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SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Optical fibre cable maintenance support, monitoring and testing systems for optical fibre trunk networks

Recommendation ITU-T L.93

International Telecommunication Union

Recommendation ITU-T L.93

Optical fibre cable maintenance support, monitoring and testing systems for optical fibre trunk networks

Summary

Recommendation ITU-T L.93 describes requirements for optical fibre cable maintenance support, monitoring and testing systems for optical fibre trunk networks.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.93	2014-05-14	15	11.1002/1000/12199

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Introduction

Trunk line communication traffic is increasing rapidly. An optical fibre line testing system is essential for reducing maintenance costs and improving service reliability in optical fibre networks. Some technologies that are used in trunk lines (e.g., wavelength division multiplexing (WDM) systems and erbium doped fibre amplifier (EDFA)) require additional functions and procedures for optical fibre line testing systems. The system requirements described in this Recommendation help to achieve reliable maintenance of optical cables for trunk lines.

Recommendation ITU-T L.93

Optical fibre cable maintenance support, monitoring and testing systems for optical fibre trunk networks

1 Scope

This Recommendation addresses optical fibre maintenance support, monitoring and testing systems for trunk optical fibre cable networks. It describes fundamental requirements, functions and test procedures for use in maintenance operations. It applies to the test equipment and methods, configuration and optical devices, such as test access devices for connecting the test equipment to the communication line, which are components of the maintenance system.

The aspects related to active monitoring to detect communication signal degradation and the status of the transmission equipment are described in [ITU-T G.697]. The functional architecture and parameters specialized for submarine applications are described in [ITU-T G.979].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.650.3] Recommendation ITU-T G.650.3 (2008), *Test methods for installed single-mode optical fibre cable links*.

[ITU-T G.652] Recommendation ITU-T G.652 (2009), *Characteristics of a single-mode optical fibre and cable.*

[ITU-T G.653] Recommendation ITU-T G.653 (2010), *Characteristics of a dispersion-shifted, single-mode optical fibre and cable*.

[ITU-T G.654] Recommendation ITU-T G.654 (2012), *Characteristics of a cut-off shifted, single-mode optical fibre and cable*.

[ITU-T G.655] Recommendation ITU-T G.655 (2009), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.656] Recommendation ITU-T G.656 (2010), *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport*.

[ITU-T G.664] Recommendation ITU-T G.664 (2012), *Optical safety procedures and requirements for optical transmission systems*.

[ITU-T G.697] Recommendation ITU-T G.697 (2012), *Optical monitoring for dense wavelength division multiplexing systems*.

[ITU-T G.979] Recommendation ITU-T G.979 (2012), *Characteristics of monitoring systems for optical submarine cable systems*.

[ITU-T L.25] Recommendation ITU-T L.25 (1996), *Optical fibre cable network maintenance*.

[ITU-T L.40] Recommendation ITU-T L.40 (2000), *Optical fibre outside plant maintenance support, monitoring and testing system*.

[ITU-T L.41] Recommendation ITU-T L.41 (2000), *Maintenance wavelength on fibres carrying signals*.

[ITU-T L.50] Recommendation ITU-T L.50 (2010), *Requirements for passive optical nodes: Optical distribution frames for central office environments*.

[ITU-T L.66] Recommendation ITU-T L.66 (2007), *Optical fibre cable maintenance criteria for in-service fibre testing in access networks*.

[ITU-T L.68] Recommendation ITU-T L.68 (2007), *Optical fibre cable maintenance support, monitoring and testing system for optical fibre cable networks carrying high total optical power*.

[ITU-T L.85] Recommendation ITU-T L.85 (2010), *Optical fibre identification for the maintenance of optical access networks*.

[IEC 60825-1] IEC 60825-1 ed3.0 (2014), *Safety of laser products – Part 1: Equipment classification and requirements*.

[IEC 60825-2] IEC 60825-2 ed3.2 (2010), *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*.

[IEC 61280-4-2] IEC 61280-4-2 ed2.0 (2014), *Fibre-optic communication subsystem test procedures – Part 4-2: Installed cable plant – Single-mode attenuation and optical return loss measurement.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 attenuation of an optical fibre cable link [ITU-T G.650.3].

3.1.2 fibre characterization [ITU-T G.650.3].

3.1.3 optical distribution frame (ODF) [ITU-T L.50].

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 optical trunk line: A part of the optical fibre cable network that is located between two central offices.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CWDM Coarse Wavelength Division Multiplexing

DCN Data Communication Network

DWDM Dense Wavelength Division Multiplexing

EDFA Erbium Doped Fibre Amplifier

FBG Fibre Bragg Grating

FS Fibre Selector

FTTx Fibre to the x, where "x" indicates the final location on the user side of any one of a variety of optical fibre architectures, e.g., FTTB, FTTC, FTTH, FTTP.

IDM	Integrated Distribution Module
ODF	Optical Distribution Frame
OPM	Optical Power Meter
OTDR	Optical Time Domain Reflectometer
OTM	Optical Testing Module
PLC	Planar Lightwave Circuit
PMD	Polarization Mode Dispersion
TAM	Test Access Module
WDM	Wavelength Division Multiplexing

5 Conventions

None.

6 Fundamental requirements

Data communication traffic in both, access networks and optical trunk lines, is rapidly increasing. Therefore, the optical fibre cable for trunk lines is becoming increasingly important because of its large transmission capacity. The fundamental requirements for optical fibre cable maintenance support, monitoring and testing systems for optical trunk lines are as follows:

– An optical fibre cable maintenance support, monitoring and testing system must perform efficiently the maintenance work described in [ITU-T L.25].

– An optical fibre cable maintenance support, monitoring and testing system should provide the surveillance, testing and control functions listed in [ITU-T L.40] to meet the system specifications for optical fibres or fibre-optic components even when applied to optical trunk lines.

– It must be safe for network operators to handle the optical fibre cables, cords and fibre-optic components of the optical fibre cable maintenance support, monitoring and testing system. Network operator safety must be in accordance with [ITU-T G.664], [IEC 60825-1] and [IEC 60825-2].

7 Specific requirements for optical trunk lines

Figure 1 shows a typical configuration of an optical trunk line as defined in clause 3. There are some additional requirements for an optical fibre line testing system for optical trunk line cable networks. In general, an optical trunk line has a long transmission distance and must have a low attenuation. Therefore, the fibre-optic devices that are inserted in the communication lines for testing must also have a low insertion loss. In addition, test equipment must provide highly accurate measurements because of the importance of the optical trunk line. Specific requirements and functions for trunk lines are described below.

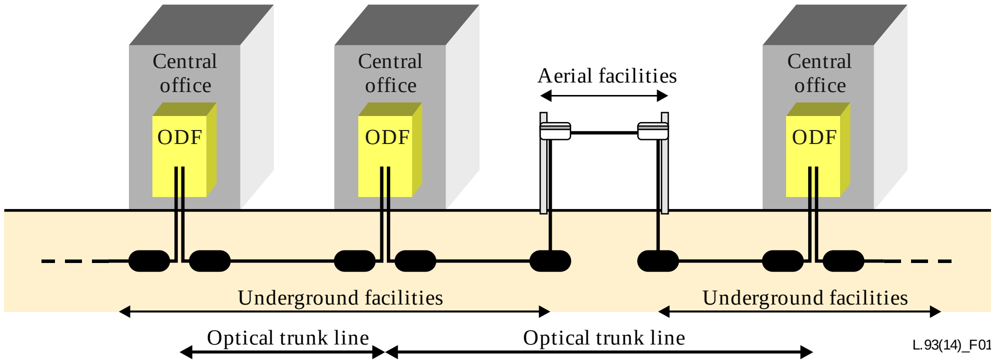

Figure 1 – Typical configuration of an optical trunk line

7.1 Applicable area

The applicable area of the optical fibre cable maintenance support, monitoring and testing systems is optical trunk lines. The characteristics of the optical fibres in this area should comply with [ITU-T G.652], [ITU-T G.653], [ITU-T G.654], [ITU-T G.655] and [ITU-T G.656].

7.2 Test access devices

There are several ways to implement the maintenance functions described in [ITU-T L.40]: Optical time domain reflectometer (OTDR) testing for optical fibre cable; optical loss testing, identification light detection and optical power monitoring of optical signals by using an optical power meter (OPM). Therefore, optical fibre cable maintenance systems should have optical branching devices for test light insertion (e.g., an optical coupler). The branching device for test use should have a low insertion loss in both the communication and test ports. Therefore, wavelength selective couplers or wavelength division multiplexing (WDM) couplers would appear to be efficient devices for testing. Also, the optical branching device should have a wide wavelength range for communication signals when the optical trunk lines accommodate services using WDM transmission systems. The operating wavelength range in terms of spectral bands is described in [b-ITU-T G.Sup39]. If applications using the L-band (1565-1625 nm) are likely to be used in the future, it is recommended that the test access device also has a transmission range up to 1625 nm for the communication port.

When the length of an optical trunk line cable exceeds the measurable range of the test equipment, branching devices must be inserted at both ends of the optical trunk line for bidirectional testing. (See clause 8.1.1) A typical configuration of the optical trunk line with test access devices is shown in Figure 2.

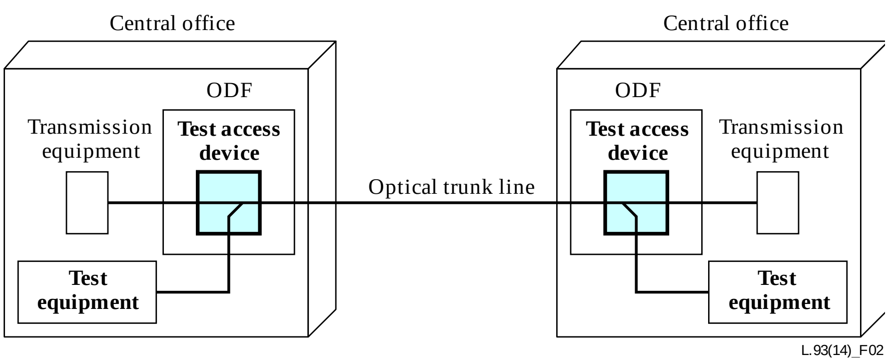

Figure 2 – Typical configuration of an optical trunk line with test access devices

7.3 Requirements for in-service monitoring

7.3.1 In-service monitoring

[ITU-T L.66] defines several requirements for in-service monitoring such as the wavelength bandwidth and optical power level of the test light, and the characteristics of the test light cut-off filter and measurement equipment. The maintenance wavelength for in-service testing is defined by [ITU-T L.41].

7.3.2 Nonlinear effects

Since optical trunk lines may carry a high total optical power, for example when accommodating a dense wavelength division multiplexing (DWDM) system, the influence of nonlinear effects between the communication signal and test light might have to be considered. Some nonlinear effects are described in [b-Agrawal]. The requirements for optical fibre cable maintenance systems for optical fibre cable carrying a high total optical power are also described in [ITU-T L.68].

8 Test methods

8.1 Methods for testing the characteristics of optical fibre cable networks

Test methods that implement the maintenance system functions are described in [ITU-T L.40].

8.1.1 OTDR testing

OTDR testing and optical loss testing are carried out to confirm the condition of an optical cable network. The methods for OTDR testing optical fibre cable and optical loss testing are described in [ITU-T G.650.3]. OTDR testing is recommended for measuring fibre characterizations such as splice loss, splice location, fibre uniformity and cable section length. The measurement technique, test apparatus and measurement procedure are described in detail in [IEC 61280-4-2].

If a more accurate evaluation of the splice loss in each connection point of the optical fibre line is required, bidirectional OTDR test results need to be considered. Examples of the bidirectional OTDR trace analysis are shown in [ITU-T G.650.3] and the measurement method is described in detail in [IEC 61280-4-2].

8.1.2 Optical loss testing

Optical loss testing is an effective way to measure link attenuation. The recommended technique is to use a light source and the OPM method as described in [IEC 61280-4-2] to compare the power level injected at one end of the link with the power level received from the other end of the link.

8.1.3 Identification light detecting

The recommended technique for optical fibre identification technology including the measurement method and the procedure is described in [ITU-T L.85].

8.2 Test methods for verifying service contracts or transmission at particular bit rates

Additional test items, which include dispersion measurements (e.g., polarization mode dispersion (PMD) and chromatic dispersion) and spectral attenuation, to confirm the attributes of an existing optical fibre cable that may be used at higher bit rates or over extended wavelength ranges (for example DWDM in the L-band or coarse wavelength division multiplexing (CWDM) over the O, E, S, C and L bands) are described in [ITU-T G.650.3]. These tests are implemented according to the requirements of the transmission equipment that will be introduced.

9 Testing and maintenance procedure

Several test functions for optical fibre cable maintenance support, monitoring and testing systems are listed in [ITU-T L.40]. The system supports various tasks involved in the construction of optical fibre cables before they are put into service, and in periodic preventative maintenance work. This clause describes the testing and maintenance procedures for the required test functions.

9.1 Confirmation of fibre condition

After optical fibre cables have been installed, the condition of the fibre should be confirmed. Since an optical fibre cable for a trunk line accommodates a large volume of communication traffic, the connection points in the optical closures and the optical fibre cable sections must be highly reliable. Therefore, OTDR testing for measuring the connection loss and reflectance at each connection point as well as a loss test for measuring the total fibre loss should be carried out after optical fibre cable installation to ensure a highly reliable network. The measured values are judged by comparison with the required values.

9.2 Fault identification between transmission equipment and fibre network

When a fault occurs in an optical trunk network, the network operator should restore the service as soon as possible. To identify a fault between transmission equipment and an optical fibre line, the network operator should first confirm the condition of the optical fibre lines in the outside optical fibre cable by employing OTDR testing and a loss test. Then, if there are no faults in the outside optical fibre cable, the network operator should check the condition of the indoor optical cable in the central office. When test access devices are installed in the transmission line, the presence and the intensity of communication light from the transmission equipment can be detected by an OPM. By employing the above procedures, the operator can confirm the condition of all sections of an optical fibre line including the indoor optical cable section between an optical distribution frame (ODF) and transmission equipment in the central office.

Appendix I

Japan's experience

(This appendix does not form an integral part of this Recommendation.)

I.1 Introduction

Data communication traffic in both, access networks and optical trunk lines, is rapidly increasing. It is expected that broadband network provisioning will require thousands of optical fibres to be accommodated in a central office for optical networks. An optical fibre line testing system is essential for reducing maintenance costs and improving service reliability in optical fibre networks. The importance of the optical fibre cables for trunk lines is increasing because that accommodates not only large transmission capacity but data traffic of mobile networks and communications of lifeline. Therefore, the efficient maintenance and surveillance of optical trunk lines should be provided for realizing highly reliable networks. This appendix describes a typical optical fibre line monitoring system for trunk lines in Japan and information about low insertion loss optical couplers for testing optical fibre cables of trunk lines.

I.2 System configuration

Figure I.1 shows a typical system configuration of optical fibre line testing system for optical trunk lines in Japan. This system consists of a control terminal, an optical testing module (OTM), which contains an OTDR and a test control unit, optical fibre selectors (FSs) that select fibres to be tested, test access modules (TAMs) to introduce a test light into an optical fibre line, and an optical filter that allows a communication light to pass but not a test light. The OTDR test wavelength is 1650 nm, which is different from the communication light wavelength and is in accordance with [ITU-T L.41]. This means that the system can perform maintenance tests on in-service fibres with no degradation in the transmission quality. The control terminal, which is located in a facility maintenance centre for outside plant, orders various optical fibre tests and administers fibre information. Integrated distribution modules (IDMs), which house OTMs, TAMs and FSs, are installed in a central office. Optical filters are installed in the TAMs. The various commands from the control terminal to the OTMs are transmitted through a data communication network (DCN). In order to apply this system to L-band transmission, the optical characteristic of the filters in the TAM and the termination cable is extended to the L-band.

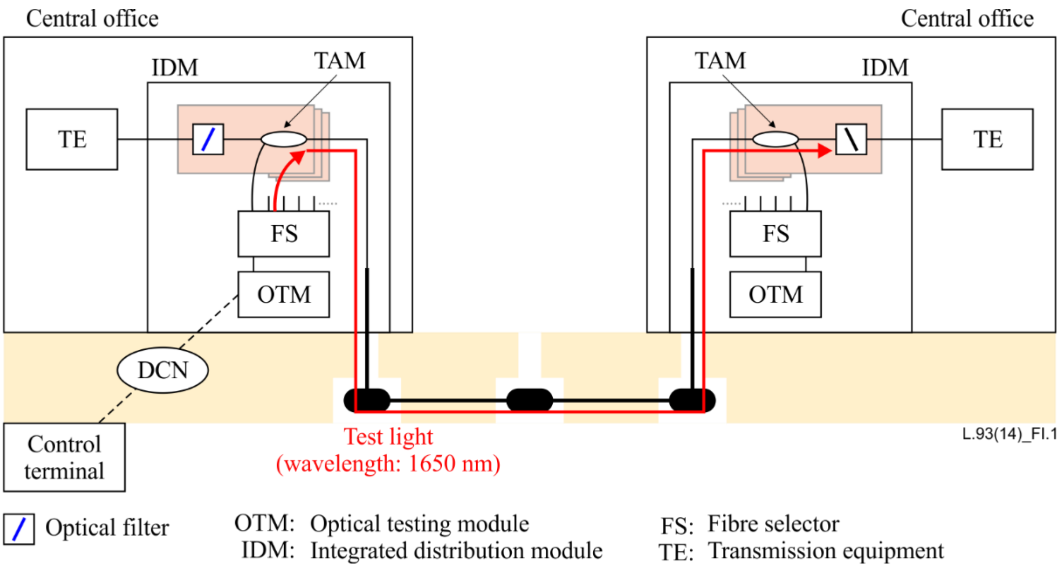

Figure I.1 – Typical configuration of optical fibre line testing system for trunk lines

I.3 Test access module

In the optical fibre line testing system, the TAM has an optical filter that cuts off only test light to avoid detrimental effect to communication signals. The fibre Bragg grating (FBG) filter has a considerable advantage in that its steep optical spectrum allows L-band communication light to pass while cutting off the 1650 nm test light. However, multiple reflections are likely to appear in the OTDR trace when FBG filters are installed at either end of the optical fibre line, because the OTDR test light pulses are strongly reflected at the FBG filters.

To suppress the ghost signal on the OTDR trace, optical characteristic required for the optical filter in the central office should be designed to suppress the reflected test light pulses sufficiently lower than the Rayleigh backscattered signal power from the fibre section.

To realize both the low insertion loss for test light and suppression of the reflection at the optical filter, reflection-type wavelength selective optical couplers are used. Taking the cost of network elements into account, the optical coupler in the TAM is fabricated by using the planar lightwave circuit (PLC) technology. Figure I.2 shows a typical structure of eight crossed optical waveguide coupler arrays that are incorporated in the TAM. The L/U-band crossed optical waveguide coupler with a high return loss uses a thin dielectric film, which separates the 1650 nm test light from the L-band communication light. Multi-arrayed circuits can be fabricated on a PLC chip and one dielectric film filter can be incorporated in the groove that traverses the cross points of the crossed optical waveguide couplers. The dielectric film filter is inserted in the groove at the cross point of two waveguides on the PLC. Adjusting the insertion angle of the filter, the reflection of the test light is sufficiently suppressed.

Port A to port B is used as a communication line. A 1650 nm test light introduced from port C is reflected by the dielectric film filter and input into the fibre line via port B. The L/U-band filter can be shared by the 8 channel ports and is not required to collimate the optical coupling between the filter and the waveguides. Figure I.3 shows example of the insertion loss spectrum of the crossed optical waveguide coupler.

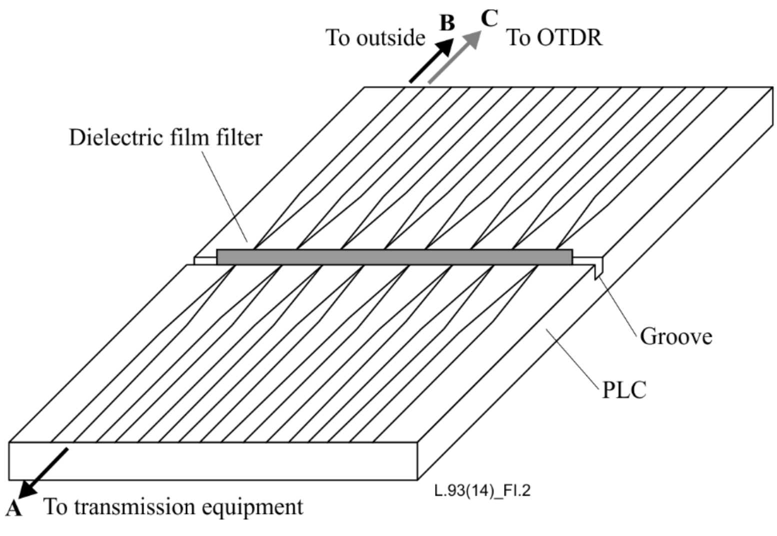

Figure I.2 – Typical structure of crossed optical waveguide coupler

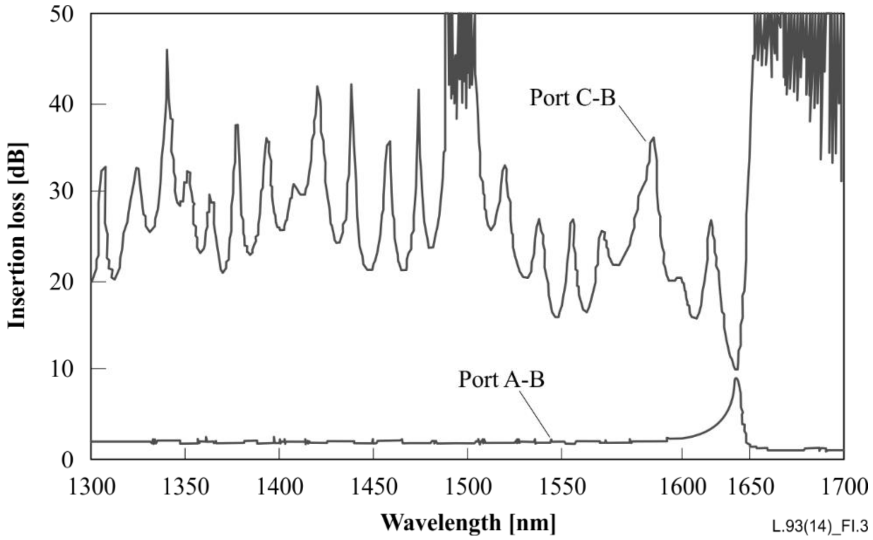

Figure I.3 – Example of insertion loss spectrum of crossed optical waveguide coupler

Thus the architecture of this wideband WDM coupler provides a low insertion loss for the test port and a high dynamic range for the testing system for in-service line monitoring. Table I.1 shows sample parameters of the crossed optical waveguide coupler. When the link loss of standard single mode fibre is 0.4 dB/km and the dynamic range of a 1650 nm OTDR with a pulse width of 1 µs is 22.1 dB, it can carry out the in-service line monitoring of about 50 km-long optical fibre line. In addition, the return loss of each port is higher than 35 dB.

Table I.1 – Sample parameters of crossed optical waveguide coupler module

Items		Values	Comments
Fibre type		Single-mode-fibre	
Insertion loss (without connector)	A-B	< 1.4 dB	1 290-1 330 nm
		< 1.4 dB	1 480-1 570 nm
		< 2.0 dB	1 570-1 615 nm
		TBD	1 615-1 625 nm
	C-B	< 2.0 dB	1 645-1 655 nm
Isolation: B-A		> 40 dB	Between 1 290-1 625 nm and 1 645-1 655 nm (higher isolation values may be required depending on the application)
Polarization dependent loss	A-B	< 0.5 dB	1 290-1 330 nm, 1 480-1 625 nm
	C-B	< 0.5 dB	1 645-1 655 nm
Return loss	A-B	> 35 dB	1 290-1 330 nm, 1 480-1 625 nm
	C	> 35 dB	1 645-1 655 nm

Bibliography

[b-ITU T G-Sup.39] ITU-T G-series Recommendations – Supplement 39 (2012), *Optical system design and engineering considerations*.

[b-Agrawal] Agrawal, G.P. (2001), Nonlinear Fiber Optics, 3rd ed. Academic Press.

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