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INTERNATIONAL STANDARD

Fibre optic interconnecting devices and passive components – Fibre optic filters – Generic specification

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FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – FIBRE OPTIC FILTERS – GENERIC SPECIFICATION

FOREWORD

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International Standard IEC 61977 has been prepared by subcommittee 86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition published in 2001. It constitutes a technical revision. The changes with respect to the previous edition include having substantially increased the number of terms, added an informative annex for example of filtering technologies and deleted quality assessment procedures.

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

FDIS	Report on voting
86B/2982/FDIS	86B/3015/RVD

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.

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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – FIBRE OPTIC FILTERS – GENERIC SPECIFICATION

1 Scope

This International Standard applies to the family of fibre optic filters. These components have all of the following general features:

– they are passive for the reason that they contain no optoelectronic or other transducing elements which can process the optical signal launched into the input port;

– they modify the spectral intensity distribution in order to select some wavelengths and inhibit others;

– they are fixed, i.e. the modification of the spectral intensity distribution is fixed and can not be tuned;

– they have input and output ports or a common port (having both functions of input and output) for the transmission of optical power; the ports are optical fibre or optical fibre connectors;

– they differ according to their characteristics. They can be divided into the following categories:

  - short-wave pass (only wavelengths lower than or equal to a specified value are passed);
  - long-wave pass (only wavelengths greater than or equal to a specified value are passed);
  - band-pass (only an optical window is allowed);
  - notch (only an optical window is inhibited).

It is also possible to have a combination of the above categories.

This standard establishes uniform requirements for optical, mechanical and environmental properties.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60027 (all parts), *Letter symbols to be used in electrical technology*

IEC 60050(731), *International Electrotechnical Vocabulary – Chapter 731: Optical fibre communication*

IEC 61300 (all parts), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures*

IEC 60617-SN, *Graphical symbols for diagrams*

IEC 60695-11-5, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

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

IEC 61930, *Fibre optic graphic symbology*

IEC Guide 102, *Electronic components – Specification structures for quality assessment (Qualification approval and capability approval)*

IECQ 01, *IEC Quality Assessment System for Electronic Components (IECQ Scheme) – Basic Rules*

IECQ 001002-3, *IEC Quality Assessment System for Electronic Components (IECQ) – Rules of Procedure – Part 3: Approval procedures*

ISO 129-1, *Technical drawings – Indication of dimensions and tolerances – Part 1: General principles*

ISO 286-1, *ISO system of limits and fits – Part 1: Bases of tolerances, deviations and fits*

ISO 1101, *Geometrical Product Specifications (GPS) – Geometrical tolerancing – Tolerances of form, orientation, location and run-out*

ISO 8601, *Data elements and interchange formats – Information interchange – Representation of dates and times*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050(731) and the following apply.

3.1 Basic terms

3.1.1
port
an optical fibre or optical fibre connector attached to a passive component for the entry and/or exit of the optical power (input and/or output port)

3.2 Component terms

3.2.1
band pass filter
device designed to allow signals between two specific wavelengths to pass

3.2.2
etalon
device consisted of a transparent plane-parallel plate with two reflecting surfaces, or two parallel highly reflecting mirrors. The varying transmission function of an etalon is caused by interference between the multiple reflections of light between the two reflecting surfaces

3.2.3
fibre Bragg grating
FBG
device which can reflect particular wavelengths of light and transmit other wavelengths

3.2.4
fibre optic filter
passive component used in fibre optic transmission to modify the spectral intensity distribution of a signal in order to pass some wavelengths and block some others

3.2.5
gain flattening filter/ gain equalizer
GFF/ GEQ
device designed to have the inverse characteristic of an optical device which has an insertion loss wavelength characteristic

3.2.6
long wavelength pass filter
LWPF
filter that passes long wavelength signals but reduces the amplitude of short wavelength signals

3.2.7
notch filter
filter that passes all wavelength except those in a stop band centred on a centre wavelength

3.2.8
reflecting type fibre optic filter
fibre optic filter in which the input and output ports are coincident

3.2.9
short wavelength pass filter
SWPF
filter that passes short wavelength signals but reduces the amplitude of long wavelength signals

3.2.10
thin-film filter
TFF
optical filter which passes a particular wavelength band and reflecting all other wavelengths by using interference effect of thin-film

3.2.11
transmitting type fibre optic filter
fibre optic filter in which the input and output ports are different

3.3 Performance terms

3.3.1
insertion loss
reduction of optical power, when transmitted between the ports of a two-port fibre optic filter expressed in decibels. It is defined as:

$$a = -10 \log \left(P_{\text{out}}/P_{\text{in}}\right)$$

where

P_{in} is the optical power launched into one of the two ports;

P_{out} is the optical power received from the other port.

The insertion loss is a function of wavelength

3.3.2
chromatic dispersion
group delay between two closely spaced wavelengths (or frequencies) inside an optical signal going through a pair of conducting ports of a WDM device. It corresponds to the difference between the arrival times of these two closely spaced wavelengths (or frequencies). Chromatic dispersion is defined as the variation (first order derivative) of this group delay over a range of wavelengths (or frequencies) especially over the channel operating wavelength (or frequency) range at a given time, temperature, pressure and humidity. It is expressed as D in terms of units of ps/nm or ps/GHz and it is a predictor of the broadening of a pulse transmitted through the device

3.3.3
free spectral range
in the case of a periodic spectral response of a fibre optic filter, the difference between two adjacent operating wavelengths

3.3.4
isolation wavelength
nominal wavelength λ_k (where $\lambda_h \neq \lambda_k$), that is nominally suppressed by a fibre optic filter

3.3.5
isolation wavelength range, stopband
specified range of wavelengths from λ_{kmin} to λ_{kmax} around the isolation wavelength λ_k, that are nominally suppressed by a fibre optic filter

3.3.6
maximum insertion loss within pass band
maximum value of the insertion loss within pass band. Figure 1 shows pass band and maximum insertion loss within pass band

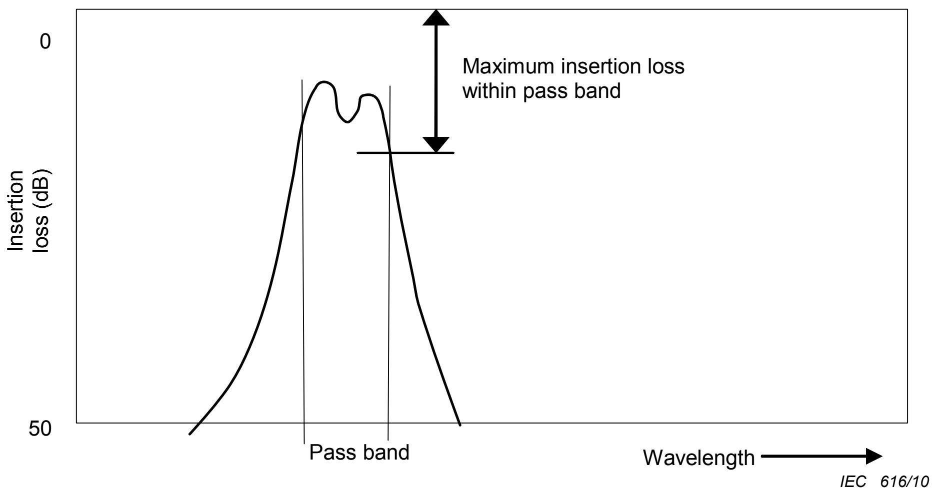


Figure 1 – Illustration of maximum insertion loss within pass band

3.3.7
maximum slope of spectral ripple
maximum value in module of the derivative of the insertion loss (for transmitting-type fibre optic filter) or return loss (for reflecting-type fibre optic filter) as a function of wavelength over the bandpass

3.3.8
minimum insertion loss within pass band
minimum value of the insertion loss within pass band. Figure 2 shows pass band and minimum insertion loss within pass band

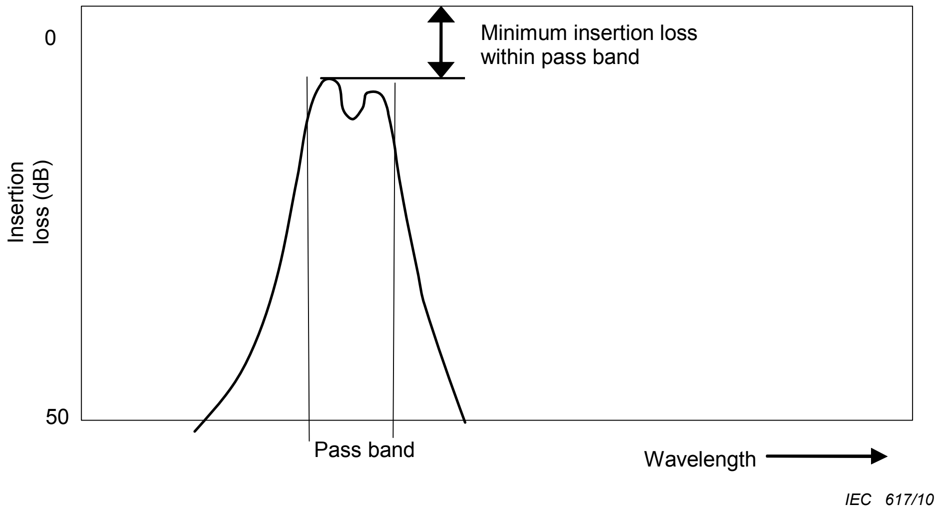


Figure 2 – Illustration of minimum insertion loss within pass band

3.3.9
operating wavelength
nominal wavelength λ_h, at which a fibre optic filter operates with the specified performances

3.3.10
operating wavelength range, bandpass
specified range of wavelengths from λ_{hmin} to λ_{hmax} around the operating wavelength λ_h, within which a fibre optic filter operates with the specified performances

3.3.11
polarization dependent loss
PDL
maximum variation of insertion loss over all the polarization states

3.3.12
polarization mode dispersion
PMD
when an optical signal passes through an optical fibre, component or subsystem, such as going through a pair of conducting ports of a WDM device, the change in the shape and rms width of the pulse due to the average delay of the travelling time between the two principal states of polarization (PSP), differential group delay (DGD), and/or to the waveform distortion for each PSP, is called PMD. PMD, together with polarization dependent loss (PDL) and polarization dependent gain (PDG), when applicable, may introduce waveform distortion leading to unacceptable bit error rate increase

3.3.13
reflectance
percentage of optical power reflected by the filter at the operating wavelength

3.3.14
return loss
fraction of input power that is returned from a port of a fibre optic filter, expressed in decibels. It is defined as:

$$RL = -10 \log \left(P_{refl} / P_{in} \right)$$

where

P_{in} is the optical power launched into the port;

P_{refl} is the optical power received back from the same port.

The return loss is a function of wavelength

3.3.15
spectral ripple (flatness)
maximum peak-to-peak variation in insertion loss (for transmitting-type fibre optic filter) or return loss (for reflecting-type fibre optic filter) over the bandpass

3.3.16
transmittance
percentage of optical power transmitted by the filter at the operating wavelength

3.3.17
wavelength dependent loss of fibre optic filter
variation of insertion loss of fibre optic filter over its operating wavelength

3.3.18
X dB-bandwidth
a) for transmitting-type fibre optic filters: defined through the spectral dependence of the insertion loss as the minimum wavelength range about the operating wavelength λ_h within which the variation of the insertion loss is less than "*X*" dB; the minimum wavelength range is determined considering the worst case shift due to temperature operating range and polarisation;
b) for reflecting-type fibre optic filters: defined through the spectral dependence of the return loss as the minimum wavelength range about the operating wavelength λ_h within which the variation of the return loss is less than "*X*" dB. The minimum wavelength range is determined considering the worst case shift due to temperature operating range and polarisation

4 Requirements

4.1 Classification

4.1.1 General

Filters are classified either totally or in part by the following categories:

– type;
– style;
– variant;
– environmental category;
– assessment level;
– normative reference extensions.

An example of a typical filter classification is as follows:

Type	Fixed
Style	– Configuration C – Fibre type: IEC type A1a – SC connector
Variant	Means of mounting
Assessment level	A

4.1.2 Type

The optic filter type shall be defined by its intended function and optical performance. There are several types of filters, for instance:

- long wavelength pass filter (LWPF);
- band pass filter (BPF);
- short wavelength pass filter (SWPF);
- gain flattening filter (GFF)/ gain equalizer (GEQ);
- notch.

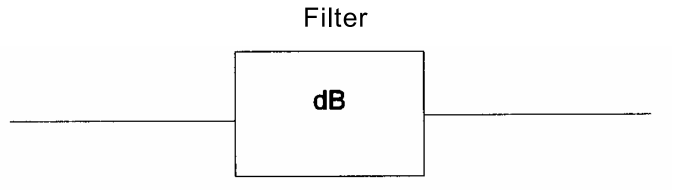
4.1.3 Style

The optic filter style shall be defined on the basis of the following elements:

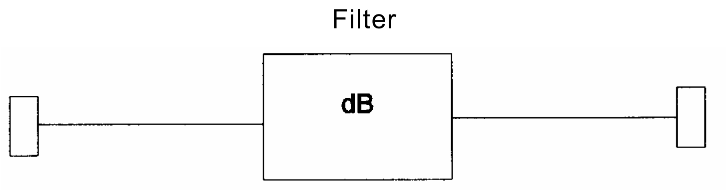
- the input and output port configuration;
- the connector set type(s), if any.

The four different input and output configurations can be scheduled as follows:

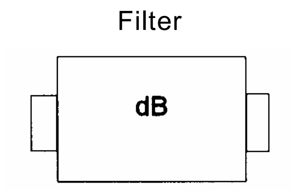
Configuration A – a device containing integral fibre optic pigtails without connectors.



Configuration B – a device containing integral fibre optic pigtails, with a connector on each pigtail.



Configuration C – a device containing fibre optic connectors as an integral part of the device housing.



Configuration D – a device containing some combination of the interfacing features of the preceding configurations.

4.1.4 Variant

The optic filter variant defines the feature that identifies the variety of structurally similar components. Examples of feature variables which create variants are:

- cable type;
- fibre type;
- housing;
- orientation of ports;
- means of mounting.

4.1.5 Assessment level

Assessment level defines the inspection levels and the acceptable quality level (AQL), of groups A and B and the periodicity of inspection of groups C and D. Relevant specifications shall specify one or more assessment levels, each of which shall be designated by a capital letter.

The following are preferred levels:

Assessment level A:

- Group A inspection: inspection level II, AQL = 4 %
- Group B inspection: inspection level II, AQL = 4 %
- Group C inspection: 24-month periods
- Group D inspection: 48-month periods

Assessment level B:

- Group A inspection: inspection level II, AQL = 1 %
- Group B inspection: inspection level II, AQL = 1 %
- Group C inspection: 18-month periods
- Group D inspection: 36-month periods

Assessment level C:

- Group A inspection: inspection level II, AQL = 0,4 %
- Group B inspection: inspection level II, AQL = 0,4 %
- Group C inspection: 12-month periods
- Group D inspection: 24-month periods

One additional assessment level may be added in the relevant specification. When this is done, the capital letter X shall be used.

4.1.6 Normative reference extensions

Normative reference extensions are used to identify independent standards specifications or other reference documents integrated into relevant specifications.

Unless a specified exception is noted, additional requirements imposed by an extension are mandatory. Usage is primarily intended to merge associated components to form hybrid devices, or integrated functional application requirements that are dependent on technical expertise other than fibre optics.

Some optical fibre filter configurations require special qualification provisions which shall not be imposed universally. This accommodates individual component design configurations, specialised field tooling, or specific application processes. In this case requirements are necessary to guarantee repeatable performance or adequate safety, and provide additional guidance for complete product specification. These extensions are mandatory whenever used to prepare, assemble or install an optical fibre splice either for field application usage or preparation of qualification test specimens. The relevant specification shall clarify all stipulations. However, design and style dependent extensions shall not be imposed universally.

Some commercial or residential building applications may require direct reference to specific safety codes and regulations or incorporate other specific material flammability or toxicity requirements for specialised locations.

Specialised field tooling may require an extension to implement specific ocular safety, electrical shock or burn hazard avoidance requirements, or require isolation procedures to prevent potential ignition of combustible gases.

4.2 Documentation

4.2.1 Symbols

Graphical and letter symbols shall, whenever possible, be taken from IEC 60027 series, IEC 60617 series and IEC 61930 unless superseded by this specification.

4.2.2 Specification system

This specification is part of the IEC specification system. Subsidiary specifications shall consist of relevant specifications. This system is shown in Table 1. There are no sectional specifications for filters.

Table 1 – The IEC specification structure

Specification level	Examples of information to be included	Applicable to
Basic	Assessment system rules Inspection rules Optical measurement methods Sampling plans Identification rule Marking standards Dimensional standards Terminology Symbol Preferred number series SI units	Two or more component families or sub-families
Generic	Specific terminology Specific symbols Specific units Preferred values Marking Quality assessment procedures Selection of tests Qualification approval and/or capability approval procedures	Component family
Relevant (Performance)	Individual values Specific information Completed quality conformance test schedules	Individual type

4.2.2.1 Relevant specification

A specific fibre optic filter is described by a corresponding relevant specification.

Relevant specifications shall specify the following as applicable:

– type (see 4.1.2);
– optic filter style (see 4.1.3);
– variant(s) (see 4.1.4);
– variant identification number(s) (see 4.6.2);
– climatic category;
– all tests required (see 4.1.5);
– assessment level (see 4.1.5);
– performance requirements (see 4.5).

4.2.3 Drawings

4.2.3.1 General

The drawings and dimensions given in the relevant specifications shall not restrict detail construction nor be used as manufacturing drawings.

4.2.3.2 Projection system

Either first angle or third angle projection shall be used for the drawings in documents covered by this specification. All drawings within a document shall use the same projection system and the drawings shall state which system is used.

4.2.3.3 Dimensional system

All dimensions shall be given in accordance with ISO 129, ISO 286 and ISO 1101. The metric system shall be used in all specifications. Dimensions shall not contain more than five significant digits. When units are converted, a note shall be added in each relevant specification.

4.2.4 Test and measurements

4.2.4.1 Test and measurement procedures

The test and measurement procedures for optical, mechanical, climatic and environmental characteristics of filters to be used shall be defined and selected preferentially from IEC 61300 series standards. The size measurement method to be used shall be specified in the relevant specification for dimensions which are specified within a total tolerance zone of 0,01 mm or less.

4.2.4.2 Reference components

Reference components for measurement purposes if required, shall be specified in the relevant specification.

4.2.4.3 Gauges

Gauges if required, shall be specified in the relevant specification.

4.2.5 Test report

The test report shall be prepared for each test conducted as required by a relevant specification. The data sheets shall be included in the qualification report and in the periodic inspection report.

Data sheets shall contain the following information as a minimum:

- title and date of test;
- specimen description including the variant identification number (see 4.6.2);
- test equipment used;
- all applicable test details;
- all measurement values and observations;

4.2.6 Instructions for use

Instructions for use, when required, shall be given by the manufacturer.

4.3 Standardisation system

4.3.1 Interface standards

Interface standards provide both manufacturers and users with all the information they require to make or use products conforming to the physical features of that standard interface. Interface standards fully define and dimension the features essential for the mating and unmating of optical fibre connectors and other components. They also serve to position the optical datum target, where defined, relative to other reference data.

Interface standards ensure that connectors and adapters that comply with the standard will fit together. The standards may also contain tolerance grades for ferrules and alignment devices. Tolerance grades are used to provide different levels of alignment precision.

The interface dimensions may also be used to design other components that will mate with the connectors. For example, an active device mount can be designed using the adapter interface dimensions. The use of these dimensions combined with those of a standard plug, provides the designer with assurance that the standard plugs will fit into the optical device mount. They also provide the location of the plugs' optical datum target.

Standard interface dimensions do not, by themselves, guarantee optical performance. They guarantee connector mating at a specified fit. Optical performance is currently guaranteed via the manufacturing specification. Products from the same or different manufacturing specifications using the same standard interface will always fit together. Guaranteed performance can be given by any single manufacturer only for products delivered to the same manufacturing specification. However, it can be reasonably expected that some level of performance will be obtained by mating products from different manufacturing specifications, although the level of performance can not be expected to be any better than that of lower specified performance.

4.3.2 Performance standard

Performance standards contain a series of tests and measurements (which may or may not be grouped into a specified schedule depending on the requirements of that standard) with clearly defined conditions, severities and pass/fail criteria. The tests are intended to be run on a "one-off" basis to prove the ability of any products to satisfy the "performance standards" requirement. Each performance standard has a different set of tests, and/or severities (and/or groupings) representing the requirements of a market sector, user group or system location.

A product that has been shown to meet all the requirements of a performance standard can be declared as complying with a performance standard but should then be controlled by a quality assurance / quality conformance programme.

A key point of the test and measurements standards, for the application of these (particularly with regard to insertion loss and return loss) in conjunction with the interface standards of inter- product compatibility, may be able to be defined. Certainly conformance on each individual product to this standard will be ensured.

4.3.3 Reliability standard

Reliability standards are intended to ensure that a component can meet performance specifications under stated conditions for a stated time period.

For each type of component, the following shall be identified (and become standard):

– failure modes (observable general mechanical or optical effects of failure);
– failure mechanisms (general causes of failure, common to several components), and failure effects (detailed causes of failure, specific to component).

These are all related to environmental and material aspects.

There is an initial "infant mortality phase" just after component manufacturing, during which many components would fail if they were deployed in the field. To avoid early field failure, all components may be subjected to a screening process in the factory, involving environmental stresses that may be mechanical, thermal and humidity related. This is to induce known failure mechanisms in a controlled environmental situation to occur earlier than would normally be seen in the unscreened population. For those components that survive (and are then sold), there is a reduced failure rate since these mechanisms have been eliminated.

Screening is an optional part of the manufacturing process, rather than a test method. It will not affect the "useful life" of a component defined as the period during which it performs according to specifications. Eventually other failure mechanisms appear, and the failure rate increases beyond some defined threshold. At this point the useful life ends and the "wear-out region" begins, and the component must be replaced.

At the beginning of useful life, performance testing on a sampled population of components may be applied by the supplier, by the manufacturer, or by a third party. This is to ensure that the component meets performance specifications over the range of intended environments at this initial time. Reliability testing, on the other hand, is applied to ensure that the component meets performance specifications for at least a specified minimum useful lifetime or specified maximum failure rate. These tests are usually done by utilising the performance testing, but increasing its duration and severity, in order to accelerate the failure mechanisms.

A reliability theory relates component reliability testing to component parameters and to lifetime or failure rate under testing. The theory then extrapolates these to lifetime or failure rate under less stressful service conditions. The reliability specifications include values of the component parameters needed to ensure the specified minimum lifetime or maximum failure rate in service.

4.3.4 Interlinking

A large number of the test and measurement standards are already in place; the quality assurance qualification approval standards which come under the banner of IECQ are already in place and have been for many years. As previously mentioned, alternative methods of quality assurance/quality conformance are being developed other than those of capability approval and technology approval, which are covered by IECQ 01, IECQ 001002-3, and IEC Guide 102.

With regard to interface, performance and reliability standards, once all these three standards are in place, the matrix given in Table 2 demonstrates some of the other options available for product standardisation.

Product A is fully IEC standardised, having a standard interface and meeting defined performance and reliability standards.

Product B is a product with a proprietary interface but which meets a defined IEC performance standard and a reliability standard.

Product C is a product which complies with an IEC standard interface but does not meet the requirements of either an IEC performance standard or a reliability standard.

Product D is a product which complies with both an IEC standard interface and performance standard but does not meet any reliability requirements.

Obviously the matrix is more complex than shown since there will be a number of interface, performance and reliability standards which will be able to be cross-related. In addition, the products may all be subjected to a quality assurance programme that could be under IEC Qualification Approval, Capability Approval, Technology Approval (as Table 3 attempts to demonstrate), or even under a national or company quality assurance system.

Table 2 – Standards interlink matrix

	Interface standard	Performance standard	Reliability standard
Product A	YES	YES	YES
Product B	NO	YES	YES
Product C	YES	NO	NO
Product D	YES	YES	NO

Table 3 – Quality assurance options

	COMPANY A			COMPANY A			COMPANY A		
	QA	CA	TA	QA	CA	TA	QA	CA	TA
Product A	X			X					X
Product B	X				X				X
Product C	X				X				X
Product D	X					X			X

4.4 Design and construction

4.4.1 Materials

The devices shall be manufactured with materials which meet the requirements of the relevant specification.

When non-flammable materials are required, the requirement shall be specified in the relevant specification, and IEC 60695-11-5 shall be referenced.

4.4.2 Workmanship

Components and associated hardware shall be manufactured to a uniform quality and shall be free of sharp edges, burrs or other defects that would affect life, serviceability or appearance. Particular attention shall be given to neatness and thoroughness of marking, plating, soldering, bonding, etc.

4.5 Performance requirements

Filters shall meet the performance requirements specified in the relevant specification.

4.6 Identification and marking

4.6.1 General

Components, associated hardware and shipping packages shall be permanently and legibly identified and marked when required by the relevant specification.

4.6.2 Variant identification number

Each variant in a relevant specification shall be assigned a variant identification number; this number shall be set out as follows:

Example:	**QC210101/US0001**	**001**	**A**
Relevant specification number	✓		
Variant number		✓	
Assessment level			✓

4.6.3 Component marking

Component marking, if required, shall be specified in the relevant specification. The preferred order of marking is:

a) port identification;
b) manufacturer's part number (including serial number, if applicable);
c) manufacturer's identification mark or logo;
d) manufacturing date;
e) variant identification number;
f) any additional marking required by the relevant specification.

If space does not allow for all the required marking on the component, each unit shall be individually packaged with a data sheet containing all of the required information which is not marked.

4.6.4 Package marking

Several devices may be packaged together for shipment.

Package marking, if required, shall be specified in the relevant specification. The preferred order of marking is:

a) manufacturer's identification mark or logo;
b) manufacturer's part number;
c) manufacturing date code (year/week, see ISO 8601);
d) variant identification number(s) (see 4.6.2);
e) the assessment level;
f) the type designations (see 4.1.2);
g) environmental category;
h) any additional marking required by the relevant specification.

When applicable, individual unit packages (within the sealed package) shall be marked with the reference number of the certified record of released lots, the manufacturer's factory identity code and the component identification.

4.7 Packaging

Packages shall include instructions for use when required by the specification (see 4.2.6).

4.8 Storage conditions

Where short-term degradable materials, such as adhesives, are supplied with the package, the manufacturer shall mark these with the expiry date (year and week numbers, see ISO 8601) together with any requirements or precautions concerning safety hazards or environmental conditions for storage.

4.9 Safety

Optical filters, when used on an optical fibre transmission system and/or equipment, may emit potentially hazardous radiation from an uncapped or unterminated output port or fibre end.

The optical filter manufacturers shall provide sufficient information to alert system designers and users about the potential hazard and shall indicate the required precautions and working practices.

In addition, each relevant specification shall include the following:

WARNING NOTE

Care should be taken when handling small diameter fibre to prevent puncturing the skin, especially in the eye area. Direct viewing of the end of an optical fibre or an optical fibre connector when it is propagating energy, is not recommended unless prior assurance has been obtained as to the safety energy output level.

Reference shall be made to IEC 60825-1, the relevant document on safety.

Annex A
(informative)

Example of filtering technologies

The operational principles of an etalon, a FBG and a TFF are shown below as representative filtering technologies

A.1 Etalon filter

Etalon can be considered as an optical resonator. It consists of a transparent plane-parallel plate with two reflecting surfaces, or two parallel highly reflecting mirrors. The varying transmission function of an etalon is caused by interference between the multiple reflections of light between the two reflecting surfaces.

The reflected beam depends on the wavelength (λ) of the light, the angle of incidence (θ), the thickness of the etalon (d) and the refractive index of the material between the reflecting surfaces (n).

If both surfaces have a reflection coefficient R, the transmission function of the etalon is given by:

$$T(\lambda) = \frac{(1-R)^2}{(1-R)^2 + 4R\sin^2(\frac{\delta}{2})}$$

where δ is the phase delay between two partial waves:

$$\delta = \frac{4\pi dn\cos(\theta)}{\lambda}$$

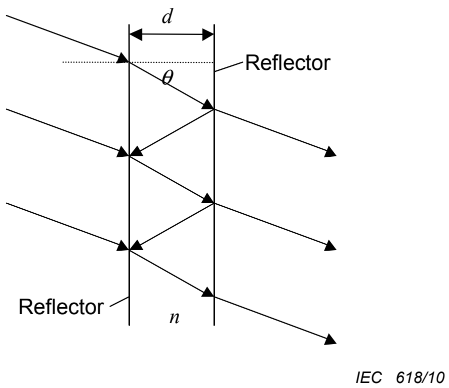


Figure A.1 – Schematic diagram of etalon

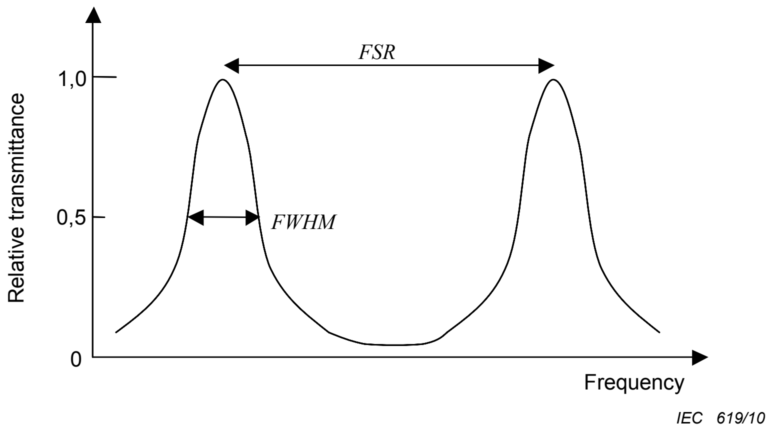


Figure A.2 – Transmission characteristic of etalon

The wavelength separation between adjacent transmission peaks as shown in Figure A.2 which is called the free spectral range (*FSR*), and is given by:

$$FWHM = \frac{FSR}{F}$$

where F is the finesse and is given by:

$$F = \frac{FSR}{FWHM} \approx \frac{\pi\sqrt{R}}{1-R}$$

Etalons with high finesse show sharper transmission peaks with lower minimum transmission coefficients. The peaks can be shifted by rotating the etalon with respect to the beam, due to the angle dependence of the transmission.

A.2 FBG

A fibre Bragg grating (FBG) can reflect particular wavelengths of light and transmit other wavelengths. It is used with an optical circulator in order to pick up reflected particular wavelengths as shown in Figure A.3.

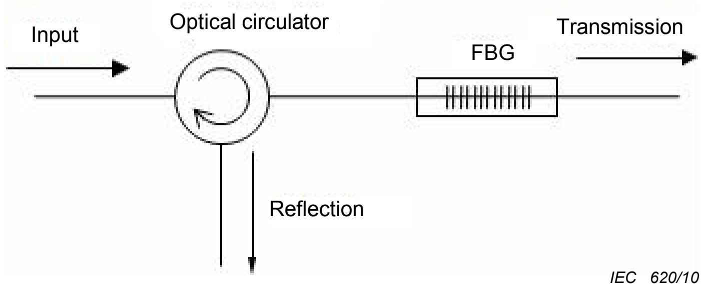


Figure A.3 – Usage of fibre Bragg grating

A FBG has a periodic variation to the refractive index of the fibre core as shown in Figure A.3 and the periodic variation to the refractive index generates a wavelength specific mirror. Therefore, a FBG can be used as an optical filter or as a wavelength-specific reflector.

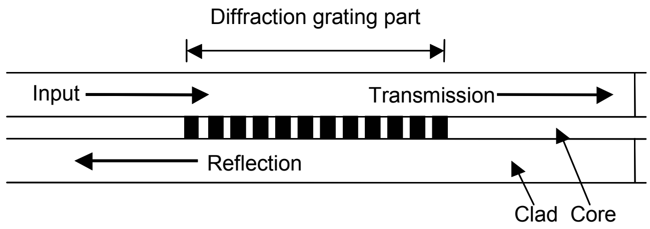


Figure A.3 – Fibre Bragg grating

The fundamental principle of a FBG is Bragg reflection. The refractive index is assumed to have a periodic variation over a defined length. The reflected wavelength (λ_B), called the Bragg wavelength, is defined by the relationship,

$$\lambda_B = 2n\Lambda$$

where n is the average refractive index of the grating and Λ is the period of the variation of the refractive index.

The bandwidth ($\Delta\lambda$), is given by,

$$\Delta\lambda = \left[\frac{2\delta n_0 \eta}{\pi}\right]\lambda_B$$

where δn_0 is the variation in the refractive index, and η is the fraction of power in the core.

The peak reflection ($P_B(\lambda_B)$) is approximately given by,

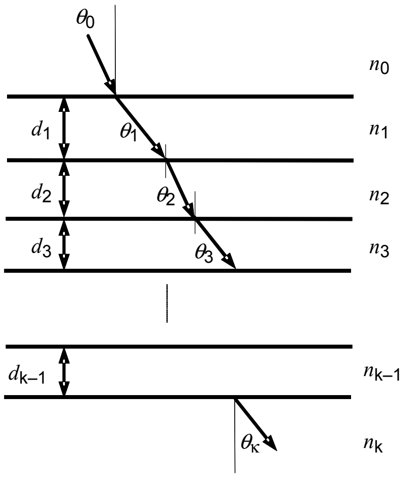
$$P_B(\lambda_B) \approx \tanh^2\left[\frac{N\eta\delta n_0}{n}\right]$$

where N is the number of periodic variations.

A.3 Thin-film filter

The fundamental structure of a thin-film filter is based on the Fabry-Perot etalon, which acts as a band pass filter. A signal at the passband wavelength passes through the filter, and other wavelengths are reflected with a high reflectivity. The centre wavelength of the passband is determined by the cavity length of the filter.

Multilayer thin-film filters are known as wavelength selective optical filters. A structure of multiplayer thin-film filters is that alternating layers of an optical coating are built up on a glass substrate. By controlling the thickness and number of the layers, the wavelength of the passband of the filter can be tuned and made as wide or narrow as desired.



IEC 622/10

where

d_k is the thickness;

n_k is the refractive index ;

θ_κ is the incident angle.

Figure A.4 – Structure of multilayer thin-film

Bibliography

IEC 60410:1973, *Sampling plans and procedures for inspection by attributes*

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