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White Paper

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Qualifying MPO Connector at 105°C to Support OBO, NPO and CPO Applications

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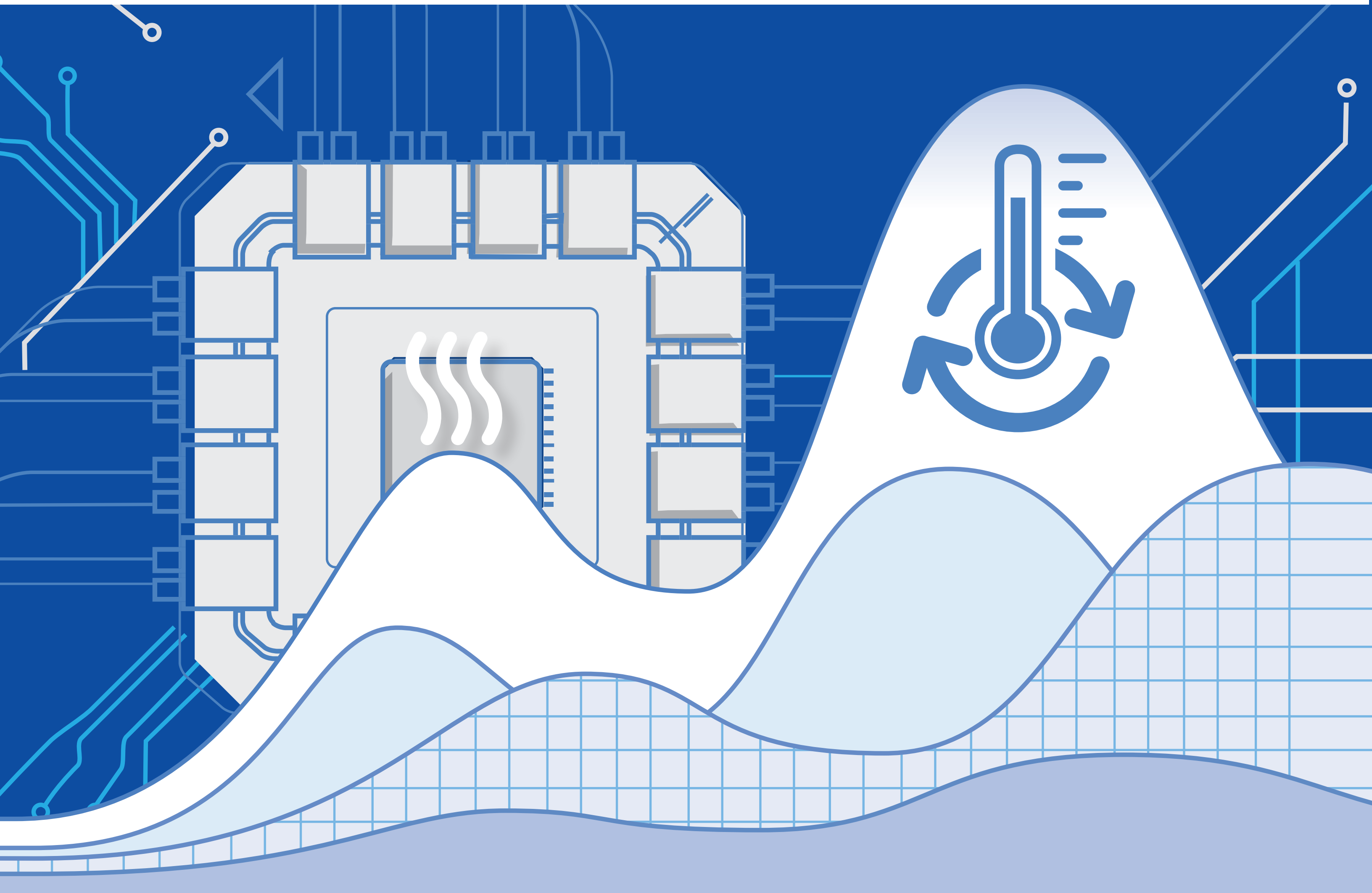

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Contents

1 Introduction

To support the exponentially increasing amounts of data traffic in the data center, the industry has been considering a shift from the front plate pluggable transceivers to emerging technologies such as Onboard Optics (OBO), Near Packaging Optics (NPO), and Co-Packaged Optics (CPO). OBO, NPO and CPO are the technology concepts to locate optics closer to the system ASIC to reduce the electrical connection distance between ASIC and Optics, which will help to reduce the power loss and overall power consumption. Bringing optics inside the system introduces new challenges of handling fibers and optical components inside the equipment box.

Another major challenge would be the needed changes to the reliability requirements on fiber optic components. Traditionally, reliability and qualification of fiber optic products follow Telcordia's General Requirements, IEC and TIA's test specifications for optical connectors and optoelectronic devices. These tests are testing parts up to 75~85°C conditions to age/accelerate, and simulate the long-term use of the products.

JEDEC has multiple testing standards for the microelectronics industry, and is often used to qualify the substrates and components that are packaged inside such communication equipment. For OBO/NPO/CPO having optical parts packaged inside such equipment, the optical parts would be required to also pass JEDEC testing specifications. Some of the JEDEC environmental test requirements from JEDEC test at temperatures beyond 100°C, which are temperatures beyond where optical components have been typically tested.

Thus, Senko Advanced Components and GlobalFoundries have jointly conducted tests under JEDEC conditions to support such applications like OBO/NPO/CPO.

2 Test Setup

To qualify the optical connectors for the use in OBO/NPO/CPO applications, we referenced test specifications by JEDEC, Temperature Cycling (JESD22-A104F), High Temperature Storage Life (JESD22-A103E.01) test specifications under JEDEC JC-14.1, and Reliability Test Methods for Packaged Devices [1,2]. Both specifications have multiple condition options. Condition G for Temperature Cycling, and Condition A for High Temperature Storage Life were selected with some modifications based on the availability of the test set up. The reliability testing requirements for Multi-Fiber optical connectors are specified by Telcordia standard GR-1435-CORE [3]. Based on the large high temperature difference between two different specifications Telcordia 85°C and JEDEC 125°C, SENKO and GF performed initial temperature testing to set up the proper first goal and confirmed current fiber connectors were unstable above 120°C. So, the experiment goal was set 105°C instead of 125°C. Since JEDEC documents do not specify the pass/fail criteria for optical components, we used the criteria using Telcordia GR-1435-CORE for Multi-Fiber Optical Connectors. Table-1 shows the summary of the test procedure and condition for each test. All connectors were unmated during thermal aging and thermal cycling tests.

Table 1 *Test conditions summary.*

43	Duration	Test Parameter	Measurement	Reference
Thermal Aging	2000 hours	105°C	Insertion Loss Return Loss Endface Geometry	JESD22-A103E.01
Thermal Cycle	1000 cycle	-40 ~ 105°C 20c/min 30min dwell	Insertion Loss Return Loss Endface Geometry	JESD22-A104F
Transmission with Applied Load	-	0° 0.49lbf 90° 0.49lbf	Insertion Loss Return Loss	GR-1435-CORE 4.6.2.4

Test Setup

To verify the mechanical tolerance of the optical connectors after aging, Transmission with Applied Load (TWAL) test was also conducted under GR-1435-CORE 4.6.2.4. The 6 samples used for Thermal Aging were also used for TWAL test.

Measurement of insertion loss (IL), return loss (RL), and end face geometry were taken for all samples at the 1310nm and 1550nm wavelength after 500th hour, and 1,000th hour of thermal aging, and 100th, 500th, 1000th and 2000th cycles of the thermal cycle. For geometry, fiber height is reported on this whitepaper as fiber height is critical for physical contact between mated connectors. Other parameters such as radius of curvature and tilt angle are also important but determined after the polishing process and are not as affected by high temperature environment. Whereas fiber height could shift at high temperature if the epoxy reached the glass transition temperature. This phenomenon is known as the fiber withdrawal. The most significant changes in fiber height were reported for mated connectors during thermal aging and thermal cycling [4, 5]. The fiber withdrawal may impact the optical performance of connectors such as IL and RL. Monitoring of IL, RL and Fiber Height was critical for this study. Pass/fail distinction for the fiber height is based on IEC 61755-3-32 (see table 1). TWAL insertion loss was measured while under load for 0deg and 90deg. As the test jumpers were terminated with bare ribbon, 0.49lbf were applied for both 0deg and 90deg. TWAL was done using a setup as below diagram (Picture 1) after the test jumpers has been aged for 2,000 hours.

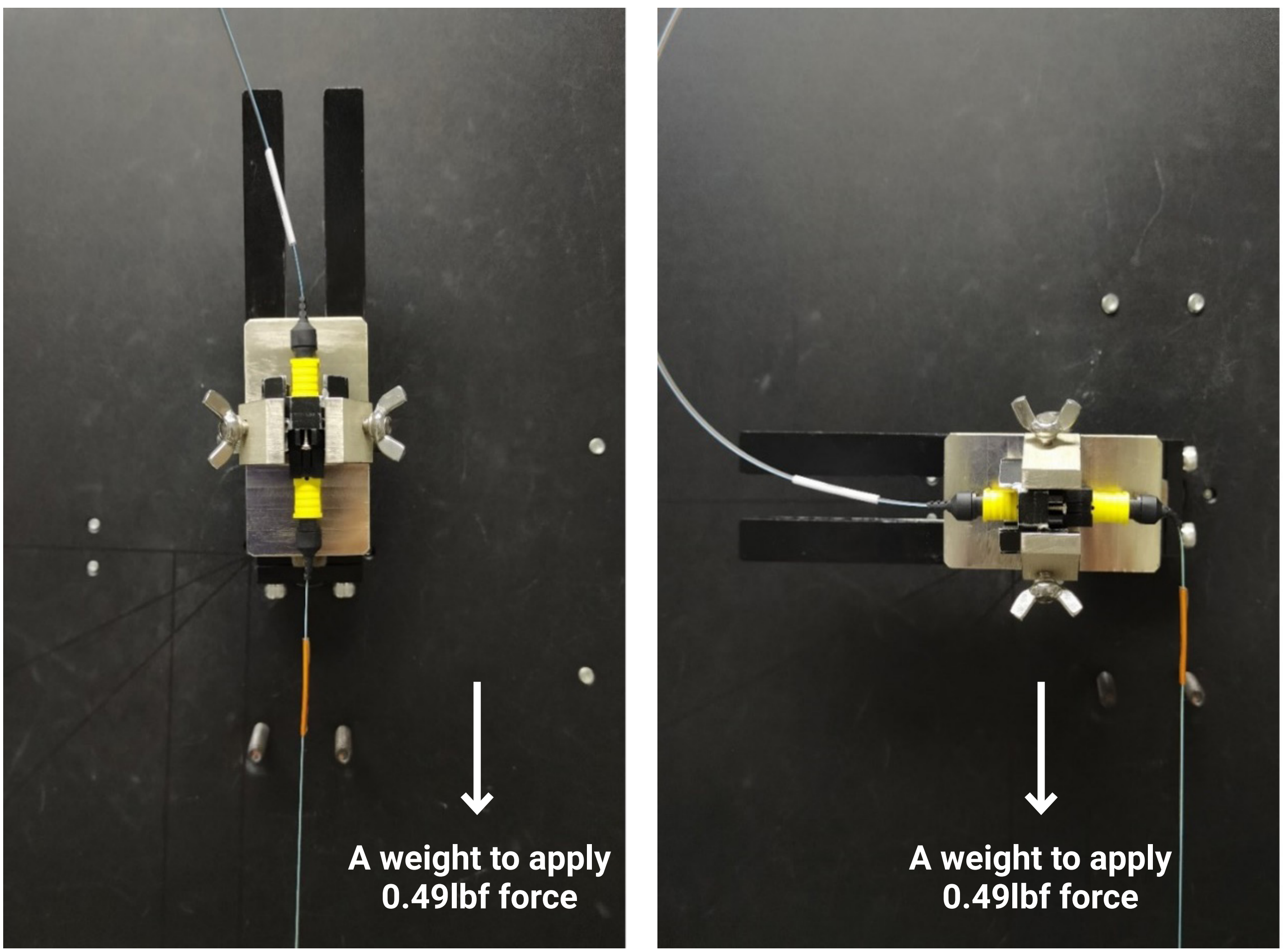


Figure 1 *TWAL setup.*

Test Setup

Jumpers under test were terminated using SENKO's MPO Plus® Premium Connector with Super Low Loss MT ferrule, 702F-F-SL12-Y01 and 702F-M-SL12-Y01 for female and male respectively. The connectors were terminated using the ITU G.652 compliant single mode 12 fiber bare ribbon. Test jumpers used ribbon instead of jacketed cables as the OBO application would require ribbon due to the limited space on board. The 12 jumpers were prepared for the thermal cycling test and 10 jumpers for the thermal aging test . The jumpers put into respective chambers were un-mated and did not have dust caps. They were mated against master jumper to measure IL and RL for each interval.

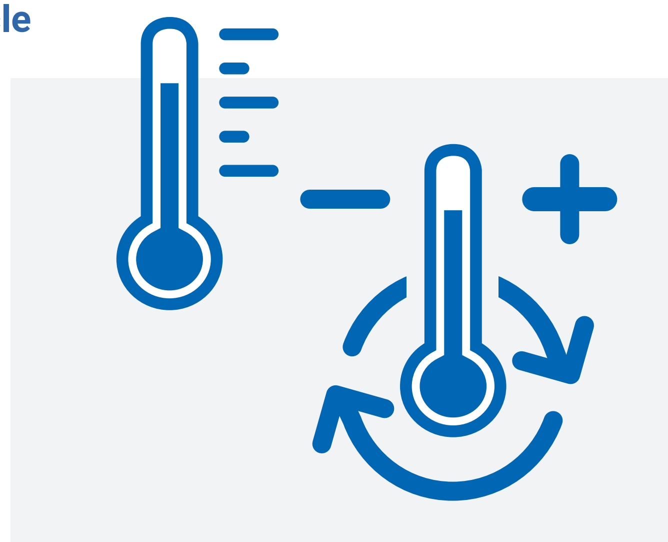
Table 2 *Relevant criteria/pass-fail distinction.*

Criteria	Minimum	Maximum	Reference
Fiber Height	1µm	3.5µm	GR-1435-CORE 4.2.1.1 IEC 61755-3-32
IL End of the Test	-	0.45dB	GR-1435-CORE 4.2.1.1*
IL Change Under Load	-	0.30dB	GR-1435-CORE 4.2.1.2*
RL End of the Test	60dB		GR-1435-CORE 4.2.1.1*
RL During Test Under Load	60dB		GR-1435-CORE 4.2.1.1*

** Based on ultra performance*

3.0 Test Results

3.1 Thermal Aging and Thermal Cycle



The result after Thermal Aging is shown in Table 3 and Figure 2-3 show the IL per fiber channel at 1310nm and 1550nm after 2,000 hours The IL results indicate there was no significant impact of 2,000 hours of aging and met the testing criteria. One sample had >0.35dB IL on CH7 at the initial measurement at 1550nm. That same channel showed an improvement after the aging test. The high loss was not observed at 1310nm on the same channel. It is highly likely there was a micro fiber bend that caused this measurement point, and less likely it was a connector component issue. Figure 4 shows the fiber height distribution per channel for before and after the thermal aging test. While there was more deviation observed after the aging, this is a common phenomenon after thermal testing [4, 5], and all fiber channels met the fiber height requirement. There were only minimal changes of RL observed at the end of test for both TC and TA.

Table 3 *Summary of thermal aging result after 2000 hours.*

Measurement Taken	Item	Min	Max	Ave	StDev
Initial Before Test	Insertion Loss (dB) 1310nm	0.34	0.00	0.09	0.07
	Insertion Loss (dB) 1550nm	0.36	0.01	0.09	0.06
	Return Loss (dB) 1310nm	87.40	73.0	85.78	1.12
	Return Loss (dB) 1550nm	83.40	74.0	81.90	0.92
	Fiber Height (nm)	2047.2	1704.2	1896.6	81.5
After 2000 Hours	Insertion Loss (dB) 1310nm	0.33	0.03	0.18	0.08
	Insertion Loss (dB) 1550nm	0.33	0.03	0.14	0.06
	Return Loss (dB) 1310nm	84.8	70.9	79.4	3.49
	Return Loss (dB) 1550nm	83.6	72.5	79.3	3.03
	Fiber Height (nm)	2477.1	1343.3	1952.2	277.6

[1] *There were 2 samples damaged due to the mishandling that are not reported in this paper.*

Thermal Aging and Thermal Cycle

Insertion Loss per Channel at 1310nm

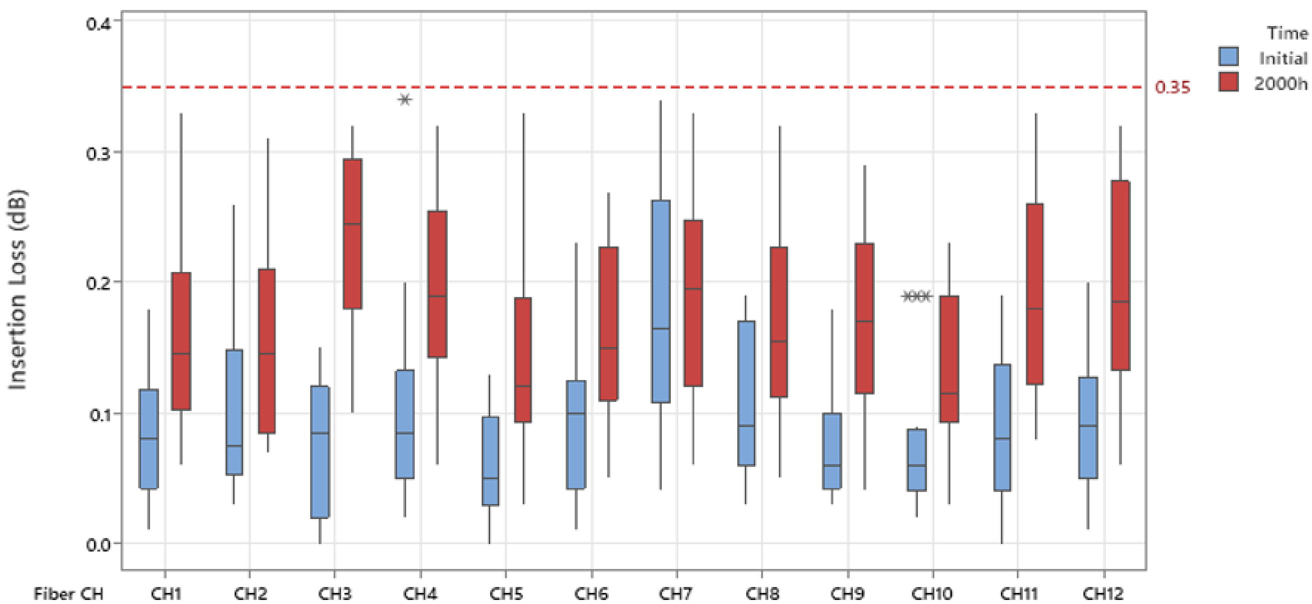


Figure 2 *Boxplot of insertion loss at 1310nm initial and after 2000 hours of thermal aging.*

Insertion Loss per Channel at 1550nm

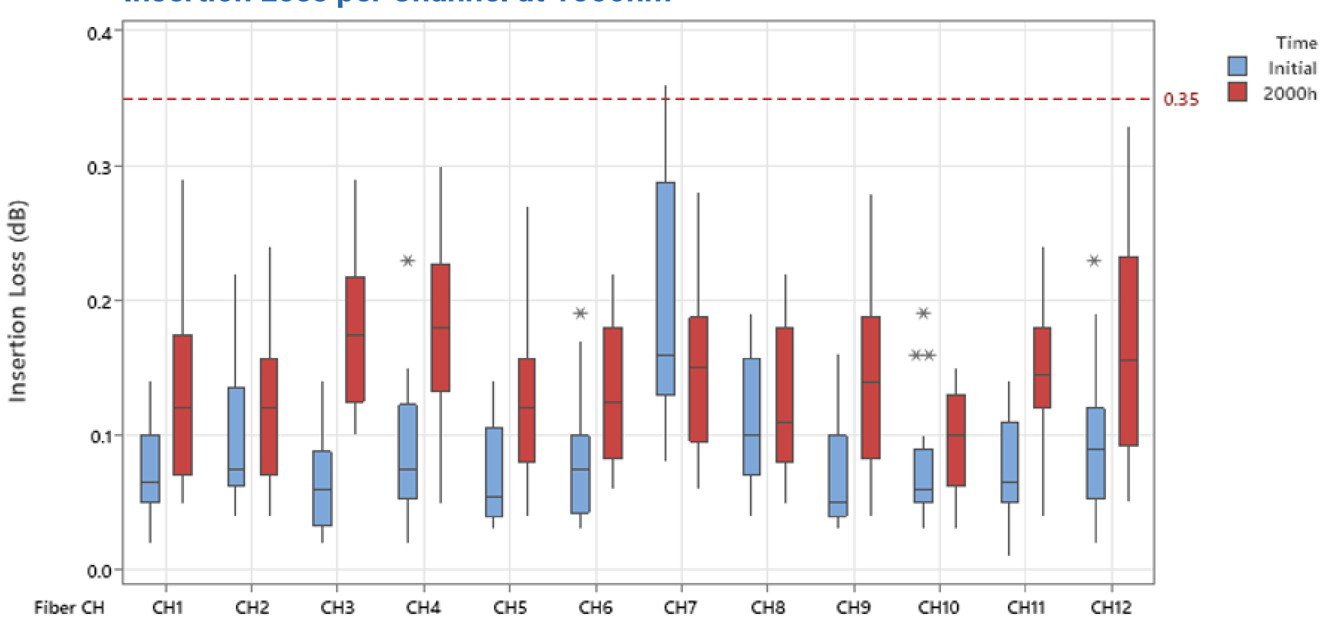


Figure 3 *Boxplot of Insertion Loss at 1550nm Initial and After 2000 hours of Thermal Aging.*

Thermal Aging and Thermal Cycle

Table 4 shows the results after 1,000 hours of thermal cycling. The IL distribution per each fiber channel before and after the thermal cycle are shown on Figure 5-6. Unlike the thermal aging test results reported above, there was no obvious change observed. Similarly, the fiber height variances before and after the thermal cycle test had a minimum impact (Figure 7), and all the samples were confirmed passing the criteria.

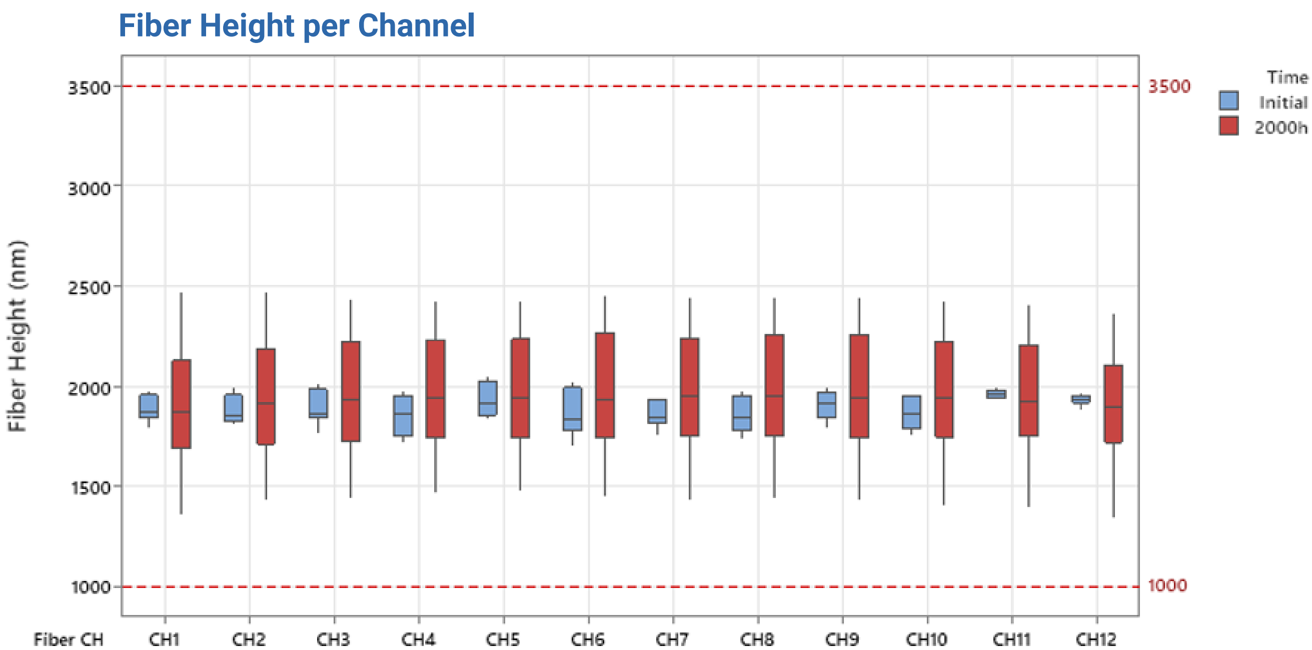


Figure 4 *Boxplot of fiber height at initial and after 2000 hours of thermal aging.*

Table 4 *Summary of thermal cycling result after 1000 cycles.*

Measurement Taken	Item	Min	Max	Ave	StDev
Initial Before Test	Insertion Loss (dB) 1310nm	0.30	0.01	0.11	0.07
	Insertion Loss (dB) 1550nm	0.30	0.01	0.11	0.07
	Return Loss (dB) 1310nm	85.0	72.0	81.0	2.3
	Return Loss (dB) 1550nm	85.0	73.70	82.3	3.11
	Fiber Height (nm)	2478.8	1637.5	2097.6	81.5
After 1000 Thermal Cycles	Insertion Loss (dB) 1310nm	0.33	0.01	0.11	217.9
	Insertion Loss (dB) 1550nm	0.30	0.01	0.10	0.07
	Return Loss (dB) 1310nm	83.3	58.1	77.6	2.69
	Return Loss (dB) 1550nm	83.5	59.6	78.2	2.57
	Fiber Height (nm)	2527.6	1498.1	2068.6	278.6

Thermal Aging and Thermal Cycle

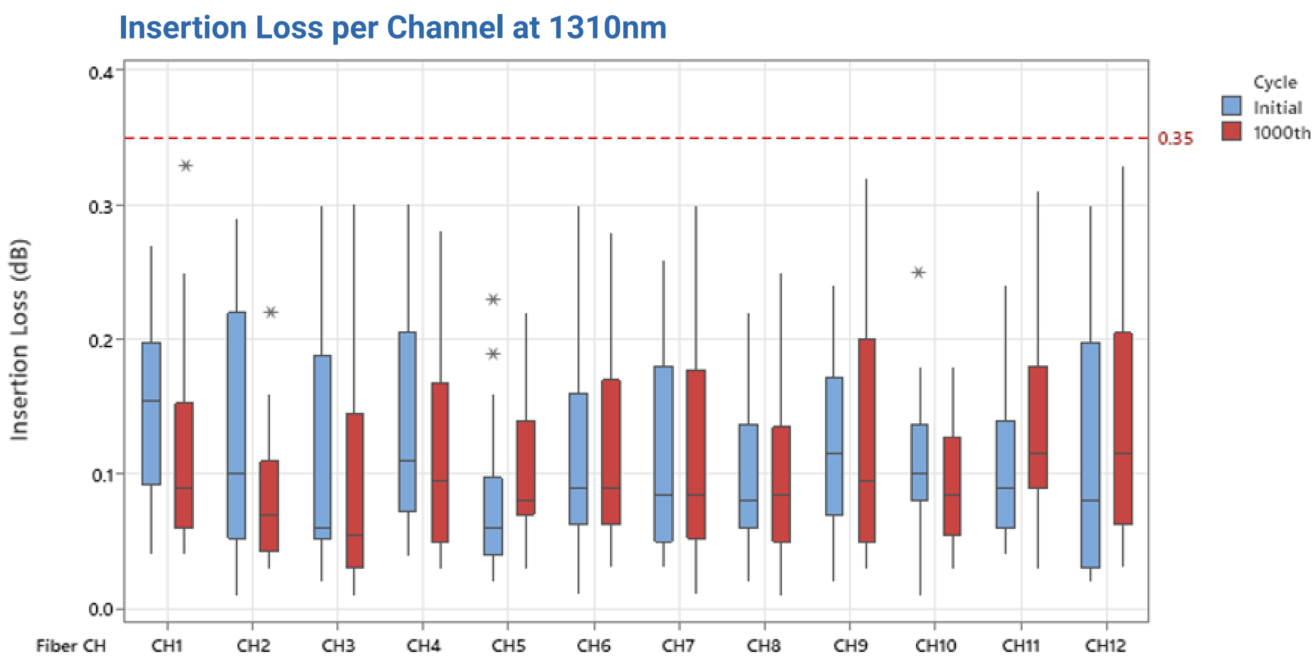


Figure 5 *Boxplot of insertion loss at 1310nm initial and after 1000 cylcles of thermal cycling.*

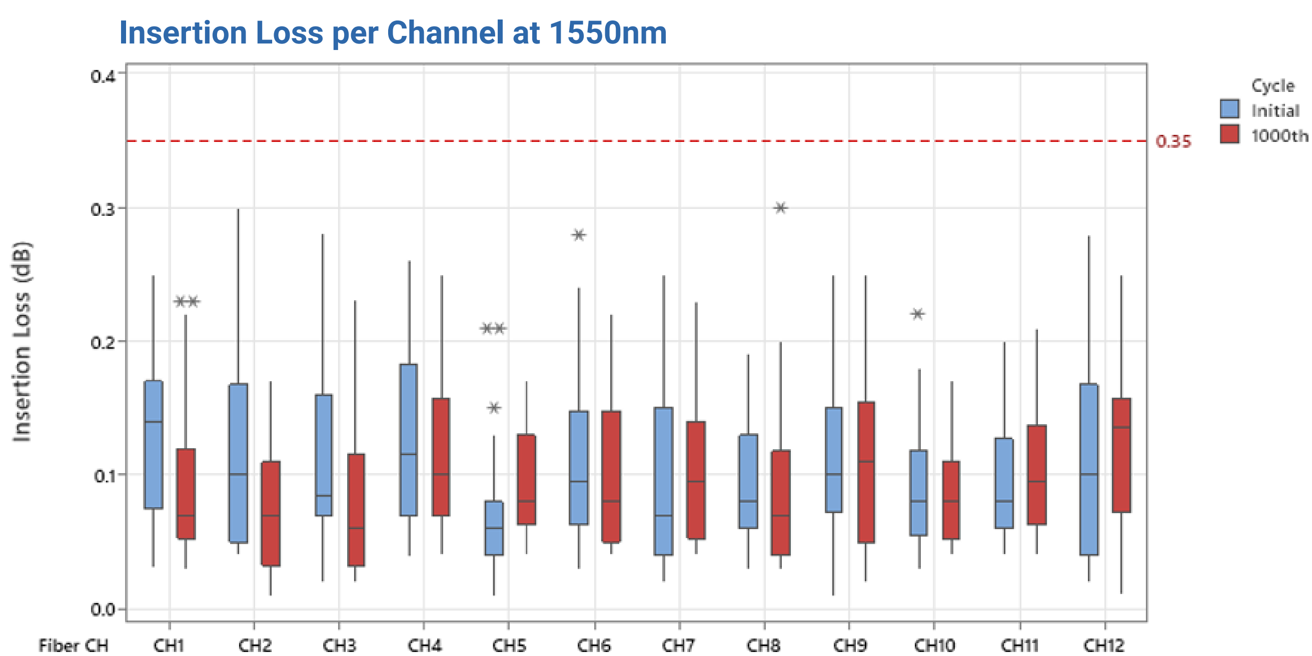


Figure 6 *Boxplot of insertion loss at 1550nm iInitial and after 1000 cycles of thermal cycling.*

Thermal Aging and Thermal Cycle

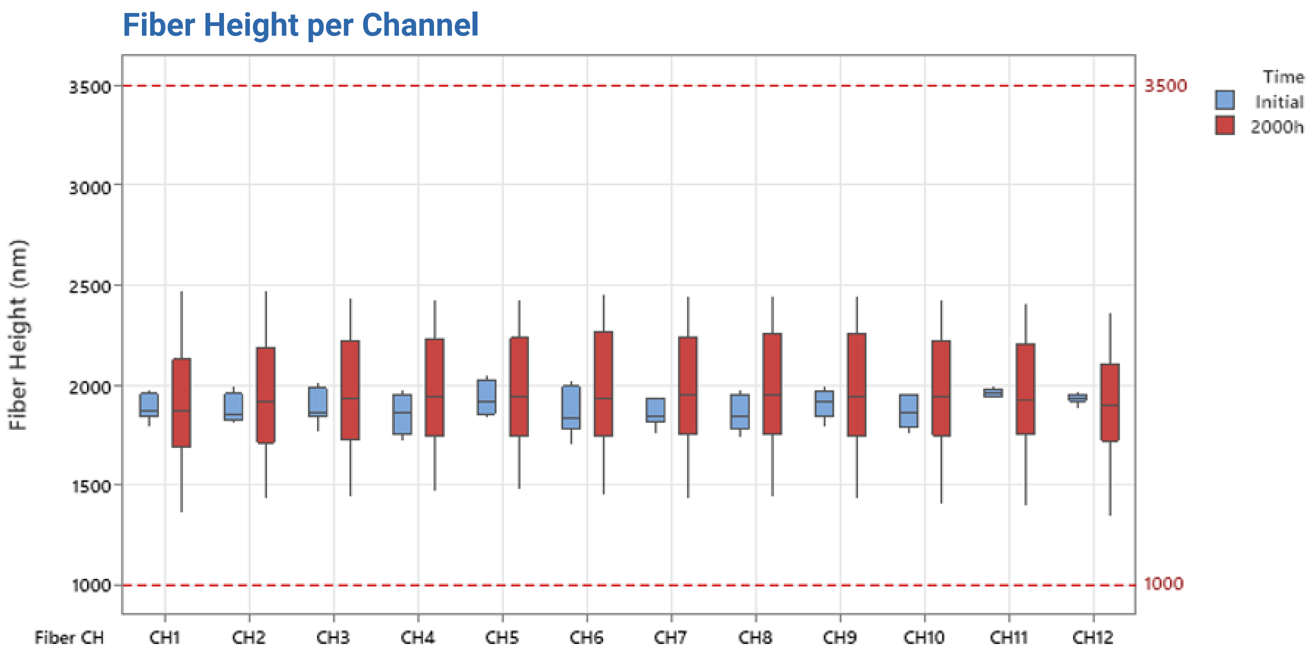
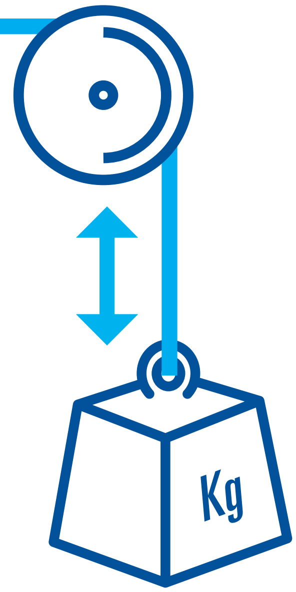


Figure 7 *Boxplot of fiber height initial and after 1000 cycles of thermal cycling.*



3.2 TWAL Test

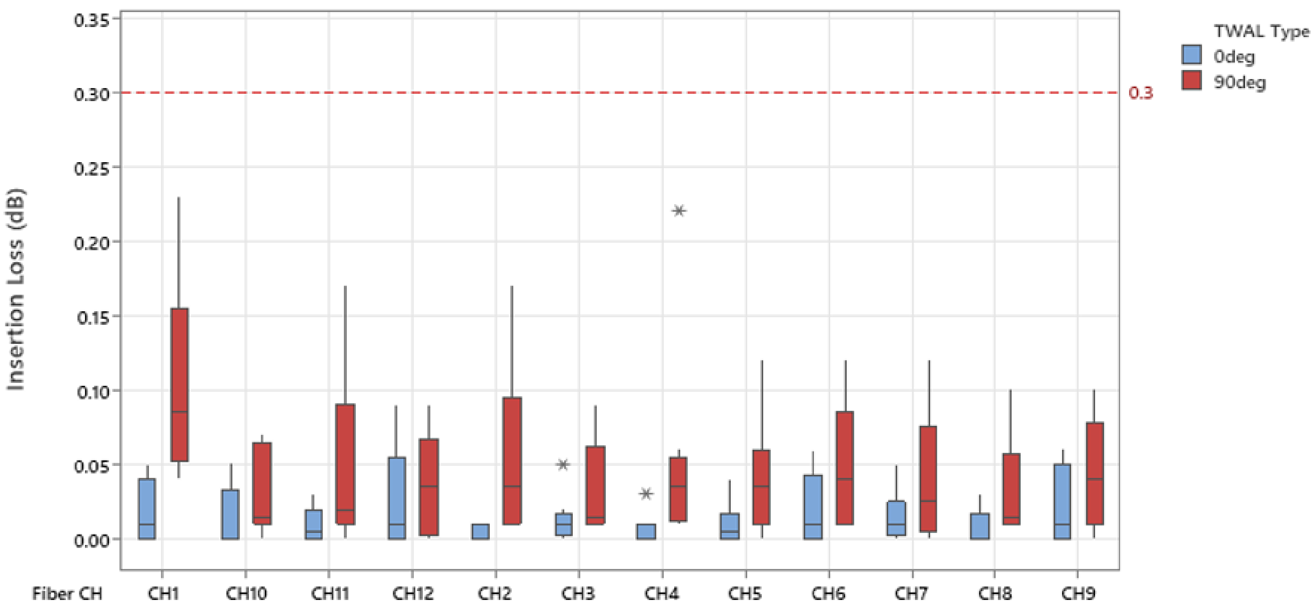
The changes of IL and the absolute values of RL after TWAL test are summarized in Table 5. IL TWAL test met the requirements of maximum IL change of 0.30dB. Only selected samples were tested to verify the mechanical strength after 2,000 hours of the thermal aging at 105deg C. Table 5 summarizes the changes of IL and the absolute values of RL after TWAL test. The boxplot of maximum IL changes under applied load at 1310nm and 1550nm are shown in Figure 8. Observing, 90 degree loads typically affect the IL se performance more and the results obtained are within the standard level.

Table 5 *Insertion loss change summary under TWAL loads.*

Measurement Taken	Item	Max	Min	Ave	StDev
Under 0deg 0.49lbf	Insertion Loss (dB) 1310nm	0.09	0.0	0.01	0.02
	Insertion Loss (dB) 1550nm	0.07	0.0	0.011	0.02
	Return Loss (dB) 1310nm	81.7	66.2	77.96	1.83
	Return Loss (dB) 1550nm	82.0	67.2	78.79	2.05
Under 90deg 0.49lbf	Insertion Loss (dB) 1310nm	0.23	0.0	0.05	0.05
	Insertion Loss (dB) 1550nm	0.24	0.0	0.05	0.05
	Return Loss (dB) 1310nm	81.10	66.2	78.15	1.80
	Return Loss (dB) 1550nm	81.60	67.1	78.86	2.01

TWAL Test

TWAL Maximum Insertion Loss Change per Channel at 1310nm



TWAL Maximum Insertion Loss Change per Channel at 1550nm

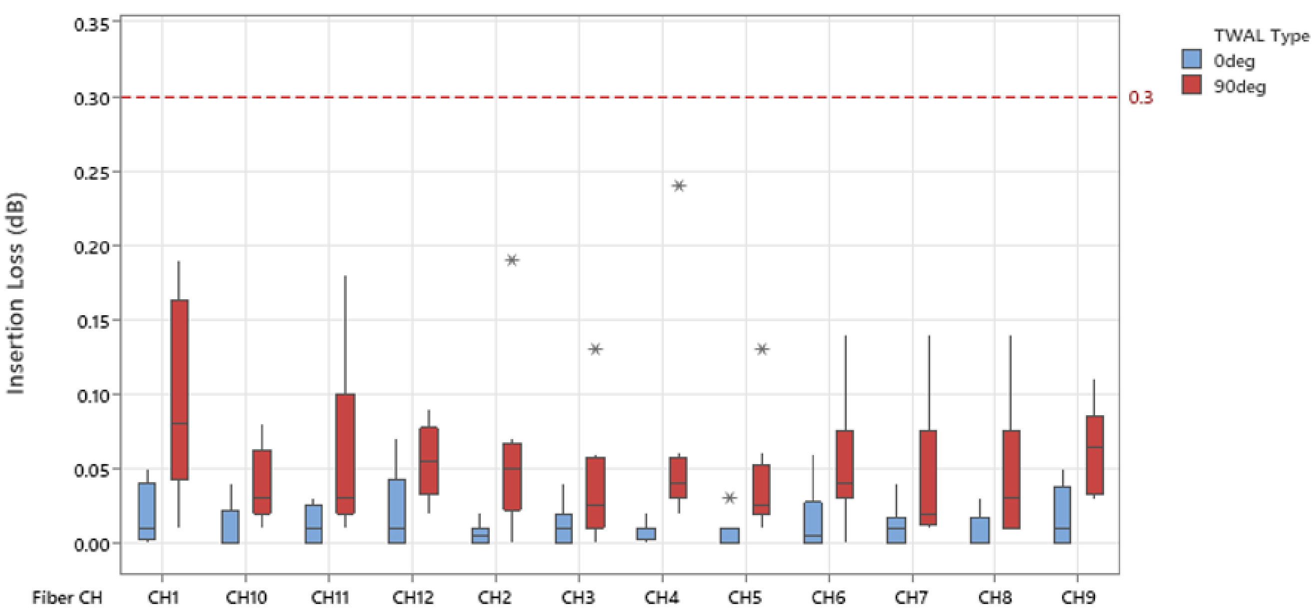
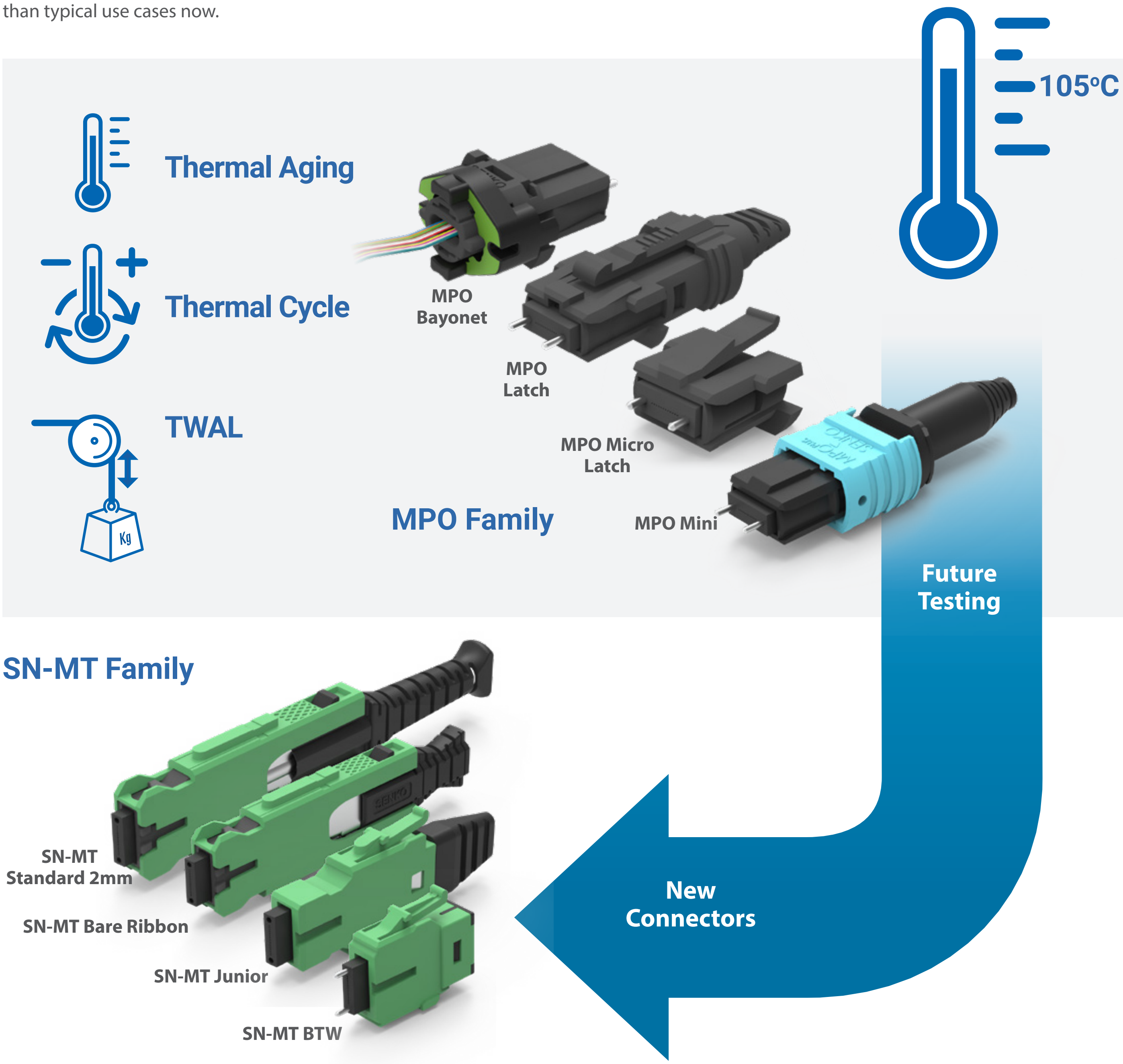


Figure 8 *Maximum insertion loss change per channel at 1310nm (top) and 1550nm (bottom) under applied load.*

Summary and Future Work

The MPO connector assemblies were tested for thermal aging, thermal cycle and TWAL tests to verify the service life of MPO connector under 105degC environment. The samples survived and passed the test criteria without having significant performance change or compromise. It provides a confidence that the Senko MPO connector and the termination methods we used for CPO and OBO of applications can withstand more sever temperature environment than typical use cases now.

The study was focused on 105degC but for future work, there is a need for further investigation of the higher temperature resistance on optical connectors including MPO and other new connector types such as SN-MT connector.



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Biography

Tiger Ninomiya is currently Sr. Technologist at SENKO Advanced Components. He is participating in the MSAs, Consortiums, and other Standard Setting Organizations, including TIA, IEC, IEEE, COBO and OIF. Within COBO, he served as a chairman of Co-Packaged Optics working group and Associate Director of Board of Director. He is currently a vice chair of TIA TR42.11 and a secretary of IEC TC 86 SC86B WG4. Tiger has been heavily involved in the development and standardization of CS and SN connectors and is continuously innovating new products to further develop optical connectivity technology.

Tatiana Berdinskikh is the founder of Novophotonics Consulting Inc. She has 25+ years of experience in fiber optics, telecommunications, optoelectronics, and photonics. Tatiana is the Canadian Technical Expert for standards activities of IEC SC 86B, SC 86C, and a Chair of the Canadian Mirror Committee of SC 86B. She was a recipient of the IEC 1906 Award for contribution to the development of cleanliness specifications for fiber optic connectors. Tatiana chairs the iNEMI (International Electronics Manufacturing Initiatives) project "Development of the best practices for expanded beam connectors in the data center applications". She has co-authored over 50 journal publications and conference papers in the field of optoelectronics and photonics, and the book "Degradation of Semiconductor Light-Emitting Diodes and Lasers". Tatiana is a member of the Professional Engineers of Ontario.

Takeshi Kasai is a Technical Specialist at SENKO Advanced Components. He joined SENKO in 2019 and was transferred to Fiber Optics Division as a purchasing staff in Tokyo office in 2020. In 2021, Takeshi was transferred to Massachusetts where he helped development of VSFF connectors including SN-MT. He is currently representing SENKO in sustainability division and is continuously innovating new products to further develop sustainable solutions for fiber connectivity.

Jason Kim is a principal member of technical staff in Advanced silicon photonics packaging in GlobalFoundries. He is currently responsible for component engineering and supply chain management of silicon photonic packaging and fiber solution. He is leading industry with passive alignment fiber solution including narrow pitch and high temperature. He has over 25+ years in the semiconductor industry as technology and quality expert. He is CQE, CQA, CSQP and 6sigma black belt as ASQ (American Society for Quality) Senior member.

Jae Kyu Cho is a Senior Member of Technical Staff within Advanced Silicon Packaging group at GLOBALFOUNDRIES in Malta, NY. Currently he serves as a project lead in packaging development projects and responsible for silicon photonic packaging solutions and OSATs engagement. Before this role, he led various CMOS package development projects, specializing in flip chip, wire bond and wafer level packaging. Prior to GLOBALFOUNDRIES, he worked as a FBEOL interconnect process development engineer at Intel and as advanced packaging material scientist at Dow Electronic Materials. He received the B.S. and M.S. degrees from Seoul National University, South Korea and the Ph.D. degree from Georgia Institute of Technology, Atlanta, GA, USA.

Norm Robson is currently a development manager in Advanced Silicon Photonics Packaging at GlobalFoundries. He currently leads a team responsible for light-in/light-out of silicon photonic chips using GlobalFoundries FotonixTM Technology. Developing techniques for fiber attach to silicon, as well as on-board lasers and advanced materials. He has over 25+ years in the semiconductor industry leading development teams for silicon photonics, 3D heterogeneous integration, embedded and stand-alone memory with IBM, Infineon Technologies, Siemens, and Marconi Electronic Device.

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