Development of 43/112 Gbit/s Optical Transceiver Modules

Eiji TSUMURA*, Ryoichi NAKAMOTO, Hideki OOE, Takashi MATSUI, Shinta KASAI, Kazushige OKI, Ryutaro FUTAMI, Hirotaka OOMORI, Yasuhiro TANAKA, Hiromi TANAKA, Kengo MATSUMOTO, Hiromi KURASHIMA and Hiroto ISHIBASHI

The authors have successfully developed optical transceiver modules operating at 43 Gbit/s and 112 Gbit/s. They are compliant with the ITU-T (International Telecommunication Union Telecommunication Standardization Sector) standard and the CFP MSA (Centum gigabit Form factor Pluggable Multi-Source Agreement) specification and they showed excellent performance with lower power consumption by leveraging in-house optical devices, ICs and optical subassemblies. This paper describes the outline of optical transceiver development and evaluation result.

Keywords: optical transceiver, ITU-T, CFP MSA, 43 Gbit/s, 112 Gbit/s

1. Introduction

The total amount of Internet traffic has been increasing continuously owing to the communication access population explosion in emerging markets and the increase of data amount per one access via high performance mobile devices such as smart phones. While the optical network equipment with much larger capacity has been developed, the ITU-T (International Telecommunication Union Telecommunication Standardization Sector) and the IEEE (Institute of Electrical and Electronic Engineers) started the standardization for 40 Gbit/s and 100 Gbit/s data transmission specification which is the next generation of conventional 10 Gbit/s data transmission. The ITU-T standardization was completed in September 2009 and the IEEE standardization was completed in June 2010 [(1)-(3)].

In parallel with the standardization described above, the industry common specifications for the pluggable optical transceiver module, which is used in the optical communication equipment to convert the electrical signal to the optical signal and vice versa, has been developed by CFP MSA (Centum gigabit Form factor Pluggable Multi-Source Agreement) and were released in March 2009 [(4)].

This paper outlines the development of optical transceiver modules operating at 43 Gbit/s and 112 Gbit/s which incorporates internally developed optical subassemblies, optical devices and ICs. The developed optical transceiver modules are compliant with the ITU-T standard, IEEE standard and CFP MSA. This paper describes particularly the compliance with ITU-T and CFP MSA.

2. Outlines of the ITU-T and IEEE Standards

Table 1 shows the outline of the ITU-T interface standards and **Table 2** shows the outline of the IEEE interface standards. The IEEE specifies the interface not only for single mode fiber (SMF) but also multi mode fiber (MMF) as media.

Table 1. Outlines of the ITU-T interface standard

Application code	C4S1-2D1	4I1-9D1F	4L1-9C1F
Data rate	43 Gbit/s	112 Gbit/s	
Operating distance	10 km	10 km	40 km
Optical fiber type	SMF		
Optical wavelength	1300 nm 4 lanes CWDM	1300 nm 4 lanes LAN WDM	
Optical signaling rate	10.75 Gbit/s, each lane	28 Gbit/s, each lane	
Electrical signaling rate	10.75 Gbit/s, each lane (total 4 lanes)	11.2 Gbit/s, each lane (total 10 lanes)	

Table 2. Outlines of the IEEE interface standard

Single mode fiber interface			
Application code	40 GBASE-LR4	100GBASE-LR4	100GBASE-ER4
Data rate	41.25 Gbit/s	103.13 Gbit/s	
Operating distance	10 km	10 km	40 km
Optical fiber type	SMF		
Optical wavelength	1300 nm 4 lanes CWDM	1300 nm 4 lanes LAN WDM	
Optical signaling rate	10.31 Gbit/s, each lane	25.78 Gbit/s, each lane	
Electrical signaling rate	10.31 Gbit/s, each lane (total 4 lanes)	10.31 Gbit/s, each lane (total 10 lanes)	

Multi-mode fiber interface		
Application code	40 GBASE-SR4	100 GBASE-SR10
Data rate	41.25 Gbit/s	103.13 Gbit/s
Operating distance	100 m	
Optical fiber type	MMF ribbon	
Optical wavelength	850 nm 4 lanes parallel	850 nm 10 lanes parallel
Optical signaling rate	10.31 Gbit/s, each lane	
Electrical signaling rate	10.31 Gbit/s, each lane (total 4 lanes)	10.31 Gbit/s, each lane (total 10 lanes)

3. CFP Optical Transceiver Module

Figure 1 shows the external view of a developed CFP optical transceiver module. A CFP optical transceiver has 148 electrical pins which enable 12 pairs of 10 Gbit/s differential data input/output. Four types of optical connector (SC duplex, LC duplex, MTP 12 and MTP 24) are supported in response to the applications. Maximum power consumption is categorized to four classes (<8 W, <16 W, <24 W and <32 W) and the thermal design of optical network equipment will be optimized based on the module power class.

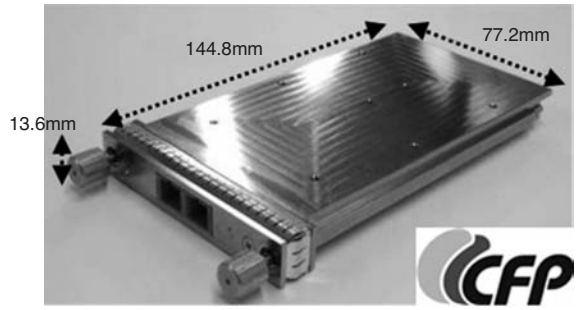

Fig. 1. CFP optical transceiver module

4. Outlines of 43 Gbit/s Optical Transceiver

4-1 Function and configuration

Figure 2 shows the block diagram of a 43 Gbit/s optical transceiver. It consists of an optical multiplexer, an optical demultiplexer, four optical transmitter modules, four optical receiver modules, a printed circuit board on which a clock data recovery IC and interface/control circuits are mounted, and other components such as electrical connector, and these components are assembled in the optical transceiver frame.

Conventional 10 Gbit/s optical modules are used as optical transmitters and receivers, and connected to an optical multiplexer or an optical demultiplexer to achieve four lanes of optical signal multiplexing or demultiplexing which is specified in the ITU-T.

A distributed feedback laser diode (DFB-LD), which converts 10.75 Gbit/s electrical signals to optical signals at the wavelength specified in the ITU-T, is assembled in an optical transmitter module. A photodiode which converts 10.75 Gbit/s optical signals to electrical signals and a preamplifier IC which amplifies photo diode electrical signals are assembled in an optical receiver module.

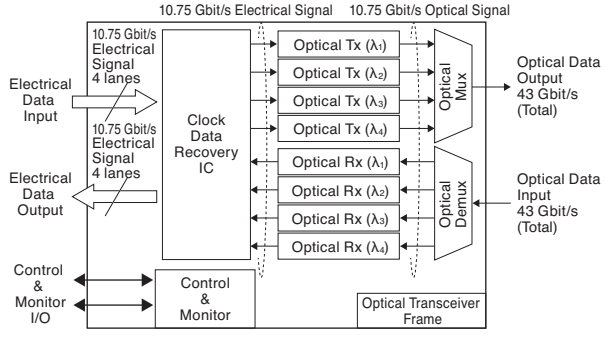

Fig. 2. Block diagram of 43 Gbit/s CFP transceiver

5. Specifications and Characteristics

5-1 Specifications

Table 3 shows the specifications of a 43 Gbit/s optical transceiver.

Table 3. 43 Gbit/s CFP transceiver specifications

		Min.	Max.	Unit
Operating temperature		0	70	˚C
Supply voltage		3.2	3.4	V
Power consumption		–	8	W
Optical transmitter characteristics				
Optical wavelength	λ_1	1264.5	1277.5	nm
	λ_2	1284.5	1297.5	nm
	λ_3	1304.5	1317.5	nm
	λ_4	1324.5	1337.5	nm
Average optical output power		-2.3	2.3	dBm
Extinction ratio		4.5	–	dB
Optical eye mask		ITU-T G.959.1		
Optical receiver characteristics				
Sensitivity		–	-10.8	dBm
Overload		2.3	–	dBm

5-2 Optical transmitter characteristics

Figure 3 shows optical waveforms at 1271 nm. The extinction ratio at 10.75 Gbit/s is larger than 7 dB and the optical eye mask margin specified in the ITU-T is larger than 35 % over the operating temperature range.

5-3 Optical receiver characteristics

Figure 4 shows bit error rate curves at 1271 nm. The receiver sensitivity at 10^{-12} bit error rate is less than -15 dBm (the ITU-T specification is -10.8 dBm) and the receiver overload is larger than 2.3 dBm over the operating temperature range.

5-4 Other characteristics

The power consumption of the optical transceiver is 5.2 W at -5°C, 5.5 W at 35°C and 6.0 W at 70°C, which is far lower than the specified power consumption of 8 W.

The developed optical transceiver is compliant with all the other CFP MSA specifications.

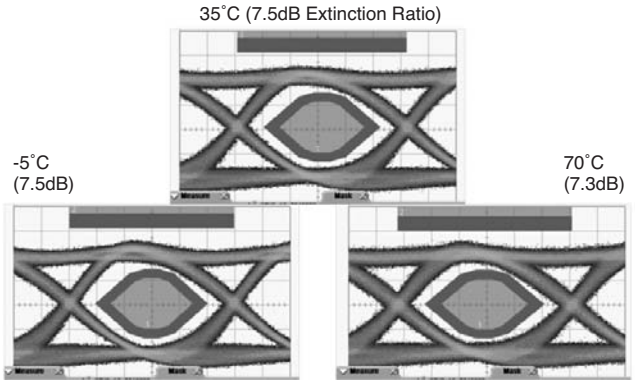

Fig. 3. Optical waveforms (10.75 Gbit/s, 1271 nm)

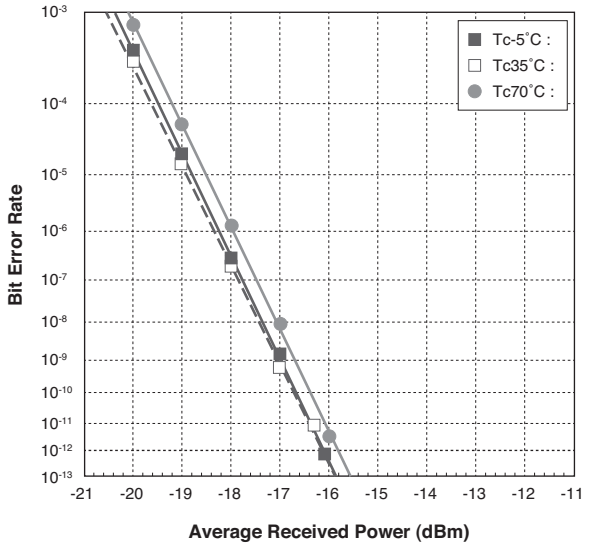

Fig. 4. Bit error rate curves (10.75 Gbit/s, 1271 nm)

6. Outlines of 112 Gbit/s Optical Transceiver

6-1 Function and configuration

Figure 5 shows the block diagram of a 112 Gbit/s optical transceiver. It consists of an optical multiplexer, an optical demultiplexer, four optical transmitter modules, four optical receiver modules, a printed circuit board on which a 10:4 gearbox IC and interface/control circuits are mounted, and other components such as electrical connector, and these components are assembled in the optical transceiver frame.

6-2 28 Gbit/s optical transmitter module [5]

Photo 1 shows the external view of a 28 Gbit/s optical transmitter module. It has 18 pins for high speed signal input, power supplies and control/monitor I/Os, and is connected via a flexible printed circuit to the printed circuit board on which a gearbox IC is mounted. The size of the module, excluding the flexible printed circuit, is 24.2 mm x 5.8 mm x 5.6 mm.

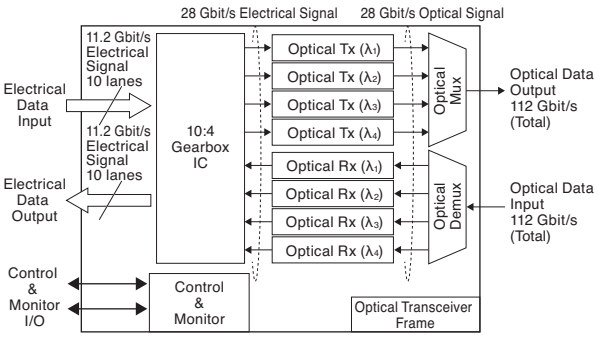

Fig. 5. Block diagram of 112 Gbit/s CFP transceiver

Photo 1. 28 Gbit/s optical transmitter module

The module consists of a driver IC which amplifies 28 Gbit/s electrical signals up to the required voltage amplitude, an electro-absorption DFB-LD (EA-DFB) which is connected to the output port of the driver IC to generate 28 Gbit/s optical signals at the wavelength specified by the ITU-T, and a thermo-electric cooler which keeps the EA-DFB chip temperature constant. The driver IC achieves a lower power consumption of 1.1 W at a power supply voltage of -5.2 V by using the in-house Indium Phosphide (InP) double-heterojunction bipolar transistor (D-HBT) process (f_t=150GHz, f_{max}=200GHz), which is suitable for higher speed and larger voltage amplitude applications.

6-3 28 Gbit/s optical receiver module

Photo 2 shows the external view of a 28 Gbit/s optical receiver module. It has 9 pins for high speed signal output and power supply, and is connected via a flexible printed circuit to the printed circuit board on which a gearbox IC

Photo 2. 28 Gbit/s optical receiver module

is mounted. The size of the module, excluding the flexible printed circuit, is 13.9 mm x 5.6 mm x 5.6 mm. The module consists of a photo diode which converts 28 Gbit/s optical signals to electrical signals and a pre-amplifier IC which amplifies photo diode electrical signals. The receiver module achieves a small signal bandwidth of 20 GHz, transimpedance of 1.5 kΩ and power consumption of 0.3 W at power supply voltage of 3.3 V by applying in-house InP D-HBT process to the pre-amplifier IC fabrication.

6-4 Other components

An optical multiplexer module multiplexes optical signals of four wavelength channels onto a single output fiber as specified by the ITU-T, whereas an optical demultiplexer module separates wavelengths in an input fiber onto ports.

A 10:4 gearbox IC consists of a multiplexer which converts 10 lanes of 11.2 Gbit/s electrical signals into 4 lanes of 28 Gbit/s electrical signals and a demultiplexer which converts 4 lanes of 28 Gbit/s electrical signals into 10 lanes of 11.2 Gbit/s electrical signals.

7. Specifications and Characteristics

7-1 Specifications

Table 4 shows the specifications of a 112 Gbit/s optical transceiver.

Table 4. 112 Gbit/s CFP transceiver specifications

		Min.	Max.	Unit
Operating temperature		0	70	˚C
Supply voltage		3.2	3.4	V
Power consumption		–	24	W
Optical transmitter characteristics				
Optical wavelength	λ_1	1294.53	1296.59	nm
	λ_2	1299.02	1301.09	nm
	λ_3	1303.54	1305.63	nm
	λ_4	1308.09	1310.19	nm
Average optical output power		-2.5	2.9	dBm
Extinction ratio		7	–	dB
Optical eye mask		ITU-T G.959.1		
Optical receiver characteristics				
Sensitivity		–	-10.3	dBm
Overload		2.9	–	dBm

(Refer to the ITU-T specifications issued in February 2012)

7-2 Optical transmitter characteristics

Figure 6 shows an optical spectrum and **Fig. 7** shows optical waveforms.

An optical spectrum superimposes four wavelengths. All of the wavelength channels are compliant with the wavelength grid specified by the ITU-T and show good signal isolation and other characteristics.

Optical waveforms at 1300 nm are shown in **Fig. 7**. An extinction ratio at 27.95 Gbit/s is larger than 9 dB and the optical eye mask margin specified by the ITU-T is larger than 40% throughout the entire operating temperature range.

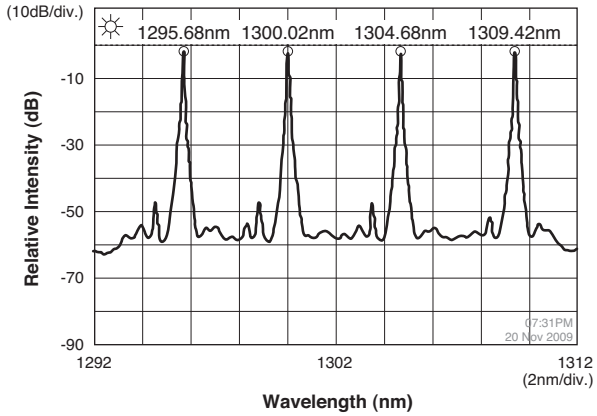

Fig. 6. Optical spectrum (Four wavelength channels superimposed)

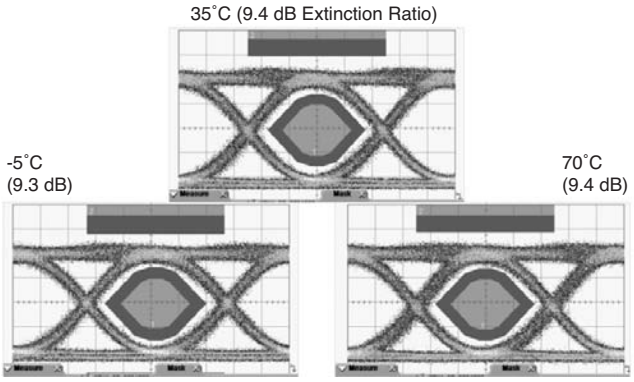

Fig. 7. Optical waveforms (27.95 Gbit/s, 1300 nm)

7-3 Optical receiver characteristics

Figure 8 shows bit error rate curves at 1300 nm. The receiver sensitivity at a bit error rate of 10^{-12} is less than -13 dBm (ITU-T specification is -10.3 dBm) and the receiver overload is larger than 2.9 dBm throughout the entire operating temperature range.

7-4 Other characteristics

The power consumption of the optical transceiver is 18.5 W at -5ºC, 19.1 W at 35ºC and 21.0 W at 70ºC, which is much lower than the specified power consumption of 24 W.

The developed optical transceiver is compliant with all the other CFP MSA specifications.

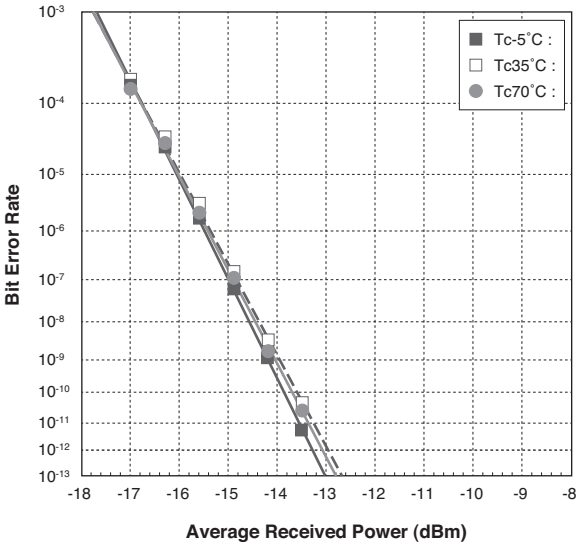

Fig. 8. Bit error rate curve (27.95 Gbit/s, 1300 nm)

8. Conclusion

We have developed optical transceiver modules operating at 43 Gbit/s and 112 Gbit/s. These modules are compliant with the ITU-T and CFP MSA specifications and show excellent performance with lower power consumption by leveraging in-house optical devices, ICs and optical subassemblies.

While the CFP optical transceiver modules are widely used for 40 Gbit/s and 100 Gbit/s transmissions, market demand has been growing for power-saving, compact optical transceiver modules. We continue to work on the development of even more power-saving and smaller CFP optical transceiver modules.

Technical Terms

*1 WDM (Wavelength Division Multiplexing): WDM refers to optical wavelength division multiplexing. WDM using 20 nm wavelength spacing is called Coarse Wavelength Division Multiplexing (CWDM), and WDM using about 4.5 nm wavelength spacing is called Local Area Network Wavelength Division Multiplexing (LAN WDM).

*2 SC duplex, LC duplex, MTP12 and MTP24: These are optical connectors. Their specifications are standardized by the IEC (International Electrotechnical Commission).

References

(1) ITU-T recommendation G.695 Optical interfaces for coarse wavelength division multiplexing applications, Oct. 2010

(2) ITU-T recommendation G.959.1 Optical transport networks physical layer interfaces, Feb. 2012

(3) IEEE 802.3ba Media Access Control Parameters, Physical Layers, and Management Parameters for 40 Gb/s and 100 Gb/s Operation

(4) CFP MSA Hardware Specification, Rev. 1.4 and CFP MSA Management Interface Specification, Rev. 1.4 (http://www.cfp-msa.org/documents.html)

(5) Taizo Tatsumi et. al., "Development of Electro-Absorption Modulator Driver ICs for 25G/40G Transmission" SEI Technical Review, No. 74, Apr. 2012

Contributors (The lead author is indicated by an asterisk (*).)

E. TSUMURA*

• Department Manager, Transmission Devices R&D Laboratories
He is engaged in the research and development of the optical transceiver module.

R. NAKAMOTO
• Transmission Devices R&D Laboratories

H. OOE
• Transmission Devices R&D Laboratories

T. MATSUI
• Transmission Devices R&D Laboratories

S. KASAI
• Transmission Devices R&D Laboratories

K. OKI
• Assistant Manager, Transmission Devices R&D Laboratories

R. FUTAMI
• Assistant Manager, Transmission Devices R&D Laboratories

H. OOMORI
• Assistant Manager, Transmission Devices R&D Laboratories

Y. TANAKA
• Assistant Manager, Transmission Devices R&D Laboratories

H. TANAKA
• Assistant General Manager, Transmission Devices R&D Laboratories

K. MATSUMOTO
• Group Manager, Transmission Devices R&D Laboratories

H. KURASHIMA
• Group Manager, Transmission Devices R&D Laboratories

H. ISHIBASHI
• Group Manager, Transmission Devices R&D Laboratories