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TECHNICAL REPORT

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Fibre optic interconnecting devices and passive components – Part 03-02: Reliability – Report of high power transmission test of specified passive optical components

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Fibre optic interconnecting devices and passive components – Part 03-02: Reliability – Report of high power transmission test of specified passive optical components

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FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS –

Part 03-02: Reliability – Report of high power transmission test of specified passive optical components

FOREWORD

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IEC 62627-03-02, which is a technical report, has been prepared by subcommittee 86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86B/3228/DTR	86B/3277/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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INTRODUCTION

Optical transmission power has increased in recent years due to the growing demands for ultra-long haul transmission systems and more applications of fibre optic amplifiers for cable television broadcasting systems. In view of these advances, concerns arise about optical fibres, fibre optic connectors and passive optical components installed in fibre optic communication systems due to the fact that these components may harm human beings due to a leakage of high-power light and the possibility of fire caused by melting and damage of these components. However, mechanisms, conditions, and factors that cause such accidents have not yet been clearly identified. Furthermore, industry standards on the reliability and long-term evaluation of optical components do not include testing with high optical power.

This technical report is based on the Optoelectronic Industry and Technology Development Association (OITDA) – Technical Paper (TP), TP04/SP_PD-2008, "Technical paper of investigation of high-power reliability for passive optical components for optical communication application".

FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS –

Part 03-02: Reliability – Report of high power transmission test of specified passive optical components

1 Scope

This part of IEC 62627 describes test data relating to high power damage of fixed optical attenuators, optical isolators and optical splitters (non-wavelength selective branching devices). It also describes the test of thermal simulation and failure mechanism analysis for the above passive optical components on high power transmission.

2 Samples for transmission test

Fixed optical attenuators, optical isolators and optical splitters (non-wavelength selective branching devices) were selected for the high power test, as these passive optical components are widely used for fibre optic transmissions systems and it is highly possible that these are used under high power conditions. Table 1 shows the specifications of the samples and Table 2 shows the manufacturer names and product codes of samples.

Table 1 – Specifications of the passive optical components use for the high power damage threshold test

Samples	Specifications
Fixed optical attenuator	Plug-style fixed attenuator (SC connector) Attenuation: 10 dB, 20 dB and 30 dB.
Optical isolator (Polarization independent)	Inline isolator (pigtail type), double stage.
Optical splitter (non-wavelength selective branching device)	Planar lightwave circuit (PLC) type, 1 input, 8 output ports.

Table 2 – Manufacturer names and product codes of samples

Samples	Manufacture names and product codes
Fixed optical attenuator	Showa Cable Systems Co., LTD., KSCAT10SL (10 dB attenuation), KSCAT20SL (20 dB attenuation) and KSCAT30D (30 dB attenuation) Seikoh-Giken Co., Ltd., FA115-10-HP5 (10 dB attenuation) and FA115-20-HP5 (20 dB attenuation)
Optical isolator	FDK Corporation, YD-4600-1-155S NEC TOKIN Corporation, IL-1550IW5038EC-011
Optical splitter	Furukawa Electric Co. Ltd., PS202-1x8-N

3 High power damage threshold test

3.1 Test conditions

Test details and measuring performances are shown in Tables 3 and 4, respectively. A step stress test was adopted in which incident power level rose step by step. Duration time was five minutes per each power level, considering the stabilization time of the temperature of the tested passive optical components. Furthermore, the tested temperature was set at 70 °C according to IEC 61300-2-14:2005. The insertion loss (IL) and return loss (RL) changes and the outer surface temperature of components were monitored, assuming that the high optical power absorbed by the passive optical component converts into heat.

Table 3 – Test details

Items	Details
Input wavelength	1 480 nm (Raman laser)
Input power	Maximum 4,4 W (forward direction test) and 5 W (backward direction test)
Test method	Step stress test in which incident power level rises step by step
Duration	Five minutes per each power level
Ambient test temperature	70 °C

Table 4 – Measurement requirements

Categories	Measurement requirements
Online monitoring	IL (1 480 nm), RL (1 480 nm) and outer surface temperature of passive optical components
Before and after the test	IL, RL, Polarisation dependent loss (PDL) for optical splitters and optical isolators and Isolation for optical isolators

For the measurements, an input light with a wavelength of 1 480 nm was used that is different from the signal wavelength. The reasons for the use of 1 480 nm are as follows:

a) High-power light sources with several watt levels are readily available at this wavelength;

b) There is no difference in absorption coefficient of metal doped fibres that are used for optical attenuators with wavelengths from 1 480 nm to 1 550 nm;

c) Various wavelengths (such as signal light, remaining excitation light, amplified spontaneous emission light) enter the optical isolator. Among them, the optical power of the excitation wavelength of 1 480 nm by an optical amplifier is stronger. The absorption coefficient of Faraday rotator at a wavelength of 1 480 nm is approximately 1 % higher than that at a 1 550 nm wavelength. Additionally, the dependency on temperature by the rotation angle of Faraday rotator is from 0,07 °C to 0,1 °C. The loss of wavelength of 1 480 nm in the forward direction is slightly larger than that of wavelength of 1 550 nm. Therefore, when evaluating the high power light, it is more appropriate to use the wavelength of 1 480 nm;

d) The absorption coefficient of adhesive in the connecting points between the optical fibre and the waveguide in the optical splitter does not have a wavelength dependency. Moreover, in the light going through the optical splitter, the light energy is stronger in the remaining excitation light wavelength of 1 480 nm.

3.2 Apparatus and measurement conditions

The measurement setup was based on the conditions specified in IEC 61300-2-14:2005. The setup is shown in Figure 1 and Figure 2. A RL monitoring coupler and an optical power meter were added to IEC 61300-2-14:2005. Two 2 × 2 20 dB optical couplers were used for high power monitoring at both the input terminal and the output terminal of the device under test (DUT).

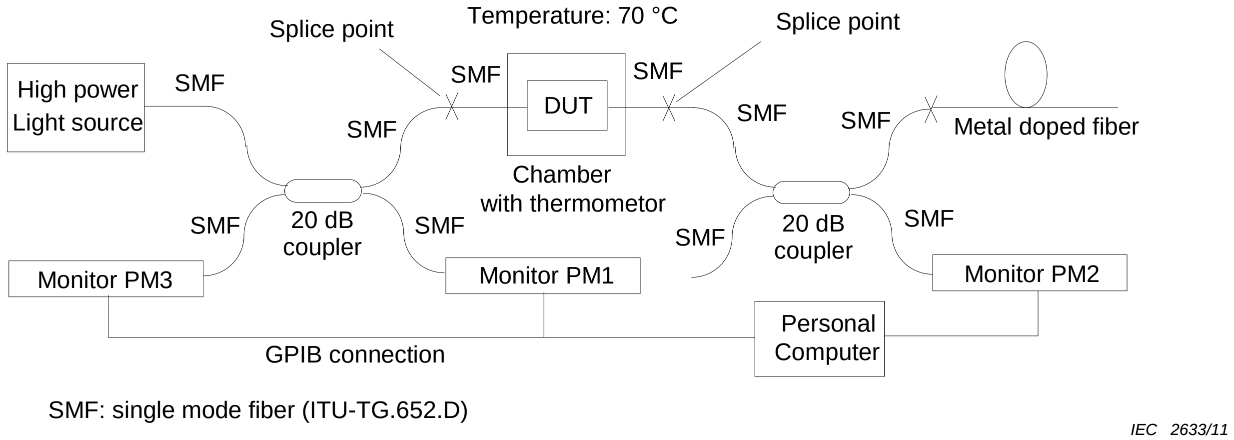


Figure 1 – Measurement setup

Table 5 shows the measuring conditions for the test. IL, PDL and isolation were measured using the signal wavelength of each device. RL was measured using the RL measuring instrument (the built-in wavelength of the light source is 1 310 nm) after the test. Due to their designs the DUTs used in this test do not have any RL wavelength dependency.

Table 5 – Measurement conditions in the test

Measurement Samples	Measurement performances	Measurement Wavelengths
Optical Attenuators	IL (dB)	1 550 nm
	RL (dB)	1 310 nm
Optical Isolators	IL (dB)	1 550 nm
	PDL (dB)	1 550 nm
	Isolation (dB)	1 550 nm
	RL (dB)	1 310 nm
Optical Splitters	IL (dB)	1 310 nm
	PDL (dB)	1 310 nm
	RL (dB)	1 310 nm

3.3 Test results

Table 6 shows the test results. In the optical isolators and the optical splitters, the outer surface temperature became stable after four minutes. No correlation was found between the attenuation of fixed optical attenuator and the incident light power at the RL reduction. However, in all the fixed optical attenuators, the change in return power was more than 10 dB. The RL of one optical isolator was observed to decrease in the return direction at an input power of 5 W. The backward direction test result of optical isolators is explained in 3.5. No damage to optical splitters was observed until an incident power of 4,4 W for forward direction and 5 W for backward direction was reached.

Table 6 – Results of high power damage threshold test

Components	Directions	Numbers of samples	Surface Temperatures	Duration times for surface temperature stability	Results
10 dB Attenuators	Plug to socket	6	89 °C	> 5 min	RL reduction at 1,4 to 2,3 W (All samples).
20 dB Attenuators	Plug to socket	3	85 °C	> 5 min	RL reduction at 1,7 to 1,9 W (All samples).
30 dB Attenuators	Plug to socket	2	75 °C	> 5 min	RL reduction at 1,4 to 1,6 W (All samples).
Optical Isolators	Forward	5	86 °C	4 min	No failure by 4,4 W.
	Backward	4	174 °C	4 min	RL reduction at 5 W (One sample).
Optical Splitters	Forward	3	87 °C	4 min	No failure by 4,4 W.
	Backward	3	158 °C	4 min	No failure by 5 W.

Figures 2(a), (b) and (c) show the test results of 10 dB attenuator. In Figure 3(a), when the incident power was 2,3 W, the return power significantly changed. At that power, the surface temperature was 89 °C (see Figure 2(b)). The change of IL was within ± 0,5 dB (see Figure 2(c)).

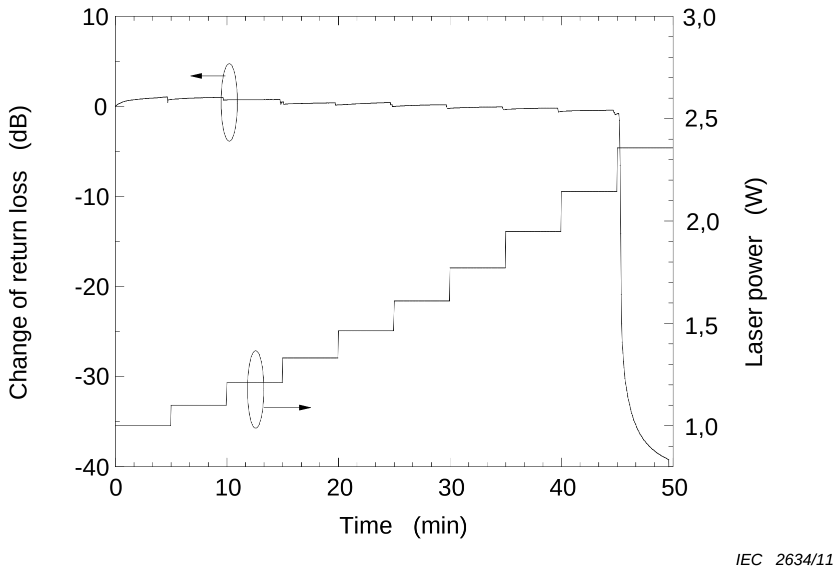


Figure 2(a) – PM3 monitor output for the measurement of RL

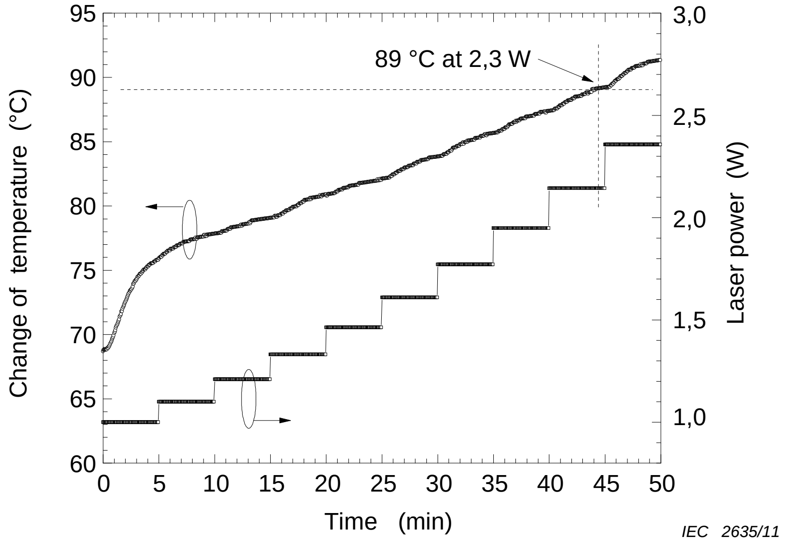


Figure 2(b) – Temperature sensor data for the surface temperature

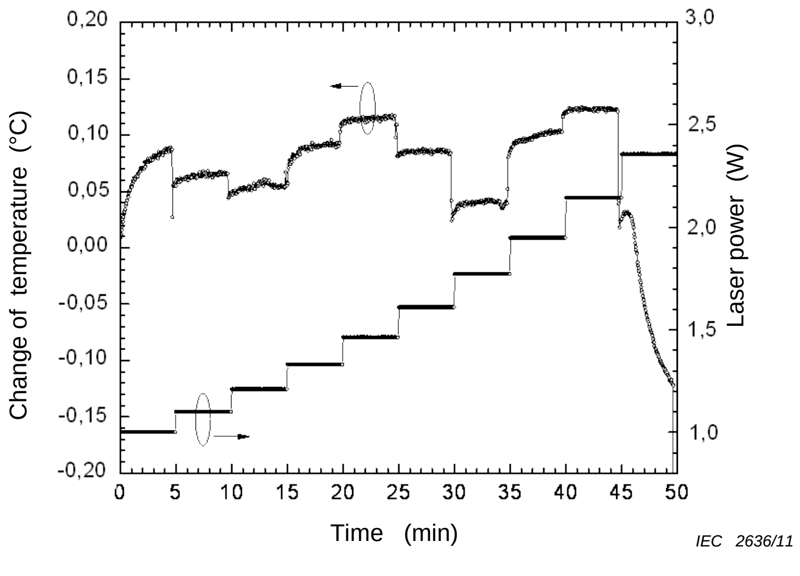


Figure 2(c) – PM2 monitor output for the measurement of IL

Figure 2 – Results for high power transmission test of 10 dB attenuator

Table 7 shows the test results of IL and RL before and after the test. While the RL was varied over 10 dB during the test in the fixed optical attenuators, the difference between the data before and after the test is small.

Table 7 – Characteristics changes before and after the test

Samples		IL		RL
10 dB Attenuators	Before	10,11 dB		53,0 dB
	After	10,13 dB		54,5 dB
20 dB Attenuators	Before	20,87 dB		53,6 dB
	After	20,9 dB		54,7 dB
30 dB Attenuators	Before	29,5 dB		49,5 dB
	After	29,9 dB		50,3 dB
		IL	**Isolation**	**RL**
Optical Isolators	Before	0,54 dB	63,1 dB	> 55 dB
	After	0,53 dB	61,8 dB	> 55 dB
		IL	PDL	RL
Optical Splitters	Before	9,55 dB	0,04 dB	> 50 dB
	After	9,53 dB	0,07 dB	> 50 dB

NOTE The values are the averages of measured samples. The measuring conditions are as shown in Table 5.

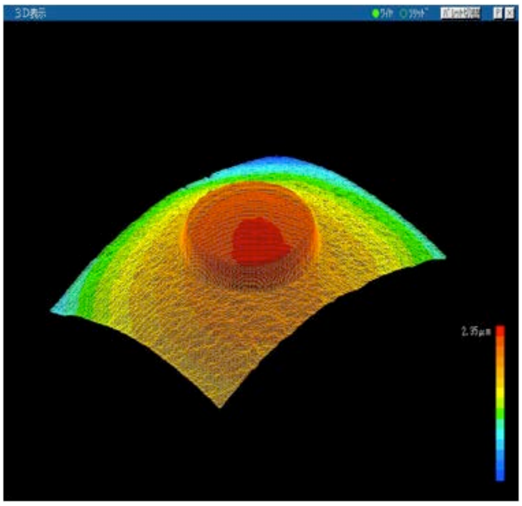
3.4 Ferrule endfaces of the attenuators

In order to investigate the cause of RL change during the test, the fixed attenuators were observed after the test. Firstly, the ferrule endface was measured using a three-dimensional measurement instrument. Table 8 shows the fibre position of ferrule endface. Figure 3 shows the pictures of ferrule endface for 30 dB attenuator. The fibres protruded slightly before the test in all the samples. but after the test they were all withdrawn. The maximum withdrawal was 0,15 μm at the input side.

Table 8 – Fibre protrusion and withdrawal in the fixed optical attenuator before and after the high power test

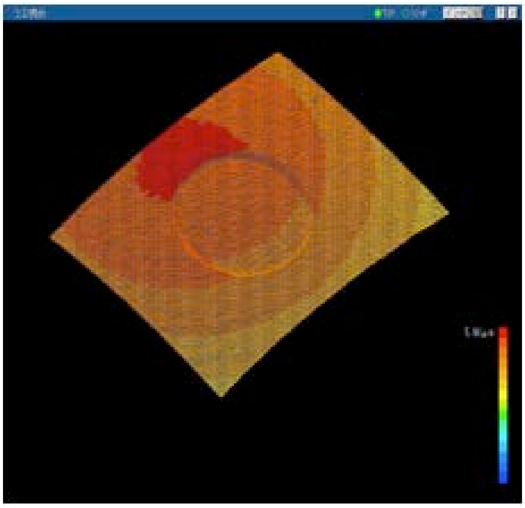
Sample	Input side		Output side	
	Before	**After**	**Before**	**After**
No.5 10 dB Attenuator	+ 0,02 μm	– 0,10 μm	No-data	– 0,01 μm
No.6 10 dB Attenuator	+ 0,02 μm	– 0,13 μm	No-data	– 0,05 μm
No.2 30 dB Attenuator	+ 0,02 μm	– 0,15 μm	No-data	– 0,06 μm
No.3 30 dB Attenuator	+ 0,01 μm	– 0,13 μm	No-data	– 0,09 μm

NOTE The positive number means fibre protrusion from the ferrule, and the negative number means fibre withdrawal.



IEC 2637/11

Figure 3(a) – Before the test



IEC 2638/11

Figure 3(b) – After the test

Figure 3 – Pictures of ferrule endfaces in the input side of 30 dB attenuator

3.5 Change of characteristics in the backward direction incidence for optical isolators

In Erbium Doped Fibre Amplifiers (EDFA), optical isolators are installed before and after the Erbium Doped Fibre (EDF) to prevent the reflectance of the signal light and to stabilize the output power. As the optical isolator placed before the EDF receives both the leakage of pumping light and the amplified spontaneous emission from the EDF, the test was conducted using the backward direction incidence of high power light.

Table 9 shows the test results. In the optical isolator, the RL only changed in sample No. 1. Figure 4 shows the monitoring result of optical isolator in this case. It was observed that the IL in the backward direction (same as isolation) changed between 30 and 40 dB as shown in Figure 4(b). It is considered that this is due to the fact that the light with a wavelength of 1 480 nm was absorbed by the Faraday rotator and its angle of rotation was changed due to the higher temperature. From the factors of light absorption ratio of garnet and the temperature dependency of rotation angle of Faraday rotator, it was estimated that the temperature increased by 100 °C or more.

After that, in order to investigate the cause of return loss degradation, the reflection point of the optical isolator was observed using the high-precision-reflect-meter (made by Agilent). As a result, the reflection point was observed in a point 7 mm from the ferrule endface as shown in Figure 5. The amount and the position of reflection proved that the optical fibre was broken in the ferrule.

Table 9 – Test result in the backward direction

Components	Sample number	Fluctuation of backward IL during the test	Fluctuation of RL during the test	Degradation of forward IL	RL after the test	Power at which damage occurred
Isolators	No.1	< 10 dB	> 30 dB	< 0,1 dB	> 55 dB	5 W
	No.2	< 10 dB	< 1 dB	< 0,1 dB	> 55 dB	–
	No.3	< 10 dB	< 1 dB	< 0,1 dB	> 55 dB	–
	No.4	< 10 dB	< 1 dB	< 0,1 dB	> 55 dB	–

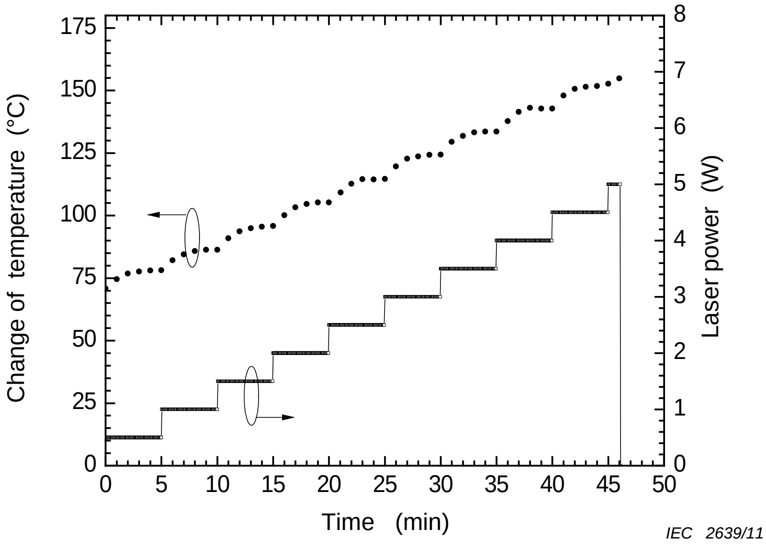


Figure 4(a) – Temperature sensor data for the surface temperature

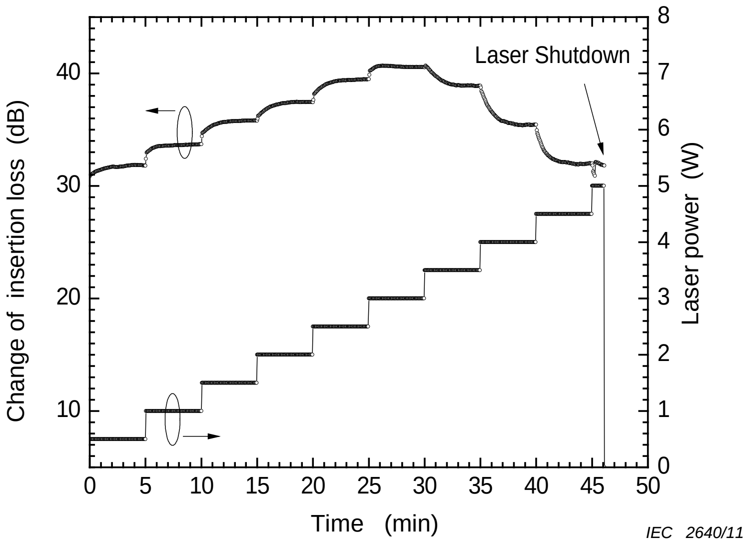


Figure 4(b) – PM2 monitor output for the measurement of IL

Figure 4 – High power test result for backward direction for optical isolator (example)

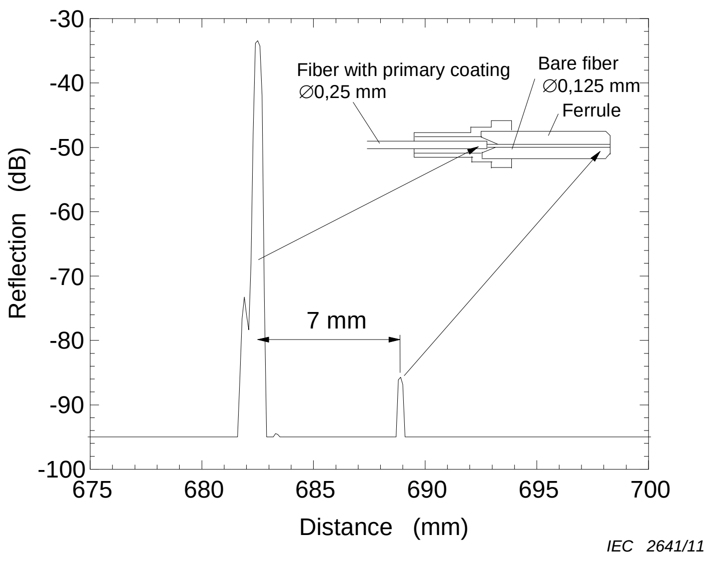


Figure 5 – Measurement result for the ferrule point of reflection in the optical isolator

4 Thermal simulation of passive optical components

4.1 Thermal simulation in the high power light

4.1.1 General

The deterioration by high power light is considered due to the change of materials triggered by higher temperature caused by light absorption. Therefore, a thermal simulation was conducted in each passive optical component.

4.1.2 Fixed optical attenuator

To consider the internal structure of fixed optical attenuator, the metal doped fibre (MDF) with a certain absorption coefficient is fixed in a ferrule using adhesive. Input and output fibre endfaces are PC (physical contact) polished. The required attenuation is obtained by adjusting the absorption coefficient and the length of MDF.

Thermal simulation assumes that light is absorbed depending on the absorption coefficient of MDF and converted into the heat. ANSYS Multi-physics Ver. 9.1 simulation software was used. The diameter of the contact point between the optical fibre in the input side and the MDF within the connector is 0,25 mm. To simplify the calculation, all the parts were converted to be a cylindrical shape. The general physical properties for thermal conductivity, specific heat and density were used.

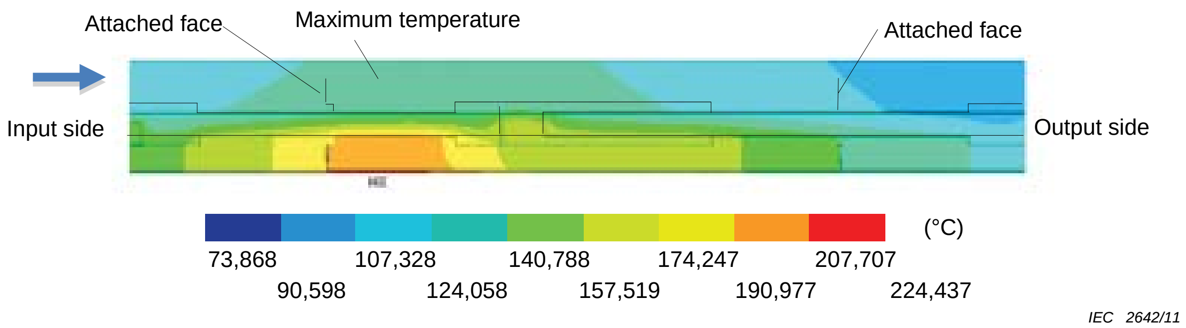


Figure 6 – Thermal distribution of fixed optical attenuator by thermal simulation (10 dB attenuator, input power: 1 W)

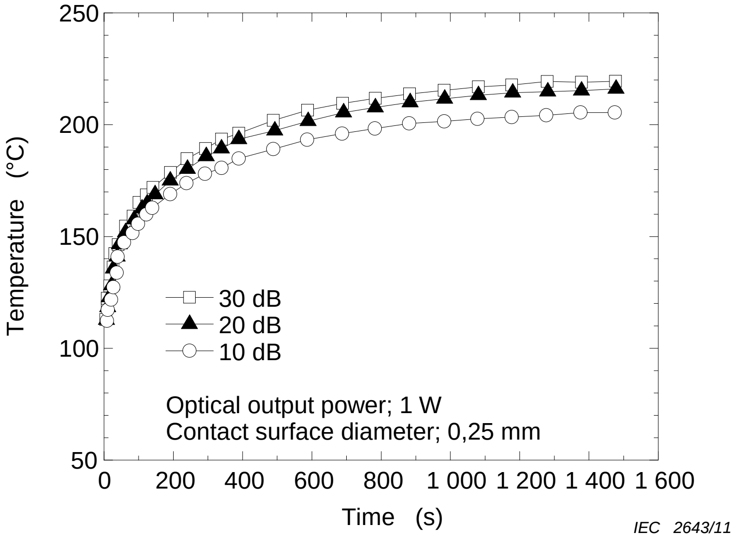


Figure 7 – Maximum internal temperature of fixed optical attenuator by thermal simulation (input power: 1 W)

Figure 6 shows the thermal distribution of the simplified cross section of the fixed optical attenuator. The light power of 1 W enters from the direction shown in the arrow. The upper side is omitted as it is centrosymmetric. Attached face means an area where the ferrule in the input side comes into contact with that in the MDF side. The temperature change in the MDF core area that had the maximum temperature is shown in Figure 7. In this case, the temperature of 10 dB attenuator was 200 °C, that of 20 dB Attenuator was 215 °C, and that of 30 dB Attenuator was 220 °C.

Figure 8 shows the temperature change of the core area, the sleeve area, and the outer package in the optical attenuator when a light power of 2 W entered. As the outer package contacted the ambient air, the temperature change was slow compared with that in the core area and the sleeve area. It was observed the temperature exceeded 200 °C within a short period of time even in the sleeve area.

The temperature of outer package was estimated to reach approximately 150 °C in the simulation. It was actually approximately 90 °C (see Table 6). The differences between the simulation result and actual data is considered to be due to the thermal conduction by ambient air from the outer package.

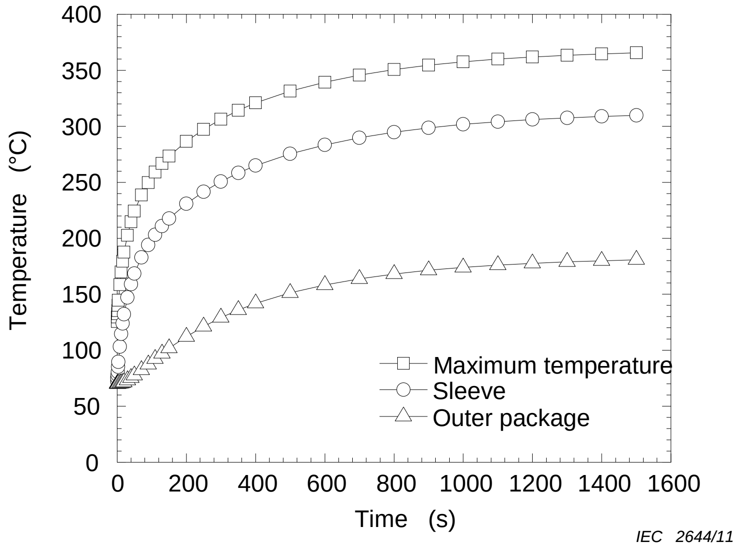


Figure 8 – Thermal simulation of fixed optical attenuator (input power: 2 W)

4.1.3 Optical isolator

Figure 9 shows the thermal simulation result of an optical isolator. When light with an input power of 5 W was used, the maximum temperature was approximately 120 °C, and the outer surface temperature was approximately 110 °C. As no material with a high light absorption rate was placed on the optical path of the optical isolator, the temperature was lower than that in the fixed optical attenuator.

In the simulation of reverse direction with the light incident power of 3 W, the maximum temperature was approximately 400 °C at the ferrule. This higher temperature of over 400 °C is assumed to have caused the broken fibre described in 3.5.

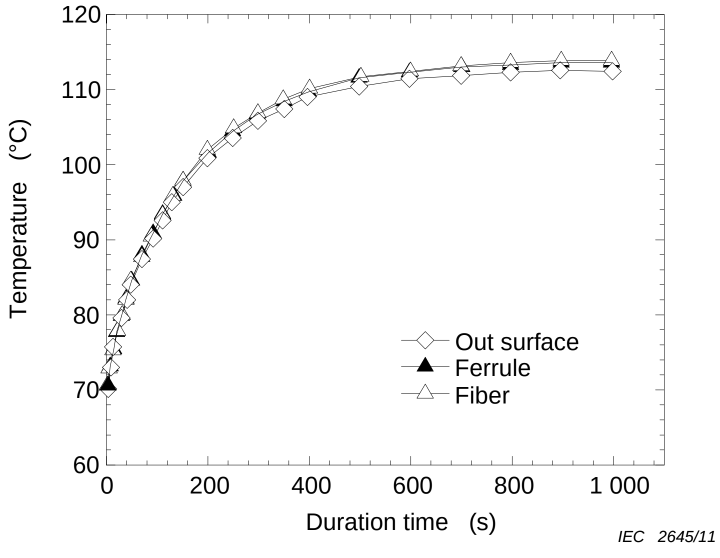


Figure 9 – Thermal simulation of optical isolator (forward direction, input power: 5 W)

4.1.4 Optical splitter

Figure 10 shows the thermal simulation result of an optical splitter. The simulation conditions use an IL of 1 dB. With a light input power of 5 W, the maximum temperature was 150 °C, which is higher than that of the actual data shown in Table 6 (87 °C). The reason for the difference is considered to be caused by the effect of heat conduction from the outer case to the air.

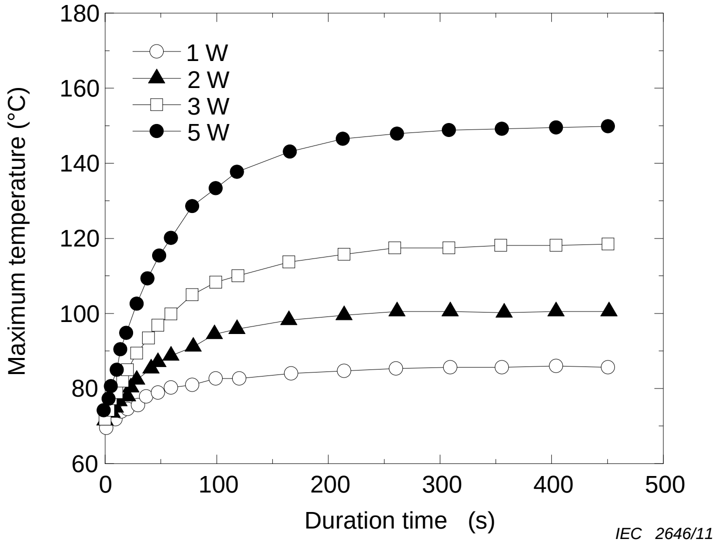


Figure 10 – Maximum internal temperature of optical splitter by thermal simulation (forward direction, input power: 5 W)

4.2 Temperature rise simulation in the medium power light

The simulation was conducted in the optical power range that is expected to be used in the actual operation range of optical attenuators. The simulation conditions are shown in Table 10. Figure 11 shows the maximum internal temperature at each attenuation value. The horizontal axis shows the attenuation converted into the absorption rate (30 dB = 0,999, 20 dB = 0,99, 10 dB = 0,9, 1 dB = 0,2, 3 dB = 0,5, 5 dB = 0,7).

Table 10 – Conditions of optical attenuator for simulation

Input Powers	1 dB attenuator			5 dB attenuator			10 dB attenuator		
	A	B	C	A	B	C	A	B	C
100 mW	x			x			x		
200 mW	x			x			x		
500 mW	x			x	x		x	x	
1 000 mW	x			x	x			x	x
Condition: A	With Housing, Ambient Temperature 70 °C								
Condition: B	Without Housing, Ambient Temperature 70 °C								
Condition: C	With Housing, Ambient Temperature 25 °C								

Figure 12 shows the relationship between the input light power and the maximum internal temperature. All the data can be approximated by a line with a slope of 70 °C on the y-axis (y = ax + 70). It is necessary to use the components at a temperature under 100 °C so that the glass transition temperature of adhesive (approximately 120 °C) is not exceeded. According to the calculation results, it was estimated that the light power that does not exceed the glass transition temperature is 200 mW in the case of 10 dB attenuator, and 300 mW in the case of 5 dB attenuator.

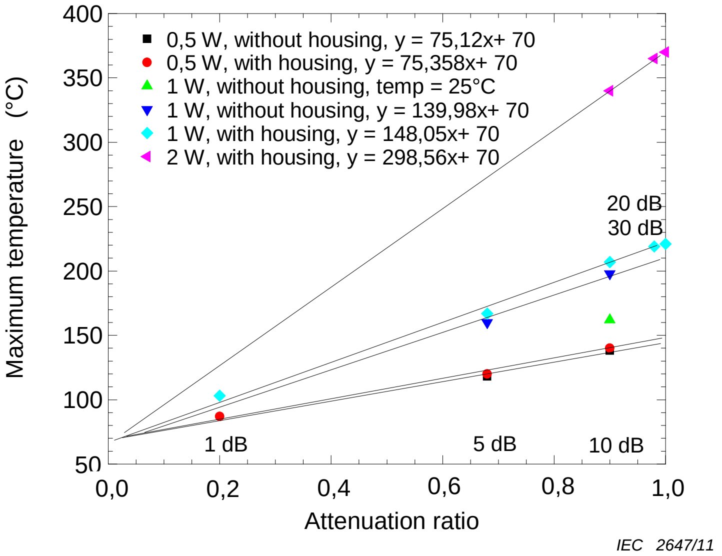


Figure 11 – Ambient temperature dependency of maximum temperature in the thermal simulation of fixed optical attenuator

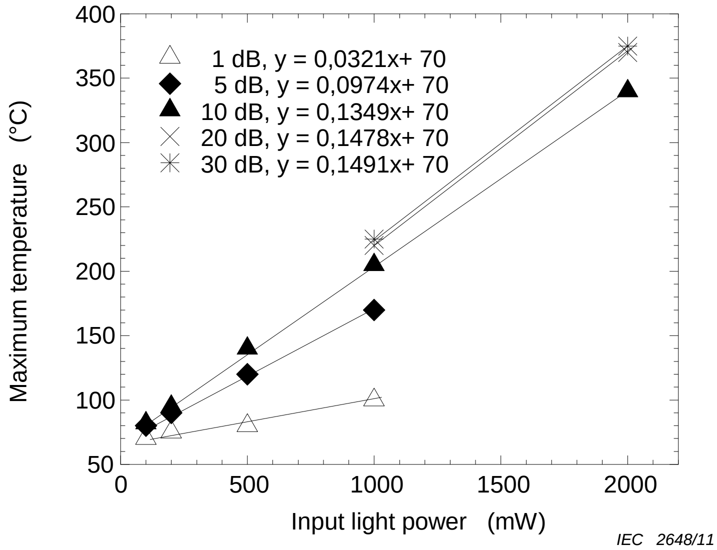


Figure 12 – Relationship between input light power and maximum temperature in the thermal simulation of fixed optical attenuator

5 Long-term test of high power light

In order to investigate the long-term reliability for high power condition, a long-term test was conducted. As this test is not intended to be a destructive test, the input light power used was 60 % of that used in the damage threshold test. The measuring performance is the same as those in Table 4. The test conditions are shown in Table 11.

Table 11 – Conditions of long-term test

Items	Optical attenuators	Optical isolators	Optical splitters
Input wavelength	1 480 nm	1 550 nm	
Input optical power	1 W	3 W	
Test temperature	70 °C		
Test duration time	500 hours		
IL	monitored	monitored	monitored
RL	monitored	monitored	monitored
Out surface temperature	monitored	monitored	monitored

Figure 13 shows the change of IL, RL and the outer surface temperature of a fixed optical attenuator under the above conditions. In sample B, the temperature changed when approximately 100 hours had passed. This was due to the temperature sensor becoming detached, and after it had been replaced the test was continued. Similarly, Figures 14 and 15 show the IL, RL and the outer surface temperature of an optical isolator and an optical splitter. No characteristic changes were observed in either case.

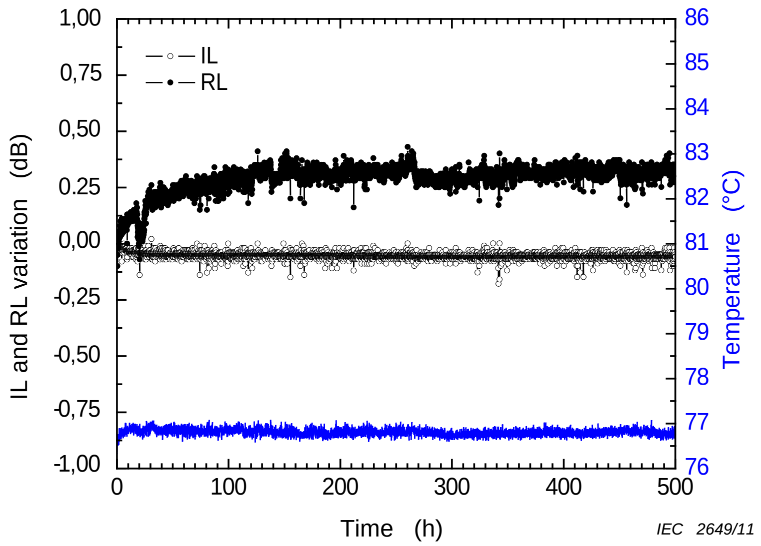


Figure 13a) – Sample A

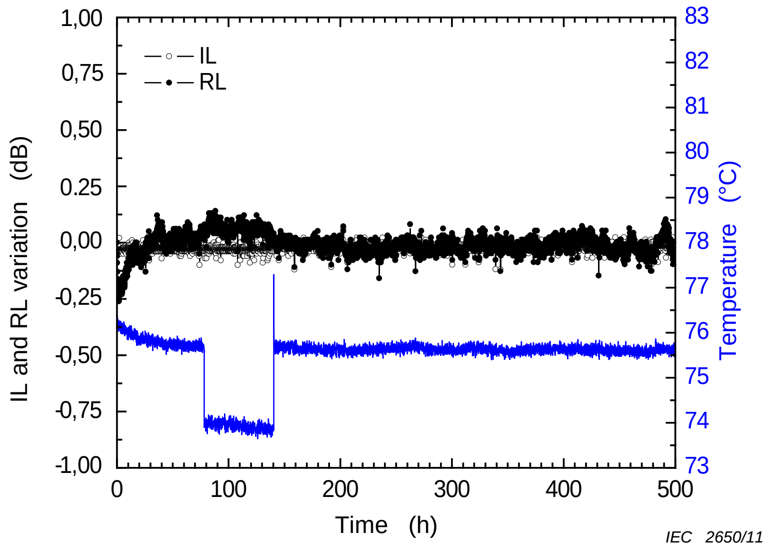


Figure 13b) – Sample

Figure 13 – Change of IL and RL of fixed optical attenuator

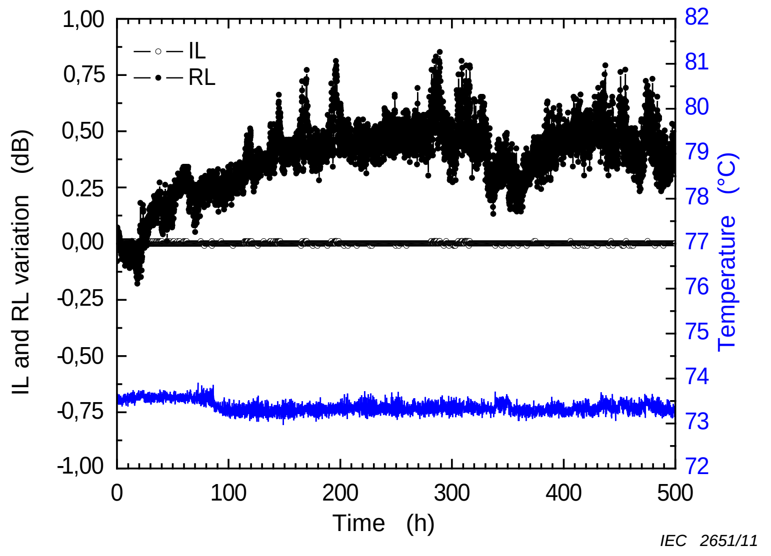


Figure 14 – Change of IL and RL of optical isolator

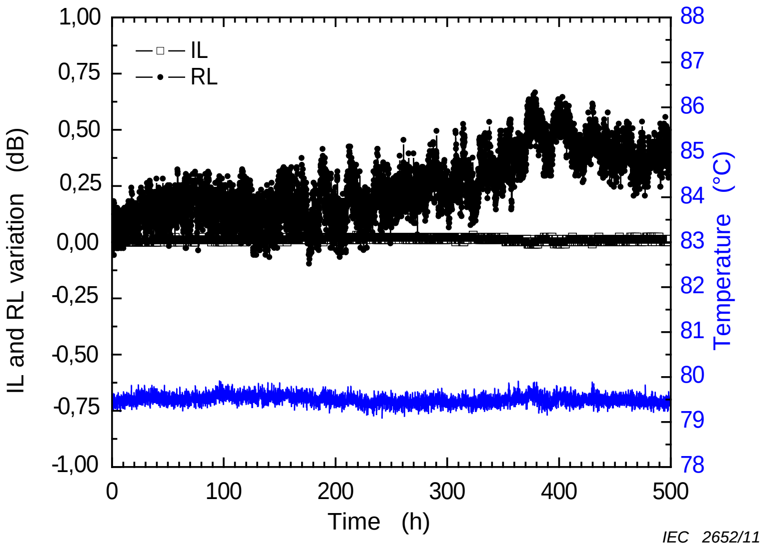


Figure 15 – Change of IL and RL of optical splitter

Table 12, 13, and 14 show the optical characteristics of a fixed optical attenuator, an optical isolator and an optical splitter before and after the long-term test. In all the samples, there was no change of optical characteristics. The protrusion of optical fibre of the fixed optical attenuator was also measured before and after the test. The result was that while some protrusion was observed, it was not big enough to have any influence on the characteristic changes.

Table 12 – Measurement result of optical characteristics and protrusion before and after the test of fixed optical attenuator

Samples		**IL** (dB)		**RL** (dB)		**Fibre protrusion** (μm)
		1 310 nm	**1 550 nm**	**1 310 nm**	**1 550 nm**	
A	Before	10,02	9,98	51,8	51,1	+ 0,034
	After	10,1	10,03	51,8	51,1	– 0,085
B	Before	9,93	10,12	54,1	55,6	+ 0,028
	After	9,82	9,98	58,4	60,2	+ 0,183

Table 13 – Measurement result of optical characteristics before and after the test of optical isolator

Samples		**IL** (dB)	**PDL** (dB)	**Isolation** (dB)	**RL** (dB)	
					Input	**Output**
A	Before	0,35	0,02	55,4	68,4	65,9
	After	0,33	0,02	54,9	67,6	63,6
B	Before	0,38	0,06	64,1	60,6	65,7
	After	0,34	0,07	62,5	63,0	64,3

Table 14 – Measurement result of optical characteristics before and after the test of optical splitter

Port No.		IL (dB)		PDL (dB)		RL (dB)	
		1 310 nm	1 550 nm	1 310 nm	1 550 nm	1 310 nm	1 550 nm
1	Before	9,86	9,84	0,06	0,04	57,9	60,4
	After	9,85	9,83	0,04	0,04	57,3	60,4
2	Before	9,91	9,64	0,04	0,06	58,9	61,7
	After	9,95	9,63	0,02	0,05	58,8	57,9
3	Before	9,94	9,64	0,04	0,04	58,9	59,1
	After	10,00	9,66	0,05	0,05	57,9	57,4
4	Before	9,70	9,64	0,05	0,04	58,2	61,7
	After	9,72	9,76	0,04	0,06	57,2	58,4
5	Before	9,82	9,78	0,04	0,03	59,3	63,0
	After	9,91	9,95	0,03	0,02	58,1	61,2
6	Before	9,89	9,63	0,03	0,05	57,4	58,6
	After	9,79	9,69	0,02	0,02	57,5	57,6
7	Before	9,91	9,64	0,02	0,05	58,7	58,6
	After	9,92	9,67	0,02	0,06	58,0	59,6
8	Before	9,82	9,79	0,04	0,04	58,6	61,2
	After	9,86	9,80	0,03	0,05	56,8	57,4

6 Assumption of failure mode

Optical fibre withdrawal was observed in the high power test of the optical attenuator. In the fixed optical attenuator, a metal doped fibre is fixed in a zirconia ferrule with adhesive. Generally, the glass transition temperature of the adhesive (approximately 120 °C) is set at a level sufficiently higher than the storage temperature of the product. As the result of test, it was considered that the temperature of the adhesive that fixes the metal doped optical fibre in the ferrule reached a high enough temperature to soften the adhesive. As a result the optical fibre was withdrawn at the head of the ferrule.

In the simulation, the temperature of the fibre core in the input side was 200 to 300 °C, and that in the output side was 150 to 250 °C. Consequently, the internal temperature exceeded the glass transition temperature of the adhesive. It is considered that the optical fibre withdrawal was due to the softening of adhesive and the difference of line expansion coefficient between zirconia and metal doped fibre, which led to the change of RL.

When the high power light was input in a backward direction for the optical isolator, the optical fibre broke. The principle of the function of optical isolator is to rotate the polarisation angle using Faraday rotator and to change the angle of incidence to the lenses by the refractive index of bi-refringent crystals. Therefore, as the light focus point of the optical path in a backward direction does not hit the fibre core, it is not concentrated in the optical fibre. The optical power of 5 W is diffused within the fibre and absorbed by the ferrule which causes a sharp rise of temperature. At this point, the surface temperature of the optical isolator reached 174 °C (actual data), and the temperature of ferrule was higher than that of the optical isolator. It is considered that the thermal distribution and the difference of thermal expansion coefficient between materials (such as glass, ferrule, adhesive, and air) generated the stress that caused the break in the optical fibre.

7 Conclusion

7.1 General

Various tests (damage threshold, long-term, and thermal simulation) were conducted by inputting high optical power to the specified passive optical components (specified fixed optical attenuators, specified optical isolators, and specified optical splitters) as shown in Table 2, and the following results were obtained.

7.2 Fixed optical attenuator

When an incident optical power of 2,3 W or higher entered the fixed optical attenuator, the RL changed remarkably even in a short period of time. However, when an incident optical power of 1 W entered over a period of 500 hours, no change of RL was observed. When checking the end face of ferrule after the breaking test, withdrawal of fibre was observed. Therefore the internal temperature was calculated by conducting a thermal simulation. In this test, it was found that internal temperature correlates with the incident optical power and the attenuation value. In the thermal simulation of medium power, it was found that the incident optical power had a limit. The limit of 10 dB attenuator was 200 mW, and that of 5 dB attenuator was 300 mW.

7.3 Optical isolator

No deterioration of optical characteristic was observed when an incident light power up to 5 W was input in the forward direction. The test was also conducted by inputting the high power light in a backward direction. The result was that one of four optical isolators showed a deterioration of RL. In this case, the temperature of external case was approximately 170 °C. Then, as the result of checking the internal reflection position using the reflect meter, it was found that the optical fibre was broken at a point 7 mm from the endface of ferrule. In the thermal simulation, it was calculated that the internal temperature rose up to approximately 400 °C. Based on these results, it was considered that the optical fibre broke due to the stress caused by the difference of thermal expansion coefficient of constituting materials.

7.4 Optical splitter

No deterioration of optical characteristic was observed with an incident light power up to 5 W for the optical splitter.

7.5 Conclusion

Based on the results of the tests and simulation, the following was found:

1) The performance deterioration of optical passive components by high power light is mainly caused by the temperature rise of materials due to the absorption of light and the stress (thermal distortion) due to the thermal distribution.
2) When conducting the test of high power light, the best way is to monitor the reflection amount on site. It is strongly recommended that the RL is monitored before, during, and after the test in future studies.
3) When estimating the deterioration, it is effective to conduct thermal simulation under the simplified model. At the same time, it should be carefully considered how to handle the waste heat when designing optical passive components used under the high power light.
4) It was found that it was necessary to maintain the internal temperature less than glass transition temperature of adhesive (approximately 120 °C) to avoid the deterioration of RL caused by the withdrawal of fibre.
5) In the high power light test, it is also useful to disassemble samples to estimate the deterioration mechanism.

Bibliography

Optoelectronic Industry and Technology Development Association (OITDA) – Technical Paper (TP), OITDA-TP04/SP_PD-2008, *"Technical Paper of investigation of high-power reliability for passive optical components for optical communication application"*

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