

High-Speed Optical Device (EML, LN-MZM) Evaluation using AH15199B Wideband Linear Amplifier

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1. Introduction

IP traffic is growing at a high rate, driven by the penetration of smartphones and expansion of social networking and video distribution services. 400GbE is used widely as a high-capacity communications method, and the IEEE802.3 ETHERNET WORKING GROUP is promoting various standardization of high-speed, high-capacity optical interfaces to support even higher capacity. Standardization of 50 Gbps and 100 Gbps/ch transmission capacity has been completed, and 200 Gbps/lane is being newly considered for IEEE 802.3dj and OIF 800ZR/1600ZR, requiring higher-speed optical interfaces.

Verifying the performance of optical devices such as EML/LN-MZM optical modulators with high-speed signals requires a high-speed, high-amplitude (1.5 – 2.0 Vpp) modulation signal source for 120 Gbaud PAM4. Anritsu provides wideband linear amplifiers suitable for evaluating the performance high-speed optical devices for R&D, verification, manufacturing, installation and maintenance.

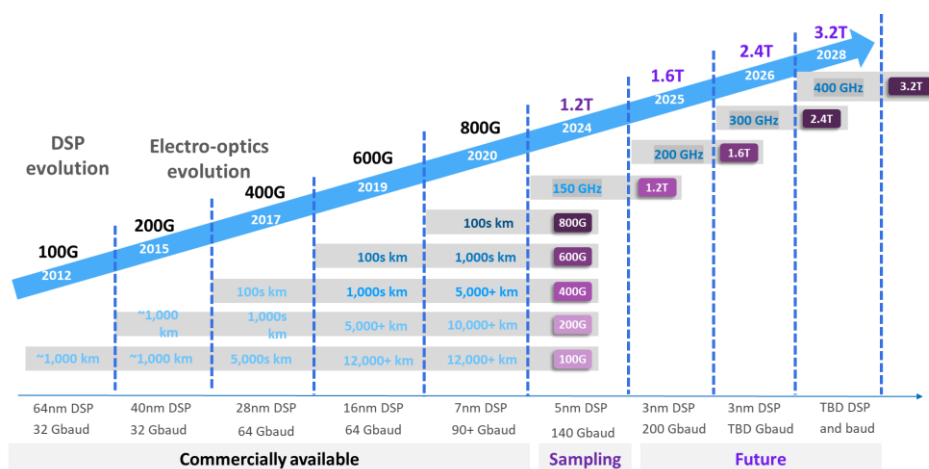
2. Interface

100GbE/200GbE/400GbE introduces multi-leveling from NRZ to PAM4 signals or 4/8 lanes multi-cores and multi-wavelengths to increase the transmission capacity per channel to 50 and 100 Gbps. 50 Gbaud PAM4 (=100 Gbps) was first adopted to transmit 100 Gbps over a single channel, but the IEEE 802.3dj 800 Gb/s and 1.6 Tb/s Ethernet Task Force is considering faster 200 Gbps/lane. A 100 Gbaud PAM4 signal transmitting 200 Gbps/lane is expected to become mainstream for 800GbE/1.6TbE. Accordingly, there is a need to support evaluation of high-speed transmissions of optical devices.

IEEE802.3dj (200 Gbps/lane) Objective (>2 km)

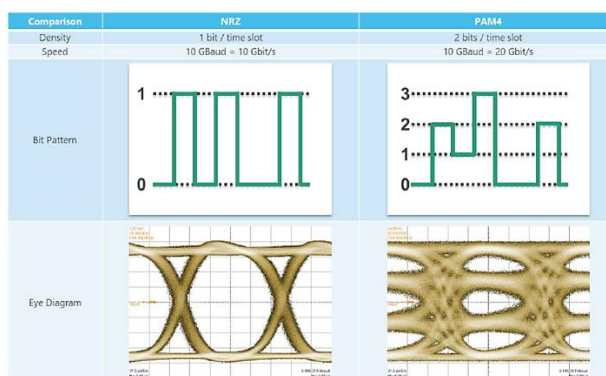
Interface Ethernet Standard	No. of Lanes	Signaling Rate	2km	10km	20km	40km
200GbE	×1	IM-DD 200 Gb/s	200GBASE-FR1	-	-	-
400GbE	×2	IM-DD 200 Gb/s	400GBASE-DR2-2	-	-	-
800GbE	×4	IM-DD 200 Gb/s	800GBASE-DR4-2 800GBASE-FR4	800GBASE-LR4	-	-
	×1	Coherent	-	800GBASE-LR1	800GBASE-ER1-20	800GBASE-ER1
1.6TbE	×8	IM-DD 200 Gb/s	1.6TBASE-DR8-2	-	-	-

As for market trends in coherent communications, 800GBASE-LR1 (10 km) and 800GBASE-ER1 (20 km/40 km) for 800GbE are being standardized in IEEE802.3dj (400 Gb/s and 800 Gb/s Ethernet Task Force), with release in July 2026. Meanwhile, standardization of 800ZR, 1600ZR and Coherent has also started in OIF, following 400ZR, and the speed of optical transmission systems beyond 1T is accelerating. In this context, it is necessary to evaluate optical devices beyond 140 Gbaud.



Roadmap for coherent optical technology

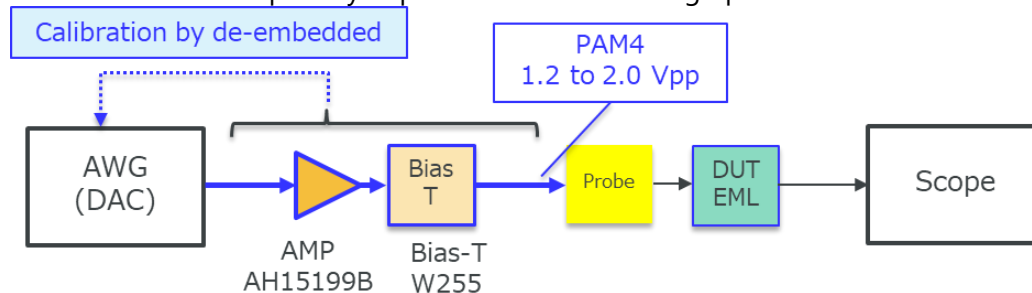
Source: Omdia 100G+ Coherent Optical Equipment Market Update – 1H23



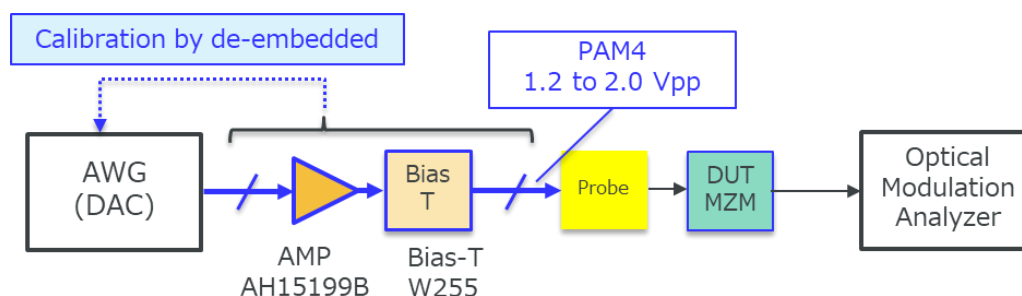
Difference between NRZ and PAM4 Modulations

3. Optical Device Evaluation Configuration and Items

The main concern when testing a device under test (DUT) is to verify the signal source waveform quality. Therefore, the effect of cables and other elements that can distort the signal must be calibrated by the AWG (DAC) de-embedding function before it is transmitted to the DUT. This is especially important when evaluating optical devices.



IMDD Optical Device(EML) Evaluation Configuration Example



Coherent Optical Device (LN-MZM) Evaluation Configuration Example

As mentioned above, evaluation of optical devices is important for both development and manufacturing. The main evaluation items are:

3.1 Optical Modulation Amplitude (PAM4: Outer OMA)

Outer OMA measures the difference between two optical power levels generated by a laser source: for NRZ signals, the high level is "1" when the source is "on" and the low level is "0" when the source is "off". This parameter is useful for determining the effectiveness of signal modulation when the extinction ratio is not high. For PAM4 signals, the high level is "3" when the light source is "on".

3.2 TDECQ

TDECQ (Transmitter Dispersion and Eye Closure Quaternary) is the ratio of the amount of noise (noise margin) added to the DUT (transmitter) and to the ideal transmitter to achieve the target SER (Symbol Error Rate), expressed in dB. A DUT transmitter is better with lower TDECQ. Unlike the NRZ signal, the mask margin test is not suitable for optical transceivers with PAM4 modulation, because the difference between adjacent amplitude levels is very small. Therefore, TDECQ was standardized as the alternative to the usual mask margin test, as shown below.

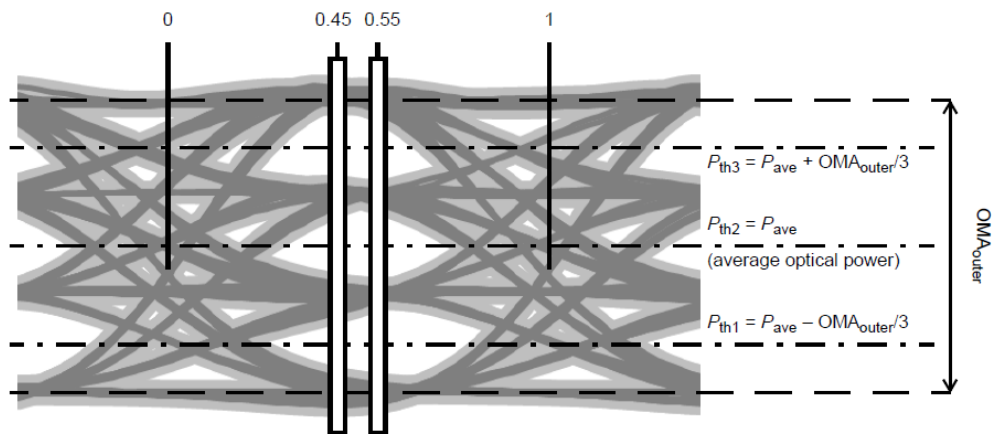


Illustration of TDECQ Measurement

Source: IEEE802.3-2022

$$R = \sqrt{\sigma_G^2 + \sigma_S^2}$$

$$TDECQ = 10\log_{10}\left(\frac{OMA_{outer}}{6} \times \frac{1}{Q_t R}\right)$$

R: RMS noise,

Qt: Consistent with BER and target SER for Gray coded PAM4 (= 3.414).

3.3 Linearity (RLM)

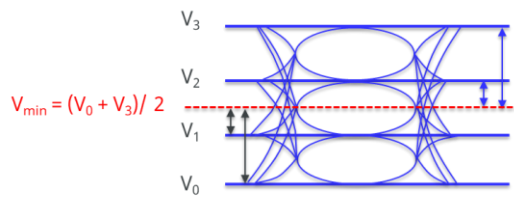
RLM (Ratio Level Mismatch) or the ratio between the eyes is another important parameter in evaluating the PAM signal. To help understand RLM evaluation, an example of a linearity evaluation comparison between a PAM4 signal with an ideal eye opening and a PAM4 signal with a nonlinear eye opening is shown below.

$$V_{min} = \frac{V_0 + V_3}{2}$$

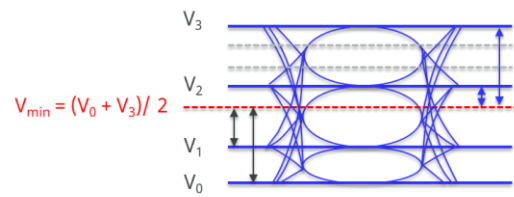
$$ES1 = \frac{V_1 - V_{min}}{V_0 - V_{min}}$$

$$ES2 = \frac{V_2 - V_{min}}{V_3 - V_{min}}$$

$$R_{LM} = \min((3 \times ES1), (3 \times ES2), (2 - 3 \times ES1), (2 - 3 \times ES2))$$



Ideal Eye
 $R_{LM} = \min((3 \times 1/3), (3 \times 1/3), (2 - 3 \times 1/3), (2 - 3 \times 1/3))$
 $= \min(1, 1, 1, 1)$
 $= 1$

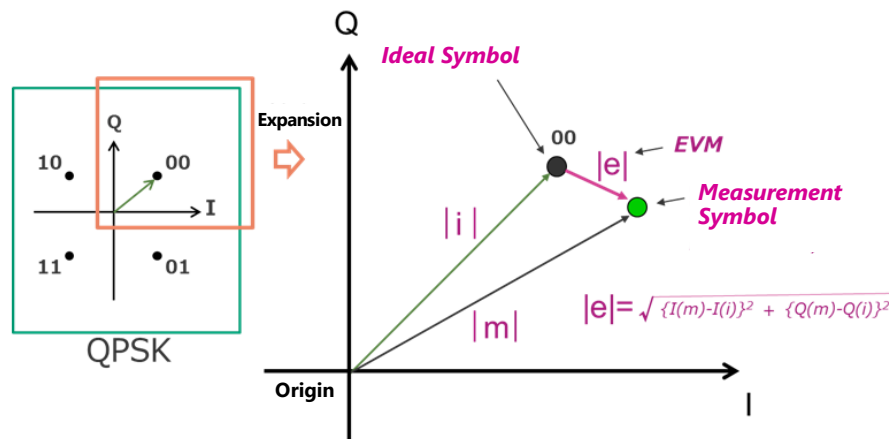


Non-linear Eye Example
 $R_{LM} = \min((3 \times 2/3), (3 \times 1/4), (2 - 3 \times 1/2), (2 - 3 \times 1/4))$
 $= \min(2, 0.75, 0.5, 1.25)$
 $= 0.5$

Linearity (RLM) Evaluation Example

3.4 EVM

EVM (Error Vector Magnitude) is an evaluation parameter defined in digital coherent specifications, such as OIF 400ZR, IEEE 400GBASE-ZR, and 400ZR+MSA. It is calculated by comparing the measured signal with an ideal reference signal to find the error vector. The EVM is the RMS (Root Mean Square) value of the error vector expressed as a percentage of the square root of the mean power of the ideal signal. The error vector is the vector magnitude at the symbol detection position.



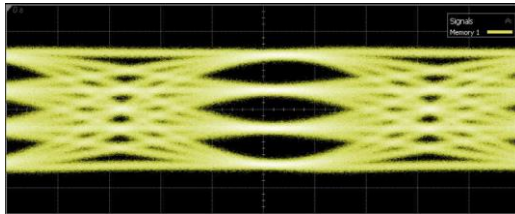
Constellation Image and EVM

4. Optical Device Margin Evaluation

Physical testing in advanced technology research and optical transceiver R&D requires deeper-level testing by evaluating the margin considering various external influences, stresses, and transmission-channel characteristics. DUT margin testing is important to ensure that the waveform quality of the signal source has a wide bandwidth margin. For example, it is very important to evaluate margin degradation of an EML/LN modulator used at 112.5 and 118 Gbaud at higher transmission rates.

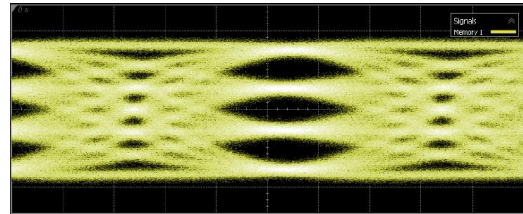
The following shows waveforms of a wideband linear amplifier evaluated with higher bandwidth signals (128 Gbaud, 140 Gbaud, 160 Gbaud) for reference.

112 Gbaud PAM4 Waveform



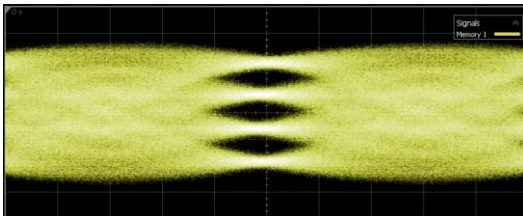
316 mV/div, 1.30 ps/div

128 Gbaud PAM4 Waveform



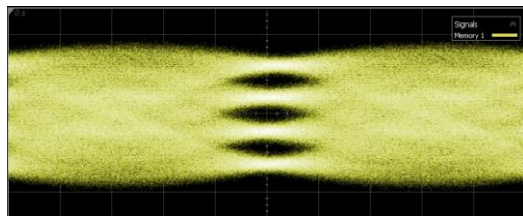
316 mV/div, 1.30 ps/div

140 Gbaud PAM4 Waveform



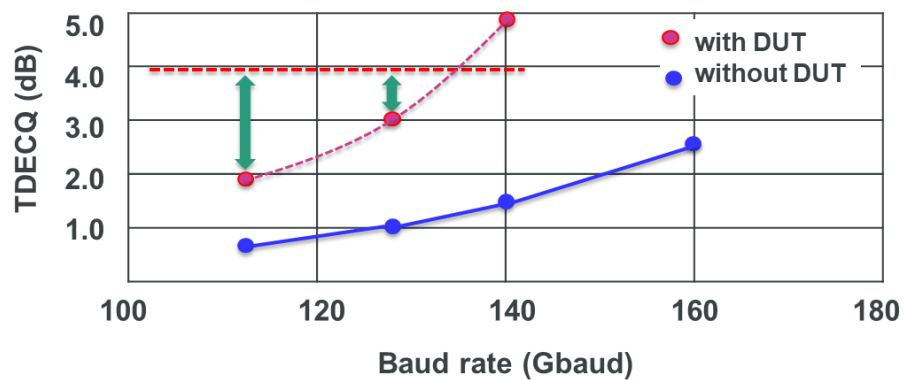
316 mV/div, 1.19 ps/div

160 Gbaud PAM4 Waveform



316 mV/div, 1.19 ps/div

An example of broadband margin evaluation of the TDECQ of an optical device using these signal sources is included. From the viewpoint of the reliability of digital communications, it is very important to verify not only that the specifications are met at the data rate used, but also that sufficient margins are retained at higher rates.



Baud Rate vs. TDECQ Example

5. Conclusion

The different evaluation items of optical devices require different measurement items and evaluation complexity. It is also necessary to perform conformance testing with adaptive standards and other products. Anritsu offers wideband linear amplifiers as signal sources, which are fully applicable to margin testing of optical devices in the 56–140 Gbaud range and beyond.

Anritsu is continuing to provide customers with the latest measurement solutions.



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