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Safety of laser products –

Part 13:
Measurements for classification of laser products

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY OF LASER PRODUCTS –

Part 13: Measurements for classification of laser products

FOREWORD

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IEC 60825-13, which is a technical report, has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
76/332/DTR	76/345/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

This technical report is to be used in conjunction with IEC 60825-1:1993 and its Amendment 1 (1997) and Amendment 2 (2001), referred to in this report as “the standard”.

A list of all parts of the IEC 60825 series, published under the general title *Safety of laser products,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

SAFETY OF LASER PRODUCTS –

Part 13: Measurements for classification of laser products

1 Scope

This part of IEC 60825 provides manufacturers, test houses, safety personnel, and others with practical guidance on methods to perform radiometric measurements or analyses to establish the emission level of laser energy in accordance with IEC 60825-1 (herein referred to as "the standard"). The measurement procedures described in this technical report are intended as guidance for classification of laser products in accordance with, that standard. Other procedures are acceptable if they are better or more appropriate.

Information is provided for calculating accessible emission limits (AELs) and maximum permissible exposures (MPEs), since some parameters used in calculating the limits are dependent upon other measured quantities.

This document is intended to apply to lasers, including extended sources and laser arrays. Users of this document should be aware that the procedures described herein for extended source viewing conditions may yield more conservative results than when using more rigorous methods.

NOTE Work continues on more complex source evaluations and will be provided as international agreement on the methods is reached.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60825-1:1993, *Safety of laser products – Part 1: Equipment classification, requirements and user's guide* [1)]
Amendment 1 (1997)
Amendment 2 (2001)

IEC 61040, *Power and energy measuring detectors, instruments and equipment for laser radiation*

ISO 11554, *Optics and optical instruments – Lasers and laser-related equipment – Test methods for laser beam power, energy and temporal characteristics*

3 Terms and definitions

For the purposes of this document, the terms and definitions contained in IEC 60825-1 as well as the following apply.

3.1
angular velocity
speed of a scanning beam in radians per second

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1) There exists a consolidated edition (1.2) of IEC 60825-1 (1993), including its Amendment 1 (1997) and Amendment 2 (2001).

3.2
beam profile
the irradiance distribution of a beam cross-section

3.3
beam waist
the minimum diameter of an axis-symmetric beam. For non-symmetric beams, there may be a beam waist along each major axis, each located at a different distance from the source

3.4
charge-coupled device
CCD
self-scanning semiconductor imaging device that utilizes metal-oxide semiconductor (MOS) technology, surface storage, and information transfer

3.5
critical frequency
the pulse repetition frequency above which a pulsed laser can be modelled as CW for the purposes of laser hazard evaluation

3.6
Gaussian beam profile
a profile of a laser beam which is operated in the lowest transverse mode, TEM_{00}

NOTE A Gaussian beam profile may also be produced by passing non-TEM_{00} laser beams through beam shaping optical elements.

3.7
measurement aperture
the aperture used for classification of a laser to determine the power or energy that is compared to the AEL for each class

3.8
pulse repetition frequency
PRF
the number of pulses occurring per second, expressed in hertz (Hz)

3.9
Q-switch
a device for producing very short, high peak power laser pulses by enhancing the storage and dumping of energy in and out of the lasing medium, respectively

3.10
Q-switched laser
a laser that emits short, high-power pulses by means of a Q-switch

3.11
Rayleigh distance
Z_r
the distance from the beam waist where the beam diameter has increased by a factor of $2^{0,5}$ for Gaussian or near-Gaussian beam profiles

NOTE Rayleigh distance is often referred to as the confocal parameter.

3.12
responsivity
R
the output of a detector expressed as $R = O/I$, where O is the detector's electrical output and I is the optical power or energy input

4 Applicability

4.1 General

This report is intended to be used as a reference guide by (but not limited to) manufacturers, testing laboratories, safety officers, and officials of industrial or governmental authorities. This report also contains interpretations of IEC 60825-1 pertaining to measurement matters and provides supplemental explanatory material.

4.2 Initial considerations

Before attempting to make radiometric measurements for the purpose of product classification or compliance with the other applicable requirements of IEC 60825-1, there are several parameters of the laser that must first be determined.

a) Emission wavelength(s)

Lasers may emit radiation at one or more distinct wavelengths.

The emission wavelength, wavelengths, or spectral wavelength distribution can typically be obtained from the manufacturer of the laser. Depending on the type of laser, the manufacturer may specify a wavelength range rather than a single value. Otherwise, the emission wavelength, wavelengths or spectral distribution can be determined by measurement, which is beyond the scope of this technical report. See 7.1 for assessing the AEL for multiple wavelengths.

b) Time mode of operation

The time mode of operation refers to the rate at which the energy is emitted. Some lasers emit continuous wave (CW) radiation; other lasers emit energy as pulses of radiation. Pulsed lasers may be single pulsed, Q-switched, repetitively pulsed, or mode locked. Measurements of scanned or modulated CW radiation at a fixed location also result in a train of pulses.

In addition, the pulse train may be encoded, but have an average duty factor (emission time as a fraction of elapsed time, expressed as a decimal fraction or percentage).

c) Reasonably foreseeable single fault conditions

The IEC 60825-1 specifies that tests shall be performed under each and every reasonably foreseeable single fault condition. It is the responsibility of the manufacturer to ensure that the accessible radiation does not exceed the AEL of the assigned class under all such conditions.

d) Measurement uncertainties

It is important to consider potential sources of error in measurement of laser radiation. Clause 5 of this technical report addresses measurement uncertainties.

e) Collateral radiation

Collateral radiation entering the measurement aperture may affect measured values of power or energy and pulse duration. Test personnel should ensure that the measurement setup blocks or accounts for collateral radiation that would otherwise reach the detector.

f) Product configuration

If measurements are being made for the purpose of classification, then the configuration(s) of the product that are intended during all operating conditions, including maintenance, service, and single fault conditions must be known. If measurements are being made to determine the requirements for safety interlocks, labels and information for the user, then the product must be evaluated under the configurations applicable for each of the defined categories of use (operation, maintenance, and service) in accordance with the standard.

IEC technical committee 76 (TC 76) recognises the existence of equivalent measurement procedures, which could yield results that are as valid as the procedures described in this technical report. This report describes measurement procedures that are adequate to meet the measurement requirements of IEC 60825-1 when measurements are needed. In many cases actual radiometric measurements may not be necessary, and compliance with the requirements of IEC 60825-1 can be determined from an analysis of a well-characterised source and the design of the actual product.

Under some circumstances it may be necessary to partially disassemble a product to undertake measurements at the required measurement location, particularly when considering reasonably foreseeable single fault conditions. Where a final laser product contains other laser products or systems, it is the final product that is subject to the provisions of the standard.

5 Instrumentation requirements

Measurement instruments to be used shall comply with the latest edition of IEC 61040 (Power and energy measuring detectors, instruments and equipment for laser radiation). Which instrument class (between class 1 and class 20 giving the approximate value of the possible measurement uncertainty) is to be used depends on the measurement precision needed.

Where instruments not fully compliant with IEC 61040 are used, the individual contributions of different parameters to the total measurement uncertainty have to be evaluated separately. The main points to be considered are those given in IEC 61040:

- change of responsivity with time;
- non-uniformity of responsivity over the detector surface;
- change of responsivity during irradiation;
- temperature dependence of responsivity;
- dependence of responsivity on the angle of incidence;
- non-linearity;
- wavelength dependence of responsivity;
- polarisation dependence of responsivity;
- errors in averaging of repetitively pulsed radiation over time;
- zero drift;
- calibration uncertainty.

Calibrations should be traceable to national standards.

Tests for the determination of measurement uncertainties of the instrument shall be done according to IEC 61040.

For measurement uncertainties of CCD arrays and cameras see ISO 11554.

6 Classification flow

Known or measured parameters of the product enable calculation of AELs and measurement conditions. In addition, fault conditions that increase the hazard must be analysed. Then, a product emission measurement (or several different measurements) will determine if the emission is within the AEL of the class under consideration.

Tables 1 to 4 of IEC 60825-1 provide the accessible emission limits. These tables have rows for the wavelength ranges and columns for the emission durations. Within each row and column entry, there exist one or more formulas containing parameters that are defined in "Notes to Tables 1 to 4" of 9.3 of IEC 60825-1.

The classification flow is illustrated in Figures 1 and 2.

First determine whether the laser is pulsed or continuous wave. If the pulse duration is greater than 0,25 s, the laser is considered continuous wave. For a continuous wave laser, refer to the flowchart in Figure 1, and for a pulsed laser refer to the flowchart in Figure 2.

Next, the wavelength must be determined.

If the laser is pulsed or scanned, the pulse width (PW) and pulse repetition frequency (PRF) must also be determined.

Which class or classes are of interest must be determined. For instance, for a low power application not in the 400 nm – 700 nm region, Class 1, Class 1M and Class 3R might be considered. For a visible wavelength source, Class 1, Class 1M, Class 2, and Class 2M might be considered.

Next, the classification time base must be determined. This can be determined in terms of default values (8.4e) in the standard), or determined from the definition of the T_2 parameter (Notes to Tables 1 to 4 in the standard), or from considering the particular temporal output properties of the product in question.

This information is needed to locate the row and column entries of Tables 1 to 4 in the standard containing the formula or formulas of interest. The parameters used in the formulas will determine what other parameters need to be determined. They include, primarily, apparent source size (or the angular subtense equivalent, α), and the measurement acceptance angle γ_p for the visible photochemical hazard. Generally, only simple extended sources are addressed in this document. Considering the source to be a small source and setting $C_6 = 1$ is a conservative estimate if the apparent source size is not known.

Next, the measurement conditions must be determined (9.3 and Table 10 in the standard) and AEL (Tables 1 to 4 in the standard). For a pulsed laser, several conditions given in 8.4f) of the standard must be evaluated to ensure all fall within the AEL.

Once the AEL has been determined, the output data should be evaluated. The output data may be provided by the manufacturer or measured directly. If output data are provided by the manufacturer, it must be verified that the measurements were performed in accordance with clause 9 of the standard. If the accessible emission is less than the AEL, the laser may be assigned to that Class. For a pulsed laser, the AEL of the Class applies for all emission durations within the time base.

If the accessible emission is not less than the AEL, a higher class AEL should be chosen and assessed. This is repeated until the AEL is not exceeded or the laser product is assigned to Class 4.

The system must be evaluated in accordance with the standard to insure that a reasonably forseeable single fault cannot cause the laser to emit radiation higher than the AEL for the assigned class. If this criterion is met, the laser classification is known.

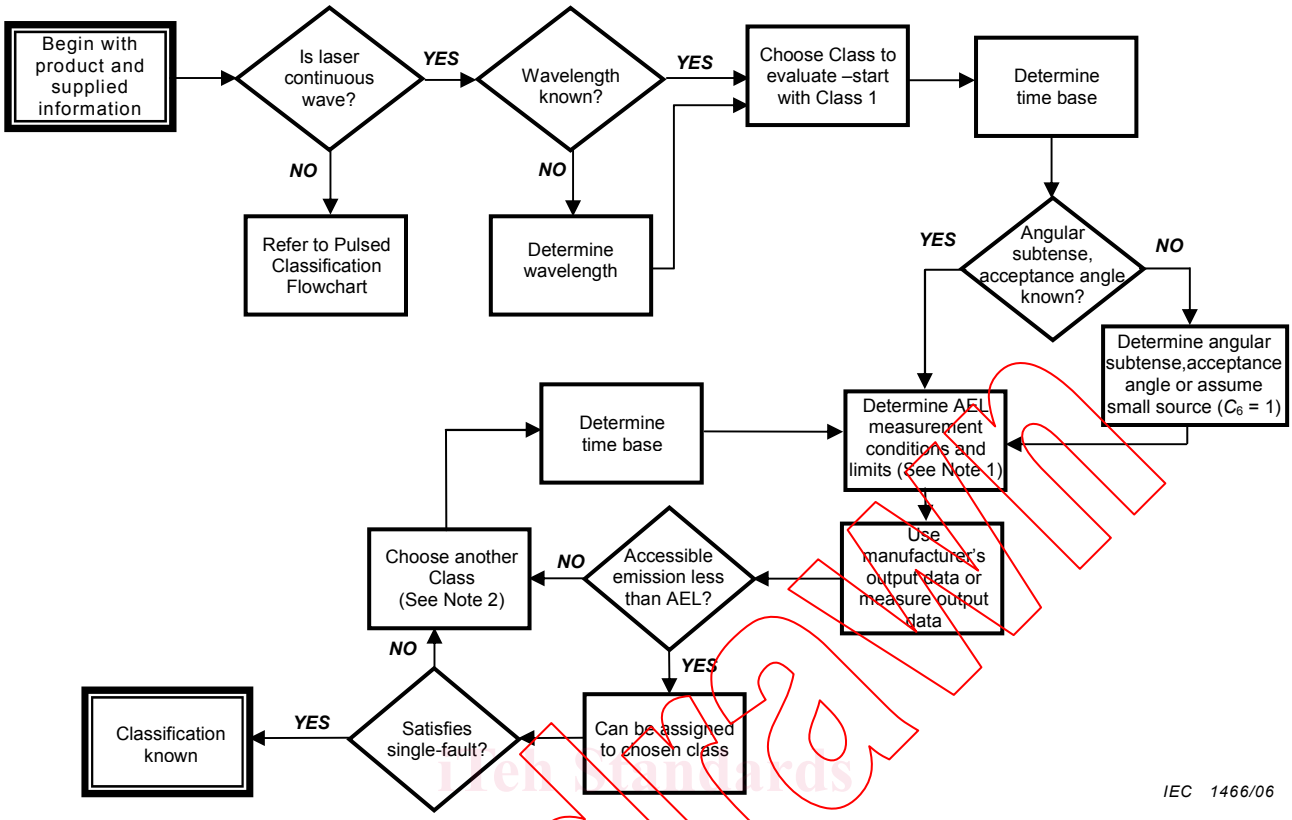

Figure 1 – Continuous wave laser classification flow