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**Test methods of passive devices
for fibre optic transmission**

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Descriptors : fibre optics, optoelectronic devices, communication cables, optical
communication systems, communication transmission lines

Reference number : JIS C 5901 : 2001 (E)

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law. Consequently **JIS C 5901 : 1987** is replaced with **JIS C 5901 : 2001**.

This revision is made based on **IEC 61300-2** series and **IEC 61300-3** series in order to facilitate the comparison between Japanese Industrial Standard and International Standard, the development of Japanese Industrial Standard identical with International Standard and the proposal of the draft of International Standard based on Japanese Industrial Standard.

Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

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Test methods of passive devices for fibre optic transmission

Introduction This Japanese Industrial Standard has been prepared based on the International Standards shown in Attached Table 1, by modifying or adding items which have differences between both Standards on test methods in some provisions and items which are preferably specified in **JIS** in an early stage although they are not specified in **JIS**.

In addition, the portions with sidelines or underlines of dots in this Standard are the matters which are specified by altering or adding the content of the original International Standards.

1 Scope This Standard specifies the common test methods of passive devices for fibre optic transmission using quartz optical fibres.

Remarks : The corresponding International Standards of this Standard shall be as shown in Attached Table 1.

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS C 0010 *Environmental testing Part 1 : General and guidance*

JIS C 0020 *Environmental testing procedures Part 2 : Tests, Tests A : Cold*

JIS C 0021 *Basic environmental testing procedures Part 2 : Tests, Test B : Dry heat*

JIS C 0022 *Basic environmental testing procedures Part 2 : Tests, Test Ca : Damp heat, steady state*

JIS C 0023 *Basic environmental testing procedures Part 2 : Tests—Test Ka : Salt mist*

JIS C 0025 *Basic environmental testing procedures Part 2 : Tests, Test N : Change of temperature*

JIS C 0028 *Basic environmental testing procedures Part 2 : Tests Test Z/AD : Composite temperature/humidity cyclic test*

JIS C 0040 *Environmental testing Part 2 : Tests—Test Fc : Vibration (sinusoidal)*

JIS C 0041 *Basic environmental testing procedures Part 2 : Tests, Test Ea and guidance : Shock*

JIS C 0042 *Basic environmental testing procedures Part 2 : Tests Test Eb and guidance : Bump*

JIS C 5900 *General rules of passive devices for fiber optic transmission*

3 Definitions For the purposes of this Standard, the definitions given in **JIS C 5900** and the following definitions shall apply.

- a) **launch condition** The conditions specifying the excitation mode distribution of incident light, when measuring the optical loss of a passive device for fibre optic transmission.

- b) **effective core diameter** The value of full width at half maximum, when the optical energy distribution is measured as the near field pattern of lateral section of optical fibre.
- c) **effective numerical aperture** The value given by $\sin\left(\tan^{-1}\frac{X}{2L}\right)$, where X is the full width at half maximum, when the optical energy distribution is measured as the far field pattern at a position apart by distance L from the end face of optical fibre.
- d) **mode field diameter** The value of overall width at a point where the optical intensity becomes $\frac{1}{e^2}$, of central value when approximating the near field pattern to Gaussian shape in a single mode fibre.
- e) **total reflection termination** At the end of optical fibre, the means to reflect again in the optical fibre the total light propagated through the inside of the optical fibre toward the end part.
- f) **no reflection termination** The means to prevent returning light from being generated due to boundary conditions of end surface at the end of optical fibre.
- g) **optical fibre for measurement** The optical fibre having the value at which the structural parameter of optical fibre or plug attached to this fibre satisfies required conditions for measurement.
- h) **optical adapter for measurement** The optical adapter in which the connection loss due to the part to be used for mutual connection of plugs and its reproducibility satisfies the conditions required for measurement.

4 Atmospheric conditions of test

4.1 Standard conditions The test and measurement, unless specially specified, shall be carried out under the standard conditions (15 °C to 35 °C in temperature, 25 % to 85 % in relative humidity, 86 kPa to 106 kPa in atmospheric pressure) specified in 5.3 of JIS C 0010. However, in case where doubt on judgment based on the measured value under the standard conditions is generated, or in the case where specially required, these shall be in accordance with 4.3. Furthermore, where the conversion is required, these shall be in accordance with 4.2.

In addition, in the case where the measurement under the standard conditions is difficult, as far as no doubt is caused on judgment, the test and measurement may be carried out under conditions other than the standard conditions.

4.2 Reference atmosphere The reference atmosphere (20 °C in temperature, 101.3 kPa in atmospheric pressure) specified in 5.1 of JIS C 0010. However, only the temperature may be taken as the reference atmosphere.

4.3 Referee conditions Referee condition I, temperature grade 2 and humidity grade 2 (20 °C ± 2 °C in temperature, 60 % to 70 % in relative humidity, 86 kPa to 106 kPa in atmospheric pressure) specified in 5.2 of JIS C 0010.

5 Appearance and structure

Information : This test method is based on **IEC 61300-3-1** *Examinations and measurements—Visual examination*.

5.1 Objective This Standard specifies the examination method on the appearance and structure of optical fibre passive devices. This test method may be used not only at any stage of the qualification or quality conformance inspection test, as a stand-alone test, but for examination before and after a mechanical performance test, a weather resistance test.

5.2 General description This test method is used for examining the configuration, workmanship, marking, and mass. It is also used for visual examination before and after a mechanical performance test, a weather resistance test.

5.3 Apparatus

- a) **Optical magnifier** Optical inspection instruments may be used as appropriate.
- b) **Dimensional measurement instruments** Vernier calipers, micrometers, etc. with sufficient accuracy may be used.
- c) **Special equipment** Gauges, colour samples, etc. may also be required to verify fit, performance, colour, finish or other specified parameters.

5.4 Procedure

- a) **Visual examination** The device under test shall be examined using the specified apparatus to verify that it meets the specified requirements.
 - 1) **Items to examine**
 - 1.1) materials used;
 - 1.2) general design and construction;
 - 1.3) workmanship;
 - 1.4) configuration;
 - 1.5) component type (type name);
 - 1.6) orientation of the ports;
 - 1.7) finish;
 - 1.8) identification of product (marking);
 - 1.9) damage;
 - 1.10) missing parts;
 - 1.11) loosening and slipping off of parts.
 - b) **Dimensions and mass** The dimensions and mass shall be measured as specified.
 - c) **Marking** The marking test shall be carried out by visual examination, unless otherwise specified.

- d) **Examination before and after mechanical performance test and weather resistance test** Visually examine the specimen at the initial measurement time. Repeat the visual examination of the number of times of test specified at the measurement time(s) during and after test. As this test method is used as part of a test or a test sequence, particular parameters of interest shall be specified individually. The list of examination criteria may be reduced if no change is expected, as, for example, materials or for design and construction.

5.5 Details to be specified in detail specifications The following details, as applicable, shall be given separately and individually.

- a) Items of examination
- b) Component type, configuration and marking
- c) Pre-conditioning procedure
- d) Post-conditioning procedure
- e) Size dimensions and mass to be measured
- f) Size measurement methods
- g) Mass measurement method
- h) Magnification of optical instrument used
- i) Inspection time(s)
- j) Acceptance/failure criteria
- k) Deviations from examination procedure

6 Optical performance test

6.1 Common apparatus Since the optical source, excitation unit, optical power meter, and temporary joint among the apparatus used in 6 Optical performance test are used in all the test, they shall be classified as the common apparatus and be shown as follows. The following apparatus shall be used. Furthermore, in each test, the apparatus which meet the individual conditions specified in Attached Table 2 shall be used.

- a) **Optical source (S)** For the optical source, unless specially specified, the stabilization optical source by the light emitting diode, (hereafter referred to as "LED") or semiconductor laser, (hereafter referred to as "LD") shall be used. Their specifications (classification of optical source, central wavelength, spectral full width at half maximum, etc.) shall be specified in the detail specification. The optical source with the output optical power, state of polarization and stability of wavelength which sufficiently satisfy the required measurement accuracy shall be used.
- b) **Excitation unit (E)** The excitation unit capable of removing the unrequired mode such as cladding mode, high dimension mode, etc. which are detrimental to measurement shall be used. The kind (the optical fibre for excitation or image-formation system), optical fibre length, attenuation (in the case of a mode scrambler), etc. shall be specified in the detail specification.

- c) **Optical power meter (D)** The optical power meter, unless specially specified, of which the linear error covering the total power level assumed is within ± 0.05 dB and of which the dynamic range required for measurement is fully obtained shall be used. Furthermore, the optical power meter which has a sufficiently small polarization dependence so that the accuracy of measurement may not be affected shall be used, and if required, a depolarizer shall be used between the device under test and the optical power meter. The photo detector should have a sufficiently large light-receptive area and the level of the optical power in the light-receptive surface should be lower than the saturation level of the photo detector by 10 dB or more.
- d) **Temporary joint (TJ)** The temporary joint is a method for temporarily combining two optical fibre ends in the state of a good stability and reproducibility, and a low loss. Unless specially specified, an optical connector, a precision V-groove, vacuum chuck, a micromanipulator, a fusion splice, a mechanical splice, etc. shall be used. If required in order to improve stability, a suitable refractive index matching material shall be used.

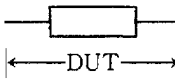
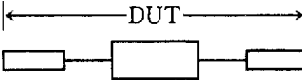
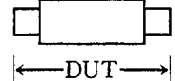
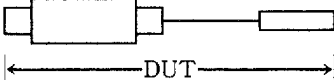
6.2 Attenuation

Information : This test method is based on **IEC 61300-3-4** *Examinations and measurements—Attenuation*. However, although the attenuation measurement methods of such as an optical passive device and an optical connector are specified in **IEC 61300-3-4**, only the attenuation measurement method of the passive device is specified in this Standard.

6.2.1 Objective This Standard specifies the test method which measures the loss (attenuation or insertion loss) of optical power produced when the optical passive devices under measurement are inserted within a length of optical fibre.

6.2.2 General description Since the attenuation measurement is specified for two optical terminals, the optical passive device (device under test, DUT) in this test shall have two optical terminals. Even if the optical passive device has two or more optical terminals, this test method shall apply. Here, the four different DUT configurations shall be specified. These configurations are classified according to the kind of terminals (an optical fibre, an optical connector, a plug or a receptacle). The reference method for measuring attenuation is with an optical power meter, and three variations in the measurement of attenuation are presented. Optical time domain reflectometry (OTDR) measurements are presented as an alternative method. The reference and alternative methods to be used for each configuration of the optical passive device are defined in Table 6.2.1.

Table 6.2.1 Configurations of passive device under measurement and test methods

Type	Configuration of device under test	Test methods	
		Reference	Alternative
1	Optical fibre to optical fibre 	Cutback method	
2	Plug to plug 	Substitution method	Insertion method
3	Receptacle to receptacle 	Substitution method	Insertion method
4	Receptacle to plug 	Substitution method	Insertion method

DUT: device under test

- a) **Launch conditions** Unless otherwise specified, launch conditions shall be in accordance with Annex B of IEC 61300-1 *Fibre optic interconnecting devices and passive components—Basic test and measurement procedures—Part 1 : General and guidance*. Launch conditions shall comply with the passive fibre optic components to be measured, and shall be specified in the detail specification.

Information : Due to the long coherence length, laser source units create a speckle pattern across the core of a multi-mode fibre which is unstable and it may become difficult or impossible for the laser sources to fulfill specified launch conditions. Therefore, for measuring passive optic components for multi-mode optical fibres (including the optical source of OTDR), it is preferable to avoid the use of LD and to use LED or other incoherent source units.

b) **Precautions**

- 1) The optical power in the optical fibre shall not be at a level high enough to generate non-linear scattering effects.
- 2) In case of the measurement of a multi-mode, the change of the mode distribution in the junction point of parts may affect loss measurement.
- 3) In case of the measurement of the optical power P_0 and P_1 , in order to avoid change in the amount of insertion loss due to bending loss, it is preferable not to move the optical fibre during test. Here, P_0 is the measurement power when there is not the device under test in the measurement circuit, and P_1 is the measurement power when there is the device under test in the measurement circuit.

6.2.3 Apparatus The following apparatus and equipment shall be required to perform this test.

- a) **Optical source (S)** The optical source which satisfies the conditions of 6.1 shall be used.
- b) **Excitation unit (E)** The excitation unit which satisfies the conditions of 6.1 shall be used.
- c) **Optical power meter (D)** The optical power meter which satisfies the conditions of 6.1 shall be used.
- d) **Temporary joint (TJ)** The temporary joint which satisfies the conditions of 6.1 shall be used.
- e) **Optical fibre for measurement** The optical fibre from an optical source to a temporary joint, the optical fibre of the optical joint code for a test, and the optical fibre of the optical joint cord for substitution shall be specified in the detail specification.
- f) **Reference plug (Pr)** The reference plugs are required in order to form complete connector assemblies in the insertion method and substitution method. The reference plugs become a part of the optical passive devices during the measurement of insertion loss. The dimensions and performance of the reference plugs shall be specified in the detail specification.
- g) **Reference adapter (Ar)** The reference adapters are required in order to form complete connector assemblies in the insertion method and substitution method. The dimensions and performance of the reference adapters shall be specified in the detail specification.
- h) **Mode filter (Mf)** In measurement in the single mode, a mode filter is required before the detector between the temporary joint and the device under test. The objective of a mode filter is to remove all optical energies other than those of a principal mode. Generally, the fibre of 2 m in length with two loops of the diameter of about 50 mm is used as the mode filter. The details of the mode filter shall be specified in the detail specification.
- i) **Optical time domain reflectometry (OTDR)** For following characteristics, those specified in the detail specification shall be used.
 - 1) Central wavelength
 - 2) Spectral width
 - 3) Pulse width

In addition, it is preferable to incorporate the attenuator for decreasing the quantity of light so that the light receptive level of OTDR may not be exceeded.

6.2.4 Procedure

- a) **Configurations of device under test and test methods** (see Table 6.2.1) To type 2 and type 3, the substitution method gives the lower loss measured value than that of the insertion method. This is because in the substitution method, the measured value of the standard optical power P_0 includes the loss in the optical joint cord for test and P_0 becomes the smaller value than that in the insertion method.

- b) **Attenuation measurement using optical power meter** The measurement of the attenuation α using the cutback method, substitution method, and insertion method is based on the use of an optical power meter. Two measurements of power are required for each measurement of insertion loss with an optical power meter.

$$\alpha(\text{dB}) = -10 \log \left(\frac{P_1}{P_0} \right) \dots\dots\dots (1)$$

where, P_0 : measurement of power without the device under test in the measurement circuit

P_1 : measurement of power with the device under test in the measurement circuit

Suitable connections shall be provided between the optical fibre and the photodetector. Connections may be with either an adapter to connect an optical fibre, or with an optical connector adapter for the appropriate connector. Although in case of the cutback method and the insertion method the connection between the optical fibre and the photodetector will be removed one time during measurement of P_0 and P_1 , the joint efficiency shall not change.

1) Method 1: Cut-back

- 1.1) For a type 1 (optical fibre to optical fibre), one optical fibre of the device under test is connected to the optical source (S) [excitation unit (E)] with a temporary joint (TJ), and the other optical fibre is connected to the optical power meter (D), and P_1 is measured. Furthermore, the optical fibre is cut at the cut point (CP) and P_0 is measured (see Fig. 6.2.1). In this case, a caution is taken for the position of the mode filter (Mf).

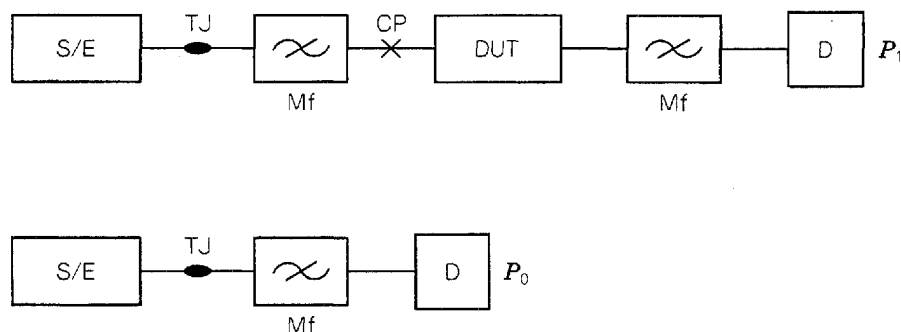


Fig. 6.2.1 Cutback method (type-1)

- 2) **Method 2: Substitution** In the substitution method, P_1 is measured with the device under test in the circuit, and P_0 is measured with a substitute patchcord being attached to the reference plug (Pr) in place of the device under test.
- 2.1) For a type 2 (plug to plug), reference adapters (Ar) are added to the reference plugs on both the optical source lead and the test patchcord (see Fig. 6.2.2).

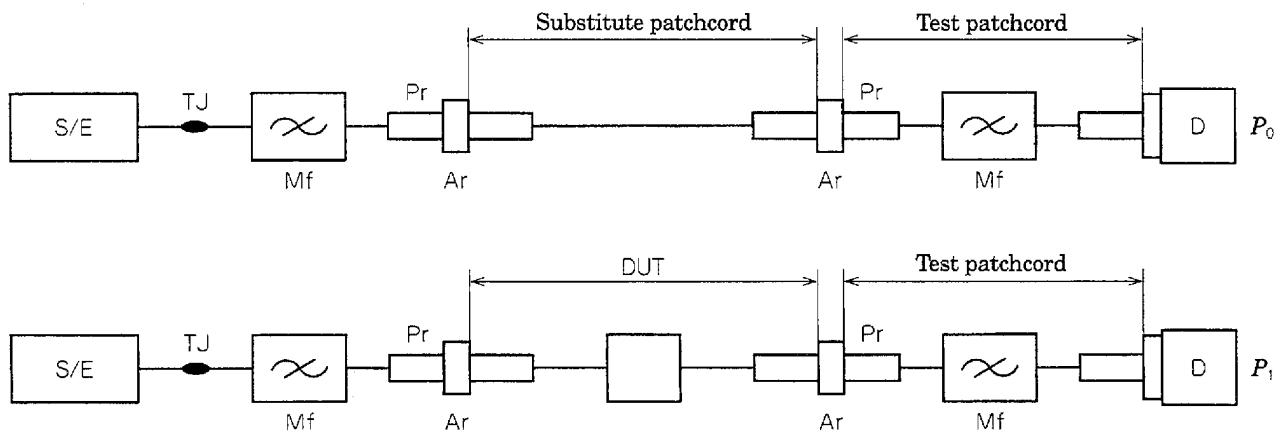


Fig. 6.2.2 Substitution method (type-2)

2.2) For a type 3 (receptacle to receptacle), the measurement is made in the same way as 2.1) without the reference adapter.

2.3) For a type 4 (receptacle to plug), the measurement is made in the same way as 2.1) with the reference adapter for one side.

3) Method 3: Insertion

3.1) For a type 2 (plug to plug), P_0 is measured with the detector connected directly to the optical fibre from the temporary joint. The device under test, the test patchcord and two reference adapters are inserted, and P_1 is measured (see Fig. 6.2.3).

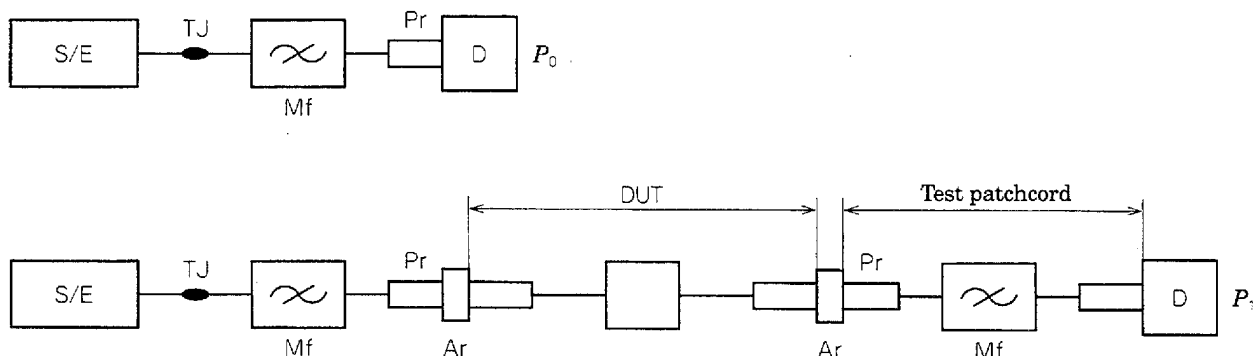


Fig. 6.2.3 Insertion method (type-2)

3.2) For a type 3 (receptacle to receptacle), the measurement is made in the same way as 3.1) without the reference adapter.

3.3) For a type 4 (receptacle to plug), the measurement is made in the same way as 3.1) with the reference adapter for one side.

c) Attenuation measurements with an OTDR

1) Measurement circuit

1.1) An OTDR measures reduction of the return light of the backscattering to the OTDR when a pulse passes through the device under test. The attenuation measurement circuit using an OTDR is shown in Fig. 6.2.4.

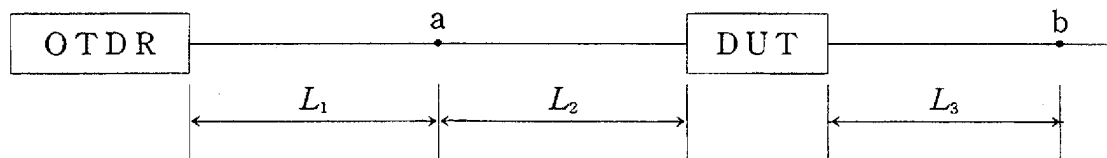


Fig. 6.2.4 Measurement circuit configuration using OTDR

- 1.2) The L_1 section is required in order to separate the influence of the OTDR. The L_2 and L_3 section length is required to be prepared according to resolution necessary for measuring the attenuation of the device under test by the OTDR. The boundary points between the L_2 section and the external section, the L_3 section and the external section shall be point a, point b, respectively.
- 1.3) Where the device under test is terminated with either an optical connector plug or a receptacle, reference plugs and adapters are added, as necessary, to form complete connector assemblies. These optical connector assemblies are measured as part of the device under test.
- 1.4) The temporary joint is required when the device under test has pigtails. When the optical fibre of a pigtail is long enough, the insertion loss of the optical fibre of a pigtail becomes a part of attenuation of the device under test, and the attenuation of temporary joint is not included in the attenuation of the device under test. When the optical fibre of a pigtail is short, the attenuation of temporary joint is included in a part of the attenuation of the device under test. The temporary joint should not be installed in the domain of L_2 or L_3 .
- 1.5) If an optical fibre is terminated with point b, it is preferable to use a temporary reflection termination. If the optical fibre has the longer length than L_3 by several pulses or more, the temporary reflection termination is not required.

2) Definition of OTDR measurement method

- 2.1) The amount of attenuation measured by the OTDR measurement should be obtained as the average of the OTDR measured values made in the both directions through the device under test.
- 2.2) In OTDR measurement, one half of the difference of the back scattered light intensity which returns from the both ends of device under test becomes the attenuation of device under test. In many OTDRs this is taken into consideration and the signal expressed on a display is the value divided by 2.
- 2.3) Differences in the backscatter coefficient of the optical fibre on either side of the device under test will result in an error in a one-way OTDR measurement. The error in a measurement made in one direction will be positive and the error in the other direction will be negative. The use of an average of readings taken in both directions cancels the error due to differences in the backscatter coefficient of the two fibres.

3) Measurement procedure

- 3.1) A typical OTDR display of the backscatter signal with non-reflective optical loss is shown in Fig. 6.2.5.

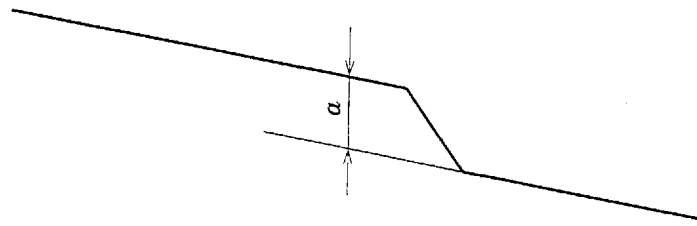


Fig. 6.2.5 OTDR locus (in case of non-reflective event)

- 3.2) A typical OTDR display of the backscatter signal from the device under test with optical loss and reflection is shown in Fig. 6.2.6. The attenuation after a peak signal is the feature of OTDR measurement, and the length of attenuation is the function of characteristics of a detector and intensity of a reflective pulse.

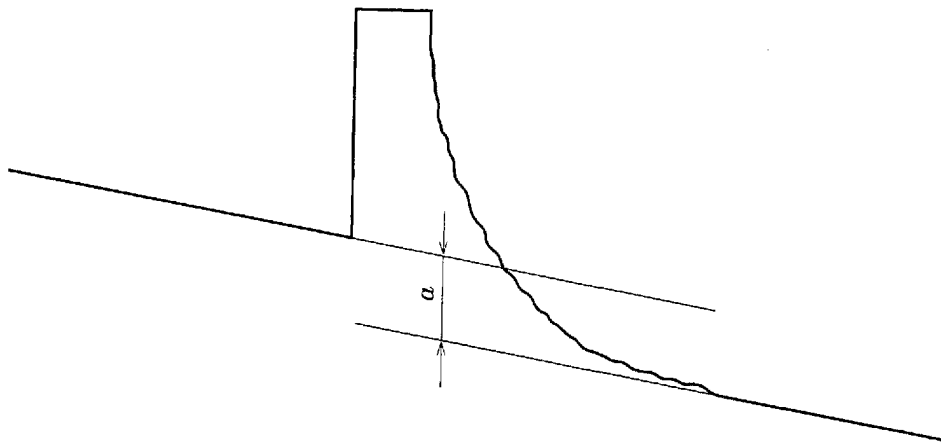


Fig. 6.2.6 OTDR locus (in case of reflective event)

- 3.3) Attenuation a is observed as the difference between OTDR locus before and after a signal passes through the device under test in Fig. 6.2.5. Or it is measured as the level difference of parallel lines of Fig. 6.2.6. These lines are the extension of the OTDR response from the optical-fibre length of L_2 and L_3 domain (see Fig. 6.2.4).

6.2.5 Details to be specified in detail specifications The following details, as applicable, shall be specified in the detail specification:

- Test method
- Optical sources (specification of optical source, peak wavelength, spectral width, presence of modulation function and its characteristics, stability of optical power, coherence, etc.)
- Optical power meters (presence of phase-detection mechanism and its characteristics, sensitivity in peak wavelength of optical source, linearity, stability, form of optical input, etc.)
- Launch conditions
- Cladding mode removal method

- f) Pretreatment process
- g) Performance requirement (allowable insertion loss)
- h) Optical fibre length (L , L_1 , L_2)
- i) Optical terminator
- j) Test patchcord (optical fibre/cable parameter)
- k) Substitute patchcord (optical fibre/cable parameter)
- l) Parameter on reference plugs
- m) Parameter on reference adapters
- n) OTDR characteristics (central wavelength, spectral width, pulse width)
- o) Deviations from this test method

6.3 Polarization dependence of attenuation

Information : This test method is based on IEC 61300-3-2 *Examinations and measurements—Polarization dependence of a single-mode fibre optic device*.

6.3.1 Objective This Standard specifies the test method which measures the polarization dependence of the attenuation of single-mode fibre optic devices. This test method can be applied to any single-mode fibre optic devices, including optical connectors, couplers, optical attenuators, isolators and optical switches. This test measures the total range of attenuation, $\Delta\alpha$, due to changes in polarization of the launch state, and for optical branching devices, measures the total range of coupling ratio, $\Delta cr(i)$.

In addition, the measurement method of the polarization dependence of return loss shall be specified in 6.6.

6.3.2 General description The following two methods are specified as the method of measuring the polarization dependence of the attenuation of optical fibre passive devices (device under test, DUT). Method 1 measures the maximum polarization sensitivity over all possible states of polarization including linear, circular and elliptical. Method 2 measures the maximum polarization sensitivity over all linearly polarized states.

- a) **Method 1** For method 1, light is launched into the input port of the device under test such that linear, circular, and elliptical states of polarization with different axes of orientation can be adjusted while the power from the output port is monitored. Furthermore, the input power is also monitored by tapping some of the power through a polarization-independent branching device. The polarization dependence of attenuation is obtained by measuring the maximum and the minimum optical power obtained by making the state of polarization change. For optical branching devices, the polarization dependence of coupling ratio is measured. Method 1 is preferred for the optical passive devices in which the state of polarization of the passing light changes.

- b) **Method 2** For method 2, the linearly polarized light is launched into the input port of device under test. The input ports shall be arranged in a straight line so that the state of polarization may not change, for example, without any external stresses, such as bends, twists, kinks or tension. The output ports may be bent as long as they are large enough not to induce bend loss (e.g. bend diameters greater than 90 mm or more). This is because, since there are no devices having a polarization dependence in the output optical path, the attenuation does not change even if the state of polarization is altered by a bend.

The linear state of polarization of the launch is typically rotated through a minimum of 180° during measurement of output optical power. If the launch power varies according to the states of polarization, this variation shall be corrected. The measurement of the reference optical power from optical source shall be performed with the cutback method (see Fig. 6.3.3) or substitution method (see Fig. 6.3.4).

6.3.3 Apparatus The following apparatus and equipment shall be required to perform this test.

- a) **Optical source (S)** The optical source which satisfies the conditions of 6.1 shall be used.
 - b) **Excitation unit (E)** The excitation unit which satisfies the conditions of 6.1 shall be used.
 - c) **Temporary joint (TJ)** The temporary joint which satisfies the conditions of 6.1 shall be used.
 - d) **Polarization adjuster (PA)** A polarization adjuster is equipment for adjusting the state of polarization of an incident light according to the measurement objective. When not specified in the detail specification, the extinction ratio of polarization of an optical source shall be 10^{-2} or less. If required, this extinction ratio of polarization shall be maintained over the range of measurement wavelength using the polarization adjuster.
- 1) **Method 1** Method 1 provides the means which can reproducibly adjust all states of polarization. The same launch power is required to be reproduced to the same polarization. Fig. 6.3.1 is an example of the polarization adjuster and it shows a linear polarizer (PL), a half-wave retardation plate (H), a quarter-wave retardation plate (Q) mounted on the rotation stage and inserted into the parallel optical path produced by two collimating lenses at the output of the monochromator. All parts are required to conform to measurement wavelength.

A linear polarizer (PL) forms a linearly polarized beam without depending on the incidence state of polarization. The quarter-wave retardation plate (Q) changes the linearly polarized light to all states of polarization including an ellipse or a circularly polarized light. The half-wave retardation plate (H) rotates through any degrees in a plane perpendicular to the propagation direction with the state of polarization formed by the quarter-wave retardation plate (Q) being maintained in the degree of polarization. All states of polarization can be made by this combination. These angles of rotation shall be adjusted with the accurate reproducibility to the common axis, respectively, and shall be read clearly. As other methods of adjusting

the state of polarization with the good reproducibility, there are the in-line optical-fibre type polarization adjuster, etc. The polarization adjuster used for measurement shall be specified in the detail specification.

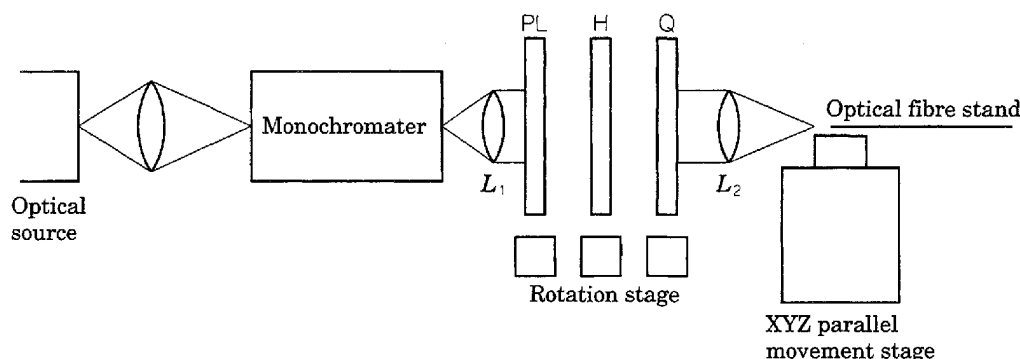


Fig. 6.3.1 An example of polarization adjuster (PA) of method 1

- 2) **Method 2** Method 2 provides the means which launch linearly polarized light and rotate it through at least 180°. Furthermore, the same launch power is required to be reproduced to the same polarized wave. Fig. 6.3.2 is an example of the polarization adjuster and it consists of a linear polarizer (PL) and a half-wave retardation plate (H) which are inserted into the parallel optical path produced at the output of the monochromator. Each of them is mounted on the rotation stage. As other methods, there are the in-line optical-fibre type polarization adjuster, etc. The polarization adjuster used for measurement shall be specified in the detail specification.

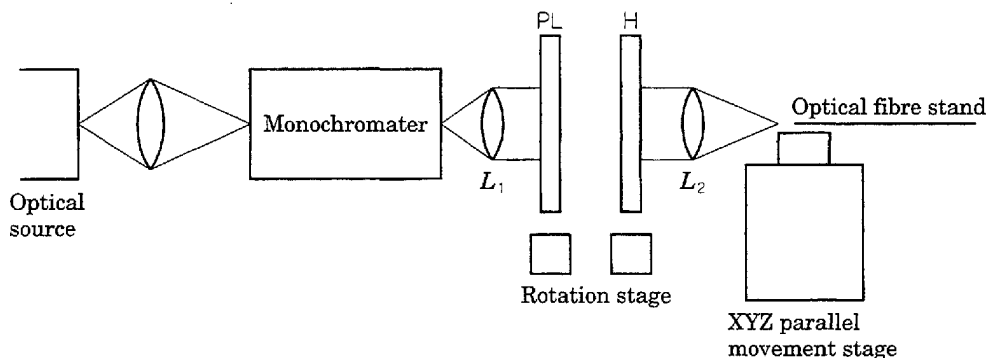


Fig. 6.3.2 An example of polarization adjuster (PA) of method 2

- e) **Input optical fibre linear deployment mechanism (method 2)** The launch lead from the device under test shall be straight. The optical fibre mount shall not induce stress in the optical fibre. Furthermore, the launch conditions shall not be disturbed during measurement. These are the necessary conditions for the state of polarization in the device under test to be a straight line.
- f) **Polarization-independent branching device (BP)** The polarization-independent branching device transmits the optical power from the input port to two output ports at the branching ratio of about 50 to 50. Unless specially specified, the polarization dependence shall be the value of not more than one-tenth of the minimum allowable polarization dependence of the device under test.
- g) **Optical power meter (D)** The optical power meter which satisfies the conditions of 6.1 shall be used.

- h) **Data read-out/recording/processing devices (C/P)** According to the state of polarization, the collection and calculation of the measured value are performed and the method of reporting the calculation result at the end of the test is provided. A computer-based system may be used to fulfil this data acquisition and analysis function.

6.3.4 Procedure

a) Precautions

- 1) Movement of any of the optical fibres during the measurement may affect the state of polarization and lead to measurement error. Therefore, care should be taken to ensure that no movement of the optical fibres or apparatus is allowed.
- 2) The wavelength dependence of the polarization of the apparatus and the device under test may affect the accuracy of the measurement. Therefore, as specified in 6.3.3 a), the spectral width of the optical source shall be 10 nm or under.
- 3) Cladding modes shall be stripped at the entry and exit ports of each element of the apparatus. If this is not accomplished by the fibre coating, cladding mode strippers are required.

- b) **Reference options** The following two options are allowed for setting the reference optical power under measurement. Option 1 is a more accurate method and should be applicable to the calibration between these options. Option 2 is effective for the apparatus used in method 1. However, since in the method 2, the optical branching device used for measurement does not necessarily carry out polarization preservation, option 2 is not suitable.

- 1) **Option 1—Cutback or substitution optical fibre** The cutback method measures the reference optical power P_1 from the optical source to the same state of polarization as that of the light measured through the device under test as shown in Fig. 6.3.3. The optical fibre which can secure the predetermined cutback length from the input port of the device under test shall be provided. As an alternative method (substitution method), as shown in Fig. 6.3.4, the optical fibre equivalent to the device under test may be replaced and the reference optical power may be measured. However, equivalence to the result with a cutback length shall be demonstrated.

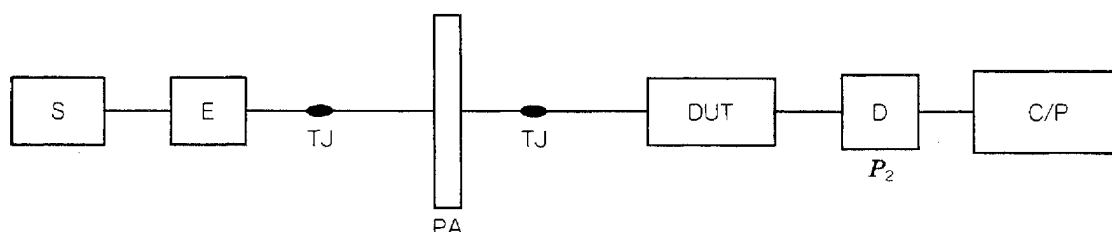


Fig. 6.3.3a Cutback method—step 1

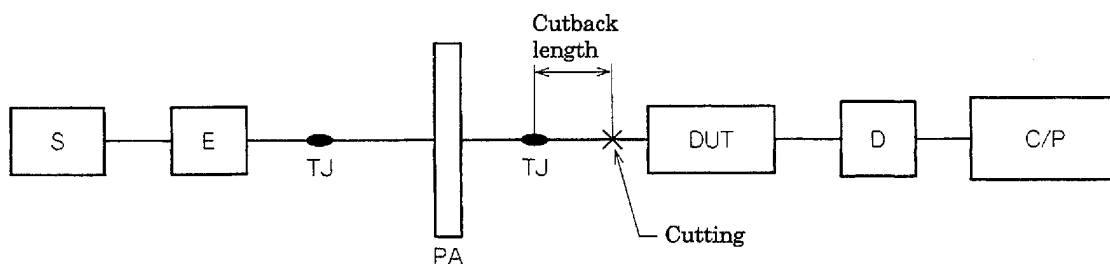


Fig. 6.3.3b Cutback method—step 2

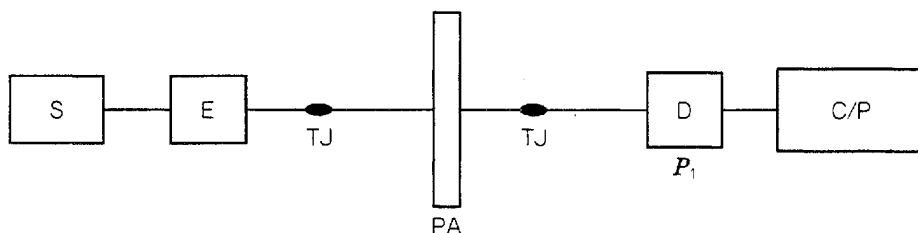


Fig. 6.3.3c Cutback method—step 3

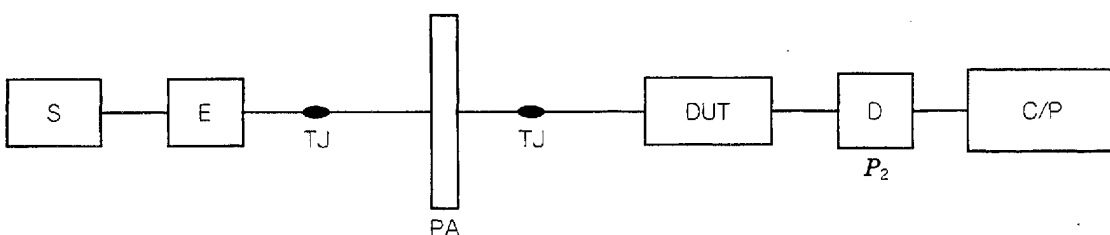


Fig. 6.3.4a Substitution method—step 1

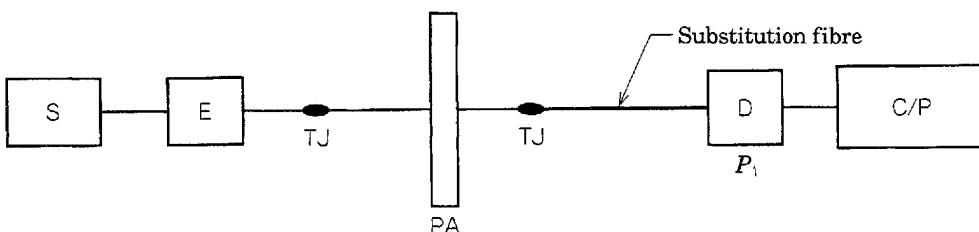


Fig. 6.3.4b Substitution method—step 2

- 2) **Option 2—Ratio measurement** As shown in Fig. 6.3.5, the polarization dependence of an optical source shall be measured by measuring a part of optical source optical power P_1 which branched from the polarization independent branching device. The optical power meter (D_1) used for measurement of P_1 shall satisfy the necessary condition of 6.1.

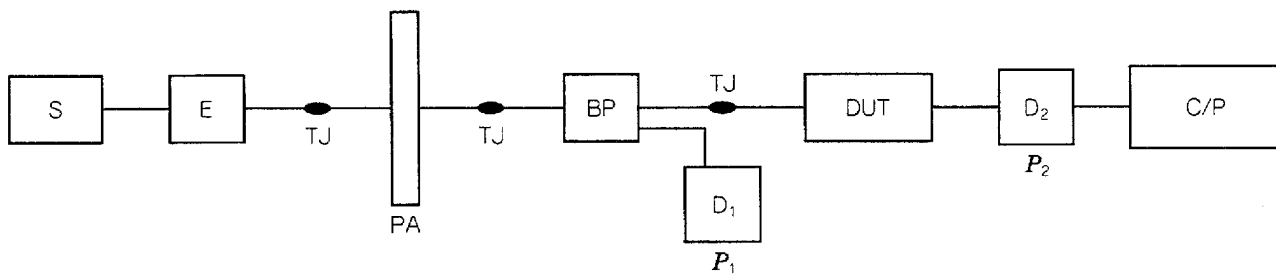


Fig. 6.3.5 Ratio measurement

c) Method 1—All states of polarization

- 1) As shown in Fig. 6.3.4b, create a system of measurement using the optical fibre for substitution equivalent to the optical fibre used for the device under test. For the (generally) partially polarized light which comes out of the excitation unit, maximize the detected signal by rotating the linear polarizer (PL) in Fig. 6.3.1 and adjusting the polarization axis.
- 2) Connect the optical fibre pigtail of the device under test to the apparatus using one of the reference options described in b). Generally, a fusion splice is used. When the end face of optical fibre does not intersect the fibre axis at right angles, the mechanical splice is not suitable since it may show the polarization dependence. If the device under test contains receptacles or optical connectors, then mating optical connectors shall be attached to the polarization adjuster and the optical power meter. The materials used, method of assembly, and any special tools shall be in accordance with the manufacturer's instructions. The measurement result will then include the combined polarization dependence of the device under test and optical connectors. The procedure of determining the polarization dependence shall be shown as follows:
- 3) Rotate the quarter-wave retardation plate (Q) by 10° in the range of angle of 0° to 180° (or the incremental angle specified in the detail specification), and measure the optical power P_2 versus the angular orientation θ of Q, and the angular orientation ϕ of the half-wave retardation plate (H). In the case of the ratio measurement method (option 2: Fig. 6.3.5), record the optical power P_1 to θ and ϕ simultaneously.
- 4) Rotate the half-wave retardation plate (H) by 10° (or the incremental angle specified in the detail specification).
- 5) Repeat the above-mentioned procedures 3) and 4) until H rotates to the angle of 180° .
- 6) In the case of the ratio measurement (option 2), proceed to the procedure 10). In the measurement (option 1) with the optical fibre for cutback or substitution, create the system of measurement as shown in Fig. 6.3.3c or Fig. 6.3.4b and measure the reference optical power P_1 .
- 7) Rotate the quarter-wave retardation plate (Q) by 10° in the range of angle of 0° to 180° (or the incremental angle specified in the detail specification), and measure the optical power P_1 versus the angular orientation θ of Q, and the angular orientation ϕ of H.

- 8) Rotate H by 10° (or the incremental angle specified in the detail specification).
- 9) Repeat the above-mentioned procedures 7) and 8) until H rotates to the angle of 180°.
- 10) Record the maximum and the minimum value of $\frac{P_2}{P_1}$. Here, P_1 and P_2 use the value at the same angular orientation θ and ϕ , respectively.
- 11) Calculate the polarization dependence according to formulae (2) and (3).

Attenuation dependence $\Delta\alpha$:

$$\Delta\alpha = 10 \log \left[\max \left(\frac{P_2}{P_1} \right) \right] - 10 \log \left[\min \left(\frac{P_2}{P_1} \right) \right] \dots\dots\dots (2)$$

where, $\max \left(\frac{P_2}{P_1} \right)$: maximum value of $\frac{P_2}{P_1}$

$\min \left(\frac{P_2}{P_1} \right)$: minimum value of $\frac{P_2}{P_1}$

Coupling ratio dependence $\Delta cr(i)$ (applicable for branching devices only):

$$\Delta cr(i) = 10 \log \left[\max \left(\frac{P_{2i}}{\sum_j P_{2j}} \right) \right] - 10 \log \left[\min \left(\frac{P_{2i}}{\sum_j P_{2j}} \right) \right] \dots\dots (3)$$

where, i : specified output port

$\sum_j$: summation over all output ports j

d) Method 2—Linear polarization only

- 1) As shown in Fig. 6.3.4b, create a system of measurement using the optical fibre for substitution equivalent to the optical fibre used for the device under test. For the (generally) partially polarized light which comes out of the excitation unit, maximize the detected signal by rotating the linear polarizer (PL) in Fig. 6.3.2 and adjusting the polarization axis.
- 2) Connect the optical fibre pigtail of the device under test to the apparatus using one of the reference options described in b). Generally, a fusion splice is used. When the end face of optical fibre does not intersect the fibre axis at right angles, the mechanical splice is not suitable since it may show the polarization dependence. If the device under test contains receptacles or optical connectors, then mating optical connectors shall be attached to the polarization adjuster and the optical power meter. The measurement result will then include the combined polarization dependence of the device under test and optical connectors. All of the launch fibres shall be deployed in a straight configuration. In order to assure that the linear state of polarization of the device under test is maintained, the optical fibre to be used between the launch and the device under test shall be not more than one eighth of fibre beat length (or 3 m).

- 3) Rotate the half-wave retardation plate (H) by the specified incremental angle in the range of angle of 0° to 180° and measure the optical power P_2 of the output side of the device under test versus the angular orientation ϕ of H. Select the regulation of the incremental angle so that the accuracy required for the determination of the maximum and minimum transmission power may be attained.
- 4) Care shall be taken so that the state of polarization when the light entering the device under test does not change and the input optical fibre does not move during measurement.
- 5) Create the system of measurement with the optical fibre for cutback or substitution (see Fig. 6.3.3c or Fig. 6.3.4b). Rotate the half-wave retardation plate (H) from 0° to 180° and measure the reference optical power P_1 versus the angular orientation ϕ of H.
- 6) Record the maximum and the minimum value of $\frac{P_2}{P_1}$. Here, P_1 and P_2 use the value at the same angular orientation ϕ , respectively.
- 7) Calculate the polarization dependence by formulae (4) and (5).

Attenuation dependence $\Delta\alpha$:

$$\Delta\alpha = 10 \log \left[\max \left(\frac{P_2}{P_1} \right) \right] - 10 \log \left[\min \left(\frac{P_2}{P_1} \right) \right] \dots\dots\dots (4)$$

where, $\max \left(\frac{P_2}{P_1} \right)$: maximum value of $\frac{P_2}{P_1}$

$\min \left(\frac{P_2}{P_1} \right)$: minimum value of $\frac{P_2}{P_1}$

Coupling ratio dependence $\Delta cr(i)$ (applicable for optical branching devices only):

$$\Delta cr(i) = 10 \log \left[\max \left(\frac{P_{2i}}{\sum_j P_{2j}} \right) \right] - 10 \log \left[\min \left(\frac{P_{2i}}{\sum_j P_{2j}} \right) \right] \dots\dots (5)$$

where, i : specified output port

$\sum_j$: summation over all output ports j

6.3.5 Details to be specified in detail specifications The following details, as applicable, shall be specified in the detail specification:

- a) Optical sources (specification of optical source, peak wavelength, spectral width, etc.)
- b) Structure specification of polarization adjuster
- c) Increase angle of half-wave retardation plate
- d) Increase angle of quarter-wave retardation plate (if used)
- e) Polarization dependence of splitting ratio of polarization-independent optical branching device (if used)

- f) Pigtail lengths
- g) Performance requirements
- h) Polarization dependence calculation method
- i) Reference option to be used
- j) Any deviations from the test procedure

6.4 Polarization dependence of attenuation based on matrix calculation method

Information : This test method is based on IEC 61300-3-12 Examinations and measurements—Polarization dependence of attenuation of a single-mode fibre optic component : Matrix calculation method.

6.4.1 Objective This Standard specifies the procedure to measure the dependence of attenuation of single-mode fibre optic components to changes in the state of the polarization of the input light. The value given by this test is the maximum variation in loss over all states of polarization of the launch light into the optic component.

6.4.2 General description This test method is an alternative to the method specified in the polarization dependence of attenuation of fibre optic devices (device under test, DUT) of 6.3. The test procedures of the polarization dependence of attenuation of 6.3 are based on manipulation of the state of polarization of light either continuously or in small incremental adjustments in order to measure maxima and minima of the attenuation of transmitted light. This test method involves the measurement of the behaviour of a device under test when illuminated by a small set of well-defined states of polarization of input light. These measurements are followed by a matrix calculation to determine the polarization dependence of loss (PDL) of the device under test. This procedure can be applied to any single-mode passive component, and determines the total range of attenuation due to changes in polarization of the launch light.

Generally, there are two matrix formalisms to describe and quantify the polarization behaviour of light in fibre optic systems, one based on the Mueller matrix and the other based on the Jones matrix.

The Mueller matrix formalism entails an optical power representation of the performance of components. This matrix is a square 16 element matrix. Here, the state of polarization of light is described as a 4 element Stokes vector. The Stokes vector of the incident light multiplied by the Mueller matrix of the device under test gives the Stokes vector of the output light, and this output light expresses the intensity and three states of polarization. In the determination of PDL of a component using Mueller matrices, it is normally not necessary to determine the full Mueller matrix but rather only the first row of the matrix, which provides complete information on light intensity but not on the resultant state of polarization.

On the other hand, the Jones matrix formalism entails an electric field representation of the polarization behaviour of components. The Jones matrix is a square four-element matrix and is used with incident light which has been described as a Jones vector. The Jones vector of the incident light multiplied by the Jones matrix of the device under test gives a Jones vector for the output light, which expresses the deviation and the amplitude component of an electric field.

For the determination of PDL, it can be shown that the Mueller and Jones representations are mathematically equivalent for fully polarized light, but for partially polarized light only the Mueller representation is applicable. The test procedure described here uses Mueller mathematics to determine PDL. Several methods to determine PDL using matrix mathematics can be defined. In this test procedure, the attenuations of the device under test corresponding to four independent states of polarization are measured. The first row of the Mueller matrix of the device under test is determined by those measured values and then its PDL can be precisely calculated.

6.4.3 Apparatus The following apparatus and equipment shall be required to perform this test:

- a) **Optical source (S)** The optical source which satisfies the conditions of 6.1 shall be used.
- b) **Temporary joint (TJ)** The temporary joint which satisfies the conditions of 6.1 shall be used.
- c) **Polarization adjuster (PA)** The polarization adjuster is the means by which the launch light can be conditioned into four well-defined states of polarization representing four linearly independent Stokes vectors. An example of this system is shown in Fig. 6.4.1.

This arrangement can launch four states of polarization consisting of circularly polarized light plus three linearly polarized states oriented at 45° with respect to each other. The input light is first conditioned to a highly linearly polarized state by polarizer (PL-A). It is then converted to circular polarization by a quarter-wave retardation plate (Q) oriented at 45° to the polarizer. The three linear states of polarization can be created sequentially by inserting, one at a time, the three polarizers labelled (PL-B), (PL-C) and (PL-D) into the beam. Polarizers (PL-B), (PL-C) and (PL-D) are oriented at 45° with respect to each other when they are in the beam.

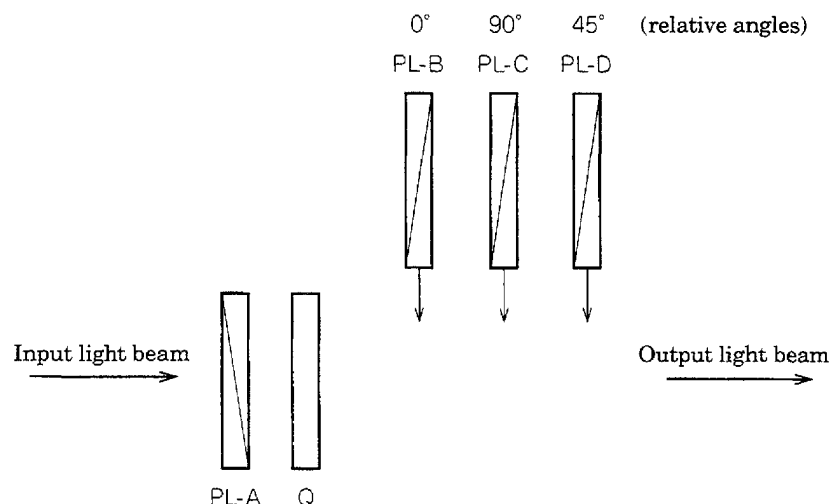


Fig. 6.4.1 Polarization adjuster (example)

- d) **Polarization independent branching device (BP)** The polarization independent branching device is a device which transfers power from its input port to two output ports with approximately a 50 : 50 splitting ratio. Unless otherwise specified, the polarization dependence shall be the value of not more than 1/10 of the minimum allowable polarization dependence of the device under test.

- e) **Optical power meter (D)** The optical power meter which satisfies the conditions of 6.1 shall be used.
 - 1) The optical power meter shall be linear over the optical power levels expected to be encountered. Any optical power meter non-linearity contributes directly to measurement error. Therefore, it is important that the optical power meters and associated amplification circuits exhibit good linearity over all measurement ranges. Precaution shall be taken to ensure that the power density on the active area of the optical power meter is always at least 10 dB below the saturation level of the optical power meter.
 - 2) The optical power meters shall have sufficient active area and be located with respect to the output fibre so as to capture all of the light exiting the output fibre of the device under test.
 - 3) The optical power meter shall be sufficiently polarization insensitive so as not to affect the accuracy of the measurement. Particularly for the measurement of the light through the device under test, it may be necessary to use a depolarizer between the device under test and the optical power meter.
- f) **Data read-out/recording/processing devices (C/P)** Provide a means to record and to perform required calculations with the light power measurements. A computer-based system may be used to fulfil this data acquisition and analysis function or it may be programmed at chip level into the data acquisition unit.

6.4.4 Procedure

- a) **Precautions** Movement of any of the optical fibres during the measurement sequence will affect the state of polarization and lead to measurement error. Therefore, care should be taken to ensure that no movement of the fibres or apparatus is allowed during measurement. The dispersion in the polarization of the elements of the apparatus and of the device under test may affect the accuracy of the measurement. Therefore the spectral width of the optical source shall be the value specified in 6.1 or in the detail specification. Cladding modes shall be stripped at the entry and exit ports of each element of the apparatus. If this is not accomplished by the fibre coating, cladding mode strippers are required.
- b) **Measurement methodology** In order to circumvent any PDL associated with the measurement apparatus it is necessary to make measurements of the device under test relative to the apparatus without the device under test (reference power measurements). All these reference power measurements are made relative to the output power levels of the polarization adjuster (PA) to circumvent optical source drift.
 - 1) Set up apparatus as shown in Fig. 6.4.2 and measure reference power levels.
 - 2) Measure the reference power corresponding to circularly polarized launch light by arranging the polarization adjuster (PA) so that polarizers (PL-B), (PL-C) and (PL-D) are not in the beam path. The detected powers at D₁ and D₂ are P₁ (mW) and P₂ (mW), respectively. Record the relative power as:

$$P_{R(circ)} = \frac{P_1}{P_2} \dots\dots\dots (6)$$

- 3) Measure the reference power corresponding to linearly polarized light at 0° relative angle by inserting the polarizer (PL-B) into the beam path. Record this as:

$$P_R(0^\circ) = \frac{P_1}{P_2} \dots\dots\dots (7)$$

- 4) Measure the reference power corresponding to linearly polarized light at 90° relative angle by inserting the polarizer (PL-C) into the beam [remove the polarizer (PL-B)]. Record this as:

$$P_R(90^\circ) = \frac{P_1}{P_2} \dots\dots\dots (8)$$

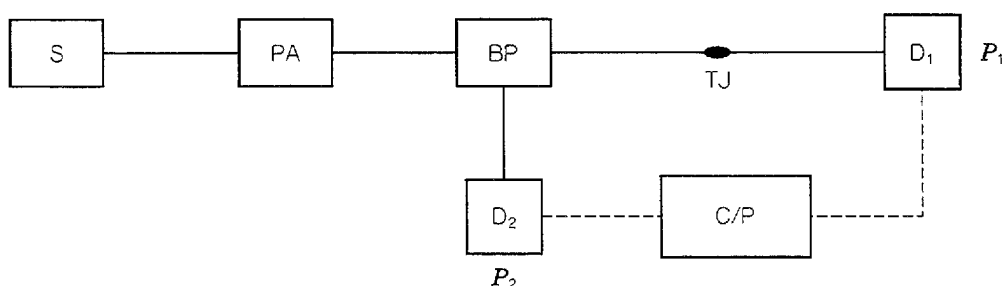


Fig. 6.4.2 Reference power measurement set-up

- 5) Measure the reference power corresponding to linearly polarized light at 45° relative angle by inserting the polarizer (PL-D) into the beam [remove the polarizer (PL-C)]. Record this as:

$$P_R(45^\circ) = \frac{P_1}{P_2} \dots\dots\dots (9)$$

Insert the device under test into the measurement system by using two temporary joints (TJ) as shown in Fig. 6.4.3.

Repeat steps 2) to 5) to obtain the corresponding power levels of launch light measured through the device under test. Record these as:

- P_M (circ)
- P_M (0°)
- P_M (90°)
- P_M (45°)

- c) **PDL calculation** The transmission factors of light through the device under test corresponding to:

- 1 linearly polarized light at 0° relative angle;
- 2 linearly polarized light at 90° relative angle;
- 3 linearly polarized light at 45° relative angle;
- 4 circularly polarized light.

are given by:

$$T_1 = \frac{P_R(0^\circ)}{P_M(0^\circ)} \dots\dots\dots (10)$$

$$T_2 = \frac{P_R(90^\circ)}{P_M(90^\circ)} \dots\dots\dots (11)$$

$$T_3 = \frac{P_R(45^\circ)}{P_M(45^\circ)} \dots\dots\dots (12)$$

$$T_4 = \frac{P_R(circ)}{P_M(circ)} \dots\dots\dots (13)$$

Then the first row of the Mueller matrix is calculated as:

$$M_{00} = \frac{(T_1 + T_2)}{2} \dots\dots\dots (14)$$

$$M_{01} = \frac{(T_1 - T_2)}{2} \dots\dots\dots (15)$$

$$M_{02} = T_3 - M_{00} \dots\dots\dots (16)$$

$$M_{03} = -T_4 + M_{00} \dots\dots\dots (17)$$

The average attenuation L_{av} of the device under test over all states of polarization may be calculated as:

$$L_{av}(\text{dB}) = -10 \log(M_{00}) \dots\dots\dots (18)$$

The PDL of the device under test is calculated as:

$$PDL(\text{dB}) = 10 \log \left(\frac{M_{00} + \sigma}{M_{00} - \sigma} \right) \dots\dots\dots (19)$$

where

$$\sigma = (M_{01}^2 + M_{02}^2 + M_{03}^2)^{\frac{1}{2}} \dots\dots\dots (20)$$

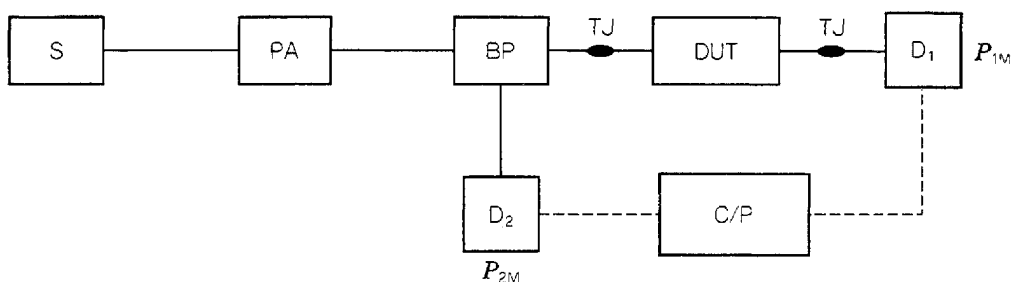


Fig. 6.4.3 PDL measurement set-up of device under test

6.4.5 Details to be specified in detail specifications The following details, as applicable, shall be specified in the detail specification:

- Optical sources (specification of optical source, peak wavelength, spectral width, etc.)
- Structure specification of polarization adjuster

- c) Polarization dependence of splitting ratio of polarization-independent optical branching device
- d) Pigtail lengths
- e) Performance requirements
- f) Deviations from this test procedure

6.5 Return loss

Information : This test method is based on **IEC 61300-3-6** *Examinations and measurements—Return loss*, but the method 3 : Method using an optical circulator and a total reflection termination is added.

6.5.1 Objective This Standard specifies the test method which measures the return loss or reflection factor of a fibre optic device under test (device under test, DUT). The return loss or reflection factor, as used in this Standard, is the ratio of the power incident on the device under test, to the total power reflected by the device under test, expressed in decibels.

Information : The return loss is mainly used in order to define all the power reflected by the optical source in an optical-fibre transmission line. The reflection factor is mainly used to define the power reflected by a point or individual components.

6.5.2 General description The following methods shall be specified for measuring the return loss of a fibre optic device.

- a) **Method 1:** Method using an optical branching device
- b) **Method 2:** Method using an optical time domain reflectometer (OTDR)
- c) **Method 3:** Method using an optical circulator and a total reflection termination

Information : Method 1 is the reference measurement method. Method 3 is specified additionally based on the present situation in this country, although it is not specified in **IEC 61300-3-6**.

6.5.3 Apparatus The following apparatus and equipment shall be required to perform this test.

Device under test (DUT) The passive optic device under test has two optical ports. These optical ports may be terminated with pigtails or with optical connectors. Master plugs with pigtails and, as required, master adapters are to be added to those ports with connector terminations so as to form complete connector assemblies with pigtails.

- a) **Method 1: Method using an optical branching device**
 - 1) **Optical branching device (BP)** The splitting ratio of the optical branching device shall be stable. It shall also be insensitive to polarization. Furthermore, the directivity should be at least 10 dB higher than the maximum return loss to be measured.

- 2) **Optical power meter (D_1 , D_2 and D_3)** The optical power meter which satisfies the conditions of 6.1 shall be used.
- 3) **Optical source (S_1 and S_2)** The optical source which satisfies the conditions of 6.1 shall be used.
- 4) **Excitation unit (E)** The excitation unit which satisfies the conditions of 6.1 shall be used.
- 5) **Temporary joint (TJ)** The temporary joint which satisfies the conditions of 6.1 shall be used.
- 6) **Optical terminator (T)** The optical fibre terminator is the method or device for terminating the optical fibre end in order to control reflection and should have the return loss of at least 20 dB greater than the maximum return loss to be measured. The following three types of optical terminations are suggested:
 - 6.1) angled fibre ends;
 - 6.2) the application of an index match material to the fibre end;
 - 6.3) attenuation in the fibre, for example with a mandrel wrap.

In the case of 6.3), it may be applied between components. For example, the measurement of P_0 in Fig. 6.5.4 may be made by applying attenuation between TJ₁ and the device under test in Fig. 6.5.1.

b) **Method 2: Method using OTDR**

- 1) **OTDR** The characteristics of OTDR is specified in the detail specification. It is preferable to incorporate the attenuator for decreasing the quantity of light so that the light receiving level of OTDR may not be exceeded.
- 2) **Temporary joint (TJ)** The temporary joint shall be in accordance with a) 5).

c) **Method 3: Method using an optical circulator and a total reflection termination**

- 1) **Optical circulator (C)** The optical circulator shall transmit a signal from the input port of light to the common port and from the common port to the output port, and shall have the function to separate a signal between the input port and the output port. The optical circulator of which the isolation between the input port and the output port has sufficient allowances for the return loss of the device under test shall be used.
- 2) **Optical power meter (D_1)** The optical power meter shall be in accordance with a) 2).
- 3) **Optical source (S_1)** The optical source shall be in accordance with a) 3).
- 4) **Optical fibre for measurement** The optical fibre for measurement shall be the optical fibre to which the plug connecting to the branching device at the one end, and the plug fitting into the total reflection termination or the device under test at the reflection side are attached and shall be specified in the detail specification.

- 5) **Total reflection termination** The total reflection termination shall be the optical fibre cord with plugs coated with gold vapor deposition etc., and made into the total reflection.
- 6) **Optical terminator (T)** The optical terminator shall be in accordance with a) 5).

6.5.4 Procedure

- a) **Method 1: Measurement of return loss with an optical branching device** The procedure of measurement of return loss with an optical branching device shall be as shown in Fig. 6.5.1.

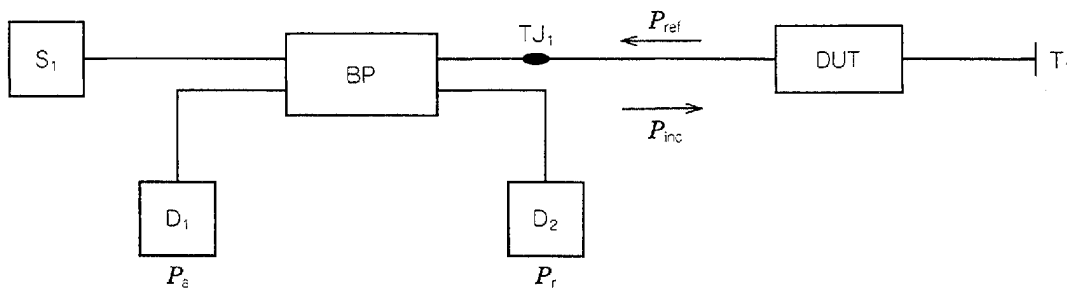


Fig. 6.5.1 Measurement of return loss with an optical branching device (method 1)

Measured values of optical power P are expressed in unit, mW.

- 1) Return loss, rl , in Fig. 6.5.1 shall be calculated according to formula (21).

$$rl(\text{dB}) = -10 \log(P_a' - P_0') + G \quad (21)$$

where,

$$P_a' = \frac{P_a}{P_r} \quad (\text{normalized optical power of } P_a) \quad (22)$$

P_r : reference optical power (mW)

P_0' : normalized value of system reflected optical power
[see formula (26)]

G : system constant (dB) [see 2)]

In formula (21), P_a' and P_0' have been normalized with P_r .

The value of P_r used to normalize P_a is the value from the measurement illustrated in Fig. 6.5.1.

The value of P_r used to normalize P_0 is the value from the measurement illustrated in Fig. 6.5.4.

This allows the measurements of P_a and P_0 to be made at different times, and for drift in the amplitude of the source to have occurred between these measurements. The return loss in formula (21) is the total return loss between TJ_1 and T_1 as observed from TJ_1 .

- 2) System constant G : Evaluate G according to either of the following two methods.

- 2.1) Method A: In the system of measurement of Fig. 6.5.1, remove the optical source (S_1), or turn off the power and measure P_{aa} after connecting the optical source (S_2) (Fig. 6.5.2). While the optical source (S_2) had been made to emit light, cut the fibre at the point "CP", connect the optical power meter (D_3), and measure P_b .

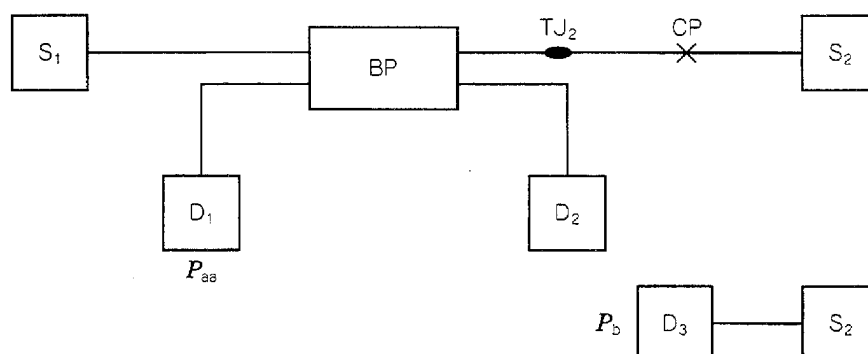


Fig. 6.5.2 Method to obtain system-constant G (procedure 1)

$$C_1 = \frac{P_{aa}}{P_b} \dots\dots\dots (23)$$

C_1 is the transfer coefficient of the optical branching device.

As shown in Fig. 6.5.3, connect the optical power meter (D_3) and measure P_c and P_{rr} .

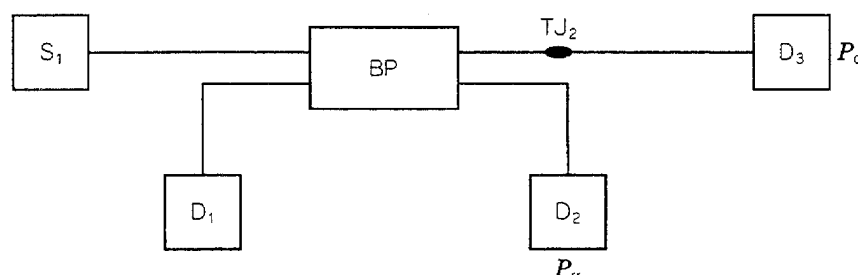


Fig. 6.5.3 Method to obtain system-constant G (procedure 2)

$$C_2 = \frac{P_{rr}}{P_c} \dots\dots\dots (24)$$

C_2 is the splitting ratio of the optical branching device.

Obtain the system-constant G according to formula (25).

$$G(\text{dB}) = 10 \log \left[\frac{C_1}{C_2} \right] \dots\dots\dots (25)$$

- 2.2) Method B: In this method, calculate G by using the optical terminator having the known return loss, R_c .

- 2.2.1) Replace the device under test in Fig. 6.5.1 with the optical fibre terminator having the known return loss, R_c .