MYNOG12

Return loss problems associated with faster optical networks

11th June, 2025

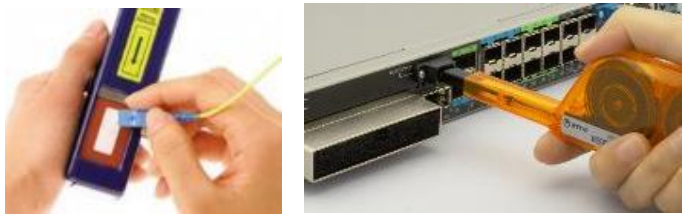
NTT Advanced Technology Corporation

AGENDA

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

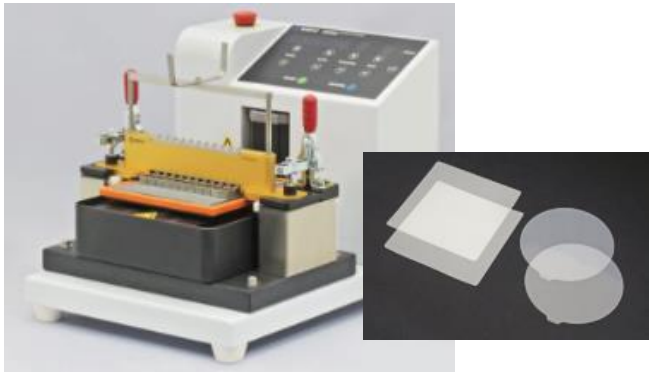
NTT-AT's core expertise

NTT-AT has more than 30 years experience to develop, manufacture, and sell products related to optical communications, such as manufacturing equipment and maintenance tools for components (optical connectors) that are important in optical fiber communications.
We have deep knowledge and expertise of optical network especially physical layer.



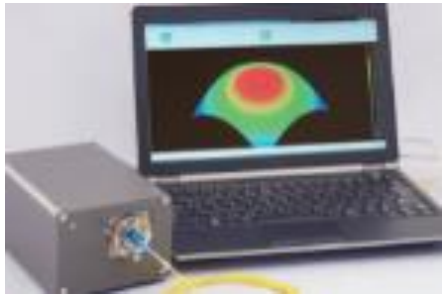
Optical Connector Cleaner

Physical layer switching device (Intelligent optical switch)



Optical connector polishing machine and polishing film

Optical adhesive



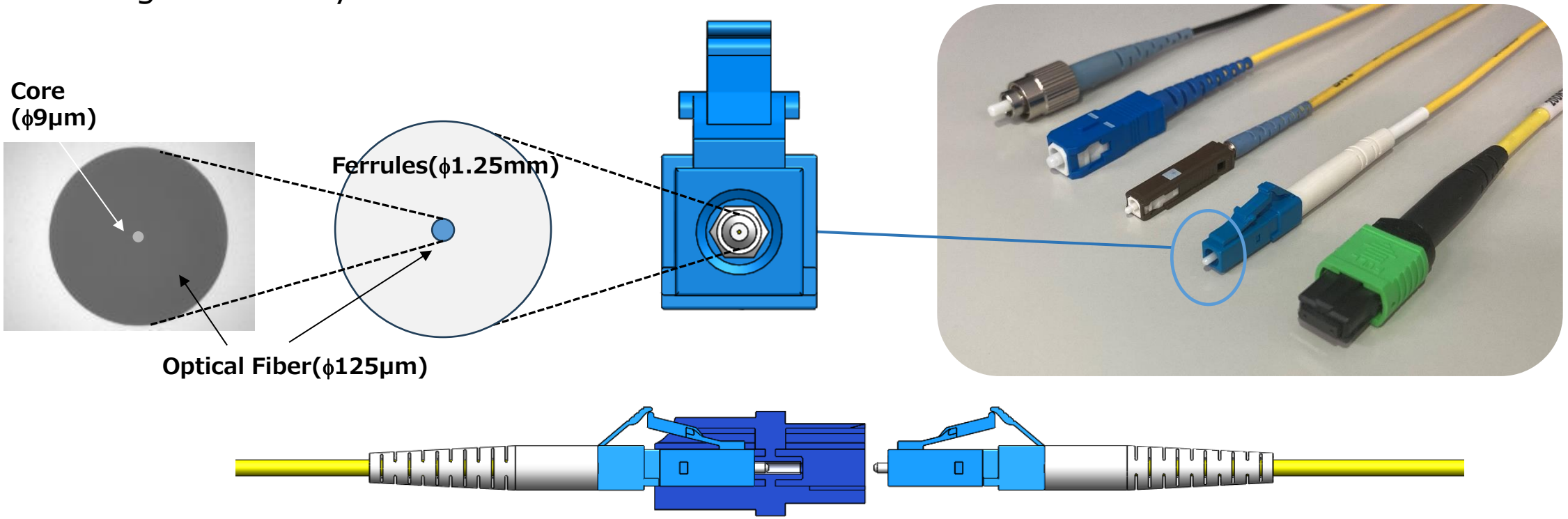
Optical connector measuring machine

Basics

Basics of optical connector

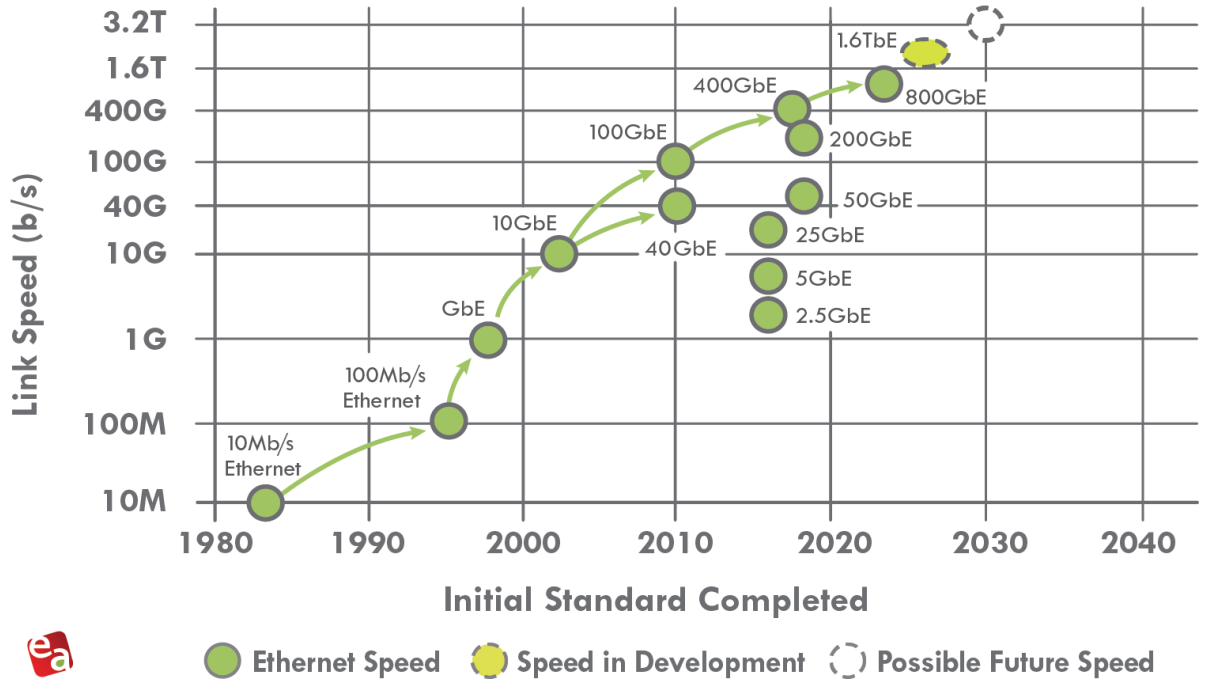
Optical connectors are parts for connecting and disconnecting optical fibers, and consist of a plug and an adapter.

It requires high precision to accurately connect small diameter optical fibers, low cost so that it can be used in large quantities in each part of the optical network, and ease of handling so that anyone can use it.

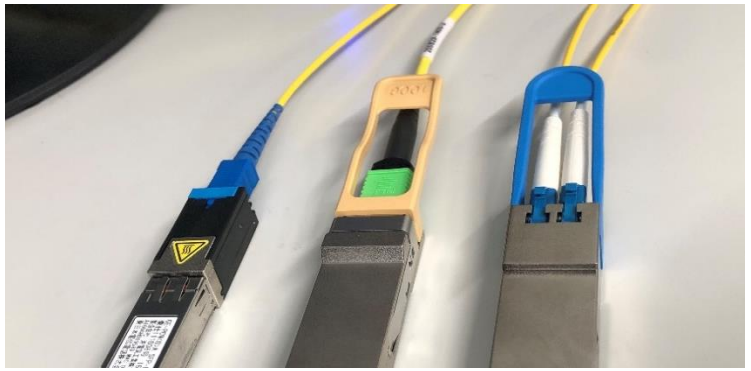


LC type optical connector

Recent optical physical layer circumstances



Higher speed Ethernet standards are being proposed, but (for now) transceiver interfaces always use optical connectors.



Excerpt from Ethernet Alliance Ethernet Roadmap 2024
https://ethernetalliance.org/technology/ethernet-roadmap/

As communication speeds increase, a new problem of communication errors caused by "**return loss**" has become apparent in optical connector connections.
Today we will focus on this case study.

Return loss

The reason why we focused on return loss

Upgrading 10GbE to 100GbE Increases the Number of Communication Errors

Increasing number of inquiries about communication trouble with faster network

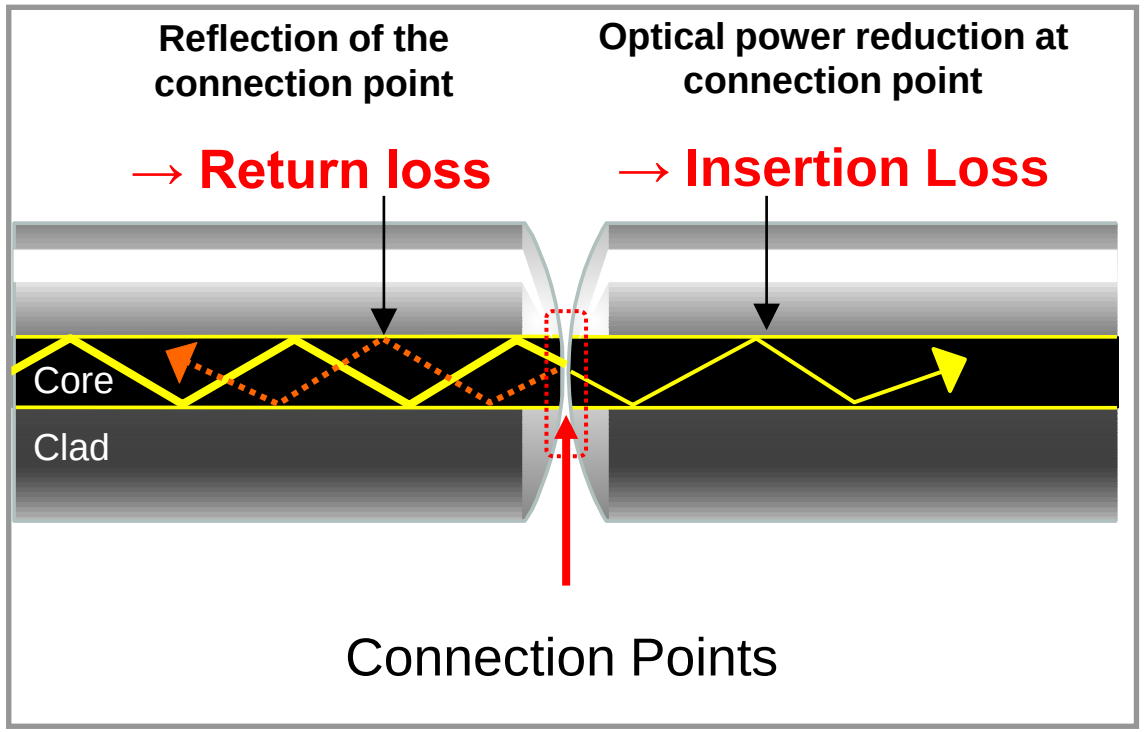
◆ **Requirement of return loss is standardized for high-speed standard exceeding 25Gbps.**

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?

◆ **Optical signal transmission at the connection point of the optical connector**



"Insertion loss" - the amount of optical power loss at the connection point

⇒ The larger the value, the lager loss

Typical value: 0.5 dB or less (approximately 10% loss)

If it exceed allowable loss,

It causes a communication error or link down

"Return loss" - The amount of reflected optical power at the connection point

⇒The larger the value, the smaller the reflected power.

Typical value: 40dB or more (0.00001% is reflected)

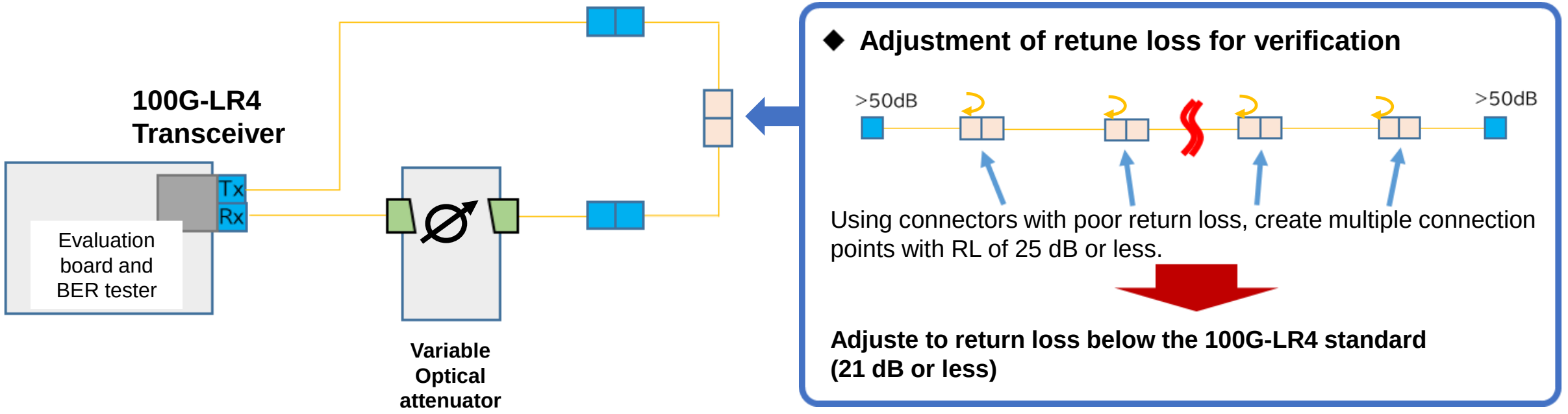
How does return loss affect communication quality?

⇒ We tried it out!

Verification configuration

① Insert multiple connections with poor return loss into the 100G-LR4 environment and adjust the total return loss to be below the standard value (21dB).

② Observe the eye pattern and measure BER*



Transceivers: Three ransceivers from different manufacturer (A,B,C)

* BER : Bit Error Rate
The bit error ratio (also BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval.

Test result: BER with poor total return loss

Even if the return loss at one connection point is lower 21 dB, bit errors did not occur immediately. Then, we increased the number of connection points with poor reflection to three points.

Bit errors were confirmed in all three tests conducted by different transceiver manufacturers.

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

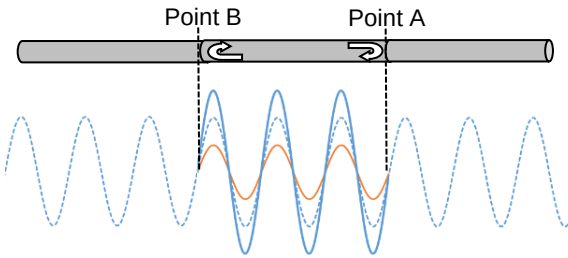
➡ Multiple reflections affect BER?

What is multiple reflection?

① The transmitted signal is reflected at connection point A.

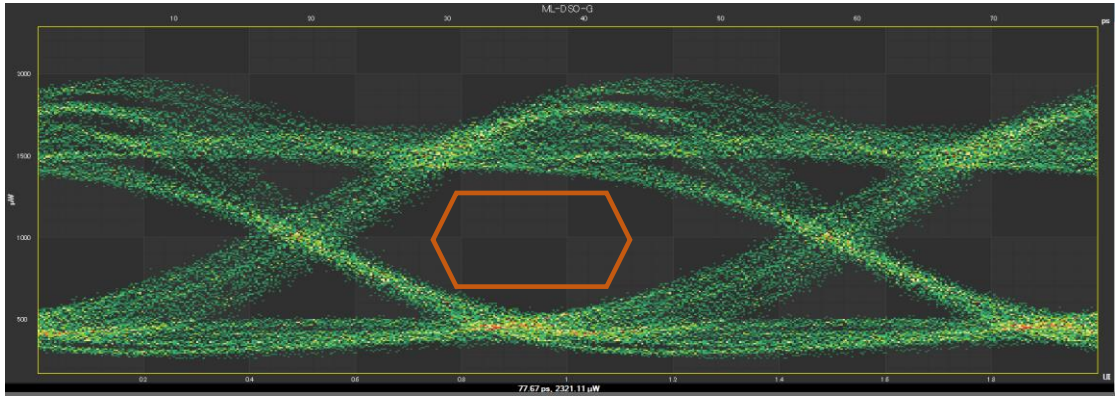
② The signal reflected at connection point A is then reflected at another connection point B.

This phenomenon in which signal continues to be reflected as a result of ① and ② being repeated is called multiple reflection.

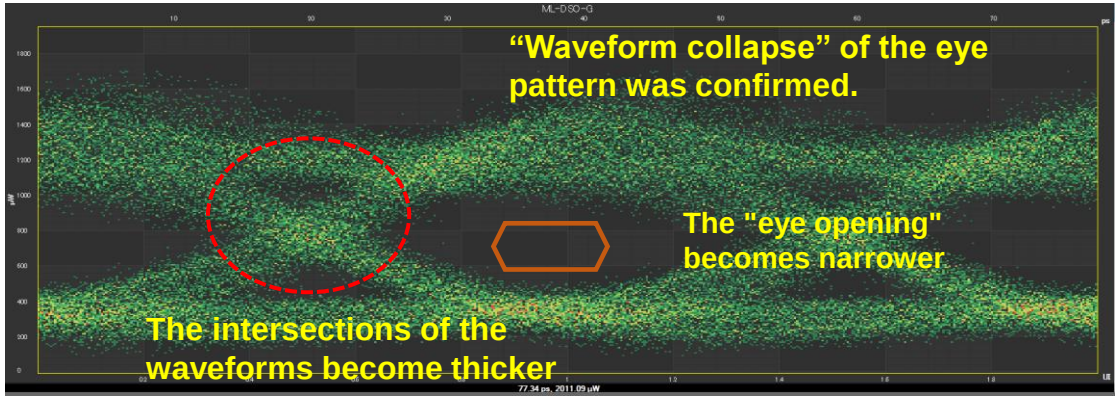


Verification results:
Eye pattern when multiple reflections occur

◆Normal



◆ Eye pattern with multiple reflections

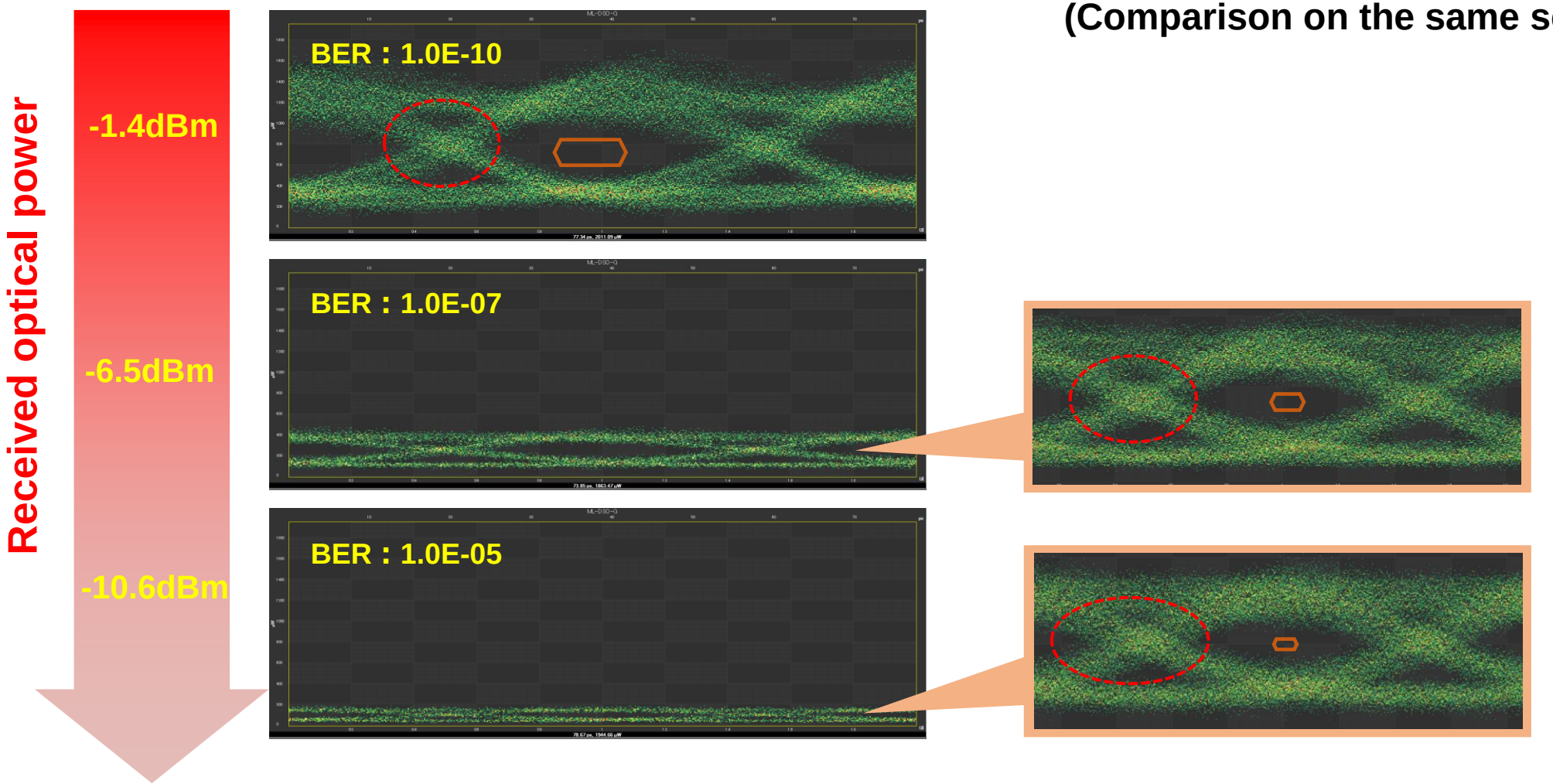


It was confirmed that waveform degradation occurs when there are multiple reflections.

A disturbed waveform with narrow "eye opening" and jitter fluctuations leads to BER degradation.

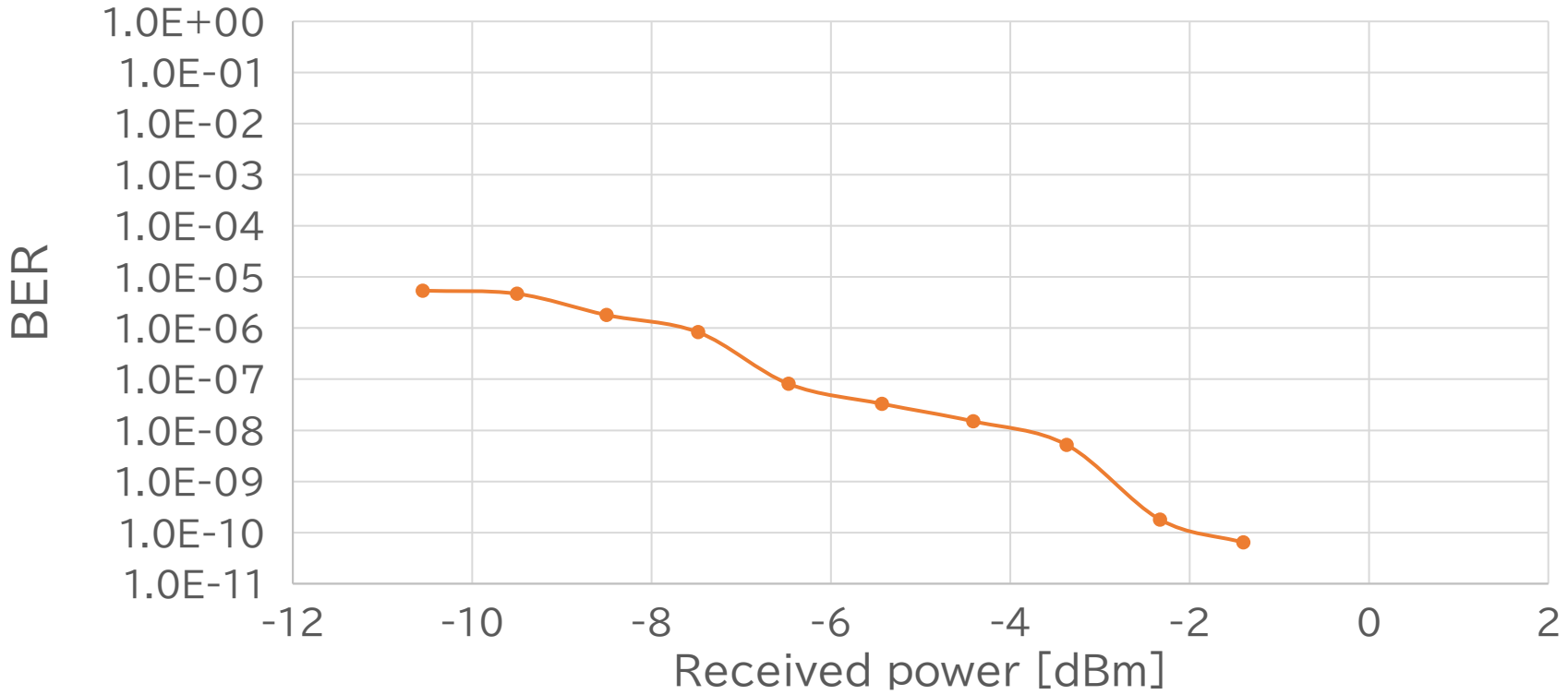
Verification results: Effects of attenuated optical power

◆ **Comparison of changing optical power when multiple reflections occur**
(Comparison on the same scale)



Verification results: Effects of attenuated optical power

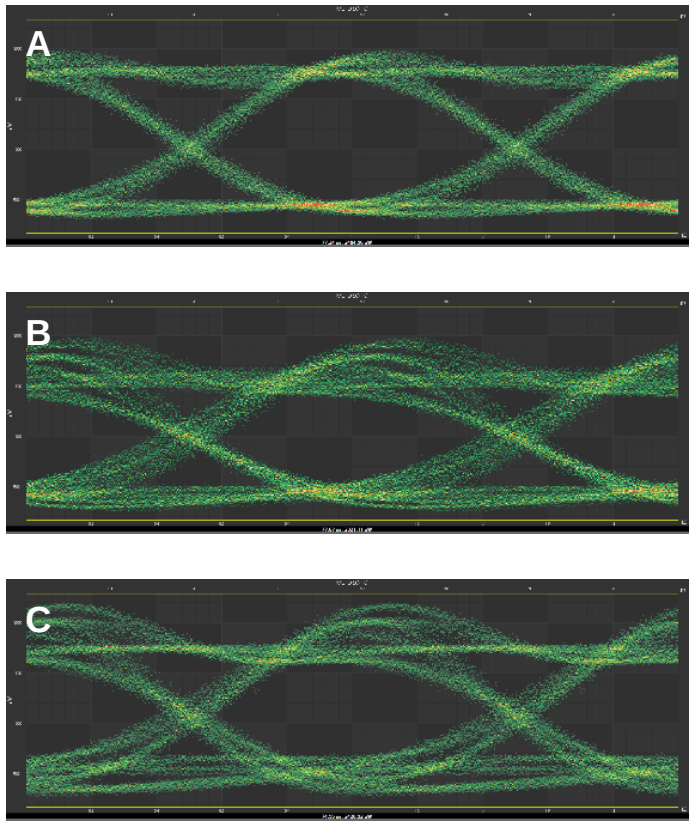
◆BER trend when optical power is attenuated due to multiple reflections



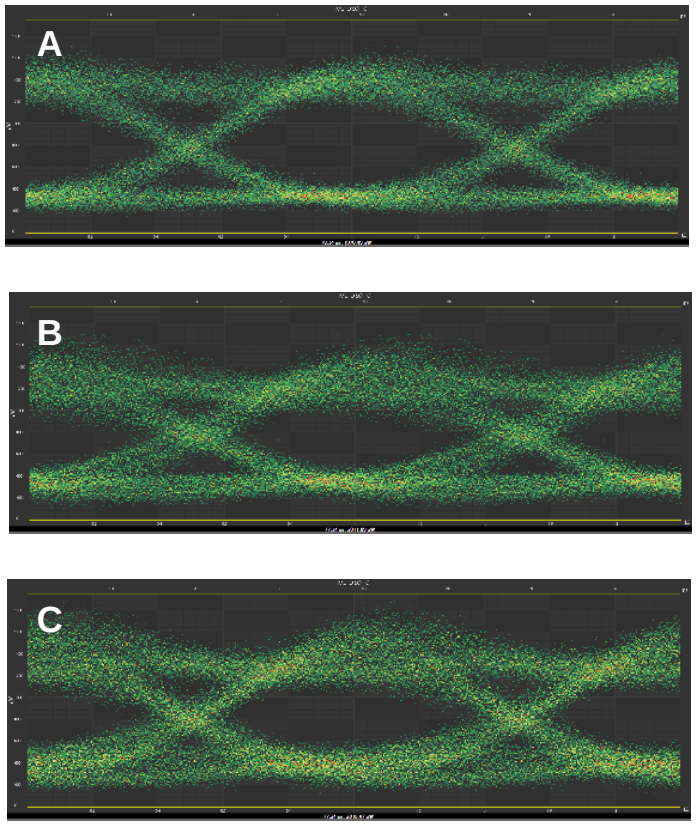
Even if received power is enough,
bit error occurs due to degradation of signal with multiple reflections

Differences between optical transceiver manufacturers ①

◆ Normal eye pattern



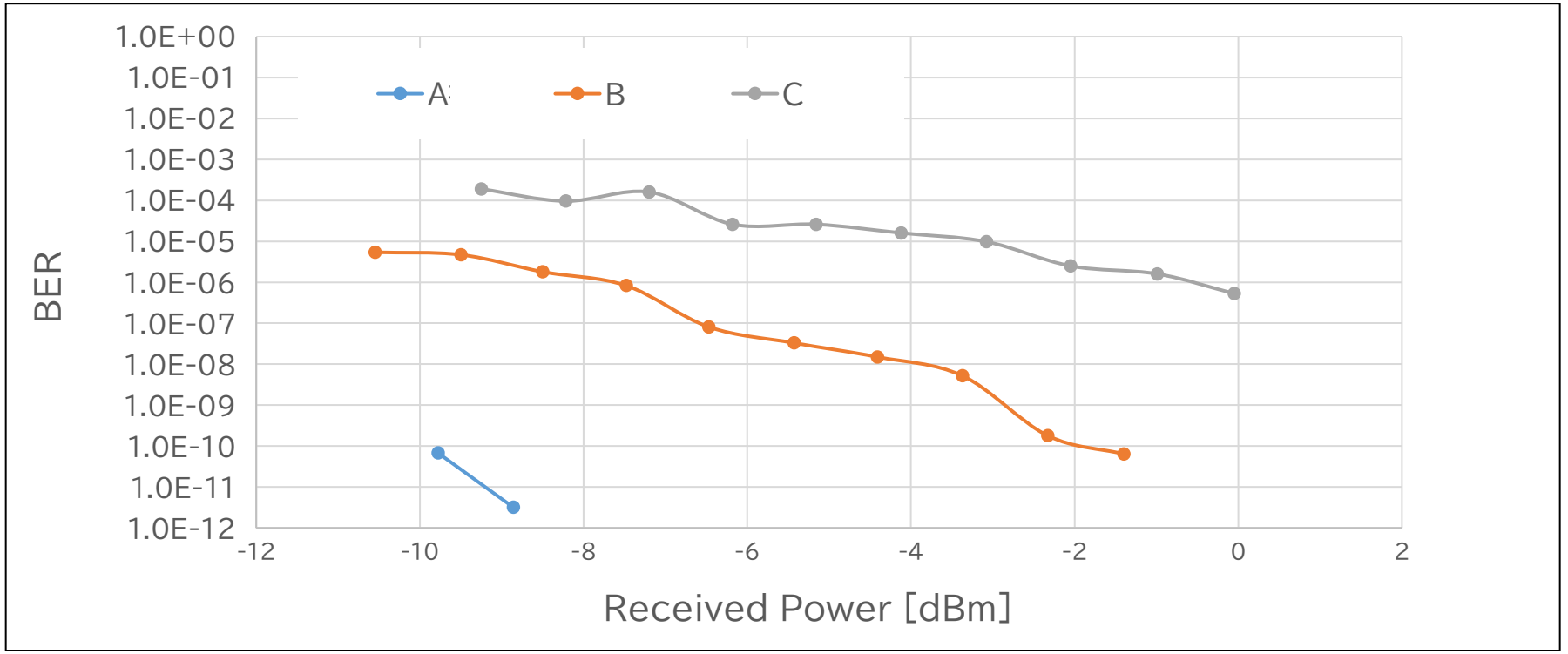
◆ Eye pattern with multiple reflections



Even the same standards-compliant products, the shape of the eye pattern differs depending on the manufacturer.

Performance Differences by Optical Transceiver Manufacturers②

◆ **BER by manufacturer**



In environments where the return loss was below the requirement value (21 dB or less), differences in performance between manufacturers were confirmed.

On the other hand, if it is within the standard value (21 dB or more), result of all manufacturers is error free.

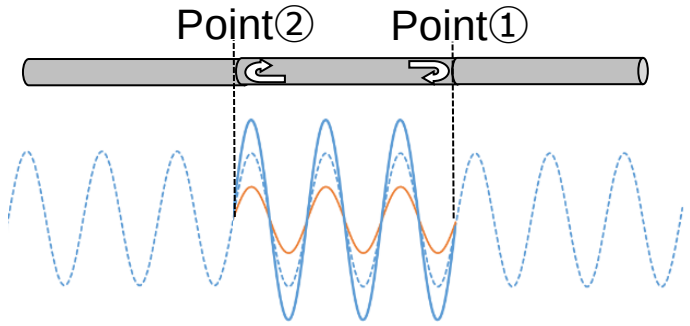
⇒ It is important to meet the requirements.

Summary: Logic behind how multiple reflections affect communication

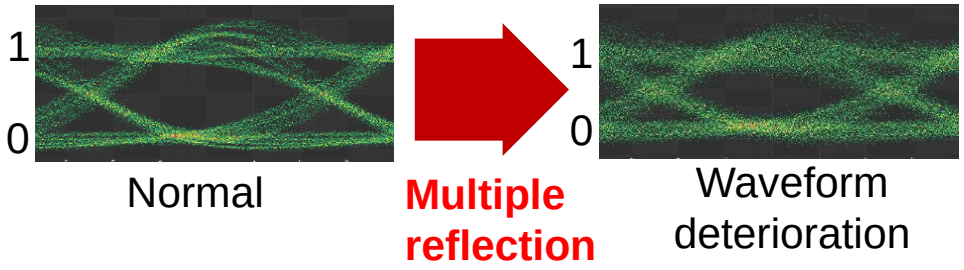
Reflected at a connection point (①) ⇄ The reflected signal is reflected at another connection point (②). = Multiple reflections occur between connection points

→ **BER increased due to waveform distortion**

◆Multiple reflection phenomenon



◆ NRZ signals (ON/OFF signal transmission by optical power) eye pattern



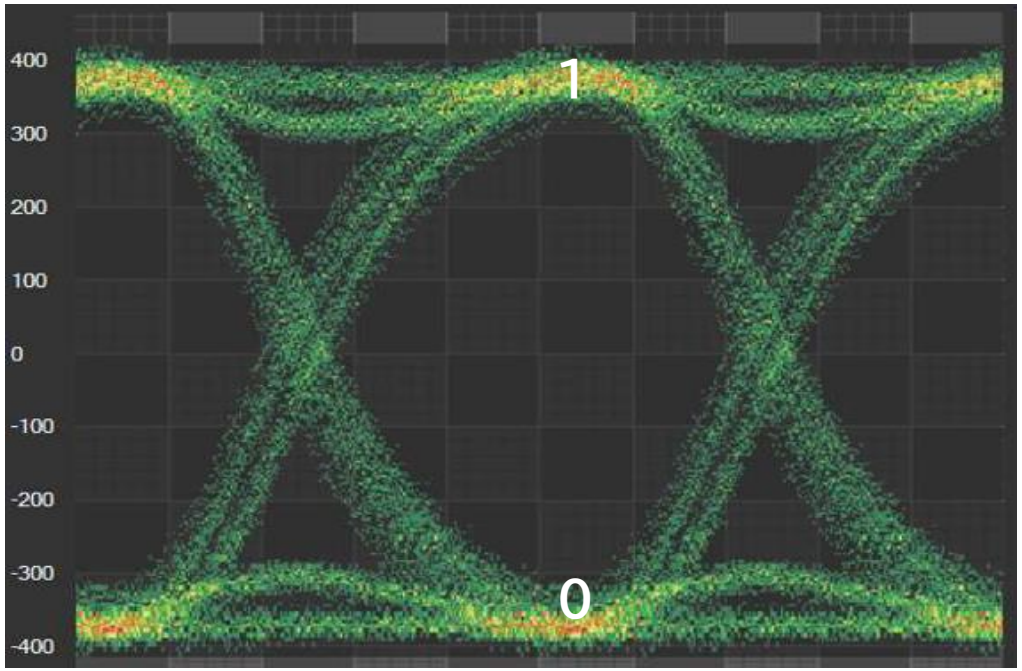
Multiple reflections cause degradation of the waveform

↓

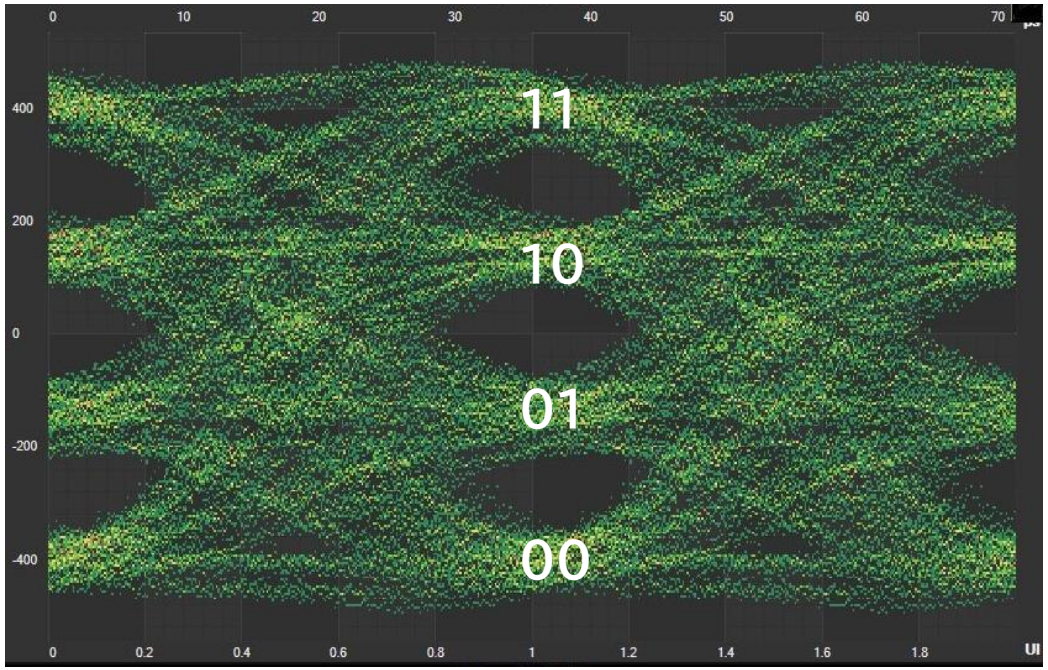
Be careful with fiber optical links that have many connection points

(reference) About PAM4 modulation

◆NRZ eye pattern



◆PAM4 eye pattern

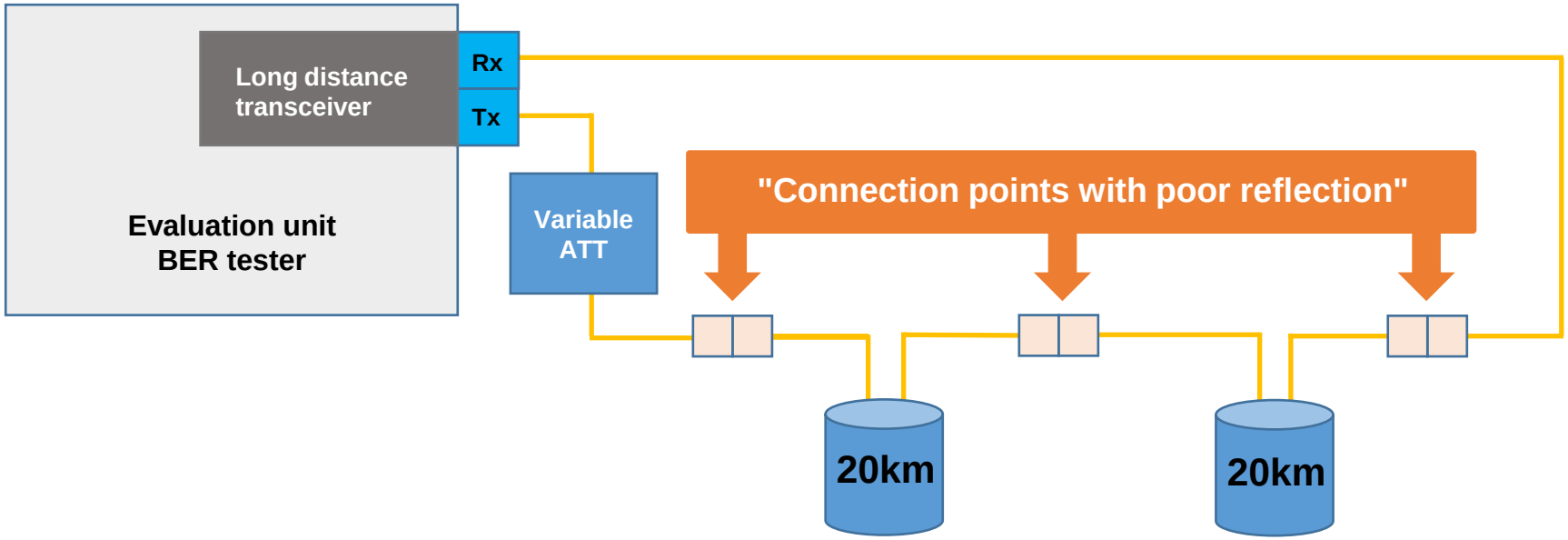


Multiple overlapping waveforms such as PAM4 make it difficult for the optical transceiver to distinguish between them. Even with FEC (error correction) function, it is more difficult to prevent signal reading errors caused by multiple reflections.

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**



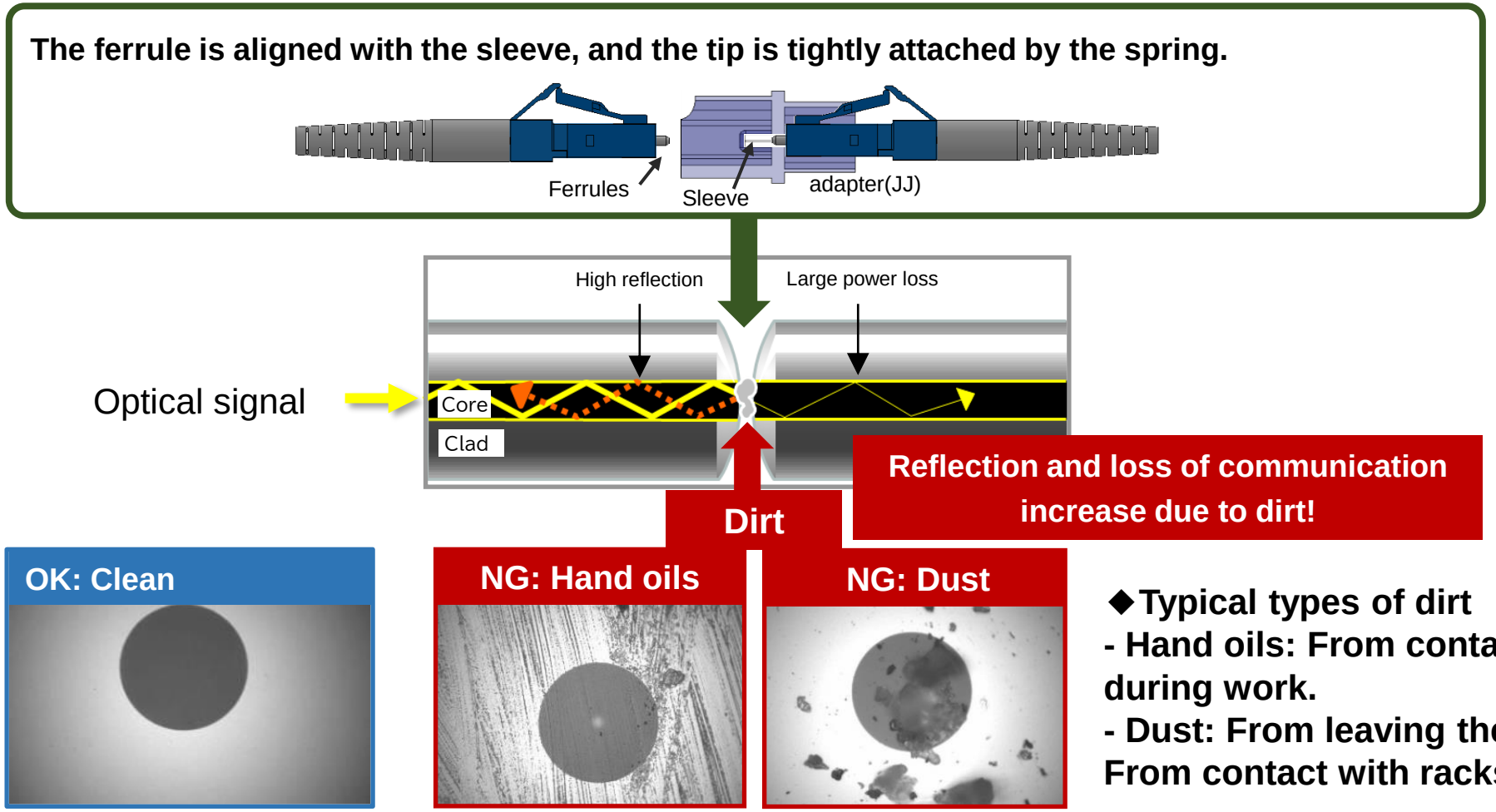
When the distance between reflection points is long, no bit errors were observed.

It is assumed that multiple reflections do not occur because the reflected light is attenuated as it passes through a long section of fiber.

Causes of poor optical properties

Causes of poor optical properties

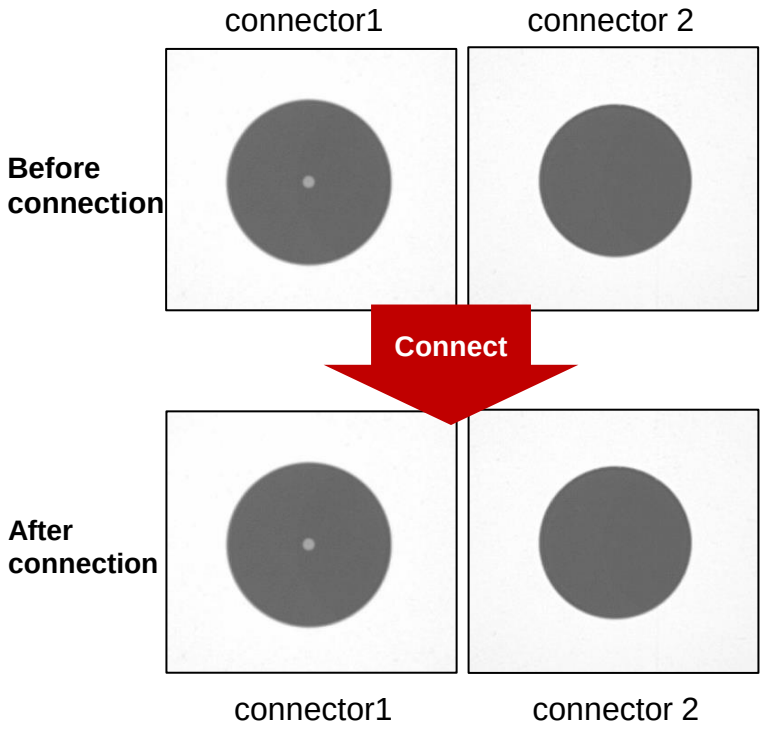
The majority of optical network problems that cause deterioration of optical characteristics are due to contamination of the end face of the connector.



◆Typical types of dirt
- Hand oils: From contact with fingers during work.
- Dust: From leaving the cap open. From contact with racks, clothing, etc.

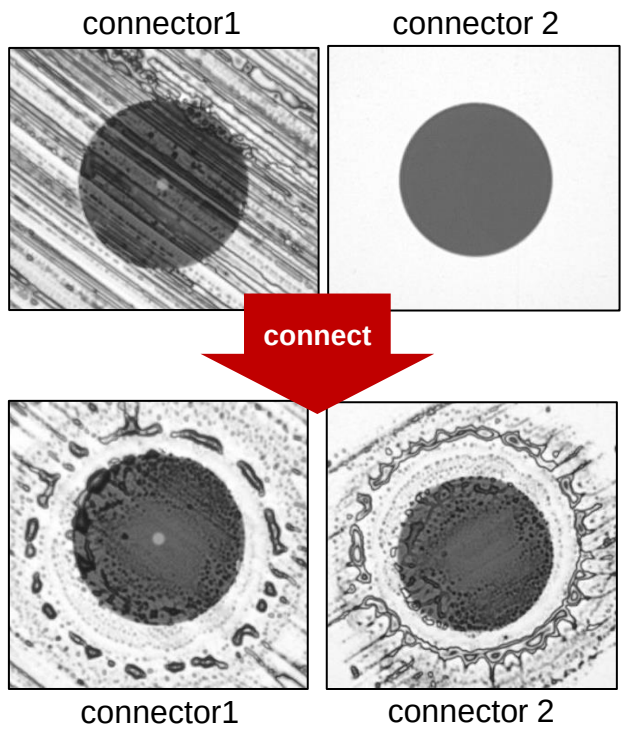
Effect of optical connector end face contamination on optical characteristics

◆ Clean end faces connection



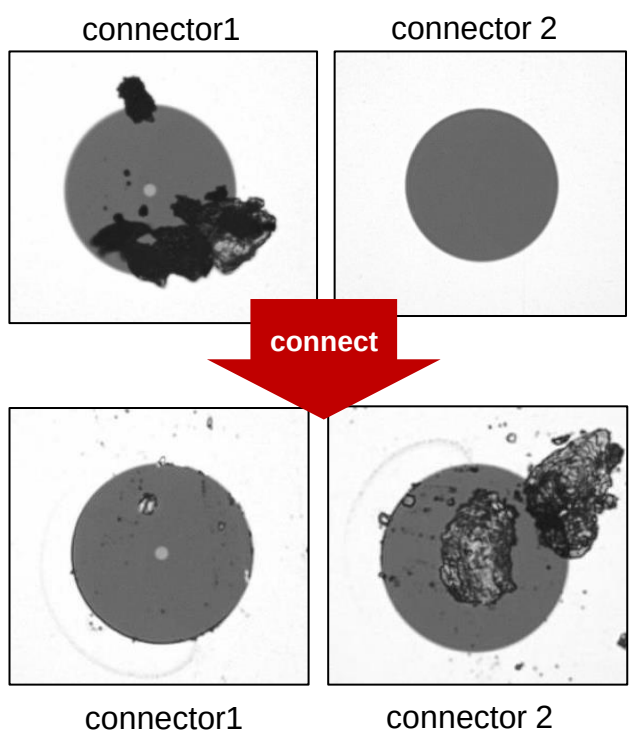
Insertion Loss [dB]	Return Loss [dB]
0.05	52.6

◆Hand oil



Insertion Loss [dB]	Return Loss [dB]
0.10	44.2

◆ Dust attached



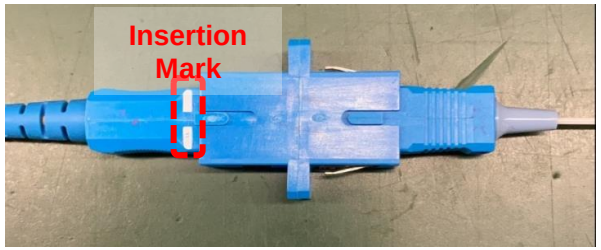
Insertion Loss [dB]	Return Loss [dB]
1.1	22.7

After connection, both connectors will get dirty

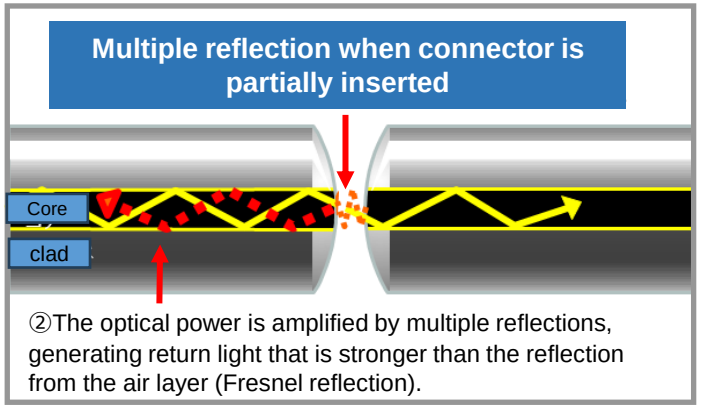
Special case: deteriorate optical characteristics

◆ Optical connector partially inserted

If the optical connector is not inserted all the way, it will be left "half-inserted," causing multiple reflections in the air space between the end faces.



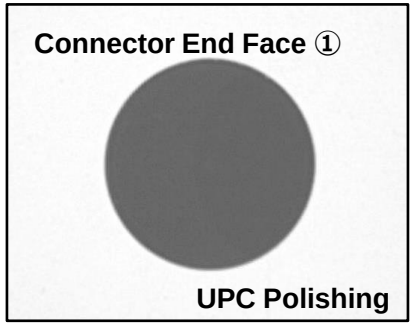
Insertion Loss [dB]	Return Loss[dB]
0.14	13.8

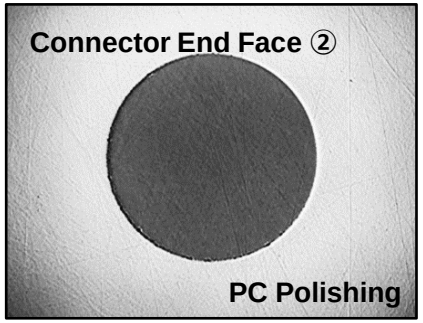


◆ The polished surface is of the old grade.

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

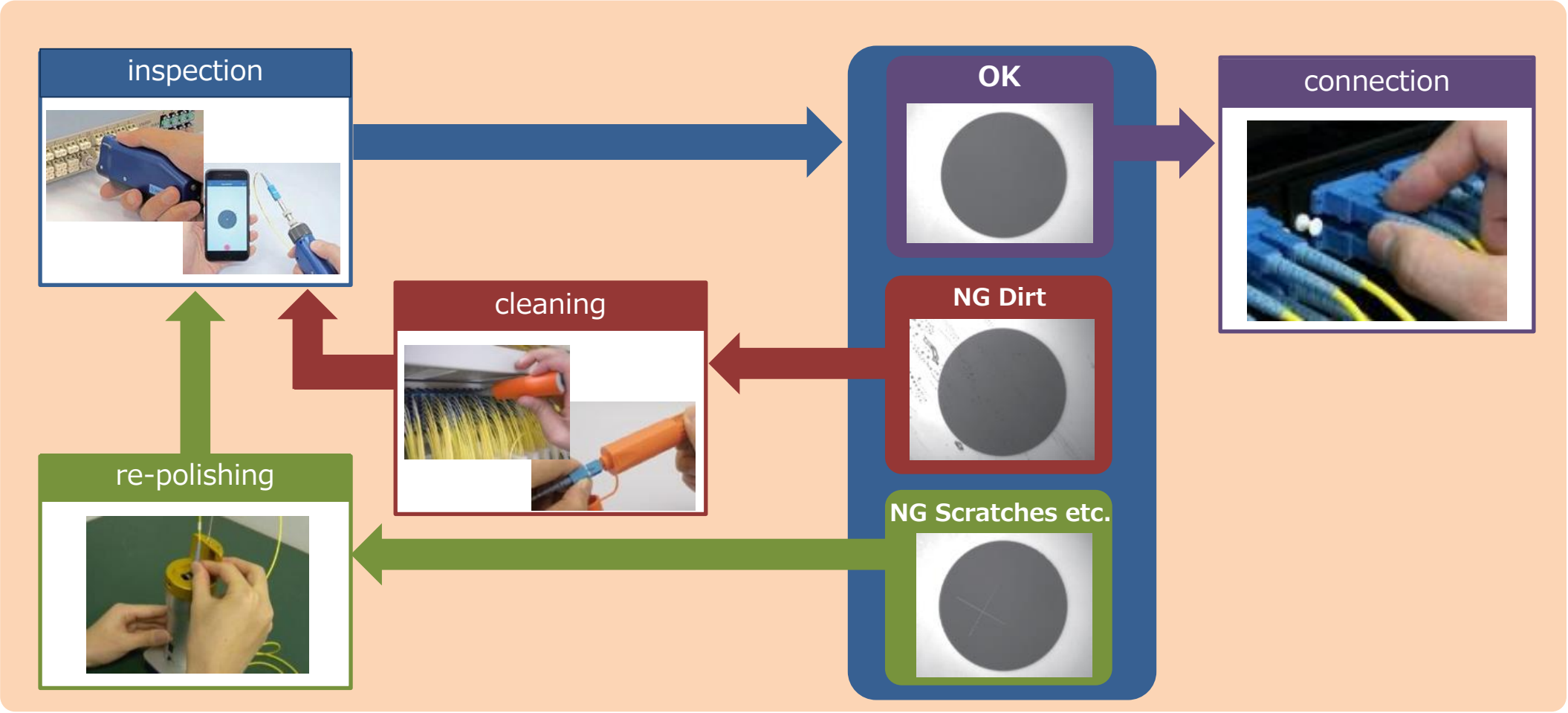




Please note that insertion loss (IL) may not be a problem and may not be detected just by measuring the optical power level.

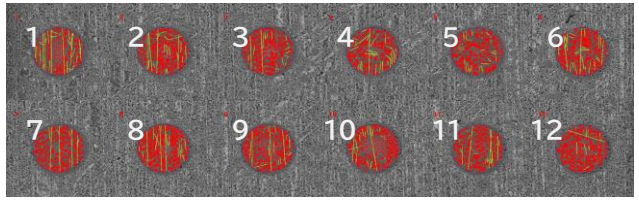
Recommended flow for connecting optical connectors

- By inspecting the end face before connecting, problems caused by dirty end faces can be prevented.
- Identifies the cause of trouble in optical connector connections by visually checking for scratches and dirt on the end face.



The difference in cleaning performance between manufacturers

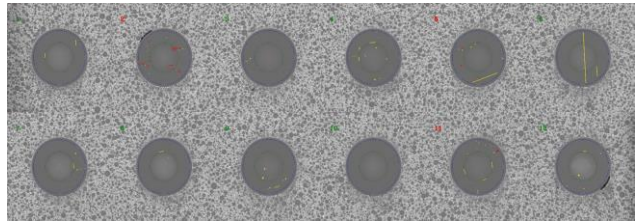
- The performance of optical connector tools varies widely from manufacturers.
- When selecting a tool, it is important to look at performance, not just price.
- Especially multi fiber connectors such as MPO and MMC, it needs to clean all fibers at once.



Heavy-dirty MPO connector

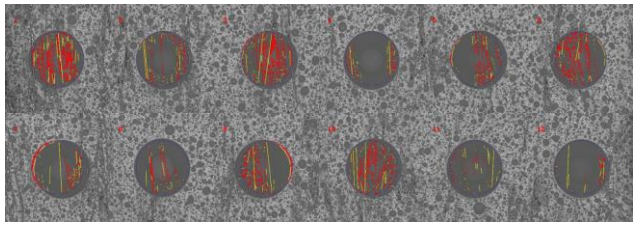
Cleaning

Cleaner A



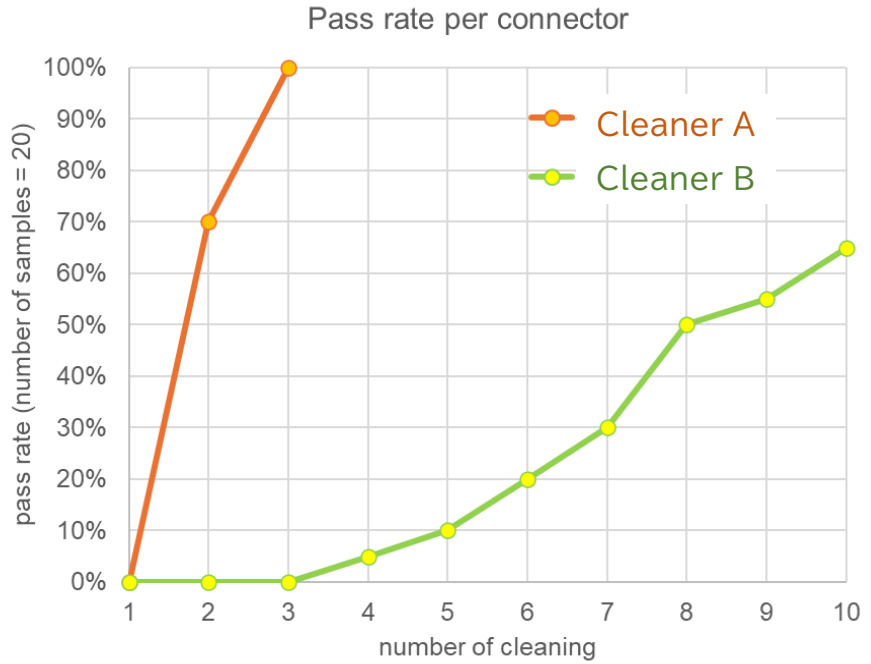
Good!

Cleaner B



Bad...

※The red color indicate contamination.



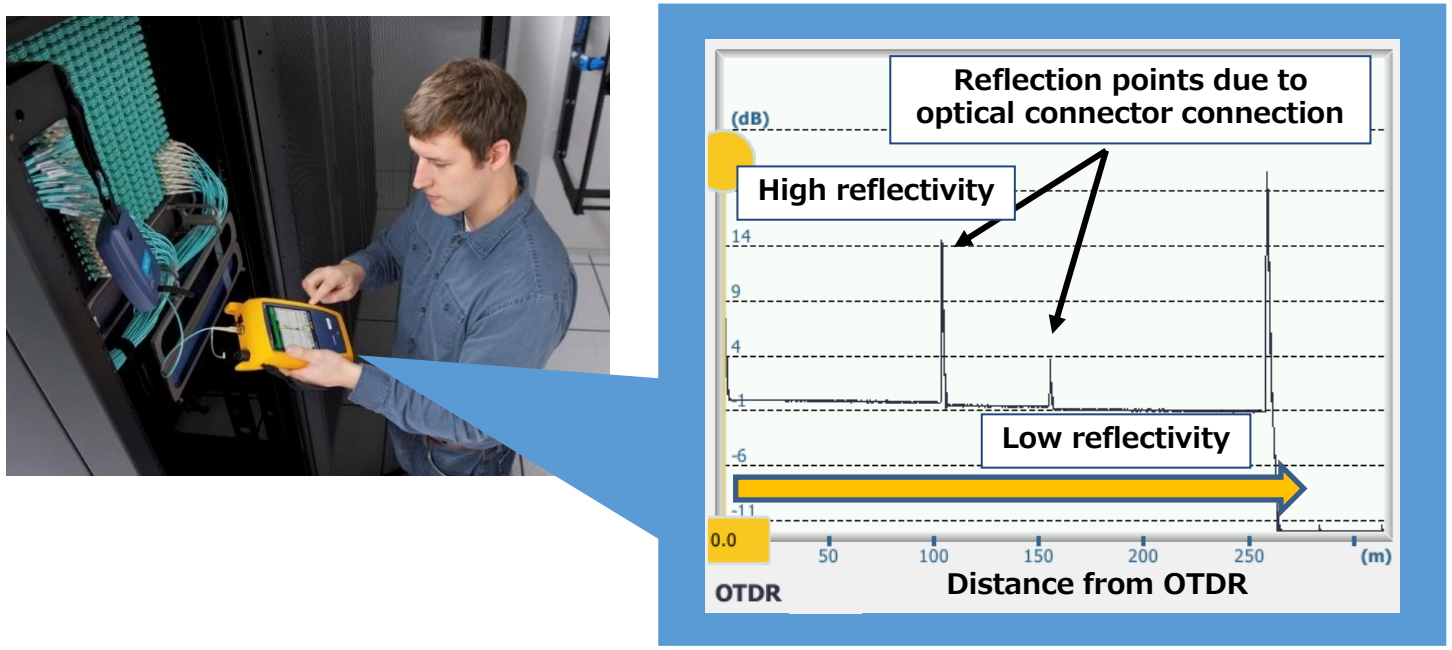
Cleaner A can clean all fibers within twice

Cleaner B need to clean 10 times to reach 70%
This means that 30% of connectors will require more than 10 cleanings.

Checking the transmission line using OTDR

◆ **OTDR is effective for measuring return loss.**

In addition to measuring the optical power level, we recommend performing OTDR measurement.



The height of the peak and the degree of drop in the line make it possible to check the degree of reflection or loss and its location.

Source : Fluke Networks

Conclusion

Key take away

◆ Multiple reflections caused the communication error and determine the amount of return loss.
⇒ Pay attention when constructing a network as Optical fiber transmission paths with many connections are more likely to have multiple reflections

◆ In the future high-speed communication environment, optical fiber transmission lines will require more stringent optical characteristics
⇒We recommend NOT only measuring the optical power level but also performing OTDR measurement.
⇒First, clean the optical connector end face. We also recommend end face inspection in important areas.

“Do not wipe optical connectors with your tie!”

Thank you

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