25 Gb/s transmission over harsh environment automotive grade GI-POF

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Third-party testing cooperation
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Introduction

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Below are action items to discuss for automotive grade GI-POF specifications.
This contribution shows results of checked items.

Item	method	Wave length	frequency response	Attenuation
Low temperature	-40 ºC	850 nm	✓	✓
		980 nm		
High temperature	105 ºC	850 nm	✓	✓
		980 nm		
High humid	85 ºC 85 % RH	850 nm		
		980 nm		
Macro bend	One turn around 10 mm diameter mandrel	850 nm	✓	✓
		980 nm		
Connection	Fiber misalignment	850 nm		
		980 nm		

- Time domain data transmission experiment (eye characteristic), in addition to frequency response measurement, was conducted.
- The measurement was carried out at Nagoya Institute of Technology.
- The measurement methods reported by Corning, OFS and KDPOF at the IEEE 802.3 OMEGA Study Group in January 2020 were referred.

Reference

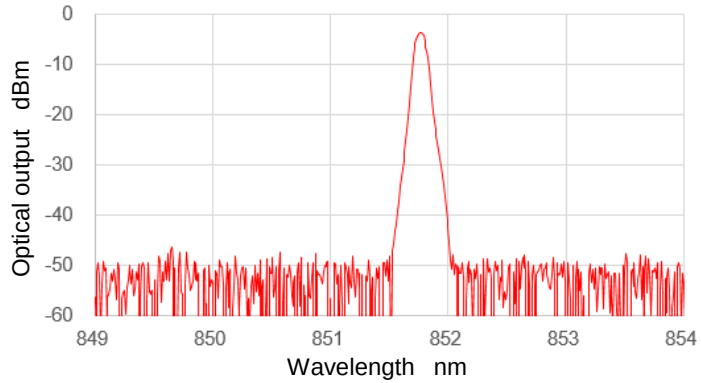
https://www.ieee802.org/3/OMEGA/public/jan_2020/perezaranda_OMEGA_02_0120_25G_Corning_fiber.pdf

https://www.ieee802.org/3/OMEGA/public/jan_2020/perezaranda_OMEGA_03_0120_25G_OFS_fiber.pdf

Frequency response (1/2)

- Vector Network Analyzer (VNA)
  Keysight “E5080B ENA Vector Network Analyzer”
  - 801 points linear sweep from 100 MHz to 40 GHz

- Reference Transmitter
  Keysight “81490A”
  - Used as a modulated laser light source connected to the VNA.
  - Wavelength: 850 nm, 35 GHzBW



- Lightwave Detector
  Keysight N4377-M40 40 GHz
  - Used for S21 response measurement with VNA.

Frequency response (2/2)

- Mode Controller
  Arden PHOTONICS LTD “MC-FC-50-N”
  - Mode controller in 50/125 um fiber with FC connectors.

- RF Cable
  JUNKOSHA “MWX342/B” (2.4 mm cable, 40.0 GHz)
  - Used to connect Reference Transmitter and VNA.

- Thermostatic chamber
  Espec “SH642”
  - -40 to 150 ºC

Test setup for frequency response

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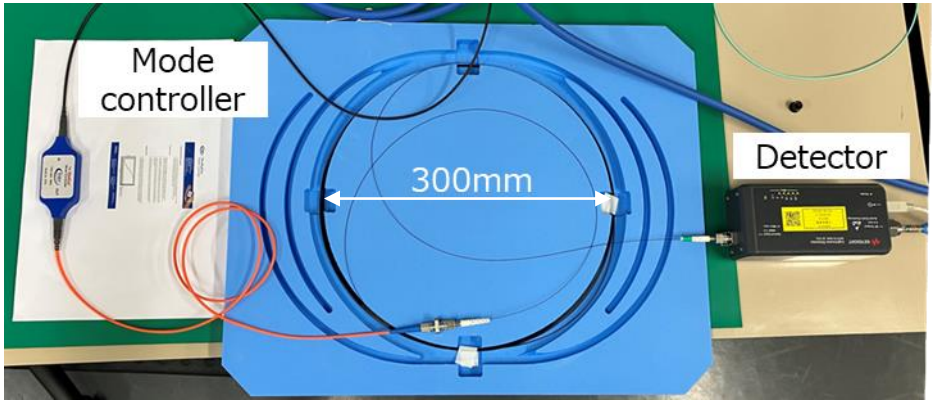
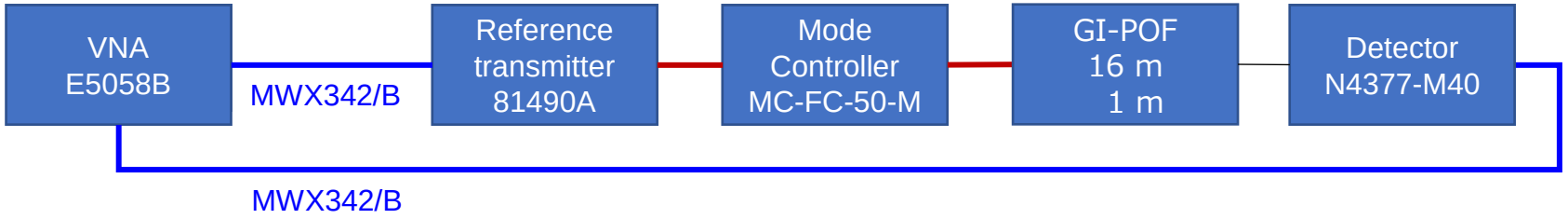
Basic Setup





Test setup for frequency response

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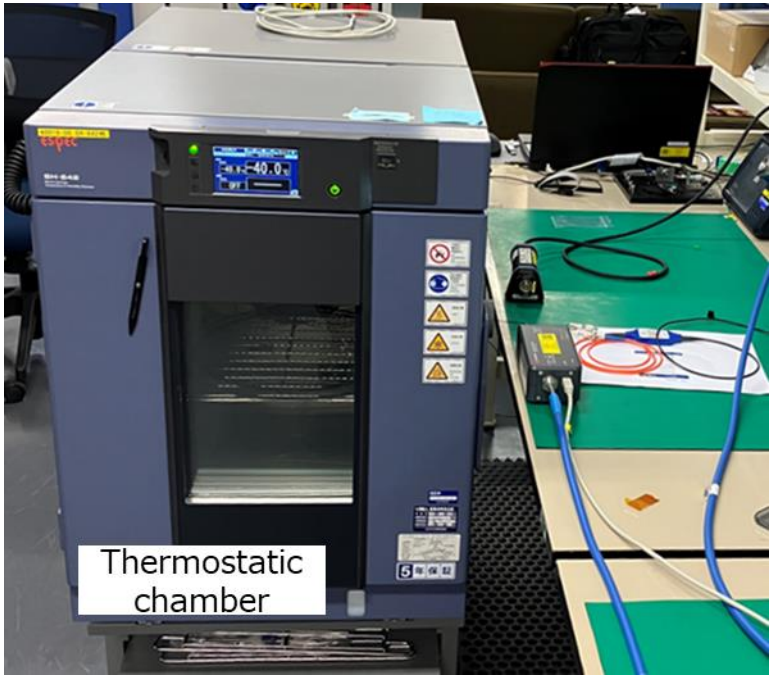
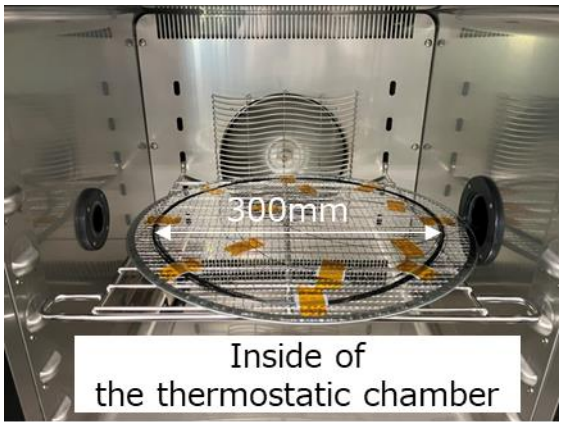
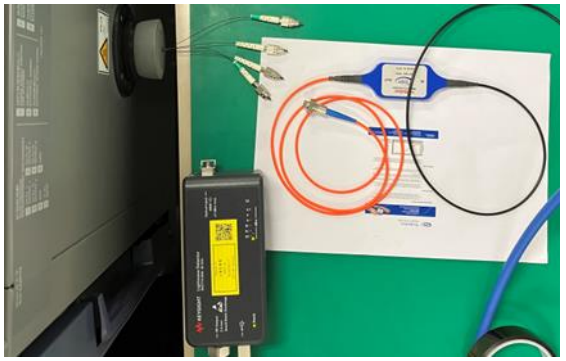
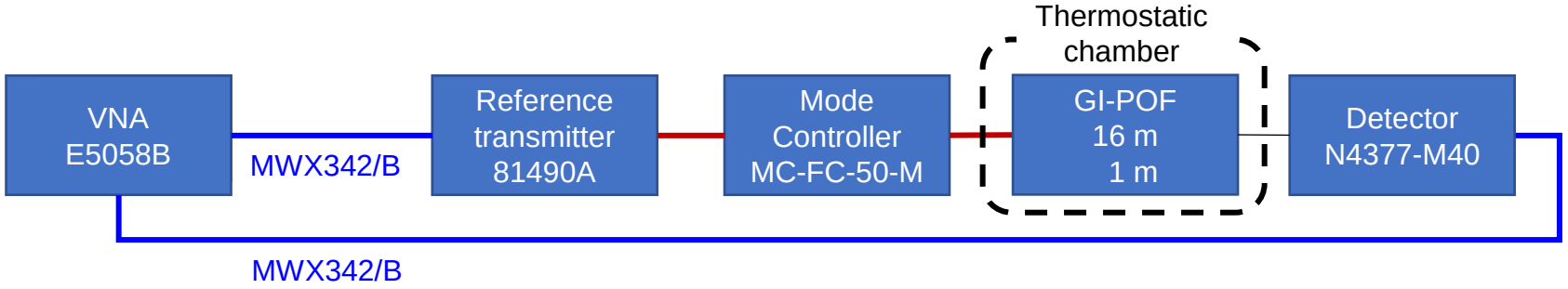
Temperature dependence evaluation









Test setup for frequency response

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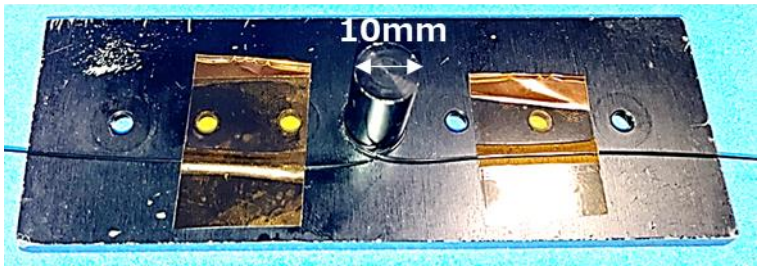
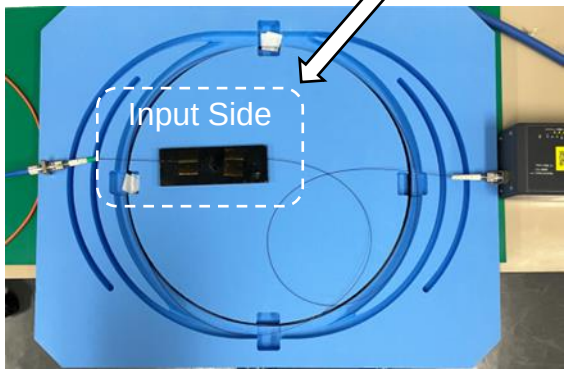
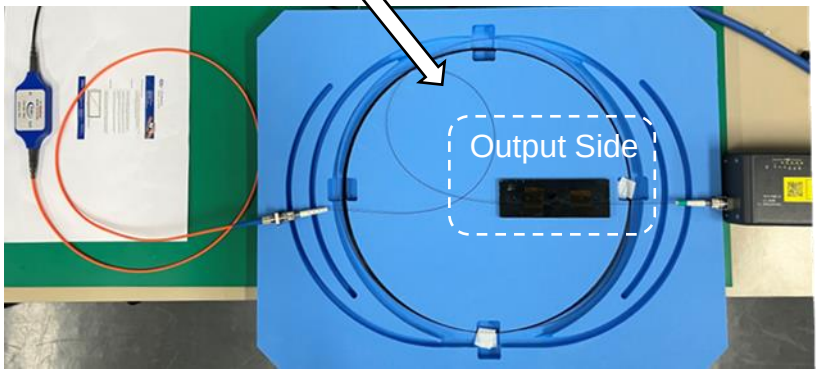
Macro bend evaluation

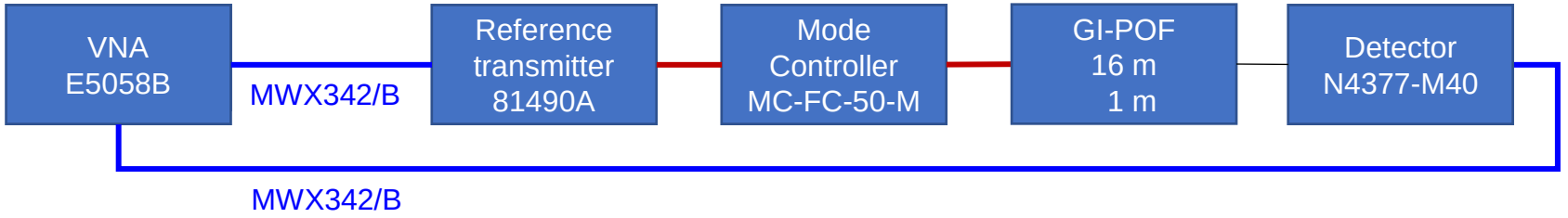


Fiber Bending tool





GI-POF 16m with bend



Time-domain data transmission (Eye characterization) 1/2

- Arbitrary Waveform Generator (AWG)
  Keysight “M8196A (92 GSa/s, 32 GHz)”
  - Used to generate time-domain RF signal that drives the VCSEL
  - Capability of real-time digital signal processing with 8 bits DAC
  - Used to provide symbol clock to oscilloscope

- Sampling Oscilloscope (DCA)
  Keysight “N1092C DCA-M (One optical and two electrical channels)”
  - Used to make the time-domain characterization with periodic arbitrary signal generated by VCSEL.

- Power-monitored attenuator for multimode fiber applications(PMA)
  Keysight “N7766A”

- Source measure unit (SMU)
  Keysight “B2902A Precision source/measure unit”
  - Bias current to VCSEL

Equipment & Software

Time-domain data transmission (Eye characterization) 2/2

- Broadband Bias-Tee
  SHF Communication Technologies AG “SHF BT65R (50 kHz to 65 GHz)”
  - Used to combine bias current with RF signal from AWG

- Transmitter module
  Vertically Integrated Systems “VIS-VCSEL (V)850 nm(Up to 50 Gb/s)”
  - Ultrahigh-speed transmitter module for test purpose with integrated 850 nm VCSEL fiber coupled to an OM3 multimode fiber(1 m) for optical output.

- RF Cable
  JUNKOSHA “MWX251/B” (2.4 mm cable, 50.0 GHz)
  - Used to connect bias tee and AWG.
  - Used to connect DAC and AWG

- Keysight N1010A FlexDCA Sampling Oscilloscope Software

Test setups

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Setup for time-domain date transmission(eye characterization)

SMU B2902A — 2.36 V, 4.0 mA

AWG M8196A — Data Out CH1+ — MWX251/B — Bias tee SHF BT65R — VCSEL VIS-VCSEL — OM3 — GI-POF 16 m — OM3 — PMA N7766A — OM3 — DCA N1092C

Data Out CH1 -

Data Out CH4+

MWX251/B

MWX251/B

Chan. B

Clock

The target specification of GI-POF

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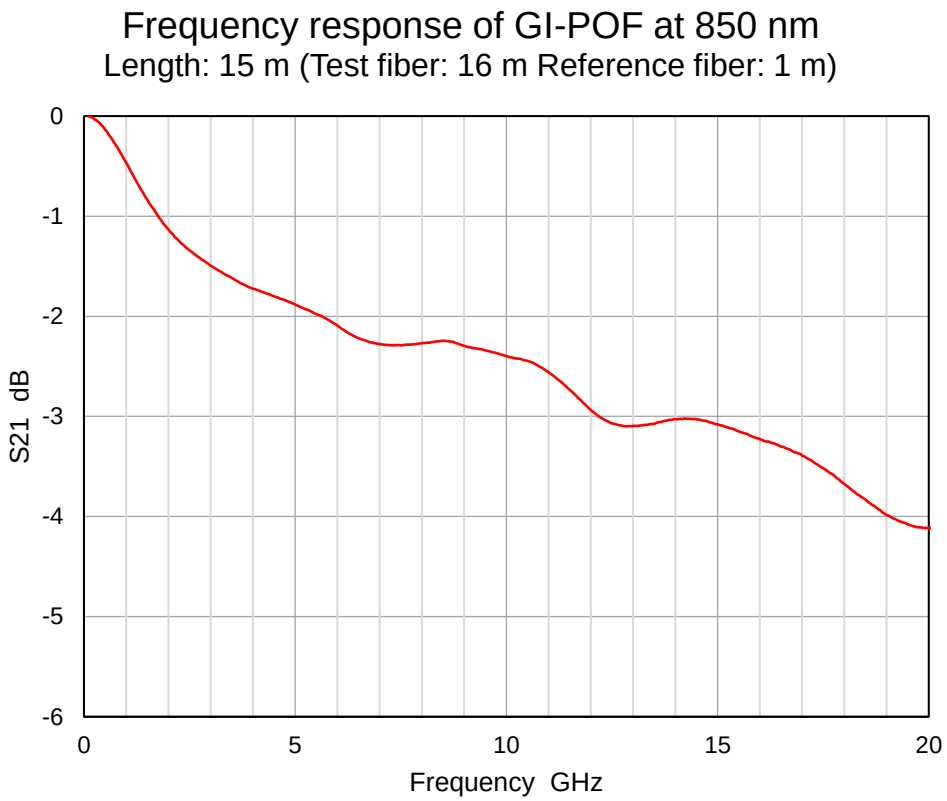
IEC A4j Proposal

Attribute	Unit	Limit
Cladding diameter	um	490 +/- 5
Cladding non-circularity	%	≤ 4
Core-cladding concentricity error	um	≤ 6
Core diameter	um	55 +/- 5
Core non-circularity	%	≤ 6
Length	km	(see 4.1)
Numerical aperture	-	0.24 +/- 0,025
Attenuation	dB/100 m	10
Minimum modal bandwidth	GHz 15 m	20

Frequency response of 15 m GI-POF
Room temperature(25+/-5 ºC)
measurements at 850 nm

Frequency response



The graph on the left is an example of the frequency response of GI-POF.
(Test fiber:16 m Reference fiber:1 m)

The frequency response of GI-POF has a downwardly convex profile, which is different from the frequency response profile of GI-GOF.

AGC evaluated the 25 Gb/s eye diagram of this test fiber and confirmed that it can be used for 25 Gb/s data communication for 15 m.

25 Gb/s Experiments of time-domain date transmission at 850 nm

Eye diagram 25 Gb/s

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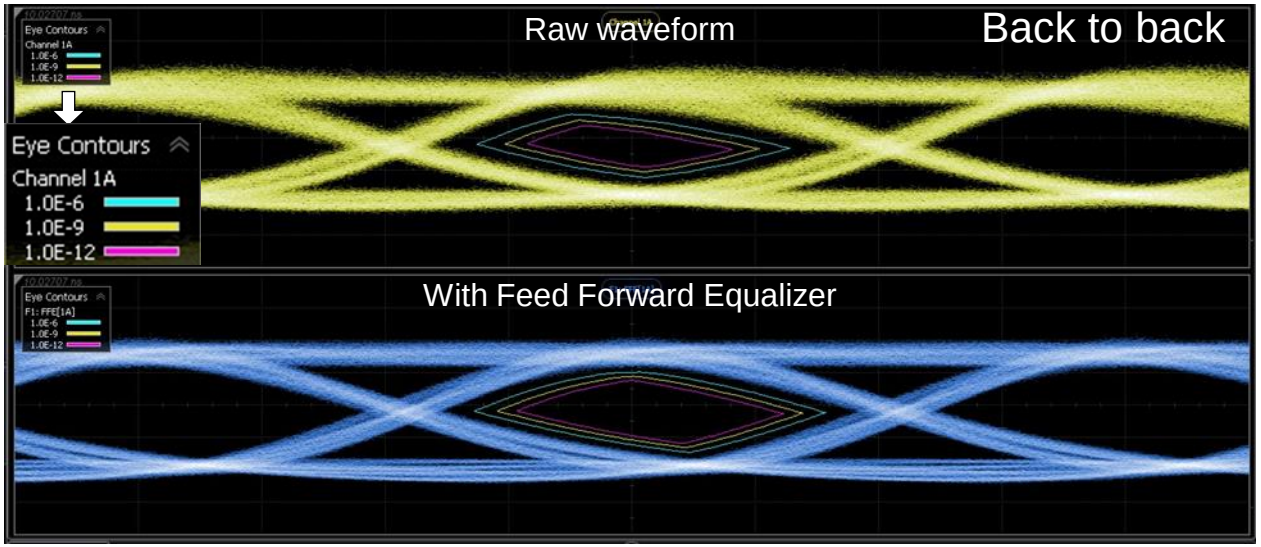
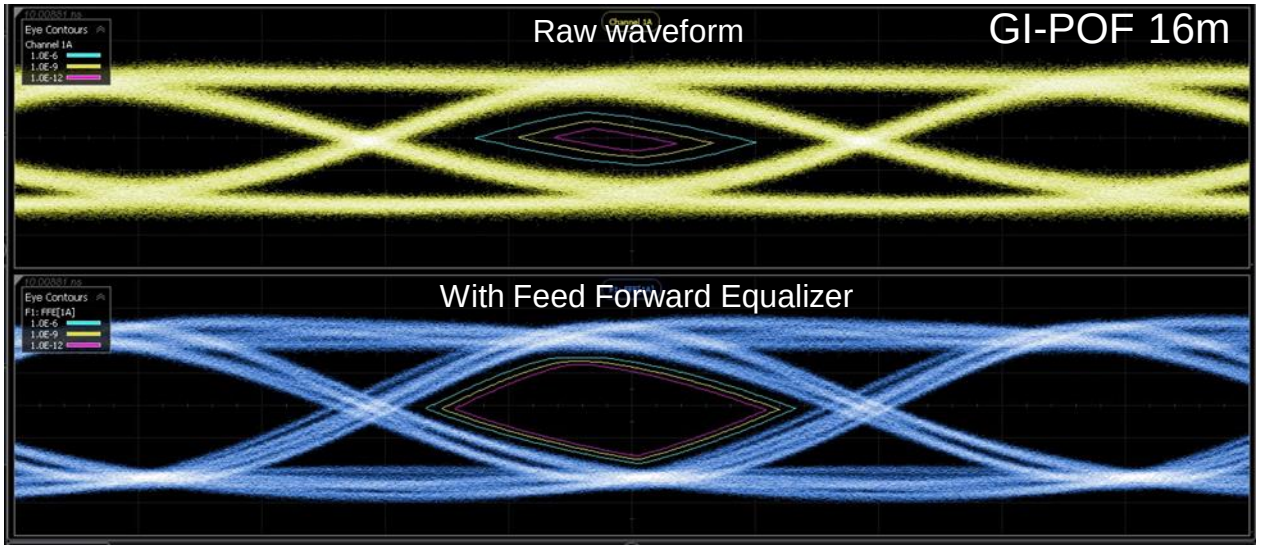
Time-domain data transmission

- Signal type: NRZ
- Bias current: 4 mA
- Baud-rate: 26.5625 GBd (Depend on IEEE Std 802.3cz PHY type 25 GBase-AU)
- DCA configuration:
  Trace 1: Raw waveform
  Trace 2: with Feed Forward Equalizer(FFE)

Eye diagram 25 Gb/s at room temperature





The colored box in the eye diagram indicates the approximate value of the bit error rate calculated from the eye diagram shape.

The eye diagram of GI-POF seems quite similar comparing with that of “Back to back”.

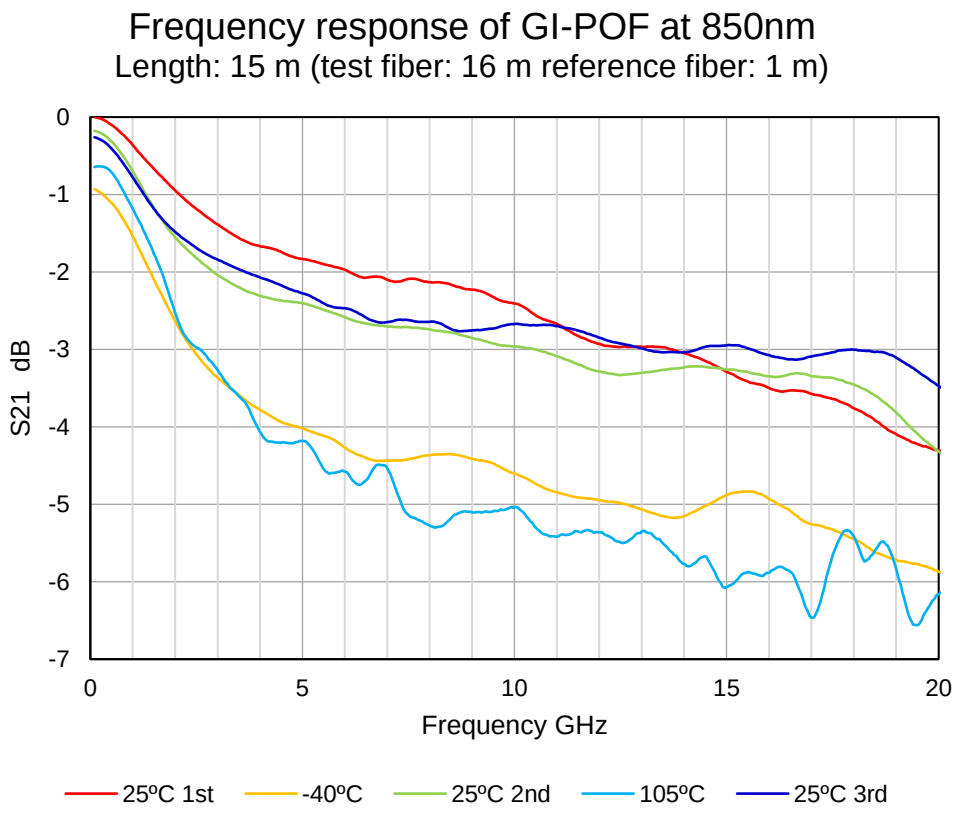
Particularly, by using FFE, the shape of the eye diagram looks almost the same.

AGC believes that fiber with this frequency response can be used for 25 Gb/s communication for 15 m.

Note:
The BERs displayed in eye opening are estimated by the Keysight eye analysis tool and is not an accurate statistical data.

Frequency response of 15 m GI-POF
at -40, 25, 105 ºC at 850 nm

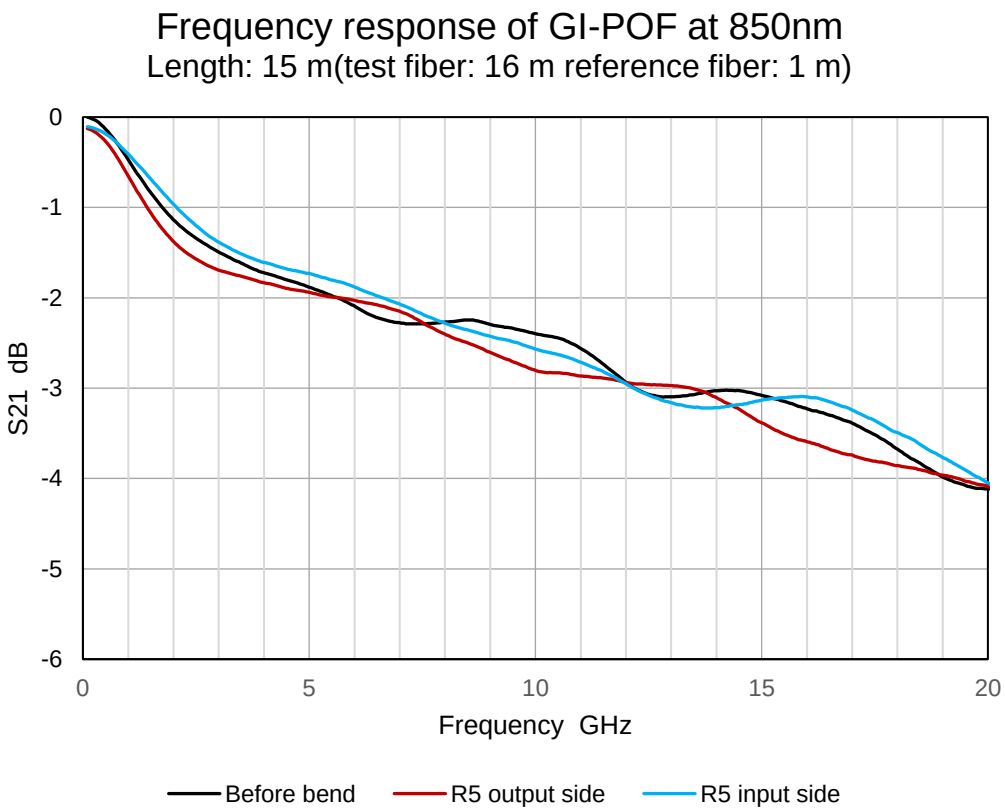
Frequency response at -40, 105 ºC



- Temperature Profile
  25 ºC 1st-> -40 ºC ->(25 ºC 2nd) ->
  105 ºC -> 25 ºC 3rd
- Soaking time
  15 min except 25 ºC 2nd(no soaking time)
- Normalizing
  Normalizing was performed using 25 ºC 1st data.
- Result
  - The insertion loss at 100 MHz increases by about 1 dB at high or low temperature.
  - The frequency response at 105 ºC has a little more noise. The cause is fiber end termination method, not the fiber characteristics.
  - Excluding the noise, -6 dB bandwidth is 20 GHz or higher for all temperatures.

Frequency response of 15 m GI-POF
in R = 5 mm Macro Bend.

Frequency response in R = 5 mm Macro Bend



- Normalizing
  Normalizing was performed using data before bending.
- Bending loss
  After bending, the insertion loss at 100 MHz increased from 0.11 dB to 0.13 dB.
  Bending loss is sufficiently small.
- Result
  - Bending loss of R = 5 mm is sufficiently small.
  - There is almost no difference in the frequency response profile before and after bending.

Conclusion

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- Frequency response profile shape at 850 nm
  Though the profile shape of GI-POF is different from that of OM3,
  the bandwidth is sufficient for 25 Gb/s for 15 m data transmission.

- The influence of temperature at 850 nm
  - At -40 ºC and 105 ºC, the insertion loss at 100 MHz increases by about 1 dB.
  - At 105 ºC, noise of frequency response is increase.
  - Two phenomena above are caused by fiber end termination method, not by the fiber characteristics.
  - Excluding the noise, -6 dB bandwidth is 20 GHz or higher for all temperatures.

- The influence of macro bend(R = 5 mm) at 850 nm
  - The influence on attenuation can be disregarded.
  - The influence on frequency response can be disregarded.

Thank you for your attention.