IEC 60825-4

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

AMENDMENT 1
AMENDEMENT 1

Safety of laser products –
Part 4: Laser guards

Sécurité des appareils à laser –
Partie 4: Protecteurs pour lasers

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

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Email: csc@iec.ch
Tél.: +41 22 919 02 11
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FOREWORD

This amendment has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment.

The text of this amendment is based on the following documents:

FDIS	Report on voting
76/383/FDIS	76/385/RVD

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

The committee has decided that the contents of this amendment and the base 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.

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- withdrawn,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

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Add the title of Annex G as follows:

Annex G (normative) Beam delivery systems

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2 Normative references

Replace the reference to IEC 60825-1 by the following new reference:

IEC 60825-1:2007, *Safety of laser products – Part 1: Equipment classification and requirements*

Add the following two new references:

ISO 14121-1:2007, *Safety of machinery – Risk assessment – Part 1: Principles*

ISO 13849-1:2006, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

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Add, after Annex F, the new Annex G as follows:

Annex G
(normative)

Beam delivery systems

G.1 General

This normative annex addresses the arrangement, installation and use of guided beam delivery systems. Laser beams can be propagated through air, gas or vacuum, whether enclosed or not (free space), and through fibre optic cables in laser processing machine applications.

This annex applies to the protective measures implemented to protect personnel against laser radiation hazards for guided beam delivery systems after the output coupler and/or the protective housing of the laser product (the requirements of which are specified in IEC 60825-1).This annex is intended to compliment the requirements applicable to the laser process enclosure (which are specified in this document and in ISO 11553-1). This annex also provides methods for assessing the risks (including reasonably foreseeable use, abuse and misuse) and provides examples of control measures to meet the normative requirements of IEC 60825-1 and this document.

This annex does not apply to beam delivery systems inside the protective housing of the laser.

This annex does not apply to beam delivery systems used in medical or communications applications.

G.2 Terms and definitions

For the purposes of this annex, the following definitions apply. They are in addition to those given in IEC 60825-1 or other parts of IEC 60825.

G.2.1
access panel
any panel which when removed or displaced gives human access to laser radiation. Sheathing around a fibre, tubing used as an enclosure component or any device serving the function of a removable or displaceable panel, can also be an "access panel" within the terms of this definition

G.2.2
beam delivery system
system comprised of all those components, including all optical beam components and potential beam paths and their enclosures, which when combined, transfer laser radiation emitted from the laser radiation generator (the laser) to the workpiece. These components may include all elements for guiding, shaping and switching the laser beam as well as the enclosure of and support for the beam path components

G.2.3
beam path components
those optical components which lie on a defined beam path (see 3.16 of IEC 60825-1)

NOTE Examples of a beam path component include a beam steering mirror, a focus lens or a fibre optic cable connector.

G.2.4
beam shaping components
those optical components introduced 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

G.2.5
beam switching components
those optical components or an assembly of components introduced in the beam path to direct or divert, under external control, the beam path along predetermined direction(s). The external control allows the beam path to be switched from one predetermined direction to another

G.2.6
fibre optic cable
optical beam guiding component that enables the transmission of laser radiation along a transparent medium. A fibre optic cable may have a glass or other core that carries the laser radiation and be surrounded by cladding. The outside of the fibre is protected by cladding and may be further protected by additional layers of other material such as a polymer or a metal to protect the fibre from mechanical deformation, the ingress of water, etc. For this annex, this term also includes other forms of transmission devices such as waveguides

G.3 General requirements

G.3.1 General considerations

The risks associated with the hazards relevant to the beam delivery systems shall be assessed as part of the overall requirements for risk assessment of the machine. The principles for risk assessment given in standard ISO 14121-1 shall be used in carrying out this assessment. This assessment shall determine the acceptable level of risk and the necessary protective measures for persons who can be exposed to those hazards, while maintaining an acceptable level of performance of the machine.

Hazards can result from, but are not limited to, the following causes:

- failures, faults or damage in the protective housing or other mechanical protective measures incorporated in the beam delivery system resulting in the inadvertent emission of laser radiation from the protective housing;
- failures or faults in the beam path components resulting in damage to the protective housing or other protective devices;
- failures or faults in the associated equipment or controls resulting in injury or malfunction or failure of the safety functions of the laser processing machine;
- failures or faults from reasonably foreseeable misuse or abuse resulting in the inadvertent emission of laser radiation from the protective housings.

The engineering and administrative controls adopted are a combination of the measures incorporated at the design stage and include those instructions to be followed by the user.

Design shall be the first consideration in the reduction of risks. Where this is not sufficient to eliminate risks to a negligible level, additional safeguarding and safe working procedures shall be considered.

NOTE Examples of risk assessments and potential solutions for risk reduction measures are shown in Clause G.6.

G.3.2 Protective housing

The requirements for protective housing are specified in 4.2.1 and 4.2.2 of IEC 60825-1.

G.3.3 Access panels and safety interlocks for beam delivery systems using free space transmission

The requirements for access panels and safety interlocks are specified in IEC 60825-1 Clause 4.3.

A safety interlock shall be provided for access panels of protective housings of free space beam delivery systems that may include beam shaping and beam switching components when:

a) The access panel is intended to be removed or displaced during maintenance or operation of the laser processing machine, and

b) The removal of the panel gives access to laser radiation levels designated by “X” in Table 1 of IEC 60825-1.

The safety interlock shall be part of a design that prevents the removal of the panel until the accessible emission levels are below the AEL defined above. Inadvertent resetting of the interlock shall not in itself restore emission values above the limits specified above.

If a deliberate override mechanism is provided, the requirements of 4.3.2 of IEC 60825-1 shall apply.

All safety interlocks, safety monitoring devices or associated safety-related control circuits shall meet the requirements specified in ISO 12100-2 and ISO 13849-1 with respect to the general requirements for guards together with the requirements related to interlock devices and safety monitoring devices and their application in safety-related control circuits.

G.3.4 Safety interlocks for beam delivery systems using fibre optic cables or other beam waveguides

Removal or displacement of a fibre optic cable (or other form of beam waveguide) in a beam delivery system shall be allowable only under at least one of the following conditions.

a) With the use of a key or tool at the point of connection to allow access, removal or displacement of the fibre optic cable by skilled or trained persons.

b) With the prevention of emission from the fibre optic cable by the termination of emission from the laser prior to access to the fibre optical cable end on the removal or displacement of the fibre optic cable. This may be accomplished by the use of interlocks at the interfaces that can be displaced.

c) Removal or displacement of the fibre optic cable without the use of a key or special tool and without the termination of laser radiation emission from the laser shall be possible only when other protective measures are provided to ensure that personnel are not exposed to laser radiation that will cause injury. These protective measures shall be clearly described in the user instructions together with the necessary procedures for their use.

When a safety interlock is used, removal of the protective housing shall not permit human access to accessible emission levels above the applicable AEL in Table 1 of IEC 60825-1. Inadvertent resetting of the interlock shall not in itself restore emission values above the applicable AEL in Table 1 of IEC 60825-1. These interlocks shall be failsafe or redundant and conform to the requirements in the applicable IEC product standard.

If a deliberate override mechanism is provided, the requirements of 4.3.2 of IEC 60825-1 shall apply.

All safety interlocks, safety monitoring devices or associated safety-related control circuits shall meet the requirements specified in ISO 12100-2 and ISO 13849-1 with respect to the

general requirements for guards together with the requirements related to interlock devices and safety monitoring devices and their application in safety-related control circuits.

G.3.5 Environmental conditions

All beam delivery systems shall meet the safety requirements defined in this annex under all expected operating conditions and foreseeable abuse and misuse appropriate to the intended purpose of the laser processing machine. Factors to be considered shall include:

- the intended environment of use;
- climatic conditions (e.g. temperature, relative humidity, etc.);
- anticipated vibration and shock;
- electromagnetic interferences.

G.4 Verification of safety requirements or protective measures

General conformance with the requirements of this annex shall be by visual inspection.

Correct functioning of control devices shall be verified according to functional tests specified by the manufacturer.

Verification procedures relating to laser radiation levels shall conform to IEC 60825-1.

Verification of the information for the user shall be confirmed by visual examination of the handbooks and any other relevant information.

G.5 Information for users

G.5.1 Technical documentation

In addition to the requirements of other standards that are used in the manufacture of the laser processing machine, the following information shall be supplied.

a) Relevant safety-related documentation and details of safe installation and use of the beam delivery system. This shall, where appropriate, include:
   1) a clear, comprehensive description of the beam delivery system, its installation and mounting and any connection to the host equipment safety-related controls;
   2) electrical supply and other control requirements;
   3) laser radiation performance limitations;
   4) information on the relevant physical environment.

b) Relevant safety-related documentation for maintenance and servicing procedures associated with the beam delivery system. This information shall include guidance on the adjustment, maintenance, replacement and repair, particularly of the protective devices and control for use by authorised service personnel.

c) List of recommended spare parts for use by authorised service personnel.

d) A description (including interconnection diagrams) of the safeguards, interlocking functions and interlocking of guards. This description shall include situations when removal or displacement of the fibre optic cable without the use of a key or special tool and without the termination of laser radiation emission from the laser shall be possible and when other protective measures are provided to ensure that personnel are not exposed to laser radiation that will cause injury. These protective measures shall be clearly described together with the necessary procedures for their use.

e) A description of the means provided, where it is necessary, to suspend the safeguarding.

G.5.2 Labelling

Access panel warning labels shall be fitted as required and described in Clause 5 of IEC 60825-1.

G.6 Examples of risk assessments

Examples of risk assessments are shown below together in Tables G.1 and G.2 with potential solutions for risk reduction measures. The list is not comprehensive and alternative technical measures (that may have identical or improved efficiency) for risk reduction can be considered.

Table G.1 – Beam delivery systems using free space beam delivery systems

Use, reasonably foreseeable misuse or abuse	Failure mechanism	Hazard	Example of risk reduction
Beam directed through beam switching device.	Beam switch emits the laser beam partly or wholly guided to an unexpected beam delivery system.	Laser radiation above Accessible Emission Limit (AEL) of Class 1 at unexpected beam delivery system.	Design the beam switching device to avoid this.
Beam directed through beam switching device.	Beam switch not in proper position - laser beam partly or wholly guided to unexpected beam delivery system.	Laser radiation above AEL of Class 1 at unexpected beam delivery system.	Monitor the beam switching device and interlock to ensure the beam switch components are in the correct positions.
Beam being propagated through the free space beam path protective housing.	Mirror or lens damage, breakage or contamination leading to higher degree of scattered radiation that may cause deformation of components in the beam delivering system.	Laser radiation above AEL of Class 1 from openings in beam delivery system.	The beam delivery protective housing to be able to tolerate the Foreseeable Exposure Limit (FEL) (as defined in 3.4 of this standard) as a passive guard, or use a correctly designed active guard considered. Consider apertures to reduce the amount of radiation scattered from a defective mirror, or limit radiation scattered as a result of misalignment. Monitor the local temperature of vulnerable beam delivery components.
Beam being propagated through the free space beam path protective housing.	Mirror breakage leading to excess heating by the laser beam resulting in the deformation of components in the beam delivering system.	Laser radiation above AEL of Class 1 from openings in beam delivery system.	The beam delivery protective housing to be able to tolerate the FEL as passive guard, or use a correctly designed active guard considered. Consider apertures to reduce the amount of radiation scattered from a defective mirror, or limit radiation scattered as a result of misalignment. Monitor the local temperature of vulnerable beam delivery components.
Beam being propagated through the free space beam path protective housing.	Mechanical deformations of protective housing. (Damage or deformation due to external forces great enough to temporarily or permanently distort the physical configuration.)	Laser radiation above AEL of Class 1 from openings in beam delivery system.	The beam path protective housing designed to tolerate reasonably foreseeable mechanical forces, or provide an alternative active guard.
Beam being propagated through the free space beam path protective housing.	Displacement of the protective housing due to vibrations etc. that may cause the beam delivery system break-up.	Laser radiation above AEL of Class 1 from openings in beam delivery system.	The use of well-tried proven design methods that tolerate foreseeable operating stresses and widely used with successful results in similar applications. Conduct regular inspection.

Table G.1 *(continued)*

Use, reasonably foreseeable misuse or abuse	Failure mechanism	Hazard	Example of risk reduction
Beam being propagated through the free space beam path protective housing.	Misalignment of mirrors.	The beam exposing the protective housing to levels higher than its Protective Exposure Limit (PEL) (as defined in 3.13 of this standard).	The use of well-tried proven design methods that tolerate foreseeable operating stresses and are widely used with successful results in similar applications. Prevent misaligned beam from propagating further in the beam delivery system. Incorporate apertures and baffles/barriers to restrict propagation. Restrict the number and extent of adjustments.
Beam being propagated through the free space beam path protective housing.	Unclear identification of beam delivery components resulting in incorrect parts being installed and subsequent damage of both the parts themselves and other parts of the machine or workpiece.	Laser radiation above AEL of Class 1 from openings in beam delivery system. Damage to associated parts of the machine.	Ensure that all beam delivery system components and parts are labelled to allow easy identification. Provide adequate instructions to minimise the risk of using incorrect parts or of incorrect assembly or adjustment. Incorporate interlocks to prevent incorrect parts or assembly.
Incorrect mounting of beam shaping optics.	Human error.	Laser radiation above AEL of Class 1 (by escaping the protected laser area, or exceeding the laser guard PEL).	Provide adequate instructions to minimise the risk of using incorrect parts or of incorrect assembly or adjustment. Conduct regular inspections.
Damage of beam shaping optics.	From collision with workpiece, overheated optics due to contamination or cooling water failure.	Laser radiation above AEL of Class 1 (by escaping the protected laser area, or exceeding the laser guard PEL).	Ensure that all beam delivery system components and parts are labelled to allow easy identification. Provide adequate instructions to minimise the risk of using incorrect parts or of incorrect assembly or adjustment. Incorporate interlocks or mechanical location keys to prevent the use of incorrect parts or incorrect assembly. Monitor the local temperature of vulnerable beam delivery components

Table G.2 – Beam delivery systems using fibre optic cables

Use, reasonably foreseeable misuse or abuse	Possible failure mechanism	Hazard	Examples of risk reduction
Beam directed through beam switching device.	Beam switch ”leaks” - laser beam partly or wholly guided to unexpected beam delivery system.	Laser radiation above AEL of Class 1 at unexpected beam delivery system.	Design the beam switching device to avoid this.
Beam directed through beam switching device.	Beam switch not in the correct position - laser beam partly or wholly guided to unexpected beam delivery system.	Laser radiation above AEL of Class 1 at the unexpected beam delivery system.	Monitor the beam switching device and interlock to ensure the beam switch components are in the correct positions.
Beam being coupled into fibre.	Damage (i.e. thermal) to coupling optics.	The coupling optical components or assemblies overheat to a degree where it damages or deforms resulting in either leaking radiation or the production of errant beams.	The coupling optical components or assemblies to be designed to handle power passively. Interlock of the beam. Monitor component temperature and interlock into the control system.
Beam being coupled into fibre.	Damaged fibre at the input surface.	Fibre connector heats up to a degree where it deforms and laser radiation is not correctly coupled into the fibre.	Fibre connector designed to handle power passively. Introduce beam monitoring schemes and interlock into the control system.
Beam in fibre optic cable.	Breakage due to mechanical forces on the fibre.	Laser radiation above AEL of Class 1 emitted from a broken fibre to the surrounding. Possible fire hazard.	Fibre to be put inside protective cover that protects from mechanical forces in the operating environment and potential misuse/abuse. Use the protective housing to limit excessive twist. Provide strain relief at the optical fibre terminations to minimise bending and twisting. Make the protective housing active guard linked into the control system (see IEC 60825-4). Monitor component temperature and interlock into the control system.
With the laser beam being directed through the fibre optic, the fibre is subjected to repetitive flexing.	Breakage due to fatigue.	Laser radiation above AEL of Class 1 emitted from a broken fibre to the surrounding.	Design the protective housing to restrict the bending radius to prevent fibre breakage. Provide strain relief at the optical fibre terminations to minimise bending and twisting. Design a reinforced protective housing to be able to tolerate the laser radiation of the inner surface at the protective housing Make the protective housing active guard linked into the control system (see IEC 60825-4).