

# PUBLICLY AVAILABLE SPECIFICATION PRE-STANDARD

Fibre optic WDM devices –  
Part 1: Generic specification

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**Fibre optic WDM devices –  
Part 1: Generic specification**

INTERNATIONAL  
ELECTROTECHNICAL  
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## FIBRE OPTIC WDM DEVICES –

### Part 1: Generic specification

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The text of this PAS is based on the following document:

This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document:

Draft PAS	Report on voting
86B/2516/NP	86B/2557/RVN

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## FIBRE OPTIC WDM DEVICES –

### Part 1: Generic specification

#### 1 Scope

This PAS 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 but only with the purpose of stabilizing device characteristics; 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 document establishes uniform requirements for the following:

- Optical, mechanical and environmental properties.
- Measurement and test procedures for quality assessment.

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

IEC 61300-1 (all parts), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures*

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

IECQ 001002 (all parts), *IEC Quality Assessment System for Electronic Components (IECQ) – Rules of Procedure*

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

ISO 129, *Technical drawings – Indication of dimensions and tolerances – General principles*

ISO 286 (all parts), *ISO system of limits and fits*

ISO 370, *Toleranced dimensions - Conversion from inches into millimetres 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 definitions given in IEC 60050-731, as well as 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

The optical properties of a fibre optic wavelength-selective branching device can be defined in terms of an  $n \times n$  matrix of coefficients, where  $n$  is the number of ports, and the coefficients represent the fractional optical power transferred between designated ports. Figure 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.

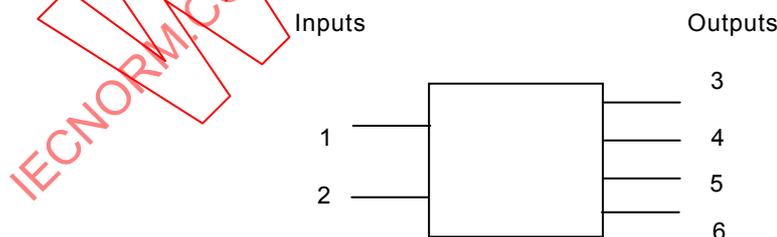


Figure 1 – Example of a six-port device, with two-input and four-output ports

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

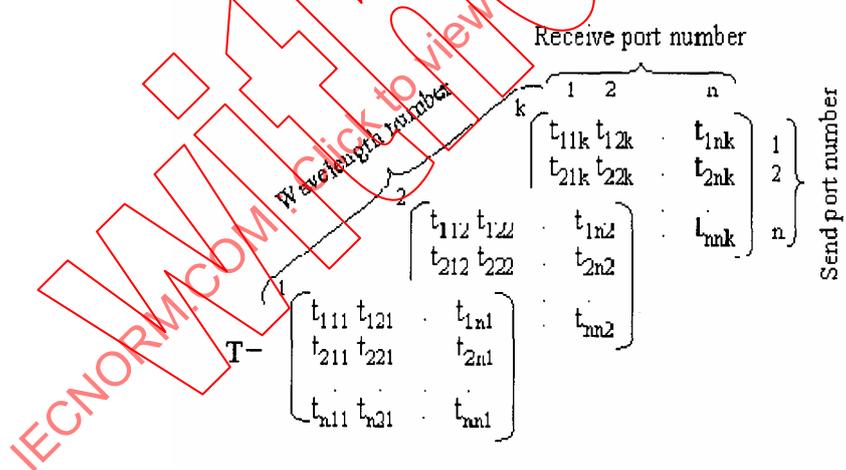
$t_{ij}$  is the ratio of the optical power  $P_{ij}$  transferred out of port  $j$  (output port) with respect to input power  $P_i$  into port  $i$  (input port), that is:

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

$t_{ij}$  is a number more than zero, and less than or equal to one ( $0 \leq t_{ij} \leq 1$ ). In a wavelength-selective branching device the coefficient  $t_{ij}$  is a function of the wavelength and may be a function of the input polarization 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,  $\lambda_k$ . For a more generic expression, the transfer matrix is shown as follows:



**3.1.3 transfer matrix coefficient**

an element  $t_{ij}$  of the transfer matrix (refer to Figure 2 below)



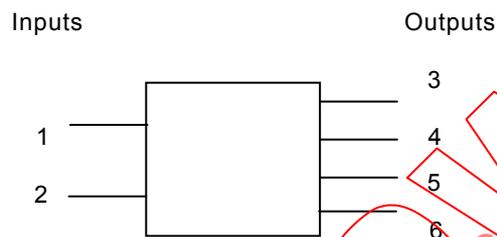
### 3.1.5 conducting ports

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  $k$  ( $a_{ik}$  nominally infinite)

NOTE Figure 3 below shows an example of a six-port device, with two input ports and four output ports. 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.



**Figure 3 – Example of a six-port device, with two-input and four-output ports**

For the example shown, if there are four operating wavelengths, then the resulting transfer matrix becomes a  $6 \times 6$  matrix: loss at  $\lambda_1$  from port 1 to port 6 would use  $a_{161}$ . Reflectance of port 2 at  $\lambda_4$  would use  $a_{224}$ . Loss from port 5 to port 2 at  $\lambda_3$  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 frequently used as a synonym for a wavelength-selective branching device

NOTE Depending on the spectral response, a WDM device may be defined either as :

- DWDM (dense WDM) device, if it is intended to operate for channel spacing equal or less than 1 000 GHz;
- CWDM (coarse WDM) device, if it 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);
- WWDM (Wide WDM) device, if it is intended to operate for channel spacing equal or greater than 50 nm.

**3.2.3****wavelength multiplexer****MUX**

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

**3.2.4****wavelength demultiplexer****DEMUX**

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

**3.2.5****interleaver**

bidirectional DWDM which has three ports, and whose 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) value of the ratio between the optical power of the specified signal and all noises

**3.3.2****isolation**

(for WDM devices) 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 is isolated at every wavelength (or frequency for a dense WDM (DWDM) device)

NOTE  $a_{ij}$  is defined in 3.1.4.

**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 4 below. The adjacent channel crosstalk has the same meaning as adjacent channel isolation.

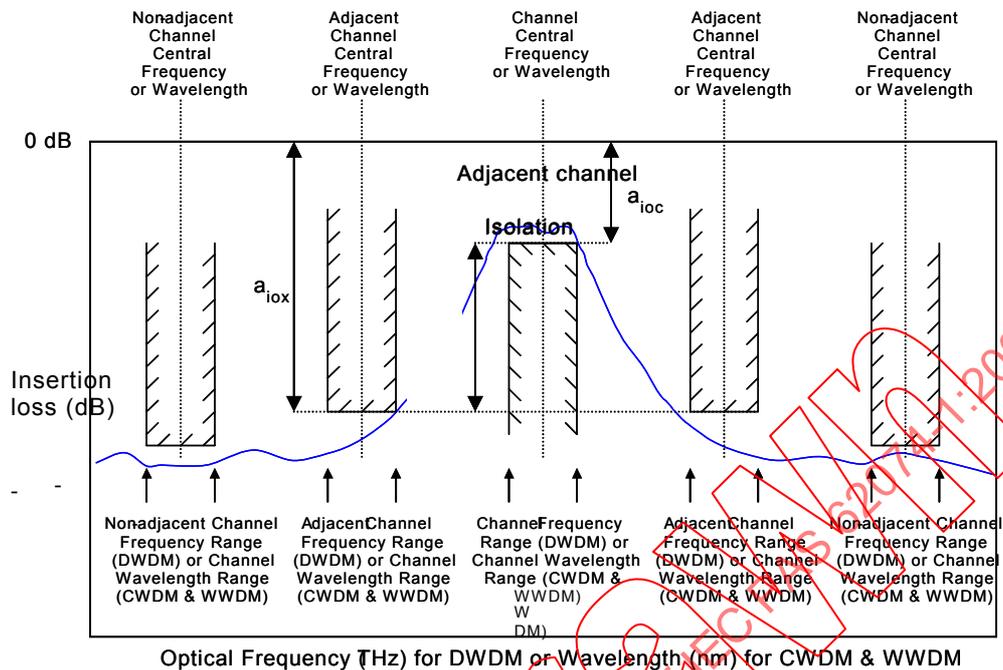


Figure 4 – Illustration of adjacent channel isolation

3.3.5

**bidirectional (near-end) crosstalk attenuation**

in a bidirectional WDM multiplexer (MUX)/demultiplexer (DMUX) device, the bidirectional (near-end) crosstalk attenuation is defined to be:

$$BCA = a_{mox}$$

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;

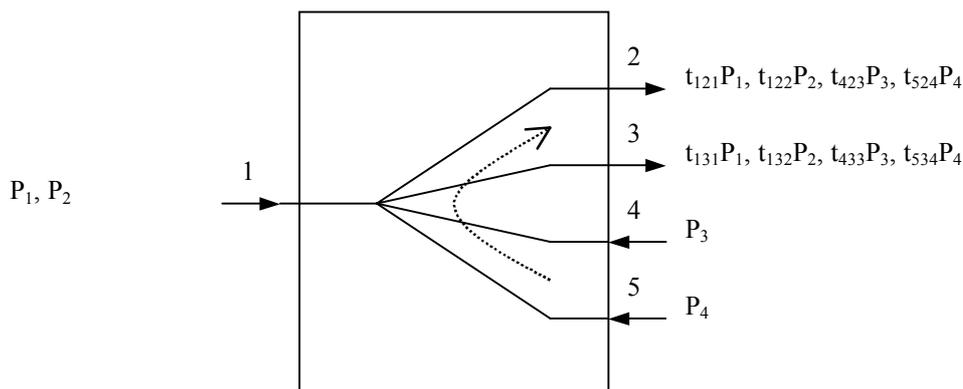
x is the wavelength number associated with port m.

3.3.6

**bidirectional (near-end) isolation**

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

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 5).



**Figure 5 – Illustration of a four-wavelength bidirectional system**

The bidirectional (near-end) isolation is therefore defined to be:

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

where

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

$a_{\text{doc}}$  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.

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

### 3.3.8

#### channel extinction

within the operating wavelength range, difference (in dB) between the minimum powers of the conducting channels (in dBm) and 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,  $f_{\text{nomi}}$ , this frequency range is from  $f_{\text{imin}} = (f_{\text{nomi}} - \Delta f_{\text{max}})$  to  $f_{\text{imax}} = (f_{\text{nomi}} + \Delta f_{\text{max}})$ , where  $\Delta f_{\text{max}}$  is the maximum channel centre frequency deviation. Nominal; channel centre frequency and maximum channel centre frequency deviation are defined in ITU-T Recommendation G.692.

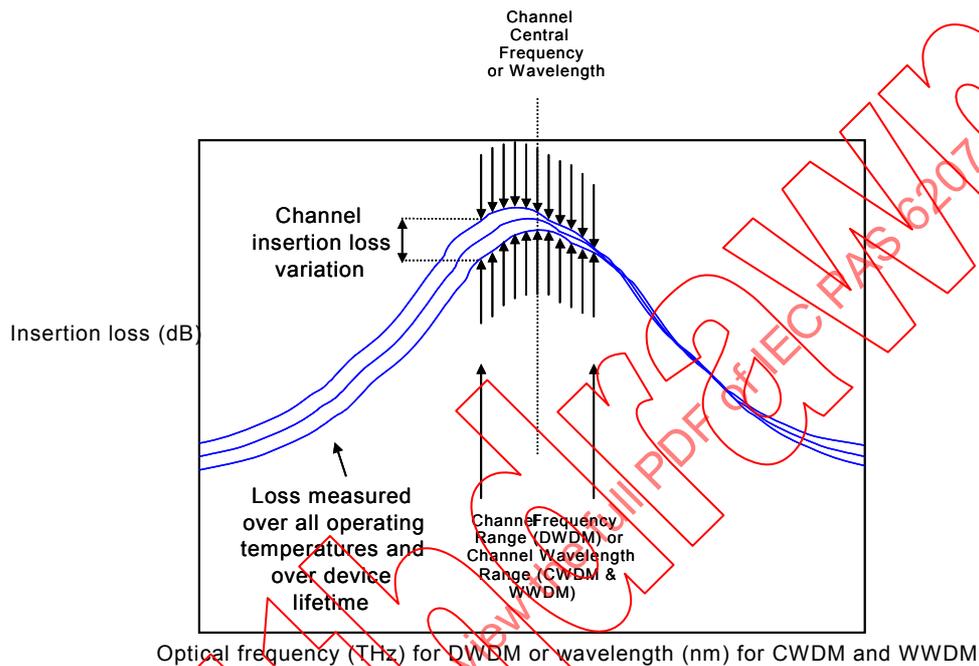
**3.3.10****channel insertion loss**

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

**3.3.11****channel insertion loss deviation**

maximum variation of insertion loss over 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) as illustrated in Figure 6 below.

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



**Figure 6 – Illustration of channel insertion loss variation**

**3.3.12****channel non-uniformity**

for a specified set of input ports, difference between maximum and 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,  $\lambda_{\text{nomi}}$ , this wavelength range from  $\lambda_{\text{imin}} = (\lambda_{\text{nomi}} - \Delta\lambda_{\text{max}})$  to  $\lambda_{\text{imax}} = (\lambda_{\text{nomi}} + \Delta\lambda_{\text{max}})$ , where  $\Delta\lambda_{\text{max}}$  is the maximum channel wavelength deviation.

**3.3.14****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

NOTE 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.

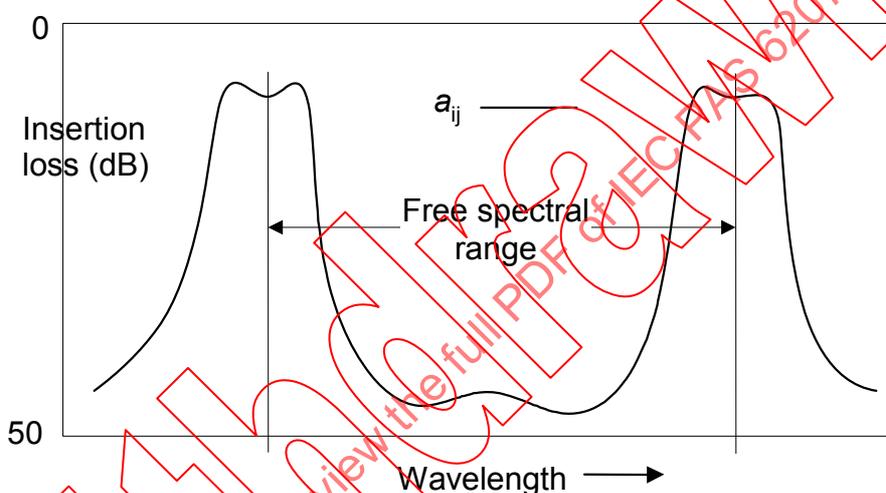
The slope of chromatic dispersion  $S$  (with units of  $\text{ps}/\text{nm}^2$  or  $\text{ps}/\text{GHz}^2$ ) corresponds to the variation (first order derivative) of  $D$  as a function of wavelength (or frequency) (or second order derivative of the group delay) over the operating wavelength (or frequency) 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).

**3.3.15**  
**directivity**

value of  $a_{ij}$  between two isolated ports which are isolated at every wavelength (or frequency for a DWDM device). For the example of 6 ports WDM devices shown in Figure 2, the directivity is  $a_{12}$  and  $a_{21}$  between two input ports, and  $a_{34}$ ,  $a_{43}$ , etc. between two output ports.

**3.3.16**  
**free spectral range**  
**FSR**

difference between two adjacent operating wavelengths for a given input output path (refer to Figure 7 below)



**Figure 7 – Illustration of free spectral range**

**3.3.17**  
**insertion loss**

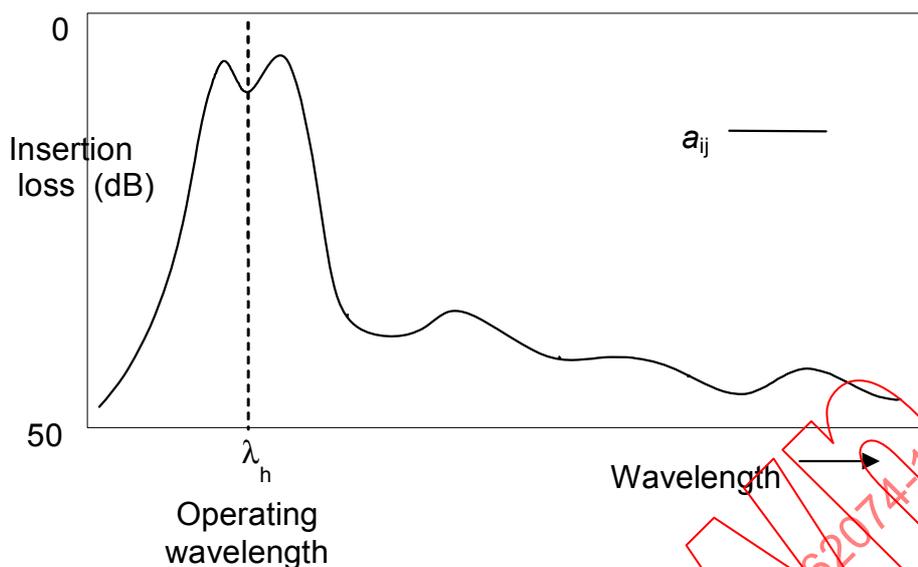
value of  $a_{ij}$  (where  $i \neq j$ ) at the operating wavelength between two conducting ports. It is the reduction in optical power between an input and output port of a passive component expressed in decibels, defined as:

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

where

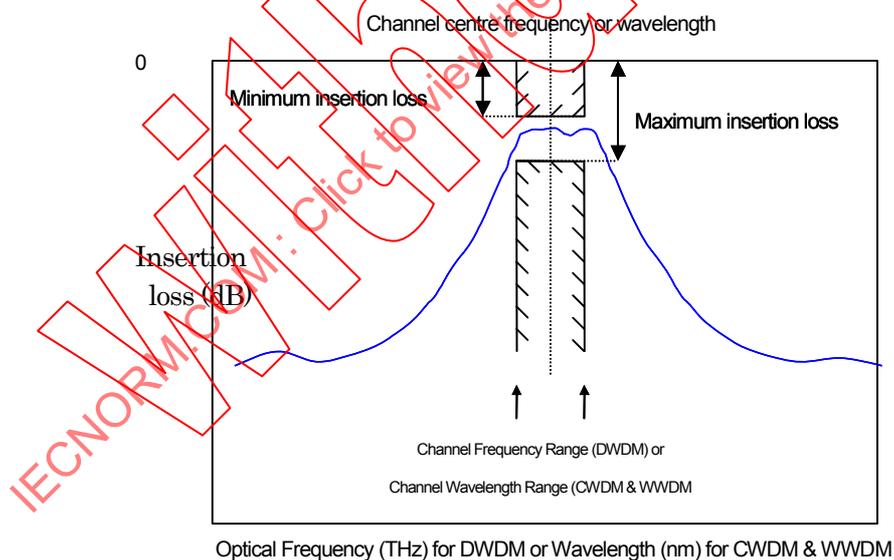
$P_{in}$  is the optical power launched into the input port;

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



**Figure 8 – Illustration of insertion loss**

For WWDM devices, it is specified as a maximum value and a minimum value at each operating wavelength range. For DWDM and CWDM devices, it is specified as a maximum value and a minimum value within the channel frequency (or wavelength) range as illustrated in Figure 9 below.



**Figure 9 – Illustration of minimum and maximum insertion loss**

### 3.3.18 isolation wavelength

For a pair of ports  $i$  and  $j$  (where  $i \neq j$ ), that are conducting ports at a wavelength  $\lambda_h$ , a nominal wavelength  $\lambda_k$  (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 10 below).

NOTE Isolation frequency is also used for DWDM device.

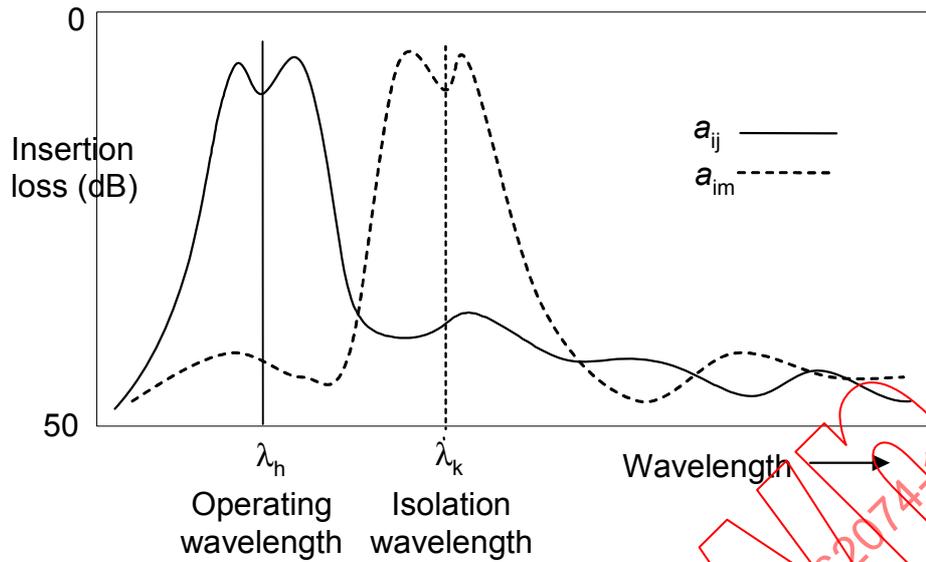


Figure 10 – Illustration of isolation wavelength

**3.3.19  
isolation wavelength range**

For a pair of ports i and j that are conducting ports at wavelength  $\lambda_h$ , the range of wavelengths from  $\lambda_{kmin}$  to  $\lambda_{kmax}$  centred about an operating wavelength  $\lambda_k$  that is an operating wavelength for a different pair of ports but at which i and j are isolated ports (refer to Figure 11 below).

NOTE Isolation frequency range is also used for the DWDM device.

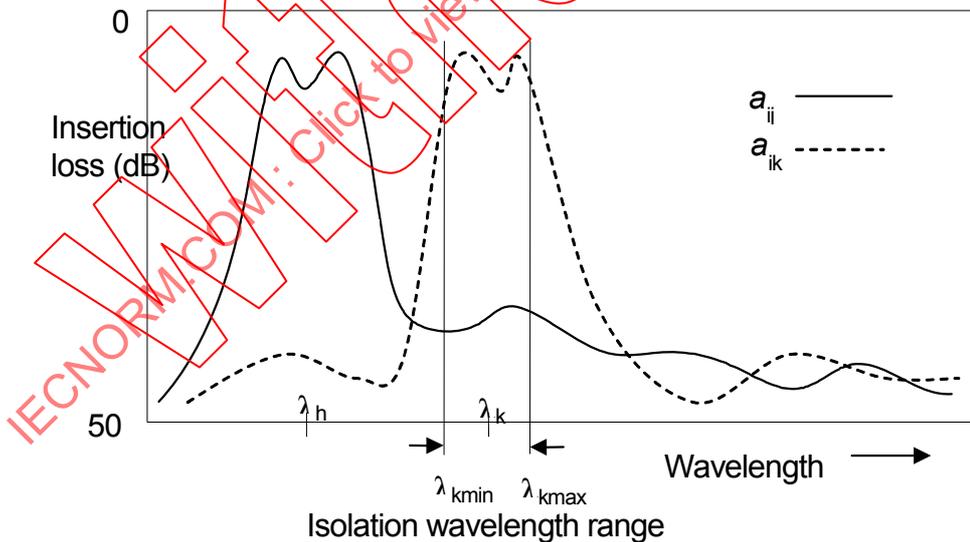


Figure 11 – Illustration of isolation wavelength range

**3.3.20  
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  $\lambda_{kmin}$  to  $\lambda_{kmax}$  centred about an isolation wavelength (or frequency)  $\lambda_k$  for any two ports i and j,  $\lambda_{kmin}$

and  $\lambda_{k\max}$  defining an operating wavelength (or frequency) range for a different pair of ports for which  $\lambda_k$  is an operating wavelength (or frequency). (Refer to Figure 12 below).

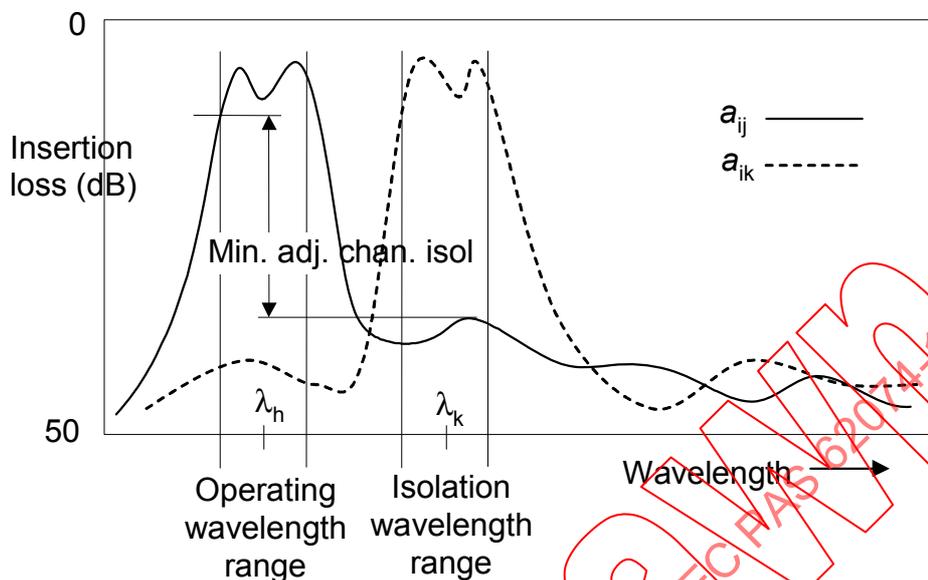


Figure 12 – Illustration of maximum adjacent channel isolation

### 3.3.21

#### 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:

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

where

$N$  is the number of channels of the device;

$\lambda_h^*$  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  $j$ ;

$\lambda_k^*$  are the wavelengths (frequencies) corresponding to the maximum value of  $t_{ij}$  in the specified ranges of wavelengths (frequencies) from  $\lambda_{k\min}$  to  $\lambda_{k\max}$  about the isolation wavelengths (frequencies)  $\lambda_k$  for the pair of ports  $i$  and  $j$ ,  $\lambda_{k\min}$  and  $\lambda_{k\max}$  defining the operating wavelength (frequency) range for the pair of ports for which  $\lambda_k$  is an operating wavelength (frequency).

### 3.3.22

#### 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 13 below).

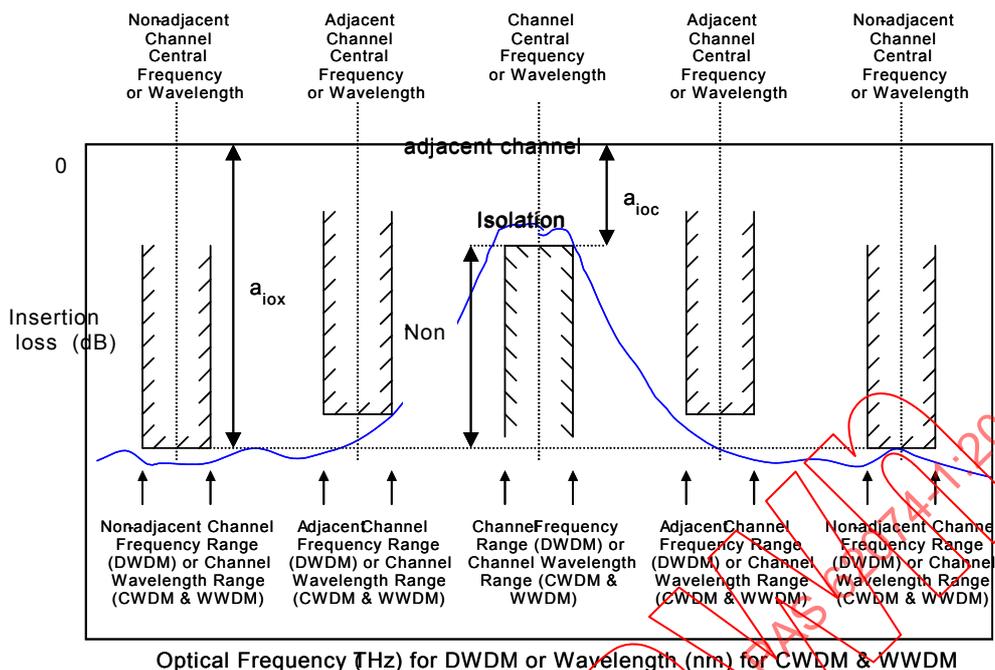


Figure 13 – Illustration of non-adjacent channel isolation

3.3.23

**operating wavelength**

nominal wavelength  $\lambda_h$ , at which a wavelength-selective branching device operates with the specified performance (refer to Figure 14 below)

NOTE Operating frequency is also used for DWDM device.

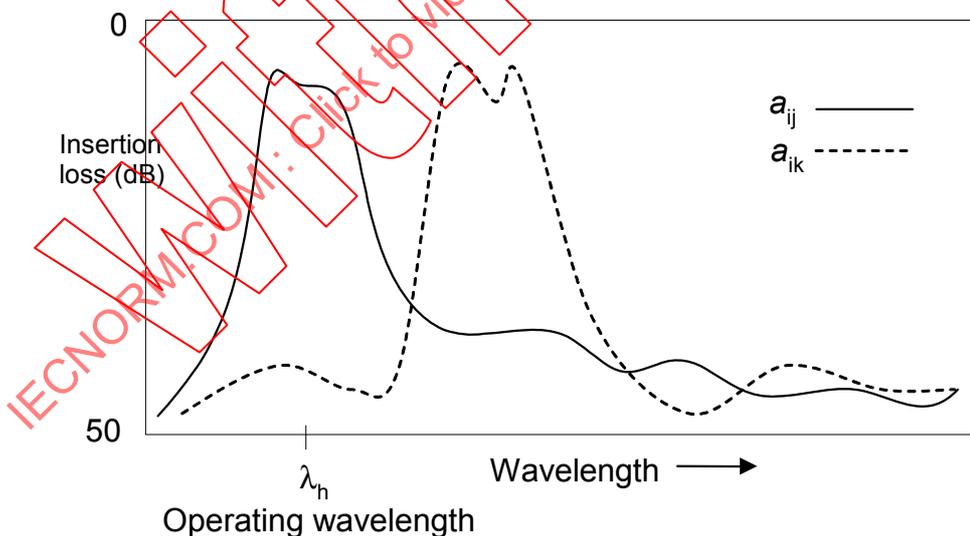


Figure 14 – Illustration of operating wavelength

3.3.24

**operating wavelength range**

passband, channel passband  
 specified range of wavelengths from  $\lambda_{hmin}$  to  $\lambda_{hmax}$  centred about an operating wavelength  $\lambda_h$ , within which a wavelength-selective branching device operates with the specified performance (refer to Figure 15 below)

NOTE 1 Term “passband” or “channel passband” is used as same meaning of operating wavelength range for DWDM devices.

NOTE 2 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  $\Delta f_{max}$  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 3 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,  $\lambda_{nomi}$ , 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.

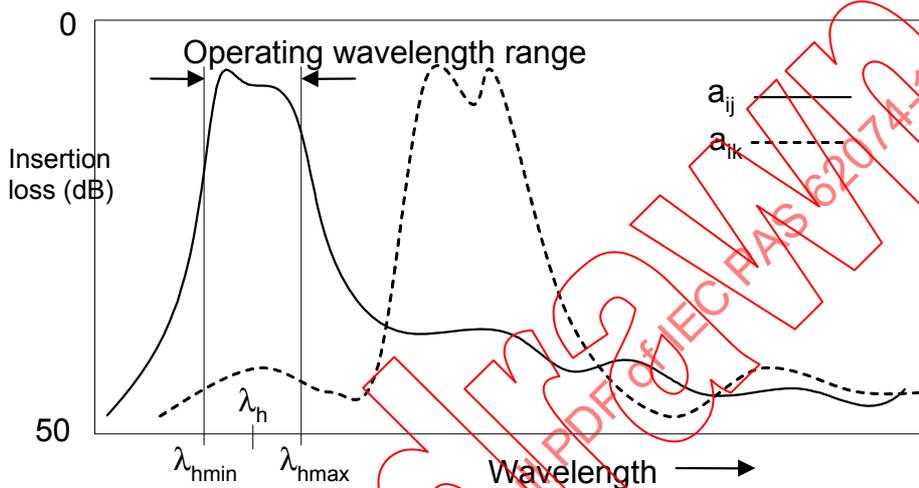


Figure 15 – Illustration of operating wavelength range

3.3.25

**out-of-band attenuation**

minimum attenuation (in dB) of channels that fall outside of the operating wavelength range

3.3.26

**polarization dependent centre wavelength (PDCW)**

maximum variation of channel centre wavelength due to a variation of the state of polarization (SOP) over all SOPs (refer to Figure 16 below).

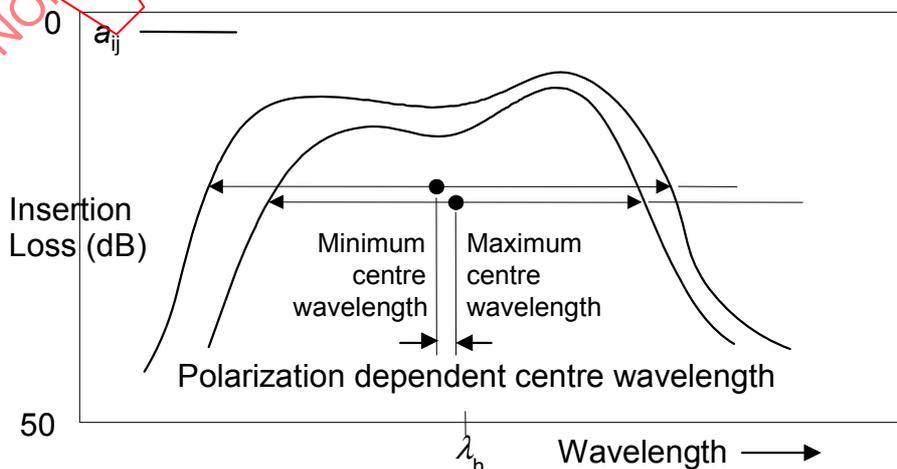


Figure 16 – Illustration of polarization dependent centre wavelength (PDCW)

### 3.3.27

#### **polarization dependent isolation**

##### **PDI**

maximum variation of isolation over all the states of polarization

### 3.3.28

#### **polarization dependent loss**

##### **PDL**

maximum variation of insertion loss due to a variation of the state of polarization (SOP) over all the SOPs

### 3.3.29

#### **polarization dependent reflectance**

maximum variation of reflectance due to a variation of the state of polarization (SOP) over all SOPs

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

### 3.3.30

#### **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 r.m.s. 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

NOTE 1 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.

NOTE 2 PMD may depend on environmental conditions.

### 3.3.31

#### **principal states of polarization**

##### **PSP**

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

NOTE 1 In the 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 2 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 3 The DGD between these two PSPs can vary with time and wavelength.

NOTE 4 A signal whose SOP is aligned with one of the PSPs will be unaffected by the amount of PMD, at least to first order.

### 3.3.32

#### **return loss**

The 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:

$$RL = -10 \log \frac{P_{refl}}{P_{in}}$$

where

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

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

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

NOTE 1 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 2 Return loss as well as reflectance may have a wavelength dependency.

### 3.3.33

#### passband ripple

maximum peak-to-peak variation of the insertion loss over the bandpass (within a channel frequency or wavelength range) (refer to Figure 17 below)

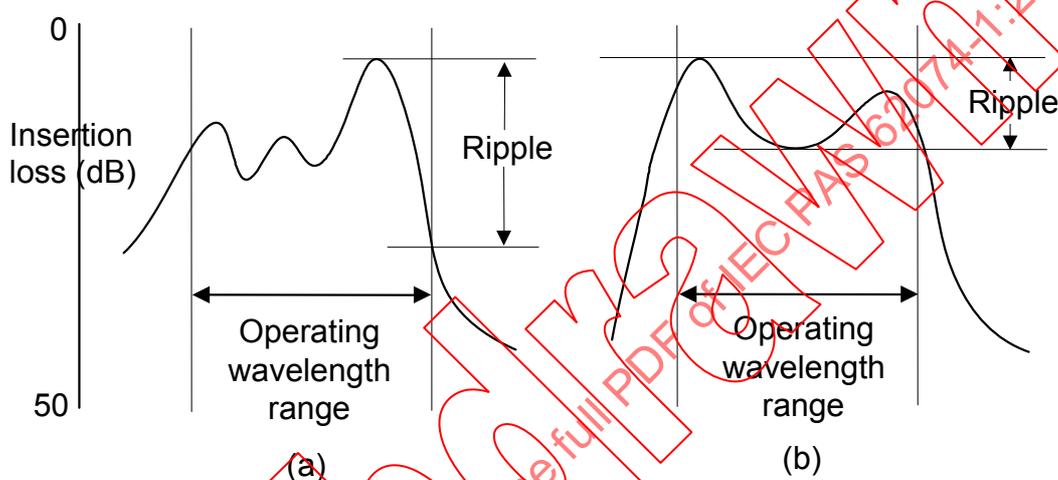


Figure 17a – At the band edges

Figure 17b – In-band

Figure 17 – Illustration of ripple

### 3.3.34

#### 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:

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

where

$N$  is the number of channels of the device;

$\lambda_h$  is the operating wavelength (frequency) for the couple of port  $i$  and  $j$ ;

$\lambda_k$  are the isolation wavelengths (frequencies) for the same pair of ports.

**3.3.35**

**wavelength dependent loss**

maximum variation of the insertion loss over operating wavelength range

**3.3.36**

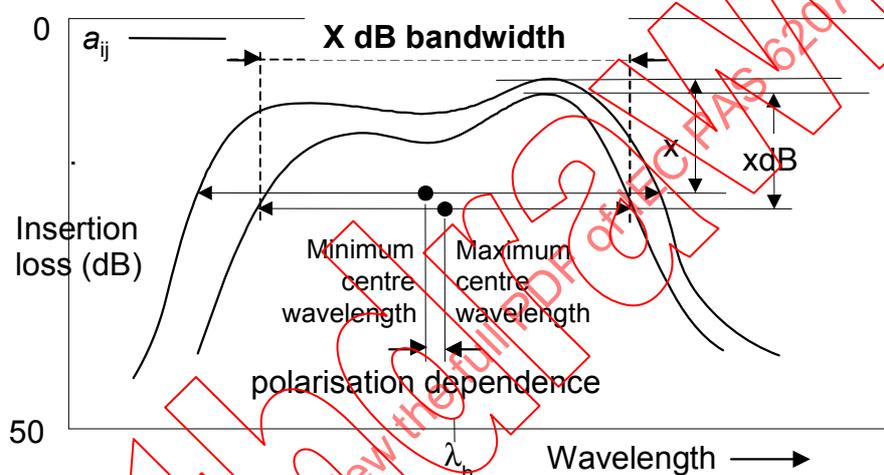
**wavelength isolation**

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

**3.3.37**

**X-dB bandwidth**

spectral dependence of  $a_{ij}$  (where  $i \neq j$ ) as the minimum wavelength range centred about the operating wavelength  $\lambda_h$  within which the variation of  $a_{ij}$  is less than “X” dB. The minimum wavelength range is determined considering thermal wavelength shift, polarization dependence and long term aging shift (refer to Figure 18 below).



**Figure 18 – 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

The requirements for fibre optic WDM devices covered by this clause are intended to aid in classifying this device in a detail specification.

### 4.1 Classification

Fibre optic WDM devices shall be classified as follows:

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

#### 4.1.1 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 .

#### 4.1.2 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:

##### 4.1.2.1 Configuration A

A device containing integral fibre optic pigtails, without connectors (see Figure 19).



Figure 19 – Wavelength-selective branching device

#### 4.1.2.2 Configuration B

A device containing integral fibre optic pigtails, with a connector on each pigtail (see Figure 20).



Figure 20 – Wavelength-selective branching device

#### 4.1.2.3 Configuration C

A device containing fibre optic connectors as an integral part of the device housing (see Figure 21).

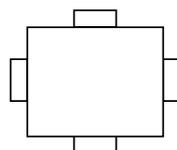


Figure 21 – Wavelength-selective branching device

#### 4.1.2.4 Configuration D

A device containing some combination of the interfacing features of the preceding configurations (see Figure 22).



Figure 22 – Wavelength-selective branching device

#### 4.1.3 Variant

The wavelength-selective branching device variant identifies those common features which encompass structurally similar components (see 5.2).

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

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

#### 4.1.4 Assessment level

Detail 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 = acceptable quality level.

One additional assessment level (other than those specified above) can be given in the detail 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 (see 5.4)

**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 PAS is part of the IEC specification system. Subsidiary specifications shall consist of blank detail specifications and detail specifications. This system is shown in Table 1. There are no sectional specifications for WDM devices.

**4.2.2.1 Blank detail specifications**

The blank detail specification lists all of the parameters and features applicable to a wavelength-selective branching device, including the type, operating characteristics, housing configurations, test methods, and performance requirements. The blank detail specification is applicable to any wavelength-selective branching device design and quality assessment requirement. The blank detail specification contains the preferred format for stating the required information in the detail specification.

**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 rule 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 Selection of tests Qualification approval and/or Capability approval procedures	Component family
Blank detail	Quality conformance test schedule Inspection requirements Information common to a number of types	Groups of types having a common test schedule
Detail	Individual values Specific information Completed quality conformance test schedules	Individual type

#### 4.2.2.2 Detail specifications

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

Detail specifications shall specify the following as applicable:

- type (see 4.1.1);
- style (see 4.1.2);
- variant (s) (see 4.1.3);
- assessment level (see 4.1.4);
- variant identification number (s) (see 4.7.1);
- performance requirements (see 4.6).

#### 4.2.3 Drawings

The drawings and dimensions given in detail specifications shall not restrict details of construction, nor shall they be used as manufacturing drawings.

##### 4.2.3.1 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.

#### 4.2.3.2 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.

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

#### 4.2.4 Measurements

##### 4.2.4.1 Measurement method

The measurement method to be used shall be specified in the detail 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 (see 5.3.8) and in the periodic inspection report (see 5.4.2).

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 (see 4.7.1);
- 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 (see 5.3.6 and 5.4.2.).

##### 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/fail criteria. The tests are intended to be run on a “once-off” basis to prove any product’s 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

A large number of the test and measurements standards come under the banner of IECQ, which are already in place and have been used for many years. As previously mentioned, other alternative methods of Quality Assurance/Quality Conformance are being developed under the banners of Capacity Approval And Technology Approval which are covered by IECQ QC01, IECQ QC001002, 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 other options available for product standardization.

**Table 2 – Standards interlink matrix**

	Interface standard	Performance standard	Reliability standard
<b>Product A</b>	Yes	Yes	Yes
<b>Product B</b>	No	Yes	Yes
<b>Product C</b>	Yes	No	No
<b>Product D</b>	Yes	Yes	No

Product A is fully IEC standardized 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.

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 a national or company quality assurance system.

**Table 3 – Quality assurance options**

	Company A			Company B			Company C		
	QA	CA	TA	QA	CA	TA	QA	CA	TA
<b>Product A</b>	X			X					X
<b>Product B</b>	X				X				X
<b>Product C</b>	X				X				X
<b>Product D</b>	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 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 Quality

Fibre optic WDM devices shall be controlled by the quality assessment procedures of the IEC 61300 series (Parts 1, 2 and 3). The measurement and test procedures of clause 4 shall be used, as applicable, for quality assessment.

#### 4.6 Performance requirements

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

#### 4.7 Identification and marking

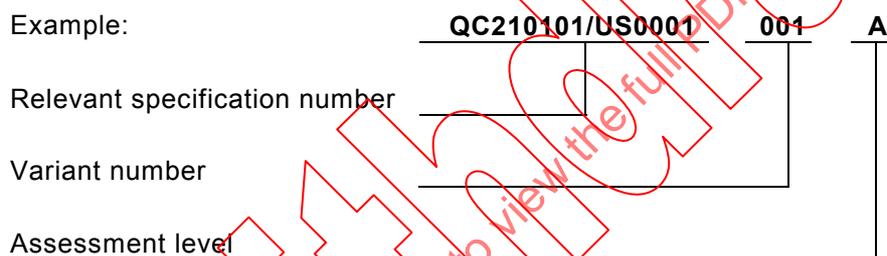
Components, associated hardware, and packages shall be permanently and legibly identified and marked when this is required by the relevant specification.

##### 4.7.1 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:



##### 4.7.2 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.

##### 4.7.3 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;