Optical Transmission Equipment | WDM | Transmission Distance Extension

Technology Reports

Function Enhancement for Compact WDM Optical Transmission Equipment in Response to Optical Fiber Depletion

The rollout of LTE services will require the construction of efficient transmission paths in rural and other areas with long transmission distances in the access interval and in areas suffering from a depletion of core optical fibers. In order to achieve the entrance transmission path to a FOMA/Xi complex base station with one bidirectional fiber, NTT DOCOMO has enhanced the functions of its compact WDM optical transmission equipment to increase transmission distance (allowable loss) to the same level as ATM equipment and to deal with the depletion of core optical fibers.

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1. Introduction

At NTT DOCOMO, the entrance-transmission-path interval is constructed using a wireless system and landline system (optical transmission equipment).

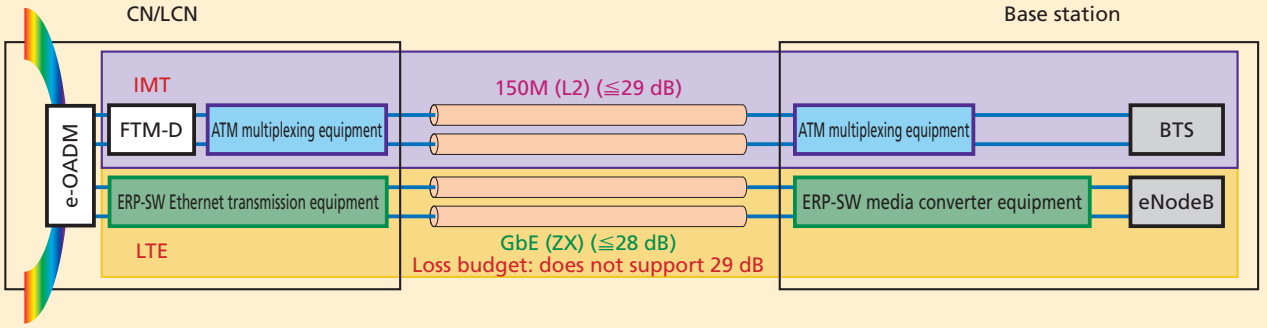
At present, the optical transmission equipment used for the landline portion of the entrance transmission path (Connection Node (CN)[*1]/Local Connection Node (LCN)[*2] to wireless base station) generally consists of Asynchronous Transfer Mode (ATM)[*3] multiplexing equipment or compact Wavelength Division Multiplexing (WDM) optical transmission equipment [1][2] for International Mobile Telecommunication (IMT) systems. And Ethernet Ring Protection-SWitch (ERP-SW)[*4] Ethernet transmission equipment [3] combined with ERP-SW media converter equipment (1GbE[*5]-BX/ZX) for LTE systems (**Figure 1** (a) (b)).

The introduction of an LTE system calls for the rapid deployment of entrance transmission paths up to LTE base stations. It is therefore desirable that the 3G Base Transceiver Station (BTS) and LTE base station (eNodeB) be installed at the same location so that antenna facilities can be shared and the service areas of those systems can be overlaid.

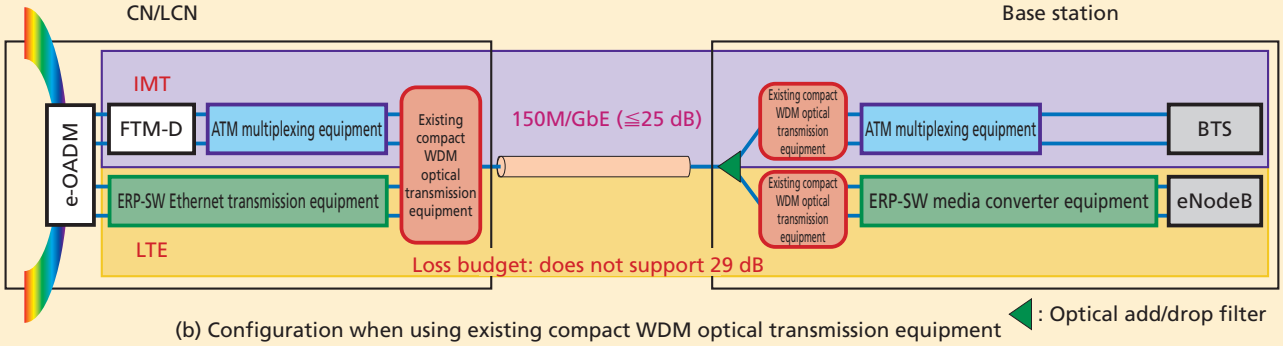
At the same time, while ATM multiplexing equipment achieves a loss budget[*6] of 29 dB, the loss budget of other equipment is no higher than 28 dB, which means that the transmission distances supported by these different types of equipment differ. As a result, installing BTS and eNodeB at the same location has not been without difficulty.

In addition, most of the optical fiber used in constructing entrance transmis-

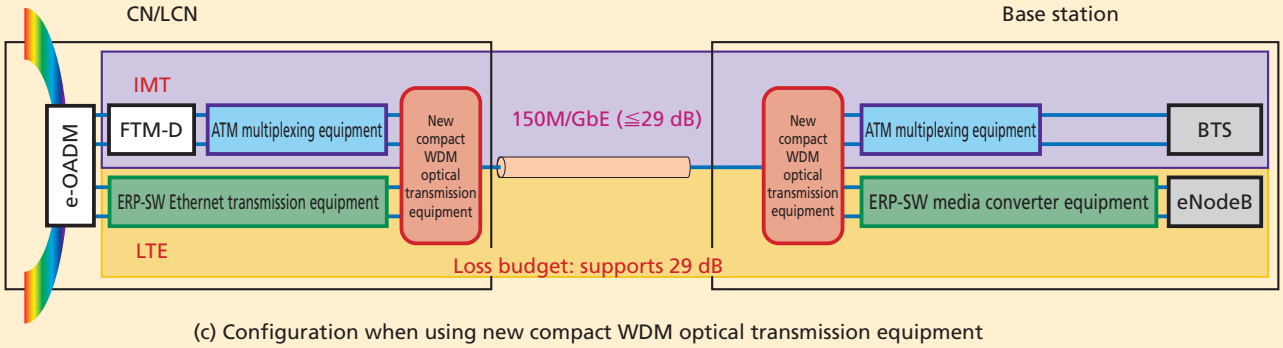
*1 **CN**: A node installed on the intra-prefectural relay plane having functions for converging and dispersing circuits to make transmission in base-station circuits more efficient.
*2 **LCN**: A node that treats the NTT subscriber optical accommodation station as a base node and that has functions for converging and dispersing circuits to efficiently consolidate NTT dark fiber.



(a) Configuration of ordinary entrance transmission path



(b) Configuration when using existing compact WDM optical transmission equipment



(c) Configuration when using new compact WDM optical transmission equipment

e-OADM : e-Optical ADD Drop Multiplexing
FTM-D : Fiber Transport Module-DOCOMO

Figure 1 Overview of entrance transmission path

sion paths has been secured by leasing dark fiber[*7], which makes it difficult to procure new optical fiber for LTE use as available fiber comes to be depleted.

In response to these issues, we have enhanced the functions of compact WDM optical transmission equipment and superposed the IMT and LTE transmission paths making it possible to reduce the number of core optical fibers and pieces of equipment required thereby reducing running costs.

*3 **ATM**: A communications scheme that transfers a stream of fixed-length frames called cells.
*4 **ERP-SW**: Ethernet transmission equipment developed to respond flexibly to increases in transmission capacity and the introduction of IP networks as part of the trend toward All-IP transmission paths. ERP-SW is the first switch in the world to implement a broadband Ethernet network transmission protocol (IEEE802.1ah).
*5 **1GbE**: Ethernet standards providing 1Gbit/s transmission speeds over optical fiber; 1000BASE-SX and 1000BASE-LX standards conform to IEEE 802.3z and the 1000BASE-BX standard conforms to IEEE 802.3ah. 1000BASE-ZX is an Ethernet standard specified by Cisco Systems.
*6 **Loss budget**: The amount of transmission loss allowed on an optical transmission path determined by the difference between the output power of the optical transmitting module and the receiving sensitivity of the optical receive module.

In this article, we describe the function enhancement and implementation of compact WDM optical transmission equipment.

2. Overview of Entrance Transmission Path

As described above, ATM multiplexing equipment is used for constructing a transmission path for IMT use. When using an L2 interface unit[*8], a loss budget of up to 29 dB can be allowed with two bidirectional optical fibers.

On the other hand, ERP-SW Ethernet transmission equipment and ERP-SW media converter equipment are used for constructing a transmission path for LTE use. A loss budget up to 22 dB can be allowed with one bidirectional optical fiber under 1000BASE-BX and one up to 28 dB can be allowed with two bidirectional optical fibers under 1000BASE-ZX, as shown in **Figure 2** (a). Existing compact WDM optical transmission equipment can also be used here achieving a loss budget of 25 dB.

Consequently, for a transmission loss of 29 dB up to an existing 3G base station, it has not been possible to construct a transmission path for an LTE base station using existing transmission equipment. In response to this situation, we developed new compact WDM optical transmission equipment with a loss budget of 29 dB, as shown in fig. 2 (b).

3. Issues and Solutions for Entrance Transmission Path Applications

3.1 Development of 4ch-MLDX

Existing compact WDM optical transmission equipment performs wavelength multiplexing and demultiplexing by an 8-channel optical multiplexer/demultiplexer board (hereinafter referred to as "8ch-MLDX") having a

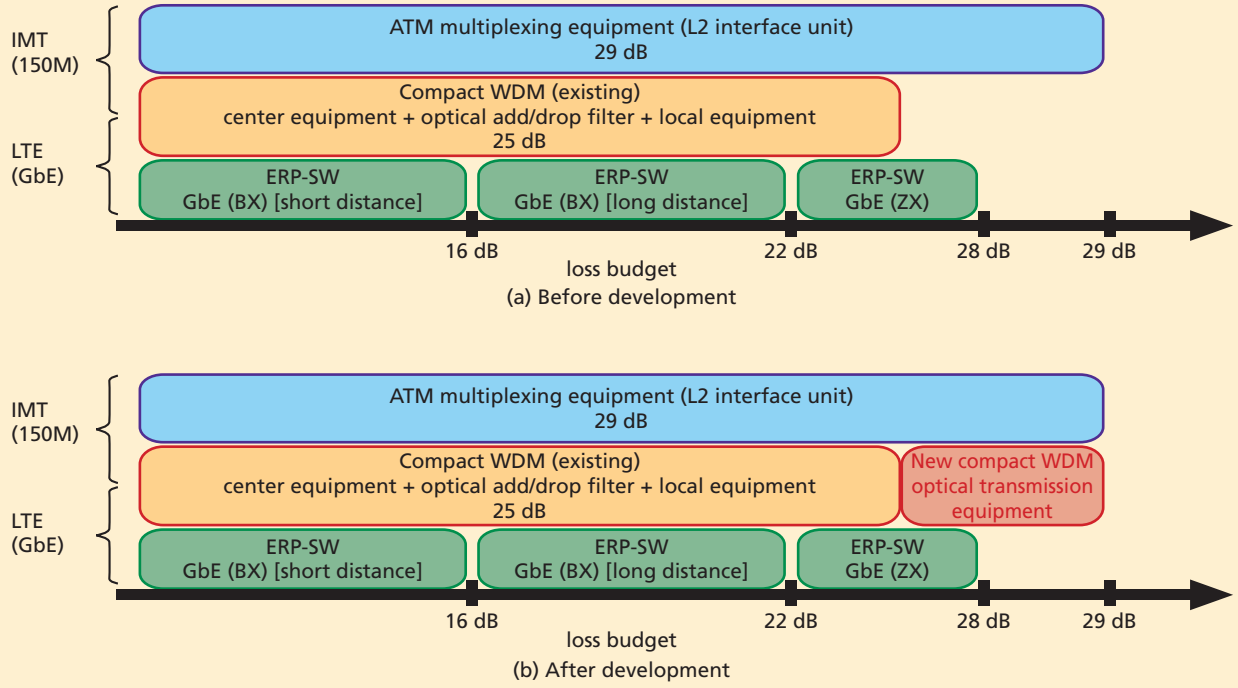


Figure 2 Loss budget of optical transmission equipment for entrance transmission path

*7 **Dark fiber**: The portion of optical fiber cables laid by telecommunications operators and other companies that is not being used by those operators and companies.

*8 **L2 interface unit**: A type of 150M optical-transmission-path interface package in ATM multiplexing equipment for use between base stations.

loss budget of 25 dB, as shown in **Figure 3** and **4**. As described above, a loss budget up to 29 dB must be allowed in order to install an LTE base station at the same location as an IMT base station.

Loss budget is determined by the transmitting power and receiving power of the WDM interface signal[*9] at transponders[*10] mounted on CN/LCN and wireless base stations and by maximum insertion loss at optical multiplexer/demultiplexer boards. With this in mind, we developed a 4-channel optical multiplexer/demultiplexer board (hereinafter referred to as "4ch-MLDX") having a relatively small maximum insertion loss.

The new 150M WDM interface signal level chart for IMT is shown in **Figure 5** and the new GbE×2 multiplexing WDM interface signal level chart for LTE is shown in **Figure 6**. Here, a loss budget of 29 dB was achieved by reducing maximum insertion loss from the 5.0 dB of the 8ch-MLDX to the 2.0 dB of the 4ch-MLDX and by improving transmitting power and receiving power (sensitivity) in the newly developed transponder. The configuration of the entrance transmission path after introducing the 4ch-MLDX is shown in fig. 1 (c).

Item	Value		Notes
Transmitting power	0	dBm	Minimum value
Maximum insertion loss at 8ch-MLDX	5.0	dB	Total of center and local equipment
Transmission loss	25.0	dB	
Receiving power	−30.0	dBm	Bit error rate 10^{-12} including penalty due to dispersion

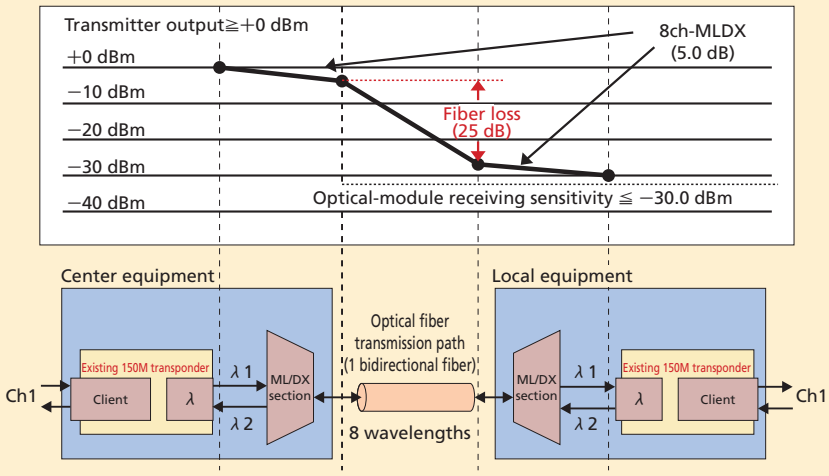


Figure 3 Existing 150M WDM interface signal level chart

Item	Value		Notes
Transmitting power	0	dBm	Minimum value
Maximum insertion loss at 8ch-MLDX	5.0	dB	Total of center and local equipment
Transmission loss	25.0	dB	
Receiving power	−30.0	dBm	Bit error rate 10^{-12} including penalty due to dispersion

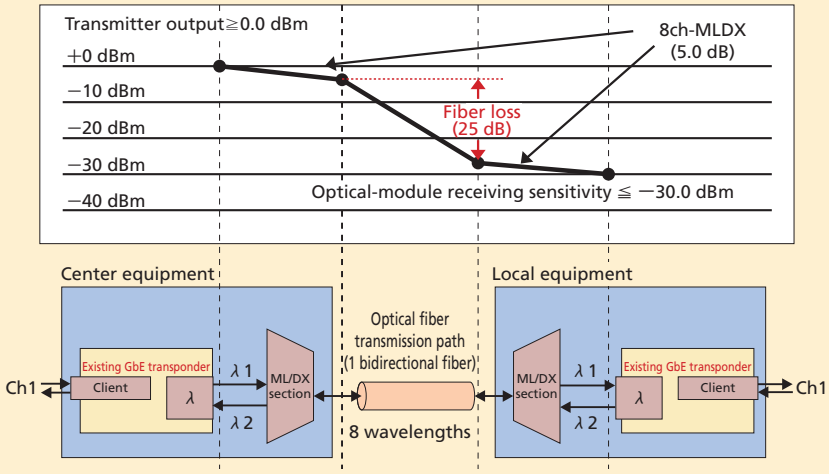


Figure 4 Existing GbE WDM interface signal level chart

*9 **WDM interface signal**: An interface signal on the wavelength-multiplexing side of a transponder.

*10 **Transponder**: In optical communications, a functional component that performs bidirectional conversion between optical fiber and electrical signals.

Item	Value		Notes
Transmitting power	0	dBm	Minimum value
Maximum insertion loss at 4ch-MLDX	2.0	dB	Total of center and local equipment
Transmission loss	29.0	dB	
Receiving power	−31.0	dBm	Bit error rate 10^{-12} including penalty due to dispersion

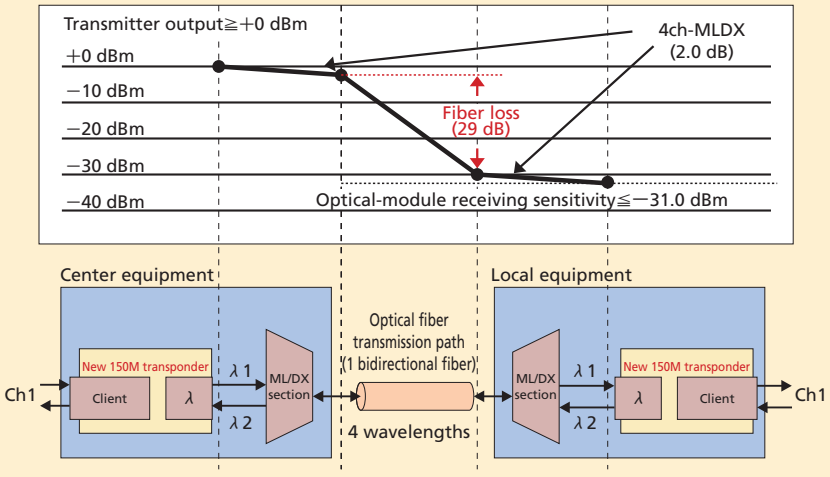


Figure 5 New 150M WDM interface signal level chart

Item	Value		Notes
Transmitting power	3	dBm	Minimum value
Maximum insertion loss at 4ch-MLDX	2.0	dB	Total of center and local equipment
Transmission loss	29.0	dB	
Receiving power	−28.0	dBm	Bit error rate 10^{-12} including penalty due to dispersion

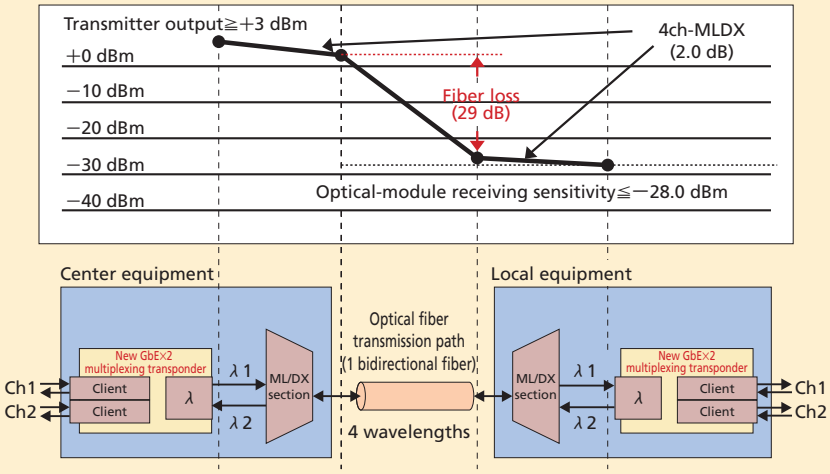


Figure 6 New GbE×multiplexing WDM interface signal level chart

3.2 Development of New Transponder

The GbE (SX/LX) interface in existing compact WDM optical transmission equipment accommodates one port[*11] per package and the corresponding transponder is a 2-slot-wide package. To raise the accommodation efficiency of the transmission path, we developed a GbE×2 multiplexing transponder in a one-slot-wide package with electrical multiplexing. We also converted the transponder of the 150M interface from a 2-slot-wide to a one-slot-wide package. Improving the transmitting and receiving power here also helped to improve the loss budget.

3.3 Development of 1U Center and Local Equipment

The use of existing compact WDM optical transmission equipment involved center equipment (height: 3U[*12]) and individual units of local equipment corresponding to different interfaces. In contrast to this configuration, we developed new 1U center equipment and multi-interface local equipment for which transponders can be selected as desired through slot mounting. This development combined with the conversion to a one-slot-wide package and electrical multiplexing produces a synergetic effect that dramatically improves accommodation efficiency (**Figure 7**).

*11 **port**: Interface for exchanging data with other equipment.
*12 **U**: Unit of height in rack mounting equipment. 1 U = 1.75 inches (44.45 mm).

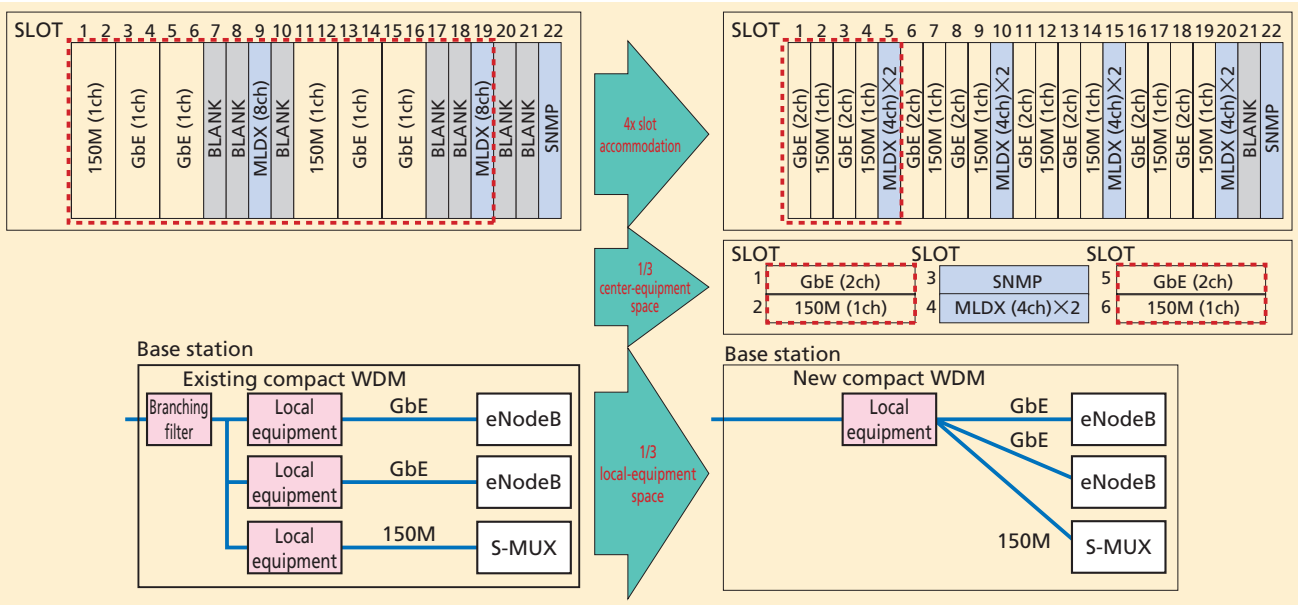


Figure 7 Improvement in accommodation efficiency

4. Conclusion

We developed and implemented a new type of compact WDM optical transmission equipment for entrance transmission paths to overcome installation-space and power-consumption limitations and reduce running costs. This equipment, which NTT DOCOMO has been progressively deploying since July 2011, achieves effective use of an optical fiber strand[*13], has an economical effect by reducing dark fiber usage fees, and contributes to the smooth deployment of entrance transmission paths for LTE use.

References

[1] Y. Matsumoto et al.: "WDM Equipment for Optical Backbone Networks," NTT DoCoMo Technical Journal, Vol. 11, No. 3, pp. 48-54, Oct. 2003 (In Japanese).
[2] T. Yonezawa et al.: "Compact WDM Equipment for Economical Construction of Entrance Optical Transmission Paths," NTT DoCoMo Technical Journal, Vol. 14, No. 3, pp. 32-37, Oct. 2006 (in Japanese).
[3] K. Morita et al.: "Ethernet Transmission Equipment ERP-SW for All-IP Transmission Paths," NTT DOCOMO Technical Journal, Vol. 12, No. 3, pp. 56-60, Dec. 2010.

*13 **Optical fiber strand**: One optical fiber inside an optical fiber cable.