INTERNATIONAL STANDARD

ISO 11553-1

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Safety of machinery — Laser processing machines —

Part 1: General safety requirements

Sécurité des machines — Machines à laser —

Partie 1: Prescriptions générales de sécurité

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 11553-1 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 9, *Electro-optical systems*, in collaboration with IEC/TC 76, *Optical radiation safety and laser equipment*.

This first edition of ISO 11553-1 cancels and replaces ISO 11553:1996, which has been technically revised.

ISO 11553 consists of the following parts, under the general title *Safety of machinery — Laser processing machines*:

— *Part 1: General safety requirements*

— *Part 2: Safety requirements for hand-held laser processing devices*

Introduction

The Machinery Safety Directive issued by the Council of the EEC 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 part of ISO 11553 is one in that series.

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

This document is a type B standard as stated in ISO 12100-1. 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.

It is applicable to machines using laser radiation to process materials. The purpose of this part of ISO 11553 is to prevent injuries to persons by

— listing potential 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:
General safety requirements

1 Scope

This part of ISO 11553 describes hazards generated by laser processing machines, as defined in 3.2, and specifies the safety requirements relating to radiation hazards and hazards generated by materials and substances. It also specifies the information to be supplied by the manufacturers of such equipment.

Requirements dealing with noise as a hazard from laser processing machines are not included in this part of ISO 11553. They will be included in a subsequent amendment.

This part of ISO 11553 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 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.

ISO 3864:1984, *Safety colours and safety signs*

ISO 11252:2004, *Lasers and laser-related equipment — Laser device — Minimum requirements for documentation*

ISO 12100-1:2003, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology*

ISO 12100-2:2003, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles*

ISO 13849-1:1999, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 14118:2000, *Safety of machinery — Prevention of unexpected start-up*

ISO 14119:1998, *Safety of machinery — Interlocking devices associated with guards — Principles for design and selection*

IEC 60204-1:1997, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60825-1:2001, *Safety of laser products — Part 1: Equipment classification, requirements and user's guide*

IEC 60825-4:1997, *Safety of laser products — Part 4: Laser guards*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100-1 and IEC 60825-1 and the following apply.

3.1
machine
assembly of linked parts or components, at least one of which moves, with the appropriate actuators, control and power circuits, joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material

[ISO 12100-1]

3.2
laser processing machine
machine in which (an) embedded laser(s) provide(s) sufficient energy/power to melt, evaporate, or cause a phase transition in at least a part of the workpiece, and which has the functional and safety completeness to be ready-to-use

3.3
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 See Table 1.

3.4
location with restricted access
location where the hazard is inaccessible to the public but may be accessible to other observers or other untrained personnel who are kept from being exposed to the hazards of laser processing by barriers or other methods

NOTE See Table 1.

3.5
location with unrestricted and uncontrolled access
location where access is not limited or controlled

NOTE See Table 1.

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

3.6
(preventive) maintenance
performance of those adjustments or procedures specified in user information, which are intended to be performed by the user for the purpose of assuring the intended performance of the product

EXAMPLES Replenishment of consumables and cleaning.

3.7
manufacturer
individual or organization that assembles the laser processing machine

NOTE 1 Where a laser processing machine is imported, the importer assumes the responsibilities of the manufacturer.

NOTE 2 An individual or organization that is responsible for modification of a machine is regarded as a manufacturer.

3.8
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 different from what was envisaged in the original design, or which affects the safety characteristics of a machine

3.9
process zone
area where the laser beam interacts with the material of the workpiece

3.10
production
phase during which the machine is used as intended, including the following operations:

— 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 The loading/unloading can be fully or partly automated or manual.

3.11
service
corrective maintenance
performance of those procedures or adjustments described in the manufacturer's service instructions which may affect any aspect of a product's performance

EXAMPLES Fault diagnosis, equipment strip-down and repairing.

3.12
subassembly
constituent part needed for proper performance of the laser processing machine

NOTE A laser processing subassembly can be of any laser class in accordance with IEC 60825-1.

3.13
workpiece
material intended to be processed, i.e. the target of the laser beam

4 Hazards

4.1 General

The following subclauses outline areas of concern associated with materials processing with lasers.

4.2 Inherent hazards

The following hazards (see ISO 12100-1 and ISO 12100-2) may be generated by a laser processing machine:

- mechanical hazards;
- electrical hazards;
- thermal hazards;
- vibration hazards;
- radiation hazards, such as
  - hazards generated by direct or reflected laser beam,
  - hazards generated by ionizing radiation,
  - hazards generated by collateral (UV, microwave, etc.) radiation produced, for example, by flash lamps, discharge tubes or RF-power sources, and
  - hazards generated by secondary radiation due to beam effect (the wavelength of the secondary radiation may be different from that of the beam);
- hazards generated by materials and substances, such as
  - hazards due to products which are used in the machine (e.g. laser gases, laser dyes, lasing gases, solvents),
  - hazards resulting from interaction between the beam and the material (e.g. fumes, particles, vapours, debris), fire or explosion,
  - hazards from associated gases (see for example 5.3.4) used to assist laser target interactions and from any fumes that are produced; these hazards include explosion, fire, toxic effects and oxygen depletion;
- hazards generated by neglecting ergonomic principles in machine design.

4.3 Hazards created by external effects (interferences)

Power conditions and the environment in which the machine operates may cause the machine to malfunction, thus giving rise to hazardous conditions and/or making it necessary for someone to intervene within hazard zones.

Additional environmental interferences include

- temperature,
- humidity,
- external shock/vibration,
- vapours, dust or gases from the environment,
- electromagnetic/radio frequency interference,
- source voltage interruption/fluctuation, and
- insufficient hardware/software compatibility and integrity.

4.4 Hazards covered by this part of ISO 11553

Only radiation hazards and hazards generated by the laser interaction with materials and substances are dealt with in this part of ISO 11553. Other potential hazards are listed in Annex A.

5 Safety requirements and measures

5.1 General requirements

The extent to which hazards are covered is indicated in the Scope. Machinery shall comply as appropriate with ISO 12100-1 and ISO 12100-2 for hazards which are not covered by this part of ISO 11553.

Manufacturers shall ensure the safety of laser processing machines by

— hazard identification and analysis,

— implementation of safety measures,

— certification and verification of the safety measures, and

— provision of appropriate information for the user.

Based on the hazard identification (see 5.2), appropriate safety measures shall be incorporated into the laser processing machine by design and manufacture.

The following requirements shall be satisfied:

— each manufacturer shall comply with the safety requirements and measures stipulated in this clause;

— the manufacturer of an installed machine shall be responsible for the compliance of the whole machine, including subassemblies.

NOTE These requirements apply even if the manufacturer and the customer/user are the same legal entity.

These measures shall take into account each hazard listed in Clause 4, and the results of the hazard analysis, and should take into account information in Annexes A and B.

5.2 Risk assessment

A risk assessment shall be performed

— for all phases of machine “life” (as applicable); for examples see ISO 12100-1;

— after each modification of the machine by the person or organization responsible for the modification.

A risk assessment includes but is not limited to

a) hazards listed in 4.2 and 4.3;

b) danger zones, particularly those associated with

   — the laser system,

   — the laser beam path/beam delivery system, and

   — the process zone;

c) "interferences” listed in 4.3.

The results of the risk assessment shall be duly documented. Concerning principles for risk assessment, see also EN 1050.

5.3 Implementation of corrective measures

5.3.1 General

Safety measures shall be incorporated in the machine by design and manufacture as specified in 5.3.2 to 5.3.4.

5.3.2 Protection against laser radiation hazards

5.3.2.1 General

5.3.2.1.1 For laser processing machines operating in locations with unrestricted and uncontrolled access, the possibility that people be exposed to levels of laser radiation exceeding the accessible emission limit (AEL) for Class 1 shall be eliminated during production. Access to radiation in excess of the AEL for which direct viewing is not permitted shall be eliminated for maintenance.

To satisfy these requirements, the following conditions shall be met.

— Unauthorized human access to a danger zone shall be prevented by engineering measures as stipulated in IEC 60825-1 and ISO 12100-1 and ISO 12100-2.

5.3.2.1.2 For laser processing machines operating in locations with restricted or controlled access, the possibility that people be exposed to levels of laser radiation exceeding the maximum permissible exposure (MPE) at the ocular exposure limits for 3×10^4 seconds exposure shall be eliminated during production (normal or otherwise).

To satisfy this requirement, the following conditions shall be met.

— A Risk Assessment shall be performed. Unauthorized human access to a danger zone should be prevented by engineering measures as specified in IEC 60825-1 and ISO 12100-1 and ISO 12100-2.

— If access cannot be prevented, exposure above the ocular MPE shall be eliminated by use of engineering or administrative controls, including Personal Protective Equipment (PPE).

5.3.2.1.3 For all laser processing machines, without regard to restricted or controlled access, the following shall apply.

— If human presence in a danger zone is unavoidable while the machine is functioning (e.g. during service), the machine shall be equipped with means for direct control of machine motion, beam direction and beam stop (see 5.3.3.5).

— The design of protective devices, such as shutters, guards, beam dissipation devices and deterring/impeding devices, shall meet the requirements specified in IEC 60825-1 and ISO 12100-1 and ISO 12100-2. A single protective device may be used to provide simultaneous protection against more than one hazard.

— Laser guards shall comply with requirements specified in IEC 60825-4.

5.3.2.2 Protection during production

The principal danger zone is usually the process zone but the danger zone shall be defined as a result of the risk assessment.

The hazard analysis shall indicate which type of guarding (local protection or peripheral protection) is to be used.

Local protection is a method of guarding to reduce laser radiation and associated optical radiation to a safe level based on a risk assessment (e.g. by means of a nozzle or a small guard fitted close to the beam focus at the workpiece) without totally enclosing the workpiece, the workpiece support and/or machine motion system.

Peripheral protection is a method of guarding to reduce laser radiation and associated optical radiation to a safe level based on a risk assessment by means of one or more distant guards (e.g. a protective enclosure) that enclose the workpiece, workpiece support and, usually, most of the machine motion system. The sort of protection will depend on several factors, for instance:

— the direction (fixed or variable) of beam propagation with regard to the workpiece;

— the type of machining operation to be realized (cutting, welding, etc.);

— the material and shape of the workpiece to be processed;

— the workpiece support;

— the visibility of the process zone.

5.3.2.3 Protection during service

During service procedures, human access to laser radiation exceeding the AEL for Class 1 is sometimes unavoidable. Machines shall therefore be designed, and appropriate safety measures provided, with respect to the following four situations (listed in order of preference):

a) servicing takes place outside danger zones;

b) servicing takes place in danger zones to which access is controlled in the same manner as during production;

c) servicing takes place in a danger zone (e.g. with open guards that are normally closed during production) but accessible laser radiation does not exceed the AEL for Class 1;

d) servicing takes place in danger zones, for example because opening of guards (normally closed during production) is necessary. In this case accessible laser radiation exceeds the AEL for Class 1.

The manufacturer shall indicate the class of accessible laser radiation and recommended safety procedures for each of these situations.

5.3.2.4 Protection during teaching, programming and programme verification

During teaching, path programming and programme verification, human access to laser radiation exceeding the AEL for Class 1 should be prevented. If this condition cannot be met, the same requirements as for servicing shall apply. See also 5.3.3.5.

5.3.3 Control means and circuits

Control means and circuits shall comply with IEC 60204-1. The design of control systems shall comply with ISO 13849-1.

NOTE Typically, this would result in Safety Category 3.

5.3.3.1 Start/stop controls

The machine stop control shall stop the machine (i.e. switch off actuators) and either isolate the laser beam or deactivate laser beam generation. The laser stop control shall deactivate beam generation.

Separate control devices may be provided for the laser system and the rest of the machine.

5.3.3.2 Emergency stop control

The emergency stop control shall comply with IEC 60204-1.

The emergency stop control shall

— deactivate laser beam generation and automatically position the laser beam stop,

— deactivate the machine (i.e. actuator power off), and

— switch off the laser power supply and discharge all stored energy.

If a laser device is used for several machines which work separately from one another, the emergency stop control located on one of the machines shall work as above, or

— deactivate the relevant machine (i.e. actuator power off), and

— isolate the laser beam optical path leading to the relevant machine.

Unexpected start-up shall be prevented by compliance with ISO 14118 and, for the emergency stop equipment, ISO 13849-1 shall apply.

5.3.3.3 Interlocks and guard control

When guards (per ISO 12100-1 and ISO 12100-2) are opened or displaced, or safety interlocks are defeated, automatic operation of the machine shall be impossible.

If the design of the machine requires occasional procedures to be carried out with one or more guards open (normally closed during production) and with power supplied to the machine actuators, then an operating mode shall be provided to make overriding of the guard(s) possible.

The selection of this operating mode shall

— be by means of a lockable mode selector,

— automatically isolate the laser beam or deactivate the laser, and

— prevent automatic operation of the machine (see ISO 14118).

A key-operated switch may be used as the mode selector.

Discrete, deliberate, interlock override mechanisms on removable access panels with safety interlocks (defeatable safety interlocks) shall meet the requirements of IEC 60825-1 for such override mechanisms.

The operation mode selected shall be clearly signalled. After this operation mode has been selected, it shall be possible to override the beam isolation (i.e. “open” the beam stop) for service procedures.

Interlocking systems shall comply with ISO 14119.

5.3.3.4 Provisions for isolation of the laser beam

Isolation of the laser beam shall be achieved by blocking and/or deflecting the laser beam to prevent it from entering the beam delivery system.

Beam isolation shall be accomplished using a fail-safe laser beam stop (shutter) located inside or immediately outside the laser. A position indicator shall show when the beam stop is in the closed position (i.e. preventing the beam from proceeding).

Suitable easily accessible means shall be provided for locking the laser beam stop in the closed position. A key-control shall be permitted for this purpose.

Additional beam stops may be provided by the machine manufacturer, for example in the following situations:

a) when there are maintenance/cleaning areas present along the beam path (beam delivery system);

b) when one laser device supplies more than one beam path, and there is a need for human intervention in one path while the beam is following one of the other paths.

5.3.3.5 Device for protection when people are inside a danger zone

As stated in ISO 12100-2:2003, 5.2.4, for situations (except production) when human presence in a danger zone is necessary, the machine shall be provided with a device for control of machine motion and laser beam emission, to be operated by the person inside the danger zone. The following requirements shall apply to this device:

a) the device shall be provided with a hold-to-run control which, when released, prevents access to radiation in excess of AEL for which direct viewing with the unaided eye is not permitted or other means of control as provided in IEC 60204-1;

b) when placed under the control of this device, all machine motions and laser beam emission shall be controllable only from this device;

c) if it is possible to enter the danger zone through a door, then it shall be possible to start laser emission using this device only after closing such doors.

This clause fulfils the requirements of ISO 12100-2:2003, 5.2.4.

5.3.4 Protection against hazards generated by materials and substances

The manufacturer shall inform the customer/user of the materials that are intended to be processed with the machine. This applies also for materials and substances unintentionally deteriorated by the laser radiation. The manufacturer shall supply suitable means for capturing the fumes and airborne particles from these materials. The manufacturer shall provide information on the threshold limit values for the fumes and particulate matter generated by machining these materials.

NOTE The safe removal and disposal of fumes and particulate matter from the machine according to local, national or regional Threshold Limit Values are the responsibility of the customer/user.

Due regard shall be given to the hazards from associated gases (e.g. oxygen) used to assist laser/workpiece interactions and from any fumes that are produced. Related hazards include explosion, fire, toxic effects, oxygen excess and oxygen depletion.

Additional information is given in Annex A.

6 Verification of safety requirements and measures

General conformance with the requirements of this part of ISO 11553, particularly those relating to the presence and positioning of guards and control devices, shall be confirmed 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.

7 Information for user

In addition to the requirements of IEC 60204-1, IEC 60825-1, ISO 11252 and ISO 12100-2, the following requirements shall be satisfied.

a) The manufacturer shall supply pertinent safety-related documentation and data, including correct maintenance and servicing procedures to the customer/user.

b) The manufacturer shall inform the user as to the responsibilities of the user relating to the removal and/or disposal of fumes and particulate material from the machine.

c) The manufacturer shall provide information on the limit values for the materials intended to be processed and for the fumes and particulate matter generated by machining these materials. The manufacturer shall also provide general information about equipment for removal of fumes and particulate matter.

d) The manufacturer shall make available suitable safety-related training to the user.

e) The manufacturer shall advise users of known potential hazards by providing a prominently placed warning statement in the user instructions and/or operator's manual.

The following items should be considered for inclusion in the user's instructions and/or operator's manual.

— IEC 60825-1 specifies protective measures for the primary laser radiation. The minimum requirement, in the case of potential exposure by a class 3B and class 4 product, is to wear protective eyewear rated for the laser power and wavelength.

— Some operations (e.g. welding) may produce intense UV and visible radiation. The minimum requirement, in the case of potential exposure to this kind of radiation, is to wear appropriate protective eyewear (e.g. a welding mask).

— Most material processing applications produce fumes and particles. When processing metals, heavy metal vapours may be produced. These can harm body tissues and organs. When processing plastics, hazardous (e.g. allergic, toxic, carcinogenic) by-products can be produced. Suitable protective measures such as guards or filtered breathing masks may be necessary.

The minimum requirements, before starting the process, are

a) to be familiar with the material to be processed, know what by-products may result, assess their risk to health and determine what precautions are necessary;

b) to employ appropriate measures to prevent or control the risk; such measures will normally require positive exhaust of fumes from the process zone and adequate purification before exhaust gases are returned to the atmosphere away from personnel;

c) to inform, instruct and train operators about the risks, and the precautions to be taken;

d) where necessary, to monitor the exposure of operators and carry out an appropriate form of surveillance of their health in compliance with local regulations;

e) to consult a pertinent authority to find out what national, state and/or local regulations must be satisfied before exhaust gases are returned into the atmosphere.

Dangerous voltage/current is used to power the laser and its associated equipment. Power supplies can contain capacitor banks which may remain charged for some time after switching the equipment off.

The minimum requirements in the case of repair is to follow the rules for electrical safety practices.

8 Labelling

Local or regional laws for labelling shall be adhered to.

The machine shall be labelled to indicate

— the name and address of the laser processing machine manufacturer,

— the manufacturing date, and

— the series or type of machine (if appropriate) and serial number (if any).

The labels shall satisfy the following requirements:

— colours, sizes and print styles of laser radiation warning labels shall be as described in IEC 60825-1;

— in addition to the labelling required by IEC 60825-1, the laser processing machine shall, after installation, carry other pertinent cautionary and warning labels (e.g. “TOXIC FUMES/PARTICLES MAY BE GENERATED BY THIS MACHINE”). The size and location of the labels shall be such as to make the appropriate labels legible from outside the danger zones without exposing anyone to any of the hazards listed in Clause 4.

The colour, size and print style of the labels shall comply with the requirements of ISO 3864.

Annex A
(informative)

Potential hazards

A.1 Examples of processing by-products

A.1.1 General

The following are examples of some of the more common by-products of material processing using lasers.

These examples are provided for information only, and are not comprehensive.

A.1.2 Ceramic processing

Oxides of aluminium (alumina), magnesium, calcium and silicon.

Beryllium oxide (highly toxic).

A.1.3 Silicon processing

Airborne Si and SiO debris (respirable; can cause silicosis).

A.1.4 Machining metals

From the medical point of view, at least the following metals and their compounds are relevant:

Mn, Cr, Ni, Co, Al, Zn, Cu, Be, Pb, Sb.

Medical effects are as follows:

— toxic: Cr^{6+}, Mn, Co;

— allergies, metal fume fever: Zn, Cu;

— lung fibrosis: Be;

— carcinogenic: Cr^{6+}, NiO.

Beryllium is very dangerous. Heavy metal fumes are created especially when cutting alloys similar to titanium, magnesium and aluminium, or Zn-bearing metals.

A.1.5 Cutting plastics

A great variety of potentially hazardous substances can be emitted. At low temperatures, aliphatic hydrocarbons are produced, whereas higher temperatures result in an increase of aromatic hydrocarbons (such as benzene, PAH) and polyhalogenated polynuclear hydrocarbons (e.g. dioxins, furanes). Particular materials can lead to emissions of cyanides, isocyanates (polyurethanes), acrylates (PMMA) and hydrogen chloride (PVC).

Medical effects include:

— toxic: cyanides, CO, benzene derivatives,

— allergens/irritants: isocyanates, acrylates,

— irritation of respiratory tract: formaldehyde, acrolein, amines,

— carcinogenic: benzene, some PAHs.

A.1.6 Welding metals

General fume emission is low compared to metal cutting. Heavy metal vapours can be expected.

See A.1.4.

A.1.7 Heat treatment

Generally no significant by-products but some heavy metal vapours may be generated.

A.1.8 Soldering and brazing

Heavy metal vapours, flux vapours and by-products can be expected.

A.1.9 Cutting paper and wood

Standard cellulose by-products, esters, acids, alcohols and benzene.

A.1.10 Unintentionally deteriorated materials

Generation of hazardous by-products from materials and substances unintentionally deteriorated by the laser radiation (e.g. optics).

Zn, Se oxides.

A.2 Examples of secondary radiation hazards

Secondary radiation hazards include optical radiation from the welding zone, bringing about

— degradation of polymers and emission of poisonous fumes and gases, particularly ozone,

— fire or explosion hazards posed by flammable materials and substances,

— X-rays from plasmas, and

— hazards to people from the emitted UV-radiation and bright visible light.

A.3 Examples of mechanical hazards

Moving machine parts can be a hazard.

Robots can punch a hole in a protective housing, damage the laser or the beam delivery system, and point the laser beam at an operator/enclosure wall/viewing window.