Update on the temperature dependence of the frequency response for 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	✓ (about reproducibility)	Presented on 13th Sep
		980 nm		
High temperature	105 ºC	850 nm	✓ (about reproducibility)	Presented on 13th Sep
		980 nm		
High humid	85 ºC 85 % RH	850 nm	✓	
		980 nm		
Macro bend	One turn around 10 mm diameter mandrel	850 nm	✓	Presented on 13th Sep
		980 nm		
Connection	Fiber misalignment	850 nm	✓	
		980 nm		

- I will explain the cause of less stability of frequency response measurement at 105ºC.

- 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

Measurement reproducibility in frequency response measurement of GI-POF

Measurement reproductivity in frequency response measurement for automotive grade GI-POF

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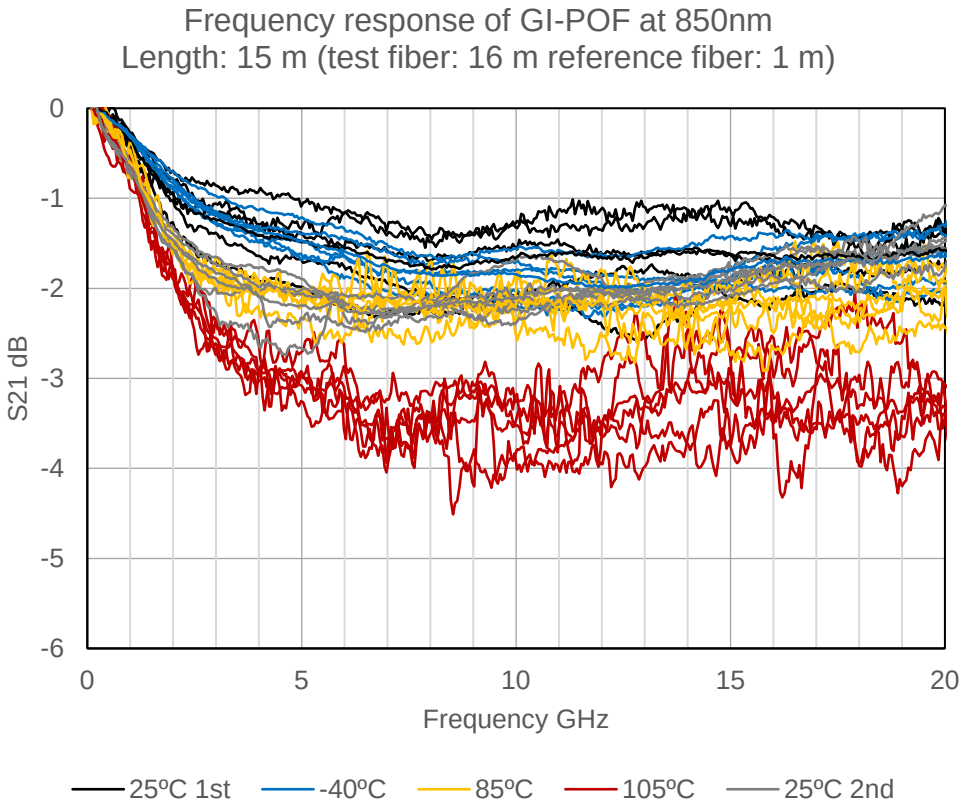
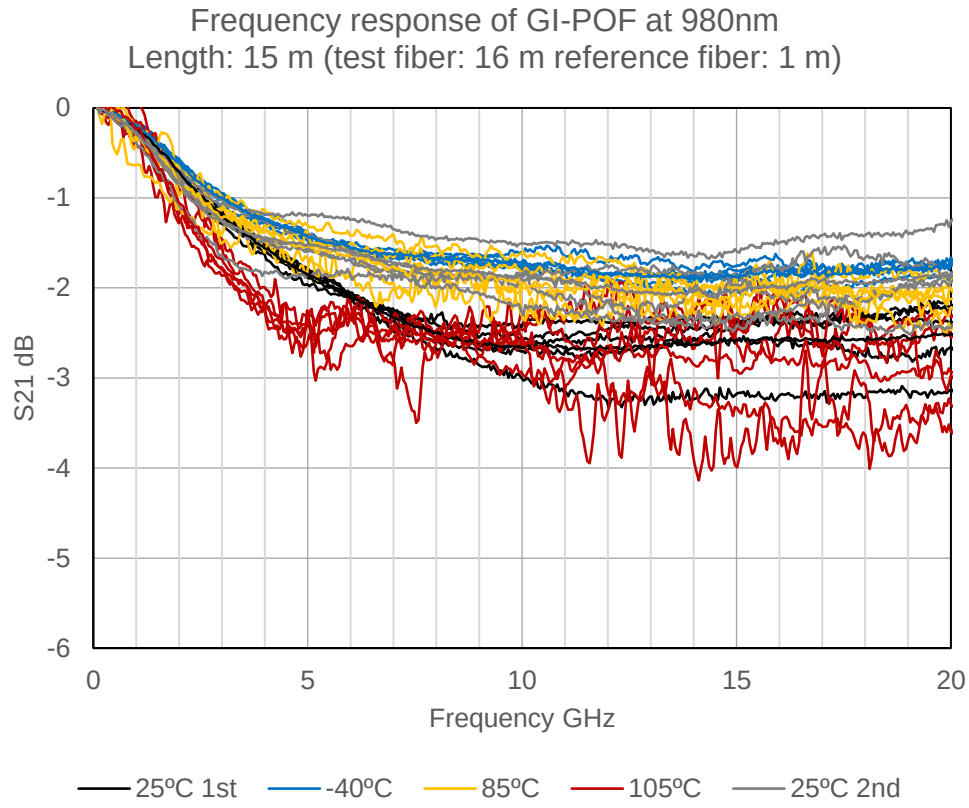
The graphs below were shown at the last ad hoc meeting on November 1st.
The poor reproducibility of the measurement values, especially at 105°C, was pointed out as a problem.

I evaluated the measurement system at first.
And I evaluated the characteristics of the sample used for this test.





Test setup for frequency response

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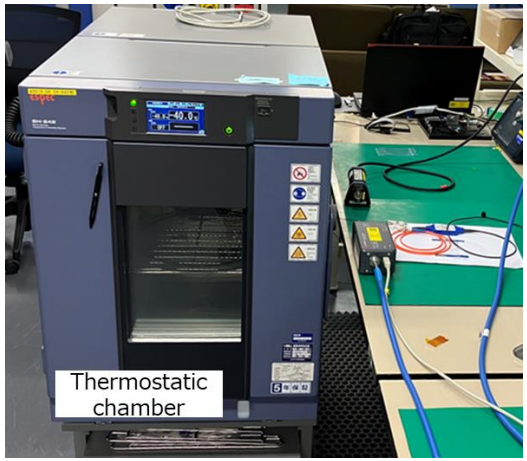
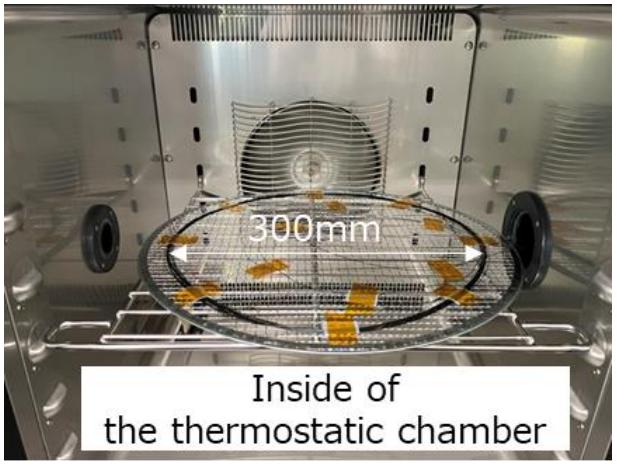
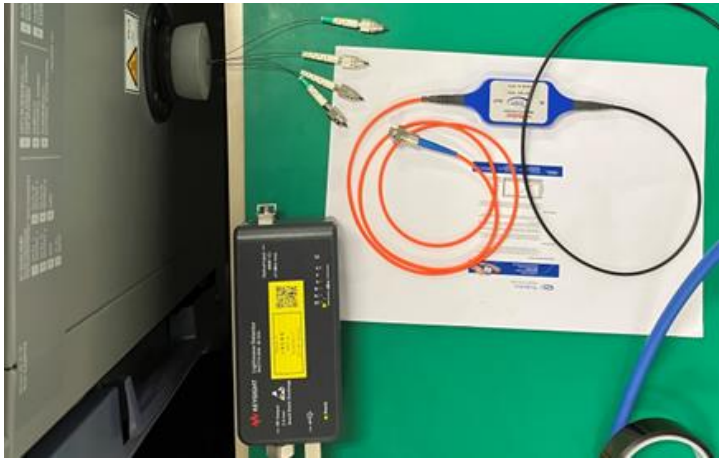
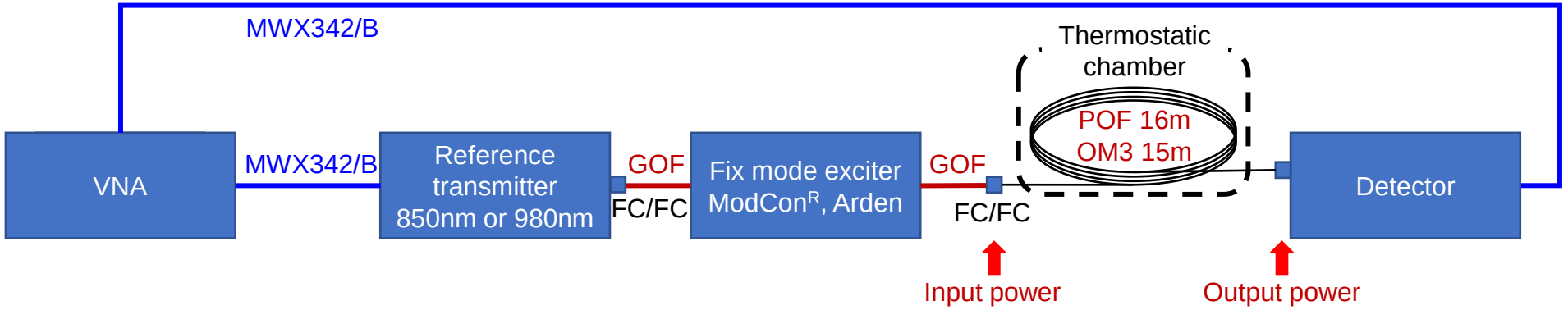
Temperature dependence evaluation





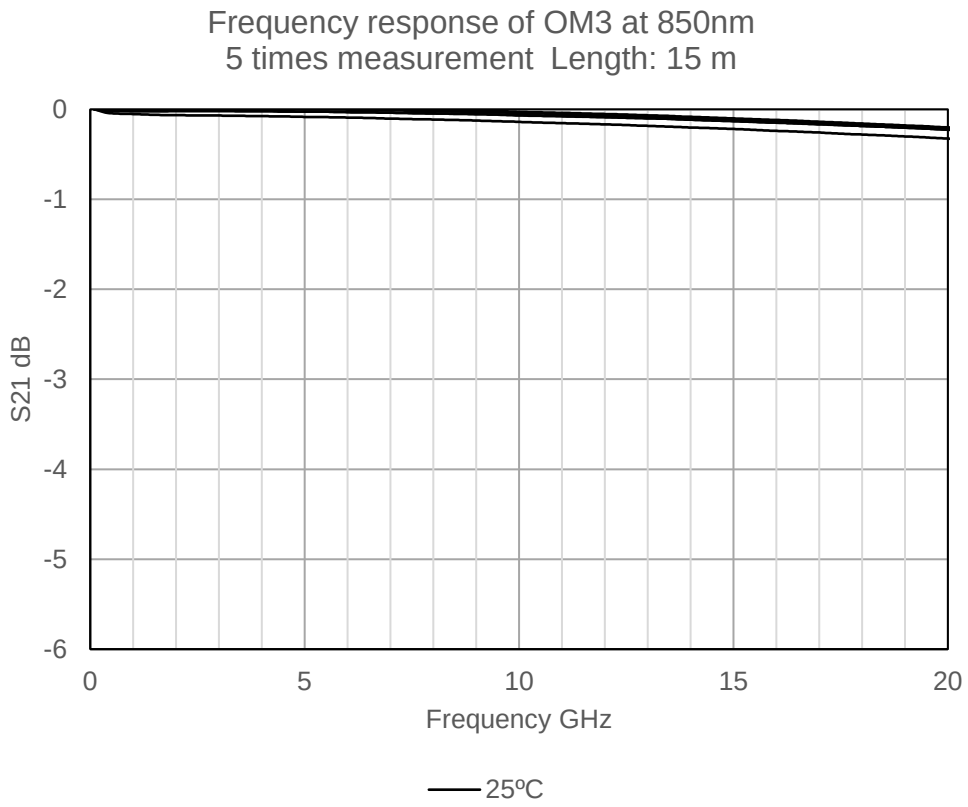


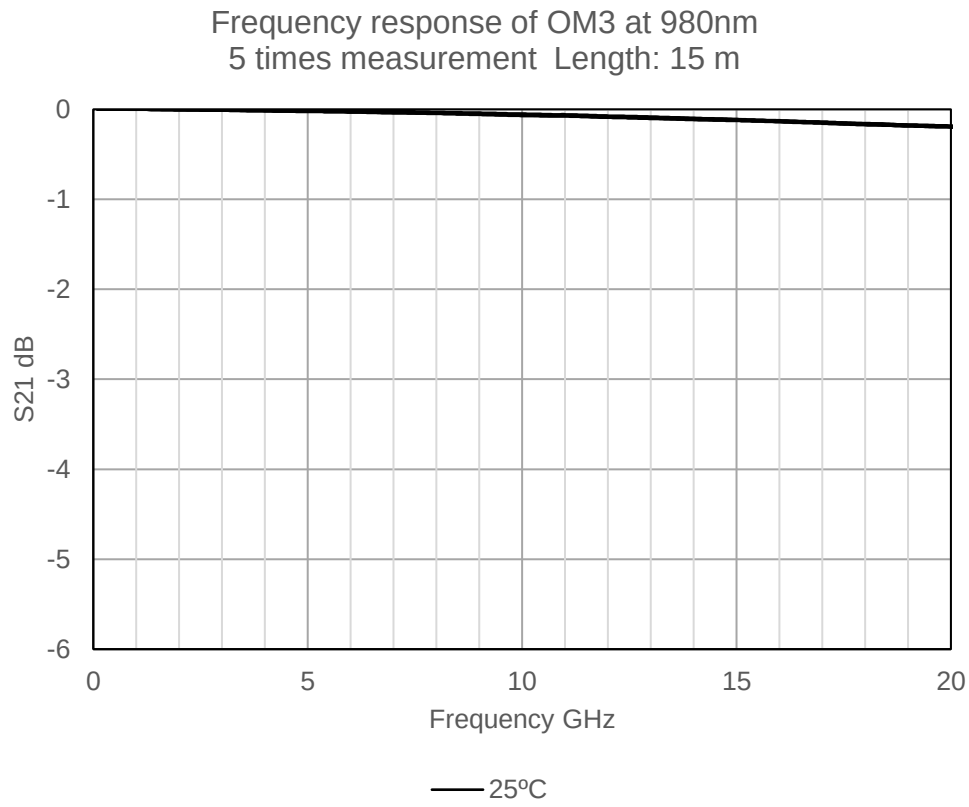


I evaluated the reproducibility of the frequency response measurement with OM3(15m) for reference. Furthermore, I measured the input and output light intensity of OM3 and POF.

Measurement reproductivity in frequency response measurement for automotive grade GI-POF

Unlike POF, OM3 has very stable measurement reproducibility even if measured with the same measurement system.



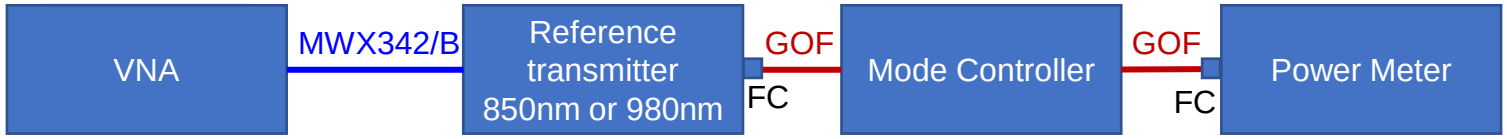


Insertion loss of GIMMFs

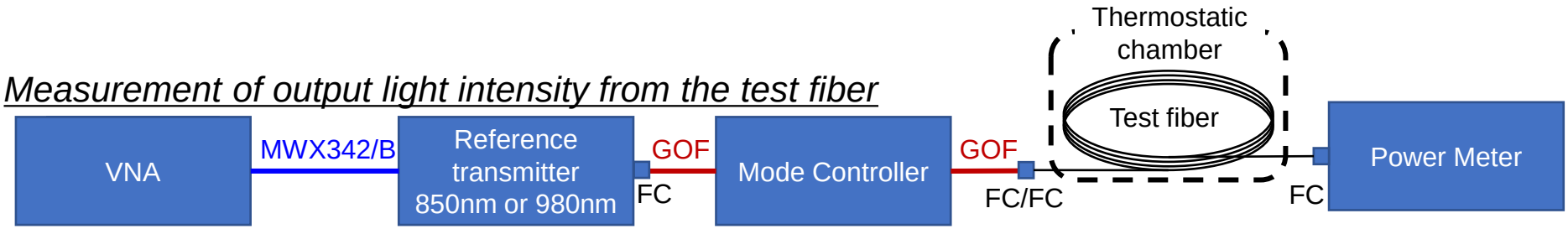
The insertion loss (incl connection and the attenuation) of POF(16m) are higher than those of OM3(15m). But light intensity is sufficient.

Based on the two facts stated previously, there is no problem with the measurement system.

Measurement of output light intensity from the mode controller

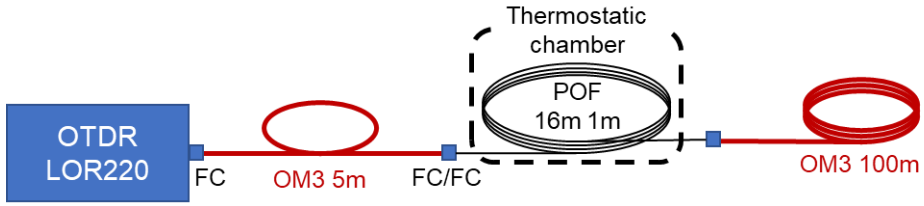


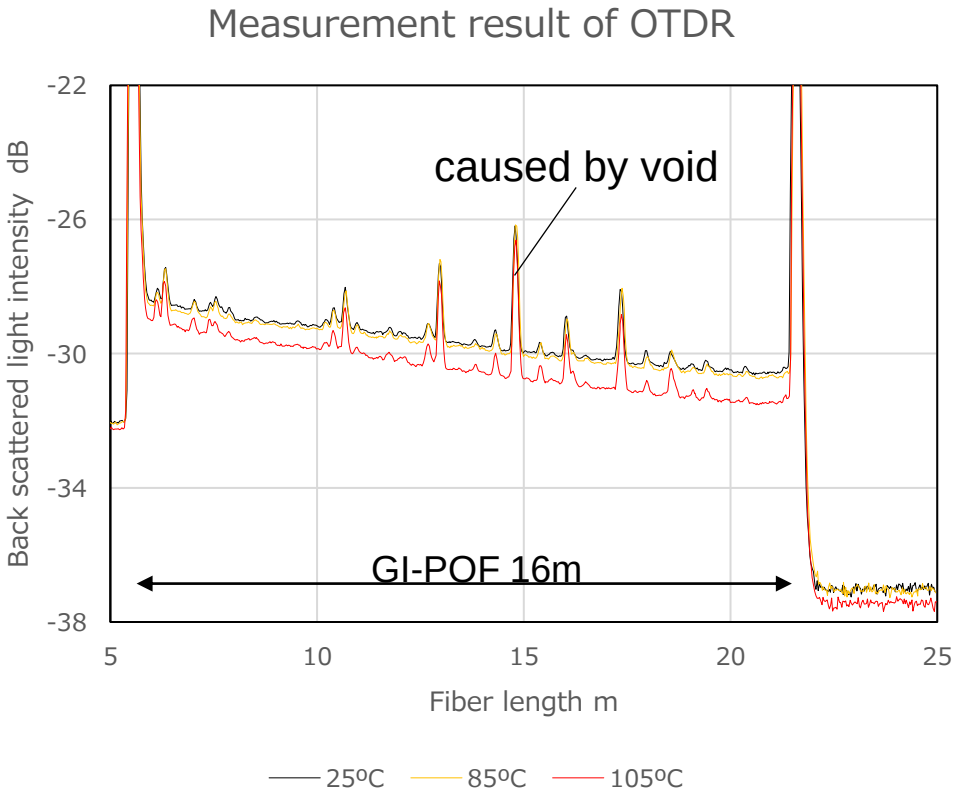
Measurement of output light intensity from the test fiber



Test fiber	Temp.	Insertion loss	
		850nm	980nm
OM3 15m	25ºC	0.09dB	0.02dB
GI-POF (A4j) 16m	25ºC	1.17dB	1.13dB
	-40ºC	1.15dB	1.02dB
	85ºC	1.02dB	1.34dB
	105ºC	1.06dB	1.55dB
	25ºC	1.18dB	1.36dB

Measurement result of OTDR (measured by AGC)





Since the most likely causes of noise are backscattered light and forward scattered light, I re-checked optical time-domain reflection.

The transmission loss of the concerned fiber was 140 dB/km at 25 °C by OTDR, which exceeded the target specification of 100 dB/km.

Normally, there are no such noticeable spikes in the graph. The spikes indicate the presence of large type of micro voids that scatter light.

Then OTDR measurements were conducted at 85 and 105 °C. The intensity of the backscattered light remains almost constant in the temperature range of 25 °C to 85 °C, but it changes significantly above 85 °C.

As the temperature rises and approaching to the glass transition temperature, the expansion rate increases significantly. The modulus of elasticity also decrease. As a result, micro voids expand. The scattering light and the transmission losses increase accordingly.

Therefor the rapid deterioration of measurement reproducibility is considered to be caused by micro voids in the fiber.

Comparison with normal fibers within the transmission loss specification.

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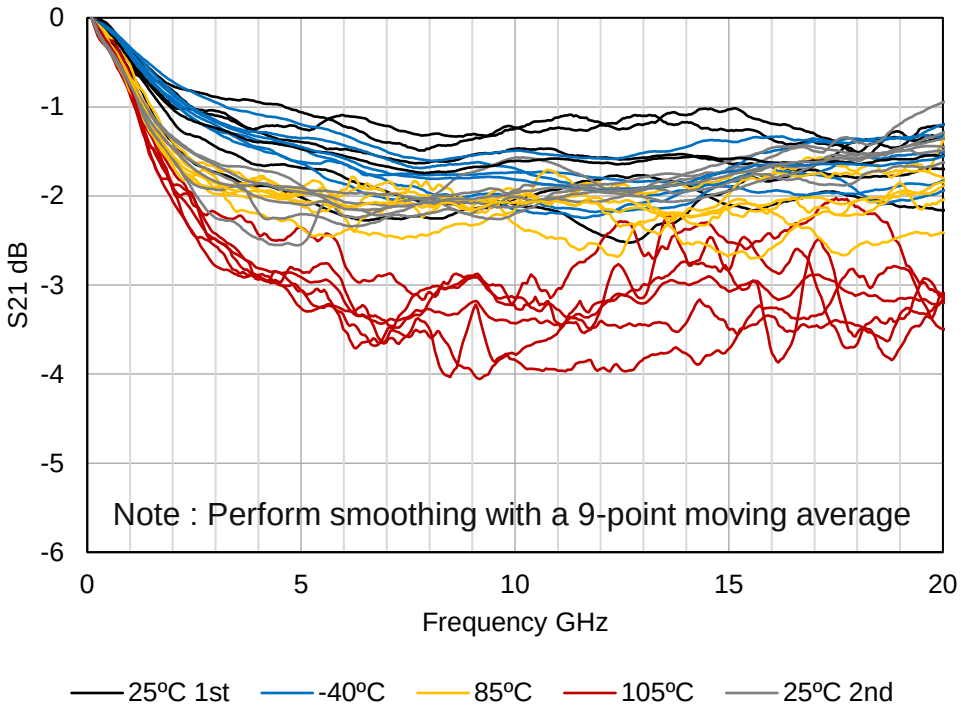
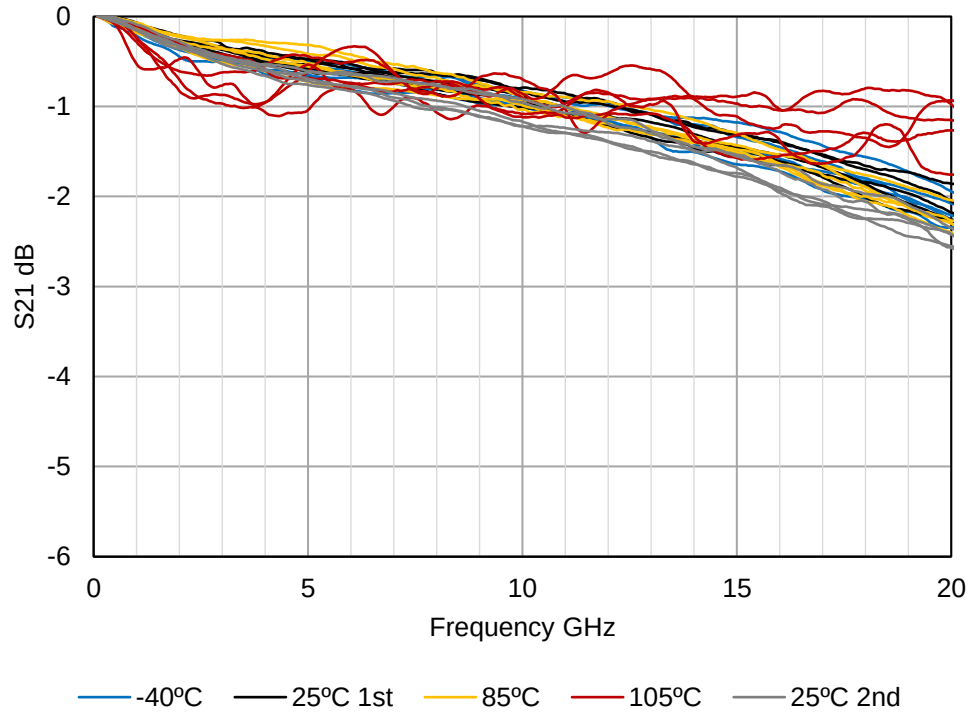
Right graph below shows the frequency response characteristics of the fibers within the transmission loss specification.

Frequency response of GI-POF at 850nm
Transmission loss:140dB/km Length: 15 m



Frequency response of GI-POF at 850nm
Transmission loss:70dB/km Length: 15 m



Comparison with normal fibers within the transmission loss specification.

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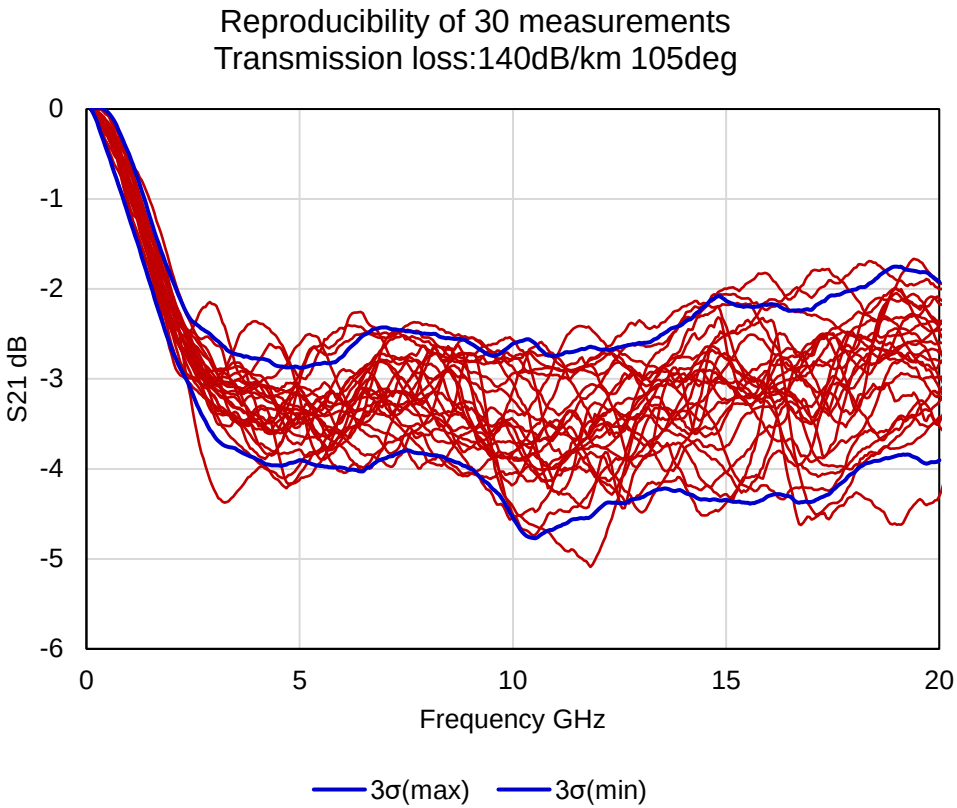
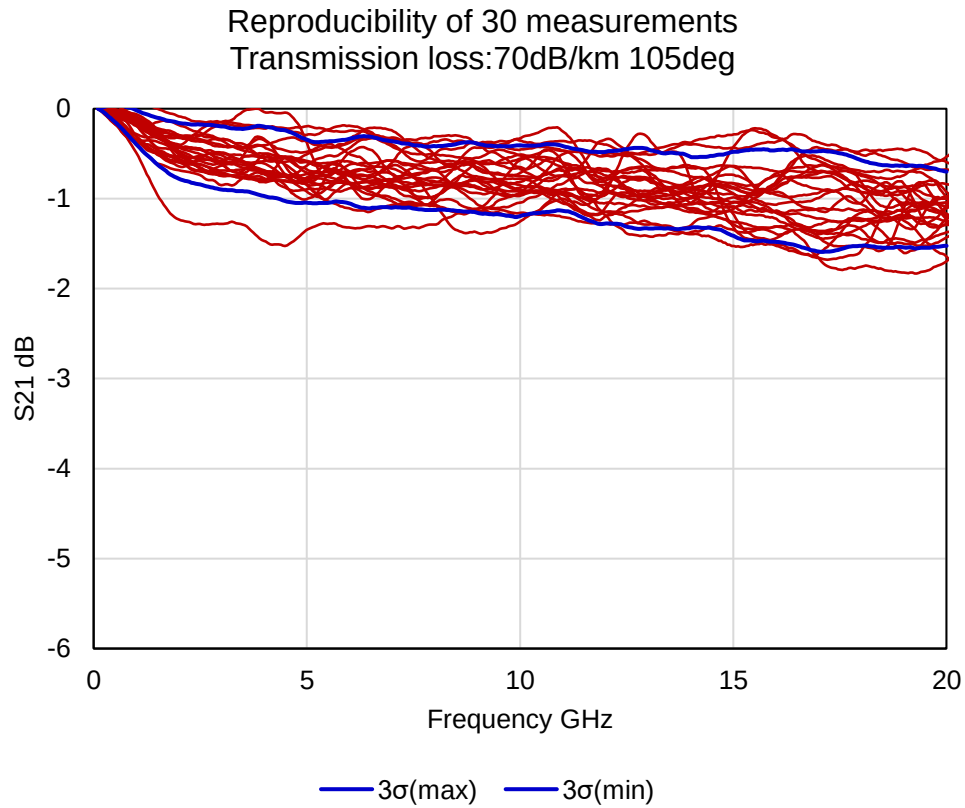
The following graph shows the plots of 30 measurements of frequency response at 105°C.
The variation in frequency response has been almost halved.

Since reducing micro voids from GI-POF is very difficult, it is hard to completely eliminate the variation in measurement reproducibility. However, I don't think that the initial characteristics will continuously deteriorate because it is a physical reversible change.





Eye diagram 25 Gb/s at 105°C

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

The upper figure shows the eye diagram of the sample which is shown in the left graph on the previous page. Although it has wide variation in frequency response, it is possible to achieve a bit error rate of 10^{-12} with an FFE filter,

The lower figure shows the eye diagram of the sample which is shown in the right graph on the previous page. In this case, it is possible to achieve a bit error rate of 10^{-12} without FFE filter.

I believe both of fiber can be used.

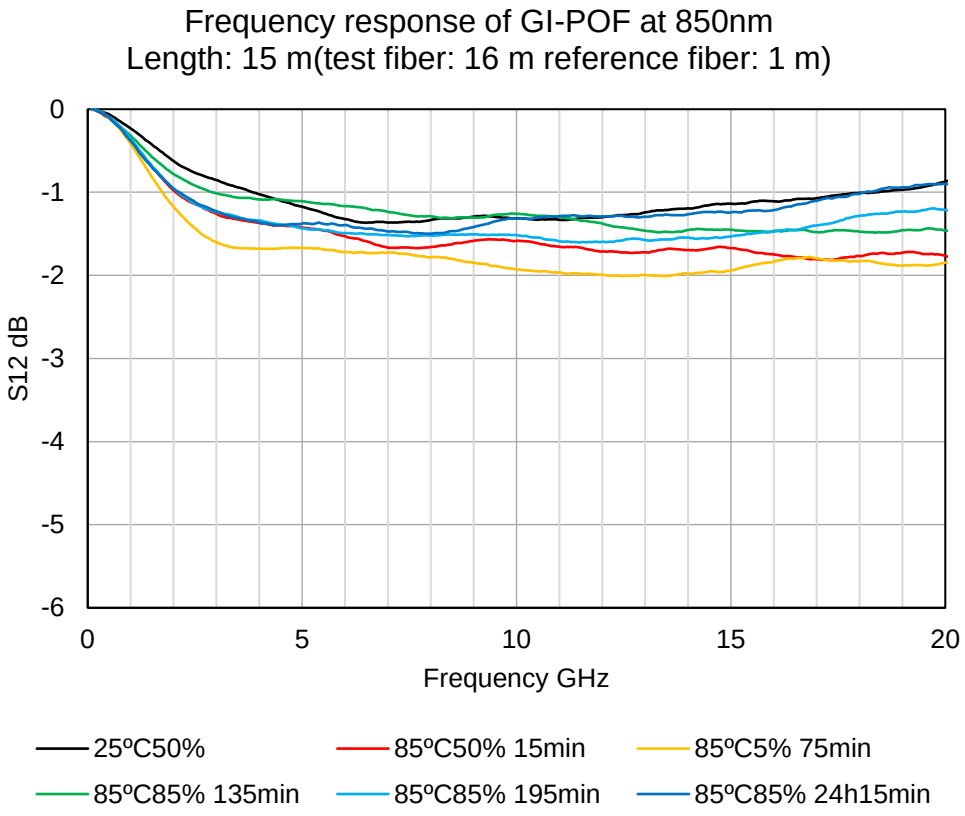
Note:
The BERs displayed in eye opening are estimated by the Keysight eye analysis tool and is not an accurate statistical data.

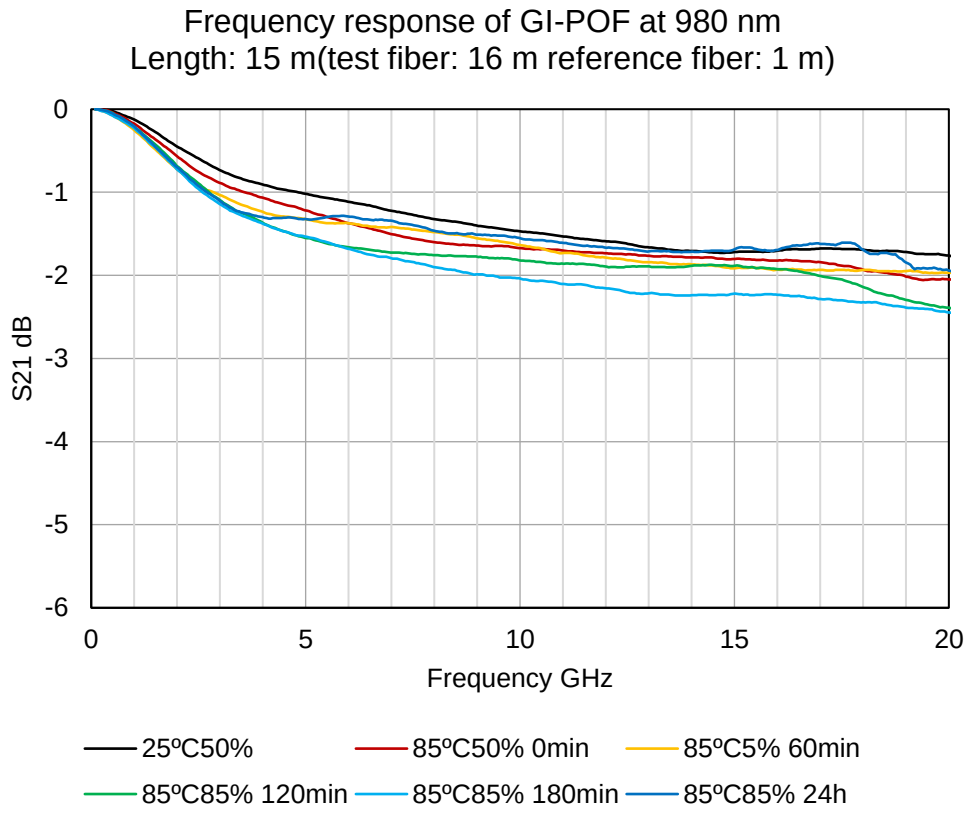
VCSEL used these measurement
VIS VM50-850M (25°C atmosphere operation)
wavelength: 850 nm
Bias current: 4mA

Impact assessment of 85ºC85%RH environment for frequency response of 15 m GI-POF

Frequency response at 85ºC85%RH

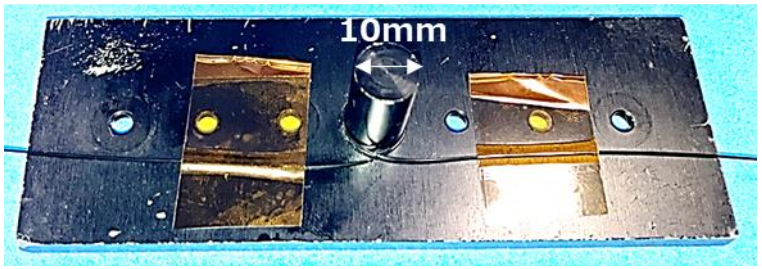
From 0h to 24h, no trend change over time was observed (within measurement variation).
It is considered that the 85ºC85%RH environment does not have a significant change on the fiber characteristics within 24 hours.



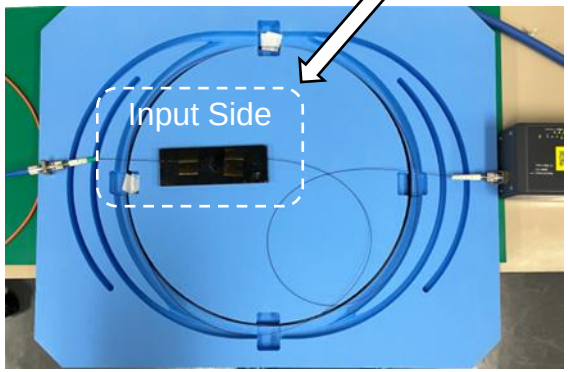


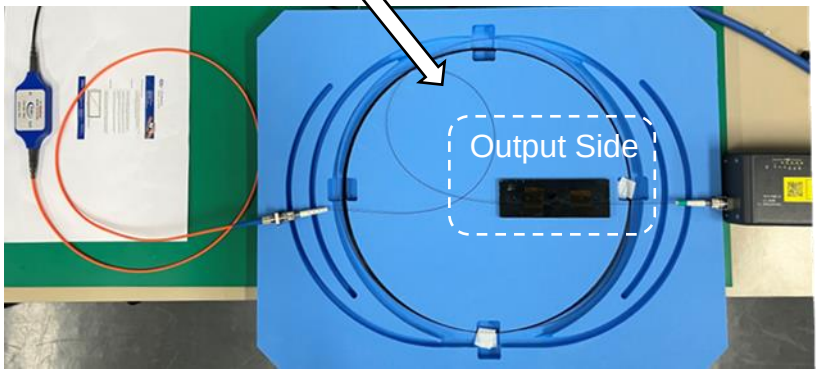
Impact assessment of R=5mm Macro Bend for frequency response of 15 m GI-POF

Setup for R=5mm Macro Bend evaluation

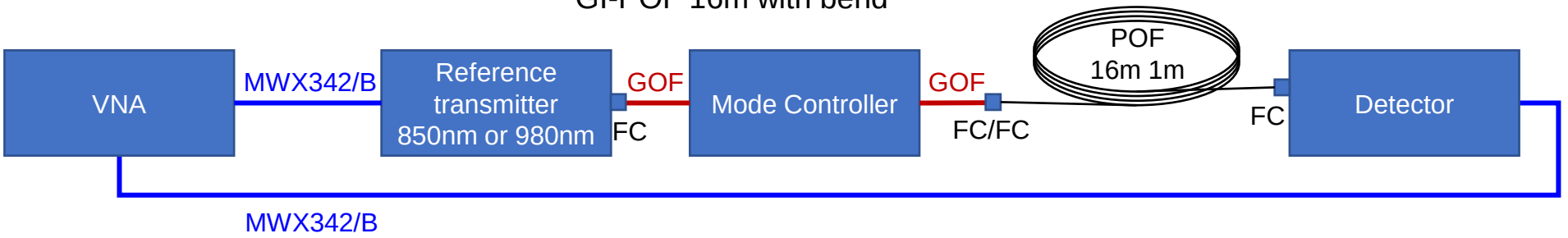


Fiber Bending tool





GI-POF 16m with bend



Frequency response in R = 5 mm Macro Bend

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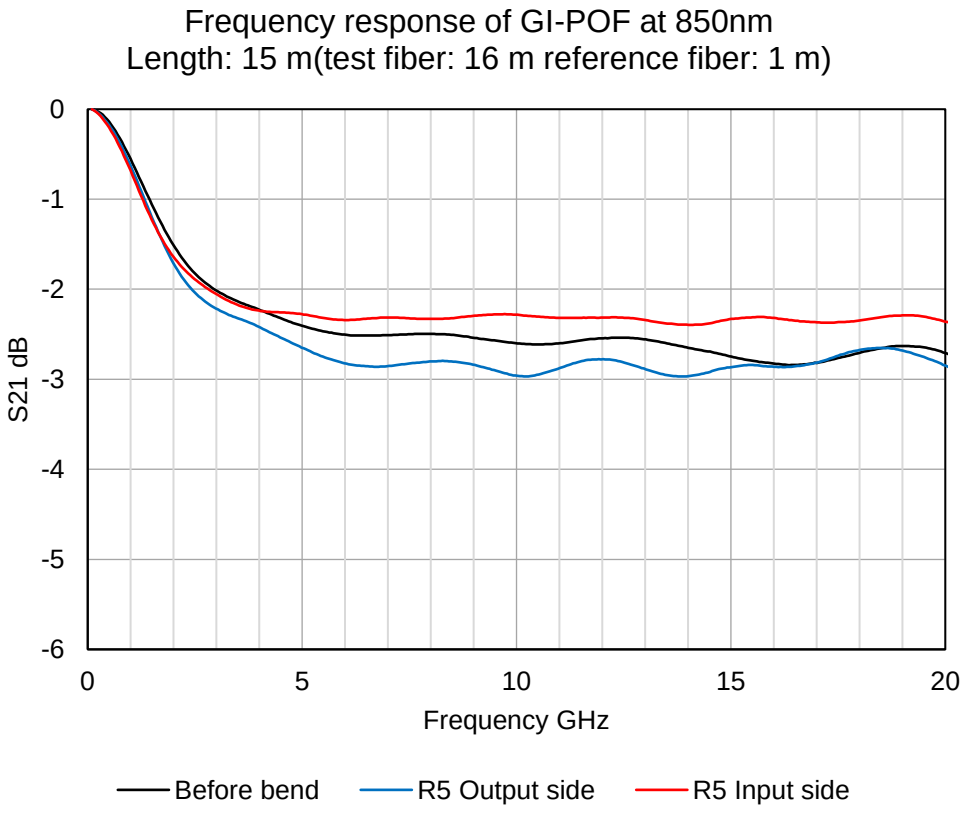
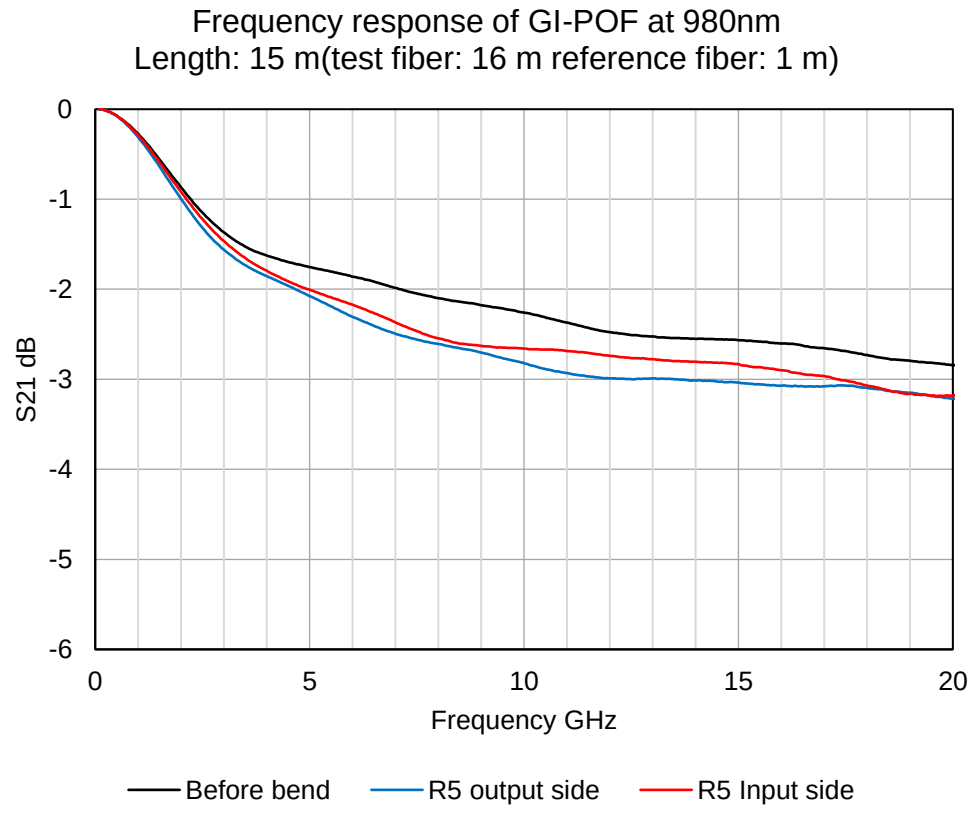
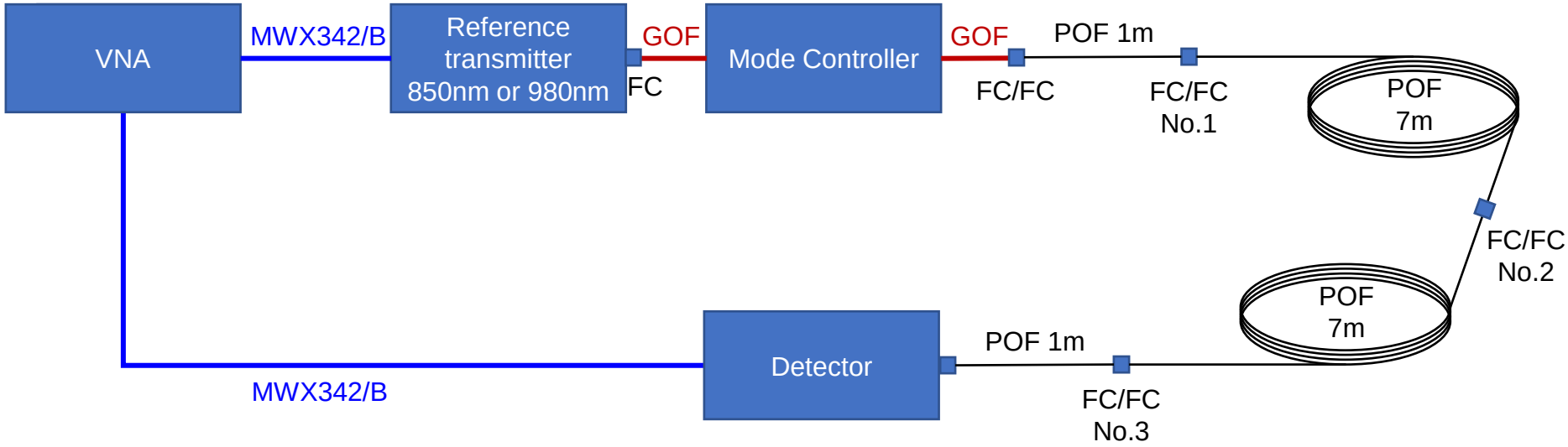
Bending Seems to affect little to the frequency characteristics of the measurement results, considering the reproducibility of the measurement.

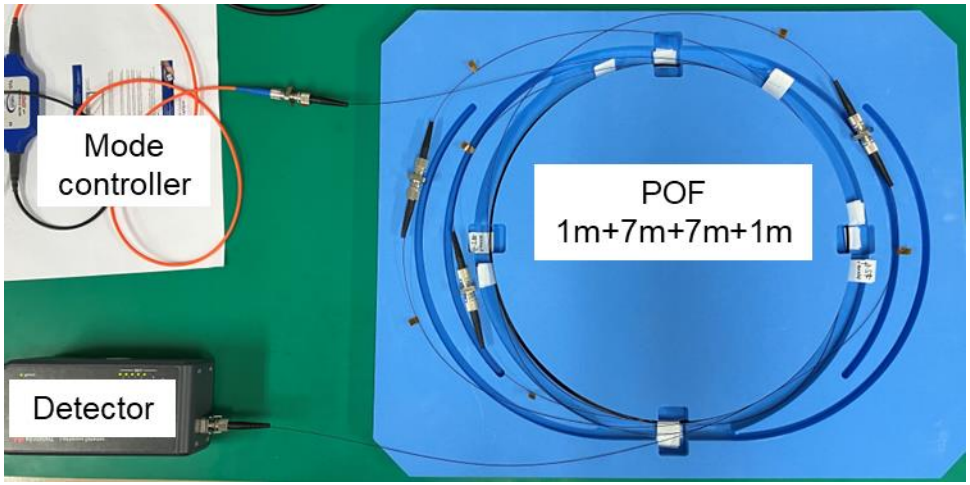




Impact assessment of 3-point connection for frequency response of 15 m GI-POF

Setup for 3 points connection evaluation





Frequency response with 3 Connection

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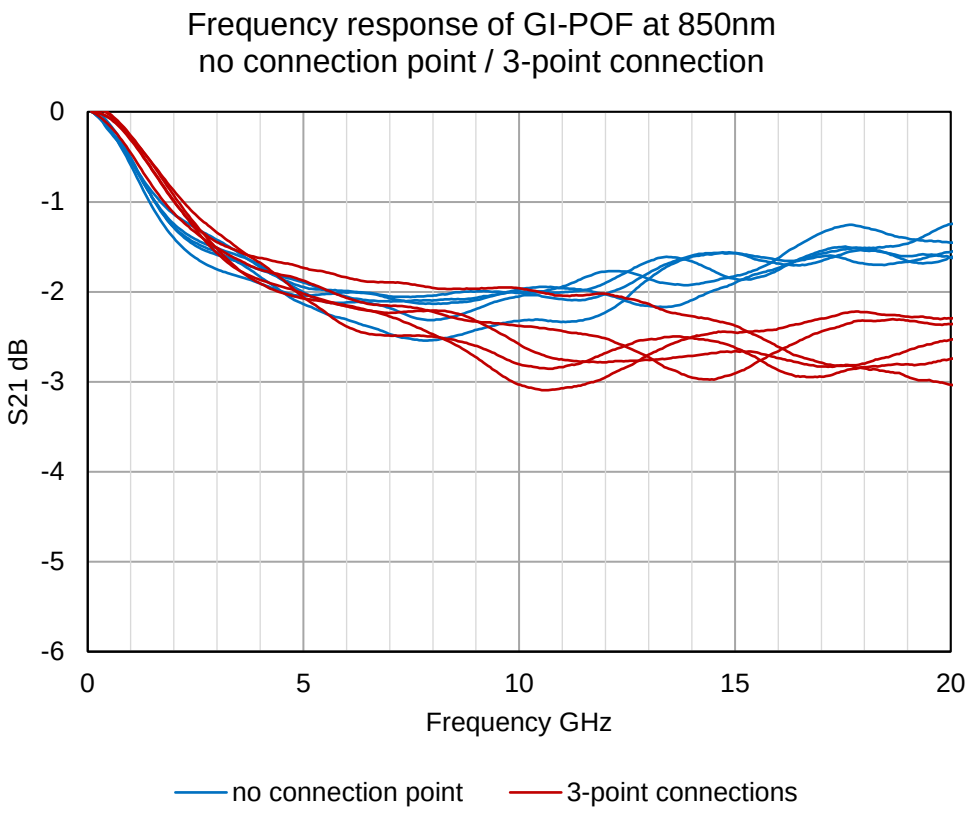
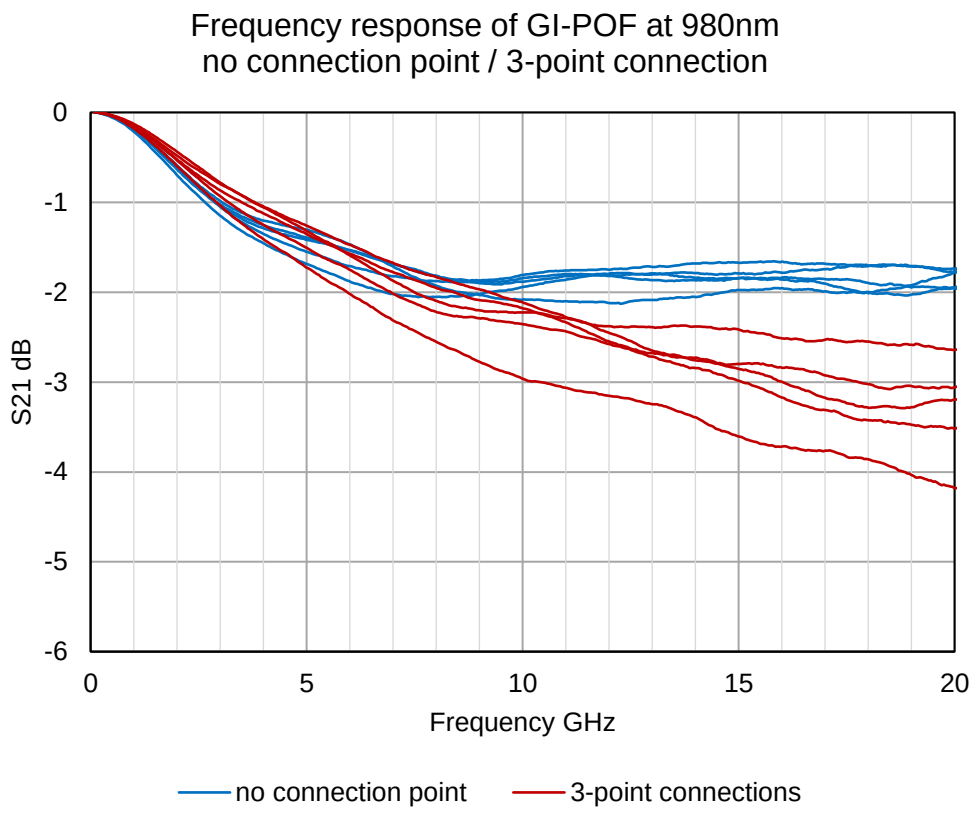
S21 gets worse about 0.5 to 1dB near 10GHz but S21 gets worse over 2dB at 20GHz.





Conclusion

Conclusion

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- Measurement reproducibility in frequency response measurement of GI-POF
  - There is no problem with the measurement system.
  - The high transmission loss by micro voids in the fiber was the cause of the poor reproducibility at 105°C.
  - It is difficult to completely improve the measurement reproducibility problem, but it is considered feasible if the product meets the quality standards.

- Frequency response of 15 m GI-POF at 85ºC85%RH.
  - It is considered that the 85ºC85%RH environment does not have a significant effect on the fiber characteristics within 24 hours. There is no problem in practice.

- Frequency response of 15 m GI-POF in R = 5 mm Macro Bend.
  - Bending Seems to affect little to the frequency characteristics of the measurement results, considering the reproducibility of the measurement.

- Frequency response of 15 m GI-POF with 3-point connections.
  - The impact up to 25 GB/s communication is small.

Thank you for your attention.

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