
AusNOG 2026

Return loss problems associated with faster optical networks

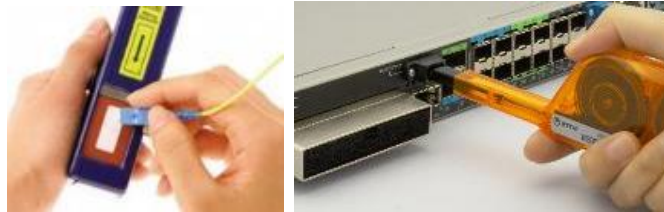
NTT ADVANCED TECHNOLOGY CORPORATION

AGENDA

- About us
- Basics of Optical network
- Return loss
- Causes of poor optical properties
- Conclusion

NTT-AT's core expertise

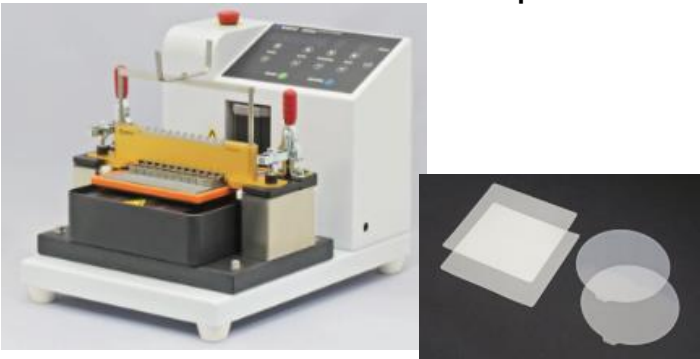
For over 30 years, we have been developing, manufacturing, and supplying products for the optical communications industry, including production equipment and maintenance tools for optical connectors. Our extensive experience has given us deep expertise in optical network technologies, especially in the physical layer.



Optical Connector Cleaner



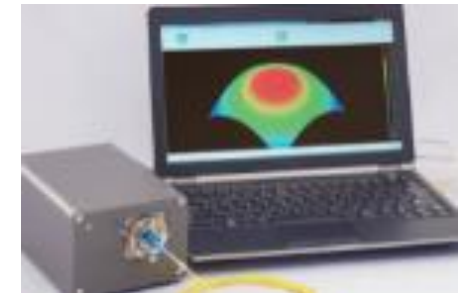
Physical layer switching device (Intelligent optical switch)



Optical connector polishing machine and polishing film



Optical adhesive



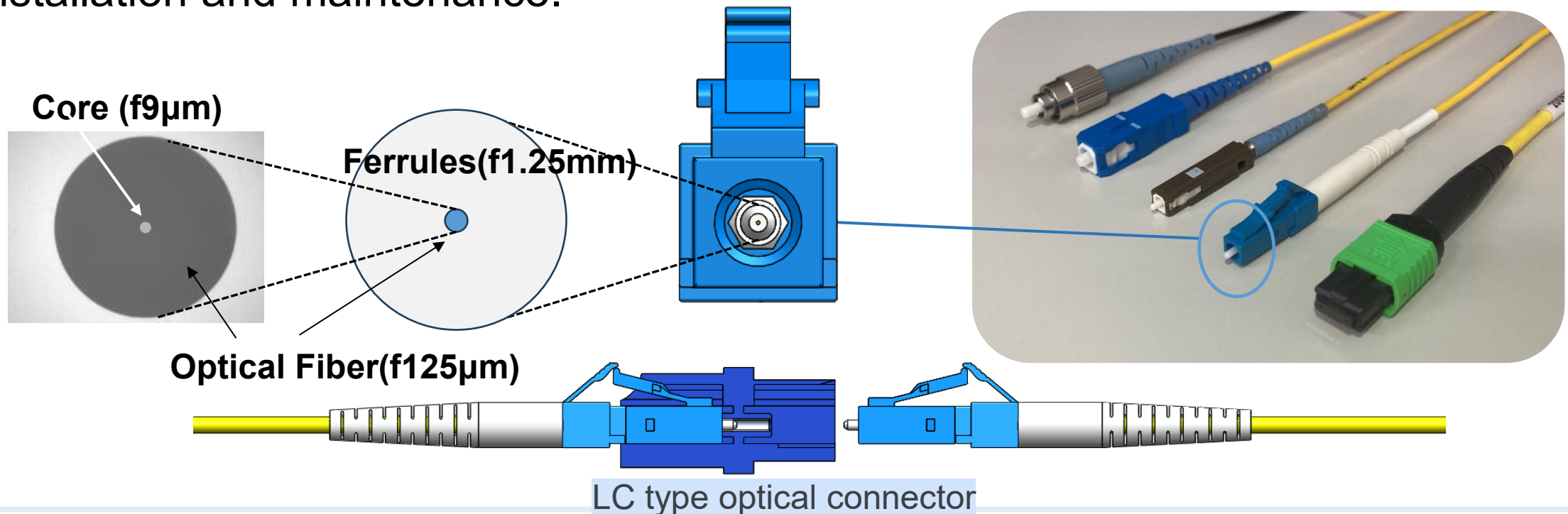
Optical connector measuring machine

Basics

Basics of optical connector

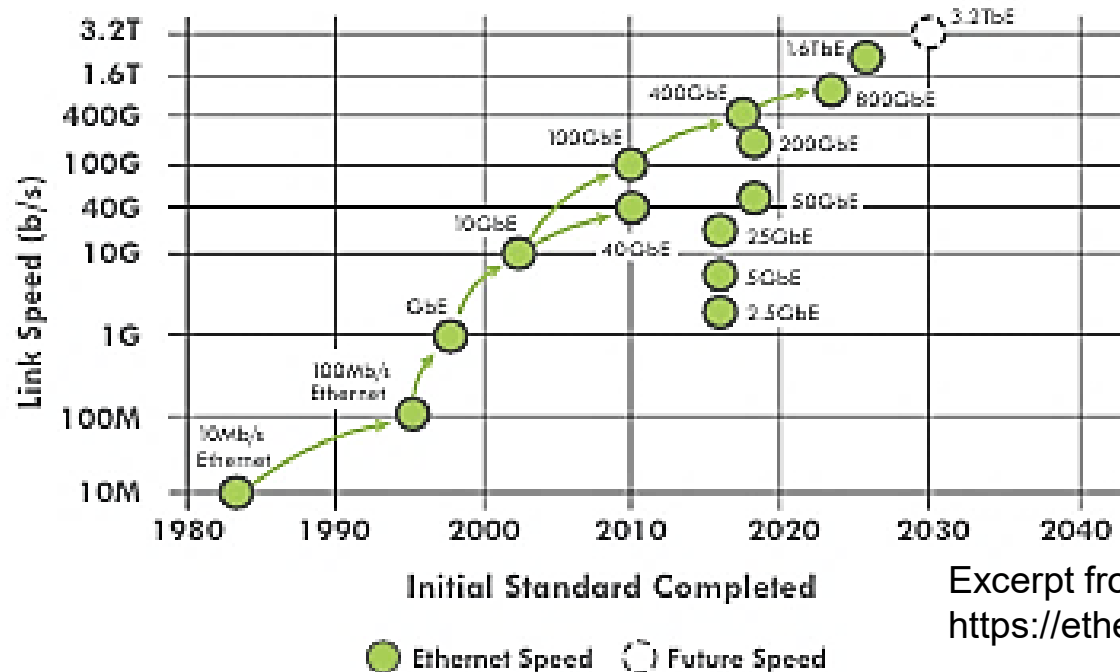
Optical connectors are used to connect and disconnect optical fibers and consist of a plug and an adapter.

They require high-precision alignment to accurately connect small-diameter fibers, cost-effectiveness for large-scale deployment, and ease of handling for efficient installation and maintenance.



Recent optical physical layer circumstances

As Ethernet speeds continue to increase, optical connectors remain the primary interface for optical transceivers.



Excerpt from Ethernet Alliance Ethernet Roadmap 2026
<https://ethernetalliance.org/technology/ethernet-roadmap/>

As network speeds increase, communication errors caused by return loss have become a growing concern in optical connector connections.

Today, I will present a case study of this issue.

Return loss

The reason why we focused on return loss



Why Do Communication Errors Increase After Upgrading from 10GbE to 100GbE?

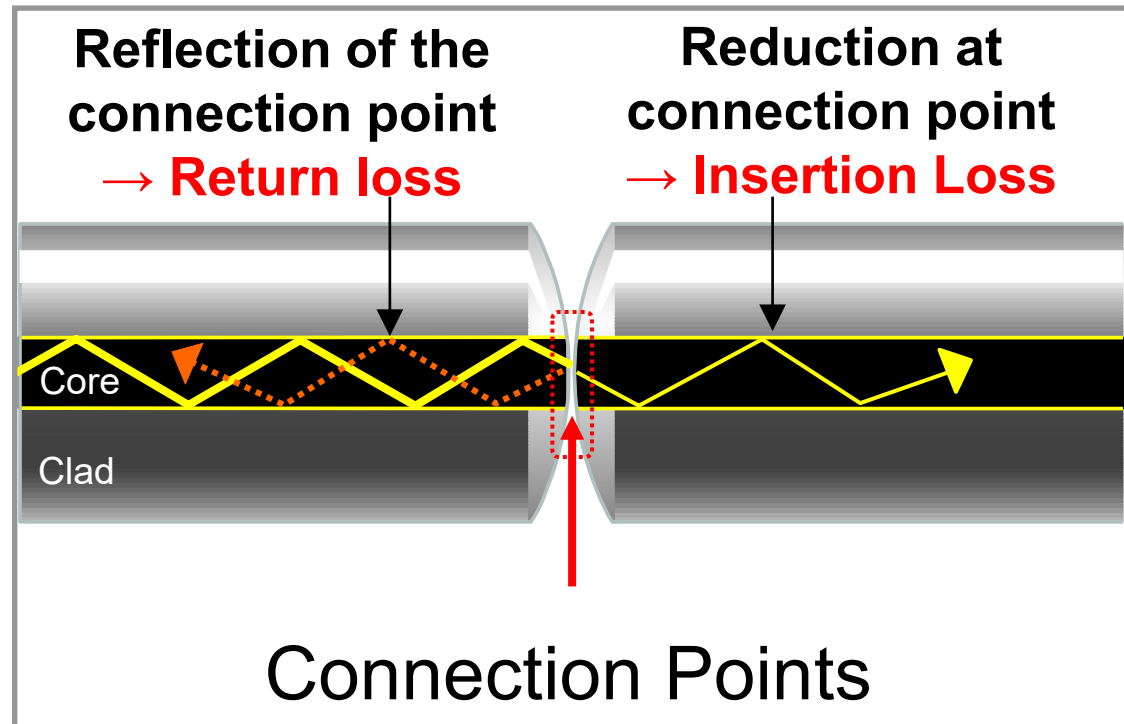
◆ IEEE standards for Ethernet transmission rates of 25 Gbps and higher.

Standard	Corresponding standard name	Fiber	Maximum connection distance	Allowable Loss[dB]	Total return loss[dB]
IEEE802.3CC	25GBASE-LR	Single Mode	10km	6.3	21dB
	25GBASE-ER	Single Mode	40km	18	21dB
IEEE802.3ba	100GBASE-LR4	Single Mode	10km	6.3	21dB
	100GBASE-ER4	Single Mode	40km	18	21dB
IEEE802.3cu	400GBASE-FR4	Single Mode	2km	4.0	25dB

Focus on return loss as a cause of increased troubles due to higher speeds

What exactly is return loss?

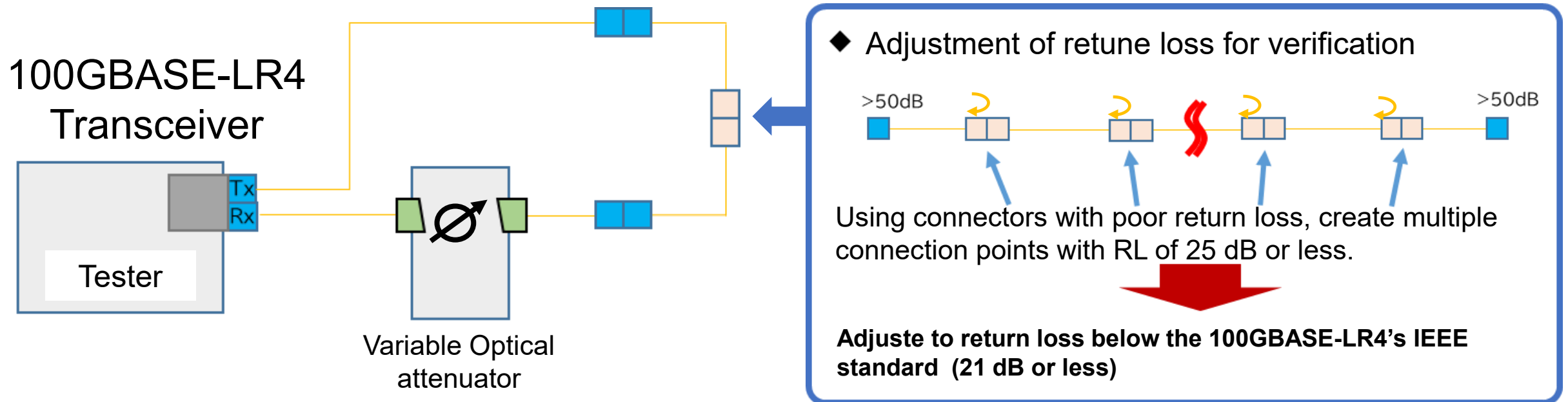
Return loss is a measure of the optical signal reflected back toward the transmitter due to reflections in the optical link



What does return loss affect? = Communication error or link down

Tests Performed by Us

- ① Create multiple return-loss connections into a 100GBASE-LR4 link and reduce the overall return loss below the IEEE specification limit of 21 dB.
- ② Observe the eye diagram and measure the bit error rate (BER).



We have also tested transceivers from different manufacturer.

Result: BER with poor total return loss

When the return loss at a single connection point was below the specified limit of 21 dB, bit errors did not occur immediately.

Then, we increased connection points with poor reflection to three.
Then Bit errors were confirmed.

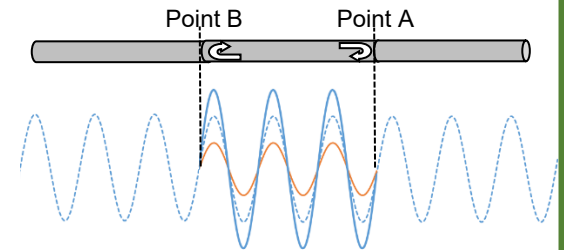
Transceiver A		
Tx	Rx	BER
2.23	-4.21	1.5E-09

Transceiver B		
Tx	Rx	BER
1.23	-4.6	1.4E-05

Transceiver C		
Tx	Rx	BER
1.75	-3.95	5.0E-06

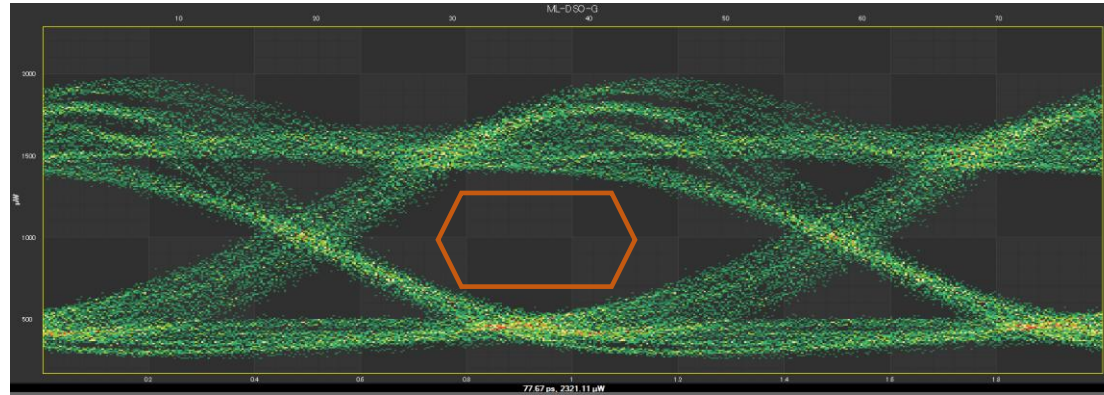
What is multiple reflection?

- ① The transmitted signal is reflected at connection point A.
- ② The signal reflected at connection point A is reflected again at connection point B. The repeated reflections between connection points are known as multiple reflections.

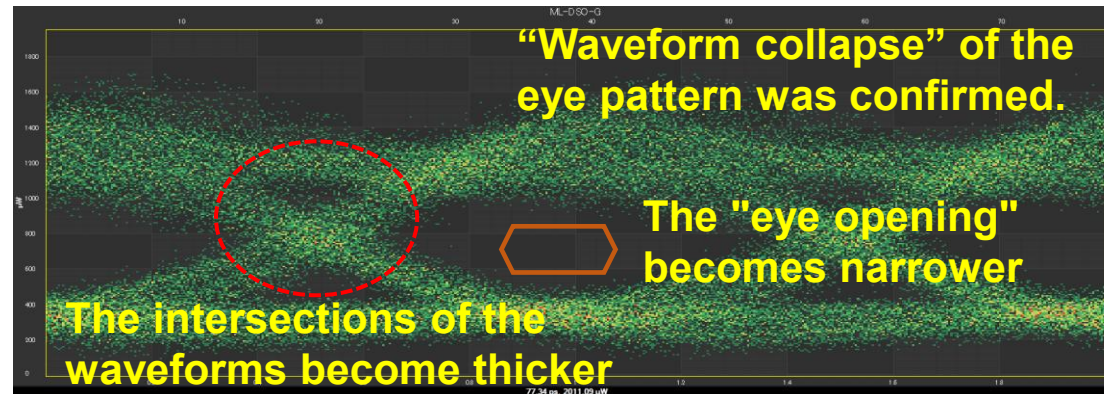


Results: Eye pattern when multiple reflections occur

◆ Normal



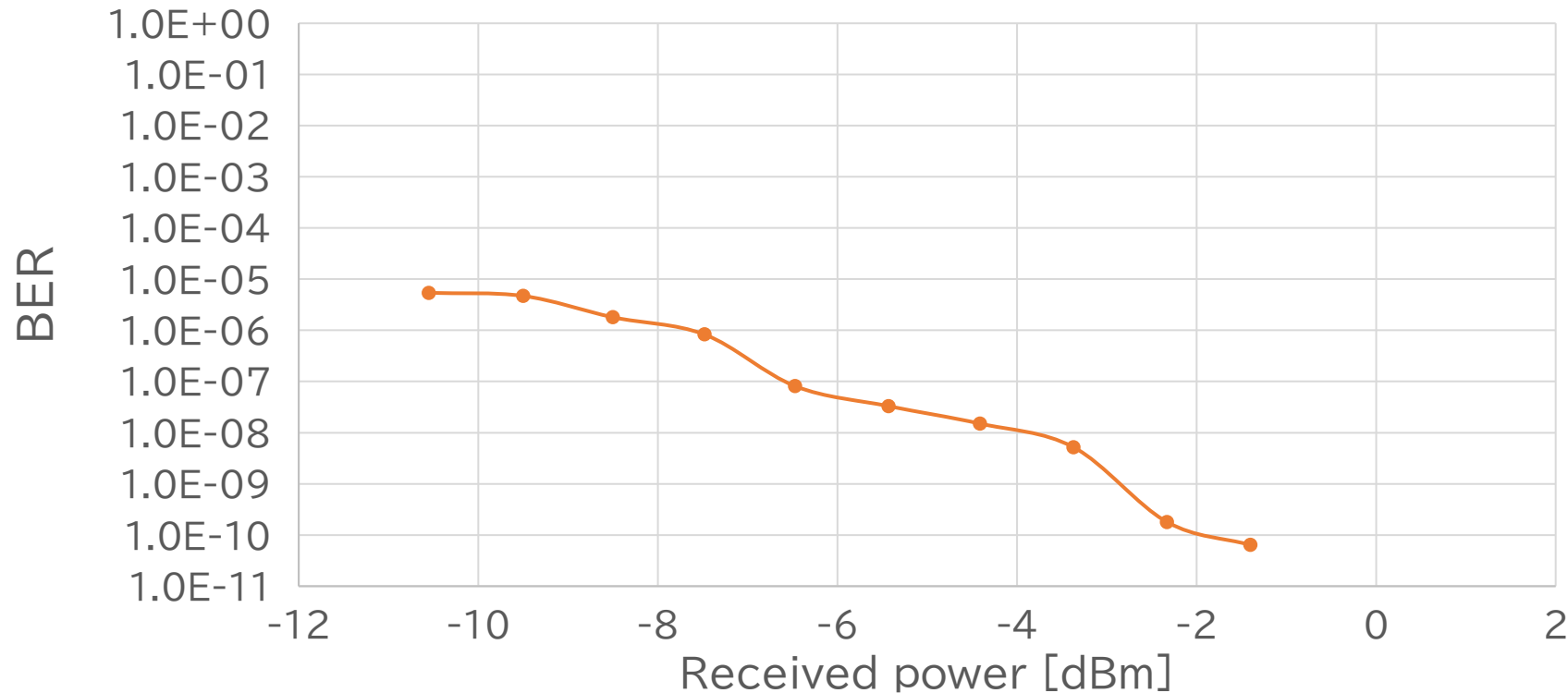
◆ Eye pattern with multiple reflections



Multiple reflections degrade signal quality, causing eye closure, increased jitter, and higher BER.

Verification results: Effects of attenuated optical power

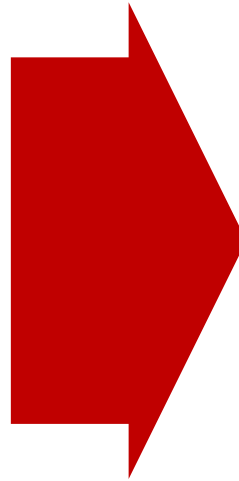
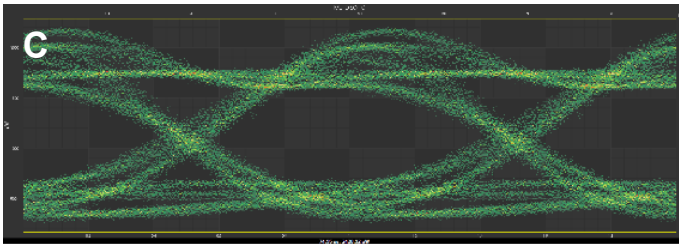
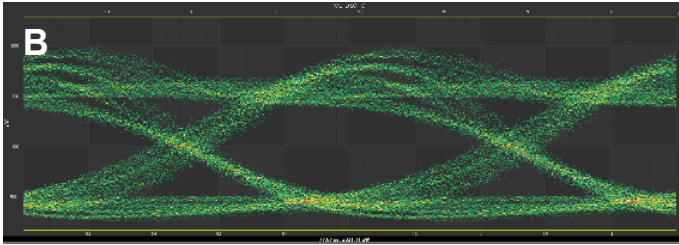
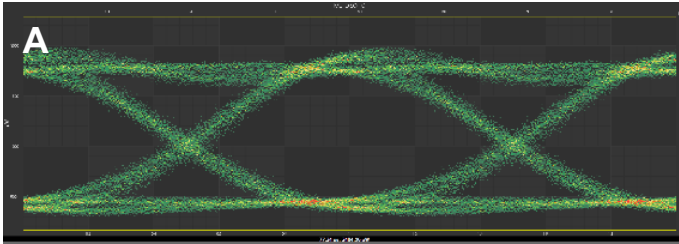
BER increases with decreasing optical power level



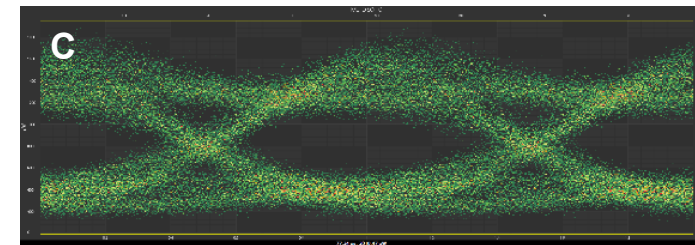
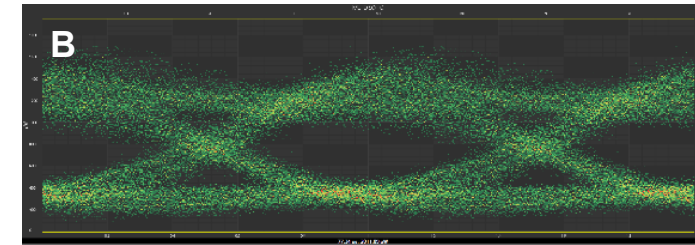
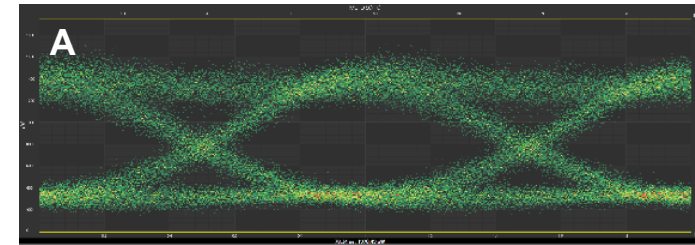
As the optical power level decreases, the impact of multiple reflections increases.

Differences between optical transceiver manufacturers ①

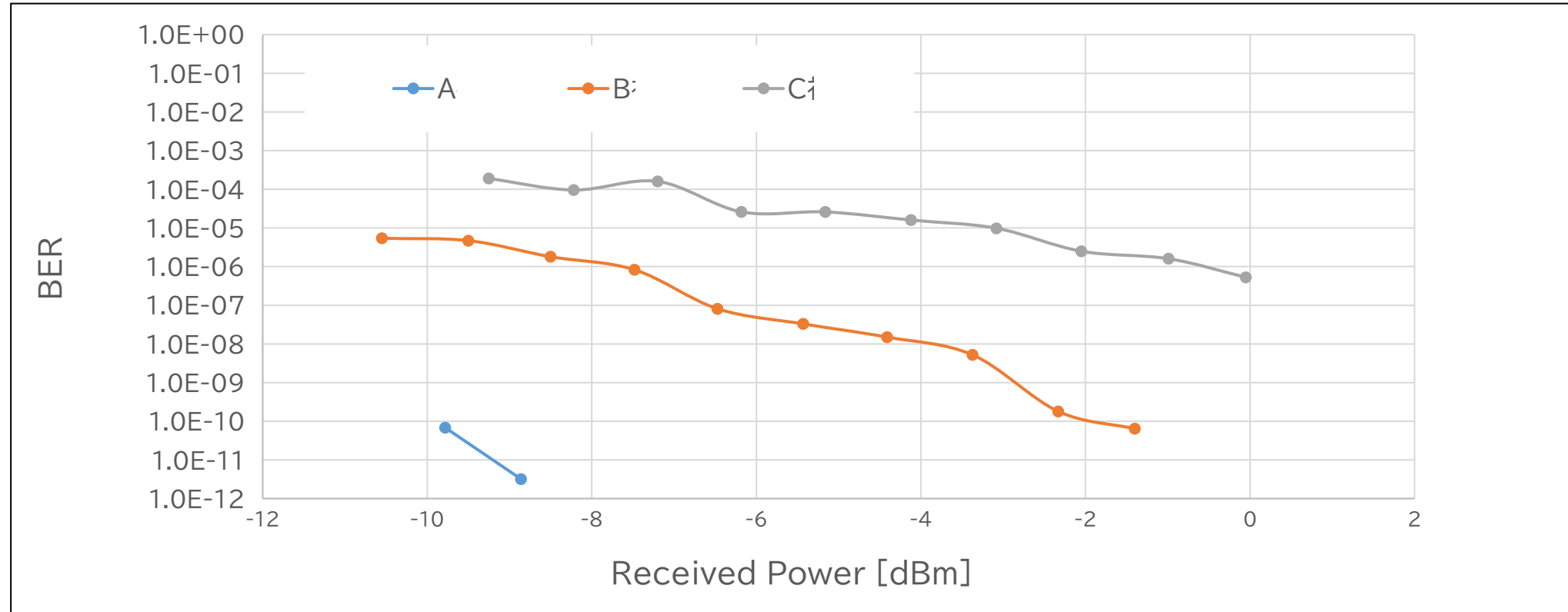
◆ Normal eye pattern



◆ Eye pattern with multiple reflections



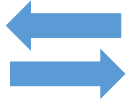
Performance Differences by Optical Transceiver Manufacturers②



Performance differences between manufacturers were observed under low return loss conditions (<21 dB).

Summary: Logic behind how multiple reflections affect communication

Reflected at a connection point (①)



The reflected signal is reflected at another connection point (②).



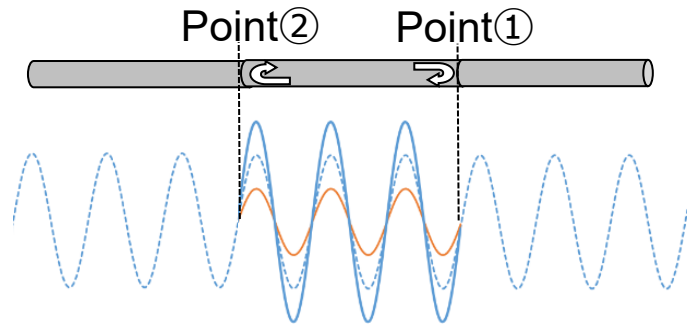
Multiple reflections occur between connection points



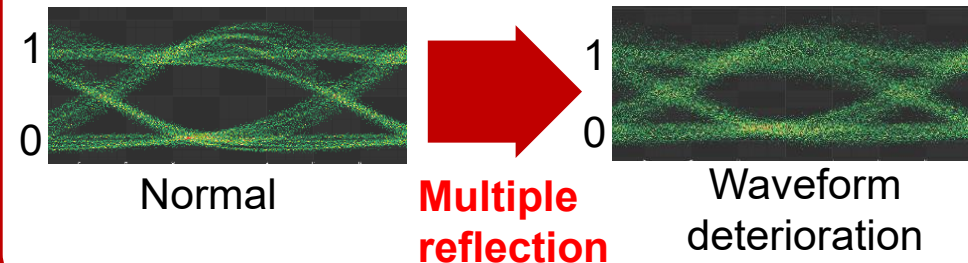
BER increased due to waveform distortion



◆ Multiple reflection phenomenon



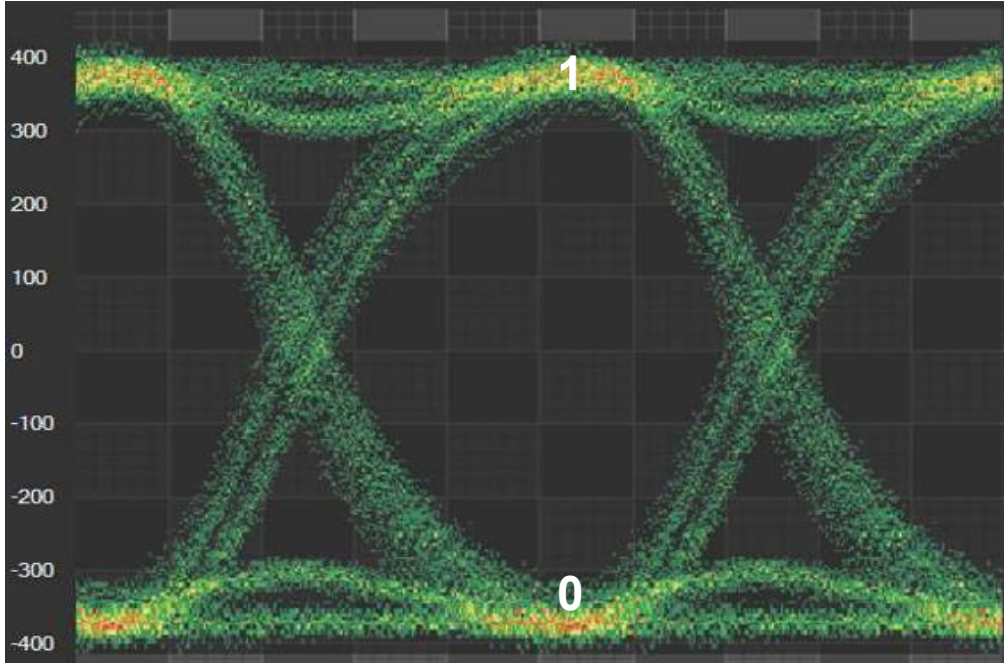
◆ NRZ signals eye pattern



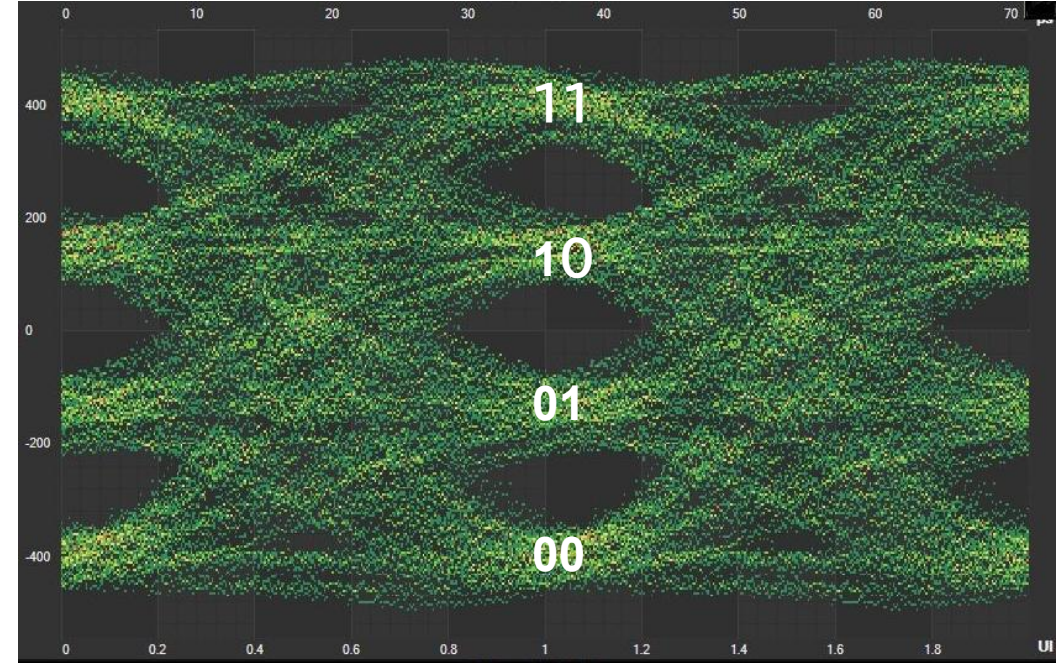
- ◆ Multiple reflections cause degradation of the waveform
- ◆ Be careful with optical network which has many connection points

(reference) About PAM4 modulation

◆NRZ eye pattern



◆PAM4 eye pattern

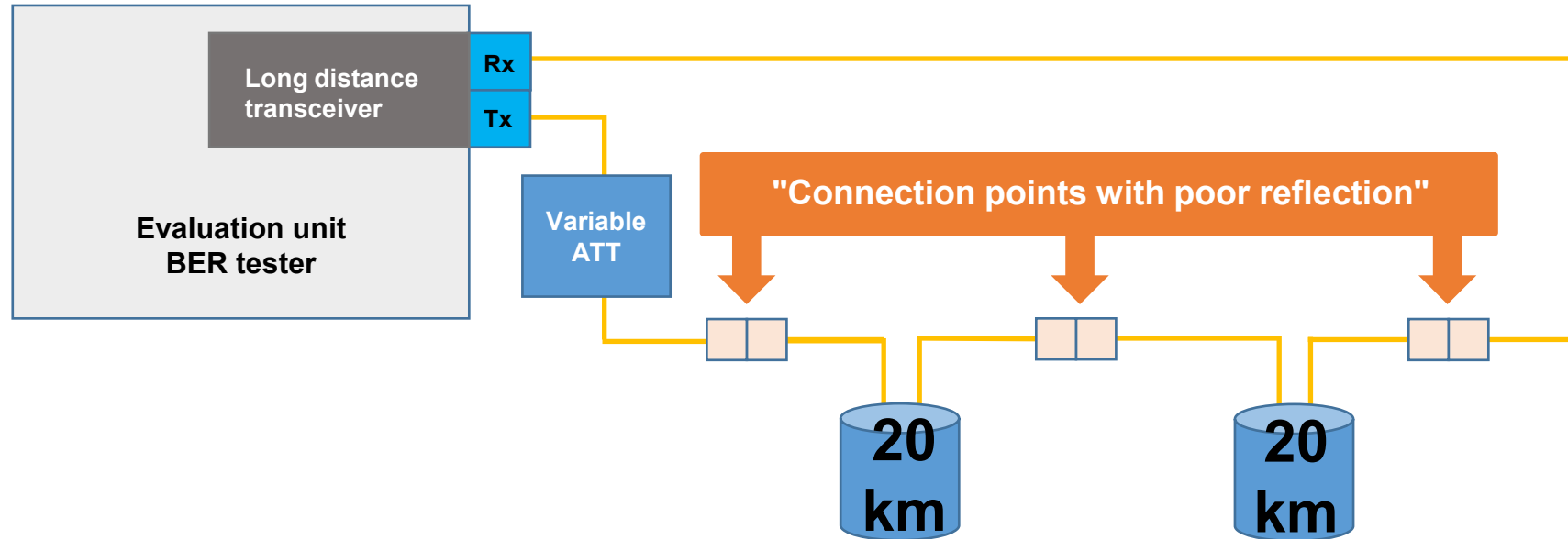


For now, PAM4 is the mainstream format for 400GbE and above. Optical fiber network will be required higher quality of optical characteristics.

(reference)

Difference in effect due to the location of "poorly reflective connection points"

◆ Insert "connection points with poor reflection" into a long-distance connection

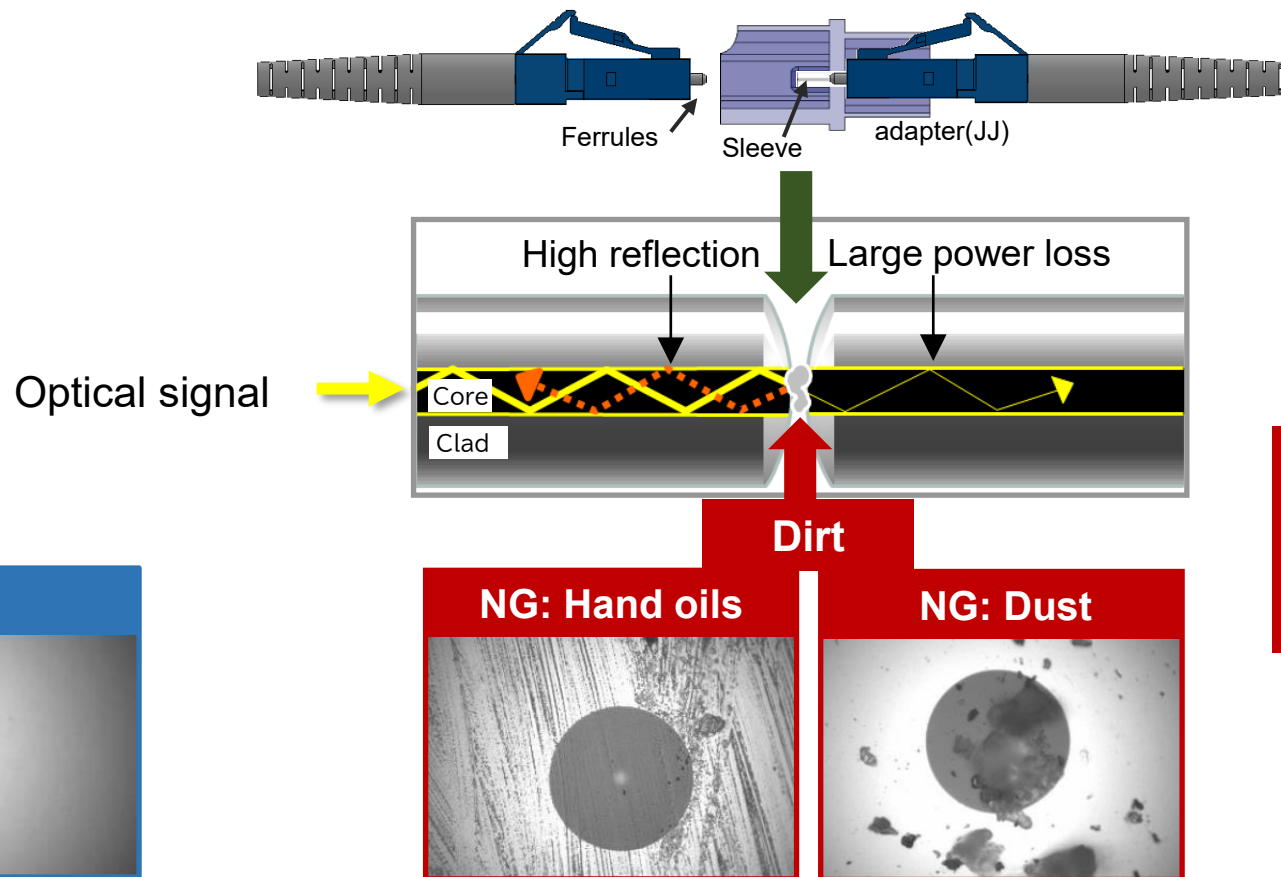


No bit errors were observed when reflection points were far apart.
The reflected signal was likely attenuated over the long fiber distance.

Causes of poor optical properties

Causes of poor optical properties

Connector contamination is the leading cause of optical performance degradation.



Reflection and loss increase due to dirt!

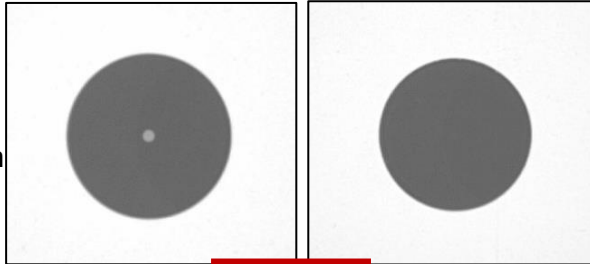
Effects of Connector Contamination on Optical Characteristics

Clean end faces connection

connector1

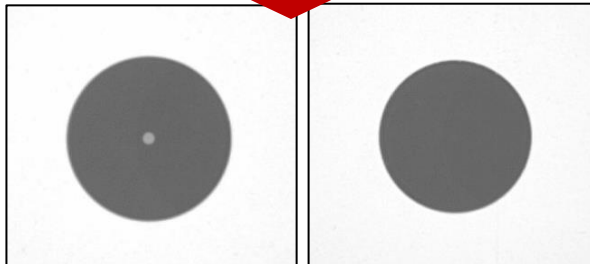
connector 2

Before
connection



Connect

After
connection



connector1

connector 2

Insertion
Loss [dB]

0.05

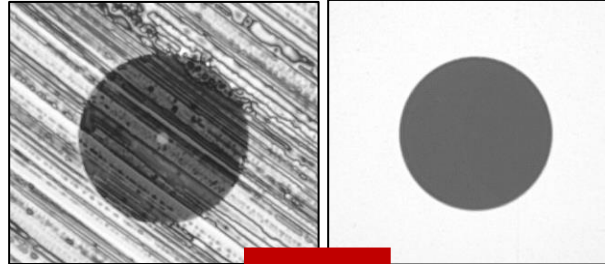
Return Loss
[dB]

52.6

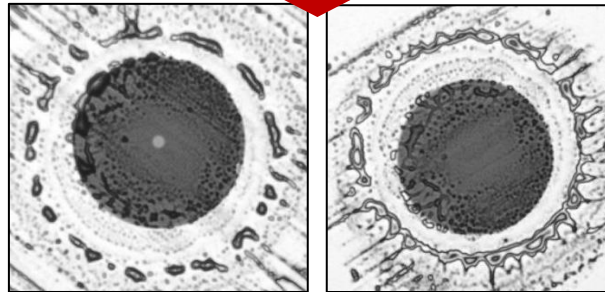
◆ Hand oil

connector1

connector 2



connect



connector1

connector 2

Insertion
Loss [dB]

0.10

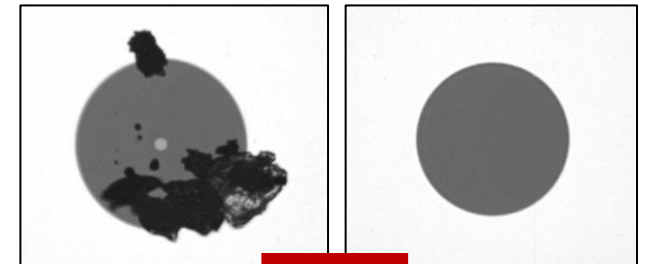
Return Loss
[dB]

44.2

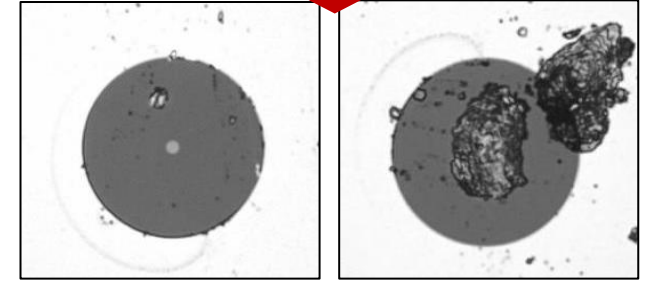
◆ Dust attached

connector1

connector 2



connect



connector1

connector 2

Insertion
Loss [dB]

1.1

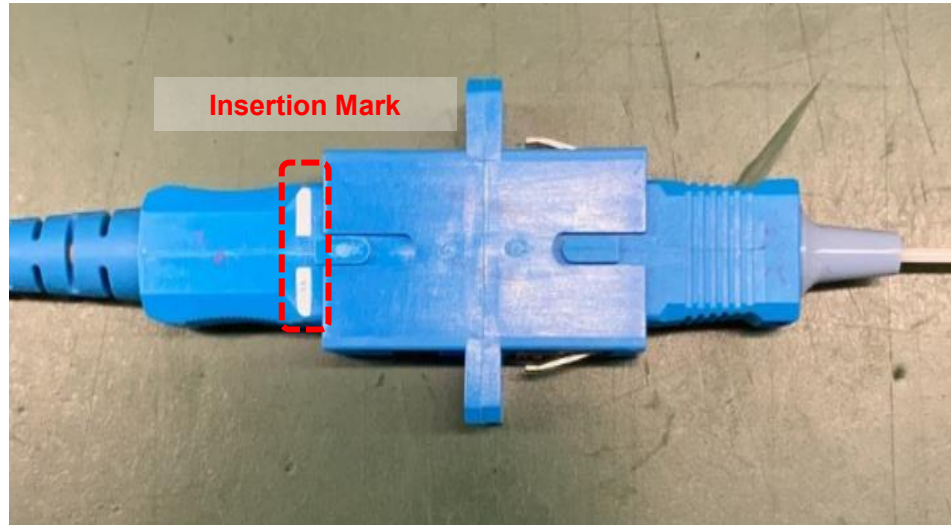
Return Loss
[dB]

22.7

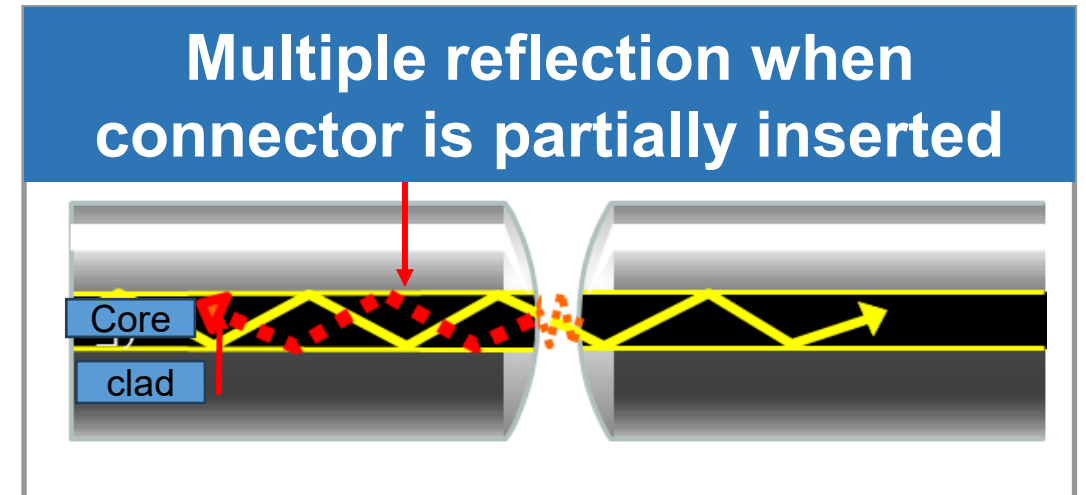
After connection, both end will get dirty

Rare cases: deteriorate optical characteristics (1)

◆ Optical connector partially inserted



Insertion Loss [dB]	Return Loss[dB]
0.14	13.8



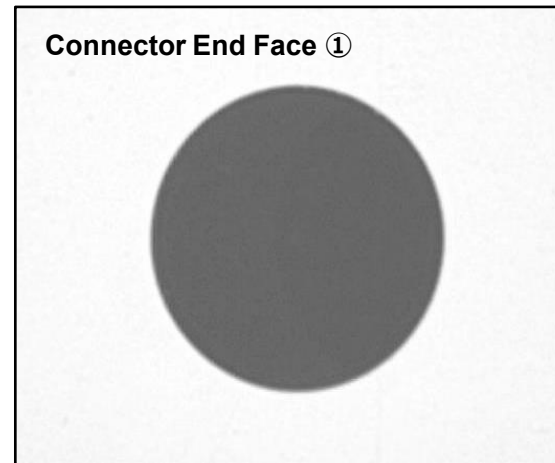
If a connector is not fully inserted, excessive reflection can occur, resulting in multiple reflections between connectors.

Rare cases: deteriorate optical characteristics

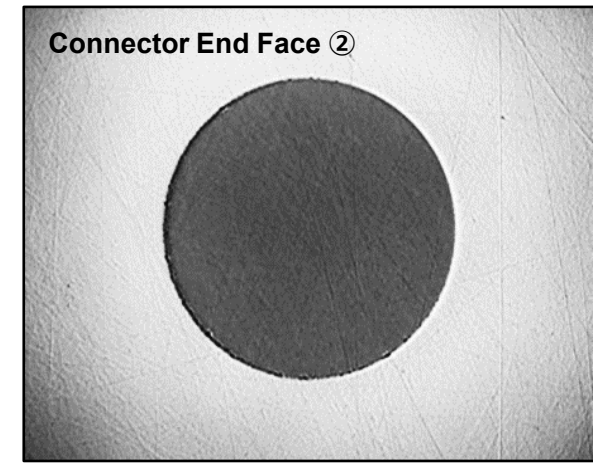
- ◆ The polished surface is of the old grade.

If the polishing quality of the end face is of the old grade (PC polishing), the return loss value is usually poor.

Polishing Grade	Return Loss
PC Polishing	25dB or higher
SPC Polishing	40dB or higher
UPC Polishing	50dB or higher



UPC Polishing

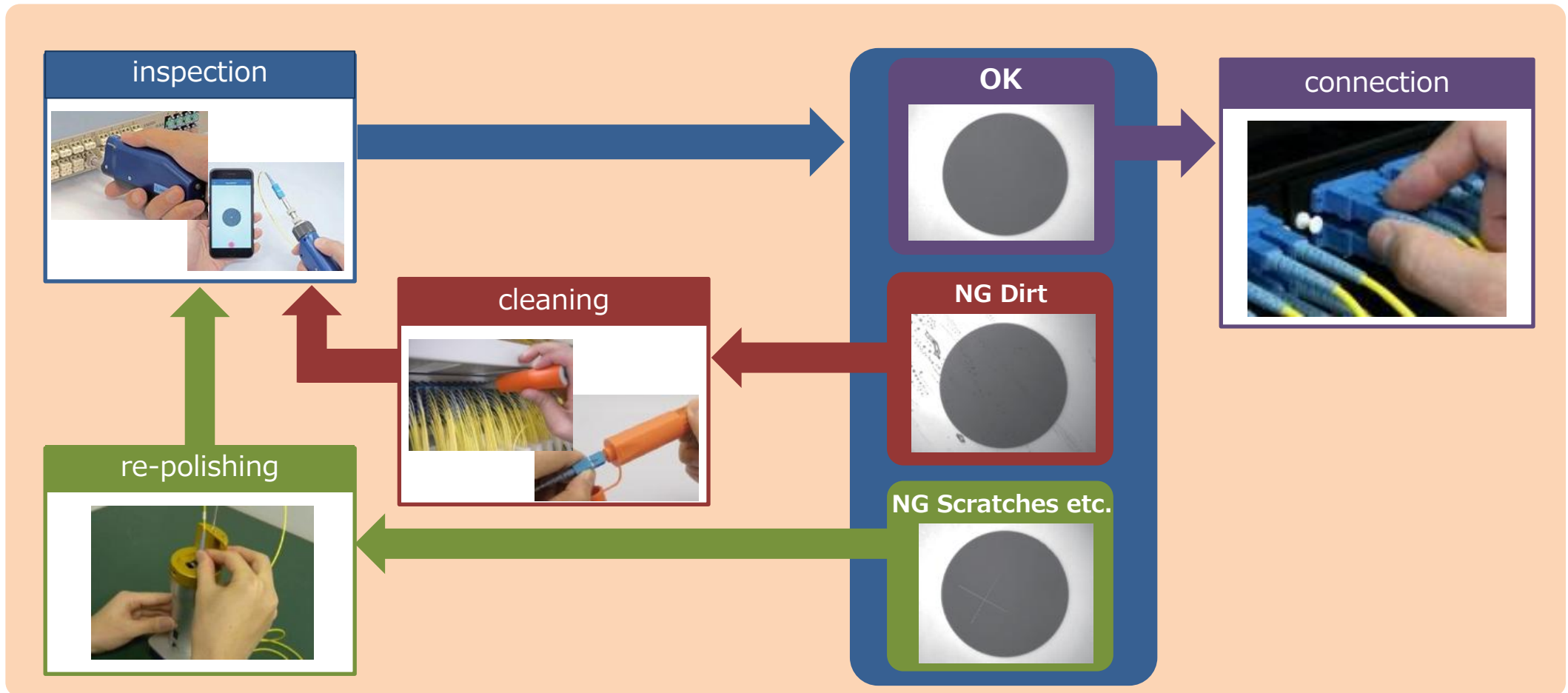


PC Polishing

Fibers that are over 20 years old may have rough polishing.

Recommended flow for connecting optical connectors

- ◆ Observing the end face before connecting, prevent problems when connecting optical connectors.



Conclusion

Key take away

◆ A common best practice in the fiber optic

"Clean Before Connect."

Since contamination is often invisible to the naked eye, connector end faces should always be assumed dirty and cleaned before connection.

Even when a connector has been protected with a dust cap, cleaning is recommended prior to mating, as contamination may still be present on the end face.



Once again, **"Clean Before Connect."**

Thank you

