



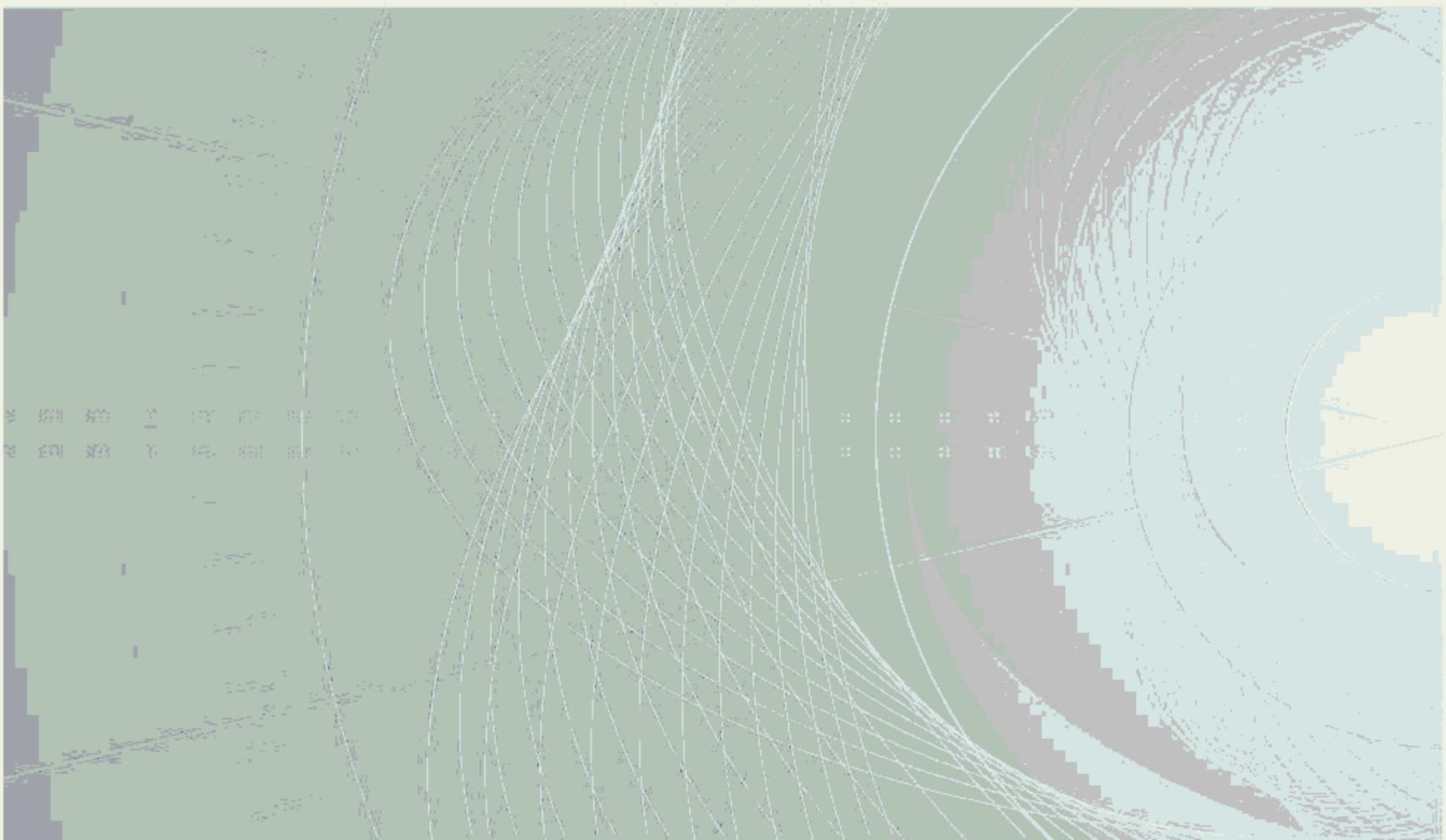
IEC 61496-2

Edition 4.0 2020-07

INTERNATIONAL STANDARD



**Safety of machinery – Electro-sensitive protective equipment –
Part 2: Particular requirements for equipment using active opto-electronic
protective devices (AOPDs)**





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**Safety of machinery – Electro-sensitive protective equipment –
Part 2: Particular requirements for equipment using active opto-electronic
protective devices (AOPDs)**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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depending on the dimensions of the light curtain 33

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SAFETY OF MACHINERY –
ELECTRO-SENSITIVE PROTECTIVE EQUIPMENT –****Part 2: Particular requirements for equipment using
active opto-electronic protective devices (AOPDs)**

FOREWORD

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International Standard IEC 61496-2 has been prepared by IEC technical committee 44: Safety of machinery – Electrotechnical aspects, in collaboration with CENELEC technical committee 44X: Safety of machinery – Electrotechnical aspects.

This fourth edition cancels and replaces the third edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Requirements and test procedures in Part 2 that were found to be common to all ESPEs have been moved to Part 1. Test procedures that are dependent on the sensing technology remain in Part 2.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
44/875/FDIS	44/878/RVD

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

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

This standard has the status of a product family standard and can be used as a normative reference in a dedicated product standard for the safety of machinery.

This standard is to be used in conjunction with IEC 61496-1:2020.

This part supplements or modifies the corresponding clauses in IEC 61496-1:2020.

Where a particular clause or subclause of IEC 61496-1:2020 is not mentioned in this Part 2, that clause or subclause applies as far as is reasonable. Where this part states "*Addition*", "*Modification*" or "*Replacement*", the relevant text of IEC 61496-1:2020 is adapted accordingly.

Clauses and subclauses which are additional to those of Part 1 are numbered sequentially, following on the last available number in Part 1. Terminological entries (in Clause 3) which are additional to those in Part 1 are numbered starting from 3.201. Additional annexes are lettered from AA onwards.

A list of all parts in the IEC 61496 series, published under the general title *Safety of machinery – Electro-sensitive protective equipment*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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

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INTRODUCTION

Electro-sensitive protective equipment (ESPE) is applied to machinery that presents a risk of personal injury. It provides protection by causing the machine to revert to a safe condition before a person can be placed in a hazardous situation.

This document provides particular requirements for the design, construction and testing of electro-sensitive protective equipment (ESPE) for the safeguarding of machinery, employing active opto-electronic protective devices (AOPDs) for the sensing function.

Each type of machine presents its own particular hazards, and it is not the purpose of this document to recommend the manner of application of the ESPE to any particular machine. The application of the ESPE should be a matter for agreement between the equipment supplier, the machine user and the enforcing authority; in this context, attention is drawn to the relevant guidance established internationally, for example, ISO 12100.

Due to the complexity of the technology of ESPEs, there are many issues that are highly dependent on analysis and expertise in specific test and measurement techniques. In order to provide a high level of confidence, independent review by relevant expertise is recommended.

SAFETY OF MACHINERY – ELECTRO-SENSITIVE PROTECTIVE EQUIPMENT –

Part 2: Particular requirements for equipment using active opto-electronic protective devices (AOPDs)

1 Scope

This clause of Part 1 is replaced by the following:

This part of IEC 61496 specifies requirements for the design, construction and testing of electro-sensitive protective equipment (ESPE) designed specifically to detect persons as part of a safety-related system, employing active opto-electronic protective devices (AOPDs) for the sensing function. Special attention is directed to features which ensure that an appropriate safety-related performance is achieved. An ESPE can include optional safety-related functions, the requirements for which are given in Annex A of IEC 61496-1:2020 and of this document.

This document does not specify the dimensions or configurations of the detection zone and its disposition in relation to hazardous parts for any particular application, nor what constitutes a hazardous state of any machine. It is restricted to the functioning of the ESPE and how it interfaces with the machine.

Excluded from this document are AOPDs employing radiation at wavelengths outside the range 400 nm to 1 500 nm.

This document can be relevant to applications other than those for the protection of persons, for example, the protection of machinery or products from mechanical damage. In those applications, additional requirements can be necessary, for example, when the materials that are to be recognized by the sensing function have different properties from those of persons.

This document does not deal with electromagnetic compatibility (EMC) emission requirements.

2 Normative references

This clause of Part 1 is applicable except as follows:

Addition:

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

IEC 61496-1:2020, *Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests*¹

IEC 62471, *Photobiological safety of lamps and lamp systems*

ISO 13855, *Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body*

ISO 20471, *High-visibility clothing – Test methods and requirements*

¹ To be published.

3 Terms and definitions

This clause of Part 1 is applicable except as follows:

Addition:

3.201

active opto-electronic protective device

AOPD

device whose sensing function is performed by opto-electronic emitting and receiving elements detecting the interruption of optical radiations generated, within the device, by an opaque object present in the specified detection zone (or for a light beam device, on the axis of the light beam)

Note 1 to entry: This note applies to the French language only.

3.202

beam centre-line

optical path joining the optical centre of an emitting element to the optical centre of the corresponding receiving element that is intended to respond to light from that emitting element during normal operation

Note 1 to entry: The optical axis of a light beam is not always on the beam centre-line.

Note 2 to entry: Physical displacement of the beam centre-line may occur as a consequence of normal operation (for example, by the use of a motor-driven mirror).

Note 3 to entry: For an AOPD that operates on a retro-reflective technique, the optical path is defined by the retro-reflector target together with the emitting and receiving elements.

3.203

effective aperture angle

EAA

maximum angle of deviation from the optical alignment of the emitting element(s) and the receiving element(s) within which the AOPD continues in normal operation

3.204

light beam device

AOPD comprising one or more emitting element(s) and corresponding receiving element(s), where a detection zone is not specified by the supplier

3.205

light curtain

AOPD comprising an integrated assembly of one or more emitting element(s) and one or more receiving element(s) forming a detection zone with a detection capability specified by the supplier

Note 1 to entry: A light curtain with a large detection capability is sometimes referred to as a light grid.

3.206

test piece

opaque cylindrical element used to verify the detection capability of the AOPD

3.207

geometrically restricted optical design

GROD

AOPD using an optic design where

- the effective aperture angle (EAA) of each emitting and each receiving element does not exceed the values given in Figure 6 and
- the axes of the optical beams are parallel and

- side lobes are minimized and
- the spacing between beam centre-lines is uniform and
- the value of detection capability is based on the complete obscuration of at least one beam for any and all positions of the test piece within the detection zone (see Figure 7).

Replacement:

3.3

detection capability

dimension representing the diameter of the test piece which:

- for a light curtain, will actuate the sensing device when placed in the detection zone;
- for a single light beam device, will actuate the sensing device when placed in the beam centre-line;
- for a multiple light beam device, will actuate the sensing device when placed in any beam centre-line

Note 1 to entry: The term "detection capability" can also be used to mean the ability to detect a test piece of the specified diameter.

4 Functional, design and environmental requirements

This clause of Part 1 is applicable except as follows:

4.1 Functional requirements

4.1.2 Sensing function

Replacement:

4.1.2.1 General requirements

The sensing function shall be effective over the detection zone specified by the supplier. No adjustment of the detection zone, detection capability or blanking function shall be possible without the use of a key, keyword or tool.

The sensing device of a light curtain shall be actuated and the OSSD(s) shall go to and remain in the OFF-state when a test piece in accordance with 4.2.13 is present anywhere within the detection zone either static (at any angle) or moving (with the axis of the cylinder normal to the plane of the detection zone), at any speed between 0 m/s and 1,6 m/s.

The sensing device of a light beam device shall be actuated and the OSSD(s) shall go to and remain in the OFF-state when a test piece in accordance with 4.2.13 is present in the beam centre-line, at any point throughout the operating distance, with the axis of the cylinder normal to the axis of the beam.

Where the supplier states that an AOPD can be used to detect objects moving at speeds greater than those specified above, the above requirements shall be met at any speed up to and including the stated maximum speed(s).

4.1.2.2 Additional requirements for AOPDs using retro-reflective techniques and for AOPDs using mixed emitters and receivers in the same assembly

4.1.2.2.1 General

AOPDs using retro-reflective techniques where the light beam traverses the detection zone more than once (over the same path) and AOPDs using mixed emitters and receivers in the same assembly shall not fail to danger if a reflective object (for example, reflective clothes) is placed at any position in the detection zone.

NOTE The use of mirrors to return the light beam is not considered to be a retro-reflective technique.

4.1.2.2.2 Sensing function

The OSSD(s) shall go to the OFF-state when a reflective object of a size equal to, or greater than, the diameter and length of the test piece (see 4.2.13) is placed in the detection zone at any position as specified in 5.2.1.4.

For a type 3 AOPD or a type 4 AOPD, under normal operating conditions, the OSSD(s) shall go to the OFF-state when a reflective object, as specified in 5.2.1.4, is placed as close as practicable in front of the sensing surface of the emitting/receiving elements.

4.1.3 Types of ESPE

Replacement:

In this document, only type 2, type 3 and type 4 ESPEs are considered. The types differ in their performance in the presence of faults and under influences from environmental conditions. In IEC 61496-1:2020, the effects of electrical and electromechanical faults are considered (such faults are listed in Annex B of IEC 61496-1:2020).

NOTE The machine supplier and/or the user will determine which type is required for a particular application.

For a type 2 ESPE, in normal operation the output circuit of at least one output signal switching device shall go to the OFF-state when the sensing function is actuated, or when power is removed from the ESPE.

A type 2 ESPE shall fulfil the fault detection requirements of 4.2.2.3.

A type 3 ESPE shall fulfil the fault detection requirements of 4.2.2.4.

A type 4 ESPE shall fulfil the fault detection requirements of 4.2.2.5.

For a type 3 or a type 4 ESPE, in normal operation the output circuit of at least two output signal switching devices shall go to the OFF-state when the sensing function is actuated, or when power is removed from the ESPE.

When a single safety-related data interface is used to perform the functions of the OSSD(s), the data interface and associated safety-related communication interface shall meet the requirements of 4.2.4.4 of IEC 61496-1:2020. In this case, a single safety-related data interface can substitute for two OSSDs in a type 3 ESPE or a type 4 ESPE.

4.2 Design requirements

4.2.2 Fault detection requirements

4.2.2.3 Particular requirements for a type 2 ESPE

Addition:

The periodic test shall verify that each light beam operates in the manner specified by the supplier.

Different configurations are considered that differ in the way the testing of the safety related performance is carried out.

Annex AA, Figure AA.1, Figure AA.2 and Figure AA.3 are examples of type 2 AOPDs where the periodic test is externally initiated and the results are externally evaluated. Annex AA, Figure AA.4 is an example of a type 2 AOPD where the periodic test is automatically initiated and evaluated internally.

Replacement:

4.2.12 Integrity of the AOPD detection capability

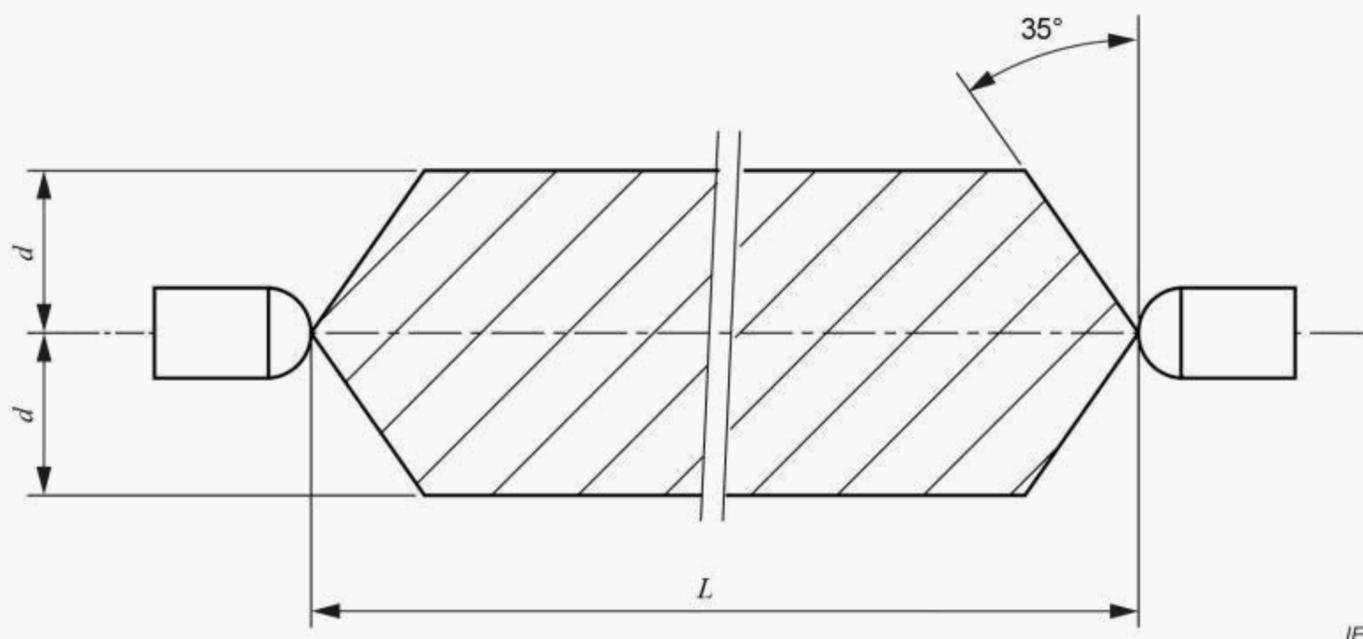
The design of the AOPD shall be such that the AOPD detection capability does not change from the value stated by the supplier when the AOPD is operated under any and all combinations of the following:

- any condition within the specification of the supplier;
- the environmental conditions specified in 4.3;
- at the limits of alignment and/or adjustment;
- over the entire detection zone.

If a single fault (as specified in Annex B of IEC 61496-1:2020), which under normal operating conditions (see 5.1.2.1) would not result in a loss of AOPD detection capability but, when occurring with a combination of the conditions specified above, would result in such a loss, that fault together with that combination of conditions shall be considered as a single fault, and the AOPD shall respond to such a single fault as required in 4.2.2.

The AOPD shall be designed and constructed to:

- a) limit the possibility of failure to danger resulting from extraneous reflections (for operating range up to 3 m, see Figure 1);
- b) limit the misalignment at which normal operation is possible.
For an operating range of 3 m the limits of Figure 2 shall be met;
- c) limit the possibility of malfunction during exposure to extraneous light in the range of 400 nm to 1 500 nm.



For type 4: $d = 131$ mm, $L = 250$ mm to 3 000 mm

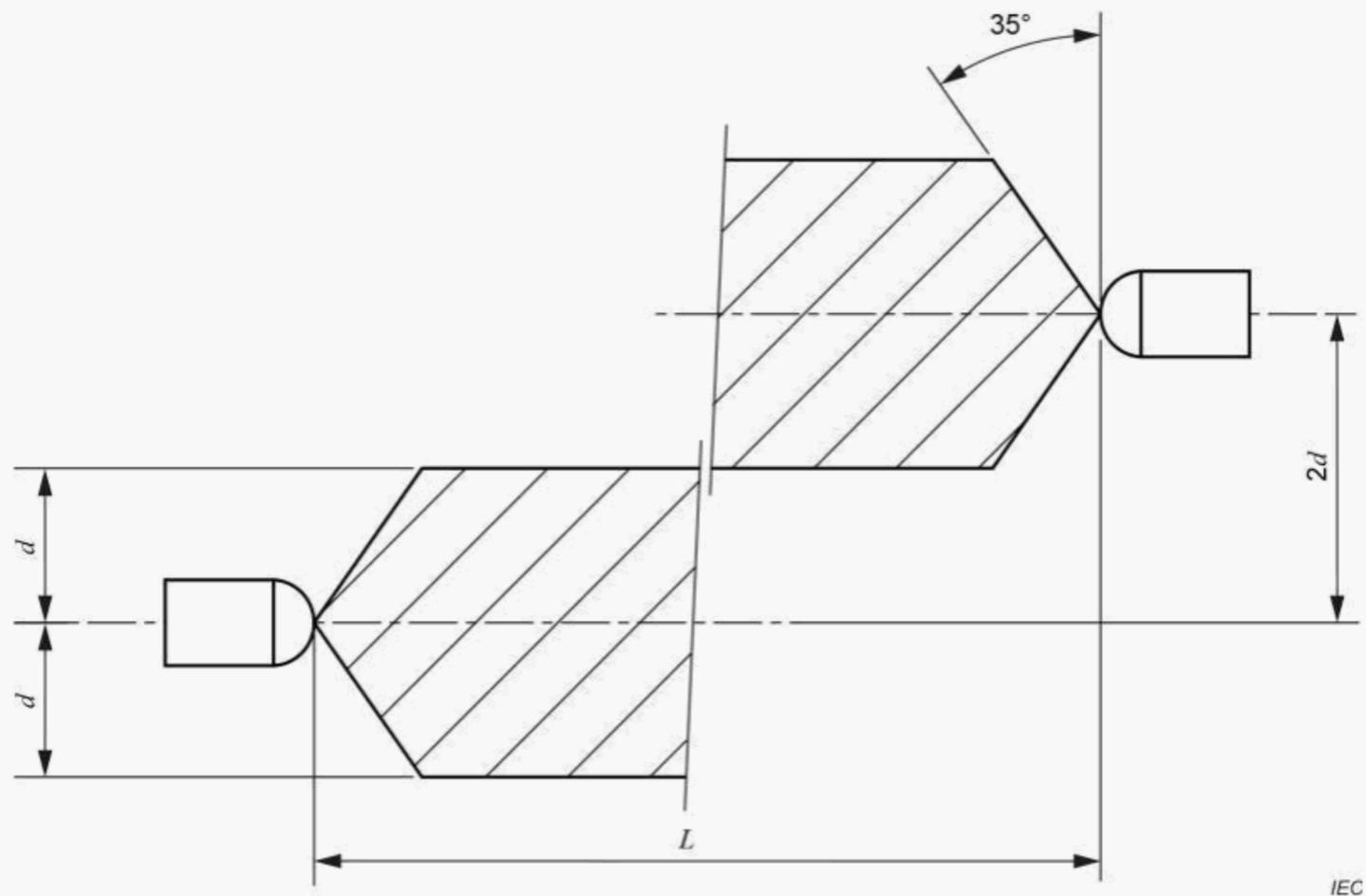
For type 3: $d = 184$ mm, $L = 375$ mm to 3 000 mm

For type 2: $d = 262$ mm, $L = 500$ mm to 3 000 mm

NOTE In this figure, extraneous reflections from surfaces outside the shaded area will not cause a failure to danger. For short ranges (250 mm for type 4, 375 mm for type 3 and 500 mm for type 2), the angle of 35° is a limit selected by the working group based on known designs of AOPDs.

Figure 1 – Limit area for the protection against the risk of beam bypass

If the AOPD is intended to provide protection when mounted very close to a reflective surface (i.e. inside the shaded area of Figure 1), the AOPD shall be designed in such a manner that no optical bypassing can occur on the reflective surfaces. For such a device, an EAA much less than $2,5^\circ$ (for example, less than $0,1^\circ$) can be necessary. In this case, Figure 1 does not apply and the limits of protection against optical bypassing shall be as specified by the manufacturer.



For type 4: $2d = 262$ mm, $L = 3\,000$ mm

For type 3: $2d = 368$ mm, $L = 3\,000$ mm

For type 2: $2d = 524$ mm, $L = 3\,000$ mm

Figure 2 – Limit of vertical and horizontal misalignment

4.2.13 Test piece

The test piece shall be cylindrical and opaque, with a minimum effective length of 150 mm. The diameter of the test piece shall not exceed the AOPD detection capability stated by the supplier.

For AOPDs using retro-reflective techniques and for AOPDs using mixed emitter/receivers in the same assembly (see 4.1.2.2), the surface of the opaque test piece shall be:

- a retro-reflecting material complying with the requirements for separate performance retro-reflective material of ISO 20471;

NOTE Table 4 of ISO 20471:2013 defines the minimum coefficient of retro-reflection for separate performance retro-reflective material as $330 \text{ cd lx}^{-1} \text{ m}^{-2}$ with an entrance angle of 5° and an observation angle of $0,2^\circ$ ($12'$).

- a mirror-type reflective surface having a reflection factor greater than or equal to 90 % at the operating wavelength, for example, polished chrome plating or polished aluminium;
- a diffuse reflective surface, white with a coefficient of diffuse reflectance in the range of 80 % to 90 % at the wavelength of the emitter. Example of suitable material is white paper.

For an AOPD detection capability of not more than 40 mm, the test piece for a light curtain shall be provided by the supplier and shall be marked with the following:

- diameter in millimetres;
- type reference and an indication of the AOPD with which the test piece is intended to be used.

When more than one detection capability can be configured on the AOPD, the supplier shall provide a test piece for each detection capability.

Verification shall be by inspection.

Addition:

4.2.14 Wavelength

AOPDs shall operate at a wavelength within the range 400 nm to 1 500 nm.

4.2.15 Radiation intensity

If the emitting device uses LED technology, the radiation intensity generated and emitted by the AOPD shall meet the requirements of exempt group in accordance with IEC 62471.

NOTE 1 Exempt group is equal to risk group zero (IEC 62471).

If the emitting device uses laser technology, the radiation intensity generated and emitted by the AOPD shall at no time exceed the maximum power or energy levels for a class 1M laser in accordance with IEC 60825-1.

NOTE 2 Class 2 devices can be used for alignment or adjustment.

5 Testing

This clause of Part 1 is applicable except as follows:

5.1 General

Addition:

In the following tests, it shall be verified that when the OSSD(s) go to the OFF-state, they remain in the OFF-state while the test piece is present in the detection zone (or light beam). If the AOPD incorporates a restart interlock, the restart interlock shall be disabled during the tests of Clause 5.

AOPD may be designed in different ways. Table 1 shows the different designs and corresponding requirements and tests as described within this document.

Table 1 – Correspondences of requirements/testing and AOPD designs

Sub-clause	Requirements and tests	Different AOPD designs					
		AOPD using only emitters or only receivers in the same assembly		AOPD using retro-reflective techniques		AOPD using emitters and receivers in the same assembly	
		GROD	Unrestricted optical design	GROD	Unrestricted optical design	GROD	Unrestricted optical design
4.1	Functional requirements	X	X	X	X	X	X
4.1.2	Sensing function	X	X	X	X	X	X
4.1.2.2	Additional requirements for AOPDs using retro-reflective techniques and for AOPDs using mixed emitters and receivers in the same assembly			X	X	X	X
4.2	Design requirements	X	X	X	X	X	X
4.2.2	Fault detection requirements	X	X	X	X	X	X
4.2.12	Integrity of the AOPD detection capability	X	X	X	X	X	X
4.2.13	Test piece	X	X	X	X	X	X
4.2.14	Wavelength	X	X	X	X	X	X
4.2.15	Radiation intensity	X	X	X	X	X	X
4.3	Environmental requirements	X	X	X	X	X	X
4.3.5	Light interference	X	X	X	X	X	X
5	Testing	X	X	X	X	X	X
5.1	General	X	X	X	X	X	X
5.1.1	Type tests	X	X	X	X	X	X
5.1.1.2	Operating condition	X	X	X	X	X	X
5.1.2	Test conditions	X	X	X	X	X	X
5.1.2.2	Measurement accuracy	X	X	X	X	X	X
5.2	Functional tests	X	X	X	X	X	X
5.2.1	Sensing function	X	X	X	X	X	X
5.2.1.2.2	Analysis of the electro-optical subsystem	X	X	X	X	X	X
5.2.1.2.3	Verification of the electro-optical subsystem for GROD	X	X	X	X	X	X
5.2.1.2.4	EAA test of GROD	X		X		X	
5.2.1.2.5	Prism test for GROD	X		X		X	

Sub-clause	Requirements and tests	Different AOPD designs					
		AOPD using only emitters or only receivers in the same assembly		AOPD using retro-reflective techniques		AOPD using emitters and receivers in the same assembly	
		GROD	Unrestricted optical design	GROD	Unrestricted optical design	GROD	Unrestricted optical design
5.2.1.3	Verification of the electro-optical subsystem for technologies other than GROD		X		X		X
5.2.1.3.2	Modelling and verification of optical subsystem model		X		X		X
5.2.1.3.3	Analysis of the detection capability by simulation		X		X		X
5.2.1.3.4	Additional tests of detection capability		X		X		X
5.2.1.3.5	Analysis of extraneous reflections		X		X		X
5.2.1.3.6	Extraneous reflections test		X		X		X
5.2.1.3.7	Misalignment test		X		X		X
5.2.1.4	Additional tests for an AOPD using retro-reflective techniques and for AOPDs using mixed emitter and receivers in the same assembly			X	X	X	X
5.4	Environmental tests	X	X	X	X	X	X
5.4.6	Light interference	X	X	X	X	X	X
5.4.6.1	General	X	X	X	X	X	X
5.4.6.2	Light sources	X	X	X	X	X	X
5.4.6.3	Test sequences	X	X	X	X	X	X
5.4.6.4	Normal operation (best alignment)	X	X	X	X	X	X
5.4.6.5	Failure to danger – Incandescent light (3 000 lux and worst-case alignment)	X	X	X	X	X	X
5.4.6.6	Failure to danger – Flashing beacon (worst-case alignment)	X	X	X	X	X	X
5.4.6.7	Failure to danger – Fluorescent light (3 000 lux and worst-case alignment)	X	X	X	X	X	X
5.4.6.8	Failure to danger – Interfering light from an emitting element of identical design	X	X	X	X	X	X

5.1.1 Type tests

5.1.1.2 Operating condition

Addition:

For the purpose of these tests, the plane of the light curtain detection zone may be either vertical or horizontal as preferred for a test.

If it can be demonstrated that the results will be the same, testing at long operating distances may be simulated by the use of neutral density filters.

5.2 Functional tests

5.2.1 Sensing function

Replacement:

5.2.1.1 General

It shall be verified that the sensing device is continuously actuated and, where appropriate, that the OSSD(s) go to the OFF-state, taking into account the operating principle of the AOPD and, in particular, the techniques used to provide tolerance to environmental interference.

For a light curtain:

- by slowly moving the test piece in the detection zone across the beams at an angle of 45° and at an angle of 90° (see Figure 3 and Figure 4) at each end of the detection zone [as near as practical to the emitter and receiver (or retro-reflector target)] and midway between the ends (see Figure 5);
- by placing the test piece in the detection zone, stationary, at any position and/or angle considered critical as a result of the analysis in 5.2.1.2.2;
- by moving the test piece in the detection zone, across the beams at the maximum speed in the range specified in 4.1.2.1, and at any other speed in that range which is considered critical as a result of the analysis in 5.2.1.2.2;
- by moving the test piece (having a length of 150 mm) through the detection zone at 1,6 m/s such that the direction of movement and the axis of the test piece are normal to the detection plane, at the extremities of the detection zone (for example, at each corner) and in any other position that is considered critical as a result of the analysis in 5.2.1.2.2.

For a light beam device:

- by placing the test piece in the beam at each end of the beam and midway along the beam such that the axis of the test piece is normal to the axis of the beam;
- by moving the test piece (having a length of 150 mm) through the beam at 1,6 m/s such that the direction of movement and the axis of the test piece are normal to the axis of the beam, at each end of the beam midway along the beam, and at any point throughout the operating distance which is considered critical as a result of the analysis in 5.2.1.2.2.

The above tests shall be performed with the AOPD operating at the minimum specified operating distance or 0,5 m, whichever is the greater, and at the maximum specified operating distance.

Detection zone of a light curtain
shown with light beams normal
to the page

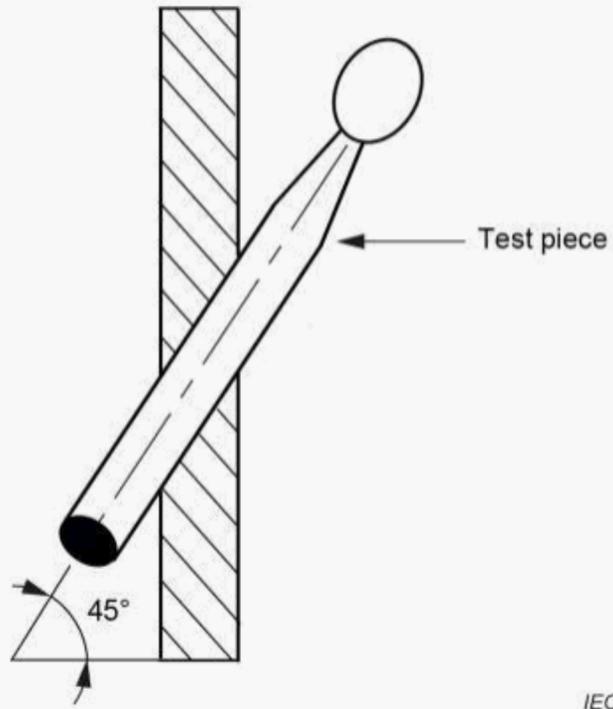


Figure 3 – Test piece at 45°

Detection zone of a light curtain
shown with light beams normal
to the page

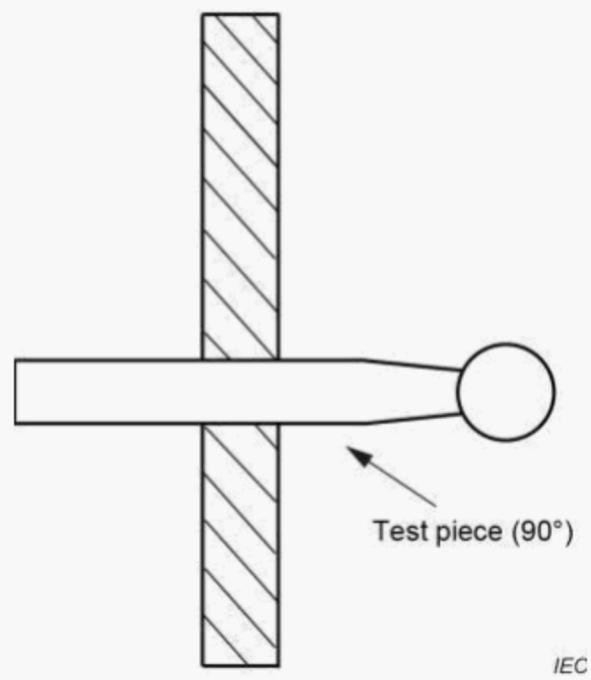


Figure 4 – Test piece at 90°

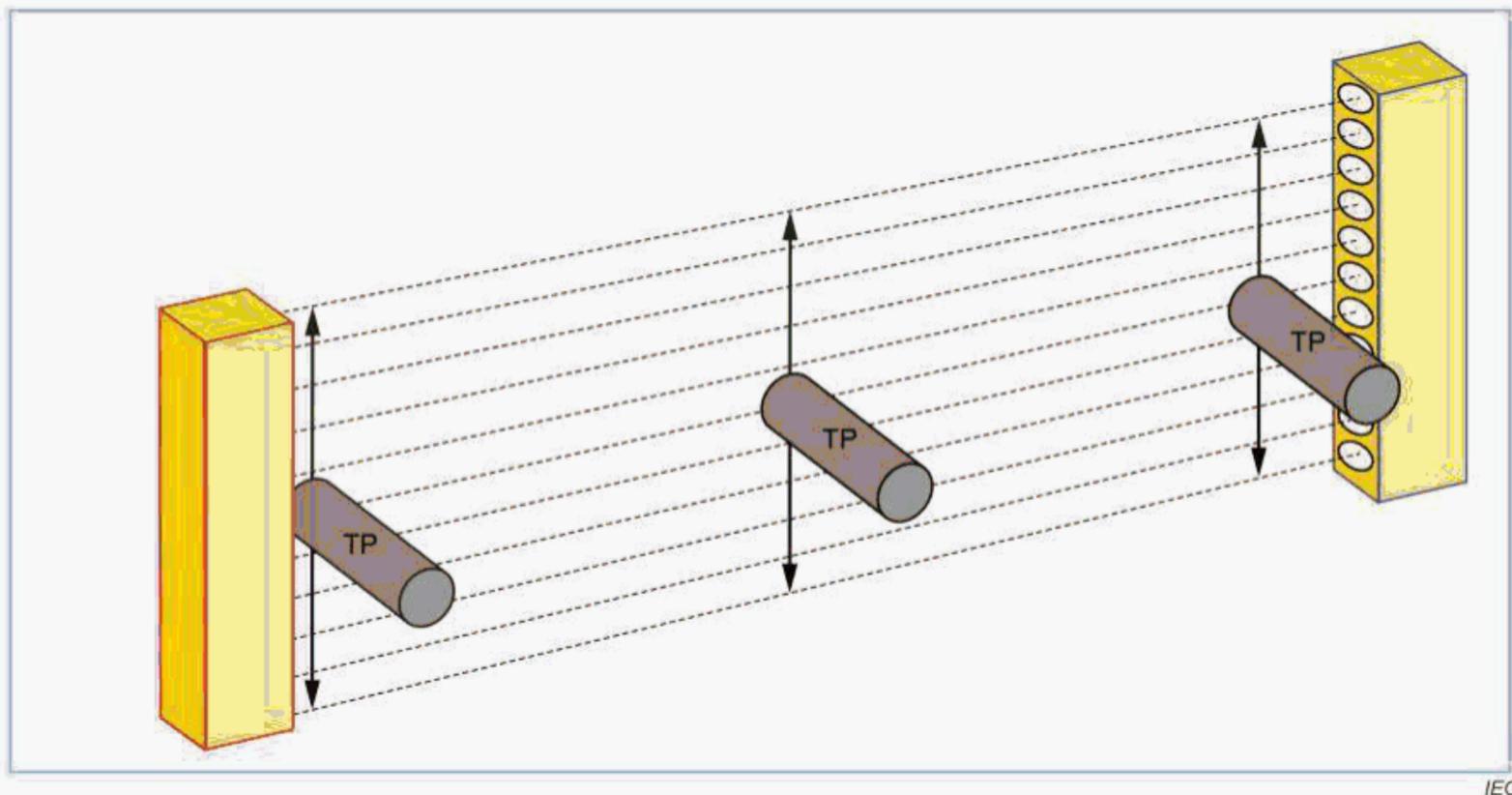


Figure 5 – Verifying sensing function by moving the test piece (TP) through the detection zone near the emitter, near the receiver/retro-reflector target and at the midpoint

5.2.1.2 Verification of integrity of detection capability

5.2.1.2.1 General

It shall be verified that the AOPD detection capability is continuously maintained or the ESPE does not fail to danger, by systematic analysis of the design of the AOPD, using testing where appropriate, taking into account all combinations of the conditions specified in 4.1.2, 4.2.12 and the faults specified in 5.3 of IEC 61496-1:2020.

5.2.1.2.2 Analysis of the electro-optical subsystem

A systematic analysis of the electro-optical subsystem shall be carried out to determine:

- the beam centre-line and the optical axes of the emitting and receiving elements;
- the spacing between beam centre-lines;
- the characteristics of the optical assemblies (e.g. lens diameter, focal length, position and dimension of the stops, shape of the lens holder, mirrors, retro-reflector targets);
- the relative intensity/sensitivity of the beams in the multi-beam devices;
- beam direction and orientation between similar elements (i.e. between one emitting subassembly and another, or between one receiving subassembly and another);
- the criteria used to determine the status of the sensing function.

The results of this analysis shall be used to determine which method is appropriate for the verification of the electro-optical subsystem and verification for integrity of detection capability.

If the analysis shows that all the criteria in 5.2.1.2.3 are met, then 5.2.1.2.3, 5.2.1.2.4 and 5.2.1.2.5 shall be used.

In all the other cases or if the analysis shows that one or more of the criteria in 5.2.1.2.3 are not met, then 5.2.1.3 (including 5.2.1.3.1 to 5.2.1.3.7) shall be used.

5.2.1.2.3 Verification of the electro-optical subsystem for GROD

GROD achieves the requirements specified in 4.2.12 by ensuring that

- the effective aperture angle (EAA) of each emitting and each receiving element does not exceed the values given in Figure 6 and
- the axes of the optical beams are parallel and
- side lobes are minimized and
- the spacing between beam centre-lines is uniform and
- the value of detection capability is based on the complete obscuration of at least one beam for any and all positions of the test piece within the detection zone (see Figure 7).

It shall be verified that all beams meet the following limits.

When GROD is used, the formula for determining minimum detection capability (d) is (see Figure 7):

$$d = P + \varnothing$$

where

d is the detection capability;

P is the beam centre-lines spacing;

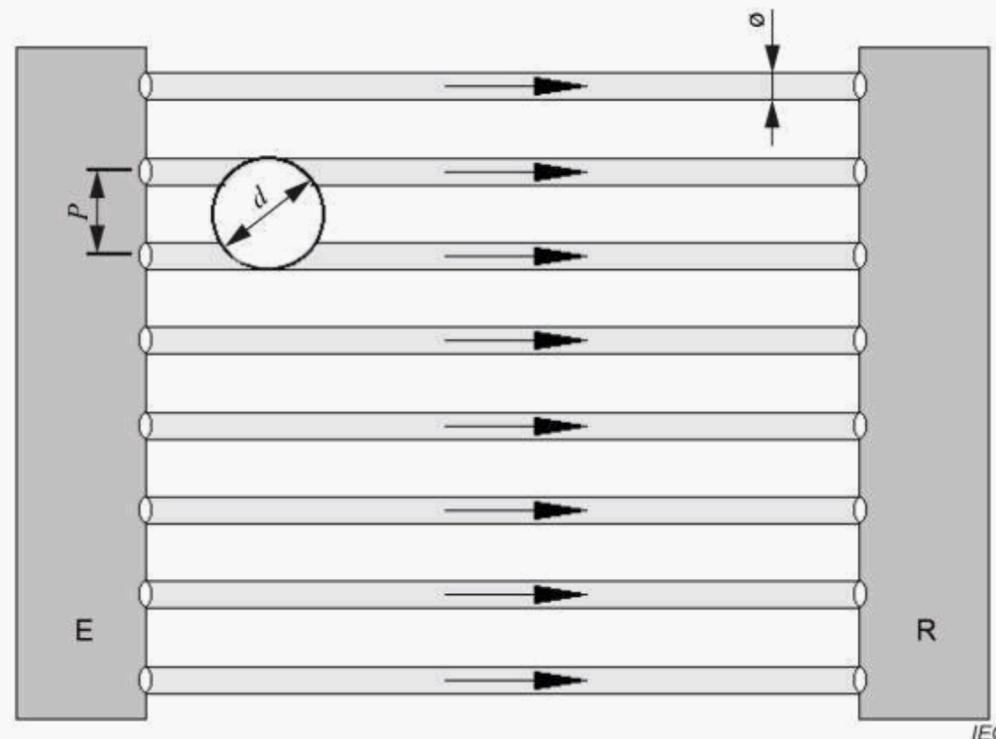
\varnothing is the lens diameter.

EXAMPLE Lens diameter (\varnothing) = 6 mm and beam spacing (P) = 8 mm

$$d = P + \varnothing = 8 \text{ mm} + 6 \text{ mm} = 14 \text{ mm}$$

Therefore, in the above example, $d = 14 \text{ mm}$.

Where lens diameters are different, the largest diameter shall be used in the calculation.



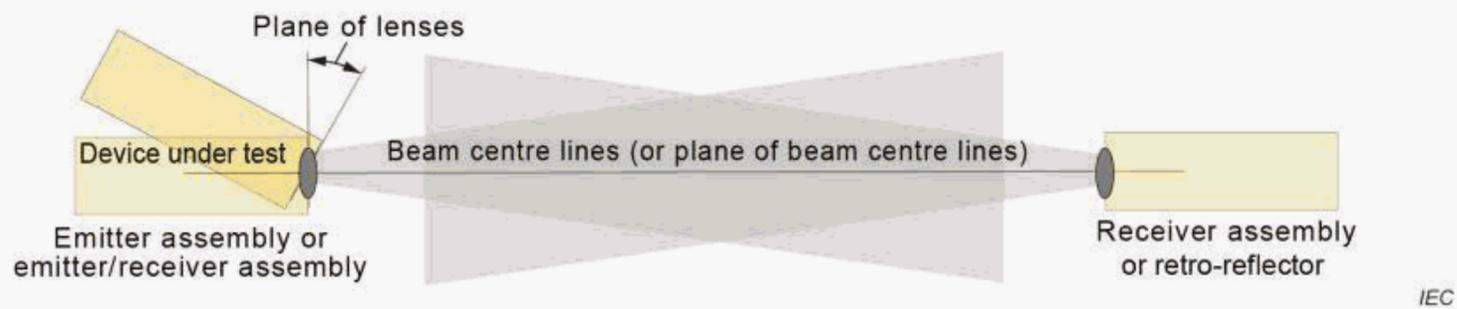
E = emitter; R = receiver

Figure 7 – Determination of the minimum detection capability

5.2.1.2.4 EAA test of GROD

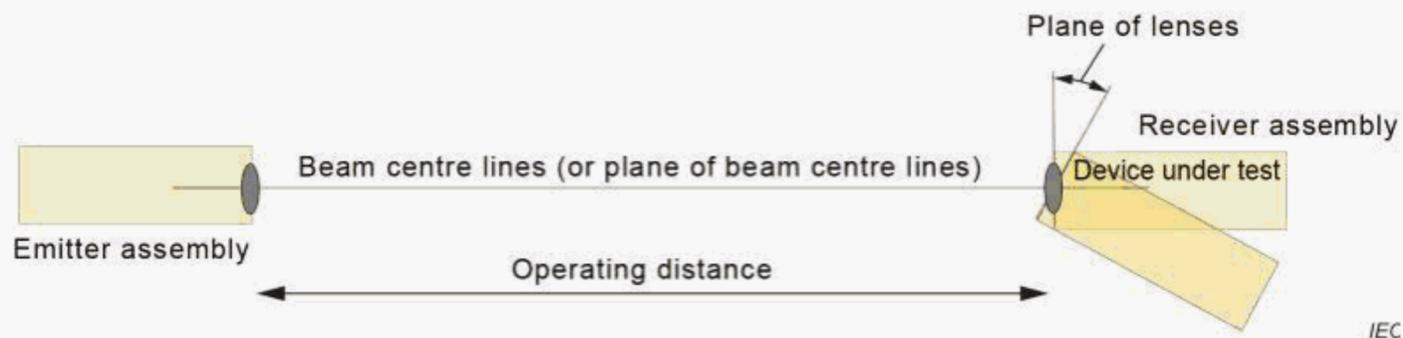
With an emitter assembly or an emitter/receiver assembly, fixed in optical alignment with a receiver assembly or a retro-reflector target, the angle of misalignment of the receiver assembly or the retro-reflector target shall be measured. With a receiver assembly or retro-reflector target fixed in optical alignment with an emitter assembly or an emitter/receiver assembly, the angle of misalignment of the emitting element or the emitter/receiver element shall be measured. These measurements shall be carried out at all the distances indicated in Figure 6 in the following manner.

The AOPD shall be optimally aligned as specified by the supplier. The AOPD should be mounted on a turntable. The tests shall be performed about the rotational axis indicated in Figure 8.



The rotation axis is defined by the intersection line of the plane of all front lenses and the plane of all beam centre-lines.

a) Rotation of the emitter assembly or the emitter/receiver assembly (receiver assembly or retro-reflector target fixed)



b) Rotation of the receiver assembly with the emitter assembly fixed

For AOPDs employing retro-reflective techniques, the test should only be carried out on the emitter/receiver assembly with the retro-reflector target fixed.

Figure 8 – Measuring method for EAA (direction)

Switch the AOPD on and carry out the procedure as follows:

- a) The emitter or emitter/receiver unit shall be turned clockwise into the 90° position; the OSSD(s) shall go to the OFF-state.
- b) The supply voltages of the complete AOPD shall be switched off and then on again.

Based on the analysis of 5.2.1.2.2, it can be necessary to wait for some time (for example, settling time of gain control circuits) between steps a) and b), and possibly also between steps b) and c).

- c) The emitter or emitter/receiver unit shall be turned back towards the aligned position until the position is reached at which the OSSD(s) go to the ON-state. This value of the angle and distance shall be recorded. Continue turning the unit in the counter-clockwise direction until the opposite 90° position is reached and record the last position at which the OSSD(s) change from the ON-state to the OFF-state.
- d) The same procedure given in steps a) to c) shall be performed in the counter clockwise direction.
- e) The same procedure given in steps a) to d) shall be applied to the opposite unit (receiver or receiver/emitter).

In cases where the minimum operating distance specified exceeds 3 m, similar tests shall be performed to determine the EAA at the minimum operating distance (see Figure 6).

The test is passed when the angles recorded in step c) (EAA) are less than the values indicated in Figure 6.

For an AOPD specified by the manufacturer to operate over long distances, tests can be carried out using neutral density filters over shorter distances, when it can be shown that the results obtained will correspond with those results obtained at the specified operating distance.

Particular attention should be given to designs where the cross-section of the beam (for an emitter) or the cross-section of the cone of reception (for a receiver) is designed to be slightly oval, elliptical, oblong or otherwise elongated in a direction which is neither horizontal nor vertical.

5.2.1.2.5 Prism test for GROD

It shall be shown that each beam in a multi-beam device and light curtain systems meets the requirements of Figure 6. One method of verifying the characteristics of each beam is with the use of a wedge prism placed in front of individual beams. The precision wedge prism offsets the EAA of the beam under test so that its individual characteristics can be evaluated. Passing the wedge prism test satisfies items a) and b) of 4.2.12.

The basis of this method is to isolate each beam so that its individual characteristics can be verified (Figure 9).

For systems with different EAAs on the emitter and receiver, this procedure can be used as a guide to develop equivalent tests. However, different angle limits need to be determined as appropriate for the design of the system being evaluated.

The AOPD shall be optimally aligned (zero position) and should be mounted on a turntable unit. A wedge prism with a beam deviation angle in accordance with MP1 of Figure 6 shall be used for testing. The height (H , Figure 10) shall be large enough to cover at least one beam but shall not be more than the dimension of the detection capability. The test (referring to Figure 10) shall be made at 3 m, or as close to 3 m as possible within the working range of the device (when the test is made at a distance other than 3 m, the formulae of Figure 6 shall be used to calculate an appropriate deviation angle).

NOTE 1 Based on the analysis of 5.2.1.2.2, tests at other distances can be necessary.

The prism angle β can be calculated with the formulae given below Figure 10.

The test procedure shall be as follows:

Switch the AOPD on and carry out the following procedure.

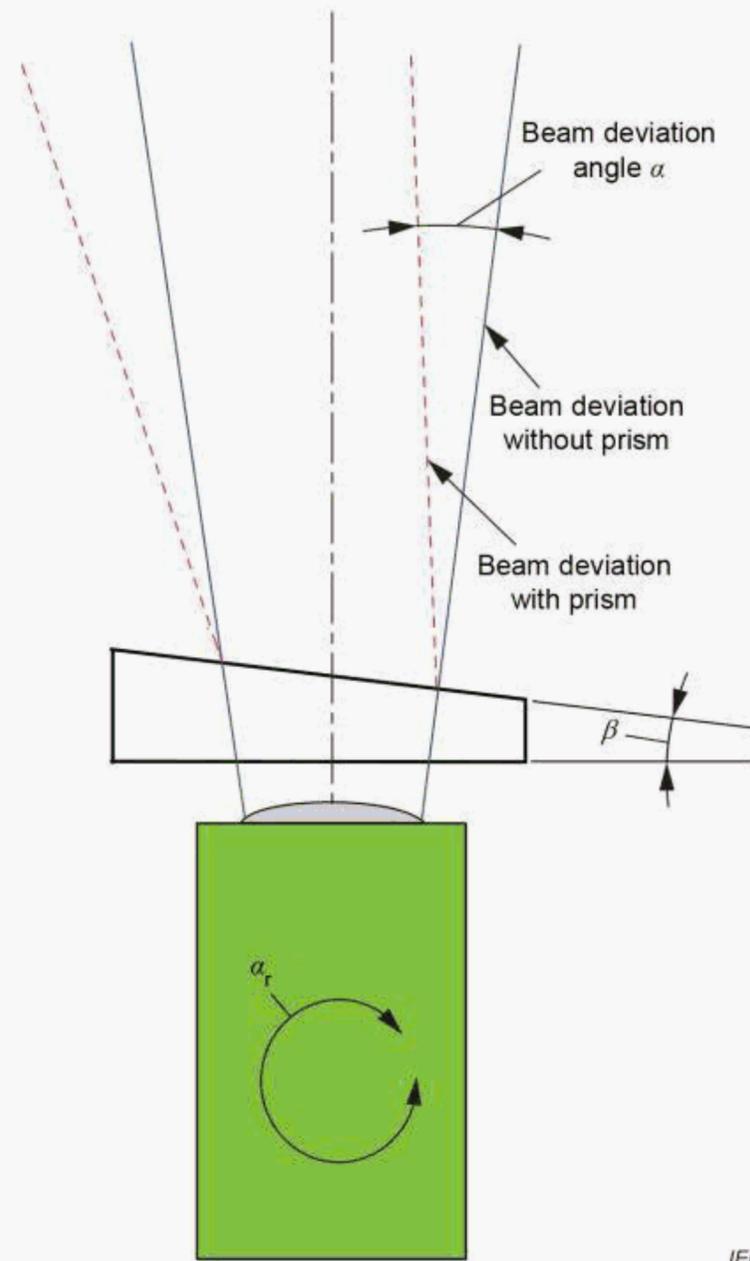
- a) The OSSD(s) shall be in the ON-state.
- b) Insert the prism centred in front of the receiving or emitting element to be tested.
- c) The OSSD(s) shall change to, and remain in, the OFF-state. If the OSSD(s) remain in the ON-state, rotate the turntable in the direction of the beam deviation until the OSSD(s) change(s) to the OFF-state. Remove the prism and verify that the OSSD(s) return to ON-state.
- d) Turn the prism 180° and insert the prism in front of the same beam to be tested. Verify that the OSSD(s) change(s) to, and remains in, the OFF-state. If the OSSD(s) remains in the ON-state, rotate the turntable in the direction of the beam deviation until the OSSD(s) change(s) to the OFF-state. Remove the prism and verify that the OSSD(s) return to the ON-state.
- e) Repeat steps c) and d), inserting the prism from opposite directions, until the OSSD(s) change(s) to the OFF-state as required without changing the position of the turntable. If such a position cannot be found, then the EAA of the beam being tested exceeds the required angle.

NOTE 2 The purpose of the above sequence of tests is to find a single position of the turntable where the OSSD(s) can be made to change to the OFF-state by inserting the prism from either direction. This will verify that the angle is the same in both directions.

- f) Bring the turntable to the zero position and then repeat steps a) to e) for each beam. While repositioning the prism, the OSSD(s) are allowed to change state.

The test procedure described shall be repeated on at least the first and last beam with the system under test rotated 90° and the prism inserted along the Y axis. The test shall be repeated for other positions if the analysis in accordance with 5.2.1.2.2 indicates that the other positions are critical.

The above test shall be carried out both in front of the emitter and in front of the receiver.



The prism should be located as close as possible in front of the optic.

To achieve very large deviation angles, it can be necessary to use a combination of prisms.

Figure 9 – Prism test to measure EAA of each beam

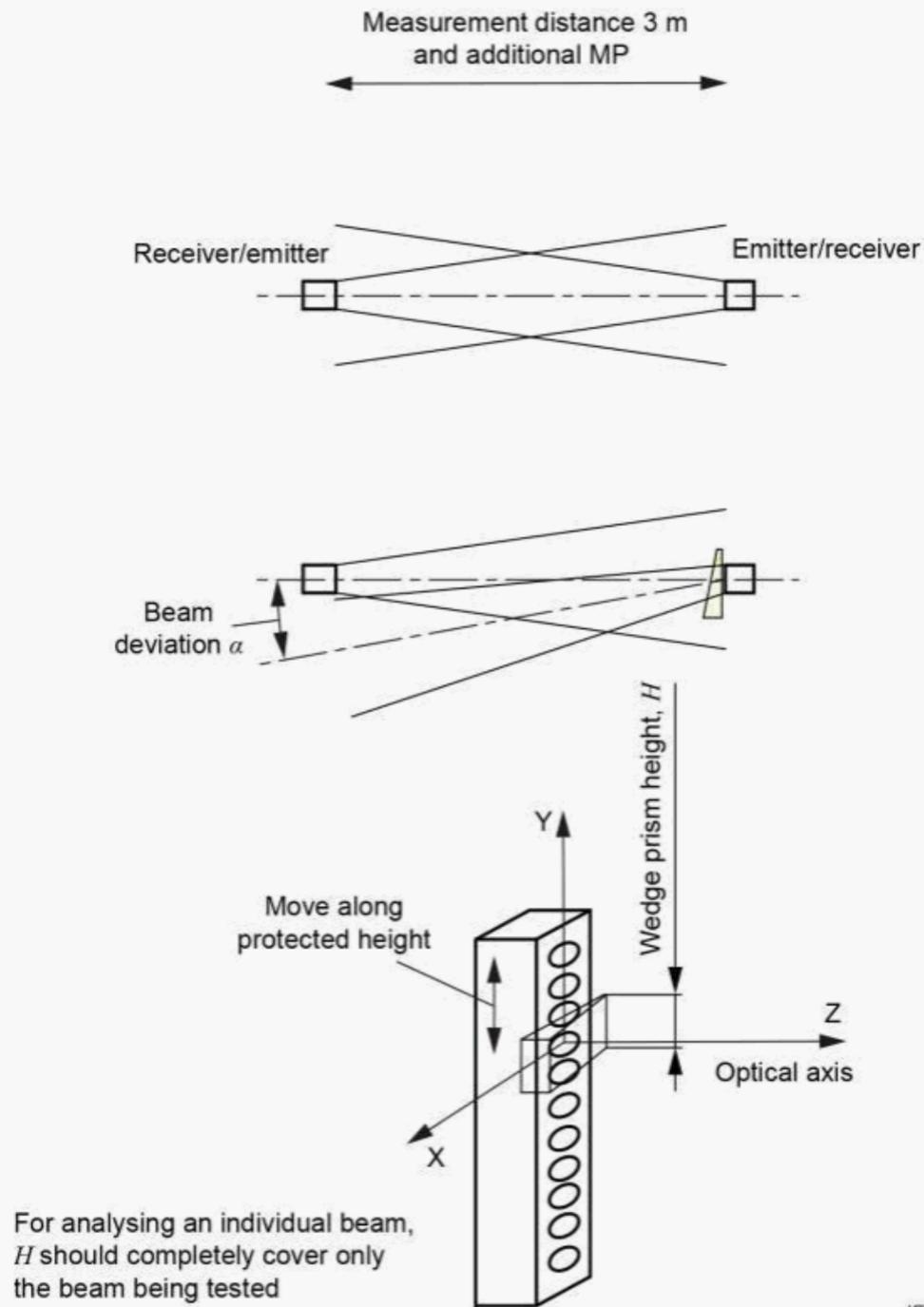


Figure 10 – EAA test using prism

Calculation of the wedge prism angle:

The wedge prism deviation angle depends on the mechanical angle of the prism used, the refraction number for the kind of glass used and on the wavelength of the light.

The angle can be calculated using the following relation:

$$\beta = \frac{\alpha}{n - 1}$$

where

β is the prism angle;

α is the deviation angle;

n is the refraction number.

Using a refraction number for the glass of 1,51 for 880 nm wavelength, the calculation for a deviation angle of 2,5° is:

$$\beta = \frac{2,5^\circ}{1,51-1} = 4,9^\circ$$

Deviation angles for different wavelengths and constant β : $\alpha = \beta (n - 1)$

Refraction (n) at 400 nm = 1,5 $\alpha = \beta (n - 1) = 4,9(1,5 - 1) = 2,45^\circ$

at 880 nm = 1,51 $\alpha = \beta (n - 1) = 4,9(1,51 - 1) = 2,5^\circ$

at 1 500 nm = 1,53 $\alpha = \beta (n - 1) = 4,9(1,53 - 1) = 2,6^\circ$

NOTE Measuring error caused by differing wavelengths for 400 nm is $-0,05^\circ$ and for 1 500 nm is $+0,1^\circ$.

5.2.1.3 Verification of the electro-optical subsystem for technologies other than GROD

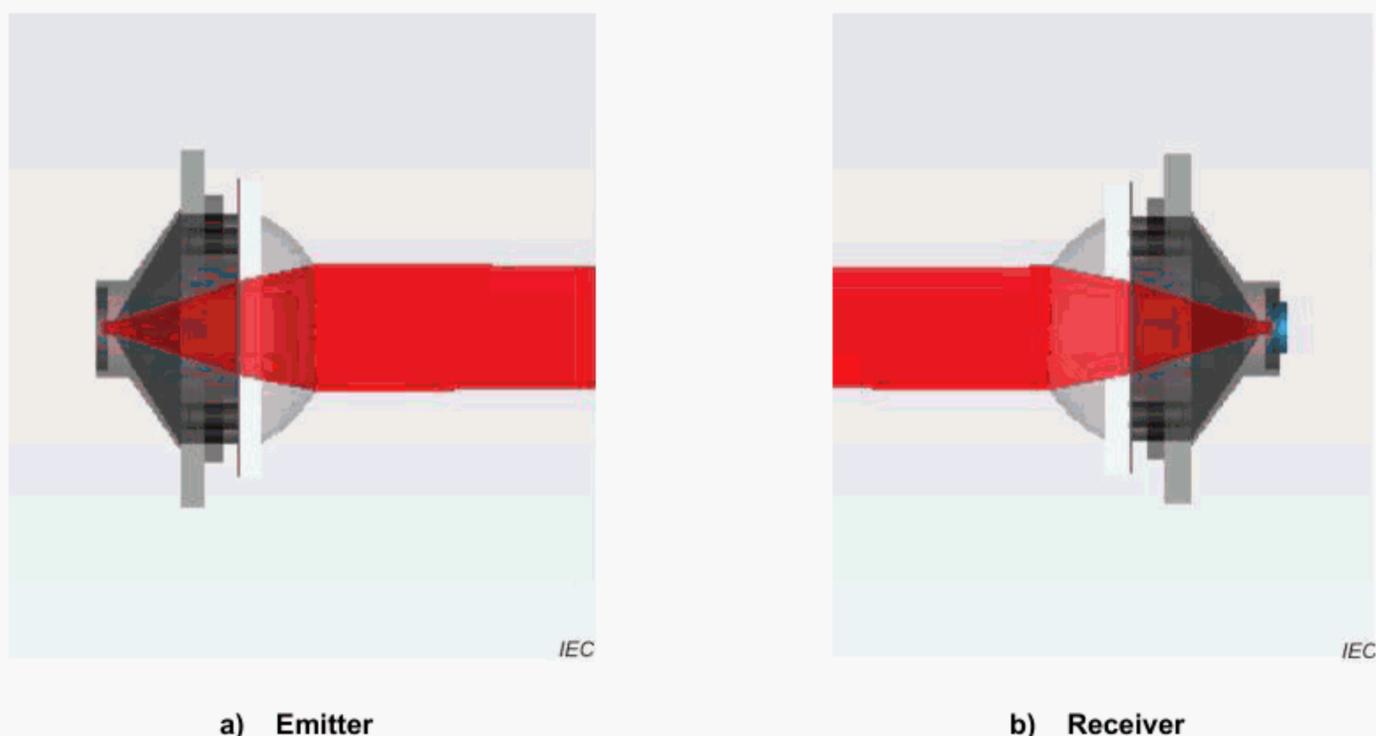
5.2.1.3.1 General

When an AOPD does not use a geometrically restricted optical design, fulfilment of the requirements of 4.1.2. and 4.2.12 shall be verified by a combination of model based simulation and tests in accordance with 5.2.1.3.2 through 5.2.1.3.7.

NOTE Since not all design techniques can be anticipated, it is possible that some of these test procedures are not suitable for a particular design technique and can require modification. Methods other than those described can be more appropriate depending on the design of the AOPD and can be used if they are shown to be equivalent.

5.2.1.3.2 Modelling and verification of optical subsystem model

The optical subsystem (see Figure 11) analysis starts with the creation of a simulation model of the emitting element and shall be extended to all optical effective elements which are used following up to and including the receiving element (for example aperture stops, beam shaping optical elements, front windows, electrical or mechanical components within the optical path).



a) Emitter

b) Receiver

Figure 11 – Example of optical subsystem

The model of the emitting element (see Figure 12) shall prove the distribution of radiant intensity used in the optical subsystem. The data used in the simulation shall be verified by measurement of the intensity distribution (see Figure 13) on the emitting element.

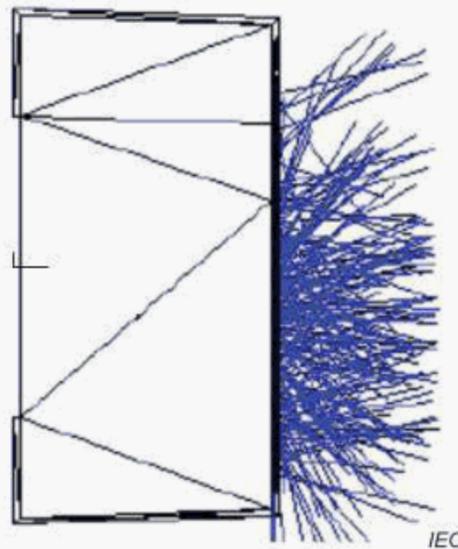


Figure 12 – Example of SMD LED Model

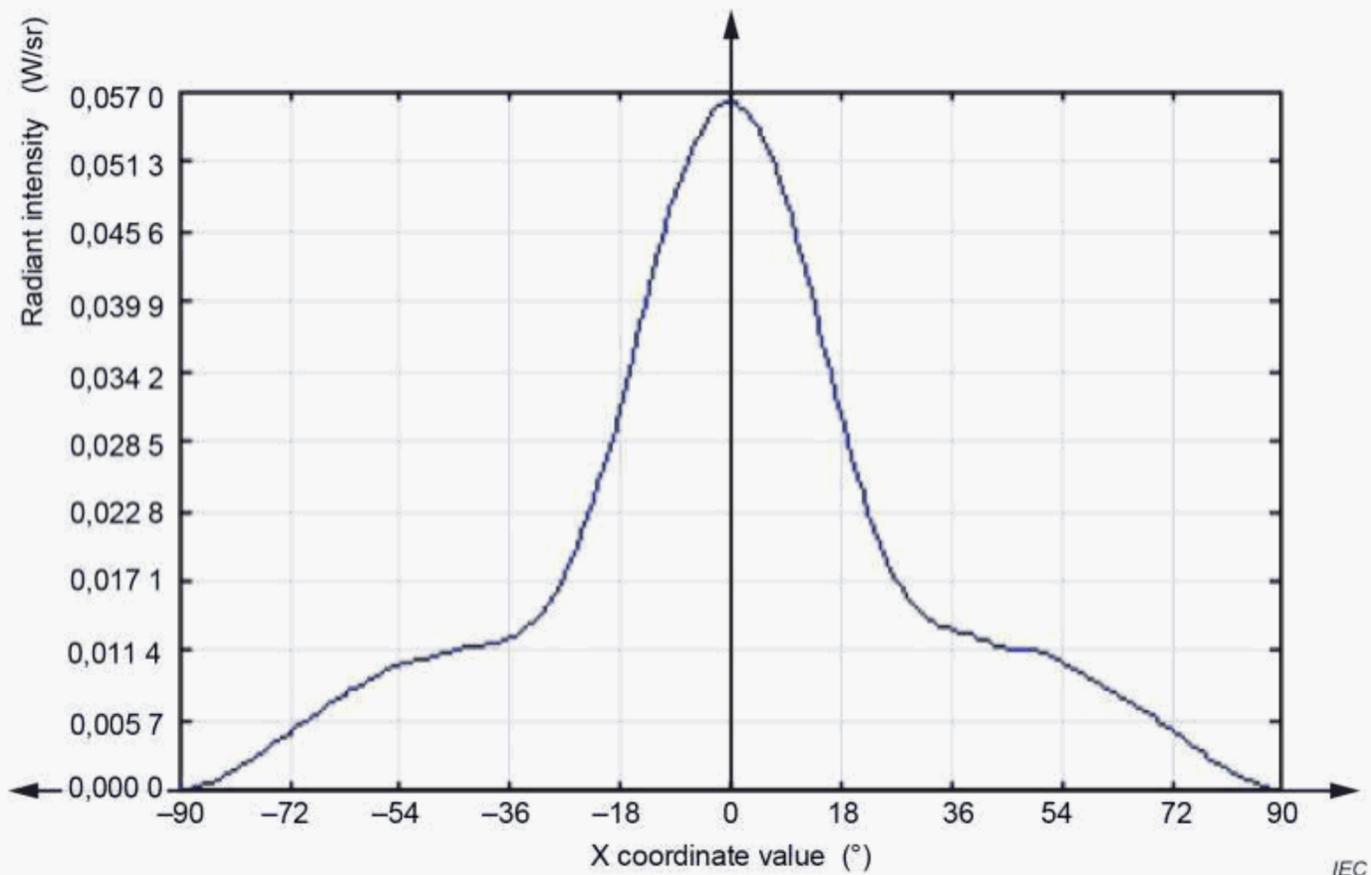


Figure 13 – Example of intensity distribution of emitting element

The model of the emitting element shall be extended with mechanical stops or aperture stops (see Figure 14), if applicable. Further optical beam shaping elements (for example lenses) shall be added and the resulting energy distribution over the aperture angle shall be demonstrated by simulation and verification measurement.

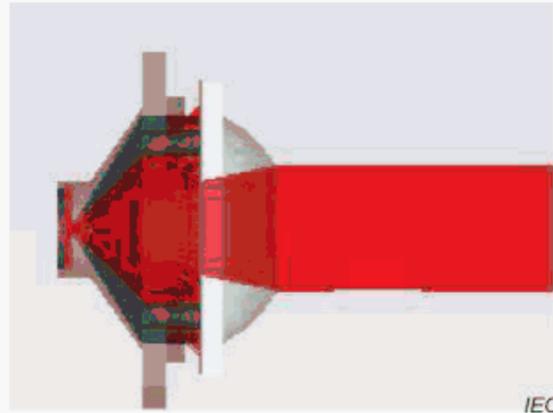


Figure 14 – Example of emitter model with beams internally blocked by aperture stop

The model of the receiving unit (for example consisting of beam shaping elements, mechanical or aperture stops and receiving element – see Figure 15) shall be verified to prove the modelling. The verification of the receiving unit shall be made by measurement of intensity distribution in the plane of the receiving element.

A calculation shall be made to compare the identified intensity/energy levels on the receiving element with the switching conditions of the sensing device.

The defined and verified model shall be able to analyse the intensity/energy distribution at any position of the optical subsystem. The model shall be modifiable to the limits of alignment and/or adjustment.

The modelling shall be made with tools that allow non-sequential ray tracing and with a number of rays that are suitable for the expected level of energy.

NOTE Only non-sequential ray tracing tools allow analysis of all beams including scattering of light and off axis bypassing.

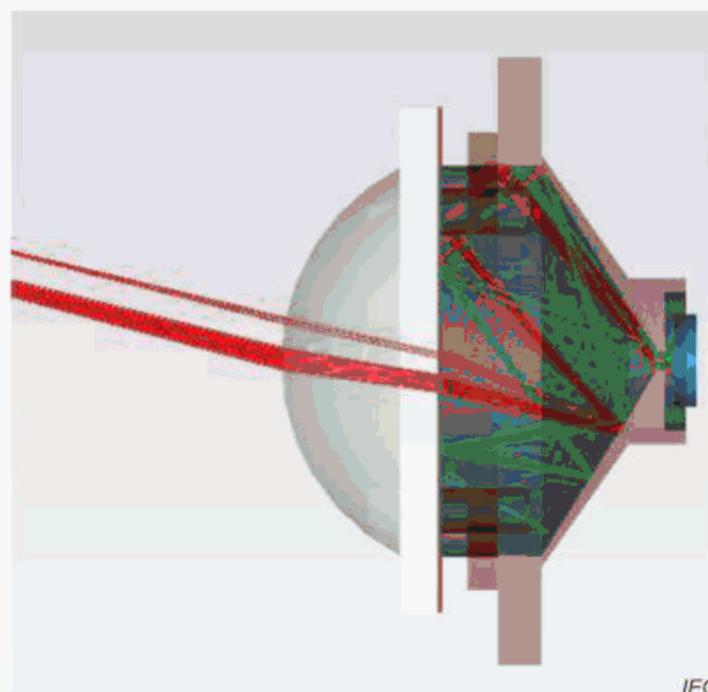


Figure 15 – Example of receiving unit with off axis beam portion reflected internally on mechanical elements

The number of analysed beams is related to the design of the ESPE. In the case of similar beam design, one beam can be sufficient if the tolerance conditions are well defined. If non-similar beam design is used, all combinations of beams necessary for analysis shall be considered.

5.2.1.3.3 Analysis of the detection capability by simulation

A test piece in accordance with the detection capability of the AOPD shall be implemented in the model of the optical subsystem (see Figure 16). A simulation for different object positions shall be made to prove that the detection capability can be achieved under worst-case design conditions. The simulation shall prove that no intensity/energy level can occur in the receiving plane that leads to failure to danger at any limits of alignment and/or adjustment over the entire operating distance.

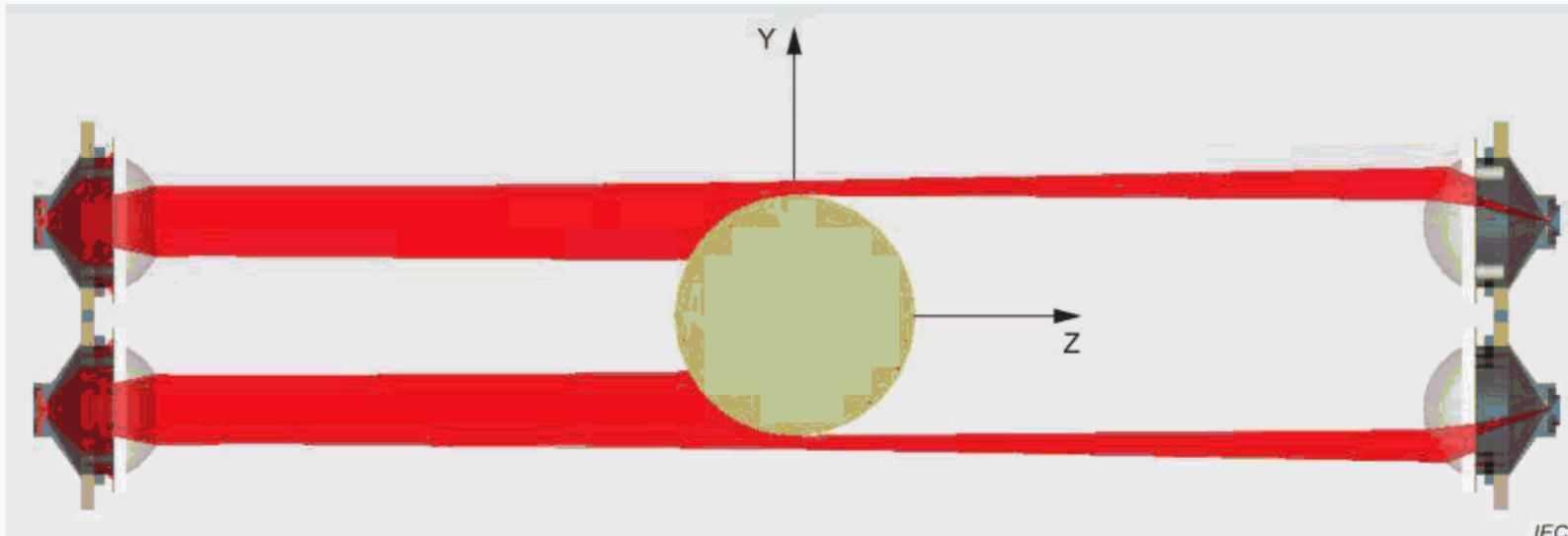


Figure 16 – Example of test piece inside model of optical subsystem with passing radiation on the receiver

NOTE The simulation in optical ray trace tools is valuable for a static condition of the test piece. Further calculations can be useful to show the influence of moving test piece.

In addition to the simulation, detection capability shall be verified by passing the tests of 5.2.1.1 and 5.2.1.3.4.

5.2.1.3.4 Additional tests of detection capability

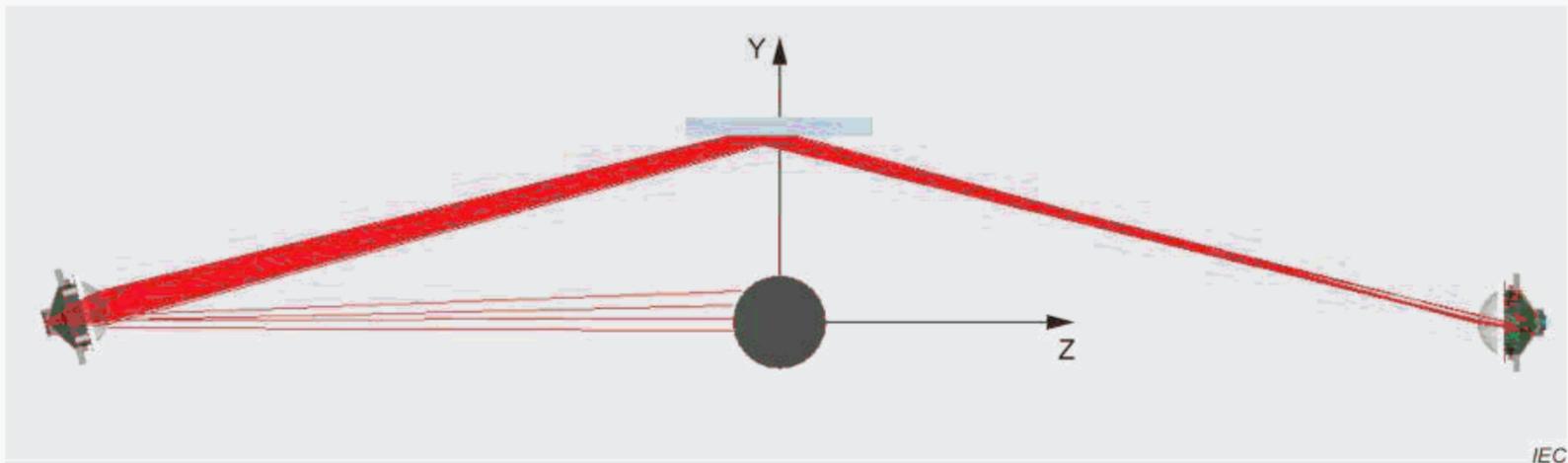
In cases where detection capability is achieved by means of technologies other than the EAA, at least the following additional detection capability test shall be carried out.

- a) Align the AOPD in accordance with the supplier's specifications.
- b) Place a neutral density filter with a transmittance of 30 % and with a dimension twice the size of the detection capability into the detection zone.
- c) Switch on AOPD and wait for 30 s (or longer, if necessary, on the basis of the analysis of 5.2.1.2.2). Verify that the OSSD(s) are in the ON-state. If the OSSD(s) are in the OFF-state, the operating distance shall be reduced and the test restarted.
- d) Insert the test piece in front of the filter. Verify that the OSSD(s) go to the OFF-state within the response time.
- e) Remove the filter and verify that the OSSD(s) continuously remain in the OFF-state.
- f) Repeat the test at several locations as determined by the analysis of 5.2.1.2.2.

The results of these tests and the systematic analysis of 5.2.1.2.2 shall be used to identify which tests in 5.4 require, in addition, a measurement of the response time.

5.2.1.3.5 Analysis of extraneous reflections

A test piece in accordance with the detection capability of the AOPD shall be implemented in the model of the optical subsystem in the presence of extraneous highly reflective surface (see Figure 17) as defined in 5.2.1.3.6. A simulation of different test piece positions and different positions of extraneous reflective surfaces at operating distances in accordance with 5.2.1.3.6 shall be made to prove that the requirements for object detection described in 5.2.1.1 are fulfilled. Any position outside the shaded limit area in accordance with Figure 1 shall be considered for extraneous highly reflective surfaces. The simulation shall prove that no intensity/energy level can occur in the receiving plane which leads to failure to danger in the presence of extraneous reflective surfaces within the limits of alignment and/or adjustment and for corresponding inclination angles of highly reflective surfaces.



NOTE The test piece is bypassed by a portion of the beam that reaches the receiving unit.

Figure 17 – Example of emitting unit adjusted at the limit

Based on the simulation, alignment positions of emitter and receiver unit and inclination angles of the highly reflective surface shall be identified which lead to maximum energy level on the receiving element. These worst-case alignment conditions shall be used in test 5.2.1.3.6.

5.2.1.3.6 Extraneous reflections test

With the AOPD aligned in worst-case alignment conditions based on analysis of 5.2.1.3.5, it shall be verified that the AOPD will not fail to danger when (a) high reflective surface(s) is(are) placed nearby. This shall apply for each beam, under all other conditions within the supplier's specification.

The test procedure shall be as follows.

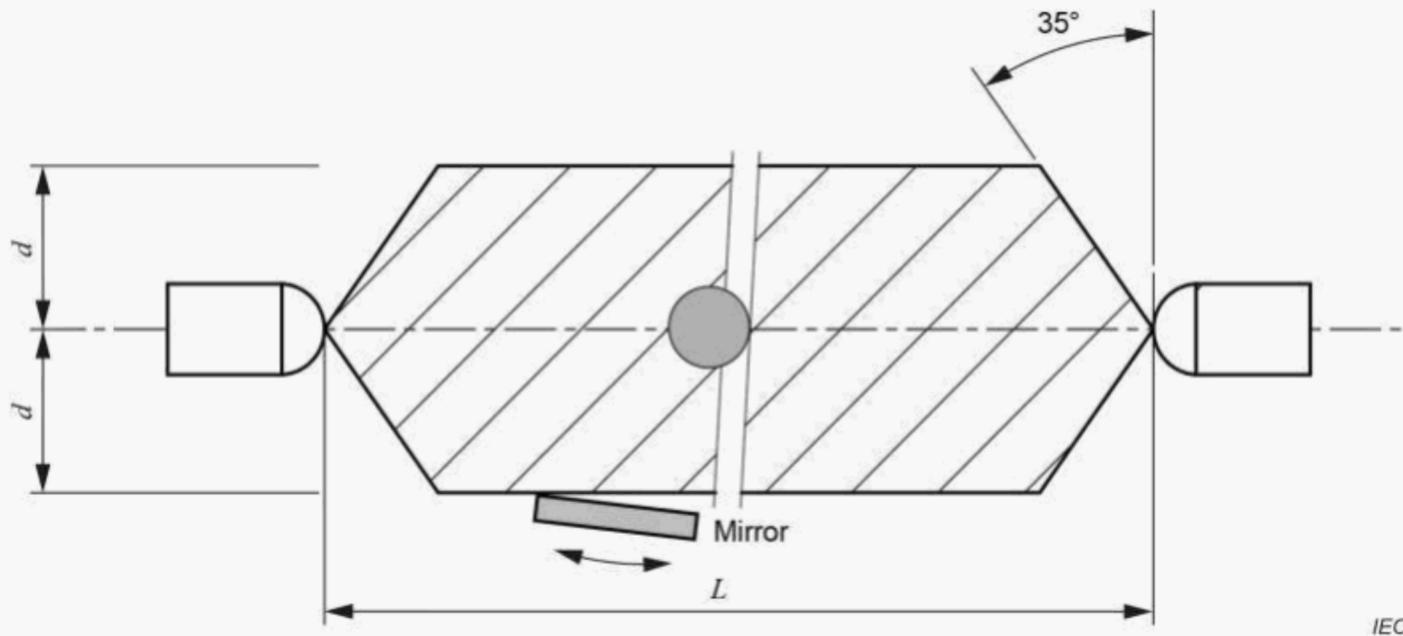
The test shall be carried out at each of the operating distances (0,5 m, 0,75 m, 1,5 m and 3,0 m) that are within the operating distance specified by the supplier. Where the minimum specified operating distance exceeds 3,0 m, the test shall be carried out at the minimum operating distance. The test shall be repeated for each beam centre-line.

After positioning the AOPD in the worst-case alignment position as identified in 5.2.1.3.5, power to the unit under test shall be switched off and then on again.

Before beginning the test, it can be necessary to wait some period of time (for example, settling time of gain control circuits) after switching power on.

With a mirror placed along the beam centre-line at a position and inclined to achieve the maximum intensity/energy level of light on the receiver as identified in 5.2.1.3.5, a C test shall be carried out with the test piece at the midpoint along the beam centre-line (see Figure 18). The mirror shall have a flat surface of at least 200 mm by 200 mm, having a minimum reflectance of 0,90 at the emitted wavelength.

When C tests are performed, the direct light path between the emitter and the receiver shall be fully obstructed by the test piece, but the indirect light path via the mirror shall not have any part of its cross-section obstructed.



For type 4: $d = 131 \text{ mm}$, $L = 250 \text{ mm}$ to $3\,000 \text{ mm}$

For type 3: $d = 184 \text{ mm}$, $L = 375 \text{ mm}$ to $3\,000 \text{ mm}$

For type 2: $d = 262 \text{ mm}$, $L = 500 \text{ mm}$ to $3\,000 \text{ mm}$

Figure 18 – Extraneous reflection test with mirror outside of limit area

5.2.1.3.7 Misalignment test

It shall be verified that the OSSD(s) remain(s) in the OFF-state for misalignments (see Figure 19) that are in excess of the angles shown in Table 2, Table 3 and Table 4, or as calculated with the formulae of Figure 19.

Table 2 – Maximum permissible angle of misalignment (in degrees) for a type 2 ESPE depending on the dimensions of the light curtain

Operating range of the light curtain (longitudinal dimension) m	Distance between beam centre-lines of outermost beams (lateral dimension) mm									
	300	450	600	750	900	1 050	1 200	1 350	1 500	1 800
	Maximum permissible angle of misalignment (γ) degrees									
Up to 3,0	51,8	33,8	25,2	20,1	16,7	14,3	12,5	11,1	10,0	8,3
4,0	71,4	45,8	33,9	27,0	22,4	19,2	16,8	14,9	13,4	11,2
5,0	93,6	58,2	42,8	33,9	28,1	24,0	21,0	18,6	16,8	14,0
6,0	122,1	71,4	51,9	41,0	33,9	29,0	25,3	22,4	20,2	16,8

Table 3 – Maximum permissible angle of misalignment (in degrees) for a type 3 ESPE depending on the dimensions of the light curtain

Operating range of the light curtain (longitudinal dimension) m	Distance between beam centre-lines of outermost beams (lateral dimension) mm									
	300	450	600	750	900	1 050	1 200	1 350	1 500	1 800
	Maximum permissible angle of misalignment (γ) degrees									
Up to 3,0	35,6	23,5	17,6	14,1	11,7	10	8,8	7,8	7	5,8
4,0	48,1	31,5	23,5	18,8	15,6	13,4	11,7	10,4	9,4	7,8
5,0	61,3	39,7	29,5	23,5	19,6	16,7	14,6	13	11,7	9,7
6,0	75,4	48,1	35,6	28,3	23,5	20,1	17,6	15,6	14,1	11,7

Table 4 – Maximum permissible angle of misalignment (in degrees) for a type 4 ESPE depending on the dimensions of the light curtain

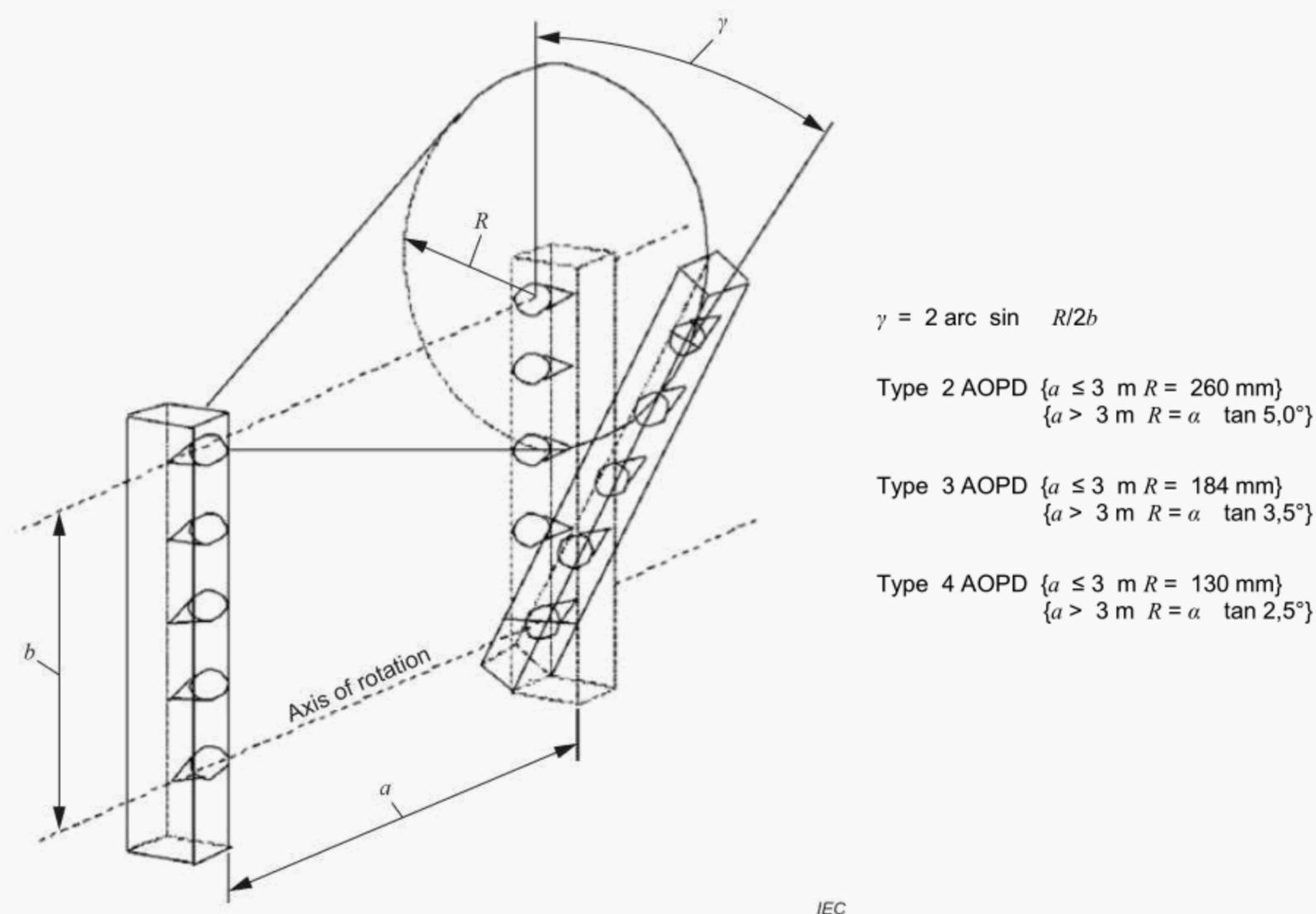
Operating range of the light curtain (longitudinal dimension) m	Distance between beam centre-lines of outermost beams (lateral dimension) mm									
	300	450	600	750	900	1 050	1 200	1 350	1 500	1 800
	Maximum permissible angle of misalignment (γ) degrees									
Up to 3,0	25,2	16,7	12,5	10,0	8,3	7,2	6,3	5,6	5,0	4,2
4,0	33,8	22,4	16,7	13,4	11,1	9,5	8,3	7,4	6,7	5,6
5,0	42,7	28,1	21,0	16,7	13,9	11,9	10,4	9,3	8,3	7,0
6,0	51,8	33,8	25,2	20,1	16,7	14,3	12,5	11,1	10,0	8,3

The test procedure shall be as follows.

The AOPD shall be optically aligned in accordance with the supplier's instructions and the OSSDs shall be in the ON-state.

As shown in Figure 19, the angle of misalignment shall be increased from 0° to the angle at which the OSSD(s) go(es) to and remain(s) in the OFF-state. That shall occur at an angle not exceeding that given in Table 2, Table 3 or Table 4, as appropriate. The angle shall then be slowly increased to 180° during which time the OSSD(s) shall remain in the OFF-state. Where γ (see Figure 19) is greater than 160°, this test need not be carried out.

NOTE As a result of the analysis of 5.2.1.2.2, modifications to the above procedure, or additional testing can be required (for example, to allow for automatic gain control).



- Key**
- a* operating range
 - b* distance between beam centre-lines of outermost beams
 - R* light spot radius
 - γ* angle of rotation in degrees

Figure 19 – AOPD misalignment test

5.2.1.4 Additional tests for AOPDs using retro-reflective techniques and for AOPDs using mixed emitters and receivers in the same assembly

The following tests shall be conducted at both the minimum operating distance or 0,5 m, whichever is the greater and maximum operating distance specified by the manufacturer.

It shall be verified that the OSSD(s) go(es) to the OFF-state when a test piece in accordance with 4.2.13 is placed in the detection zone and normal to the optical axes of the light beams. This test shall be conducted near the emitter/receiver elements, 200 mm in front of the retro-reflector target, midway along the beam and in any other position identified by the electro-optical analysis.

In the case of a type 3 or type 4 AOPD, it shall be verified that the OSSD(s) go(es) to the OFF-state when a reflective object of a size 200 mm × 200 mm is placed as close as practical in front of the sensing surface of the emitting/receiving element(s).

The reflective object shall consist of a flat reflective surface conforming to the requirements for separate performance retro-reflective material of ISO 20471.

NOTE Table 4 of ISO 20471:2013 defines the minimum coefficient of retro-reflection for separate performance retro-reflective material as 330 cd lx⁻¹ m⁻² with an entrance angle of 5° and an observation angle of 0,2° (12').

The analysis of the electro-optical subsystem described in 5.2.1.2.2 shall be used to determine if a reflective surface greater than 200 mm × 200 mm is needed.

Addition:

5.2.9 Wavelength

The emitted wavelength shall be verified either by inspection of the device data sheets or by measurement.

5.2.10 Radiation intensity

The radiation intensity shall be verified by measurement in accordance with IEC 60825-1 or IEC 62471 and by inspection of the technical documentation provided by the supplier.

NOTE Simplified testing methods for verification of this requirement are being developed.

5.4 Environmental tests

5.4.6 Light interference

5.4.6.1 General

Replacement:

Each test shall be carried out at an operating distance of 3 m (or the closest normal operating distance to 3 m as specified by the supplier) and under the stated conditions as a minimum requirement. Additional tests shall be carried out under different combinations of operating distances and environmental conditions when:

- the supplier states higher immunity levels, which shall be verified by testing at those levels with appropriate light sources; and/or
- the analysis of 5.2.1.2.2 shows such tests to be necessary.

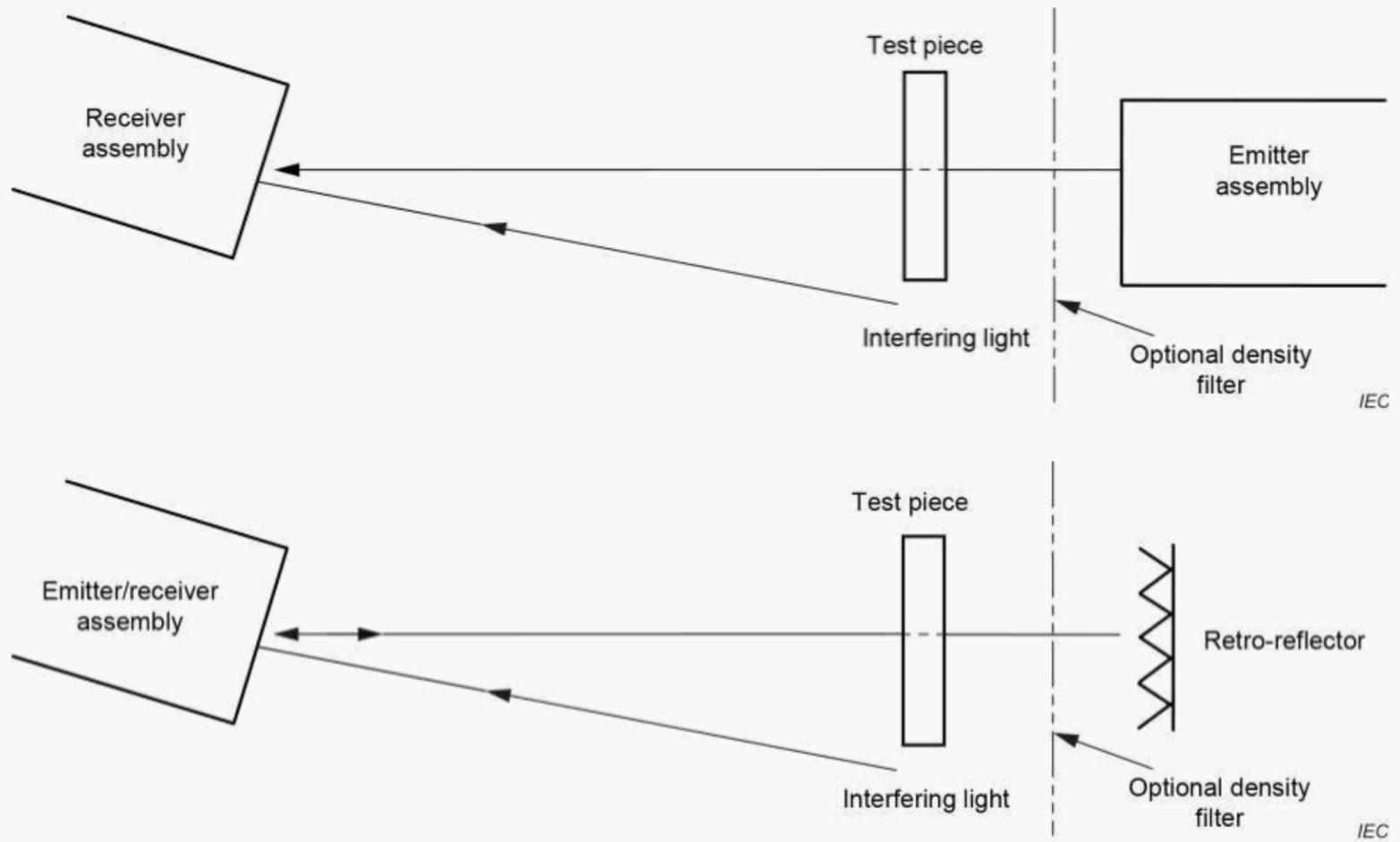
During B tests and C tests, the test piece shall be introduced into the detection zone in such a manner that the interfering light is not interrupted.

For the tests in 5.4.6.4, the system shall be optimally aligned in accordance with the manufacturer's instructions. The tests in 5.4.6.5, 5.4.6.6 and 5.4.6.7 require that the interfering light be directed along the optical axis (or as close as practical) of a receiving element(s) and with the emitting element(s) at maximum angular misalignment at which normal operation continues (worst-case alignment). The test arrangement used shall be compatible with the characteristics of the AOPD under test, as determined by the analysis and tests of 5.2.1.2.2 and 5.2.1.2.4, and any further analysis and characterization which proves to be necessary (see Figure 20, Figure 21, Figure 22 and Figure 23 for examples).

NOTE As a result of the diversity of designs, no single test arrangement is suitable for all types of AOPD. An example of a test configuration is illustrated in Figure 20.

During the tests, long-range operation can be simulated by density filters, as illustrated in Figure 20, providing that results are not affected. If a density filter is used, then all tests should be performed after the filter is installed.

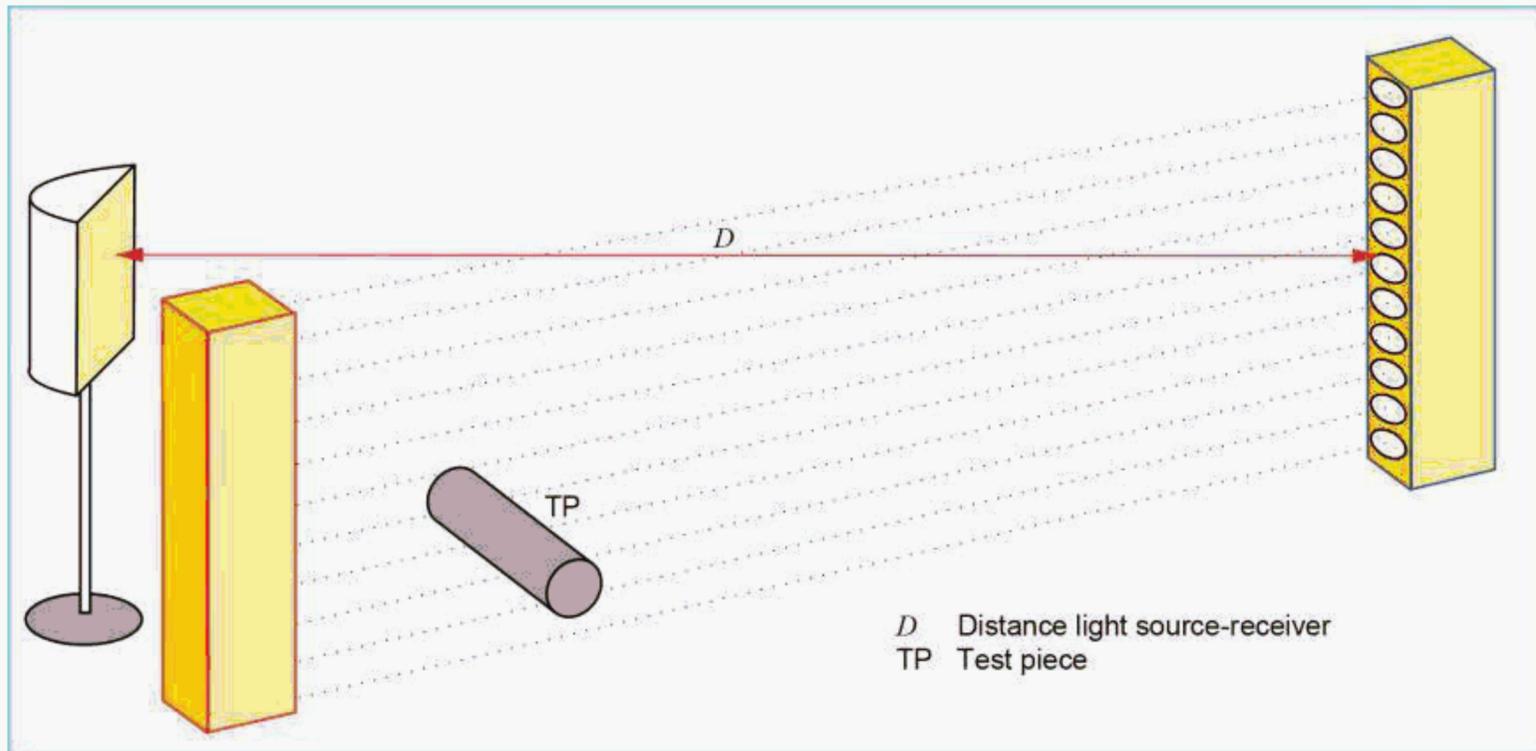
The test arrangement shall not modify the characteristics of the light reaching the receiving elements of the AOPD in any way that affects the operation of the AOPD. Where reflectors, mirrors, filters, beam splitters, windows, etc. are employed, it shall be verified that any alteration of the characteristics of the light (for example spectral distribution or polarization) is without significant effect.



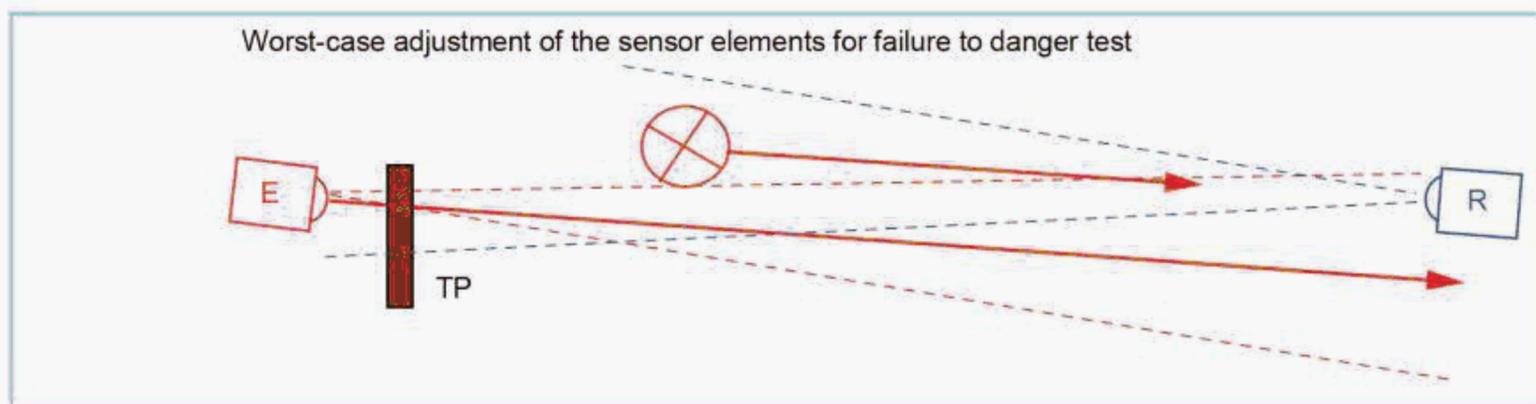
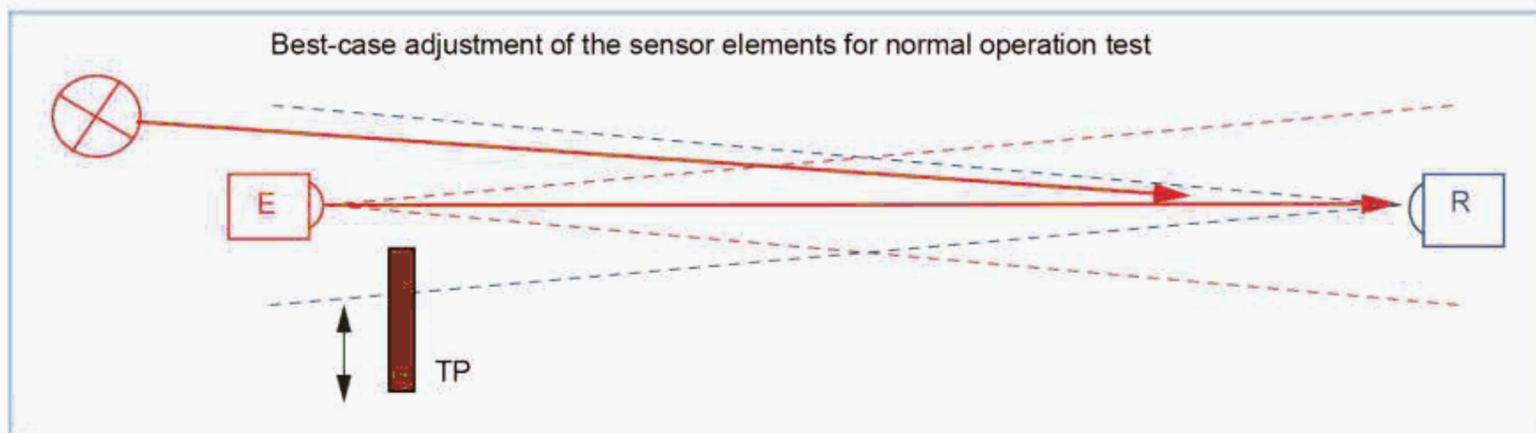
NOTE 1 Receiver or emitter/receiver assemblies are operated at maximum possible misalignment for fail to danger tests.

NOTE 2 Density filters can affect polarization.

Figure 20 – Light interference test – Direct method



The distance between emitter and receiver is 3 m
 For the distance *D* between receiver and light source, see the table below



IEC

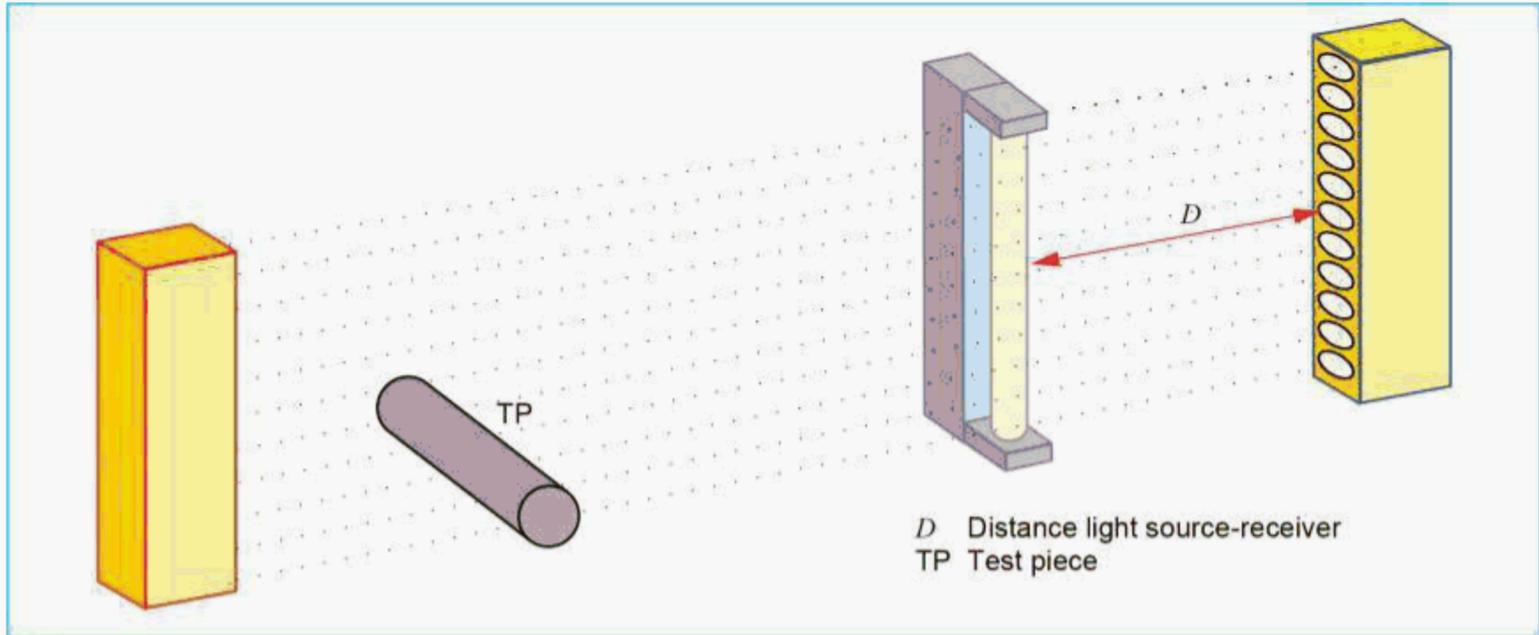
Test parameters

Distance (<i>D</i>)	Lux	Description
2 m ^a	3 000	Distance for fail to danger test
3 m ^a	1 500	Distance for normal operation test

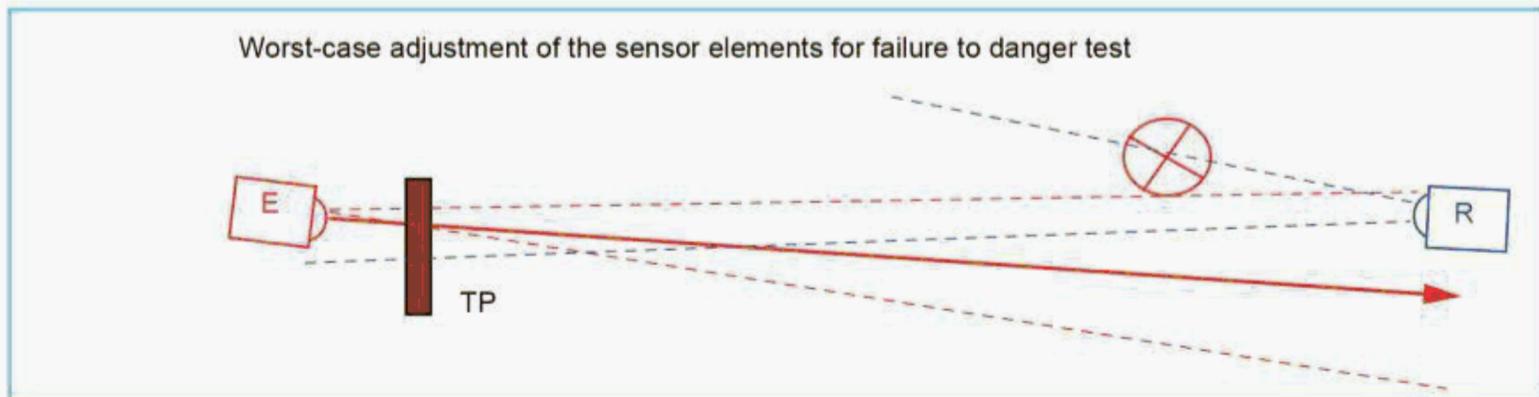
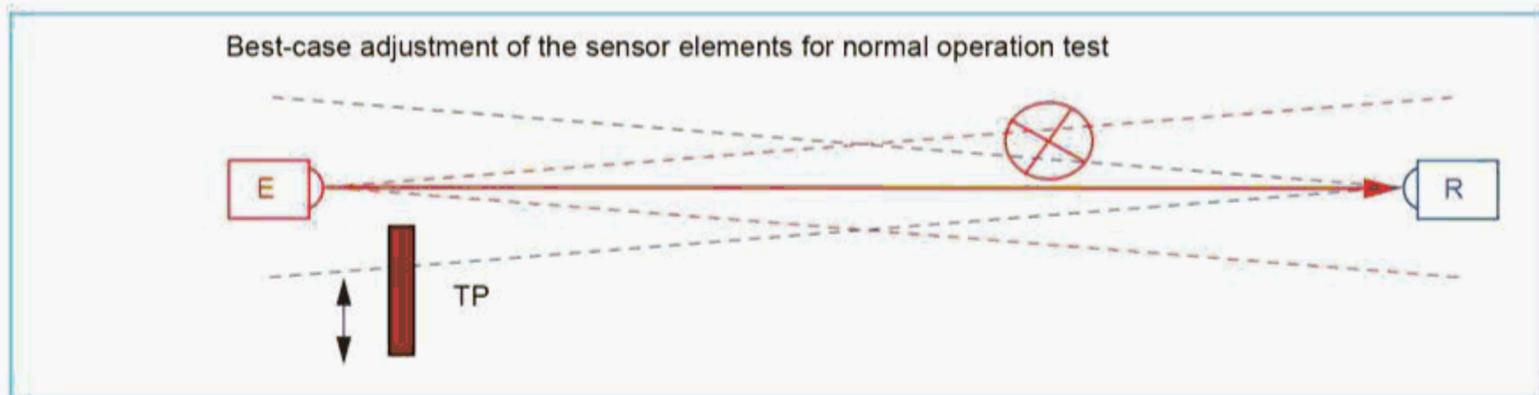
^a The exact distances depend on the lamp type.

E = emitter; R = receiver

Figure 21 – Light interference test – Test set-up with incandescent light source



The distance between emitter and receiver is 3 m
 For the distance D between receiver and light source, see the table below



IEC

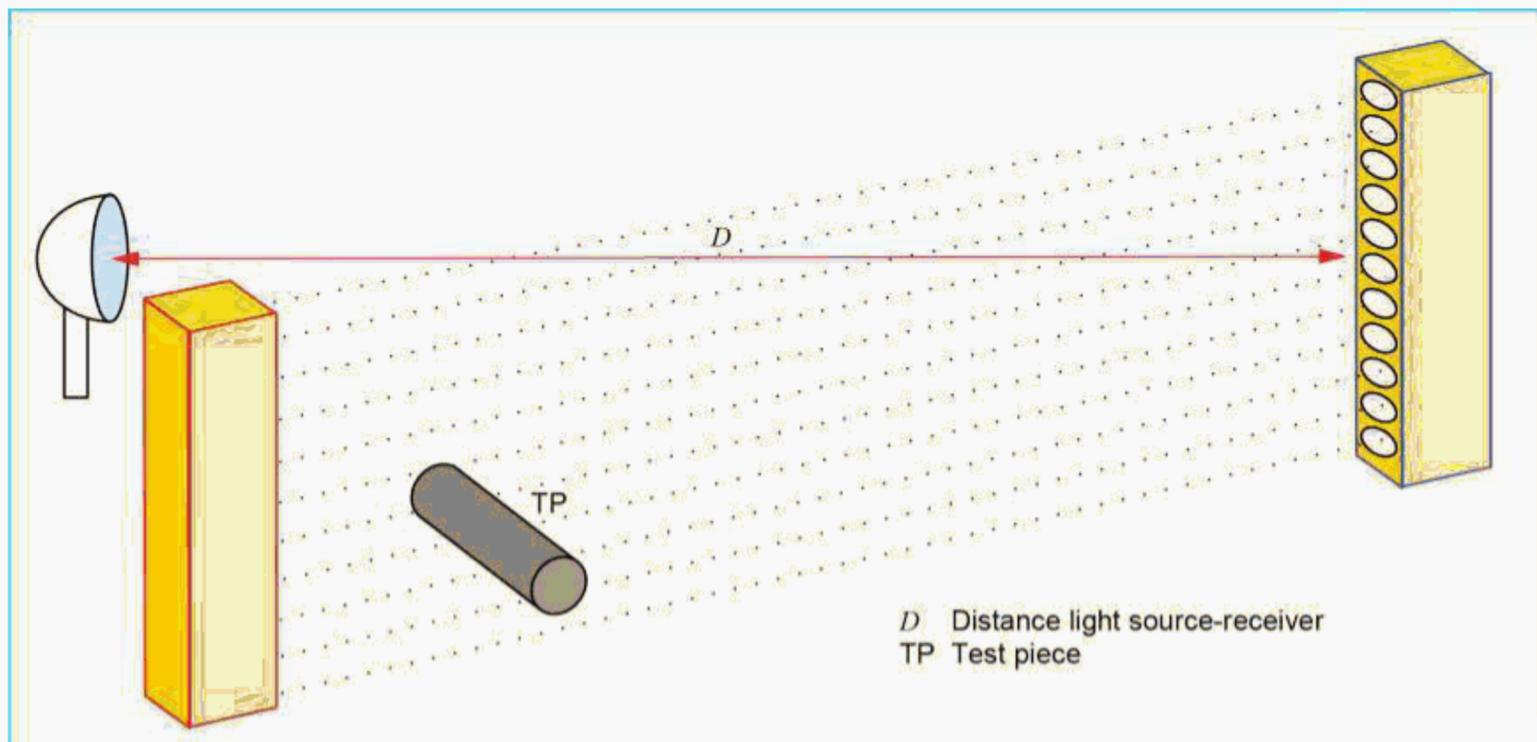
Test parameters

Distance (D)	Lux	Description
12 cm ^a	3 000	Distance for fail to danger test
21 cm ^a	1 500	Distance for normal operation test

^a The exact distances depend on the lamp type.

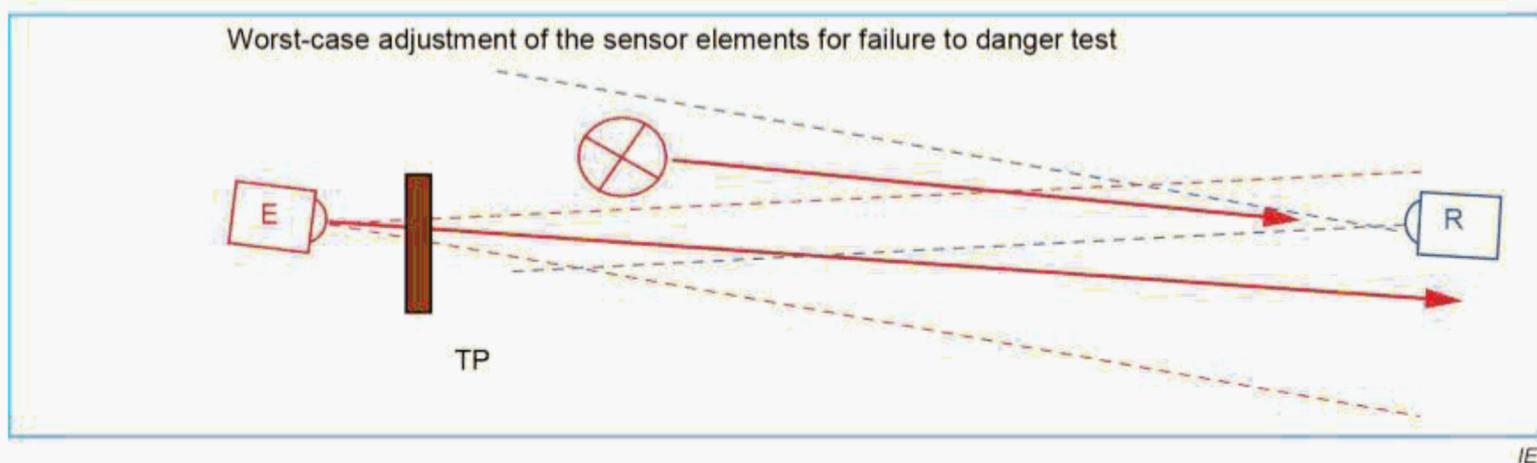
E = emitter; R = receiver

Figure 22 – Light interference test – Test set-up with fluorescent light source



The distance between emitter and receiver is 3 m

For the distance D between receiver and light source, see the table below



Test parameters

Distance (D)	Description
1,0 m	Distance for fail to danger test

E = emitter; R = receiver

Figure 23 – Light interference test – Test set-up with flashing beaconlight source

Addition:

5.4.6.4 Normal operation (best alignment)

The ESPE shall continue in normal operation throughout test sequence 1 in 5.4.6.3 using each of the following types of interfering light, directed along the optical axis of one or more receiving elements:

- the incandescent light source of 5.4.6.2 producing a light intensity of 1 500 lux measured at the plane of the receiving element(s) (Figure 21);
- the fluorescent light source of 5.4.6.2 producing an intensity of 1 500 lux at the plane of the receiving element(s) (Figure 22). This test shall be performed with three variations, using light from the centre and light from each end (anode and cathode areas) of the tube.

NOTE One objective of the test using the fluorescent light source is to check the susceptibility of the AOPD to high-frequency modulated optical radiation.

5.4.6.5 Failure to danger – Incandescent light (3 000 lux and worst-case alignment)

There shall be no failure to danger during test sequence 2 of 5.4.6.3 using the incandescent light source of 5.4.6.2 directed along the optical axis of one or more receiving elements, producing a light intensity of 3 000 lux \pm 300 lux, measured at the plane of the receiving elements (Figure 21).

5.4.6.6 Failure to danger – Flashing beacon (worst-case alignment)

There shall be no failure to danger during test sequence 3 of 5.4.6.3 using the flashing beacon light source of 5.4.6.2 directed along the optical axis of one or more receiving elements (Figure 23).

5.4.6.7 Failure to danger – Fluorescent light (3 000 lux and worst-case alignment)

There shall be no failure to danger with the radiation of the fluorescent light source of 5.4.6.2 producing an intensity of 3 000 lux at the plane of the receiving element(s) (Figure 22). This test shall be performed with three variations, using light from the centre and light from each end (anode and cathode areas) of the tube. Test sequence 2 of 5.4.6.3 shall be used.

5.4.6.8 Failure to danger – Interfering light from an emitting element of identical design

There shall be no failure to danger of a type 3 or type 4 ESPE when the radiation from the emitting elements of an AOPD of identical design is directed towards the receiving elements of the AOPD under test, either directly or via the retro-reflector target if used. A minimum of six positions shall be selected, representative of worst-case conditions as determined by the analysis of 5.2.1.2.2. The AOPD shall operate at the maximum working distance specified by the supplier. Test sequence 3 of 5.4.6.3 shall be used. Either the test piece shall be detected or the OSSD(s) shall go to the OFF-state.

Where different codes are required to prevent interference, these codes should be used in accordance with the manufacturer's instructions during the performance of these tests.

Based on the analysis, the most critical combination can require that tests are performed on AOPDs of different size and detection capability.

6 Marking for identification and safe use

This clause of Part 1 is applicable except as follows:

6.1 General

Addition:

Add to b):

- When separate parts of the AOPD have different detection capabilities, those parts and their detection capabilities shall be marked on the outside of the AOPD. When that is not practicable (for example, due to lack of space), the information shall be included in the accompanying documents.
- The minimum and maximum operating distances shall be marked.
- Should the OSSD be able to go to the ON-state when the receiving elements and the emitting elements are incorrectly mounted, i.e. 180° misalignment, the AOPD shall be marked so that the correct mounting position relative to each other is clearly identified.
- For light curtains, the limits of the detection zone shall be clearly marked.
- Marking shall be provided to indicate the beam centre-line(s).

NOTE The beam centre-line(s) is one of the factors used to determine the position of the AOPD.

7 Accompanying documents

This clause of Part 1 is applicable except as follows:

Addition to f):

When different parts of the AOPD have different detection capabilities, the size of the test piece for each different part together with the different detection capabilities shall be given together with the corresponding procedure for checking the detection capabilities and the operation of the visual indicator(s). Information about the size of an object that will never be detected should also be provided.

Addition to i):

The details of any precautions to be taken when installing the AOPD shall be given, including the EAA(s) of the specified device(s), together with any other relevant installation drawings giving details on how the AOPD detection capability may be affected by any reflective surfaces on or near the machine or on the material being worked.

Addition to v):

Details of the penetration of the test piece into the detection zone that is necessary to ensure actuation of the sensing device, for all possible directions of approach, in relation to an identifiable datum on the AOPD (for example beam centre-line(s)) shall be given.

The maximum speed of movement of the test piece, or equivalent up to which the detection capability is maintained, shall be given.

When the AOPD is provided with means for adjustment of the spatial position of the light curtain, the range of adjustments and the corresponding position of the detection zone shall be shown in diagrammatic form in the accompanying documents. For a light curtain, clearly legible drawings shall be provided to ensure that emitting elements and receiving elements are correctly mounted with respect to each other, particularly to avoid 180° misalignment.

Addition to ff):

If a particular form of light radiation is known to interfere with the AOPD, a statement similar to the following shall be included: "Additional measures may be necessary to ensure that the AOPD does not fail to danger when this form of light radiation is present in a particular application (for example, use of cableless control devices on cranes, radiation from weld spatter or effects from stroboscopic lights)."

Additions:

- nn) information on how to calculate the minimum distances in accordance with ISO 13855 when blanking or reduced resolution is implemented. Explain that when blanking is used, the minimum distance should always relate to the minimum (worst-case) object detection capability.
- oo) information can be found in IEC 62046 describing additional means that may be required to prevent access to the hazard zone through the blanked areas of the detection zone (including effects of reflective surfaces).
- pp) recommendation that a responsible person verifies the detection zone using an appropriate test piece after its configuration.
- qq) appropriate instruction on how to minimize light interference from an emitting element of identical design.
- rr) information about procedures for permanent fixing of retro-reflector targets as part of the AOPD.

Annex A (normative)

Optional functions of the ESPE

Annex A of Part 1 applies except as follows.

A.1 General

Addition to the list of optional functions:

- blanking (see Clause A.10);
- reduced resolution (see Clause A.11);
- selection of pre-defined reduced resolution configurations (see Clause A.12).

Addition:

A.10 Blanking

A.10.1 General

Blanking is an optional feature provided for AOPDs, which allows masking of one or more areas, each of a defined size, either locally fixed (fixed blanking) or movable (floating blanking) in the detection zone. In this way, attached objects or machine parts can be masked and not be detected by the AOPD. The stated optical resolution and the detection capability outside the blanked areas shall remain unchanged.

A.10.2 Functional requirements

Blanked beams shall be monitored for continued interruption of light.

NOTE 1 This is to ensure that the blanked areas of the detection zone remain obstructed to the extent possible by mechanical means.

NOTE 2 It is possible that the position of mechanical guards and machine parts can slightly shift due to machine vibration or other influences and therewith affect the number of beams being blanked. This implies that the stated detection capability at the borders of the blanked areas could be reduced by one or more beams.

NOTE 3 During normal operation (while a beam is blanked), it is sometimes not possible to detect the failure of the beam.

Configuration and setup of blanked areas (teach-in) shall be carried out by authorized persons only. This shall be assured by the use of key, keyword or tool. During the configuration, the OSSD(s) shall be in the OFF-state.

A.10.3 Verification

Verify by inspection and test, that:

- the OSSD(s) go to and remain in the OFF-state, when one or more of the blanked beams are unblocked (i.e. verify monitoring);
- the stated detection capability of the AOPD is maintained outside the blanked areas, with the exception of a possible reduced detection capability at the borders of the blanked areas;
- configuration of blanking areas is not possible without the use of key, keyword or tool;
- the OSSD(s) are in the OFF-state during configuration.

A.11 Reduced resolution

A.11.1 General

Reduced resolution (also referred to as unmonitored blanking) changes the detection capability of the AOPD. It shall ensure that objects in the detection zone (cables, tubes, etc.) of a diameter up to a certain size smaller than the detection capability are ignored. Any object equal to or larger than the detection capability shall be detected.

NOTE 1 For example, a contiguous group of one or more beams can be specified as "don't care" (i.e. the state of these beams is ignored and is not monitored). Interrupting these beams will not cause the OSSDs to go to the OFF-state.

Reduced resolution can be effective over the entire detection zone or partly within defined fixed or moving zones only.

NOTE 2 When calculating the positioning of the AOPD according to ISO 13855, the selected reduced resolution is used.

A.11.2 Functional requirements

Selection and activation of a reduced resolution other than the stated basic optical resolution of the AOPD shall not be possible without the use of a key, keyword or tool.

During configuration of the detection capability the OSSDs shall remain in the OFF-state.

The detection capability of the selected reduced resolution shall be verified with an appropriate test piece. Test pieces for any selectable optical resolution up to 40 mm shall be provided by the supplier.

A.11.3 Verification

Verify by inspection and test, that:

- selection and activation of a reduced optical resolution is not possible without the use of a key, keyword or tool;
- the detection capability of any selectable optical resolution is as configured throughout the specified detection field and can be verified with the appropriate test pieces.

A.12 Selection of pre-defined blanking or reduced resolution configurations

A.12.1 General

A.12.2 to A.12.5 do not apply if safety distances are calculated in all cases according to the maximum selectable value of resolution. In this case the manufacturer shall give appropriate information in the accompanying documents. The detection capability as marked on the enclosure (see IEC 61496-1:2020, 6.1 c)) shall state only the maximum selectable value of resolution. These requirements shall be verified by inspection.

NOTE 1 The automatic selection of a blanking/reduced resolution configuration(s) is not a muting function (as described in Clause A.7 of IEC 61496-1:2020).

NOTE 2 When using different blanking configurations, an unintended change caused by a failure can be detected intrinsically by the monitoring function.

A.12.2 Functional requirements for a type 2 AOPD

If an AOPD has more than one blanking/reduced resolution configuration, a single fault shall not lead to an unintended change from one blanking/reduced resolution configuration to another or such a failure shall result in a lock-out condition as a result of a periodic test.

Where the input selection signals are derived from device(s) external to the AOPD, this device(s) should meet the relevant requirements of other appropriate standards (for example ISO 13849-1, IEC 62061).

Single faults that prevent an intended change from one selected blanking/reduced resolution configuration to another shall cause the AOPD to go to a lock-out condition when a demand requires an activation of another blanking/reduced resolution configuration or an activation of an additional blanking/reduced resolution configuration or as a result of a periodic test. The specified response time(s) shall be maintained in this case or the AOPD shall go to a lock-out condition as a result of a periodic test.

NOTE It is possible that each blanking/reduced resolution configuration has a different response time as specified by the manufacturer.

A.12.3 Functional requirements for a type 3 or type 4 AOPD

If an AOPD has more than one blanking/reduced resolution configuration, a single fault shall not lead to an unintended change from one blanking/reduced resolution configuration to another. In cases where a single fault which does not cause a failure to danger of the AOPD is not detected, the occurrence of further faults internal to the AOPD shall not cause a failure to danger.

Where the input selection signals are derived from device(s) external to the AOPD, this device(s) should meet the relevant requirements of other appropriate standards (for example ISO 13849-1, IEC 62061).

Single faults that prevent an intended change from one selected blanking/reduced resolution configuration to another shall cause the AOPD to go to a lock-out condition when a demand requires an activation of another blanking/reduced resolution configuration or an activation of an additional blanking/reduced resolution configuration. The specified response time(s) shall be maintained in this case.

NOTE It is possible that each blanking/reduced resolution configuration has a different response time as specified by the manufacturer.

A.12.4 Verification for a type 2 AOPD

The functional requirements for the selection of blanking/reduced resolution configurations shall be verified as follows:

- verification that a single fault does not lead to an unintended change from one selected blanking/reduced resolution configuration to another or the failure results in a lock-out condition as a result of a periodic test;
- verification that a single fault does not prevent an intended change from one selected blanking/reduced resolution configuration to another or the failure results in a lock-out condition as a result of a periodic test;
- verification that common cause failures cannot lead to a deactivation or variation of the blanking/reduced resolution configurations;
- verification that the specified response time of the AOPD is maintained in the case of switching between different blanking/reduced resolution configurations or the AOPD goes to a lock-out condition as a result of a periodic test.

It is necessary to consider that persons may already be within the detection zone at the moment of switching between different blanking/reduced resolution configurations.

A.12.5 Verification for a type 3 or type 4 AOPD

The functional requirements for the selection of blanking/reduced resolution configurations shall be verified as follows:

- verification that a single fault does not lead to an unintended change from one selected blanking/reduced resolution configuration to another;
- verification that a single fault does not prevent an intended change from one selected blanking/reduced resolution configuration to another;
- for type 3 – verification that further faults will not lead to a failure to danger shall be carried out in accordance with 5.3.4;
- for type 4 – verification that further faults will not lead to a failure to danger shall be carried out in accordance with 5.3.5;
- verification that common cause failures cannot lead to a deactivation or modification of the blanking/reduced resolution configurations;
- verification that the specified response time of the AOPD is maintained in the case of switching between different blanking/reduced resolution configurations.

It is necessary to consider that persons may already be within the detection zone at the moment of switching between different blanking/reduced resolution configurations.

Addition:

Annex AA (informative)

Type 2 AOPD periodic test configurations

AA.1 Externally initiated and evaluated periodic test

The test is externally initiated and the safety related performance is externally evaluated.



Figure AA.1 – Single beam sensing device

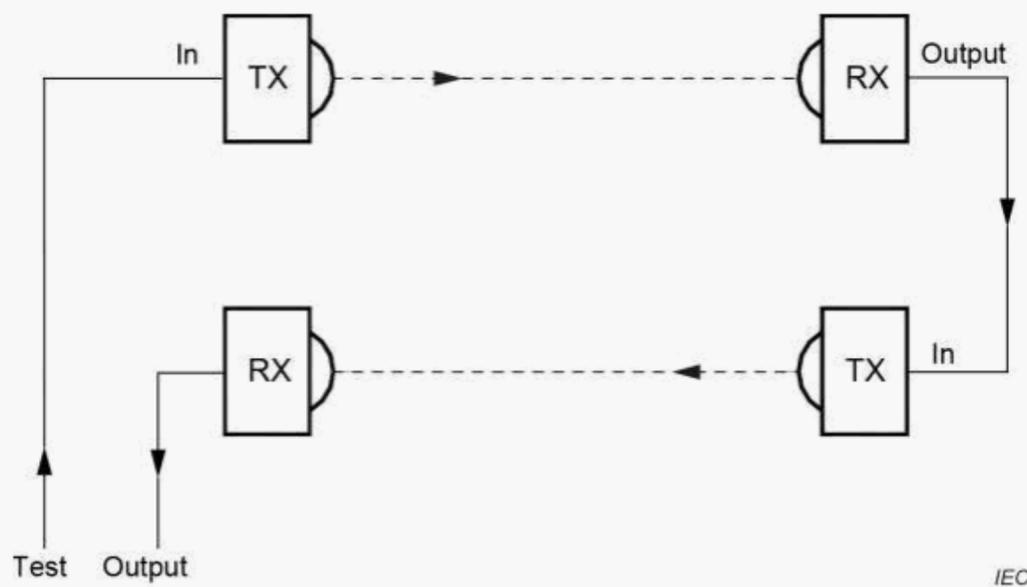


Figure AA.2 – Series connection of single beam sensing devices

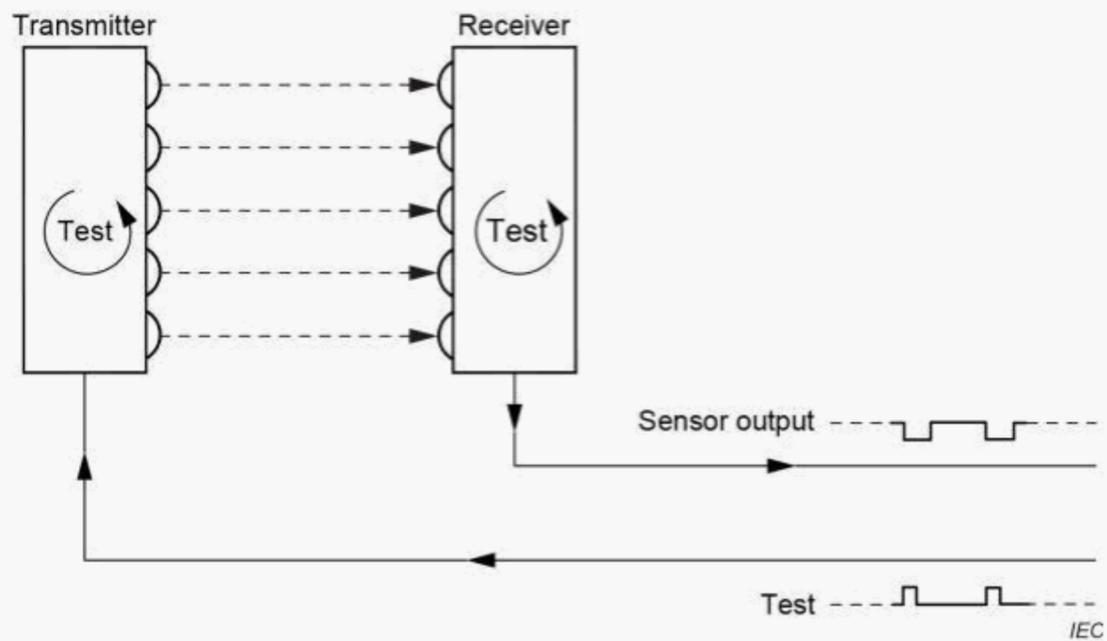


Figure AA.3 – Assembly of multiple beams tested individually

AA.2 Internally initiated and evaluated periodic test

The test is internally initiated and the safety related performance is internally evaluated. See Figure AA.4.

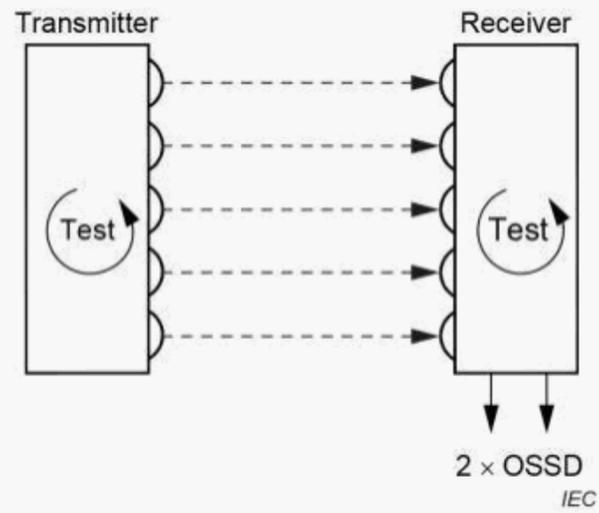


Figure AA.4 – Example of type 2 AOPD with internal test

NOTE Other configurations are possible.
