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Safety of machinery — Laser processing machines —

Part 1: Laser safety requirements

Sécurité des machines — Machines à laser —

Partie 1: Exigences de sécurité laser

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 9, *Laser and electro-optical systems*, in collaboration with IEC/TC 76, *Optical radiation safety and laser equipment*.

This second edition cancels and replaces the first edition (ISO 11553-1:2005), which has been technically revised with the following main changes:

— the terms "beam delivery systems", "beam path components", "beam shaping components", "beam switching components" and "fibre optic cable" and "fibre connector" were added;

— the document was restructured;

— the Title was adapted;

— other hazards than laser radiation hazards are not considered in this document but are described in Annex A;

— operating modes (automatic mode, setting mode, manual intervention mode, service mode) and the operating mode selector switch were added;

— Clause 5 is separated in requirements regarding different locations and the different modes of operation;

— in Clause 6 the verification procedures were described in more detail;

— Annex B was deleted.

A list of all the parts of ISO 11553 can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The Machinery Safety Directive issued by the European Parliament and the Council of the EC outlines essential and mandatory requirements that must be met in order to ensure that machinery is safe. In response, CEN/CENELEC initiated a programme to produce safety standards for machines and their applications. This document is one in that series.

It has been prepared as a harmonized standard to provide a means of conforming to the essential safety requirements of the Machinery Directive and associated EFTA Regulations.

This document is a type B standard as stated in ISO 12100. The provisions of this document may be supplemented or modified by a type C standard.

For machines which are covered by the scope of a type C standard and which have been designed and built according to the provision of that standard, the provisions of that type C standard take precedence over the provisions of this type B standard.

The purpose of this document is to prevent injuries to persons by

— listing potential laser radiation hazards generated by machines containing lasers,

— specifying safety measures and verifications necessary for reducing the risk caused by specific hazardous conditions,

— providing references to pertinent standards, and

— specifying the information which is to be supplied to the users so that they can establish proper procedures and precautions.

Safety of machinery — Laser processing machines —

Part 1: Laser safety requirements

1 Scope

This document describes laser radiation hazards arising in laser processing machines, as defined in 3.7. It also specifies the safety requirements relating to laser radiation hazards, as well as the information to be supplied by the manufacturers of such equipment (in addition to that prescribed by IEC 60825).

Requirements dealing with noise as a hazard from laser processing machines are included in ISO 11553-3:2013.

This document is applicable to machines using laser radiation to process materials.

It is not applicable to laser products, or equipment containing such products, which are manufactured solely and expressly for the following applications:

— photolithography;

— stereolithography;

— holography;

— medical applications (per IEC 60601-2-22);

— data storage.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 3864 (all parts), *Graphical symbols — Safety colours and safety signs*

ISO 11145:2018, *Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13849-1:2015, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13849-2:2012, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

ISO 13850:2012, *Safety of machinery — Emergency stop function — Principles for design*

IEC 60204-1:2016, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60825-1:2014, *Safety of laser products — Part 1: Equipment classification and requirements*

IEC 60825-4:2006, *Safety of laser products — Part 4: Laser guards*

IEC 62061:2005, *Safety of machinery — Functional safety of safety-related electrical, electronic and programmable electronic control systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11145:2018, ISO 12100:2010, IEC 60825-1:2014 and IEC 60825-4:2006 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp.

— IEC Electropedia: available at http://www.electropedia.org/

3.1
beam delivery system
system comprised of all components, including all optical beam components and potential beam paths and enclosures, which when combined, transfer laser radiation emitted from the laser (according to definition in IEC 60825-1:2014) to the workpiece. The beam delivery system can include all elements for guiding, shaping and switching the laser beams as well as the enclosure of and support for the beam path components

[SOURCE: IEC 60825-4:2006/AMD 2:2011, G.2.1, modified — replaced "workpiece. These components may include" by "workpiece and where the components can include" and changed laser beam to laser beams.]

3.2
beam path component
optical component which lies on a defined beam path

Note 1 to entry: See IEC 60825-1:2014, 3.16.

EXAMPLE A beam steering mirror, a focus lens, a fibre optic cable or a fibre optic cable connector.

3.3
beam shaping component
optical component integrated in the beam path to transform the profile or cross-section of the laser beam by means of apertures, reflective, refractive or diffractive optical components

EXAMPLE Lens or integrating optical element for hardening applications.

3.4
beam switching component
optical component or an assembly of components introduced in the beam path to direct or divert, under external control, the beam path along (a) predetermined direction(s)

Note 1 to entry: The external control allows the beam path to be switched from one predetermined direction to another.

3.5
fibre optic cable
optical beam guiding component that enables the transfer of laser radiation along a transparent medium

Note 1 to entry: The fibre optic cable can be equipped with sensors to monitor breakage and/or temperature.

Note 2 to entry: A fibre optic cable can have a glass or another core that carries the laser radiation and is surrounded by cladding. The outside of the fibre is protected by cladding and can be further protected by additional layers of other materials such as polymer or a metal to protect the fibre from mechanical deformation, ingress of water, etc. In this document, this term also includes other forms of transmission devices such as waveguides.

3.6
fibre connector
fibre component, that connects the fibre optic cable with other components in the beam path

Note 1 to entry: The fibre connector can be equipped with sensors to monitor its position (connected/disconnected).

Note 2 to entry: Typically, fibre connectors connect the fibre with the laser and the laser processing head.

3.7
laser processing machine
machine in which (an) embedded laser(s) provide(s) sufficient energy or power to melt, evaporate, or cause a phase transition in at least a part of the workpiece, and which is ready to use in function and safety

3.8
hazard area
danger zone
space within and/or around machinery in which a person can be exposed to a hazard

Note 1 to entry: Laser hazard area, within which the beam irradiance or radiant expose exceeds the MPE including the possibility of accidental misdirection of the laser beam (see definition according to IEC 60825-1:2014).

3.9
process zone
<laser processing machines> area where the laser beam interacts with the material of the workpiece

3.10
location with controlled access
location where the hazard is inaccessible except to authorized persons who have received adequate training in laser safety and servicing of the system involved

Note 1 to entry: The access to the location is controlled by authorization systems, e.g. keys, password.

Note 2 to entry: See Table 1.

EXAMPLE Service engineers that need to work in a guarded laser hazard area, or in excess of the MPE respectively. Protective measures include, besides technical and administrative means, adequate personal protective equipment (laser protective eyewear, protective clothing).

3.11
location with restricted access
location where the hazard is inaccessible to the public but may be accessible to other observers or other personnel untrained in laser safety

Note 1 to entry: The location with restricted access, for which personnel are kept from being exposed to the laser radiation hazards by guards/walls, barriers or other methods.

Note 2 to entry: See Table 1.

EXAMPLE Performing service at a laser processing machine located in a shop floor, which is the restricted area. The laser hazard area is screened by means of vertical mobile laser guards/walls, which are labelled with safety signs respectively. Reflected laser radiation can propagate to upper floors or scaffold platforms. Personnel having access to the shop floor is trained in organizational measures, so that they follow the organizational safety measures (prohibitions/warnings).

3.12
location with unrestricted and uncontrolled access
location where access is not limited or controlled

Note 1 to entry: All people, including the public can have access to the location.

Note 2 to entry: See Table 1.

Note 3 to entry: If the machine is used under public access, servicing can take place by generating locations with restricted access or locations with controlled access.

EXAMPLE Typically, these machines are exhibited or demonstrated on fairs and exhibitions. Since the public can have access to the location, no hazards may emanate from the laser processing machine.

Table 1 — Description of locations

Location	Controlled	Restricted	Unrestricted and uncontrolled
People	Authorized and trained in laser safety	Personnel untrained in laser safety but not the public	All, including the public

3.13
automatic mode
production
<laser processing machines> operating mode, during which the machine is used as intended (normal use), including

— loading and unloading of parts and/or materials to be processed,

— processing during which the laser beam works alone or in conjunction with other tools

Note 1 to entry: During automatic mode (normal use) safeguarding equipment is closed.

Note 2 to entry: The loading/unloading can take place fully or partly automated or manual.

3.14
setting mode
<laser processing machines> operating mode, during which laser adjustments or settings are carried out by the operator

Note 1 to entry: This is required for changes e.g. of the workpiece, the processing movement paths or the process parameters. During setting mode safeguarding equipment is open, but safety measures, such as significantly reduced speed, or step-mode, reduced laser output power, allow the operator to intervene in the process.

3.15
manual intervention mode
<laser processing machines> operating mode, during which single workpieces can be laser processed and the process can be observed by the operator

3.16
service mode
<laser processing machines> operating mode, in which the machine is operated, to carry out corrective actions

EXAMPLE Fault diagnosis, equipment strip-down and repairing, cleaning of optical elements or adjustments or alignment.

3.17
operating mode selector switch
<laser processing machines> switch or another selection device, which allows the use of the laser processing machine in several control or operating modes, requiring different protective measures and/or work procedures and which can be locked in each position

Note 1 to entry: The selection device includes but is not limited to software.

3.18
modification
change to the machine, which makes it capable of processing materials in a manner which differs from the original design, or which makes it capable of processing materials differently from how it was envisaged in the original design, or which affects the safety characteristics of a machine

3.19
subassembly
constituent part needed for proper performance of the laser processing machine

Note 1 to entry: A laser processing subassembly can be of any laser class in accordance with IEC 60825-1:2014.

3.20
workpiece
material intended to be processed by laser radiation, i.e. the target of the laser beam

3.21
maximum permissible exposure
MPE
level of laser radiation to which, under normal circumstances, persons may be exposed without suffering adverse effects

Note 1 to entry: The MPE levels represent the maximum level to which the eye or skin can be exposed without consequential injury immediately or after a long time and are related to the wavelength of the laser radiation, the pulse duration or exposure duration, the tissue at risk and, for visible and near infra-red laser radiation in the range 400 nm to 1 400 nm, the size of the retinal image. Maximum permissible exposure levels are (in the existing state of knowledge) specified in IEC 60825-1:2014, Annex A.

Note 2 to entry: The MPE values given in IEC 60825-1:2014, Annex A are informative and are provided so that the manufacturer can calculate the NOHD, perform a risk analysis and inform the user about safe usage of the product. Exposure limits for the eye and the skin of employees in the workplace and the general public are in many countries specified in national laws. These legally binding national exposure limits might differ from the MPEs given in IEC 60825-1:2014, Annex A.

[SOURCE: IEC 60825-1:2014, 3.59, modified — in Notes to entry, included IEC 60825-1:2014 before Annex A indication for clarity.]

3.22
nominal ocular hazard area
NOHA
area within which the beam irradiance or radiant exposure exceeds the appropriate corneal maximum permissible exposure (MPE), including the possibility of accidental misdirection of the laser beam

Note 1 to entry: If the NOHA includes the possibility of viewing through optical aids, this is termed the "extended NOHA".

[SOURCE: IEC 60825-1:2014, 3.64]

3.23
foreseeable exposure limit
FEL
maximum laser exposure on the front surface of the laser guard, within the maintenance inspection interval, assessed under normal and reasonably foreseeable fault conditions

[SOURCE: IEC 60825-4:2006, 3.4]

4 Hazards generated by laser radiation

4.1 General

A number of different hazards can emanate from a laser processing machine. This document is (exclusively) addressed to the specific hazards resulting from laser radiation arising in laser processing machines.

Secondary hazards, which are caused by laser beam/material interaction, such as the generation of hazardous substances (fumes, vapours, gases), fire/explosion risks or the generation of secondary radiation, e.g. UV-radiation or ionizing radiation, are not considered in this document.

Other hazards which can emanate from a laser processing machine are given in Annex A.

Particular hazards are also covered by harmonized standards (examples):

For noise reduction and noise measurement methods for laser processing machines and hand-held processing devices and associated auxiliary equipment (accuracy grade 2) see ISO 11553-3:2013, Annex A.

For assessment and reduction of risks arising from radiation (laser and ionizing radiation excluded) emitted by machinery see EN 12198-1 to EN 12198-3.

For the evaluation of the emission of airborne hazardous substances, generated during laser material processing (such as particulate and gaseous substances; e.g. fumes, vapours, gases) see EN 1093 (all parts).

For reduction of risks to health resulting from hazardous substances emitted by machinery see ISO 14123-1 and ISO 14123-2.

4.2 Laser radiation hazards/sources of laser radiation emission

Laser radiation hazards can originate from a direct laser beam or a reflected/scattered laser beam. The normal use as well as malfunctions/reasonably foreseeable fault conditions have to be considered.

Possible emission sources of a direct beam are:

a) aperture of an embedded laser source,

b) beam delivery system within a laser processing machine,

c) laser beam emitted from the processing head (to the workpiece),

d) laser beam emitted from a scanning unit (to the workpiece).

Possible emission sources of a reflected beam are:

— elements (with reflective surface) within the beam delivery system of the laser processing machine,

— the workpiece holder (if the workpiece is missing),

— elements in the processing zone,

— elements inside the housing of a machine (e.g. handling system, suction pipes, parts of guards),

— the workpiece, processed by the laser processing machine.

The optical properties (e.g. surface roughness and reflectivity) of the material exposed to the laser beam decisively determine the kind of reflection (direct/specular reflection or scattered reflection) and thus the risk level. This has impact on both the foreseeable exposure limit (FEL) at the inner surface of a machine enclosure/guard or the resulting irradiance or the radiant exposure at a machine workplace or at a certain distance to the machine.

Inadequate design or malfunctions of laser components and machinery equipment can also be the reason for laser radiation hazards/emission (or a misguided laser beam):

— damaged optical fibre cable,

— damaged passive optical elements (e.g. mirrors, lenses),

— misaligned beam path (inadequate optical elements, incorrectly positioned),

— not properly working active beam guiding and shaping elements,

— not properly working handling system or robot positioning of the laser processing head,

