OIF

OIF 400ZR Interoperability White Paper
OFC 2025 Plugfest

Abstract: The Optical Internetworking Forum (OIF) has been instrumental in standardizing coherent optics at the physical layer, with the 400ZR implementation agreement (IA) being a significant achievement. This white paper reports on the performance evaluation of 400ZR and OpenZR+ pluggable modules in a multi-vendor interoperability environment, conducted during the OIF OFC 2023, OIF ECOC 2023, and OIF OFC 2024 Plugfest. The tests focused on the required optical signal to noise ratio (rOSNR) for maintaining a post-FEC error-free link over a dense wavelength-division multiplexing (DWDM) optical line system (OLS). The evaluation involved 10 different QSFP-DD optical pluggable modules from various vendors, tested using Anritsu's 400G transport tester (Network Master MT1040A) and other optical measurement equipment. The results demonstrated the interoperability and performance of these modules, providing confidence to network operators in deploying multi-vendor ZR environments with high channel density and efficiency.

1 Introduction

The Optical Internetworking Forum (OIF) serves the industry by driving the electrical, optical, and management interfaces that enable efficient and reliable optical networks. OIF continues to play a key role in the standardization of coherent optics at the physical layer. The 400ZR implementation agreement (IA), The OIF-400ZR IA [1], is one of the latest achievements that helps the industry build 400Gbps optical network ecosystems.

OIF investigated the performance of 400ZR pluggable modules and OpenZR+ pluggable modules through a multi-vendor interoperable environment at the OIF OFC 2023 Plugfest, OIF ECOC 2023 Plugfest and OIF OFC2024 Plugfest. The investigation addressed the impact on OSNR performance when multiple different pluggable modules were paired together with their transmitter (Tx) and receivers (Rx) over a dense wavelength-division multiplexing (DWDM) optical line system (OLS). The noise level of the 400 Gbps link was controlled to find the required optical signal to noise ratio (rOSNR) threshold of the receiver, which was the minimum optical signal to noise ratio to maintain a post-FEC error-free link.

In this white paper, we will report the demonstration results of interoperability testing using our products for testing and measuring optical signals which meet such industry needs. The measurements were performed at the most recent OIF Plugfest. A total of 10 different QSFP-DD pluggable modules were provided by 10 vendors. The results were anonymized as “Vendor A-J”. The key parameter receiver rOSNR was measured in each group under the same test configuration in the prior Plugfest. This test used the center channel in C band at 193.7THz

Overall, the goal is to provide confidence to network operators that multi-vendor ZR environments continue to exist and high efficiency and high channel density can be achieved on their network.

2 Test Setup

The block diagram of the Anritsu evaluation system is shown in Figure 1. Briefly, QSFP-DD Optical Pluggable Module which supports 400ZR, supplied from each vendor, was inserted into a 400G transport tester (MT1040A, Anritsu) which supports 400ZR/OpenZR+/OpenROADM. MT1040A was used for controlling the module and for reading the measurement parameters from the registers on the module. The optical output from the Tx part of the module was first introduced to an Erbium-doped fiber amplifier (EDFA, NCS1001, Cisco). In this Plugfest, we performed tests for 400ZR modules with the optical outputs of -10 dBm. In order to equalize the signal optical power, the gain of the EDFA was set to +20 dB. The amplified output was mixed with the amplified spontaneous emission (ASE) light whose intensity was adjusted by the variable optical attenuator (VOA, VOA-1002, Quantifi Photonics) through a 10:90 fiber coupler. The mixed light of 400ZR signal and ASE light was introduced into a 50:50 fiber coupler and divided into two paths. One path was introduced to an optical spectrum analyzer (OSA, MS9740B, Anritsu) to measure the optical spectrum of the signal light and calculate the OSNR value. The other path was introduced into the Rx part of the 400ZR module inserted into another MT1040A after passing through an optical tunable filter (NCS1001, Cisco) and a VOA (VOA-1002, Quantifi Photonics). After the VOA, the optical power was monitored with an optical power meter (OPM, Power-1401, Quantifi Photonics). When using both the Tx and Rx parts of the same module, or for a loopback configuration, one MT1040A was used, and the inserted 400ZR module was used as both Tx and Rx.

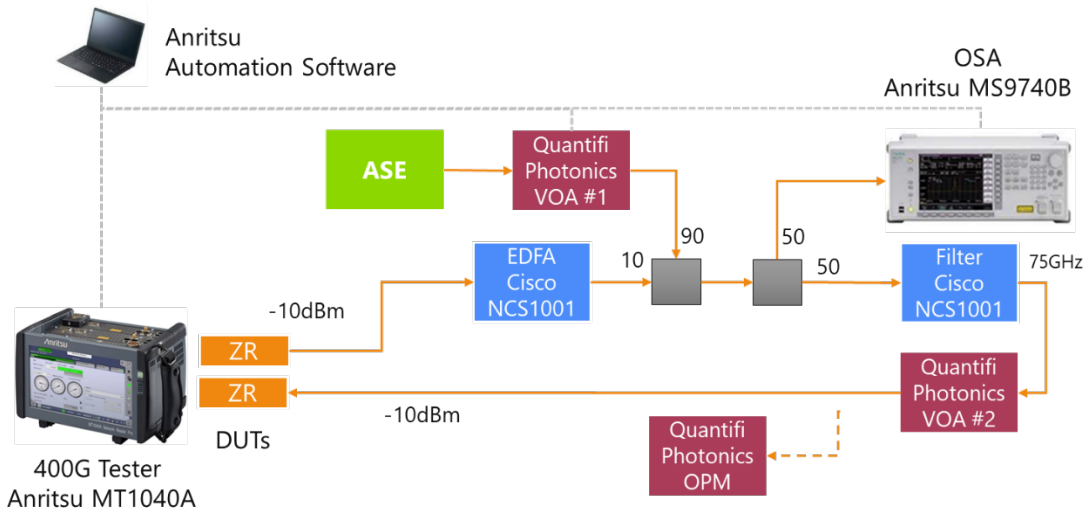

Figure 1. Block diagram of the evaluation setup of Anritsu in the OFC Plugfest.

3 Test Procedure

We performed the test with the following setup.

First, the MT1040A, 400ZR/OpenZR+/OpenROADM Tester, was set up as follows:

- 400ZR application
- Grid: 75GHz
- Frequency：Channel 24 (193.700 THz)
- Output Power：-10 dBm

The gain of the EDFA was set to +20 dB for the -10-dBm modules. The filter was set up as follows:

- Grid：75G
- Frequency：Channel 24 (193.700 THz)

The Frequency parameters were changed according to the Tx parameters to match the transmitting wavelength.

In the test, the rOSNR value was first estimated roughly. The attenuation of the VOA was set to a certainly high value where no ASE output was introduced into the measurement. From this situation, the attenuation was gradually decreased in 1dB steps. When the Rx transceiver gave an uncorrected error frame, the attenuation value was recorded, and the first estimation stage was completed.

Second, in order to determine the rOSNR value precisely, we monitored the connection for 30 seconds and checked whether an uncorrected frame was detected or not. If an uncorrected frame was detected, the attenuation was increased by 0.1 dB, and the connection was checked. This scheme was repeated until no uncorrected frames was detected. When no uncorrected frame was detected, the OSNR value obtained by the OSA was recorded as rOSNR.

4 Test results

4.1 rOSNR measurement of loopback configuration

First, the rOSNR value was measured for each transceiver with loopback configuration, where Tx and Rx are from the same transceiver. The results are summarized in Table 1. As shown in Table 1, for channel 24 with a frequency of 193.700 THz or a wavelength of 1547.75 nm, the rOSNR value of the transceiver was less than 26 dB/0.1 nm. This result indicates that all the transceivers meet the requirements described in the OIF-400ZR Rx OSNR tolerance [1].

Table 1. rOSNR value measured with a loopback configuration.

The module's output power was -10 dBm. The unit is dB/0.1 nm. The channel is indicated in the leftmost column. The alphabets A-J indicate each vendor producing 400ZR transceivers.

	A	B	C	D	E	F	G	H	I	J
Ch. 24	22.44	22.74	22.92	23.19	23.38	23.77	23.94	24.11	25.9	24.63

4.2 rOSNR measured for different transceiver Tx and Rx combinations

Next, we measured the rOSNR values for different transceiver Tx and Rx combinations. It should be noted that interconnection of any Tx and Rx combination was successfully established. The rOSNR values were measured for the module combinations with a lower output of -10 dBm. The results of the modules are summarized in Tables 2 respectively. For Tables 2, the values in the diagonal cells correspond to the rOSNR values measured with the loopback configuration described in Section 4(1).

The data shown in Tables 2 are summarized as histograms shown in Figures 2. As shown in Figures 2, the histogram shows broad pattern of distribution between 22.5 – 26.5dB/0.1nm with the peak of around 23.5-24.0 dB/0.1 nm. The mean and standard deviation of the rOSNR values is 23.85 and 0.85 dB/0.1 nm, respectively.

Figure 3 plots the rOSNR distribution of multiple vendors Rxs relative to each Tx. The x-axis represents the rOSNR of each vendor's Tx-Rx loopback. It is observed that for a specific Tx, the rOSNR of each vendors' Rx varies significantly.

Most vendor combinations met the OIF-400ZR IA Rx OSNR requirement of ≤26dB/0.1nm. However, two vendor pairs exceeded the rOSNR limit, with values ranging from 26.2 to 26.38dB/0.1nm.

Table 2. Measured rOSNR value for combinations of Tx and Rx modules.

The unit is dB/0.1 nm. The alphabets A-J corresponds to the same vendors as those in Table 1.

Anritsu 193.7 THz		Tx										
		A	B	C	D	E	F	G	H	I	J	Average
Rx	A	22.44	24.18	22.53	22.63	23.52	23.25	23.35	22.67	23.53	24.14	23.22
	B	23.31	22.74	22.69	22.8	23.46	23.31	23.38	22.72	24.45	23.71	23.26
	C	23.16	23.92	22.92	23.15	23.7	23.87	23.54	22.88	25.21	24.37	23.67
	D	23.28	23.54	23	23.19	23.8	24.08	23.71	23.16	25.44	24.25	23.75
	E	22.8	22.77	22.59	23.8	23.38	23.45	23.71	22.69	24.63	23.98	23.38
	F	23.31	23.16	22.98	23.33	23.9	23.77	23.86	23.01	25.67	24.47	23.75
	G	23.63	23.32	22.96	23.34	24.06	23.96	23.94	23.23	25.21	24.27	23.79
	H	24.43	23.98	23.69	23.89	25.74	25.14	24.59	24.11	26.2	25.77	24.75
	I	24.64	23.87	23.55	24.15	25	25.11	24.53	23.48	24.63	25.24	24.42
	J	24.35	24.18	23.95	24.21	24.99	24.93	24.46	23.9	26.38	25.9	24.73
	Average	23.54	23.57	23.09	23.45	24.16	24.09	23.91	23.19	25.14	24.61	23.87

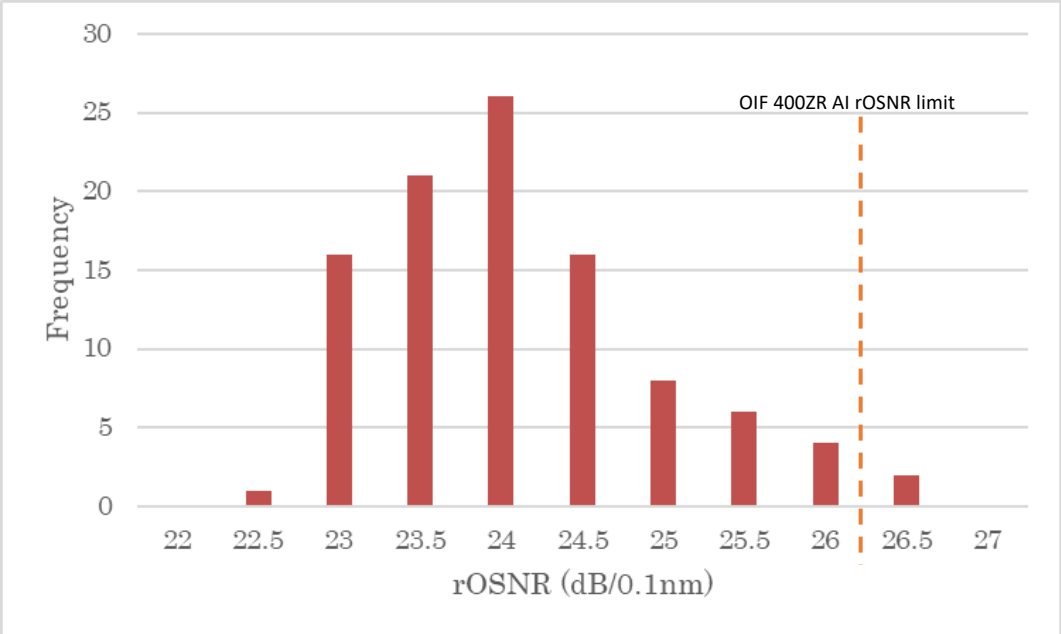

Figure 2. The histogram of the rOSNR value summarized in Table 2.

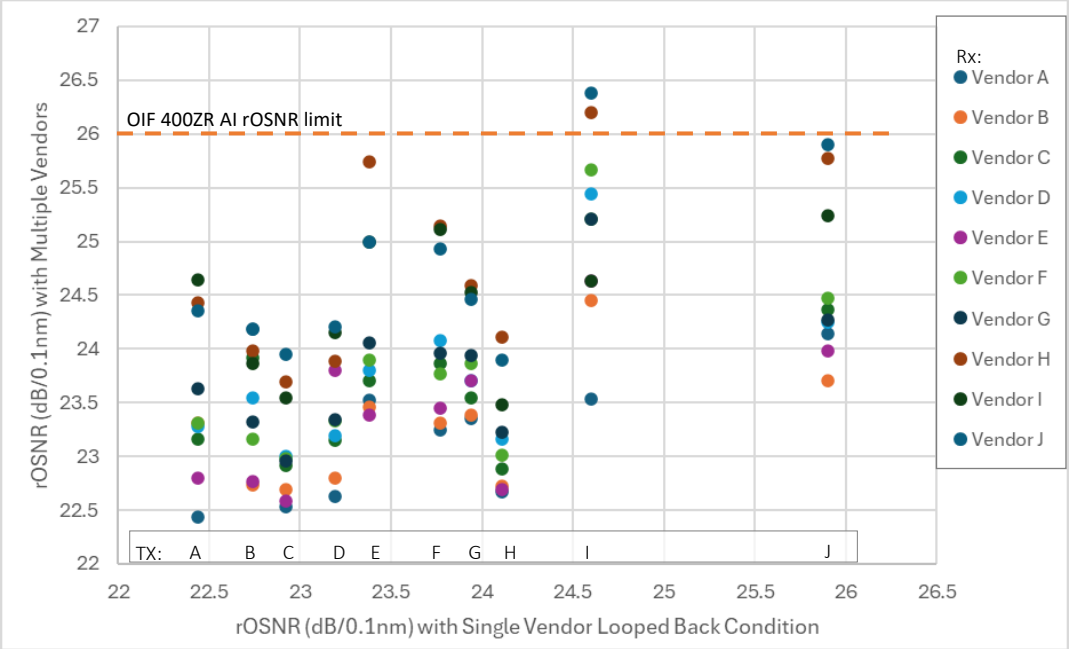

Figure 3. Plot the rOSNR distribution for multiple vendors' Rx relative to each Tx. The alphabets A-J correspond to the same vendors as in Table 2.

5 Summary

The Optical Internetworking Forum (OIF) has played a crucial role in standardizing coherent optics at the physical layer, with the OIF-400ZR IA being one of its latest achievements. Through multi-vendor interoperability tests at various Plugfests, the OIF investigated the performance of 400ZR and OpenZR+ pluggable modules, focusing on the required optical signal to noise ratio (rOSNR) threshold to maintain a post-FEC error-free link.

We evaluated the rOSNR values of 100 combinations of 400ZR modules. For all 100 combinations, the rOSNR value was successfully measured with our system. Our tests demonstrated that most vendor combinations met the OIF-400ZR IA Rx OSNR requirement of ≤26 dB/0.1 nm. However, two pairs slightly exceeded this limit. These findings highlighted the variability in rOSNR performance across different vendor combinations and underscore the importance of thorough testing to ensure compliance with industry standards.

Overall, the results provide confidence to network operators that multi-vendor ZR environments can achieve high efficiency and high channel density, ensuring reliable optical network performance.

6 Acknowledgement

We highly appreciate OIF for this valuable opportunity at the Plugfest. We are also very grateful towards Cisco and Quantifi Photonics for generously providing their EDFA and Filter, and VOA and OPM, respectively.

7 Participating 400ZR Module Vendors

Accelink

Ciena

Cisco

Coherent

Eoptolink

HG Genuine

Hisense

Juniper

Marvell

Precision Optical Technologies

8 References

[1] OIF Implementation Agreement 400ZR, OIF-400ZR-03.0, *October 08, 2024*

[2] OIF, "Open400ZR+ Interoperability White Paper ECOC2023 Plugfest", https://www.oiforum.com/wp-content/uploads/OIF_Open400ZRplus_Interoperability_White_Paper_ECOC2023_Plugfest.pdf

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About the OIF:

For more than two decades, OIF has accelerated progressive transformation in optical networking by serving as the only global industry forum driving the electrical, optical and control interoperability that enables a more efficient and reliable network. Its active member ecosystem collaborates through a transparent and fast-paced process to develop, validate and publish Implementation Agreements (IAs) and technical white papers that are critical to accelerating market adoption of optical networking technologies.

Based on established methodologies including the documentation of industry requirements, bringing forward member-driven technical solutions, validation testing and free publishing, OIF's interoperability solutions are vital to the global network.

With more than 130 member companies spanning component suppliers to network operators, OIF members strive to identify the industry's needs and requirements and rapidly develop solutions that directly impact and facilitate global connectivity in the open network world. Information on the OIF can be found at http://www.oiforum.com.

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