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## Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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|                  |                        |
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| 1  | 2                                          | (3)                          | 4               | 5                                                                                                                                  | (6)                                                                      | 7                                                  |
|----|--------------------------------------------|------------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------|
| MB | Clause No./ Subclause No./Annex (e.g. 3.1) | Paragraph/ Figure/Table/Note | Type of comment | Comment (justification for change) by the MB                                                                                       | Proposed change by the MB                                                | Secretariat observations on each comment submitted |
|    | 3.1                                        | Definition 1                 | ed              | Definition is ambiguous and needs clarifying.                                                                                      | Amend to read '...so that the mains connector to which no connection...' |                                                    |
|    | 6.4                                        | Paragraph 2                  | te              | The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK. | Delete reference to UV photometer.                                       |                                                    |

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|
| IEC TC 113 : NANOTECHNOLOGY FOR ELECTROTECHNICAL PRODUCTS AND SYSTEMS                                                                                                                                                                                                                                                                                                                       |                                                                    |
| SECRETARIAT:<br>Germany                                                                                                                                                                                                                                                                                                                                                                     | SECRETARY:<br>Mr Norbert Fabricius                                 |
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| ASPECTS CONCERNED:                                                                                                                                                                                                                                                                                                                                                                          |                                                                    |
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|                                                                                                                                                                                                                  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TITLE:<br><b>Nanomanufacturing - Key control characteristics - Part 3-1: Nanophotonic products - Photoluminescence quantum yield of luminescent nanomaterials: absorption and photoluminescence spectroscopy</b> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

PROPOSED STABILITY DATE: 2030

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –****Part 3-1: Nanophotonic products – Photoluminescence quantum yield of luminescent nanomaterials: absorption and photoluminescence spectroscopy**

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IEC 62607-3-1 has been prepared by IEC technical committee 113: Nanotechnology for electrotechnical products and systems. It is an International Standard.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

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

- a) ...;
- b)

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

| Draft       | Report on voting |
|-------------|------------------|
| 113/xxxx/XX | 113/xxxx/XX      |

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement available at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/publications](http://www.iec.ch/publications).

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under [webstore.iec.ch](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.

## INTRODUCTION

### The luminous efficiency of solid state luminescence

SSL devices is a critical measurement for their overall efficiency and standard methods to perform these measurements have been established for the final products. The same need for performance assessment exists for the luminescent materials on which these light-emitting diode (LED) manufacturers rely; however, no such standard for the assessment of luminescent materials currently exists. This standard provides SSL manufacturers a universal means for comparing luminescent nanomaterials from different suppliers, and potentially for luminescent materials for LEDs in general.

A critical measurement parameter for luminescent materials used in the life and material sciences and in solid-state lighting is the quantum efficiency or photoluminescence quantum yield. The latter term is used in the following due to its frequent use also for the characterization of the performance of molecular luminophores or emitters as the test method described here can be generally used for the determination of this key performance parameter of all molecular and nanoparticle emitters in a transparent matrix such as a solution.

The photoluminescence quantum yield is defined in this standard as the number of photons emitted into free space by an emitter such as a luminescent nanoparticle divided by the number of photons absorbed by the nanoparticle at the chosen excitation wavelength. Suppliers of all kinds of luminophores including QDs and luminescent nanomaterials typically measure only quantum efficiencies or quantum yields of transparent luminophore solutions or dispersions only relatively to due to the ease of such measurements. These measurements are commonly done at low luminophore concentrations to minimize effects such as nanoparticle agglomeration and signal distortions by luminophore reabsorption.

However, in end-use applications such as solid-state lighting, the actual concentration of the luminescent nanomaterials may be significantly different. For example, concentrated luminescent nanoparticle formulations (in either the solid or liquid state) may be required to achieve a desired luminous flux and correlated colour temperature in an SSL device.

This standard codifies this test method for the first time and establishes a test method for the relative determination of the photoluminescence quantum yield of transparent liquid luminophore samples such as solutions of molecular emitters and colloidal suspensions of small luminescent nanoparticles. The standard may be also applied to luminophores in transparent solid matrices such as luminescent nanoparticles embedded in polymer matrices with proper consideration of specific characteristics of such solid luminescent materials like possible polarization effects requiring the use of polarizers for the accurate determination of photoluminescence quantum yields by this relative test method.

In addition, the absorbance of these solid luminophore systems at the respective excitation wavelength must be high enough to enable the accurate determination of the number of absorbed photons. This can present a challenge, e.g., for thin films of luminescent nanomaterials coated on glass optics or applied directly to light emitted diodes.

Overall, this test method is intended to enable suppliers and purchasers to compare the performance of one material to another, both in their raw (solution) phase as well as their technologically relevant (solid) phase of matter.

This part of IEC 62607 covers the relative measurements of the key control characteristic photoluminescence quantum yield (used in the following instead of quantum efficiency), defined as the number of emitted photons per number of absorbed photons of different types of molecular and nanocrystalline luminophores (emitters) in transparent matrices like solutions/dispersions using relative optical methods. This implies experimental methods such as absorption and photoluminescence spectroscopy and, mandatory, a fluorescence quantum yield standard of known quantum yield value traceable to a national standard.

The document describes the procedures to be followed for the relative measurement of photoluminescence quantum yields such as the usage of identical instrument settings for sample and quantum yield standard including their choice based upon screening measurements with sample and standard and requirements on the accurate calibration of the spectrophotometer and particularly the spectrofluorometer employed as well as precautions to be taken when performing reproducible measurements of the quantum yield of molecular luminophores and luminescent nanomaterials in transparent matrices.

In addition, recommendations on the calibration of the optical instruments utilized for this test method and suitable reference materials (termed also spectral fluorescence standards) are given as well as recommendations on well-characterized reference materials (termed also fluorescence quantum yield standards) for relative quantum yield measurements are given that are commercially available.

This standard does not cover the determination of the absolute quantum yield in transparent materials, neither is it applicable for the determination of quantum yield in scattering media.

# NANOMANUFACTURING – KEY CONTROL CHARACTERISTICS –

## Part 3-1: Nanophotonic products - Photoluminescence quantum yield of luminescent nanomaterials: absorption and photoluminescence spectroscopy

### 1 Scope

This part of IEC 62607 establishes a standardized method to determine the key control characteristics

- photoluminescence quantum yield for luminescent nanomaterials in transparent matrices by
- absorption and photoluminescence spectroscopy.

The photoluminescence quantum yield is derived by using a calibrated spectrophotometer in combination with a spectrofluorometer.

- Photoluminescence quantum yield is defined as the number of emitted photons per number of absorbed photons of different types of molecular and nanocrystalline luminophores (emitters) in transparent matrices like solutions/dispersions using relative optical methods.
- The method is applicable for luminescent nanomaterials which includes nano-objects such as spherical and rod-shaped quantum dots, nanophosphors, nanofibers, nanocrystals, nano platelets and structures containing these materials that are small enough not to introduce light scattering or for which the refractive index of dispersed nanomaterial and matrix closely match, thereby preventing or at least strongly reducing light scattering also for larger nano-object sizes.
- In principle, this method is also suitable for the determination of the photoluminescence quantum yield of molecular luminophores and luminescent nanoparticles in transparent solid matrices, meeting the previously stated size restrictions. For these systems, the accurate relative determination of the photoluminescence quantum yield can require the use of polarizers as luminophores can be susceptible to polarization effects in solid matrices.
- This test method is not suited for the determination of the photoluminescence quantum yield of scattering dispersions of luminescent nanomaterials such as semiconductor quantum rods with a large aspect ratio. Measurement of the photoluminescence quantum yield of scattering luminophore systems such as dispersions of larger nano-objects or powders of luminescent nanoparticles and differently sized phosphors requires the usage of integrating sphere spectroscopy.
- Fields of application include the determination of the fluorescence quantum yields of transparent dispersions of semiconductor quantum dots or other nanoobjects.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CIE 017/E:2011, *International Lighting Vocabulary*.

### 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>
- CIE Online E-ILV: available at <https://cie.co.at/e-ilv>

### 3.1 General terms

#### 3.1.1

##### key control characteristic

##### KCC

product characteristic which can affect safety or compliance with regulations, fit, function, performance, quality, reliability, or subsequent processing of the final product

Note 1 to entry: The measurement of a key control characteristic is described in a standardized measurement procedure with known accuracy and precision.

Note 2 to entry: It is possible to define more than one measurement method for a key control characteristic if the correlation of the results is well-defined and known.

[Source: IEC/TS 62565-1, 3.1]

[SOURCE ISO/IEC Guide 99: 2007, 2.3 modified - Note 1 changed and note 2 to 4 removed]

#### 3.1.2

##### measurement

process of experimentally obtaining one or more values that can reasonably be attributed to a quantity

Note 1 to entry: If the quantity is a key control characteristic, the measurement is an essential part of the quality management system.

[SOURCE ISO/IEC Guide 99: 2007, 2.1 modified - Note 1 changed and note 2 to 3 removed]

#### 3.1.3

##### measurement accuracy

closeness of agreement between a measured quantity value and a true quantity value of a measurand

Note 1 to entry: The concept 'measurement accuracy' is not a quantity and is not given a numerical quantity value. A measurement is said to be more accurate when it offers a smaller measurement error.

[SOURCE: ISO/IEC Guide 99: 2007, 2.13, modified – Notes 2 and 3 to entry removed]

#### 3.1.4

##### measurement method

process of experimentally obtaining one or more values that can reasonably be attributed to a quantity

Note 1 to entry: If the quantity is a key control characteristic, the measurement is an essential part of the quality management system.

[SOURCE ISO/IEC Guide 99: 2007, 2.5 modified - Note 1 changed]

#### 3.1.5

##### measurement principle

phenomenon serving as a basis of a measurement