IEC TS 62876-4-1

Edition 1.0 2025-02

TECHNICAL SPECIFICATION

Nanomanufacturing – Reliability assessment –
Part 4-1: Nanophotonic products – Optical stability test of quantum dot enabled light conversion films: Temperature, humidity and light exposure

IEC TS 62876-4-1:2025-02(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC TS 62876-4-1

Edition 1.0 2025-02

TECHNICAL SPECIFICATION

Nanomanufacturing – Reliability assessment –
Part 4-1: Nanophotonic products – Optical stability test of quantum dot enabled light conversion films: Temperature, humidity and light exposure

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 07.120

ISBN 978-2-8327-0165-2

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

NANOMANUFACTURING –
RELIABILITY ASSESSMENT –

Part 4-1: Nanophotonic products – Optical stability test of quantum dot enabled light conversion films: Temperature, humidity and light exposure

FOREWORD

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.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
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) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TS 62876-4-1 has been prepared by IEC technical committee 113: Nanotechnology for electrotechnical products and systems. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
113/866/DTS	113/886/RVDTS

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 Technical Specification 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. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62876 series, published under the general title *Nanomanufacturing – Reliability assessment*, 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 webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

Quantum dots (QDs), as luminescent nanomaterials, exhibit broad absorption spectra and narrow emission spectra. Using the same excitation source to excite QDs of different particle size, it is possible to emit spectra with different peak wavelengths. Based on the above characteristics, QDs are used in display products, which can greatly improve the display colour gamut.

Nowadays, as a typical product of quantum dot technology application, quantum dot enabled light conversion film (Q-LCF) is widely used in the display field. Under normal working conditions, Q-LCF in a backlight module will be continuously irradiated by high-energy excitation light (such as blue light) to emit converted light. Under the combined action of water vapour and oxygen from the environment, the optical properties of the QDs in Q-LCF will slowly deteriorate. In order to ensure the quality and stability of Q-LCF products, it is essential to scientifically design a reliability test standard to evaluate product quality. Reliability assessment can be used, for example, to authorize advancement to the next step in product development, or to authorize progress payments, or to proceed with delivery and acceptance of products.

This document provides reliability test and evaluation criteria for Q-LCF. In this document, Q-LCFs are used as the test objects. Accelerated aging tests containing stress factors of temperature, humidity, light are imposed on the test objects to obtain performance shift data and change trend.

NANOMANUFACTURING –
RELIABILITY ASSESSMENT –

Part 4-1: Nanophotonic products – Optical stability test of quantum dot enabled light conversion films: Temperature, humidity and light exposure

1 Scope

This part of IEC 62876, which is a Technical Specification, establishes a general reliability testing programme to verify the reliability of the performance of quantum dots nanomaterials, and quantum dot enabled light conversion films (Q-LCFs).

The Q-LCF is used as subassemblies for the fabrication of nano-enabled photoelectrical display devices, mainly liquid crystal display (LCD) currently, with other components.

This testing programme defines standardized aging conditions, methodologies and data assessment for Q-LCF product.

The results of these tests define a stability under standardized aging conditions for quantitative evaluation of the reliability of the Q-LCF.

The procedures specified in this document were designed for Q-LCF but can be extended to serve as a guideline for other kinds of light conversion films or related subassemblies as well.

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.

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-78:2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC TS 62565-4-4:2025, *Nanomanufacturing – Product specifications – Part 4-4: Nanophotonic products – Blank detail specifications: Quantum dot enabled light conversion films*

IEC 62595-2-1:2016, *Display lighting unit – Part 2-1: Electro-optical measuring methods of LED backlight unit*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Terms, definitions and abbreviated terms

3.1 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

3.1.1
quantum dot
QD
crystalline nanoparticle that exhibits size-dependent properties due to quantum confinement effects on the electronic states

[SOURCE: ISO/TS 27687:2008, 4.7]

3.1.2
quantum dot enabled light conversion film
Q-LCF
optical film based on quantum dots that converts high energy light at a particular wavelength into low energy light at another wavelength

3.1.3
invalid edge
edge of Q-LCF with a significant decline in optical performance, failing to function

3.2 Abbreviated terms

BLU	backlight unit
FWHM	full width at half maxima
LCE	light conversion efficiency
QD	quantum dot
Q-LCF	quantum dot enabled light conversion film
λ_{p}	peak wavelength
L_{v}	luminance

4 General requirements

4.1 Q-LCF

The Q-LCF is typically an individual subassembly which will be used by an assembler to fabricate display panel product to be sold to the end user. The purpose of this document is to assess the reliability of the Q-LCF. The test samples shall be selected randomly from a group of films cut from a big Q-LCF in a clean environment such that test samples are representative for the ensemble film. The physical size of the samples shall be no less than 18 cm × 18 cm. The samples shall not show visible curling, cracking, damage, wrinkles, and no scratches or dirt on the surface.

4.2 Tests

4.2.1 General

All the tests in this document fall into the class of accelerated aging tests. These tests are designed to expose the test samples of Q-LCFs to specific well-defined and reproducible stress factors that accelerate critical failure mechanisms. Being able to quantify the response of the Q-LCFs under different stages of product development and application, such as for the early development stage, allows for efficient development cycles to improve the stability of the Q-LCFs. For the industrial application, the effective service life of electronic devices shall be no less than 30 000 h. This is too long and time consuming to carry out the text practically, so it is essential to develop accelerated aging tests to evaluate the stability of a novel technology or product, which is essential and helpful for its industrial acceptance.

The photoelectrical devices fabricated with Q-LCF will face different stresses from the environment during their service period. To evaluate the reliability, a suitable selection of relevant stress factors is important in order to reflect realistic conditions. An overview of typical stress factors that Q-LCFs are exposed to is shown in Figure 1.

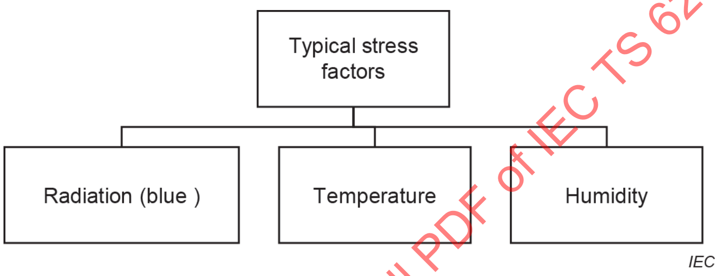

Figure 1 – Overview of stresses that Q-LCF are exposed to in service environments

General reliability testing is performed by repeated measurements of the performance of test samples before and after exposure to a stress or a combination of stresses for a period of time. A typical procedure is shown in Figure 2. After initial characterization, the sample is submitted to the stress environment for a regular time interval. After the exposure interval the sample is conditioned for measurement, characterized and then re-exposed. This document provides certain combinations of suggested stresses so that appropriate stress conditions can be selected. In addition, it defines the procedures and equipment that are required in order to perform reliable and reproducible reliability measurements.

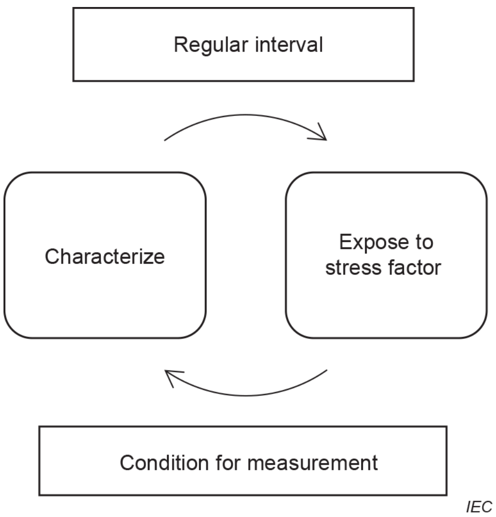

Figure 2 – General reliability test procedure

The stress tests that are recommended are combinations of a limited number of well-defined stresses. Table 1 gives an overview of recommended values for the typical stresses which are encountered in many testing protocols.

Table 1 – Summary of stresses utilized in this document

Stress	Typical values					
Temperature	−40 °C	40 °C	65 °C	70 °C	85 °C	Thermal cycling −40 °C to 85 °C
Humidity	≤ 10 % RH	85 % RH	95 % RH	≤ 10 % RH	≤ 10 % RH	≤ 10 % RH
Light (average irradiance of the light receiving surface of the sample)	dark	40 W/m^2 to 1 000 W/m^2	dark	200 W/m^2 to 5 000 W/m^2	dark	dark

The typical test conditions given in Table 1 are recommended, different combinations of temperature, humidity and light exposure may be selected according to actual needs of different industrial applications or different regions. The variation limits of optical properties of Q-LCFs should be no more than 15 %, or may be determined in consultation by supply and requisitioning parties.

4.2.2 Quantity of specimens

All reliability testing shall be performed on statistically relevant sample groups. While the sample groups should generally be chosen as large as possible, the group size shall be at least three samples for each of the tests performed in the case of small samples.

The tests are not intended to be performed in sequence. Test samples can only be subjected to one particular test, so that several of the stress tests can be performed in parallel to expedite the testing. To fully assess reliability, groups of test samples should be subjected to each of the tests. Acceptable reliability levels should be determined by the manufacturer or agreed between manufacturer and user.

4.2.3 Equipment specifications

In order for the testing to be acceptable, all tests shall be performed in qualified and calibrated equipment that allows for the monitoring of the environmental conditions.

Detailed specifications are listed in relevant subclauses.

4.2.4 Test methods

All the test methods recommended in this document fall into the class of "accelerated aging tests". These tests expose the test samples to a selected but tightly controlled set of stress parameters in specialized testing equipment, in order to perform quantitative stability testing. An overview of all the recommended tests with the preferred main control parameters is shown in Table 2. The test time should be determined by the manufacturer or agreed between manufacturer and user.

Table 2 – Summary overview of relevant test methods and main control parameters

Parameter	Test ID and description				
	T1 High temperature and blue light exposure	**T2** Damp heat and blue light exposure	**T3** Damp heat	**T4** Low temperature	**T5** Thermal cycling
Temperature	70 °C	40 °C	65 °C	−40 °C	Per cycle: 85 °C for 30 min, lowering temperature to −40 °C for 5 min, and −40 °C for 30 min, increasing temperature to 85 °C for 5 min
Humidity	≤ 10 % RH	85 % RH	95 % RH	≤ 10 % RH	≤ 10 % RH
Light (average irradiance of the light receiving surface of the sample)	2 000 W/m^2	80 W/m^2	dark	dark	dark

4.2.5 Caution

Some types of quantum dots contain cadmium. Cadmium exerts toxic effects on the kidneys as well as the skeletal and respiratory systems. It is classified as a human carcinogen. Caution shall be taken during the test:

Persons conducting the test shall wear the following personal protective equipment:

a) chemical splash goggles for eye protection;

b) disposable nitrile gloves for hand protection;

The gloves shall be immediately replaced with new gloves when contamination occurs.

c) laboratory coat, closed-toed, impervious footwear for skin and body protection.

All waste and contaminated disposables shall be disposed of as hazardous waste.

NOTE 1 Local laws and regulations can exist with regard to disposal of hazardous waste.

This caution also applies in measurement.

During test, laboratory coat, gloves and protective goggles shall be worn to prevent possible damage from high temperatures and blue light in the experimental chamber.

NOTE 2 National regulatory conditions can also exist.

4.3 Measurements

4.3.1 General

In order to obtain representative and comparable data, all measurements shall be performed with qualified and calibrated date acquisition equipment.

The measurement of Q-LCF is based on optical properties, which are luminance, chromaticity coordinates, λ_p, FWHM, width of invalid edge, LCE.

A spectral radiance measurement instrument is used for measurement of luminance, chromaticity coordinates, λ_p, FWHM, width of invalid edge and LCE.

Film ruler or optical microscope is used for measurement of width of invalid edge.

4.3.2 General testing conditions

The test conditions shall meet the following requirements.

a) Ambient temperature: 21 °C to 25 °C.

b) Relative environmental humidity: 40 % to 60 %.

c) Atmospheric pressure: 86 kPa to 106 kPa.

4.3.3 Measurement instrument specifications

a) Spectral radiance measurement instrument

   A spectral radiance measurement instrument such as luminance meter can measure the average value of spectral radiance and luminance within a fixed angle of view.

   The instrument shall meet the following requirements:

   – the wavelength error shall be less than 0,3 nm;
   – the measurement field of view shall not be less than 0,2°;
   – the spectral bandwidth shall not be greater than 5 nm, and shall be an integer multiple of the sampling interval;
   – chromaticity measurement precision shall be ±0,002;
   – the linearity error shall be less than 1,0 %;
   – the stability error shall be less than 1,5 %;
   – the brightness inaccuracy shall be less than 5 %;
   – the instrument shall have a brightness calculation function.

b) Film ruler

   The film ruler shall be a ruler with a measuring range of at least 100 mm and the smallest scale 1 mm or less.

c) Optical microscope

   The optical microscope shall have its own light source, the measurement precision shall not be less than 0,1 mm, and it shall be able to measure the size of the test sample.

4.3.4 Conditioning

All the samples taken out from the chamber shall first stabilize under measurement environment for a while. Measurements of optical properties (chromaticity coordinates, luminance and LCE) of Q-LCF shall be conducted in simulated direct-lit BLU, which reflects the real application effects produced by Q-LCF. Simulated direct-lit BLU as measurement platform comprises LEDs, transparent sample placement table, Q-LCF sample, and prism film in sequence. The distance between LEDs and sample placement table shall be suitable for Q-LCF receiving enough excitation light. The working current of LEDs is adjusted to a suitable intensity of excitation light. The specifications of the prism film should be agreed with the user.

4.3.5 Data collection

Data acquisition during reliability testing shall fulfil the following minimum measurement frequency.

For the Q-LCF samples, measurement is conducted at 0 h, 24 h, 72 h, 168 h, 336 h, 504 h, 1 000 h. However, measurement of invalid edge is usually conducted at 1 000 h or longer time as invalid edge occurs much slower.

4.3.6 Measurement methods of Q-LCFs in simulated direct-lit BLU

The measurement methods of luminance and chromaticity coordinates of the simulated direct-lit BLU shall be as specified in IEC 62595-2-1:2016. λ_p and FWHM can be obtained or calculated from the measurement of luminance and chromaticity coordinates at the same time by luminance meter or other similar instruments. LCE shall be measured in accordance with IEC TS 62565-4-4:2025. The measurement position of each specific Q-LCF sample shall remain in the same zone for data comparison: the centre zone of the sample is recommended for measurement.

4.3.7 Measurement methods of width of invalid edge

a) Measurement method by optical microscope

   The optical microscope with software is magnified to the right power and is used to take photos and measure the width of invalid edges of four sides of the rectangular test sample of Q-LCFs.

   1) Install lens on the microscope, the total magnification is 40× to100×.
   2) Put one sample on the mechanical stage and fasten it; adjust the microscope and the sample; find invalid edge with colour different from that of the valid zone by eye, so that invalid edge of Q-LCF is in the centre of the field of view.
   3) Look for the maximum width through the eyepiece, use the software of the microscope to take photos and measure the maximum width of invalid edge. Try at least three times to confirm the maximum width.
   4) Repeat three times for the other edges.
   5) Record the biggest value from the whole data and set as the width of invalid edge.

b) Measurement method by film ruler

   A UV light source (365 nm) is set up to excite the edges of the Q-LCF. See Figure 3 for reference.

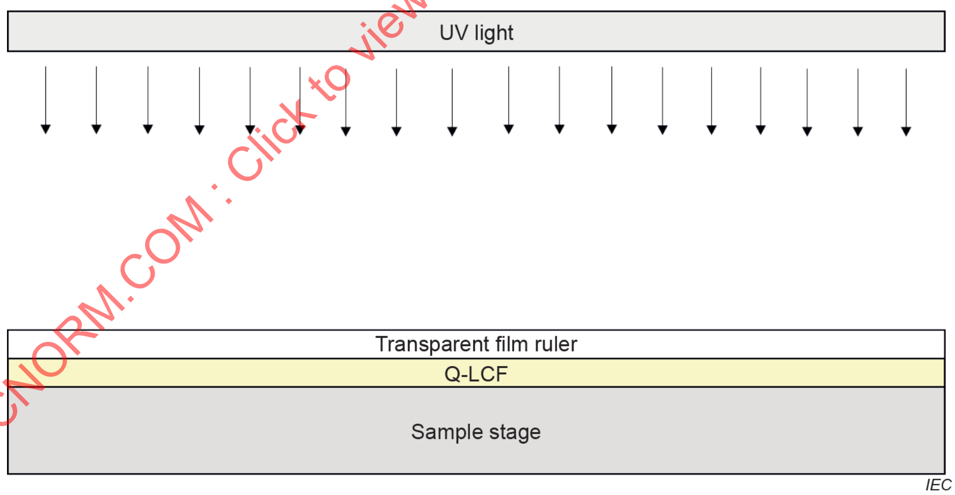

Figure 3 – Example of measurement setup for invalid edge

   1) Put the transparent film ruler on the Q-LCF.
   2) Turn on the UV light source and make the whole Q-LCF be irradiated.
   3) Start with one edge, look for three locations with possible maximum width by looking for the colour difference between invalid edge and valid zone by eye.
   4) Use the film ruler to measure three potential maximum widths; record the maximum one as the width of this invalid edge.
   5) Repeat three times for the other edges at different area.
   6) Record the biggest value from all the data as the width of invalid edge.

4.3.8 Pass or fail criteria

The reliability level of QLCFs can be evaluated using the change degree of four KCC parameters during accelerated aging tests:

a) the shift of chromaticity coordinate;
b) the degree of light attenuation;
c) the variation of LCE;
d) the width of invalid edge.

Different types of display devices and different application scenarios require different reliability level of QLCF, so that different test conditions of accelerated aging tests will be adopted. Pass or fail criteria shall be agreed between manufacturer and user based on the practical application requirements. The criteria as detailed in Table 3 come from the requirements of end users. If the change degree is less than the limits given in Table 3, the display performance of device assembled with Q-LCF cannot be affected noticeably. Irrelevant properties and characteristics for the application can be classified as "not applicable" or "not specified". A case study is given in Annex A.

Table 3 – Pass or fail criteria

No.	Test object	Measurement parameters				
1	Q-LCFs	ΔLCE	ΔL_v	$\lvert\Delta x\rvert$	$\lvert\Delta y\rvert$	Δl
		≤ 15 %	≤ 15 %	≤ 0,015	≤ 0,015	≤ 2 mm
Δx and Δy refer to chromaticity coordinate shift. Δl refers to maximum width of invalid edge Qualified is recorded as OK. Failure is recorded as NG. The criteria are the change limits recommended; however, different accelerated aging test conditions shall be adopted in accordance with different requirements in practical industrial application.						

5 Test methods

5.1 T1 – High temperature and blue light exposure

5.1.1 Purpose

To determine the ability of the samples to withstand thermal and irradiation stress.

5.1.2 Temperature and light

Typical temperatures used in this test are 40 °C, 65 °C, 70 °C. Average irradiances (W/m^2) of the light receiving surface of the sample used in this test are 100 W/m^2 to 5 000 W/m^2. Testing at 70 °C and 2 000 W/m^2 is recommended.

5.1.3 Data logging

For the Q-LCF samples, measurement is conducted at 0 h, 24 h, 72 h, 168 h, 336 h, 504 h, 1 000 h. Measurement of invalid edge is conducted at 1 000 h or longer time as invalid edge occurs slower. The total exposure time in stress test shall be recorded in hours.

5.1.4 Output

Luminance, chromaticity coordinates, λ_p, FWHM and LCE of Q-LCF should be extracted from the fluorescence spectrum and plotted over time. The final change value of invalid edge shall be recorded; plotting change data over aging time is not required.

5.1.5 Required equipment

a) Constant temperature test chamber

The chamber shall keep constant temperature. The temperature range should be at least 100 °C, and the temperature precision should not be less than 1 °C.

b) Lighting assembly

The lighting assembly located in the test chamber provides irradiation for Q-LCF, which shall meet the following requirements:

1) The lighting assembly shall include a light source, a sample stage, the test sample and a prism film, and each component shall be perpendicular to the propagation direction of the light source, as shown in Figure 4.
2) The specifications of the prism film shall be agreed with the user.
3) The λ_p and FWHM of the light source shall be consistent with the setting of light source of display product applied with Q-LCF. Typically, the peak wavelength of the light source is 447,5 nm ± 2,5 nm, and the FWHM is 18 nm ± 3 nm.
4) The light intensity for the accelerated aging test shall satisfy the average irradiance of the light receiving surface of the sample on the sample stage.
5) The ratio of the minimum irradiance of the sample received to the average irradiance of the sample received on the sample stage shall not be less than 90 %.

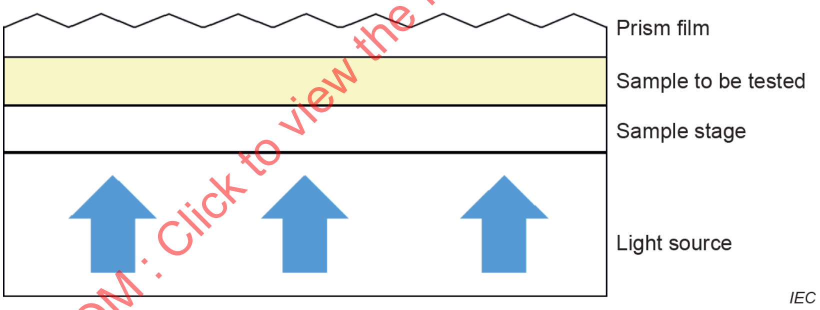

Figure 4 – Lighting assembly

5.2 T2 – Damp heat and blue light exposure

5.2.1 Purpose

To determine the ability of the samples to withstand the effects of penetration of humidity at elevated temperature and irradiation.

5.2.2 Temperature, humidity and light

Typical temperatures used in this test are 40 °C, 65 °C, 85 °C. Typical humidities used in this test are 85 % RH, 90 % RH, 95 % RH. Average irradiances (W/m^2) of the light receiving surface of the sample used in this test are 40 W/m^2 to 500 W/m^2. Testing at 40 °C, 85 % RH and 80 W/m^2 is recommended.

5.2.3 Data logging

Refer to 5.1.3.

5.2.4 Output

Refer to 5.1.4.

5.2.5 Required equipment

a) Constant temperature and humidity test chamber

   The chamber can keep constant temperature and constant humidity. The temperature range should be less than −40 °C, and the temperature precision shall not be less than 1 °C. The humidity range should be at least 98 % RH, and the humidity precision shall not be less than 5 % RH.

b) Lighting assembly shall be as specified in 5.1.5 b).

5.3 T3 – Damp heat

5.3.1 Purpose

To determine the ability of the samples to withstand the effects of long-term penetration of humidity at elevated temperature.

5.3.2 Procedure

The test shall be carried out in accordance with IEC 60068-2-78:2012, 4.4.

5.3.3 Temperature and humidity

There are three typical combinations: (40 °C, 95 % RH), (65 °C, 95 % RH), and (85 °C, 85 % RH). Choose conditions according to the stability of the sample to allow for reasonable experimental length and data density.

5.3.4 Data logging

Refer to 5.1.3.

5.3.5 Output

Refer to 5.1.4.

5.3.6 Required equipment

Refer to 5.2.5 a).

5.4 T4 – Low temperature

5.4.1 Purpose

To determine the ability of the samples to withstand the effects of low temperature.

5.4.2 Temperature

Typical temperatures used in this test are −40 °C, −20 °C. Testing at −40 °C is recommended. Humidity is not controlled; however, actual humidity shall be recorded and reported. Usually, the humidity will be less than or equal to 10 % RH in the chamber.

5.4.3 Data logging

Refer to 5.1.3.

5.4.4 Output

Refer to 5.1.4.

5.4.5 Required equipment

The thermal cycling test chamber shall meet the requirements of IEC 60068-2-1:2007. The temperature range should be less than or equal to −40 °C, and the temperature precision shall not be less than 1 °C.

5.5 T5 – Thermal cycling

5.5.1 Purpose

To determine the ability of the sample to withstand thermal mismatch, fatigue and other stresses caused by repeated changes of temperature.

5.5.2 Temperature

The samples shall be cycled between temperatures of −40 °C ± 2 °C, 25 °C ± 2 °C and 85 °C ± 2 °C. In each cycle, raise the temperature to 85 °C and maintain for 30 min, lower the temperature to 25 °C and maintain for 5 min, and lower the temperature to −40 °C and maintain for 30 min. The total number of cycle recommended here is 100 cycles or more. Humidity is not controlled; however, actual humidity shall be recorded and reported.

5.5.3 Data logging

Measurement of sample from T5 is conducted after 100 cycles.

5.5.4 Output

Refer to 5.1.4.

5.5.5 Required equipment

The thermal cycling test chamber shall meet the requirements of IEC 60068-2-27:2008, the cycling temperature range should be at least −40 °C to 100 °C, and the temperature precision shall not be less than 1 °C.

6 Report

Performance characteristics and details of any failures and re-tests shall be prepared by testing laboratories in accordance with ISO/IEC 17025. Each test report shall include at least the following information:

a) a title;

b) name and address of the test laboratory and location where the tests were carried out;

c) unique identification of the report on each page;

d) name and address of the client, where appropriate;

e) description and identification of the sample tested;

f) characterization and condition of the test item;

g) date of receipt of test item and date(s) of test, where appropriate;

h) identification of test method used;

i) reference to sampling procedure, where relevant;

j) number of devices in the test and number of devices that failed during testing;

k) any deviations from, additions to or exclusions from the test method, and any other information relevant to a specific test, such as environmental conditions;

l) measurements, examinations and derived results supported by tables, graphs, sketches and photographs as appropriate;

m) a statement of the estimated uncertainty of the test results (where relevant);

n) a signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the report, and the date of issue;

o) where relevant, a statement to the effect that the results relate only to the items tested;

p) a statement that the certificate or report shall not be reproduced except in full, without the written approval of the laboratory.

A copy of this report shall be kept by the laboratory and manufacturer for reference purposes.

Annex A
(informative)

Case study of Q-LCF reliability assessment

A.1 Test sample

The test samples were cut from a sheet of 139,7-cm (55-in) Q-LCF with 330-μm thickness, and which showed no rolled edges, cracks, breaks, wrinkles, surface scratches, or dirt on the surface. The Q-LCF was cut into 20 cm × 20 cm square pieces as test specimens, so as to cover the sample stage of the lighting assembly. Three test specimens were taken randomly as a group of parallel test specimens, named NJ-s1-1, NJ-s1-2 and NJ-s1-3. A total of five groups were prepared for five types of accelerated aging test of reliability assessment in Table 2.

A.2 Test method

One type of accelerated aging test of reliability assessment was carried out for each group of test specimens. The test methods in Clause 5 and test conditions in Table 2 were adopted.

A.3 Test results

The test results of T1, T2 and T3 groups at 0 h, 168 h, 336 h, 1 008 h, 1 334 h, 2 016 h and 3 000 h, T4 group at 0 h and 1 008 h, and T5 group at 0 h, 100 cycles were collected during accelerated aging tests, except that the width of invalid edge was collected only at 0 h and 3 000 h during accelerated aging test. The initial value and end value of the test results are listed in Table A.1, the pass or fail judgement was given in accordance with the criteria in Table 3. The change degree in chromaticity coordinate x, y, L_v, LCE under condition of T1 to T5 during the accelerated aging test are plotted in Figure A.1.

Table A.1 – Test results of Q-LCF accelerated aging tests

Test ID	Test specimens code	Data point	Chromaticity coordinate x	Chromaticity coordinate y	L_v	l (mm)	LCE
T1	NJ-s1-1	Initial value	0,296 9	0,251 6	1 687 cd/m^2	0	62,6 %
		Value at 1 008 h	0,289 9	0,244 2	1 665 cd/m^2	0,5	63,5 %
		Change	−0,007 0	−0,007 4	99 %	0,5	101,4 %
	NJ-s1-2	Initial value	0,297 8	0,252 6	1 698 cd/m^2	0	62,2 %
		Value at 1 008 h	0,291 3	0,245 4	1 686 cd/m^2	0,5	63,0 %
		Change	−0,006 5	−0,007 2	99 %	0,5	101,4 %
	NJ-s1-3	Initial value	0,296 3	0,250 3	1 689 cd/m^2	0	62,5 %
		Value at 1 008 h	0,290 3	0,244 4	1 679 cd/m^2	0,55	63,4 %
		Change	−0,006 0	−0,005 9	99 %	0,55	101,4 %
	Average value of change		−0,006 5	−0,006 8	99 %	0,52	101,4 %

Test ID	**Test specimens code**	**Data point**	**Chromaticity coordinate** x	**Chromaticity coordinate** y	L_v	l (mm)	**LCE**
T2	NJ-s1-4	Initial value	0,297 2	0,251 7	1 700 cd/m^2	0	62,4 %
		Value at 1 008 h	0,296 3	0,249 5	1 739 cd/m^2	0,2	64,7 %
		Change	−0,000 9	−0,002 2	102 %	0,2	103,7 %
	NJ-s1-5	Initial value	0,296 6	0,251	1 706 cd/m^2	0	62,3 %
		Value at 1 008 h	0,295 9	0,249 2	1 745 cd/m^2	0,2	64,4 %
		Change	−0,000 7	−0,001 8	102 %	0,2	103,4 %
	NJ-s1-6	Initial value	0,295 1	0,250 4	1 704 cd/m^2	0	62,1 %
		Value at 1 008 h	0,294 4	0,248 6	1 744 cd/m^2	0,2	64,2 %
		Change	−0,000 7	−0,001 8	102 %	0,2	103,4 %
	Average value of change		−0,000 8	−0,001 9	102 %	0,2	103,5 %
T3	NJ-s1-7	Initial value	0,297 9	0,252 2	1 709 cd/m^2	0	62,7 %
		Value at 1 008 h	0,295 1	0,248 1	1 682 cd/m^2	2	62,6 %
		Change	−0,002 8	−0,004 1	98 %	2,0	99,8 %
	NJ-s1-8	Initial value	0,297 4	0,252 1	1 711 cd/m^2	0	62,5 %
		Value at 1 008 h	0,295 1	0,248 3	1 695 cd/m^2	2,1	62,4 %
		Change	−0,002 3	−0,003 8	99 %	2,1	99,7 %
	NJ-s1-9	Initial value	0,295 9	0,250 9	1 710 cd/m^2	0	62,6 %
		Value at 1 008 h	0,293 6	0,247 2	1 694 cd/m^2	2	62,5 %
		Change	−0,002 3	−0,003 7	99 %	2,0	99,8 %
	Average value of change		−0,002 5	−0,003 9	99 %	2,0	99,8 %
T4	NJ-s1-10	Initial value	0,212 3	0,140 5	1 326 cd/m^2	0	62,5 %
		Value at 1 008 h	0,210 7	0,137 2	1 296 cd/m^2	0	61,7 %
		Change	−0,001 6	−0,003 3	98 %	0	98,7 %
	NJ-s1-11	Initial value	0,212 7	0,141 1	1 329 cd/m^2	0	62,5 %
		Value at 1 008 h	0,211 2	0,137 9	1 300 cd/m^2	0	61,6 %
		Change	−0,001 5	−0,003 2	98 %	0	98,6 %
	NJ-s1-12	Initial value	0,211 6	0,139 8	1 328 cd/m^2	0	62,4 %
		Value at 1 008 h	0,210 1	0,136 7	1 300 cd/m^2	0	61,6 %
		Change	−0,001 5	−0,003 1	98 %	0	98,7 %
	Average value of change		−0,001 5	−0,003 2	98 %	0	98,7 %