25 Gbit/s Optical Transmitter Modules for Optical Transceiver

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For a 100 Gbit/s optical transceiver that satisfies the demand of high speed transmission, the authors have developed two types of 25 Gbit/s optical transmitter modules so that a user can select a module depending on transceiver architectonics. One of the two modules has an in-house driver IC for Electro-absorption (EA) modulator integrated in a laser chip and the other has no driver IC. These transmitter modules are transmitter optical sub-assembly (TOSA) type devices with flexible printed circuit (FPC) and LC receptacle. The evaluation results showed good modulation characteristics, lower power consumption and long-term reliability. This paper describes the outline of 25 Gbit/s optical transmitter module structure and evaluation results.

Keywords: Electro-absorption Modulator Integrated Laser Diode, TOSA, IEEE802.3ba, CFP module

1. Introduction

The amount of data transmission goes on increasing due to the high functionalization of mobile terminals, spread of social media and cloud computing. In addition, global online population is growing, especially in emerging countries. To meet the demand of data transmission, high-speed and large-capacity are required for network equipment like optical transmission equipment and optical switched/routers.

In IEEE*1, 10 Gbit/s Ethernet (10GbE) was standardized as a transmission specification in 2002. Eight years later, in 2010, 100 Gbit/s Ethernet (100GbE) was standardized as the next generation specification(1). Among the 100GbE specifications, 100GBASE-LR4 (transmission distance: 10 km) and 100GBASE-ER4 (transmission distance: 40 km) are the specifications for middle/long distance between routers/switches or between neighboring data centers when using single mode fiber. In ITU-T*2 recommendation, G.959.1 (4I1-9D1F and 4L1-9C1F respectively)(2) are determined as specifications corresponding to the IEEE's specifications.

The optical transmitter modules we have developed are one of the key components in the optical transceiver (CFP)*3 (3) which converts an electrical signal to an optical signal and vice versa in the optical transmission equipment and optical switch/router. In the optical transceiver, the 100 Gbit/s electrical signal is divided into four 25 Gbit/s electrical signal lanes so that the data rate is suppressed per a lane, and four 25 Gbit/s lanes are allocated respectively to four optical transmitter modules whose wavelengths are four different ones, called LAN-WDM*4.

We have developed 25 Gbit/s optical transmitter modules employing Electro-Absorption (EA) modulator integrated DFB laser (hereinafter referred to as "EA-DFB laser"*5) for 100 Gbit/s optical transceiver.

In addition, when we commercialized these products, we developed two types of optical transmitter modules, including an in-house laser-diode driver IC(4) built-in type (hereinafter referred to as "driver IC built-in type") and a type without a laser-diode driver IC (hereinafter referred to as "non-IC built-in type"), so that a user can select a transmitter module depending on the transceiver architectonics. In this paper, we describe the configurations, characteristics and long-term reliability of 25 Gbit/s optical transmitter modules.

2. Specifications

Table 1 shows the specifications of the optical transmitter module.

Table 1. Optical transmitter module specifications (Transmission distance: 10 km)

		Min.	Max.	Unit
Bit rate		-	27.95	Gbit/s
Operating case temperature		-5	75	°C
Laser set temperature		40	48	°C
Laser operating current		-	100	mA
Optical output power		0	3	dBm
RF extinction ratio		4	-	dB
Optical wavelength	L0	1295.56 +/- 0.7		nm
	L1	1300.05 +/- 0.7		nm
	L2	1304.58 +/- 0.7		nm
	L3	1309.14 +/- 0.7		nm
Eye mask		ITU-T G.959.1		
TEC power consumption			0.75	W

Each optical transmitter module has one of wavelengths of L0, L1, L2 and L3. One set of 4 wavelengths is mounted on 100 Gbit/s optical transceiver module.

3. Optical Transmitter Module Configurations

Photo 1 shows the appearance of two types of optical transmitter modules, a driver IC built-in type (left photo) and non-IC built-in type (right photo). These are transmitter optical sub-assembly (TOSA) type devices and each package size, excluding flexible printed circuit, is 24.2×5.6×5.6 mm^3 in the driver IC built-in type and 18.2×5.6×5.4 mm^3 in the non-IC built-in type. Also, the size of the latter one matches the 10Gbit/s XMD-MSA*6 specification.

The driver IC built-in type module has two 9 pins flexible printed circuits, while the non-IC built-in type has one 8 pins flexible printed circuit as an electrical input interface. An LC receptacle is adopted in both type modules as an output optical interface.

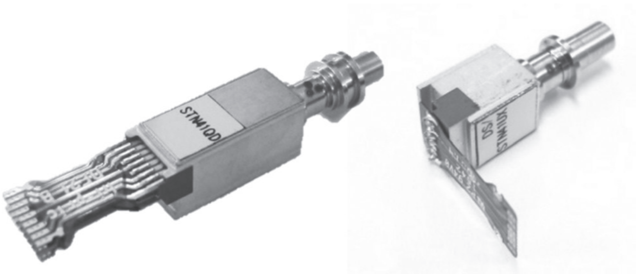

Photo 1. Optical transmitter modules (Left: driver IC built-in type, Right: non-IC built-in type)

Figures 1 and 2 depict the block diagrams of driver IC built-in type and non-IC built-in type respectively. Both modules have an EA-DFB laser common to the two types and Photo-Diode (PD) for monitoring optical output power. Also, Thermo-Electric-Cooler (TEC) for maintaining EA-DFB laser set temperature, thermistor (TH) and lens are installed. Light from the EA-DFB laser is passed through an isolator and then is focused to fiber stub in the receptacle by the lens optical coupling system.

The driver IC built-in type has an InP-based in-house driver IC for operating the EA-DFB laser and the driver IC is connected to the EA-DFB laser through a 50 ohm (Ω) transmission line.

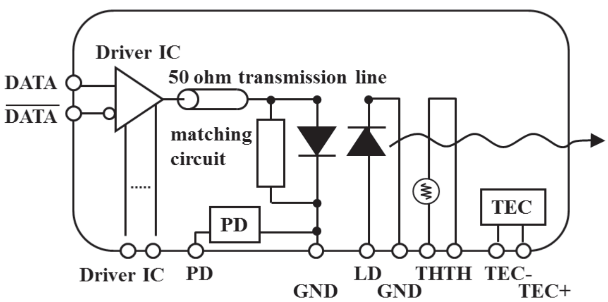

Fig. 1. Block diagram of driver IC built-in type

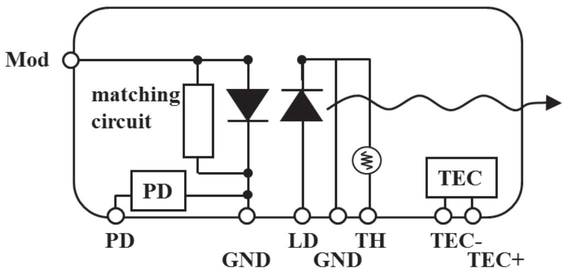

Fig. 2. Block diagram of non-IC built-in type

4. Characteristics

4-1 DC characteristics

Figure 3 shows the graph of the laser forward current versus optical output power (I-L characteristic), and **Fig. 4** shows the graph of DC extinction ratio characteristic in applying reverse voltage to the EA modulator as examples of DC characteristics of the EA-DFB laser. In **Fig. 3**, the laser threshold current is 17 mA, and DC optical output power at the laser operating current: 80 mA is about 4 mW (about 6 dBm). This is enough DC output power to meet the specification of output power under modulation. Meanwhile, DC extinction ratio characteristic in **Fig. 4** indicates more than 15 dB for input voltage: 2 Vpp.

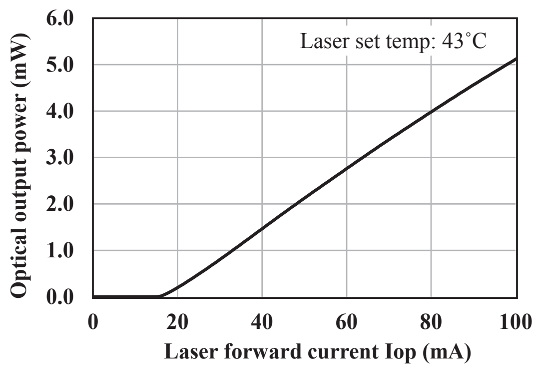

Fig. 3. Laser forward current vs. optical output power (I-L characteristic)

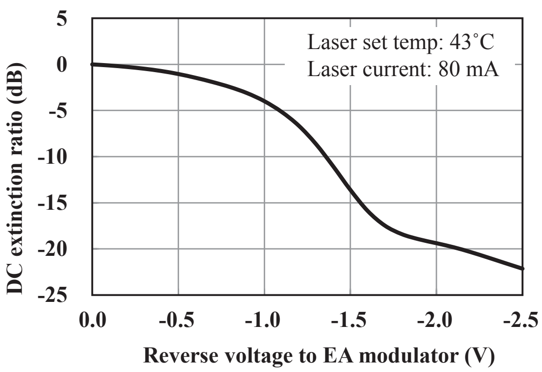

Fig. 4. EA modulator DC extinction ratio characteristic

4-2 Modulation characteristics

Figure 5 shows optical waveforms of optical transmitter modules; **Fig. 5 (a)** driver IC built-in type and **Fig. 5 (b)** non-IC built-in type. These are measured under the conditions where the bit rate is 27.95 Gbit/s, test pattern is NRZ PRBS2^{31}-1 and after passing the 4^{th} order Bessel-Thomson filter.

In **Fig. 5 (a)**, RF extinction ratio is more than 9 dB and mask margin specified by ITU-T is more than 40 % over the operating case temperature range. Meanwhile, in the case of non-IC built-in type, the EA-DFB laser is on the TEC and, therefore, optical waveform is hardly affected by the operating case temperature. **Fig. 5 (b)** shows an optical waveform at 25˚C, which is a good characteristic compatible with that of driver IC built-in type.

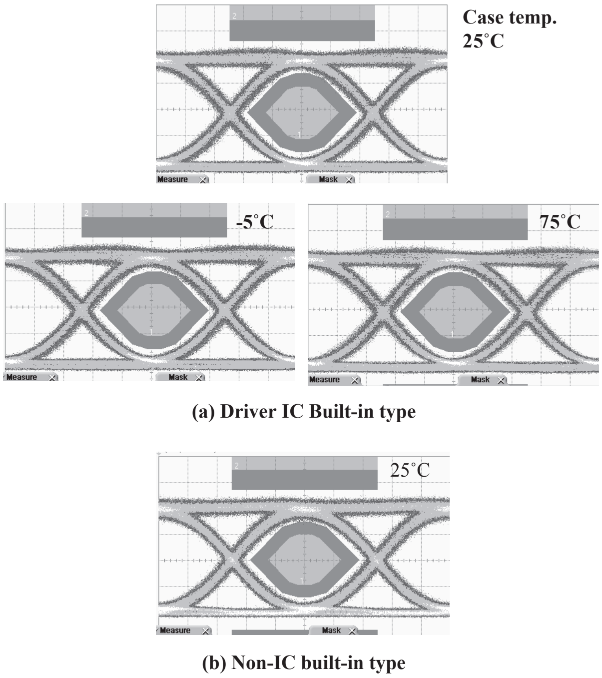

Fig. 5. Back-to-back Optical waveforms

4-3 Power consumption

Figure 6 indicates an example of case temperature dependency of power consumption in the driver IC built-in type module (Laser operating current = 80 mA, Laser set temperature = 45˚C). The total power consumption of the optical transmitter module is determined by the sum of power consumption in the EA-DFB laser, driver IC and TEC, so the power consumption of the driver IC built-in type module is larger than that of the non-IC built-in type module. The ratio of TEC power consumption (dotted line in **Fig. 6**) in the total amount (solid line in **Fig. 6**) gets larger at high case temperature as TEC keeps the laser set temperature constant. Total power consumption of optical transmitter module is less than 2 W at the highest case temperature; 75˚C.

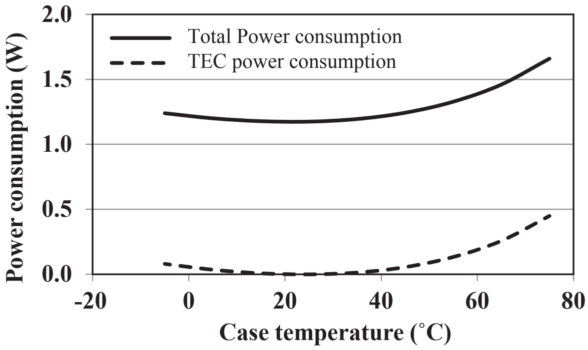

Fig. 6. Case temperature dependency of power consumption (Driver IC built-in type)

5. Long-term Reliability

To confirm the long-term reliability of the optical transmitter module, we carried out a high temperature operating test on the basis of Telcordia GR-468-CORE(5). **Figures 7 and 8** show output power variation and wavelength variation respectively in the driver IC built-in type module (Aging conditions; Atmospheric temperature Ta = 85˚C, Laser set temperature = 40˚C, Laser operating current = 100 mA and driver IC operating). Optical output power variation in the **Fig. 7** is within the range of +/-10 % over 2,000 hours. Meanwhile, the wavelength indicates long-term stability in the **Fig. 8**.

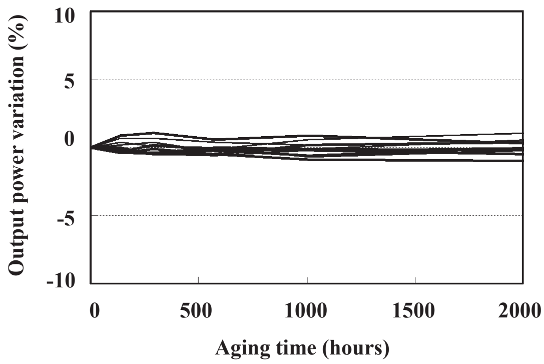

Fig. 7. Output power variation in the aging test

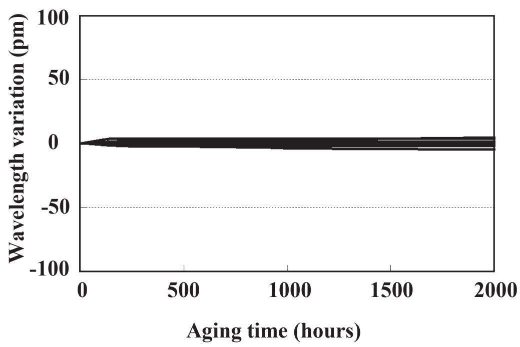

Fig. 8. Wavelength variation in the aging test

6. Conclusion

We have developed two types of 25 Gbit/s optical transmitter modules for 100 Gbit/s optical transceiver. One of the two modules has an in-house driver IC and the other has no driver IC. Both optical transmitters show good DC and modulation characteristics over the case temperature range. Thus, a user of the optical transceiver is able to select an optical transmitter module depending on the transceiver architectonics.

Technical Terms

∗1 IEEE (The Institute of Electrical and Electronic Engineers): An organization that makes standards for electrical and electronic engineering, telecommunications and computer engineering, etc. In particular IEEE 802.3 working group is in charge of standardization of Ethernet.

∗2 ITU-T (International Telecommunication Union Telecommunication Standardization Sector): One of the sectors in ITU, a specialized agency of the United Nation. ITU-T coordinates international standards for telecommunication.

∗3 CFP (Centum gigabit Form factor Pluggable): Hot-pluggable optical transceiver form factor which enable to operate at 40 Gbit/s and 100 Gbit/s.

∗4 LAN-WDM (Local Area Network-Wavelength Division Multiplexing): Transmission systems in which 4 lanes with about 5 um (800 GHz) spacing (i.e. 1295.56 nm, 1300.05 nm, 1304.58 nm and 1309.14 nm) are wavelength multiplexed over a single fiber. LAN-WDM system does not require highly precious tuning of laser operating temperature compared with DWDM system because the wavelength spacing is wider than about 0.4 nm (50 GHz) in the DWDM system.

∗5 EA-DFB Laser (Electro-Absorption Distributed-Feed Back Laser): Integrated laser chip composed of DFB laser emitting light continuously and electro-absorption modulator modulating light intensity.

∗6 XMD-MSA: An agreement on 10 Gbit/s optical transmitter and receiver between multiple manufacturers to standardize specifications of external dimensions and electrical/optical characteristics, and to develop compatible products.

References

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