UL 61496-2

STANDARD FOR SAFETY

Safety of Machinery – Electro-Sensitive Protective Equipment – Part 2: Particular Requirements for Equipment Using Active Opto-Electronic Protective Devices (AOPDs)

UL Standard for Safety of Machinery – Electro-Sensitive Protective Equipment – Part 2: Particular Requirements for Equipment Using Active Opto-Electronic Protective Devices (AOPDs), UL 61496-2

Third Edition, Dated February 9, 2021

Summary of Topics

This new edition of ANSI/UL 61496-2 is an adoption of IEC 61496-2, Safety of Machinery – Electro-Sensitive Protective Equipment – Part 2: Particular Requirements for Equipment Using Active Opto-Electronic Protective Devices (AOPDs) (third edition issued January 2013) as an IEC-based UL standard, with US National Differences.

The new requirements are substantially in accordance with Proposal(s) on this subject dated July 3, 2020.

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ANSI/UL 61496-2-2021

UL 61496-2

Standard for Safety of Machinery – Electro-Sensitive Protective Equipment – Part 2: Particular Requirements for Equipment Using Active Opto-Electronic Protective Devices (AOPDs)

First Edition – January, 2002

Third Edition

February 9, 2021

This ANSI/UL Standard for Safety consists of the Third Edition.

The most recent designation of ANSI/UL 61496-2 as an American National Standard (ANSI) occurred on February 9, 2021. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

CONTENTS

Preface (UL) 5

NATIONAL DIFFERENCES 7

FOREWORD 9

INTRODUCTION 11

1 Scope 13
1DV Modification of last sentence in 2nd paragraph of Clause 1 as follows: 13
2 Normative references 13
2DV Modification of Clause 2 to delete the following reference: 14
3 Terms and definitions 14
4 Functional, design and environmental requirements 15
4.1 Functional requirements 15
4.2 Design requirements 17
4.3 Environmental requirements 20
5 Testing 21
5.1 General 21
5.2 Functional tests 24
5.4 Environmental tests 44
6 Marking for identification and safe use 53
6.1 General 53
7 Accompanying documents 54

Annex A (normative) Optional functions of the ESPE

A.1 General 56
A.9 Blanking 56
A.9.1 General 56
A.9.2 Functional requirements 56
A.9.3 Verification 56
A.10 Reduced Resolution 57
A.10.1 General 57
A.10.2 Functional requirements 57
A.10.3 Verification 57
A.11 Selection of pre-defined blanking or reduced resolution configurations 57
A.11.1 General 57
A.11.2 Functional requirements for a type 2 AOPD 58
A.11.3 Functional requirements for a type 4 AOPD 58
A.11.4 Verification for a type 2 AOPD 58
A.11.5 Verification for a type 4 AOPD 59

Annex B (normative) Catalogue of single faults affecting the electrical equipment of the ESPE, to be applied as specified in 5.3

Annex AA (informative) Type 2 AOPD periodic test configurations

AA.1 Externally initiated and evaluated periodic test 61
AA.2 Internally initiated and evaluated periodic test 62

Bibliography

Index

Preface (UL)

This UL Standard is based on IEC Publication 61496-2: Third Edition, Safety of Machinery – Electro-Sensitive Protective Equipment – Part 2: Particular Requirements for Equipment Using Active Opto-Electronic Protective Devices (AOPDS). IEC publication 61496-2 is copyrighted by the IEC.

Efforts have been made to synchronize the UL edition number with that of the corresponding IEC standard with which this standard is harmonized. As a result, one or more UL edition numbers have been skipped to match that of the IEC edition number.

This UL Standard 61496-2 Standard for Safety of Machinery – Electro-Sensitive Protective Equipment – Part 2: Particular Requirements for Equipment Using Active Opto-Electronic Protective Devices (AOPDS) is to be used in conjunction with the third edition of UL 61496-1. The requirements for equipment using active opto-electronic protective devices (AOPDS) are contained in this Part 2 Standard and UL 61496-1.

Requirements of this Part 2 Standard, where stated, amend the requirements of UL 61496-1.

Where a particular subclause of UL 61496-1 is not mentioned in UL 61496-2, the UL 61496-1 subclause applies.

Note – Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

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NATIONAL DIFFERENCES

National Differences from the text of International Electrotechnical Commission (IEC) Publication 61496-2, Safety of machinery – Electro-sensitive protective equipment – Part 2: Particular requirements for equipment using active opto-electronic protective devices (AOPDS), copyright 2013 are indicated by notations (differences) and are presented in bold text.

There are five types of National Differences as noted below. The difference type is noted on the first line of the National Difference in the standard. The standard may not include all types of these National Differences.

DR – These are National Differences based on the **national regulatory requirements**.

D1 – These are National Differences which are based on **basic safety principles and requirements**, elimination of which would compromise safety for consumers and users of products.

D2 – These are National Differences from IEC requirements based on existing **safety practices**. These requirements reflect national safety practices, where empirical substantiation (for the IEC or national requirement) is not available or the text has not been included in the IEC standard.

DC – These are National Differences based on the **component standards** and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE – These are National Differences based on **editorial comments or corrections**.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

Modification / Modify - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.

Deletion / Delete - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

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FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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 third edition cancels and replaces the second edition published in 2006. It constitutes a technical revision.

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

a) Requirements have been corrected and made easier to understand.

b) Test procedures have been revised to make them easier to perform and to improve repeatability.

c) Guidance is provided for the evaluation and verification of AOPDs using design techniques for which the test procedures of this part are not sufficient.

This standard has the status of a product family standard and may 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 61496-1:2012.

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

Where a particular clause or subclause of Part 1 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 Part 1 is adapted accordingly.

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

CDV	Report on voting
44/651/CDV	44/670/RVC

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

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

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 publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore. iec. ch" in the data related to the specific publication. At this date, the publication will be

• reconfirmed,

• withdrawn,

• replaced by a revised edition, or

• amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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 part of IEC 61496 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 standard 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.

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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 may include optional safety-related functions, the requirements for which are given in Annex A of IEC 61946-1:2012 and of this part.

1DV DE ***Modification of last sentence in 2nd paragraph of Clause 1 as follows:***

Replace reference to "IEC 61946-1:2012" with "IEC 61496-1:2012"

This part of IEC 61496 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 part are AOPDs employing radiation at wavelengths outside the range 400 nm to 1500 nm.

This part of IEC 61496 may 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 may be necessary, for example, when the materials that are to be recognized by the sensing function have different properties from those of persons.

This part does of IEC 61496 not deal with EMC emission requirements.

2 Normative references

This clause of Part 1 is applicable except as follows:

Additional references:

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

IEC 61496-1:2012, *Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests*

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*

EN 471:2003, *High-visibility warning clothing for professional use – Test methods and requirements*.

2DV DC *Modification of Clause 2 to delete the following reference:*

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

3 Terms and definitions

NOTE At the end of this standard there is an index which lists, in alphabetical order, the terms and acronyms defined in Clause 3 and indicates where they are used in the text.

This clause of Part 1 is applicable except as follows:

Additional definitions:

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

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

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).

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

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 the OFF-state when a test piece in accordance with 4.2.13 is placed 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 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.

NOTE The purpose of this requirement is to ensure that the OSSD(s) go to the OFF-state when a person or part of a person passes through the detection zone or light beam. Based on a dimension of 150 mm and a walking speed of 1,6 m/s, a minimum OFF time of 80 ms was determined to be adequate.

When the OSSD(s) go to the OFF-state, they shall remain in the OFF-state while the test piece is present in the detection zone (or light beam) or for at least 80 ms, whichever is greater.

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 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 part of IEC 61496, only type 2 and type 4 ESPEs are considered. The types differ in their performance in the presence of faults and under influences from environmental conditions. In Part 1, the effects of electrical and electromechanical faults are considered (such faults are listed in Annex B, Part 1). It is the responsibility of the machine manufacturer and/or the user to determine which type is required for a particular application.

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

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 have a means of periodic test.

A type 4 ESPE shall fulfil the fault detection requirements of 4.2.2.5 of IEC 61496-1:2012.

For 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), then the data interface and associated safety-related communication interface shall meet the requirements of 4.2.4.4 of IEC 61496-1:2012. In this case, a single safety-related data interface can substitute for two OSSDs in 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.

For a type 2 AOPD where the periodic test is internally initiated and evaluated, single faults that lead to the loss of the automatically initiated internal test shall be detected and shall result in a lock-out condition.

4.2.2.4 Particular requirements for a type 3 ESPE

This subclause of Part 1 is not applicable.

Additions:

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.

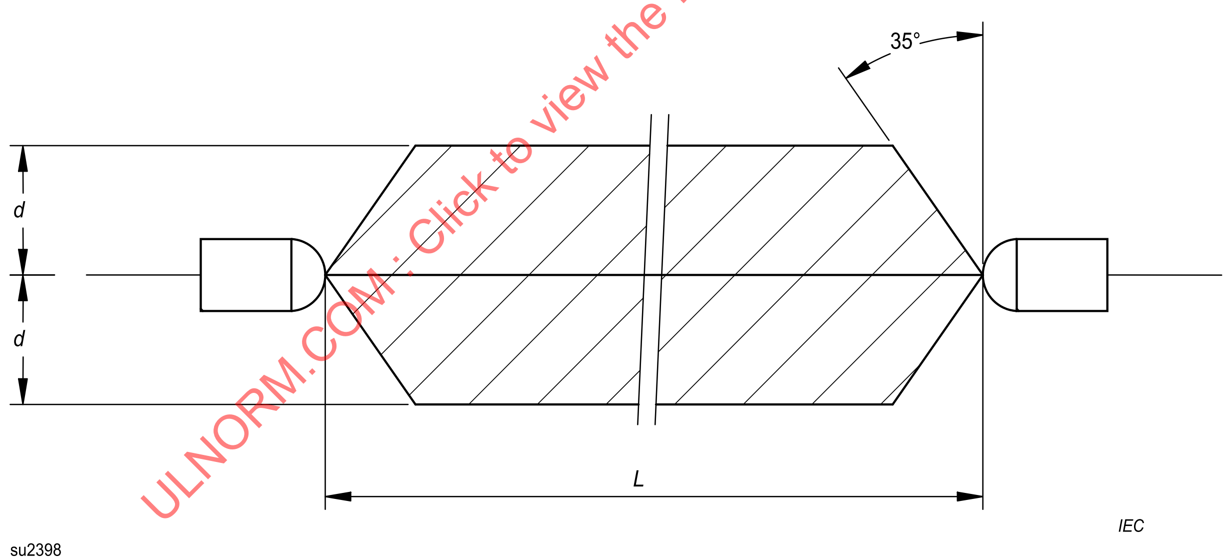
If a single fault (as specified in Annex B of IEC 61496-1:2012), which under normal operating conditions (see 5.1.2.1 of IEC 61496-1:2012) would not result in a loss of AOPD detection capability but, when occurring with a combination of the conditions specified above, would result in such a loss, that 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 to 3 000 mm

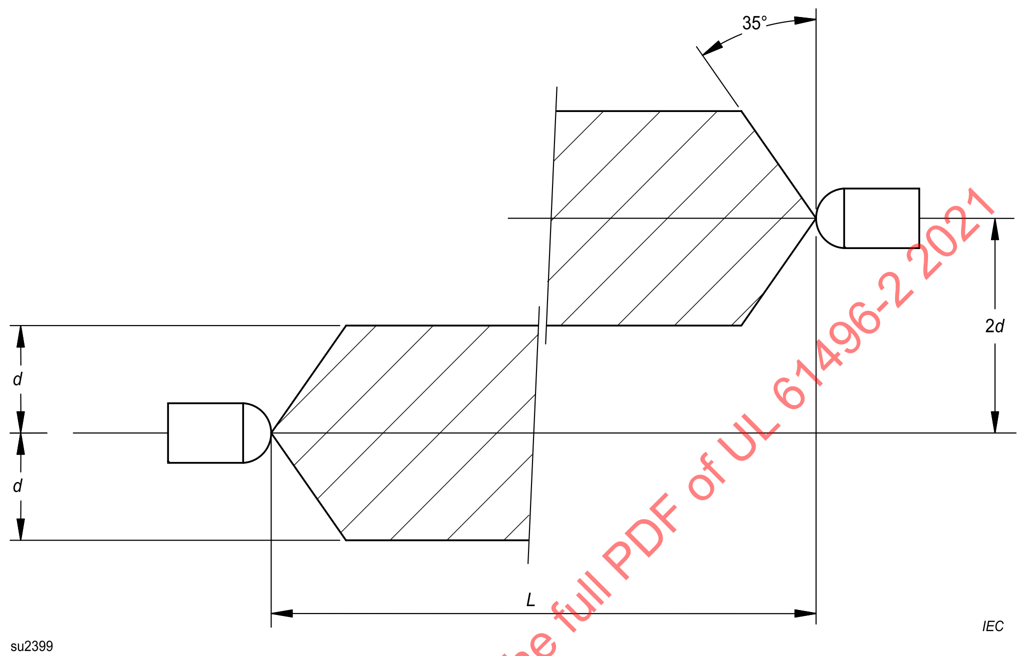
For type 2: d = 262 mm, L = 500 to 3 000 mm

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 and 500 mm for a 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° (for example, less than 0,1°) 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: 2*d* = 262 mm, *L* = 3 000 mm

For type 2: 2*d* = 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 conforming to the requirements for retro-reflection of EN 471 class 2 or equivalent;

NOTE Table 5 in EN 471:2003 defines the minimum coefficient of retro-reflection for class 2 material as 330 cd lx^{-1} m^{-2} with an entrance angle of 5° and an observation angle of 0,2° (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.

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 to 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 accessible emission limits (AEL) for a class 1M device in accordance with 8.2 of IEC 60825-1:2007.

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

4.2.15DV D2 ***Modification of 2nd paragraph of Clause 4.2.15 to replace with the following:***

If the emitting device uses laser technology, the radiation intensity generated and emitted by the AOPD shall at no time exceed the accessible emission limits (AEL) for a class 1M device in accordance with the Center for Devices and Radiological Health of the Food and Drug Administration.

4.3 Environmental requirements

Addition:

4.3.5 Light interference

The ESPE shall continue in normal operation when subjected to

– incandescent light;

– flashing beacons;

– fluorescent light operated with high-frequency electronic power supply.

The ESPE shall not fail to danger when subjected to

– incandescent light (simulated daylight using a quartz lamp);

– stroboscopic light;

– fluorescent light operated with high-frequency electronic power supply;

– for a type 4 AOPD, radiation from an emitting assembly (or element) of identical design. Combination of technical measures and installation and configuration procedures in accordance with the information for use provided by the manufacturer shall be tested.

NOTE For type 2 AOPDs the risk of failure to danger from an emitting element of identical design can be reduced by installation measures supplied by the manufacturer.

These requirements shall be met when the AOPD conforms to the tests in 5.4.6.

No requirements are given for immunity to other extraneous light sources which may cause abnormal operation or failure to danger. A requirement for the supplier to inform the user of potential problems is given in (ff) of Clause 7 (in this part and IEC 61496-1:2012).

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) or for at least 80 ms, whichever is greater. If the AOPD incorporates a restart interlock, the restart interlock shall be disabled during the tests of this clause.

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

Table 1
Correspondences of requirements/testing and AOPD designs

Subclause	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			X	X	X	X

Table 1 Continued on Next Page

Table 1 Continued

Subclause	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
	emitters and receivers in the same assembly						
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	
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

Table 1 Continued on Next Page

Table 1 Continued

Subclause	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
5.2.1.3.7	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 – Stroboscopic light (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.

5.1.2 Test conditions

5.1.2.2 Measurement accuracy

Addition to first paragraph:

– for angular measurement: ± 0,1°;

– for light intensity measurement: ± 10 %.

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)] 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.

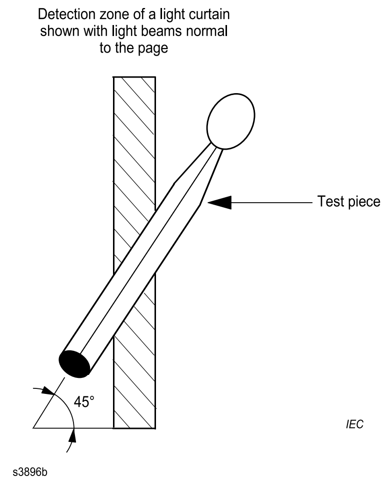


Figure 3

Test piece at 45°

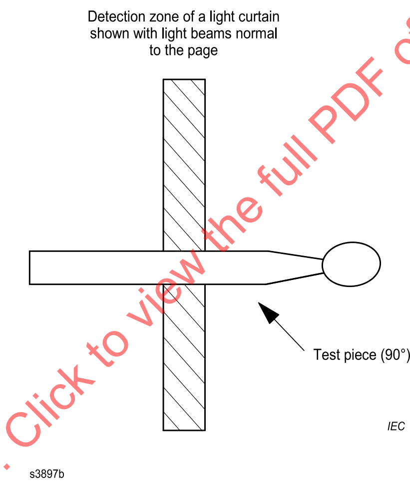


Figure 4

Test piece at 90°

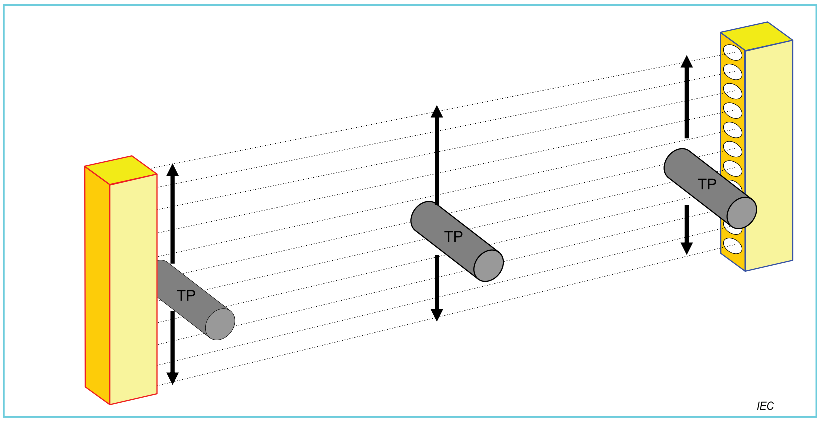


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Figure 5

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 61496-1:2012.

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:

a) the beam centre-line and the optical axes of the emitting and receiving elements;

b) the spacing between beam centre lines;

c) the characteristics of the optical assemblies (e.g. lens diameter, focal length, position and dimension of the stops, shape of the lens holder)

d) the relative intensity/sensitivity of the beams in the multi-beam devices;

e) beam direction and orientation between similar elements (i.e. between one emitting subassembly and another, or between one receiving subassembly and another);

f) 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

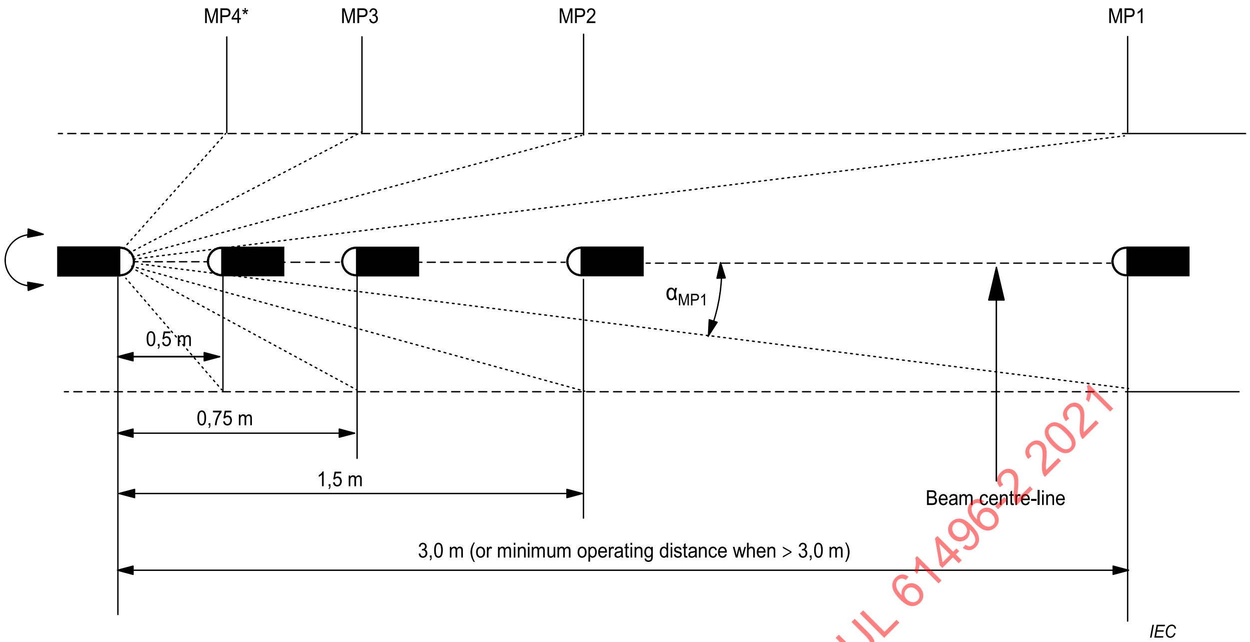
– the axes of the optical beams are parallel and

– 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.



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Type 2 AOPD	MP1	MP2	MP3	MP4		Type 4 AOPD	MP1	MP2	MP3	MP4
α Limit values degrees	5	10	19,3	27,7		α Limit values degrees	2,5	5	10	14,7
* MP measuring point										

The effective aperture angle should be determined according to 5.2.1.2.4

Measurements should be carried out at each of the measuring points MP1 to MP4 (or if minimum distance is greater than 3,0 m, at MP1 only).

NOTE 1 The limit values for intermediate distances between MP1 and MP4 can be calculated using the formula:

$$\alpha = \tan^{-1}(d / L)$$

where

d = 262 (for type 2) or d = 131 (for type 4)

and L is the distance between emitter and receiver (or DUT and retro-reflector target).

For distances greater than 3,0 m, use the α limit for MP1.

NOTE 2 For retro-reflector systems, the value of α is one-half of the value shown in the table above.

Figure 6

Limit values for the effective aperture angle (EAA)

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

$$d = P + \varnothing$$

where

d = detection capability

P = beam centre-lines spacing

$\varnothing$ = 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, detection capability = 14 mm.

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

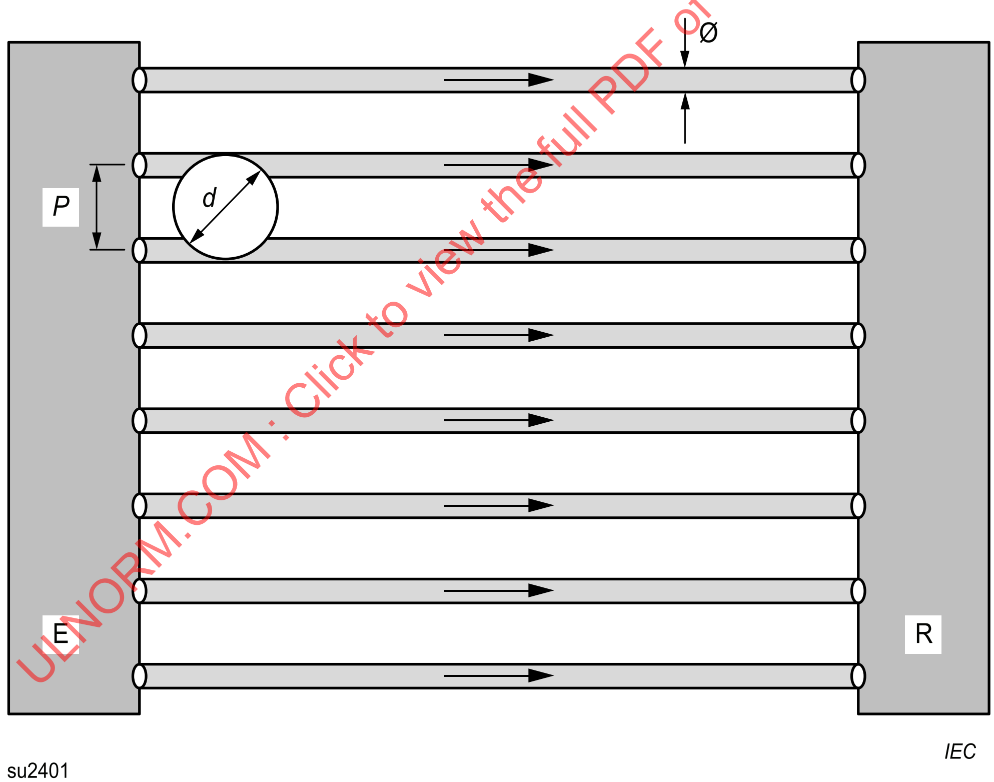


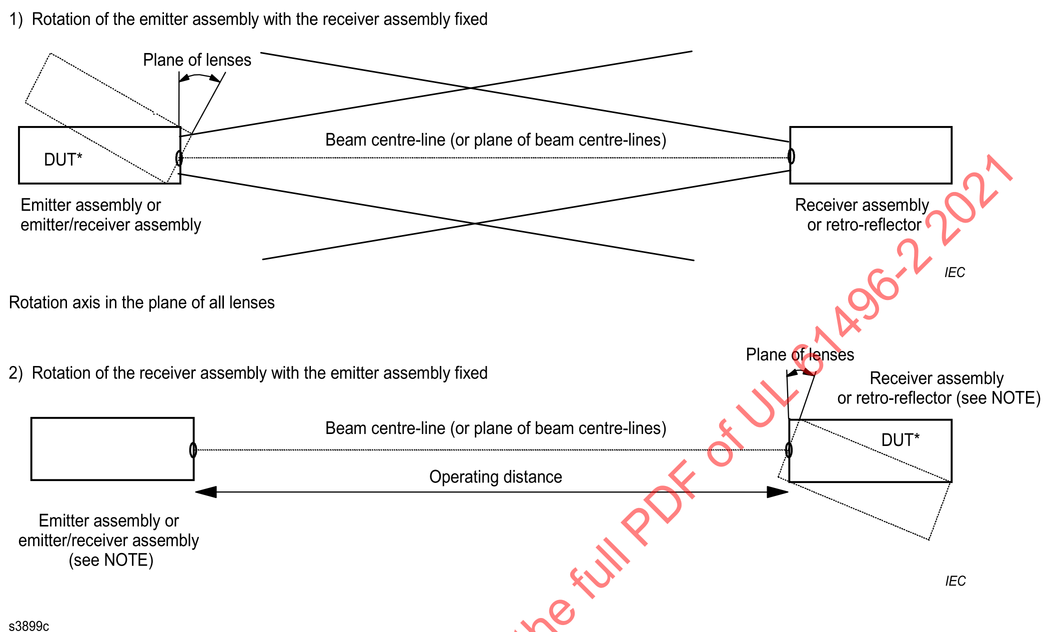
Figure 7

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 with an angle scale. The tests shall be performed about the rotational axis indicated in Figure 8.



* DUT: device under test

For light curtains employing retro-reflective techniques, the test should only be carried out on the sensing unit 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 the steps of this procedure.

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 shown in Figure 11.

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.

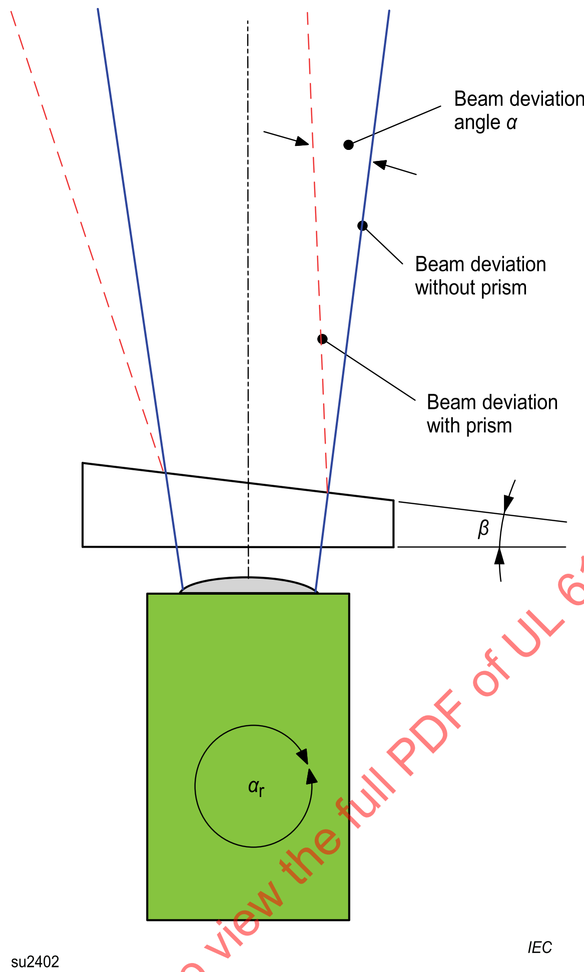
e) Repeat steps c) and d), inserting the prism from opposite directions, until the OSSD(s) change(s) to the OFF-state as required without changing the position of the turntable. If such a position cannot be found, then the EAA of the beam being tested exceeds the required angle.

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 to 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

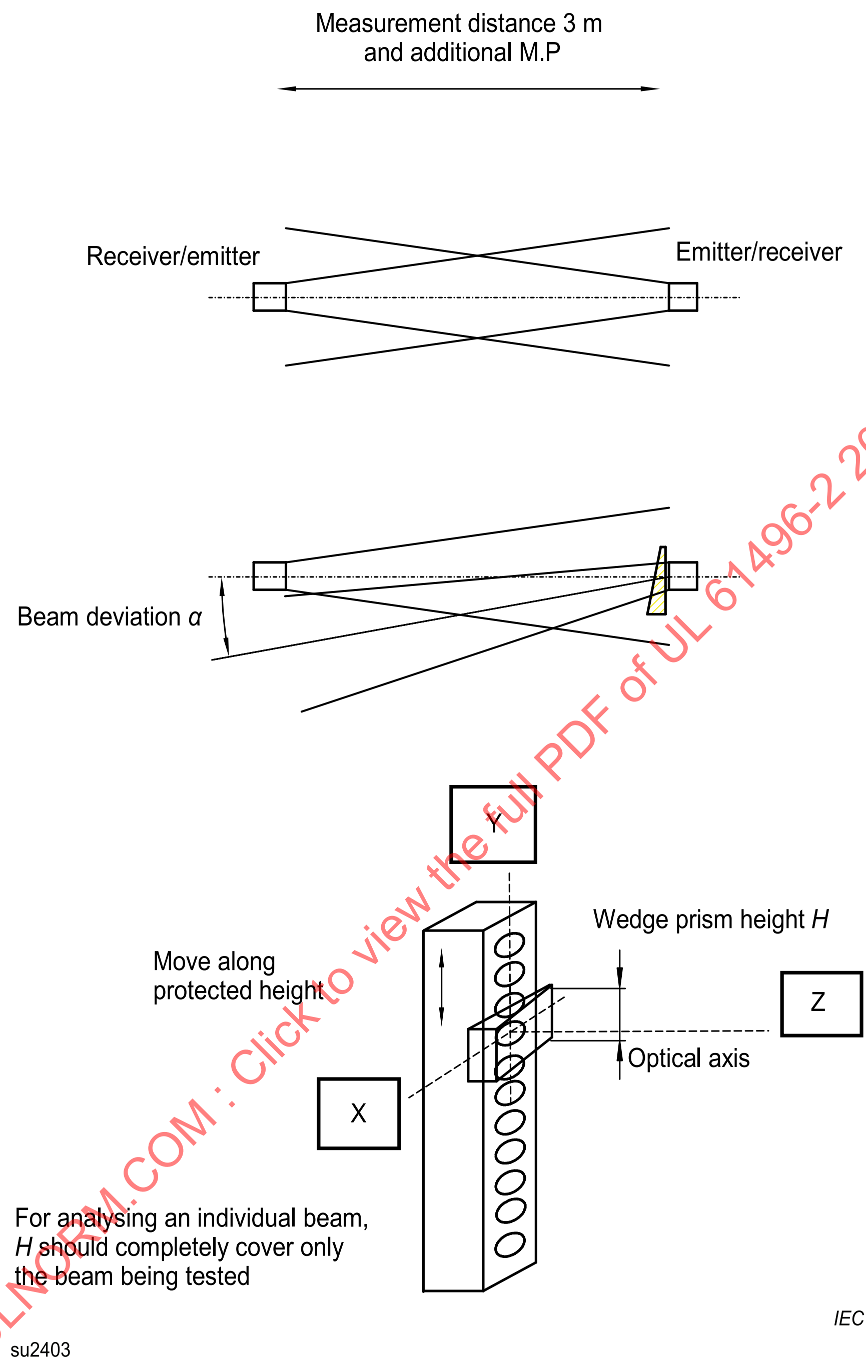


Figure 10

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:

$$\beta = \frac{2,5°}{1,51 - 1}$$

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

Refraction (*n*)	at	400 nm	=1,5	$\alpha = \beta\,(n\text{-}1)$	= 4,9(1,5-1) = 2,45°
	at	880 nm	=1,51	$\alpha = \beta\,(n\text{-}1)$	= 4,9(1,51-1) = 2,5°
	at	1 500 nm	=1,53	$\alpha = \beta\,(n\text{-}1)$	= 4,9(1,53-1) = 2,6°

NOTE Measuring error caused by differing wavelengths for 400 nm, it is −0,05° and for 1 500 nm, it is +0,1°.

Figure 11
Design calculations for a wedge prism

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 subclauses 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 12) 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).

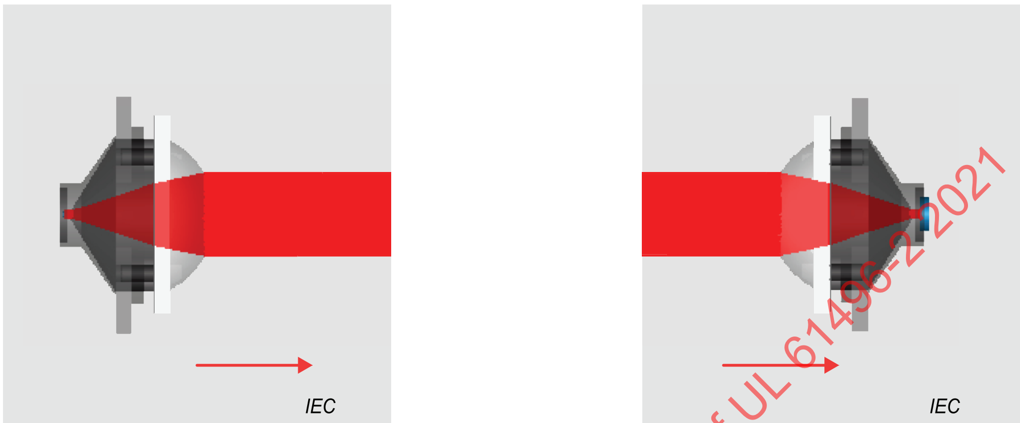


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Figure 12

Example of optical subsystem: Emitter on left – Receiver on right

The model of the emitting element (see Figure 13) 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 14) on the emitting element.

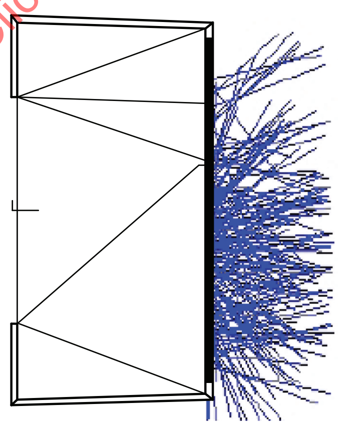

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Figure 13

Example of SMD LED Model

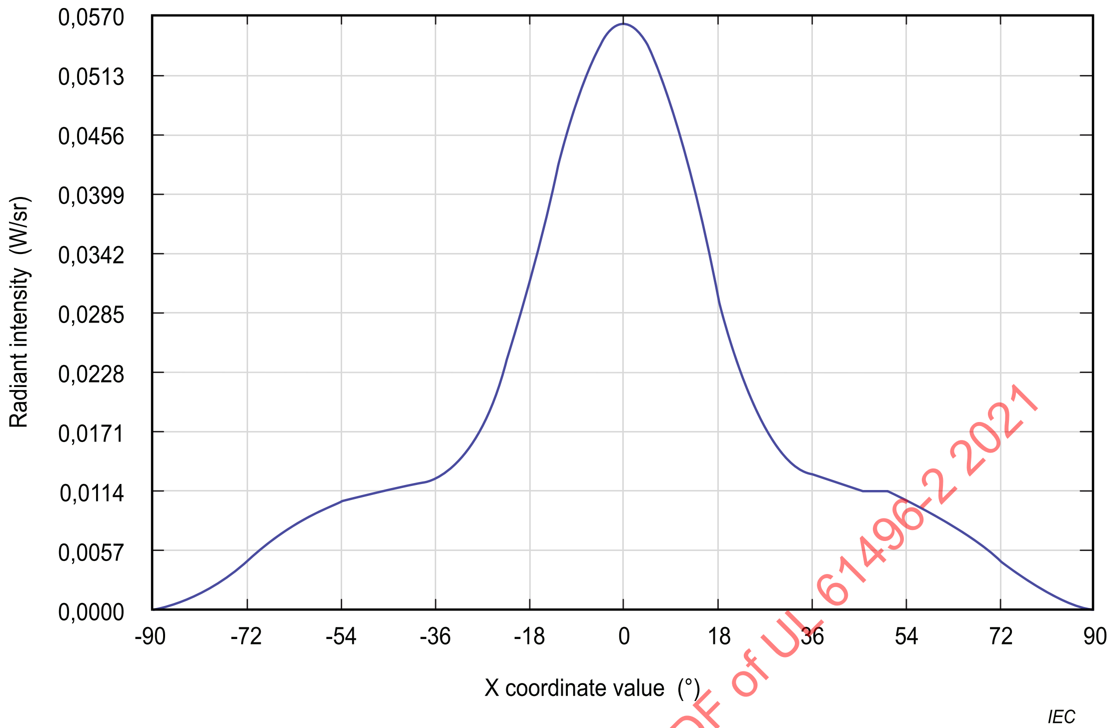

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Figure 14

Example of intensity distribution of emitting element

The model of the emitting element shall be extended with mechanical stops or aperture stops (see Figure 15), 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.

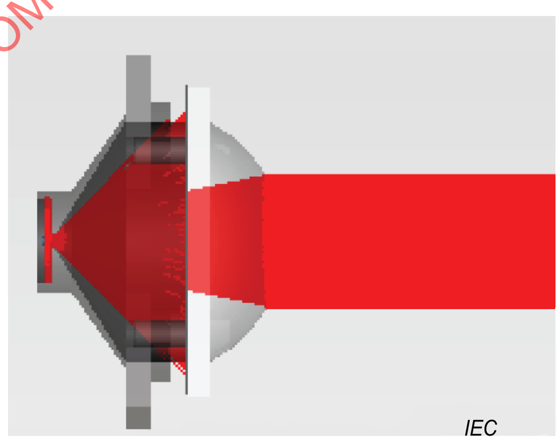

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Figure 15

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 16) 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.

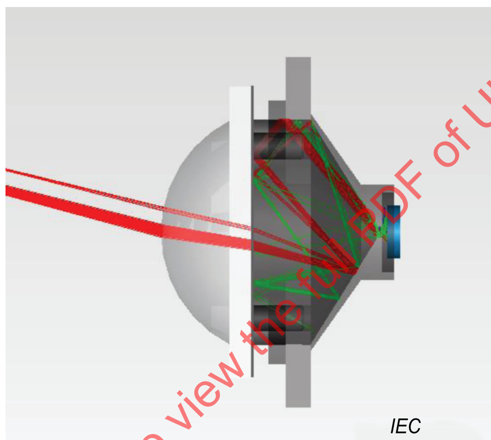

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Figure 16

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 nonsimilar 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 17). 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.

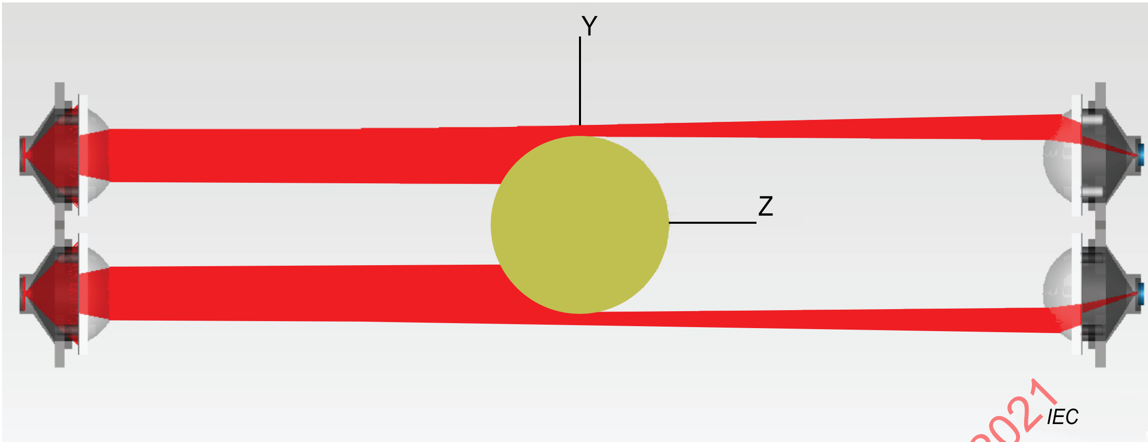

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Figure 17

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 suppliers 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;

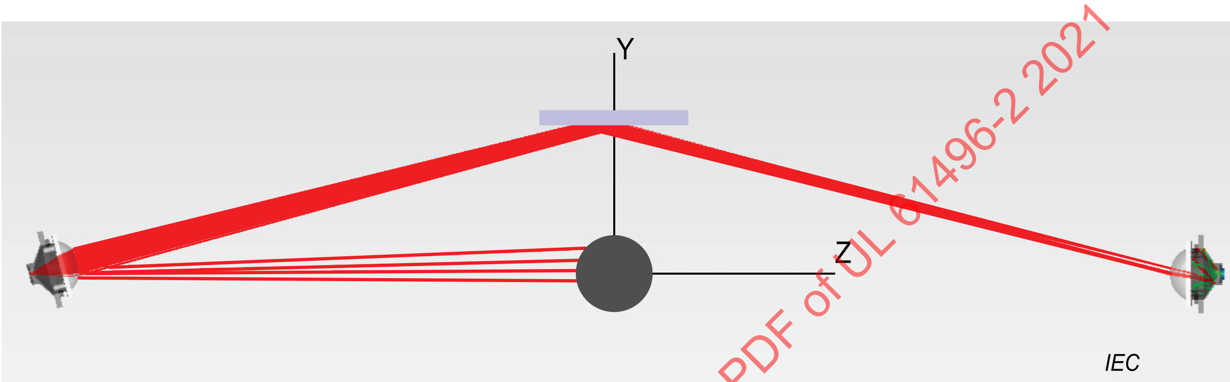
e) remove the filter and verify that the OSSD(s) continuously remain in the OFF-state;

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 18) 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 to 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 to 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.



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

Figure 18

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:

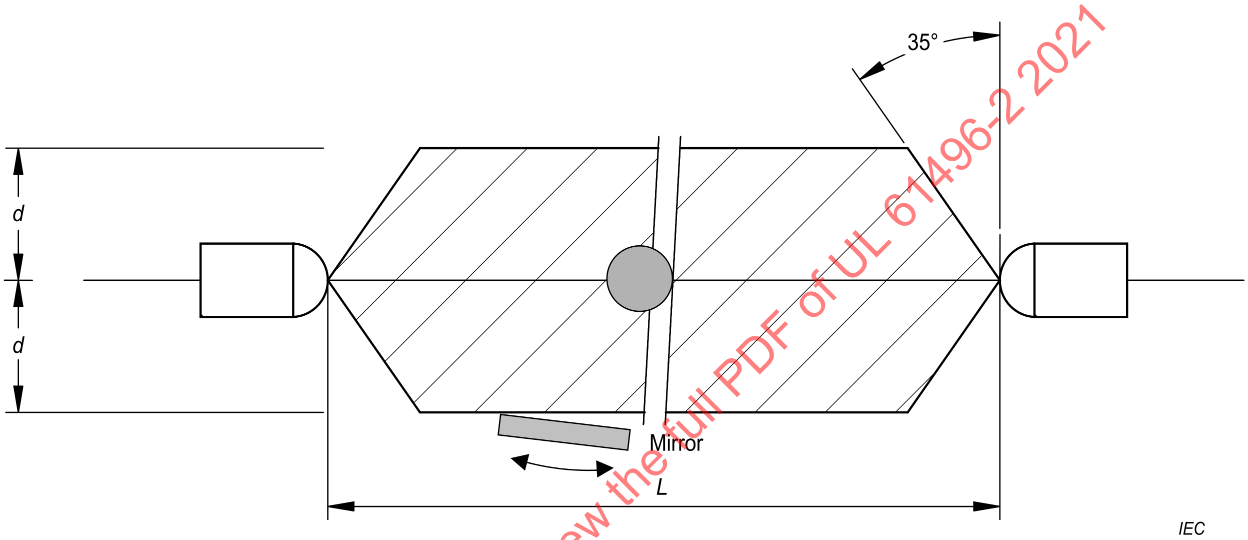
The test shall be carried out at each of the operating distances (0,5 m, 0,75 m, 1,5 m and 3,0 m) that are within the operating distance specified by the supplier. Where the minimum specified operating distance exceeds 3,0 m, the test shall be carried out at the minimum operating distance. The test shall 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 19). 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.



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For type 4: d = 131 mm, L = 0 to 3 000 mm

For type 2: d = 262 mm, L = 0 to 3 000 mm

Figure 19

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 20) that are in excess of the angles shown in Table 2 and Table 3, or as calculated with the formulae of Figure 20.

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 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 20, 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 or Table 3, 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 20) 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).

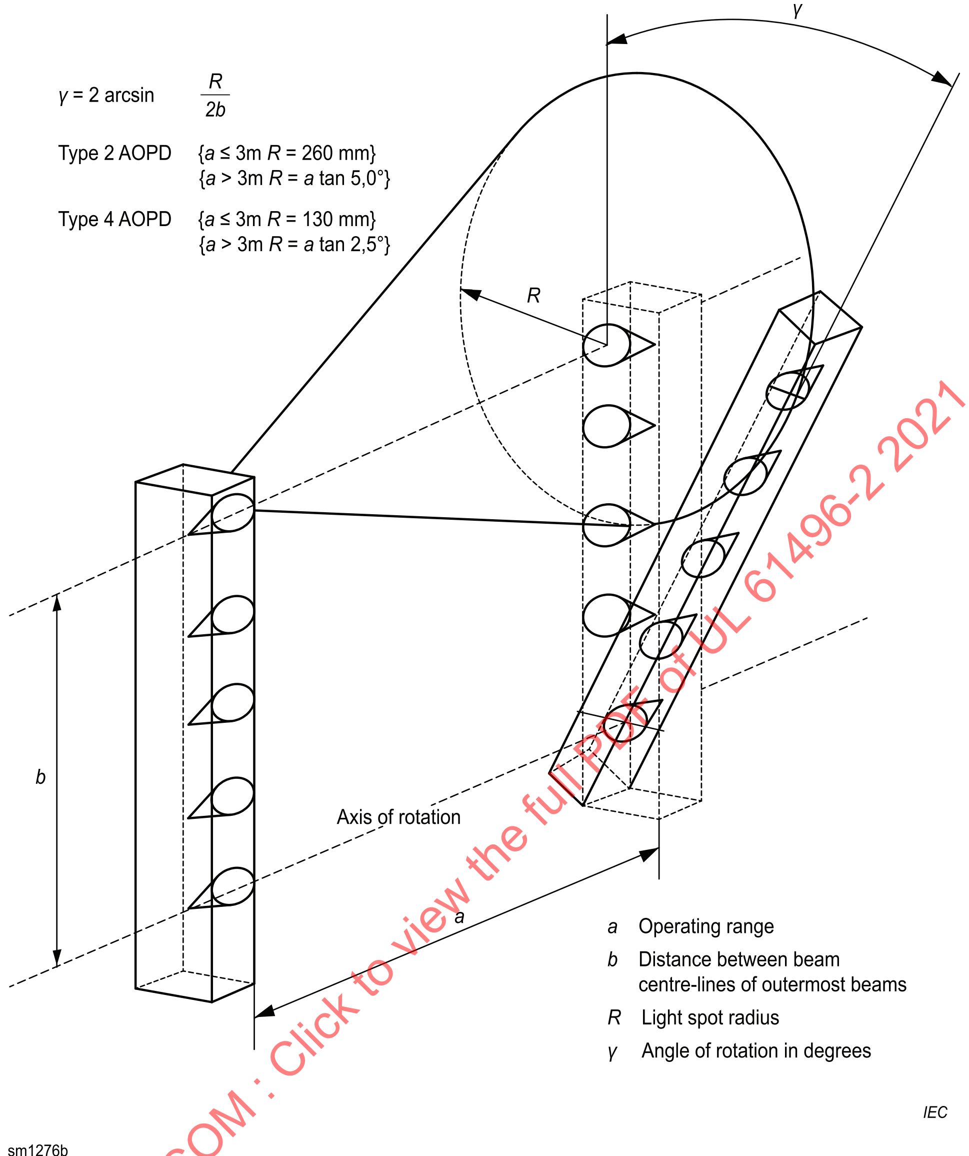


Figure 20

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 axis 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 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 retro-reflection of EN 471 class 2 or equivalent.

NOTE Table 5 in EN 471:2003 defines the minimum coefficient of retro-reflection for class 2 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.

Additional functional tests:

5.2.9 Wavelength

The transmitted 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.

5.2.10DV D2 ***Modification of 1st paragraph of Clause 5.2.10 to replace with the following:***

The radiation intensity shall be verified by measurement in accordance with the Center for Devices and Radiological Health of the Food and Drug Administration, inspection of the supplier's declaration.

5.4 Environmental tests

Additional environmental tests:

5.4.6 Light interference

5.4.6.1 General

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.

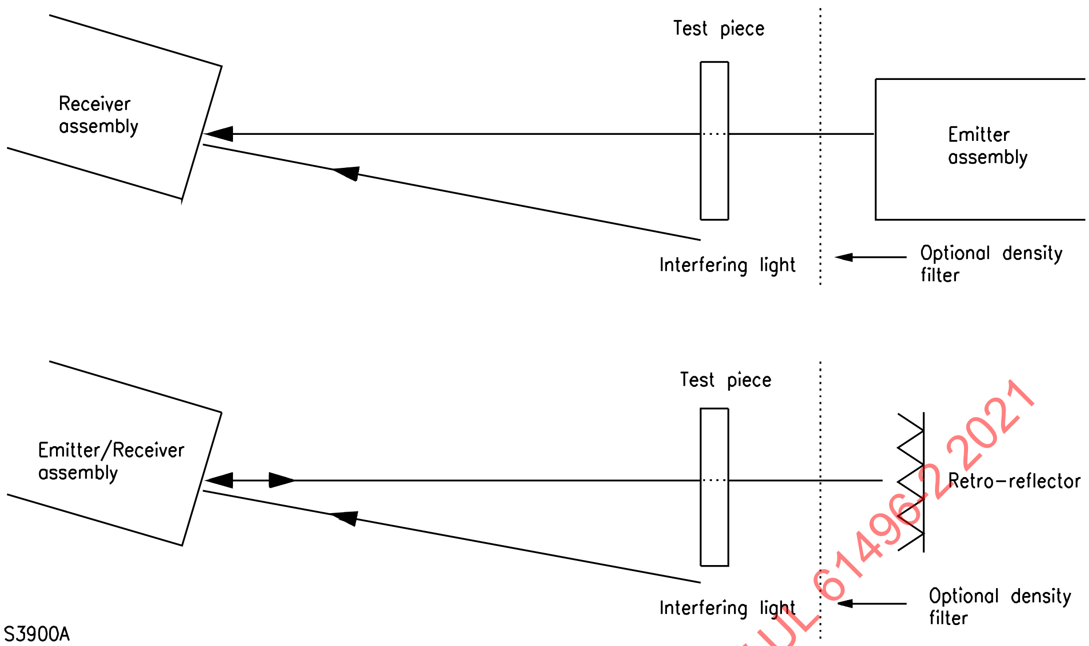
During B tests and C tests, the test piece shall be introduced into the detection zone in such a manner that the interfering light is not interrupted.

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 21, Figure 22, Figure 23, Figure 24 and Figure 25 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 21.

During the tests, long-range operation can be simulated by density filters, as illustrated in Figure 21, 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.

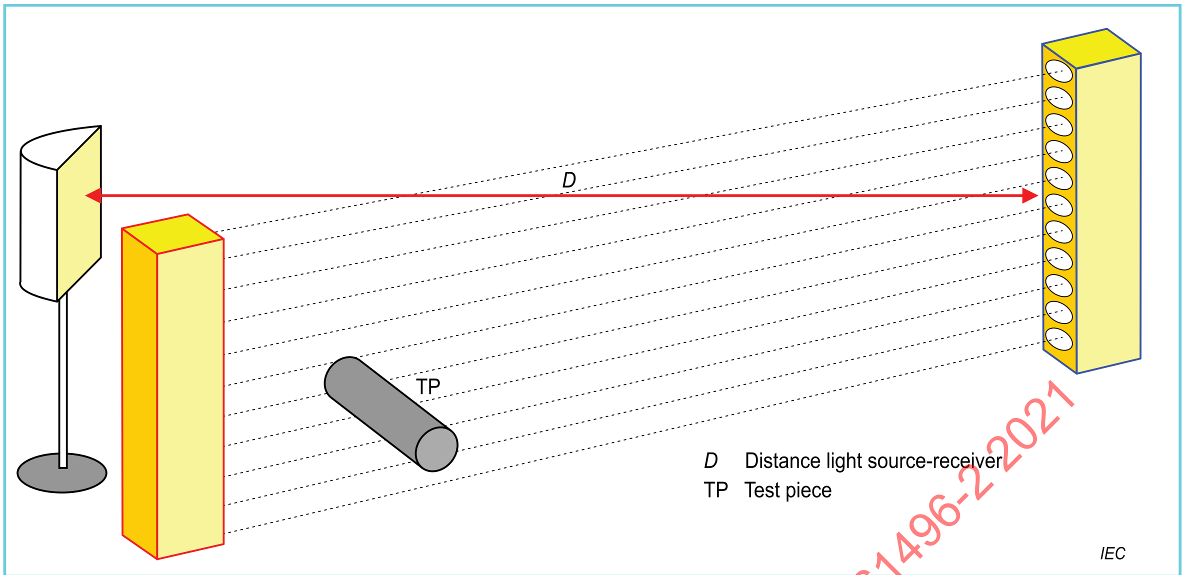


NOTE 1 Receiver or emitter/receiver assemblies are operated at maximum possible misalignment for fail to danger tests.

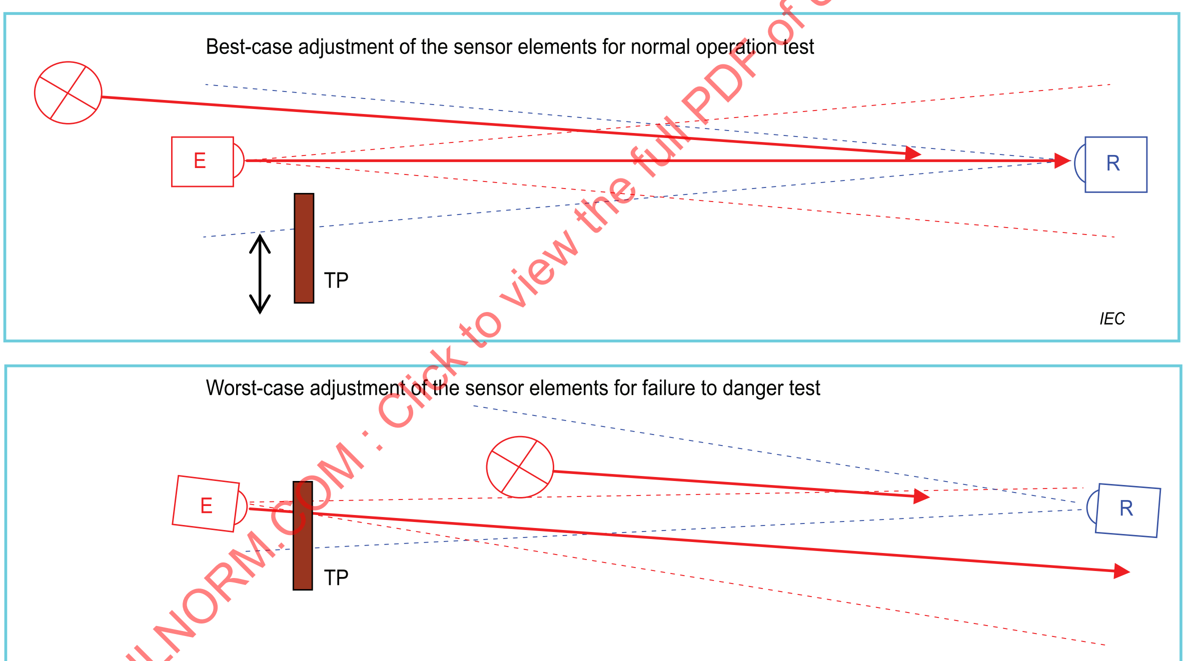
NOTE 2 Density filters can affect polarization.

Figure 21

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



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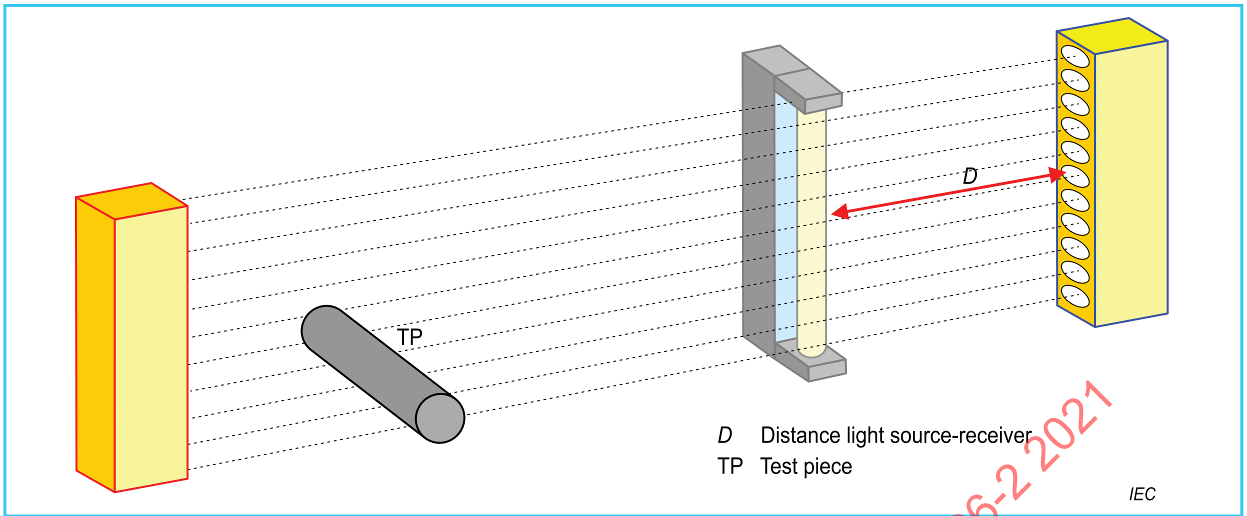
Test parameters

Distance (*D*)	Lux	
2 m [a]	3 000	Distance for fail to danger test.
3 m [a]	1 500	Distance for normal operation test.

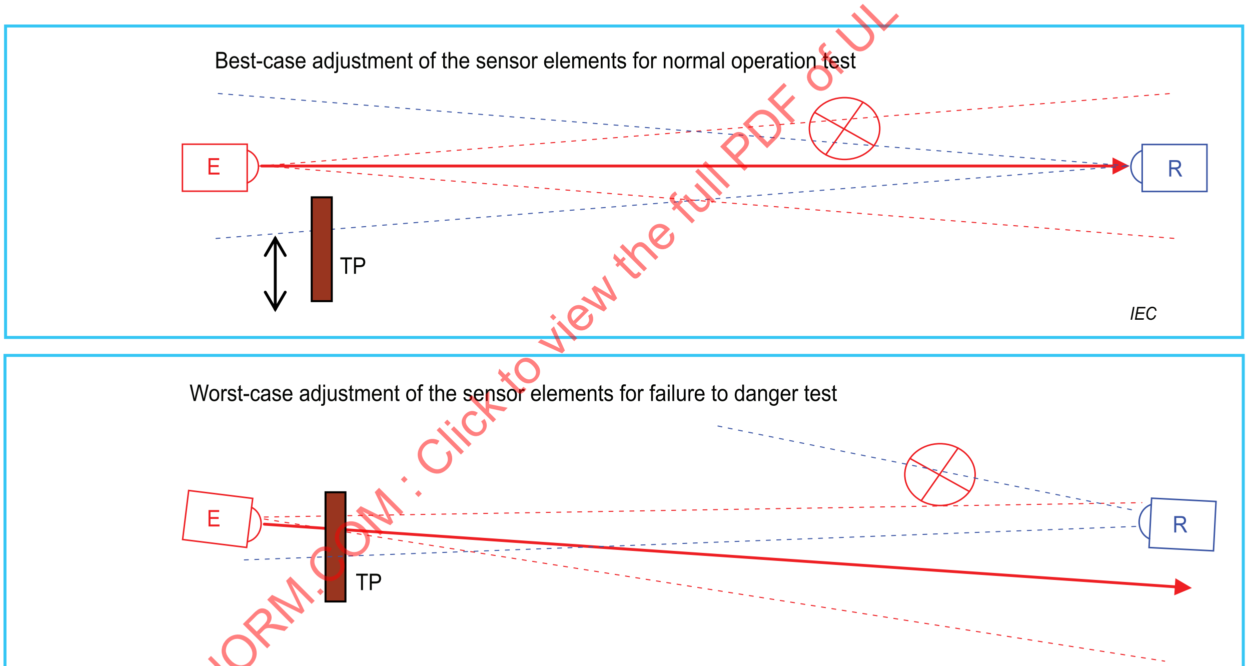
[a] The exact distances depend on the lamp type.

Figure 22

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



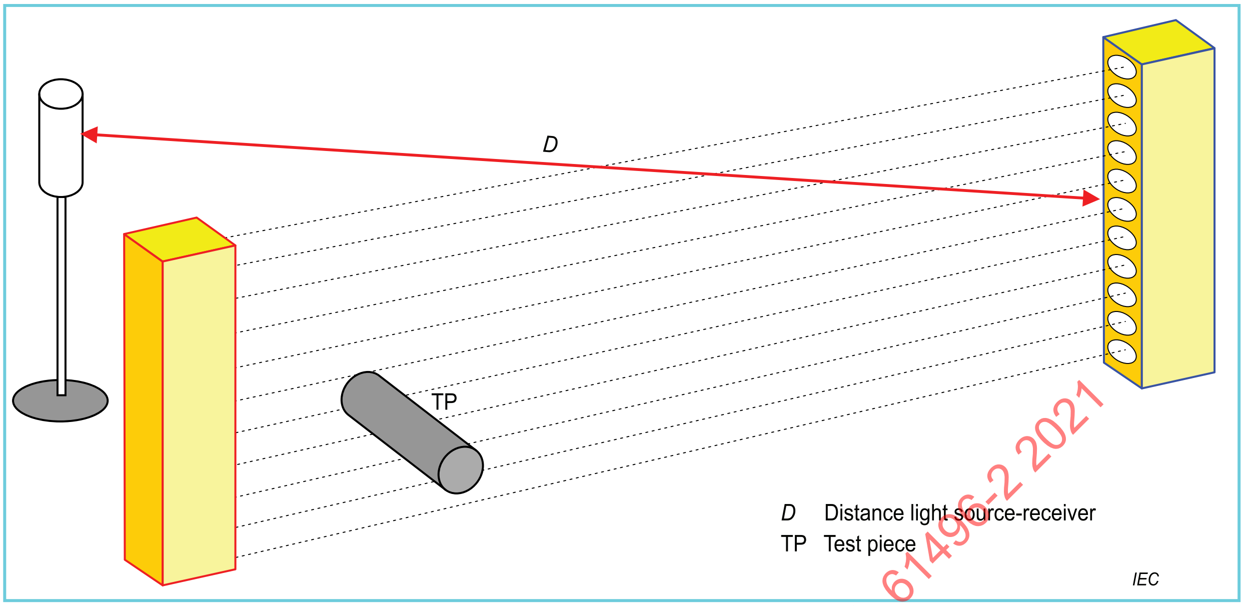
su2413

Test parameters

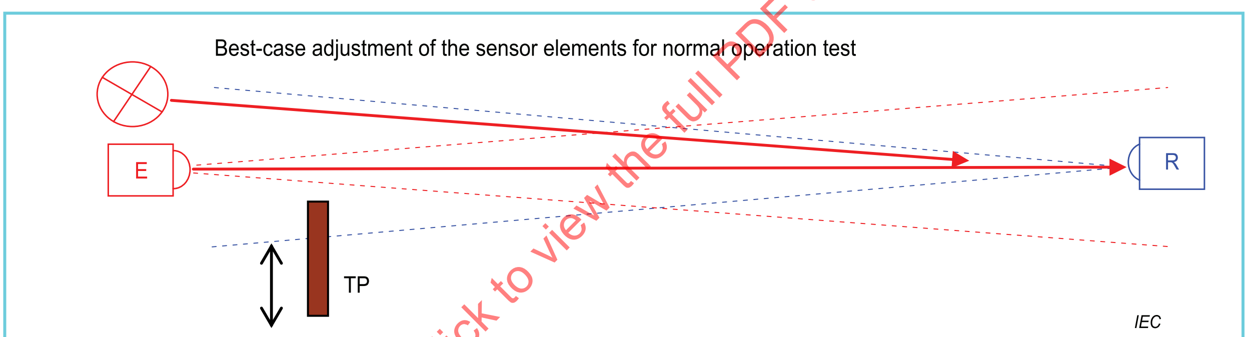
Distance (*D*)	**Lux**	
12 cm [a]	3 000	Distance for fail to danger test.
21 cm [a]	1 500	Distance for normal operation test.
[a] The exact distances depend on the lamp type.		

Figure 23

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



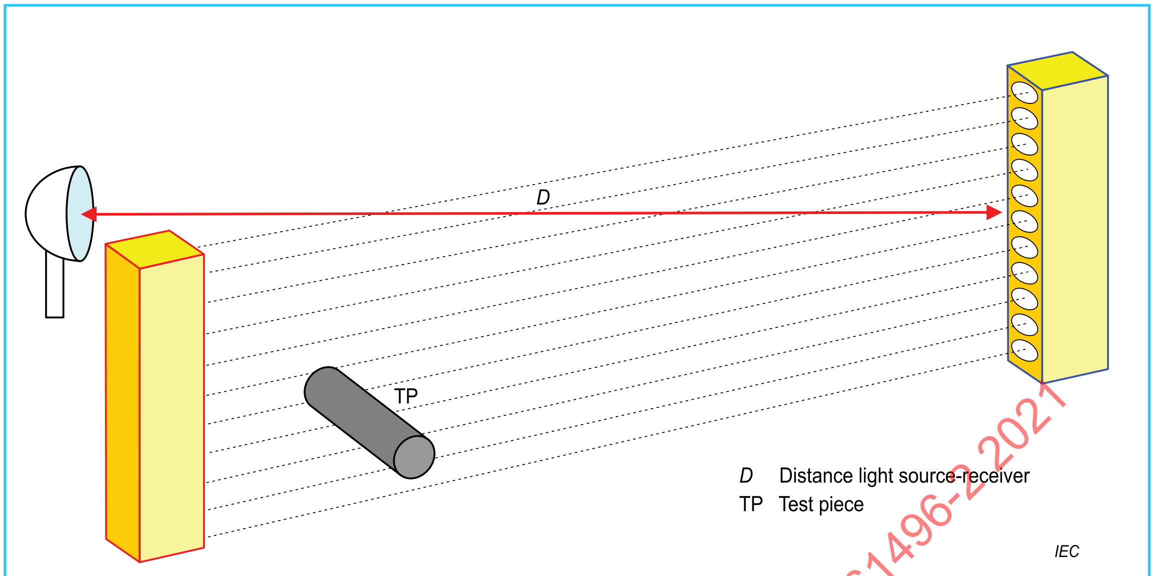
su2414

Test parameters

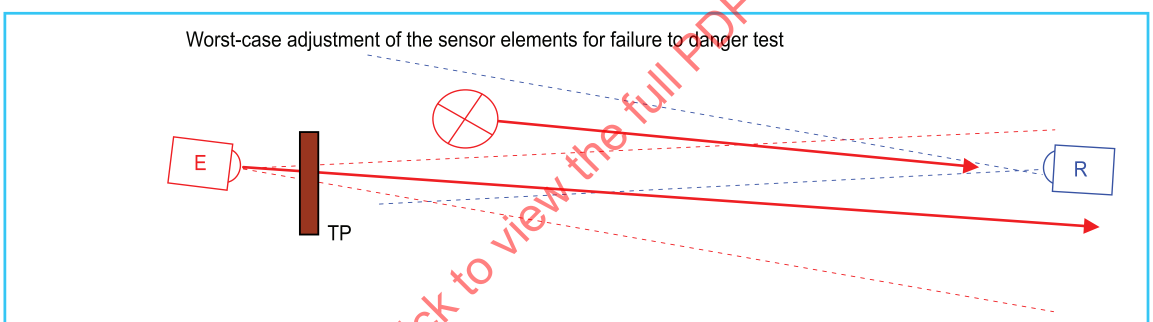
Distance (*D*)	
3,0 m	Distance for normal operation tests

Figure 24

Light interference test – Test set-up with flashing beacon light source



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



su2415 IEC

Test parameters

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

Figure 25

Light interference test – Test set-up with stroboscopic light source

5.4.6.2 Light sources

The light sources shall be as follows.

a) Incandescent light source: a linear tungsten halogen (quartz) lamp with the following characteristics:

– colour temperature:	3 000 K to 3 200 K;
– input power:	500 W to 1 kW rated power;
– rated voltage:	any value within the range 100 V to 250 V;
– supply voltage:	rated voltage ± 5 %, sinusoidal a.c. at 48 Hz to 62 Hz;
– length:	150 mm to 250 mm nominal.

NOTE A lamp with a diffuse finished front window is also acceptable. This source produces a beam of near uniform intensity with known spectral distribution and having a predictable modulation at twice the supply frequency. It is used to simulate both sunlight and workplace incandescent lighting.

b) Fluorescent light source: a linear fluorescent tube with the following characteristics:

– size:	T8 × 600 mm (26 mm nominal diameter);
– rated power:	18 W to 20 W;
– colour temperature:	3 000 K to 6 000 K, used in combination with an electronic ballast having the following characteristics:
– operating frequency:	25 kHz to 50 kHz;

– power rating corresponding to the tube and operated at its rated supply voltage ± 5 %, without a reflector or diffuser.

c) Flashing beacon light source: a light source employing a xenon flash tube (without enclosure, reflector or filter) having the following characteristics:

– flash duration:	between 40 μs and 1 200 μs (measured to the half-intensity point);
– flash frequency:	between 0,5 Hz and 2 Hz;
– input energy per flash:	3 J to 5 J.

d) Stroboscopic light source: a stroboscope employing a xenon flash tube (without enclosure, reflector or filter) having the following characteristics:

– flash duration:	from 5 μs to 30 μs (measured to the half-intensity point);
– flash frequency:	5 Hz to 200 Hz (adjustable range);
– input energy per flash:	0,05 J (at 200 Hz) to 0,5 J(at 5 Hz).

The position of the flash tube shall be fixed during the test.

5.4.6.3 Test sequences

NOTE The A, B, and C tests below are defined in 5.2.3 of IEC 61496-1:2012.