IEC 62074-1

Edition 1.0 2009-07

INTERNATIONAL STANDARD

Fibre optic interconnecting devices and passive components – Fibre optic WDM devices –
Part 1: Generic specification

IEC 62074-1:2009(E)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE W

ICS 33.180.01; 33.180.20

ISBN 978-2-88910-613-4

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – FIBRE OPTIC WDM DEVICES –

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FOREWORD

International Standard IEC 62074-1 has been prepared by subcommittee SC86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

This standard cancels and replaces IEC/PAS 62074-1 published in 2007. This first edition constitutes a technical revision.

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

FDIS	Report on voting
86B/2850/FDIS	86B/2889/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 maintenance result 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- withdrawn,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 WDM DEVICES –

Part 1: Generic specification

1 Scope

This part of IEC 62074 applies to fibre optic wavelength division multiplexing (WDM) devices. These have all of the following general features:

- They are passive, in that they contain no optoelectronic or other transducing elements; but they may use temperature control only the purpose to stabilize the characteristics of devices; they exclude any optical switching function.
- They have three or more ports for the entry and/or exit of optical power, and share optical power among these ports in a predetermined fashion depending on the wavelength.
- The ports are optical fibres or optical fibre connectors.

This standard establishes uniform requirements for the 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 (IEV) – Chapter 731: Optical fibre communication*

IEC 60617, *International Standard Database Snapshot – 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(all parts), *Safety of laser products*

ISO 129-1, *Technical drawings – Indication of dimensions amd tolerances – General principles*

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

ISO 370, *Toleranced dimensions – Conversion from inches into millimeters and vice versa*

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*

ITU-T Recommendation G.671:2005, *Transmission characteristics of optical components and subsystems*

ITU-T Recommendation G.692:1998, *Optical interfaces for multichannel systems with optical amplifiers*

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 term definitions

3.1.1
port

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)

3.1.2
transfer matrix
optical properties of a fibre optic wavelength-selective branching device can be defined in terms of an *n* x *n* matrix of coefficients, where *n* is the number of ports, and the coefficients represent the fractional optical power transferred between designated ports

NOTE The detail explanation of transfer matrix is shown in Annex A.

3.1.3
transfer matrix coefficient
element t_{ij} of the transfer matrix

NOTE The detail explanation is shown in Annex A.

3.1.4
logarithmic transfer matrix
transfer matrix whose matrix element a_{ij} is a logarithmic value of transfer matrix element t_{ij}

NOTE The detail explanation is shown in Annex A.

3.1.5
conducting ports
two ports *i* and *j* between which t_{ij} is nominally greater than zero at a specified wavelength

3.1.6
input/output port pair
conducting ports *i* and *j* (t_{ij} nominally greater than zero) that are isolated from any other ports *j* (a_{ij} nominally infinite). The ports are numbered sequentially, so that the transfer matrix is developed to show all ports and all possible combinations. The port numbering is arbitrary.

NOTE Figure 1 below shows an example of a six-port device, with two input ports and four output ports.

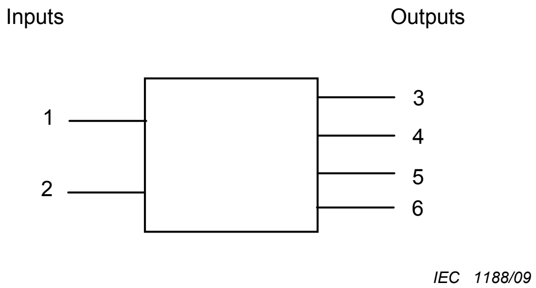


Figure 1 – Example of a six-port device, with two-input and four-output ports

If there are four operating wavelengths, then the resulting transfer matrix becomes a 6×6×4 matrix: loss at λ_1 from port 1 to port 6 would use a_{161}. Reflectance of port 2 at λ_4 would use a_{224}. Loss from port 5 to port 2 at λ_3 would use a_{523}

3.1.7
isolated ports
two ports *i* and *j* between which t_{ij} is nominally zero, and a_{ij} is nominally infinite at a specified wavelength

3.1.8
channel
another term for operating wavelength (or frequency)

3.1.9
channel spacing
centre-to-centre differences in frequency or wavelength between adjacent channels in a WDM device

3.2 Component definitions

3.2.1
wavelength-selective branching device
passive component possessing three or more ports which shares optical power among its ports in a predetermined fashion, without any amplification, switching, or other active modulation but only depending on the wavelength, in the sense that at least two different wavelength ranges are nominally transferred between two different couples of ports

3.2.2
wavelength division multiplexer
WDM
term which is frequently used as a synonym for a wavelength-selective branching device

3.2.3
dense WDM device
DWDM
WDM device which is intended to operate for channel spacing equal or less than 1 000 GHz

3.2.4
coarse WDM device
CWDM
WDM device which is intended to operate for channel spacing less than 50 nm and greater than 1 000 GHz (about 8 nm at 1 550 nm and 5,7 nm at 1 310 nm)

3.2.5
wide WDM device
WWDM
WDM device which is intended to operate for channel spacing equal or greater than 50 nm

3.2.6
wavelength multiplexer
MUX
WDM (DWDM, CWDM or WWDM) which has *n* input ports and one output port, and which function is to combine *n* different optical signals differentiated by wavelength from *n* corresponding input ports on to a single output port

3.2.7
wavelength demultiplexer
DEMUX
WDM (DWDM, CWDM or WWDM) which has one input port and *n* output ports, and which function is to separate *n* different optical signals differentiated by wavelength from a single input port to *n* corresponding output ports

3.2.8
interleaver
bidirectional DWDM which has three ports, and which function is to separate *n* different optical signals differentiated by wavelength from a single input port to odd channel signal to one output port and even channel signal to the other output port alternately

3.3 Performance parameter definitions

3.3.1
crosstalk
for WDM devices, the value of the ratio between the optical power of the specified signal and all noises

3.3.2
isolation
for WDM devices, the value of the ratio between the optical power of the specified signal and the specified noise

3.3.3
add-drop isolation
value of the optical power reduction in decibels a_{ij} between an input i, and an output port j, that are isolated at every wavelength (or frequency for a dense WDM (DWDM) device). a_{ij} is a logarithmic transfer element

3.3.4
adjacent channel isolation (adjacent channel crosstalk)
unidirectional (far-end) isolation with the restriction that *x*, the isolation wavelength number, is restricted to the channels immediately adjacent to the (channel) wavelength number associated with port *o*

NOTE This is illustrated in Figure 2 below. The adjacent channel crosstalk has the same meaning as adjacent channel isolation.

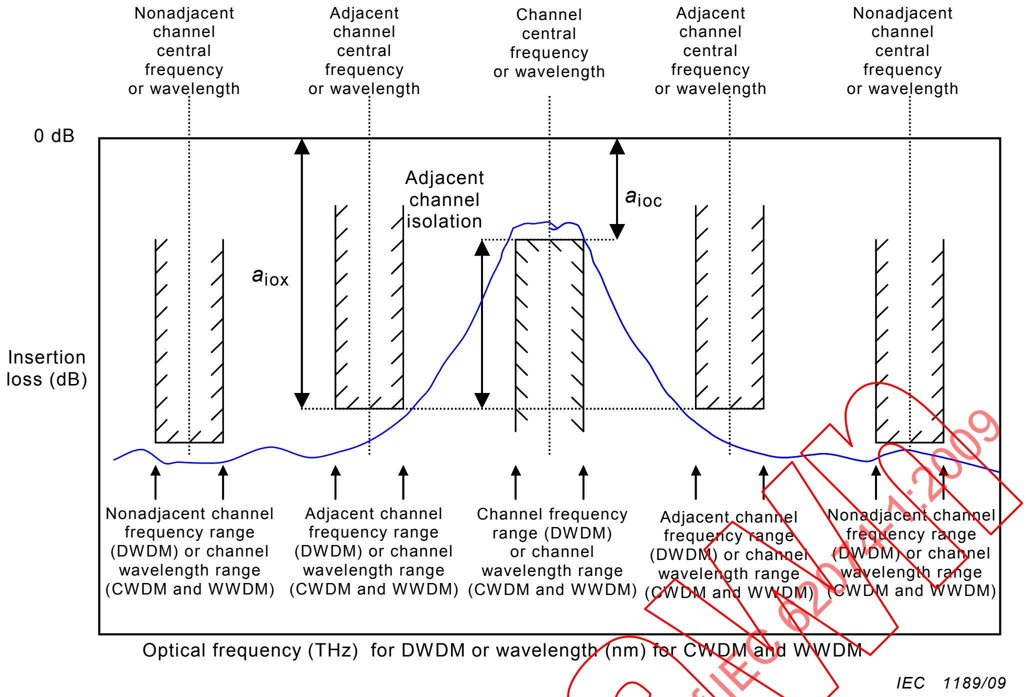


Figure 2 – Illustration of adjacent channel isolation

3.3.5
bidirectional (near-end) crosstalk attenuation
the (near-end) crosstalk attenuation for a bidirectional WDM multiplexer (MUX)/demultiplexer (DMUX) device

$$BCA = a_{mox}$$

where

a_{mox} is an element of the logarithmic transfer matrix;

m is the MUX input port number;

o is the DMUX output port number;

x is the wavelength number associated with port m.

3.3.6
bidirectional (near-end) isolation
(near-end) isolation for a bidirectional WDM-MUX/DEMUX device. Because bidirectional WDM-MUX/DMUX devices have both input channels and output channels at the same side of the device, input light for one direction can appear on the output port for the other direction. The bidirectional (near-end) isolation is defined to be:

$$I_B = a_{mox} - a_{doc}$$

where

a_{mox} is an element of the logarithmic transfer matrix;

a_{doc} is an element of the logarithmic transfer matrix;

d is the DMUX input port number;

o is the DMUX output port number;

c is the (channel) wavelength number associated with port o;

m is the MUX input port number;

x is the wavelength number associated with port *m*.

NOTE 1 In the example given below of a four-wavelength bidirectional system, wavelengths 1 and 2 travel from left to right and wavelengths 3 and 4 from right to left (see Figure 3).

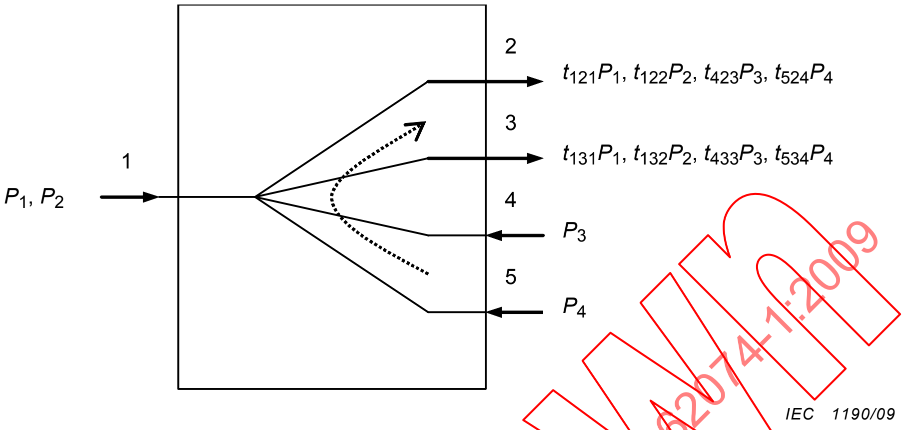


Figure 3 – Illustration of a four-wavelength bidirectional system

NOTE 2 For the example given above, the bidirectional isolation of port 2 to wavelength 3 is $a_{423} - a_{121}$.

3.3.7

centre wavelength deviation

differences between the centre wavelength and nominal wavelength (frequency) of the specified channel for DWDM devices. Where centre wavelength is defined as the centre of the wavelength range which is x dB less than the peak of insertion loss for the specified channel

NOTE 0,5, 1 or 3 are generally used for x.

3.3.8

channel extinction

within the operating wavelength range, the difference (in dB) between the minimum powers of the conducting channels (in dBm) and the maximum power of the isolated channels (in dBm)

3.3.9

channel frequency range

frequency range within which a DWDM device is required to operate with a specified performance. For a particular nominal channel frequency, f_{nomi}, this frequency range is from $f_{imin} = (f_{nomi} - \Delta f_{max})$ to $f_{imax} = (f_{nomi} + \Delta f_{max})$, where Δf_{max} is the maximum channel centre frequency deviation. Nominal; channel centre frequency and maximum channel centre frequency deviation are defined in ITU-T Rec. G.692

3.3.10

channel insertion loss

term used for WDM devices which has the same meaning as insertion loss

3.3.11

channel insertion loss deviation

maximum variation of the insertion loss over the operating wavelength range (channel frequency range for a DWDM device or channel wavelength range for a coarse WDM (CWDM) and a wide WDM (WWDM) device)

NOTE Channel insertion loss deviation should not to be confused with ripple defined below.

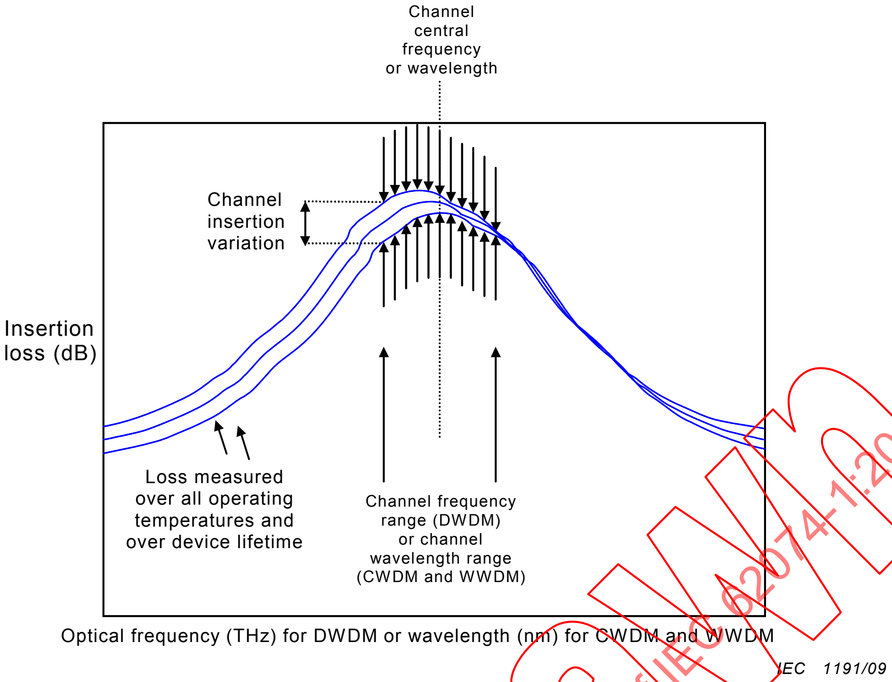


Figure 4 – Illustration of channel insertion loss variation

3.3.12
channel non-uniformity
for a specified set of input ports the difference between the maximum and the minimum insertion loss at the output

3.3.13
channel wavelength range
wavelength range within which a CWDM or WWDM device is required to operate a specified performance. For a particular nominal channel centre wavelength, λ_{nom}, this wavelength range from $\lambda_{imin} = (\lambda_{nom} - \Delta\lambda_{max})$ to $\lambda_{imax} = (\lambda_{nom} + \Delta\lambda_{max})$, where $\Delta\lambda_{max}$ is the maximum channel wavelength deviation

3.3.14
chromatic dispersion
group delay difference 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

3.3.15
slope of chromatic dispersion
slope of chromatic dispersion *S* (with units of ps/nm^2 or ps/GHz^2) corresponds to the variation (first order derivative) of *D* as a function of wavelength (or frequency) (or second order derivative of the group delay) over the operating wavelength (or frequency) range, channel per channel. It is particularly critical in the context of large channel counts (DWDM) or over a wide wavelength range (CWDM or WWDM)

3.3.16
directivity
value of a_{ij} between two isolated ports which are isolated at every wavelength (or frequency for a DWDM device)

NOTE For the example of 6 ports WDM devices shown in Figure 1, the directivity is a_{12} and a_{21} between two input ports, and a_{34}, a_{43}, etc. between two output ports.

3.3.17
free spectral range (FSR)
difference between two adjacent operating wavelengths for a given input output path (refer to Figure 5 below)

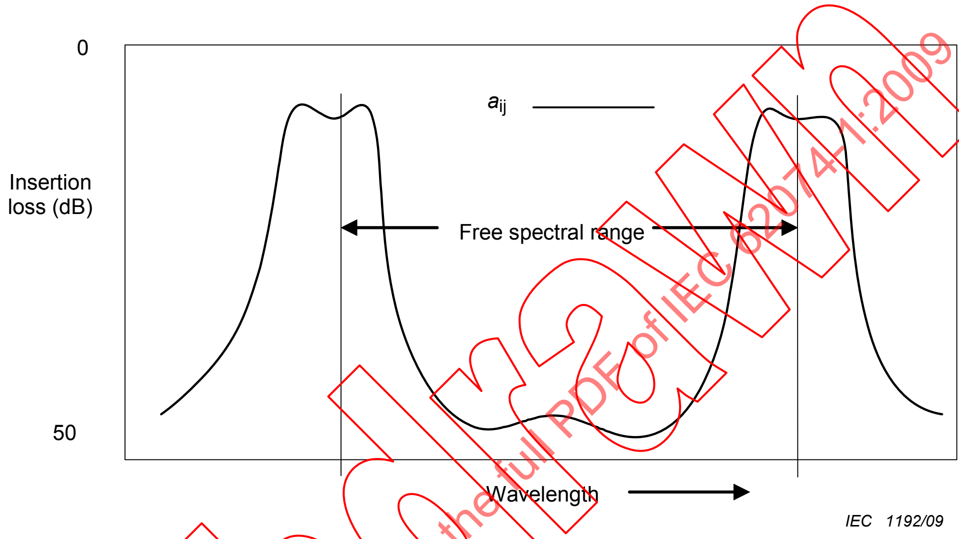


Figure 5 – Illustration of free spectral range

3.3.18
insertion loss
value of a_{ij} (where $i \neq j$) at the operating wavelength between two conducting ports. It is the reduction in optical power between an input and output port of a passive component expressed in decibels. It is defined as:

$$IL = -10\,log\left(\frac{P_{out}}{P_{in}}\right)$$

where

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

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

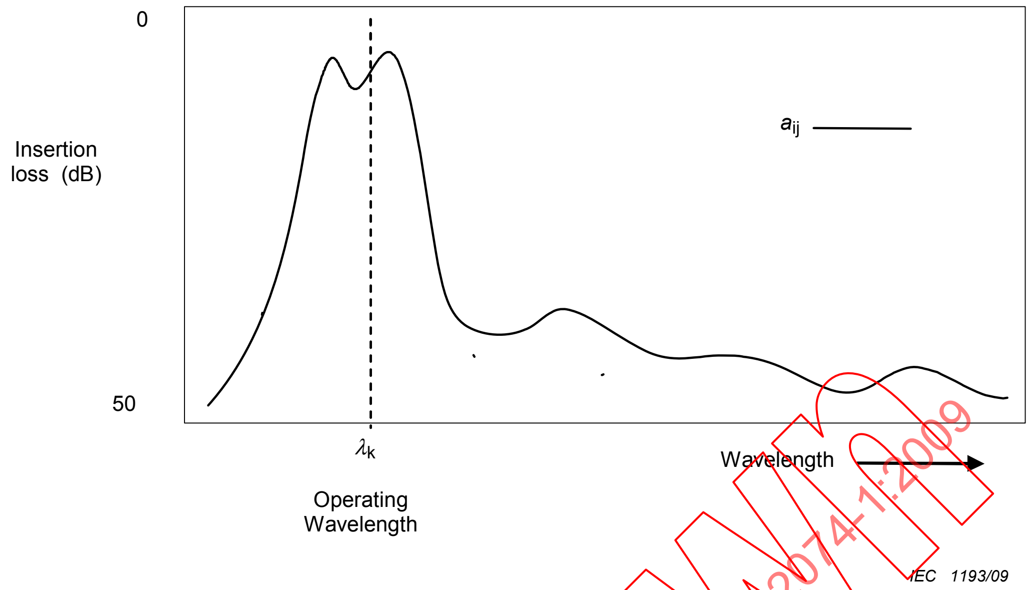


Figure 6 – Illustration of insertion loss

NOTE For WWDM devices, it should be specified as a maximum value and a minimum value at each operating wavelength range. For DWDM and CWDM devices, it should be specified as a maximum value and a minimum value within the channel frequency (or wavelength) range as illustrated in Figure 7 below.

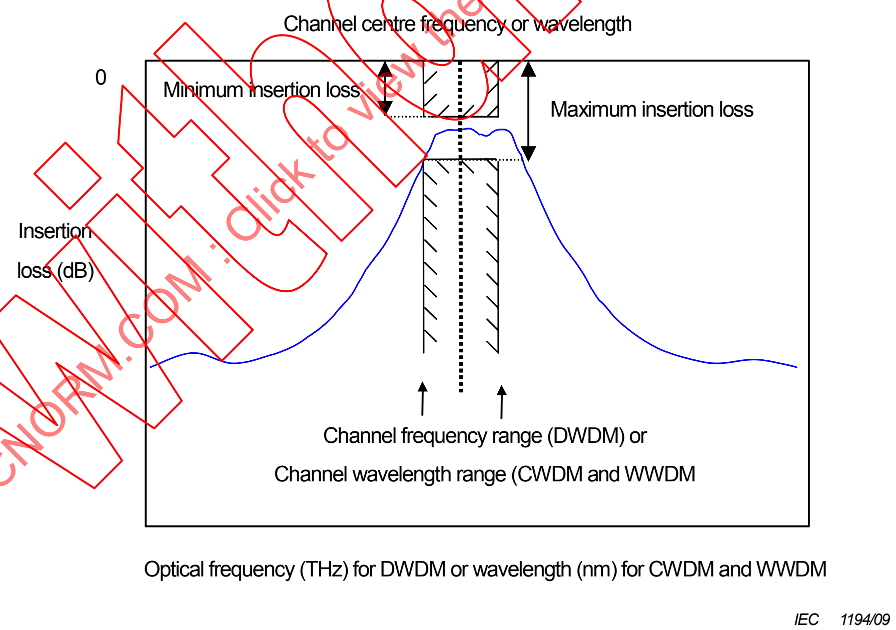


Figure 7 – Illustration of minimum and maximum insertion loss

3.3.19
isolation wavelength
for a pair of ports *i* and *j* (where $i \neq j$), that are conducting ports at a wavelength λ_h, a nominal wavelength λ_k (where $\lambda_h \neq \lambda_k$), that is an operating wavelength for a different pair of ports, at which *i* and *j* are isolated ports (refer to Figure 8 below)

NOTE Isolation frequency is also used for DWDM device.

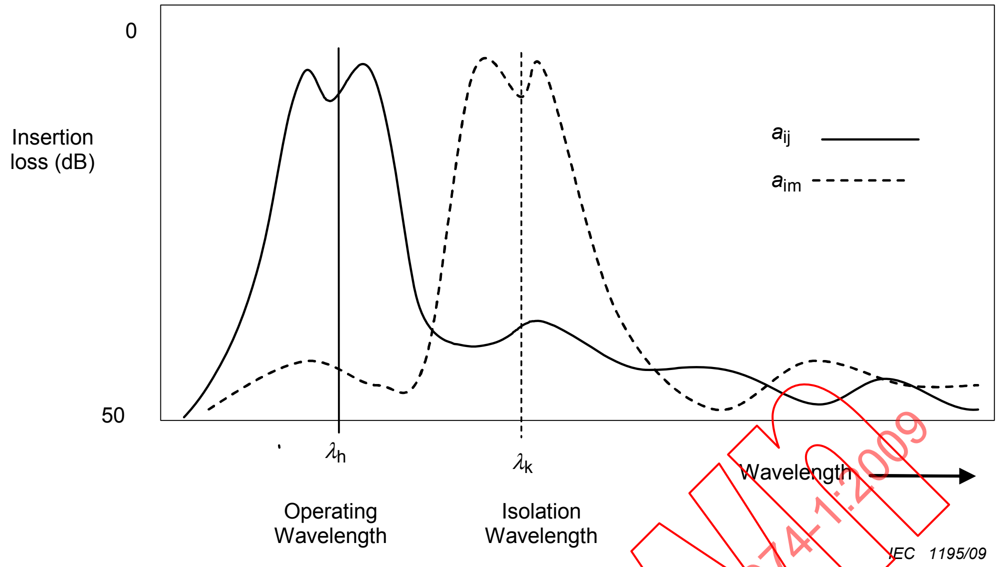


Figure 8 – Illustration of isolation wavelength

3.3.20
isolation wavelength range
for a pair of ports *i* and *j* that are conducting ports at wavelength λ_h, the range of wavelengths from λ_{kmin} to λ_{kmax} centred about an operating wavelength λ_k that is an operating wavelength for a different pair of ports but at which *i* and *j* are isolated ports (refer to Figure 9 below)

NOTE Isolation frequency range is also used for DWDM device.

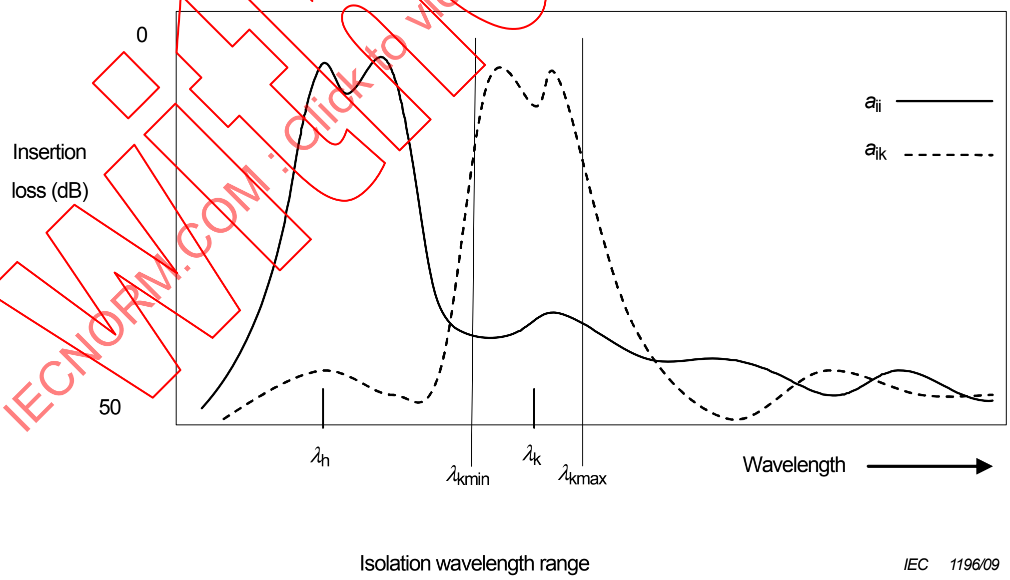


Figure 9 – Illustration of isolation wavelength range

3.3.21
minimum adjacent channel isolation
difference between the minimum peak of a_{ij} in the operating wavelength (or frequency) range and the maximum value of a_{ij} in a specified range of wavelengths (or frequencies) from λ_{kmin} to λ_{kmax} centred about an isolation wavelength (or frequency) λ_k for any two ports *i* and *j*, λ_{kmin}

and λ_{kmax} defining an operating wavelength (or frequency) range for a different pair of ports for which λ_k is an operating wavelength (or frequency). (Refer to Figure 10 below)

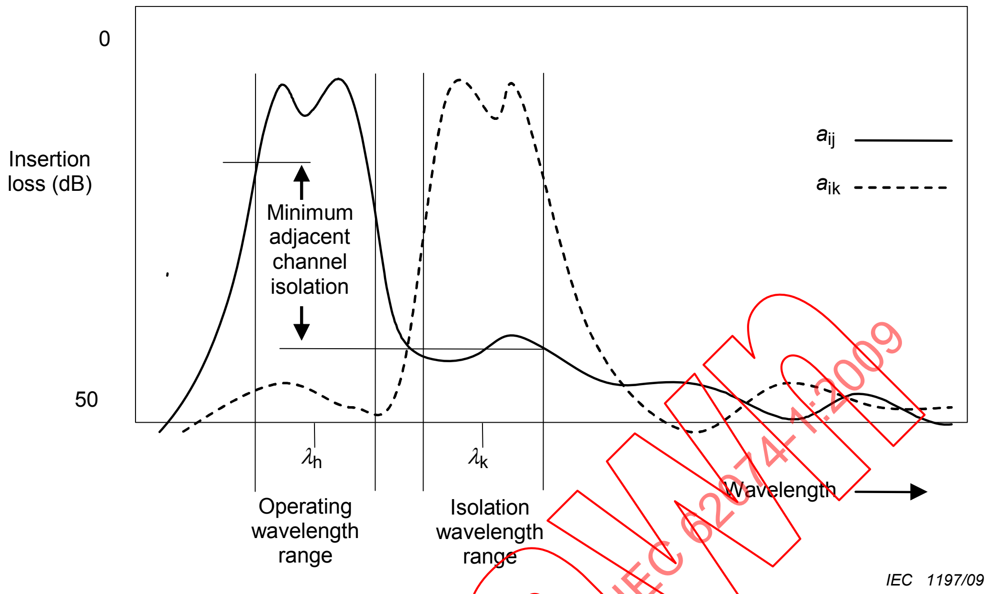


Figure 10 – Illustration of maximum adjacent channel isolation

3.3.22
maximum total channel isolation
for any two ports *i* and *j* (where $i \neq j$) the worst case of the cumulative isolation due to the maximum spectral contributions about all the isolation wavelengths (frequencies) is defined as:

$$I_{tot}^{max} = -10 \cdot Log\left[\frac{t_{ij}(\lambda_h^*)}{\sum_{k(k\neq h)}^{N} t_{ij}(\lambda_k^*)}\right]$$

where

N is the number of channels of the device;

λ_h^* is the wavelength (frequency) corresponding to the minimum peak of t_{ij} in the operating wavelength (frequency) range for the pair of ports *i* and *j*;

λ_k^* are the wavelengths (frequencies) corresponding to the maximum value of t_{ij} in the specified ranges of wavelengths (frequencies) from λ_{kmin} to λ_{kmax} about the isolation wavelengths (frequencies) λ_k for the pair of ports *i* and *j*, λ_{kmin} and λ_{kmax} defining the operating wavelength (frequency) range for the pair of ports for which λ_k is an operating wavelength (frequency)

3.3.23
non-adjacent channel isolation
unidirectional (far-end) isolation with the restriction that the isolation wavelength (frequency) is restricted to each of the channels not immediately adjacent to the channel associated with port *o* (refer to Figure 11 below)

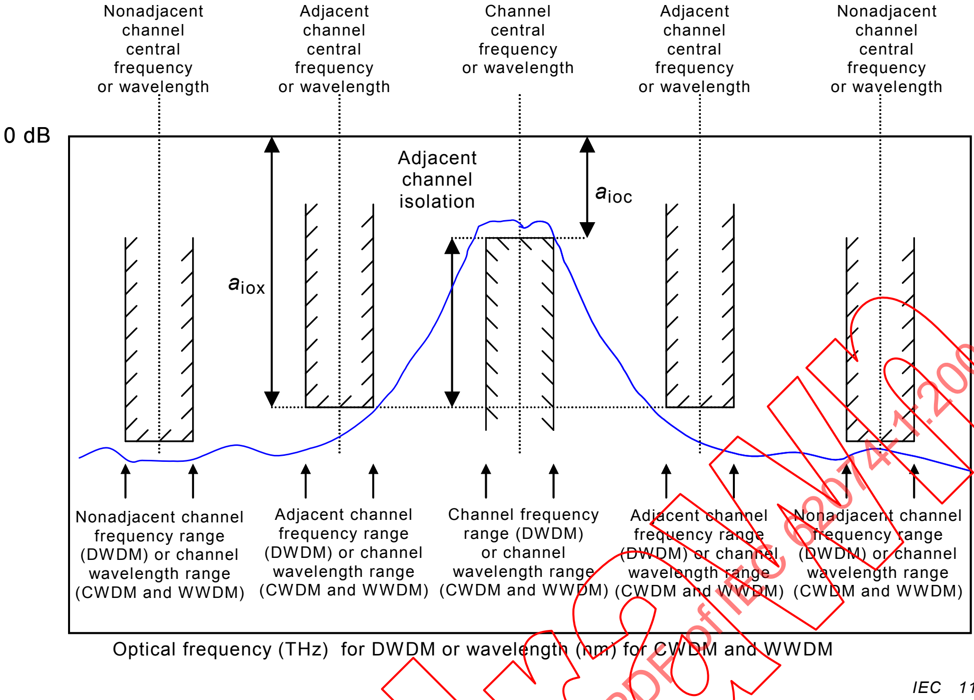


Figure 11 – Illustration of non-adjacent channel isolation

3.3.24
operating wavelength
nominal wavelength λ_h, at which a wavelength-selective branching device operates with the specified performance (refer to Figure 12 below)

NOTE Operating frequency is also used for DWDM device.

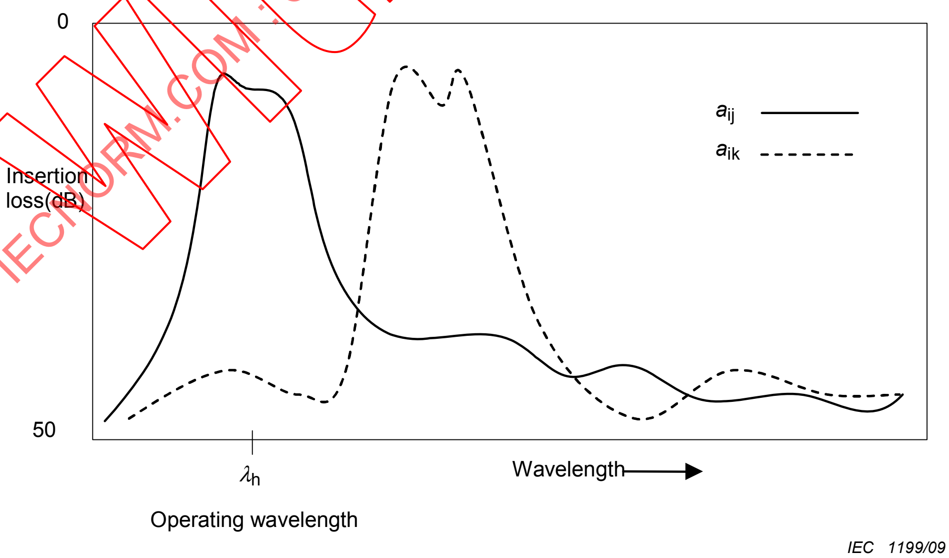


Figure 12 – Illustration of operating wavelength

3.3.25
operating wavelength range (passband, channel passband)
specified range of wavelengths from λ_{hmin} to λ_{hmax} centred about an operating wavelength λ_h, within which a wavelength-selective branching device operates with the specified performance (refer to Figure 13 below). A term “passband” or “channel passband” is used as same meaning of operating wavelength range for DWDM devices

NOTE 1 Channel frequency range is also used for DWDM device. It is the frequency range within which a DWDM device is required to operate with a specified performance. For a particular nominal channel centre frequency, f_{nomi}, this frequency range is from $f_{imin} = (f_{nomi} - \Delta f_{max})$ to $f_{imax} = (f_{nomi} + \Delta f_{max})$, where Δf_{max} is the maximum channel centre frequency deviation. Nominal channel centre frequency and maximum channel centre frequency deviation are system parameters defined for instance in ITU-T Recommendation G.692.

NOTE 2 Channel wavelength range is also used for CWDM. It is the wavelength range within which a CWDM device is required to operate with a specified performance. For a particular nominal channel centre wavelength, λ_{nomi}, this wavelength range is from $\lambda_{imin} = (\lambda_{nomi} - \Delta\lambda_{max})$ to $\lambda_{imax} = (\lambda_{nomi} + \Delta\lambda_{max})$, where $\Delta\lambda_{max}$ is the maximum channel wavelength deviation.

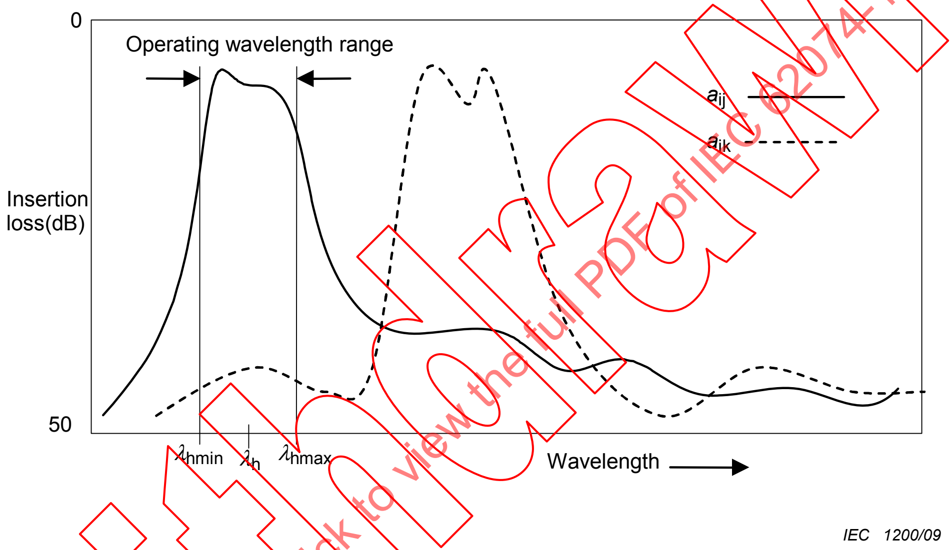


Figure 13 – Illustration of operating wavelength range

3.3.26
out-of-band attenuation
minimum attenuation (in dB) of channels that fall outside of the operating wavelength range

3.3.27
polarisation dependent centre wavelength (PDCW)
maximum variation of channel centre wavelength due to a variation of the state of polarisation (SOP) over all SOPs (refer to Figure 14 below)

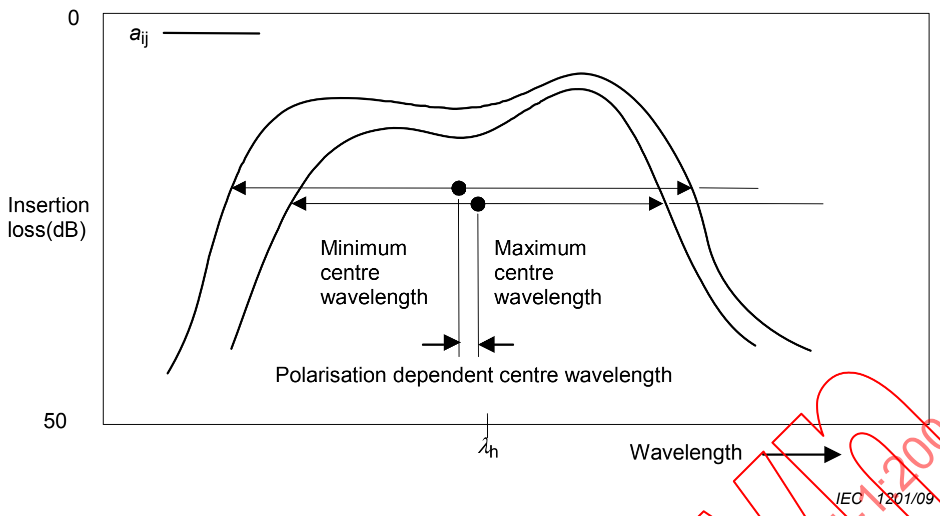


Figure 14 – Illustration of polarisation dependent centre wavelength (PDCW)

3.3.28
polarisation dependent isolation
PDI
maximum variation of isolation over all the states of polarisation

3.3.29
polarisation dependent loss
PDL
maximum variation of insertion loss due to a variation of the state of polarisation (SOP) over all the SOPs

3.3.30
polarisation dependent reflectance
maximum variation of reflectance due to a variation of the state of polarisation (SOP) over all SOPs

NOTE For DWDM device polarisation dependent centre frequency may also be used.

3.3.31
polarisation 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 polarisation (PSP), differential group delay (DGD), and/or to the waveform distortion for each PSP, is called PMD. PMD, together with polarisation dependent loss (PDL) and polarisation dependent gain (PDG), when applicable, may introduce waveform distortion leading to unacceptable bit error rate increase

NOTE PMD may depend on environmental conditions.

3.3.32
principal states of polarisation
PSP
at a given optical frequency (or wavelength), the two input (and orthogonal) states of polarisation (SOP) for which the corresponding output SOP are independent of optical frequency to first order.

In absence of PDL, the PSPs are orthogonal SOPs with the fast axis PSP having the shortest arrival time and the slow axis PSP having the longest, the DGD being the difference between these two arrival times

NOTE 1 An optical fibre, component or subsystem is typically characterized by two PSPs that are an intrinsic function of the material birefringence and the induced external and internal stresses acting on it.

NOTE 2 The DGD between these two PSPs can vary with time and wavelength.

NOTE 3 A signal whose SOP is aligned with one of the PSPs will be unaffected by the amount of PMD, at least to first order.

3.3.33
return loss
value of a_{ij} (where i = j) at the operating wavelength. It is the fraction of input power that is returned from the input port of a passive component expressed in decibels. It is defined as:

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

where

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

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

NOTE 1 For WWDM devices, it should be specified as a minimum value at each operating wavelength range. For CWDM devices, it should be specified as a minimum value within the channel wavelength range. For DWDM devices, it should be specified as a minimum value within the channel frequency range.

NOTE 2 Return loss is also a system/network parameter and has a positive sign; reflectance may also be a component (for instance in the context of a network element) or interface parameter and has a negative sign.

NOTE 3 Return loss as well as reflectance may have a wavelength dependency.

3.3.34
passband ripple
maximum peak to peak variation of the insertion loss over the bandpass (within a channel frequency or wavelength range) (refer to Figure 15 below)

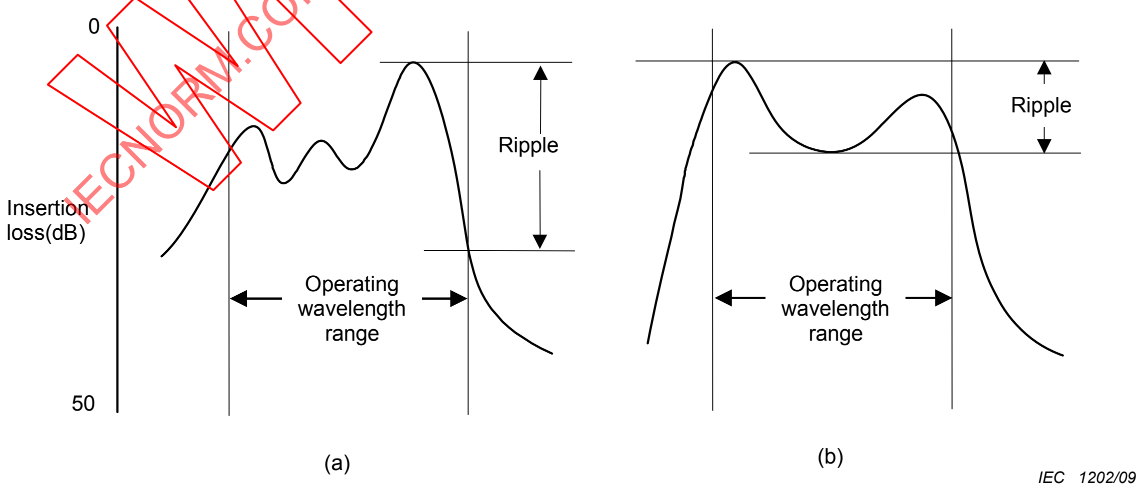


Figure 15 – Illustration of ripple (a) at the band edges and (b) in-band

3.3.35
total channel isolation
for any two ports *i* and *j* (where $i \neq j$) it is the cumulative isolation due to the contributions at all the isolation wavelengths (frequencies). It is defined as:

$$I_{\text{tot}} = -10 \cdot Log\left[\frac{t_{ij}(\lambda_h)}{\sum_{k(k \neq h)}^{N} t_{ij}(\lambda_k)}\right]$$

where

N is the number of channels of the device;

λ_h is the operating wavelength (frequency) for the couple of port *i* and *j*;

λ_k are the isolation wavelengths (frequencies) for the same pair of ports.

3.3.36
wavelength dependent loss
maximum variation of the insertion loss over operating wavelength range

3.3.37
wavelength isolation
value of a_{ij} (logarithmic transfer coefficient, where $i \neq j$) at the isolation wavelength range

3.3.38
X-dB bandwidth
it is defined through the spectral dependence of a_{ij} (where $i \neq j$) as the minimum wavelength range centred about the operating wavelength λ_h within which the variation of a_{ij} is less than "X" dB. The minimum wavelength range is determined considering thermal wavelength shift, polarisation dependence and long term aging shift (refer to Figure 16 below)

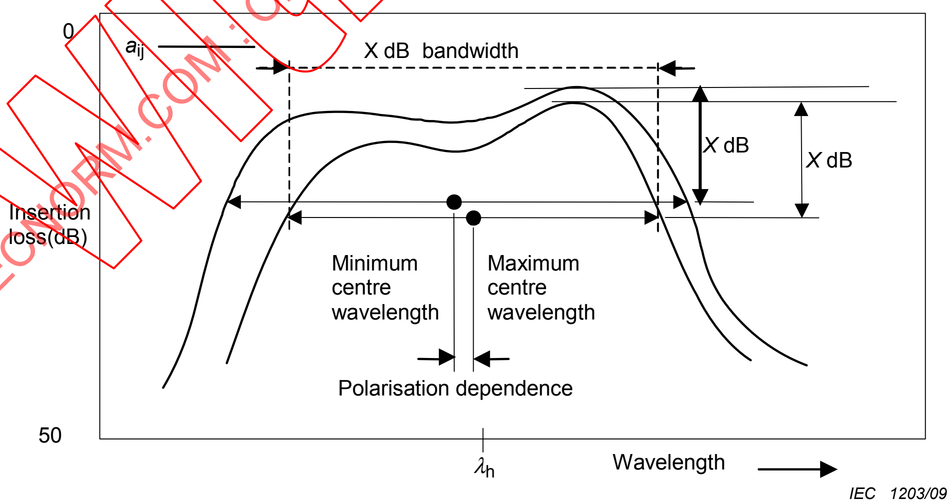


Figure 16 – Illustration of X-dB bandwidth

NOTE For a wavelength-selective branching device, the operating wavelength range and the X-dB bandwidth corresponding to different operating wavelengths are not necessarily equal.

4 Requirements

4.1 Classification

4.1.1 General

Fibre optic WDM devices shall be classified as follows:

- type;
- style;
- variant;
- environmental category;
- assessment level;
- extensions.

4.1.2 Type

Each type is defined in terms of a schematic diagram and a general form of transfer matrix as shown in the examples given in Annex A, which include:

- wavelength multiplexer;
- wavelength demultiplexer;
- wavelength multiplexer and demultiplexer;
- wavelength router;
- wavelength channel add/drop.

The main characteristics of each type are as follows:

- transmissive or reflective;
- bidirectional or unidirectional;
- tree or star;
- any combination of the above;
- active temperature control or passively compensated .

4.1.3 Style

Fibre optic WDM devices may be classified into styles based on the fibre type(s), the connector type(s), cable type(s), housing shape and the configuration. The configurations of branching device ports are classified as follows:

Configuration A

A device containing integral fibre optic pigtails, without connectors (see Figure 17).

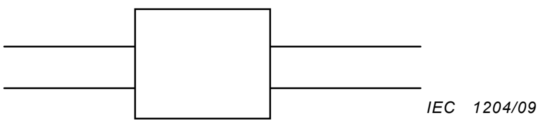


Figure 17 – Wavelength-selective branching device

Configuration B

A device containing integral fibre optic pigtails, with a connector on each pigtail (see Figure 18).

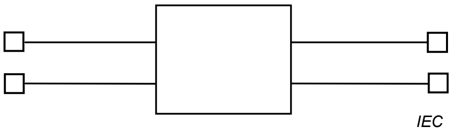


Figure 18 – Wavelength-selective branching device

Configuration C

A device containing fibre optic connectors as an integral part of the device housing (see Figure 19).

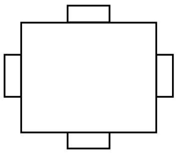


Figure 19 – Wavelength-selective branching device

Configuration D

A device containing some combination of the interfacing features of the preceding configurations (see Figure 20).

Figure 20 – Wavelength-selective branching device

4.1.4 Variant

The wavelength-selective branching device variant identifies those common features which encompass structurally similar components.

Examples of features which define a variant include, but are not limited to the following:

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

4.1.5 Assessment level

Relevant specifications shall specify one or more assessment levels, each of which shall be designated by a capital letter. The assessment level defines the relationship between groups A and B inspection levels and groups C and D inspection periods.

The following are the 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.

AQL is acceptable quality level.

One additional assessment level (other than those specified above) can be given in the relevant specification. When this is done, the capital letter X shall be used.

NOTE Groups A and B are subject to lot-by-lot inspection. Groups C and D are subject to periodic inspection.

4.1.6 Normative reference extension

Other documents may be referenced.

4.2 Documentation

4.2.1 Symbols

Graphical and letter symbols shall, whenever possible, be taken from IEC 60027 and IEC 60617.

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 WDM devices.

Table 1 – Three-level IEC specification structure

Specification level	Examples of information to be included	Applicable to
Basic	Assessment system rules Inspection rules Optical measuring methods Environmental test methods Sampling plans Identification rules Marking standards Dimensional standards Terminology standards Symbol standards Preferred number series SI units	Two or more component families or subfamilies
Generic	Specific terminology Specific symbols Specific units Preferred values Marking Quality assessment procedures	Component family

Specification level	Examples of information to be included	Applicable to
	Selection of tests Qualification approval and/or Capability approval procedures	
Relevant	Individual values Specific information Completed quality conformance test schedules	Individual type

Relevant specifications

A specific wavelength-selective branching device is described by a corresponding relevant specification. Within the constraints imposed by this generic specification, the relevant specification may be prepared by any national committee of the IEC, thereby defining a particular wavelength-selective branching device design as an IEC standard.

Relevant specifications shall specify the following as applicable:

- type (see 4.1.2);
- style (see 4.1.3);
- variant (s) (see 4.1.4);
- assessment level (see 4.1.5);
- variant identification number (s) (see 4.6.2);
- performance requirements (see 4.5).

4.2.3 Drawings

4.2.3.1 General

The drawings and dimensions given in relevant specifications shall not restrict details of construction, nor shall they 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 129-1, ISO 286-1 and ISO 1101.

The metric system shall be used in all specifications.

Dimensions shall not contain more than five significant digits.

Conversion between systems of units shall be according to ISO 370. When units are converted, a note shall be added in each relevant specification.

4.2.4 Measurements

4.2.4.1 Measurement method

The measurement method to be used shall be specified in the relevant specification for any 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 data sheets

Test data sheets 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 of test and date;
- specimen description including the type of fibre and the variant identification number;
- test equipment used and date of latest calibration;
- all applicable test details;
- all measurement values and observations;
- sufficiently detailed documentation to provide traceable information for failure analysis.

4.2.6 Instructions for use

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

4.3 Standardization system

4.3.1 Performance standards

Performance standards contain a series of set 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/fall criteria. The tests are intended to be run on a "once-off" basis to prove any products ability to satisfy the "performance standards" requirement. Each performance standard has a different set of tests, and or severities (and or groupings) represents 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 performance standards is the selection of test and severities from the tests and measurements standards, for application in conjunction with interface standards on inter product compatibility (this particularly relates to attenuation and return loss). Certainly conformance of each individual product to this standard will be ensured.

4.3.2 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 need to be identified (and appear in the reliability 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.

Initially, just after component manufacture, there is an "infant mortality phase" during which many components would fail if they were deployed in the field. To avoid early field failure, all components may be subjected to screen 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 duration and severity to accelerate the failure mechanisms.

A reliability theory relates component reliability testing to component parameters and to lifetime or failure rate are 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.

4.3.3 Interlinking

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 other options available for product standardisation.

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

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

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

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 the test in IEC 60695-11-5 shall be cited as reference.

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 will affect life, serviceability, or appearance. Particular attention shall be given to neatness and thoroughness of marking, plating, soldering, bonding, etc.

4.5 Performance requirements

Fibre optic WDM devices shall meet the performance requirements specified in appropriate IEC performance standard.

4.6 Identification and marking

4.6.1 General

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

4.6.2 Variant identification number

Each variant in a relevant specification shall be assigned a unique identification number. This number shall be set out as follows:

- relevant specification number;
- a three digit variant number;
- a letter indicating assessment level.

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 fibre optic WDM devices may be packed 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);
e) the type designation (see 4.1.2);
f) the assessment level;
g) 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 Safety

Fibre optic WDM devices, 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 fibre optic WDM devices manufacturers shall make available 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 of output level.

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

Annex A
(informative)

Transfer matrix

A.1 General

The optical properties of a fibre optic wavelength-selective branching device can be defined in terms of an n x n matrix of coefficients, where n is the number of ports, and the coefficients represent the fractional optical power transferred between designated ports. Figure A.1 shows the one example of six port device which has two input ports and four output ports. The ports are numbered sequentially. So, the possible combinations of two ports are six by six, total 36 combinations. These 36 combinations are expressed by a matrix.

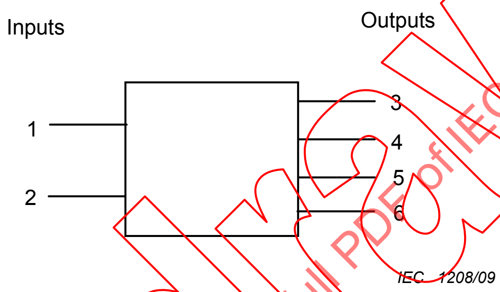


Figure A.1 – Example of a six-port device, with two-input and four-output ports

A.2 Transfer matrix

In general, the transfer matrix T is:

$$T = \begin{bmatrix} t_{11} & t_{12} & \cdot & \cdot & \cdot & t_{1n} \\ t_{21} & & & & & \\ \cdot & & & & & \\ \cdot & & & t_{ij} & & \\ \cdot & & & & & \\ t_{n1} & & & & & t_{nn} \end{bmatrix}$$

where

t_{ij} is the ratio of the optical power P_{ij} transferred out of port j (output port) with respect to input power P_i into port i (input port), that is:

$$t_{ij} = P_{ij} / P_i$$

t_{ij} is a number more than zero, and less than or equal to one ($0 \le t_{ij} \le 1$). In a wavelength-selective branching device, the coefficient t_{ij} is a function of the wavelength and may be a function of the input polarisation or modal power distribution.

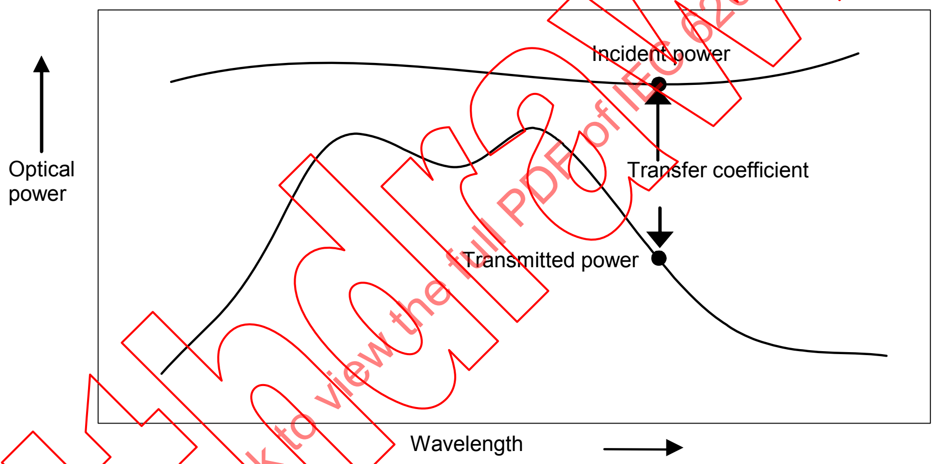
Single-mode fibre optic WDM devices may operate in a coherent fashion with respect to multiple inputs. Consequently, the transfer coefficients may be affected by the relative phase and intensity of simultaneous coherent optical power inputs at two or more ports.

The wavelength dependency of the transfer matrix coefficient should be considered. A matrix coefficient may be expressed as t_{ijk}, where k is the wavelength number, λ_k. For more generic expression, the transfer matrix is shown as follows.

$$T = \left[\begin{bmatrix} t_{111} & t_{121} & . & t_{1n1} \\ t_{211} & t_{221} & . & t_{2n1} \\ . & . & . & . \\ t_{n11} & t_{n21} & . & t_{nn1} \end{bmatrix}, \begin{bmatrix} t_{112} & t_{122} & . & t_{1n2} \\ t_{212} & t_{222} & . & t_{2n2} \\ . & . & . & . \\ t_{n12} & t_{n22} & . & t_{nn2} \end{bmatrix}, \ldots\ldots\ldots\ldots\ldots \begin{bmatrix} t_{11k} & t_{12k} & . & t_{1nk} \\ t_{21k} & t_{22k} & . & t_{2nk} \\ . & . & . & . \\ t_{n1k} & t_{n1k} & . & t_{nnk} \end{bmatrix} \right]$$

A.3 Transfer matrix coefficient

An element t_{ij} of the transfer matrix (refer to Figure A.2 below).



IEC 1209/09

Figure A.2 – Illustration of transfer matrix coefficient

A.4 Logarithmic transfer matrix

In general, the logarithmic transfer matrix is:

$$A = \begin{bmatrix} a_{11} & a_{12} & . & . & . & a_{1n} \\ a_{21} & & & & & \\ . & & & & & \\ . & & & a_{ij} & & \\ . & & & & & \\ a_{n1} & & & & & a_{nn} \end{bmatrix}$$

where

a_{ij} is the optical power reduction in decibels out of port j with unit power into port i, that is:

$$a_{ij} = -10 \log t_{ij}$$