YD

COMMUNICATIONS INDUSTRY STANDARD

OF THE PEOPLE'S REPUBLIC OF CHINA

ICS 33.180.01
M 33

YD/T 1465-2006

Technical Conditions for 10Gbit/s Small Form Factor Pluggable Transceiver Module

10Gbit/s 小型化可插拔光收发合一模块技术条件

Issued on: June 8, 2006 **Implemented on: October 1, 2006**

Issued by: Ministry of Industry and Information Technology of PRC

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Foreword

This Standard is one of a series of standards for optical transmitter / receiver modules, whose names and structures are as follows:

- YD/T 1199.1-2002, *Technical requirements of SDH optical transmitter/optical receiver modules - SDH 10Gb/s optical receiver modules*;
- YD/T 1199.2-2002, *Technical requirements of SDH optical transmitter/optical receiver modules - SDH 10Gb/s optical transmitter modules*;
- YD/T 1111.1-2001, *Technical Requirements of SDH Optical Transmitter/Optical Receiver Modules - 2.488320 Gb/s Optical Receiver Modules*;
- YD/T 1111.2-2001, *Technical Requirements of SHD Optical Transmitter / Optical Receiver Modules - 2.488320 Gb/s Optical Transmitter Modules*
- YD/T 1321.1-2004, *Technical conditions of the transponder with multiplex/demultiplex functions Part 1: 2.5Gbit/s transponder*;
- YD/T 1321.2-2004, *Technical condition of the transponder with multiplex/demultiplex functions Part 2: 10Gbit/s transponder*;
- YD/T 1465-2006, *Technical Conditions for 10Gbit/s Small Form Factor Pluggable Transceiver Module*.

With the development of technology, it shall formulate follow-up relevant standards.

During the development process of this Standard, it has considered the actual development of China's optical module, and referred to interface specification documents of International Telecommunication Union Telecommunications Sector Recommendations ITU-T G691, Institute of Electrical and Electronics Engineers IEEE 802.3ae, US Telcordia GR-468-core, MIL-STD-883E, and XFP MSA.

Annex A, Annex B and Annex C are informative; Annex D is normative.

This Standard was proposed by and shall be under the jurisdiction of China Communications Standardization Association.

The main drafting organization of this Standard: ZTE Corporation.

Technical Conditions for 10Gbit/s Small Form Factor Pluggable Transceiver Module

1 Scope

This Standard specifies the technical requirements and test methods for 10Gbit/s small form factor pluggable transceiver module (hereinafter referred to as XFP module); including terms, definitions, optical interface technical requirements and test methods, electrical interface technical requirements and limit working conditions, reliability test classification and test methods, product inspection and product management of optical module of XFP module.

This Standard is applicable to XFP module's photoelectric parameter measurement and inspection of in-board, short-range, medium-range, long-range STM-64, 10GE, 10GFC. Other optical communication systems which are similar to 10Gbit/s, can refer to the implementation.

This Standard is only applicable to XFP module which uses the none-return-to zero code.

2 Normative references

The following standards contain the provisions which, through reference in this Standard, constitute the provisions of this Standard. For dated references, subsequent amendments (excluding corrections) or revisions do not apply to this Standard. However, the parties who enter into agreement based on this Standard are encouraged to investigate whether the latest versions of these documents are applicable. For undated reference documents, the latest versions apply to this Standard.

GB/T 2829-2002, *Sampling procedures and tables for periodic inspection by attributes (Apply to inspection of process stability)*;

GB 9254-1998, *Information technology equipment -- Radio disturbance characteristics -- Limits and methods of measurement*;

GB/T 17626.2-1998, *Electromagnetic compatibility -- Testing and measurement techniques -- Electrostatic discharge immunity test*;

GB/T 17626.3-1998, *Electromagnetic compatibility -- Testing and measurement techniques -- Radiated, radio-frequency, electromagnetic field*

immunity test;

YD/T 1014-1999, *Technique criterion for STM-64 optical line terminal equipment*;

YD/T 1017-1999, *Network node interface for the Synchronous Digital Hierarchy*;

YD/T 1111.1-2001, *Technical Requirements of SDH Optical Transmitter/Optical Receiver Modules - 2.488320 Gb/s Optical Receiver Modules*;

YD/T 1111.2-2001, *Technical Requirements of SHD Optical Transmitter/Optical Receiver Modules - 2.488320 Gb/s Optical Transmitter Modules*;

YD/T 1199.1-2002, *Technical requirements of SDH optical transmitter/optical receiver modules - SDH 10Gb/s optical receiver modules*;

YD/T 1199.2-2002, *Technical requirements of SDH optical transmitter/optical receiver modules - SDH 10Gb/s optical transmitter modules*;

YD/T 1272.1-2003, *Optical fiber connector Part 1: type LC*;

ITU-T G691 (2003), *Optical interfaces for single-channel STM-64, STM-256 and other SDH systems with optical amplifiers*;

ITU-T G692 (1998), *Optical interfaces for multichannel systems with optical amplifiers*;

ITU-T G693 (2001), *Optical interfaces for intra-office systems*;

ITU-T G709 (2001), *Interfaces for the optical transport network*;

ITU-T G783 (2004), *Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks*;

ITU-T G825 (2000), *The control of jitter and wander within digital networks which are based on the synchronous digital hierarchy (SDH)*;

ITU-T G957 (1999), *Optical interfaces for equipment and systems relating to the synchronous digital hierarchy*;

ITU-T G959.1 (2003), *Optical transport network physical layer interfaces*;

IEEE 802.3ae-2002, *CSMA/CD Access Method and Physical Layer Specifications (10GE)*;

DUT	Device Under Test
EMC	Electro Magnetic Compatibility
ESD	Electro-Static Discharge
FEC	Forward Error Correction
HBM	Human Body Model
ISI	Inter-symbol Interference
LSB	Least Significant Bit
LVDS	Low-Voltage Differential Signals
LVTTL	Low Voltage Transistor-Transistor Logic
MPI	Main Path Interface
MSA	Multi Source Agreement
MSB	Most Significant Bit
MLM	Multi-longitudinal Mode
NRZ	Non-Return-to Zero
OTU2	Optical channel transport unit of level 2
PECL	Positive Emitter-Coupled Logic
PMD	Physical Medium Dependent
RMS	Root Mean Square
SCL	Serial Clock
SDA	Serial Data
SDH	Synchronous Digital Hierarchy
SERDES	Serializer-Deserializer
SLM	Single Longitudinal Mode
SMF	Single-Mode Fiber
STM-64	Synchronous Transport Module of order 64
TDP	Transmitter and Dispersion Penalty
VCSEL	Vertical Cavity Surface-Emitting Laser
VSR	Very Short Reach
WAN	Wide Area Network
WIS	WAN Interface Sublayer
XFI	10 Gigabit Serial Electrical Interface
XFP	10 Gigabit Small Form Factor Pluggable Module
10GE	10 Gbit/s Ethernet
10GFC	10 Gbit/s Fibre Channel

4 Test reference point and optical module classification

4.1 Test reference point

The XFP optical module test reference points for telecommunication services (e.g. SDH) are shown in Figure 1 (see ITU-T G.691), of which the main processing rates are STM-64 and OTU2 (see ITU-T G.709). The test reference

(@BER=10^{-12}) dBm						
Minimum overload point (dBm)	-1	-1	-1	-1	-1	-1
Receiver reflection coefficient (max) (dB)	-14	-14	-27	-27	-27	-27
Maximum optical channel cost (dB)	1	1	2	2	1	2
(a) Target distance is only used for classification but not specification; (b) The exit-factory test value of the worst receiving sensitivity should be 2 to 3 dB better than the value at the end of life.						

Table 4 Short distance STM-64 optical interface technical parameters

Application code		S-64.1	S-64.2a	S-64.2b	S-64.3a S-64.5a	S-64.3b S-64.5b
		P1S1-2D1	P1S1-2D2a	P1S1-2D2b	P1S1-2D3a P1S1-2D5a	P1S1-2D3b P1S1-2D5b
Target distance (a) (km)		20	40	40	40	40
Light source type		SLM	SLM	SLM	SLM	SLM
Operating wavelength range (nm)		1290 ~ 1330	1530 ~ 1565	1530 ~ 1565	1530 ~ 1565	1530 ~ 1565
Average transmitting power	Max. (dBm)	+5	-1	+2	-1	+2
	Min. (dBm)	+1	-5	-1	-5	-1
Spectral characteristics	-20 dB spectral width (nm)	To be studied	To be studied	To be studied	To be studied	To be studied
	Minimum side mode rejection ratio (dB)	30	30	30	30	30
	Chirp parameter (rad)	Not used	To be studied	To be studied	To be studied	To be studied
Minimum extinction ratio (dB)		6	8.2	8.2	8.2	8.2
Maximum dispersion (ps/nm)		70	800	800	130	130
Transmitting eye diagram		Comply with the specification of 6.2.2				
Worst receiving sensitivity (b) (@BER=10^{-12}) dBm		-11	-18	-14	-17	-13
Minimum overload point (dBm)		-1	-8	-1	-8	-1
Receiver reflection coefficient (max) (dB)		-14	-27	-27	-27	-27
Maximum optical channel cost (dB)		1	2	2	1	1
(a) Target distance is only used for classification but not specification;						

6.4 10GFC optical interface

The meaning of 1200-X-Y-Z, the 10GFC application code, is explained as follows:

(1) X refers to optical fiber:

- SM: single-mode fiber;
- MX: multimode fiber (M5 refers to 50 μm multimode fiber; M5E refers to 50 μm multimode fiber of higher mode bandwidth; M6 refers to 62.5 μm multimode fiber).

(2) Y refers to laser:

- SN: serial short wavelength laser (850 nm);
- LL: serial long wavelength laser (1310 nm).

(3) Z refers to distance:

- L: long distance;
- I: intermediate distance.

Example: 1200-MX-SN-I represents 10GFC application code which uses multimode optical fiber, 850 nm laser and intermediate transmission distance (300 m); 1200-SM-LL-L represents 10 GFC application code which uses single mode optical fiber, 1310 nm laser and long transmission distance (10 km).

According to T11 Project 1413-D (2003), 10GFC optical interface can refer to 10GE's PMD optical interface specifications. In specific, 1200-MX-SN-I corresponds to 10GBASE-SR; 1200-SM-LL-L corresponds to 10GBASE-LR.

7 Main technical parameters of electrical interface

7.1 XFI interface

10Gbit/s serial electrical interface XFI can support service data of 9.95Gbit/s ~ 11.09Gbit/s, as shown in Table 14.

Table 14 Data rate supported by XFI

Table 16 Optional synchronous reference clock specifications

Parameters	Symbol	Conditions	Min. value	Typical value	Max. value	Unit
Clock differential input impedance	Z_d		80	100	120	Ω
Differential input clock amplitude (p-p)		AC coupling, PECL logic	640		1600	mV
Reference clock duty ratio			40		60	%
Rise / fall time of output clock	t_r/t_f	20% ~ 80%	200		1250	ps
Reference clock frequency	f_0			Signal code rate / 64		MHz
CMU reference clock tilt distortion	TD		- 10		10	UI
Single sideband phase noise		@ 1 kHz			- 85	dBc/Hz
		@ 10 kHz			-108	
		@ 100 kHz			-128	
		@ 1 MHz			-138	
		@ 10 MHz			-138	
NOTE The reference clock frequency is fixed and equals to 1/64 of code rate.						

To reduce power consumption and electromagnetic interference, XFI uses peak-to-peak 500 mV differential signal. Both XFI transmitters and receivers are AC couplings. The differential reference impedance of XFI's drive, transmission line and receiver is 100 Ω. Common mode reference impedance is 25 Ω. Point B at the module (transmitting section) is shown in Table A.1 of Annex A. Electrical characteristics specifications of XFI interface of point C (receiving section) is shown in Table A.2 of Annex A. Electrical characteristics specifications of point A, point D at serializer / de-serializer and XFI interface of single board's point B and point C can refer to INF-8077i of XFP MSA organization.

7.2 Low-speed electrical signals

The low-speed electrical signals are LVTTL level and pulled up to VCC3, including the control signals and warning signals: : Mod_NR, Mod_DeSel, Interrupt, TX_Dis, Mod_ABS, RX_LOS, P_Down / RST.

Mod_NR, i.e. Module Not Ready; module is not ready. High level output indicates that transmitter's or receiver's data is not correct, such as, transmitting data is out of lock, receiving data is out of lock, laser module of transmitter is in fault.

5	LVTTL-I	Tx-DIS	Tx disable; laser turned off; effective at high level	4
6		V_{cc5}	+5 V power supply	
7		GND	Module ground	1
8		V_{cc3}	+3.3 V power supply	
9		V_{cc3}	+3.3 V power supply	
10	LVTTL-I/O	SCL	I^2C clock	2
11	LVTTL-I/O	SDA	I^2C data	2
12	LVTTL-O	Mod-Abs	Absent; module absent; effective at high level	2
13	LVTTL-O	Mod-NR	Not ready; module not ready; effective at high level	2
14	LVTTL-O	RX-LOS	Input signal lost; effective at high level	2
15		GND	Module ground	1
16		GND	Module ground	1
17	CML-O	RD-	Received data is inversely output	
18	CML-O	RD+	Received data is positively output	
19		GND	Module ground	1
20		V_{cc2}	+1.8V power supply	3
21	LVTTL-I	P_Down/RST	Power down: the high level requires the module to limit power consumption (< 1.5 watts)	4
			Reset: falling reset along the table	
22		V_{cc2}	+1.8V power supply	3
23		GND	Module ground	1
24	PECL-I	RefCLK+	Received clock is positively input	
25	PECL-I	RefCLK-	Received clock is inversely input	
26		GND	Module ground	1
27		GND	Module ground	1
28	CML-I	TD-	Transmitted data is inversely input	
29	CML-I	TD+	Transmitted data is positively input	
30		GND	Module ground	1

NOTE

(1) Module ground (working ground) are separated with module housing;

(2) Use 4.7 ~ 10 kΩ resistance to pull up to +3.15V ~ +3.45V on single board;

(3) V_{cc2} can be less than +1.8V through VPS control;

(4) Use 4.7 ~ 10 kΩ resistance to pull up to +3.15V ~ +3.45V inside module.

9 Measuring methods

9.1 Optical emission wavelength, average transmit optical power, extinction ratio, eye diagram, edge touch suppression ratio, spectral width measurement

Figure 16 Measurement configuration of jitter characteristics

9.4.2 Measurement conditions

(a) check the working conditions of the module for the test;

(b) pay attention to take electrostatic protection measures.

9.4.3 Measurement steps

(a) connect the measurement configuration as shown in the figure;

(b) input STM-64 signal by the SDH analyzer with jitter measurement function; check SDH analyzer; if the measured optical power of each module is appropriate; ensure that the measuring system works as normal;

(c) when measuring output jitter, enter the instrument output jitter measurement status, select the measurement filter required by the specification, measure the output jitter value without input jitter. The measurement time shall not be less than 60s. Record the output jitter values of different measurement filters and determine whether qualified;

(d) when measuring input jitter tolerance, enter the instrument input jitter tolerance measurement status, select suitable input jitter tolerance template, measure and record the input jitter tolerance amplitude curve, determine if it meets template requirements;

(e) when measuring jitter transfer function, enter instrument jitter transfer function measurement status, select suitable jitter transfer function template; connect the dotted line in the diagram to calibrate the instrument first, then measure as indicated by the solid line; record the jitter transfer function curve and determine if it meets template requirements.

9.5 Other measurements

The measurements of other indicators of 10GE service like stressed receiver sensitivity, the cost of transmitters and dispersion (TOP) can refer to corresponding parts of sub-clause 52.9 of IEEE 802.3ae.

10 Reliability test

10.1 Classification of reliability test

Reliability test can be classified into:

Special test	ESD protection	Telcordia GR-468-CORE	XFI connector, human body model, withstanding 500 V; Other connectors except XFI connector, human body model, withstanding 2 kV; Module housing, contact discharge of 8 kV, air discharge of 15 kV	-	6	-
(a) LPTTA = batch allowable disagreement rate; (b) SS = the minimum acceptable number of samples; (c) C = the number of acceptable failures associated with SS.						

10.2.2 Mechanical integrity test, durability test, special test methods

The mechanical integrity test of XFP optical module shall be carried out according to the relevant method in MIL-STD-883E;

The durability test, special test methods of XFP optical module shall be carried out according to the relevant method in Telcordia GR-468-CORE.

10.2.3 Failure criteria for mechanical integrity test, durability test, special test

After the mechanical integrity test, durability test, special test are completed, under same test conditions, in case of one of the following situation, it shall be determined as failure:

(a) the optical module cannot work as normal;

(b) the optical interface or electrical interface of the optical module can not meet the technical requirements; or the optical power change exceeds 1dB (tentative); or the sensitivity change exceeds 2dB (tentative);

(c) the device or package is cracked; the device is misaligned.

10.3 Electromagnetic compatibility test

10.3.1 Electromagnetic compatibility test classification

Electromagnetic compatibility test of XFP optical module is divided into radio-frequency electromagnetic field immunity test and radio-frequency electromagnetic field radiation emission test.

10.3.2 Radio-frequency electromagnetic field immunity test conditions and methods

Three anti refer to anti-moisture, anti-salt spray and anti-mildew. The general principles are as follows:

(a) reasonable choice of metal materials; selection of materials that are chemically stable under atmospheric conditions such as stainless steel;

(b) note that the potential difference between different metals, controlled in a certain range;

(c) apply a corrosion resistant overlay;

(d) avoid unreasonable structural design; eliminate spot welding, cake access, crevice corrosion at thread fastening.

12 Product inspections

The product inspections of XFP optical module include exit-factory routine inspection, sampling inspection and type inspection.

12.1 Exit-factory routine inspection

All XFP optical module products should be routinely tested. The test content is as follows:

12.1.1 Optical and electrical measurements

The XFP optical module operates at rated operating conditions. It measuring indicators should comply with “optical interface technical requirements” of this Standard.

12.1.2 High temperature aging

At the maximum rated operating ambient temperature, the aging time of the XFP optical module should be at least 24h.

12.2 Sampling inspection

The sampling inspection method shall be carried out according to GB/T 2829-2002.

12.2.1 Appearance inspection

Visually inspect the appearance of XFP optical module product.

Failure criteria: product surface has obvious scratches, stains; product identification is not clear or product identification is not solid.

12.2.2 Optical and electrical indicator measurements

delivery.

13.1 Instructions on use

The instructions on use is the reference for use. It should contain the following main content:

(a) the name, model of XFP optical module;

(b) the working principle, main technical indicators of XFP optical module;

(c) normal working conditions and extreme working conditions;

(d) mounting dimensions and pin functions;

(e) precautions for use; add eye-catching marks for safety issues.

13.2 Product marks

Due to product quality assurance requirements and traceability requirements, the product marks must be affixed to the product or to the product packaging. The marking content mainly includes:

(a) manufacturer of XFP optical module;

(b) model of XFP optical module;

(c) production serial number, date of production and quality inspector number;

(d) eye-catching mark for optical transmission device's safety;

(e) enterprise product performance standards.

13.3 Packaging

The product packaging shall meet the following basic requirements:

(a) meet the basic requirements of product law of China; there should be product instructions on use and product marks in the box; product name, manufacturer, date of exit-factory on the surface of packaging box; shockproof and anti-pressure requirements;

(b) for photoelectric module, it shall take anti-static measures;

(c) there should be clear marks of anti-static and laser radiation level.

13.4 Storage

Annex B

(Informative)

Specifications for low-speed electrical signals

Specifications for low-speed electrical signals are shown in Table B.1.

Table B.1 Low-speed electrical signal specifications

Parameter	Symbol	Min. value	Max. value	Unit	Condition
XFP Interrupt, Mod_NR, RX_LOS	V_{OL}	0.0	0.40	V	Pull up to host_V_{CC}, measure at the single board side, I_{OL} (max) = 3mA
	V_{OH}	host_V_{CC} - 0.5	host_V_{CC} + 0.3	V	Pull up to host_V_{CC}, measure at the single board side
XFP TX_Dis, P_Down/RST	V_{IL}	-0.3	0.8	V	Pull up to V_{CC3}, measure at the module side. I_{IL} (max) = – 10μA
	V_{IH}	2.0	V_{CC3} + 0.3	V	Pull up to V_{CC3}, measure at the module side. I_{IH} (max) =10μA
XFP SCL & SDA	V_{OL}	0.0	0.40	V	Pull up to host_V_{CC}, measure at the single board side. I_{OL} (max) =3mA
	V_{OH}	host_V_{CC} - 0.5	host_V_{CC} + 0.3	V	Pull up to host_V_{CC}, measure at the single board side
XFP SCL & SDA	V_{IL}	- 0.3	V_{CC3} × 0.3	V	Pull up to V_{CC3}, measure at the module side. I_{IL} (max) = – 10μA
	V_{IH}	V_{CC3}*0.7	V_{CC3} + 0.5	V	Pull up to V_{CC3}, measure at the module side. I_{IH} (max) =10μA
Leakage current	I_I	-10	10	μA	
SDA/SCL I/O pin capacitance	C_i		14	pF	10pF for XFP IC I/O pin, 4 pF for XFP PCB trace
Total capacitance of SDA/SCL bus	C_b		100	pF	At 400 kHz, 3.0 kΩ Rp, max

Table C.1 I^2C timing specifications

Parameter	Symbol	Min. value	Max. value	Unit	Condition
Clock frequency	f_{SCL}	0	400	kHz	
Clock pulse width (Low)	t_{LOW}	1.3		μs	
Clock pulse width (High)	t_{HIGH}	0.6		μs	
Bus idle time	t_{BUF}	1.3		μs	Time from STOP to START
START holding time	$t_{HD \cdot STA}$	0.6		μs	
START building time	$t_{SU \cdot STA}$	0.6		μs	
Data holding time	$t_{HD \cdot DAT}$	0		μs	
Data building time	$t_{SU \cdot DAT}$	0.1		μs	
Input rising time (100 kHz)	$t_{R \cdot 100}$		1000	ns	$(V_{IL \cdot MAX} - 0.15) - (V_{IH \cdot MIN} + 0.15)$
Input rising time (400 kHz)	$t_{R \cdot 400}$		300	ns	$(V_{IL \cdot MAX} - 0.15) - (V_{IH \cdot MIN} + 0.15)$
Input falling time (100 kHz)	$t_{F \cdot 100}$		300	ns	$(V_{IH \cdot MIN} + 0.15) - (V_{IL \cdot MAX} - 0.15)$
Input falling time (400 kHz)	$t_{F \cdot 400}$		300	ns	$(V_{IH \cdot MIN} + 0.15) - (V_{IL \cdot MAX} - 0.15)$
STOP building time	$t_{SU \cdot STO}$	0.6		μs	
Building time of selected bus	Host_select_setup	2		ms	
Holding time of selected bus	Host_select_hold	10		μs	
Bus release time	Deselect_Abort	2		ms	The time from single board announces to release bus to the module officially releases bus.

ID basic functions			
128	1	Transceiver module type (Identi?er)	XFP is 06H
129	1	Transceiver module expanded type (Ext. Identi?er)	Including power consumption level, if equipped with CDR function, if input reference clock required
130	1	Optical connector type (Connector)	LC is 07H
131 ~ 138	8	Transceiver module application code (Transceiver)	Including the codes when applying SDH, 10GE, 10GFC
139	1	Signal encoding method (Encoding)	such as 64B/66B, 8B/10B, SDH frame, RZ/NRZ, etc.
140	1	The minimum rate (BR-Min)	The unit is 100 Mbit/s
141	1	The maximum rate (BR-Max)	The unit is 100 Mbit/s
142	1	The transmission distance supported by standard single mode fiber (Length (SMF)-km)	The unit is km. 225 indicates that the distance exceeds 254 km; 0 indicates that it is not applicable to single mode fiber transmission.
143	1	The transmission distance supported by high mode bandwidth 50 μm multi-mode fiber (Length (B-50 μm))	The unit is 2m. 255 indicates that the distance exceeds 508 km; 0 indicates that it is not applicable to high mode bandwidth 50 μm multi-mode fiber transmission.
ID basic functions			
144	1	Transmission distance supported by 50 μm multi-mode fiber (Length (50 μm))	The unit is 1m. 225 indicates that the distance exceeds 254 km; 0 indicates that it is not applicable to 50 μm multi-mode fiber transmission.
145	1	Transmission distance supported by 62.5 μm multi-mode fiber (Length (62.5 μm))	The unit is 1m. 225 indicates that the distance exceeds 254 km; 0 indicates that it is not applicable to 62.5 μm multi-mode fiber transmission.
146	1	Transmission distance supported by copper wire (Length (Copper))	The unit is 1m. 225 indicates that the distance exceeds 254 km; 0 indicates that it is not applicable to copper wire transmission.
ID basic functions			
147	1	Device technology (Device Tech)	Including the laser type of the transmitter, the detector type of the receiver; if with wavelength control,

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