED safety, it is worth noting that EU member states have just begun the implementation of the recent 2006 EU Directive on Artificial Optical Radiation (EU AORD). Similar to concerns with electromagnetic compatibly, and acoustic noise hazards, the AORD is aimed at ensuring that all workers within the EU are protected from sources of potentially harmful (artificial) optical radiation: the term artifical denotes that the sun is not included, being covering by existing health and safety legislation. Work undertaken towards this new EU directive is expected to extend and modify the picture with regard to LED product safety in forthcoming yearsl especially as it endorses a risk assessment based approach to the optical radiation hazard assessment that may be required to go beyond the recommendations and limits of any particular optical radiation standard.

In summary for the EU, product safety compliance requirements for LED and laser sources indicate a need presently to follow the safety standard EN 60825-1:2001, which is a laser-based product safety standard that includes LEDs. This situation will likely remain unchanged until the EN standard is revised and updated, and may even be overtaken by any preliminary findings toward implementing the AORD.

United States

In the USA, work on laser safety standardisation has not tended to include LED safety to the same extent as that undertaken by the IEC; furthermore safety guidance is dictated by national rather international considerations. Accordingly in the US, laser product safety is mandated via the US Code of Federal Regulations (CFR), specifically 21 CFR 1040.10 and 21 CFR 1040.11, with these latter regulations issued by the Centre for Devices and Radiological Health (CDRH), a division of the Food and Drug Administration (FDA). Vendors supplying laser products to and within the USA must register their products with the CDRH and they must comply with, and be classified according to, CFR requirements.

However, for the sake of simplicity and as a move towards harmonisation,

Key standards and guidelines relating to optical radiation safety

Document Reference	Title	Comment
Health Physics, September 1997, volume 73, number 3	Guidelines on limits of exposure to broadband optical radiation (0.38 to 3 µm)	Available as a download from the ICNIRP website. Applicable to broadband, conventional, non-laser sources including LEDs. Use of spectral radiance units provides flexibility in selection of measurement distance from (apparent) source to collection aperture.
ANSI/IESNA RP 27 parts 1 to 3	Photobiological safety of lamps and lamp systems	Issued by IESNA and extensively drawn upon for the CIE and IEC lamp safety standards documents below.
CIE S 009: 2002	Photobiological safety of lamps and lamp systems	Contains human eye and skin exposure limits to optical radiation. Measurement distance from (apparent) source location to collection aperture is 200 mm.
IEC 62471: 2006	Photobiological safety of lamps and lamp systems	Identical to CIE S 009: 2002
IEC 60825-1: 2001 (now superseded by the 2007 edition see below.)	Safety of laser products (Part I: Equipment classification and requirements)	Lasers and LED sources included in the scope of the standard. Contains maximum accessible emission limits for each laser product class, plus eye and skin exposure limits. Measurement distance from (apparent) source location to collection aperture varies from 14mm (magnifier viewing) to 100 mm (naked eye viewing). Also includes a test for telescopic viewing.
IEC 60825-1: 2007	Safety of laser products (Part I: Equipment classification and requirements)	LEDs removed from scope in recognition of existing lamp safety standards which are deemed by the IEC laser safety committee to be more appropriate for LED risk/hazard assessment.

the CDRH have since 2001 recognised (via "Laser Notice 50") the value of the IEC laser safety standard IEC 60825-1 for laser classification and they will accept laser products that are compliant with this standard; provited that is, that certain additional criteria listed in Laser Notice 50 are met. Presently, it is not clear what the US stance is towards product classification and registration of LED products, particularly as they do not appear to be referenced directly within the CFR. However, work is now ongoing to establish a US LED safety committee to tackle LED safety, and recently Underwriters Laboratories Inc, announced a programme of activity towards safety certification of LED sources for use in luminaries (see www.ledsmagazine.com/news/4/5/16). In terms of personnel exposure to laser (but not LED) sources it is noted that in addition to the work of the CDRH, the American National Standards Institute (ANSI) publishes a user standard ANSI Z136.1:2007 for the safe use of laser sources.

In the interim, the author would recommend that US LED vendors adopt the IEC 62471:2006 ("lamp") standard as a starting basis for LED safety assessment, bearing in mind the above comments concerning the identification of the most hazardous viewing position and the potential need to consider optically aided viewing.

Summary

In summary, it is clear that the issue of LED product safety standardisation has been in a state of flux for a number of years, while the issue of a "lamp" versus a "laser" assessment has been discussed. To some extent this matter can now be considered resolved in the favour of the "lamp" based assessment by the publication of IEC 62471:2006, and the removal of LEDs from the scope of IEC 60825-1:2007.

This is not necessarily the end of the matter: the unique nature of LED devices and product applications will likely pose hazards that exist beyond the limitations of the present standards, and these will require a thorough investigation to be made over the coming period. Interested readers and those concerned with LED safety should pay careful attention to the work presently being undertaken by their national and international safety standards representatives.

Disclaimer

The contents of this article reflect the author's own opinions, and do not reflect the views of any standards body or organization.

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