5.Aug.2020
TECHNICAL BULLETIN MOST-02
TORAY Industries.Inc.

TECHNICAL BULLETIN

- Toray Plastic Optical Fiber Cord for MOST -

- Products Code –

- PFEU-CD1001-23-ABD (Orange)
- PFEU-CD1001-23-ABG (Green)

CONTENTS

Innovation by Chemistry

Table.The basic characteristics

Chapter No.	Items		Units	Min.	Value type	Max.
2.1	Core	Material	–	Polymethyl Methacrylate (PMMA)		
3.3		Diameter	mm	0.931	0.976	1.021
2.1	Cladding	Material	–	Fluorinated Polymer		
3.3		Diameter	mm	0.955	1.000	1.045
4.2	Numerical aperture		–	0.45	0.50	0.55
2.1	1st jacket	Material	–	Polyamide12 (PA12)		
3.2		Diameter	mm	1.49	1.52	1.55
–		Colour	–	Black		
3.4		Concentricity to fiber	mm	–	–	0.06
2.1	2nd jacket	Material	–	Basis material Polyamide		
3.1		Diameter	mm	2.23	2.30	2.37
		Colour	–	Products code		RAL No.
2.2			Orange	PFEU-CD1001-23ABD		2008
			Green	PFEU-CD1001-23ABG		6018
3.4		Concentricity to fiber	mm	–	–	0.10
–	Number of fibers		Fibers	–	1	–
2.3	Packaging (Core diameter of bobbin)		mm	–	315	–
–	Temperature range of use		℃	-40	–	85
	Relative humidity		%	–	–	85
	Adhesion : Inner jacket to fiber		N	25	–	–
	Adhesion : Outer jacket to inner jacket		N	10	20	30

Concentricity

Test Conditions

Temperature T = R.T.(23℃)
Method = By Microscope

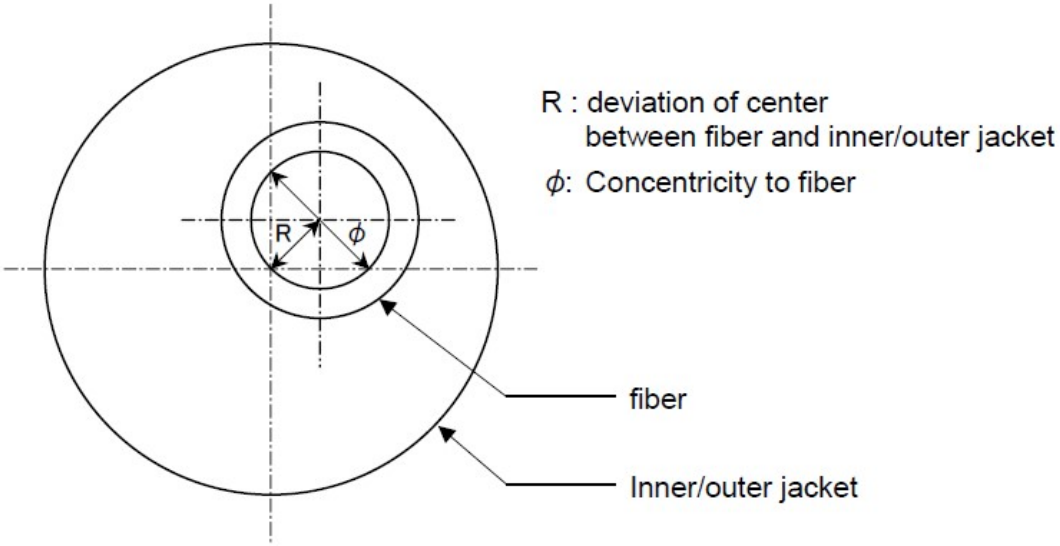

Fig. Concept of concentiricity

Results

	Concentricity to fiber (mm)		
	Mean	Min.	Max.
Inner jacket	0.031	0.008	0.057
Outer Jacket	0.046	0.022	0.072

Spectral Attenuation

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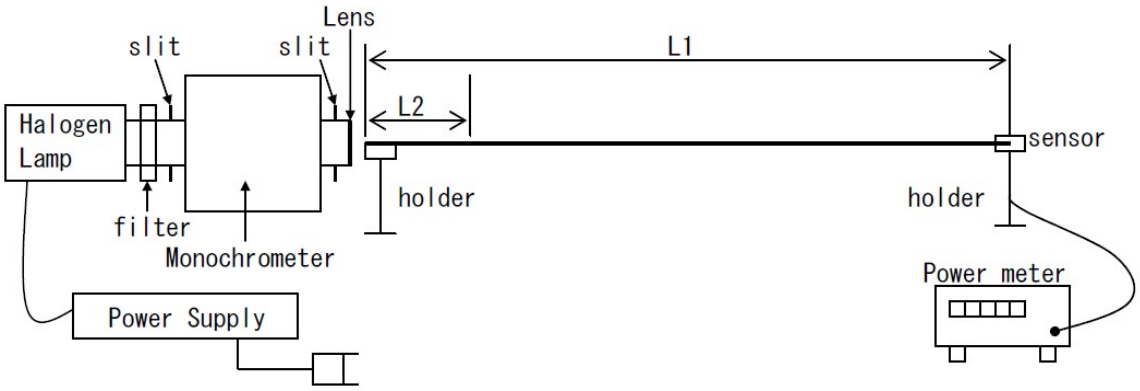
Test Conditions

Test Method = Cut Back method (20m/2m)
Temperature T = R.T.(23℃)
Light Source = Halogen Lamp with Monochrometer
Wavelength λ = 620,630,640,650,660,670,680,690nm
Spectrum FWHM ⊿λ ≦ 8 nm
Launch NA LNA = 0.50

Device Setup



Attenuation Loss (dB/m)=(P1-P2)/(L2-L1)
L1,L2 : Sample Length (m)
P1 : Transmitted Light Power at Cord Length L1 (dBm)
P2 : Transmitted Light Power at Cord Length L2 (dBm)

Sample preparation

	Condition 1	Condition 2
Temperature	70℃	85℃
Relative Humidity	-	85%
Annealing Time	10 hours	50 hours

Test Result

Table 1 Attenuation for each wavelength and estimated attenuation on condition 1

	Attenuation (dB/m) for each wave length							
	620nm	630nm	640nm	650nm	660nm	670nm	680nm	690nm
Mean	0.45	0.38	0.23	0.17	0.21	0.28	0.31	0.35
Min.	0.44	0.37	0.22	0.16	0.20	0.27	0.30	0.34
Max.	0.46	0.41	0.24	0.18	0.22	0.29	0.33	0.36

Table 2 Attenuation for each wavelength and estimated attenuation on condition 2

	Attenuation (dB/m) for each wave length							
	620nm	630nm	640nm	650nm	660nm	670nm	680nm	690nm
Mean	0.47	0.39	0.25	0.19	0.24	0.31	0.33	0.37
Min.	0.46	0.38	0.24	0.18	0.23	0.30	0.32	0.36
Max.	0.48	0.40	0.27	0.20	0.25	0.32	0.34	0.38

NA (Numerical Aperture)

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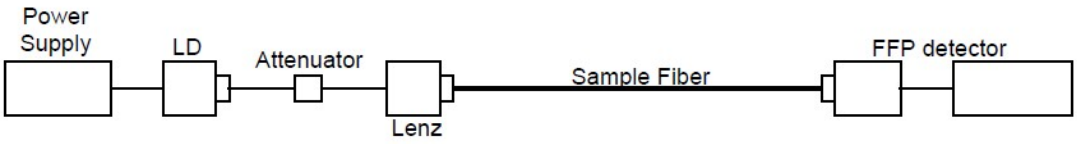
Test Conditions

Test Method		=	Based on IEC 60793-1-C6
Temperature	T	=	R.T.(23℃)
Wavelength	λ	=	650 nm ± 5 nm (LD)
Spectrum FWHM	$\Delta\lambda \leqq$		5 nm
Launch NA	LNA	=	0.65
Sample Length	L	=	2 m

Device Setup



Calculations

The half angle between the points of pattern at which the intensity are 5% of the maximum is recorded as θ_5.

Numerical Aperture is calculated using the following formula :

$$NA = \sin \theta_5$$

Test Result

	Mean	Min.	Max.
NA (-)	0.50	0.49	0.51

Optical Insulation

Test Conditions

Sample		=	(a) cord (b) bare fiber
Light Tight seal		=	One side
Bending radius	Rb	=	25 mm
Bending rounds	r	=	3.3 rounds (0.5m)
Sample Length	L	=	3 m
Temperature	T	=	R.T.(23℃)
Light Source		=	Halogen lamp 12V-50W
Driving Current	I	=	4.5 A
Irradiated Area	Ri	=	Abt. 80mmϕ

Device Setup

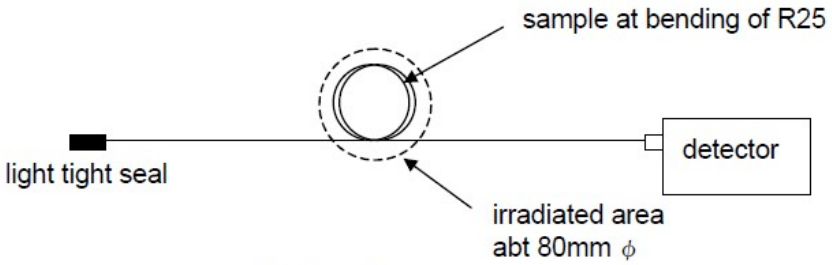


Fig. Device set-up

Results

		Mean	Min.	Max.
Detected Light Power (dBm)	(a) cord	-	-	-70*
	(b) bare fiber	-35.2	-35.4	-34.6
Relative Light Efficiency (dB)	(b)-(a)	(34.8)	34.6	-

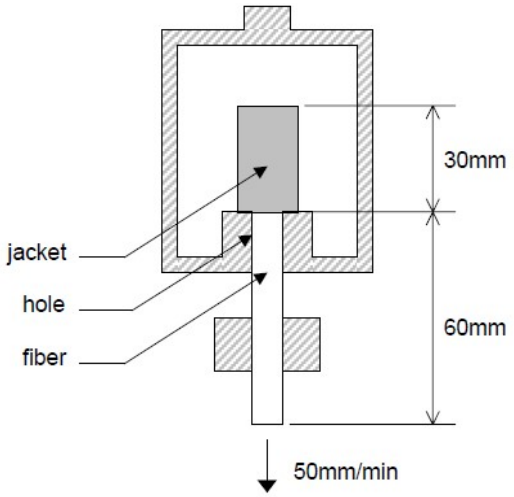
* : The marginal detected power is -70dBm.

Adhesion (tight fit)

Test Conditions

Temperature	T	=	R.T.(23℃)
Tensile speed	V	=	50 mm/min
Sample length	L	=	90 mm
Length for strip	LB	=	30 mm

Device Setup



Results

	Mean	Min.	Max.
Inner jacket to fiber	30	27	33
Outer to inner Jacket	13	10	17

Tension performance of the fiber with inner jacket

Test Conditions

Temperature	T	=	R.T.(23℃)
Sample		=	Fiber with inner jacket
Length under stress	IB	=	200 mm
Max. load	F	=	60 N
Tensile speed		=	100 mm/min
Hold time at max. load		=	2 min
Sample Length	L	=	Abt. 400 mm

Device Setup

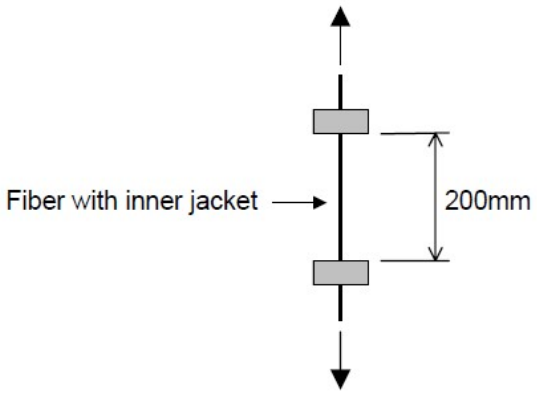


Fig. Device set-up

Procedure

1. The sample is stressed above condition.
2. After conditioning, the length of released sample is measured as L'(mm).
3. Residual elongation ε(%) is calculated from equation;

   ε(%) = (L'-200) / 200 × 100

Results

Elongation (%)	≦ 2

Resistance to bending (bending stiffness)

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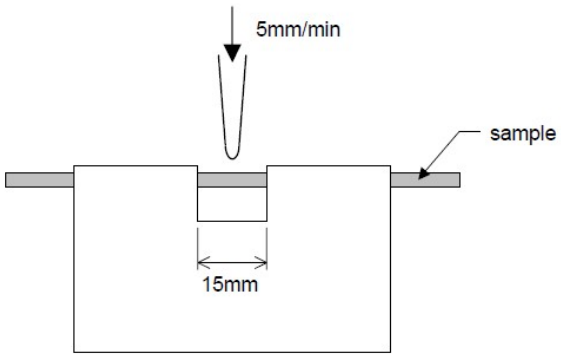
Test Conditions

Temperature	T	=	R.T.(23℃)
Tensile speed	V	=	5 mm/min
Sample Length	L	=	100 mm
Distance of jaws		=	15 mm

Device Setup



Results

	Mean	Min.	Max.
Resistance to Bending ∂F / ∂s (N/mm)	11	10	12

Bending Radiuses

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Test Conditions

Wavelength	λ =	660 nm (LED)	
Spectrum FWHM	Δλ≦	25 nm	
Sample Length	L =	10 m	

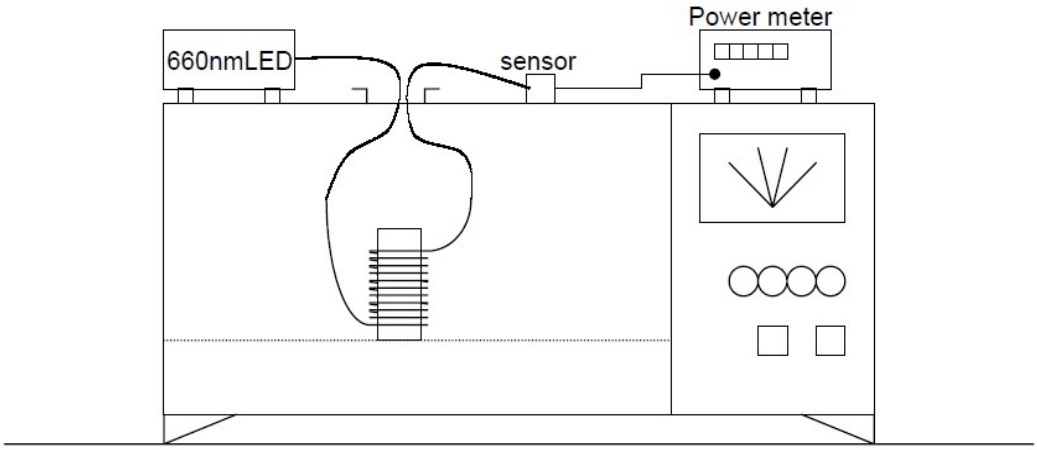
Condition 1

Bending radius	R =	25 mm
Strain Length	=	10 windings
Temperature	T =	85 ℃
Relative Humidity	RH =	90 %
Exposing time	=	1000 hours

Condition 2

Bending radius	R =	10 mm
Strain Length	=	10 windings
Exposing time	=	60 seconds
Drying Temperature	T =	85 ℃
Drying time	=	96 hours

Device Setup



Results

Table 1 Attenuation after condition 1

Exposing Time (h)	Attenuation (dB)		
	Mean	Min.	Max.
1000	0.5	0.4	0.7

Table 2 Attenuation after condition 1 and condition 2

Drying Time (h)	Attenuation (dB)		
	Mean	Min.	Max.
96	0.4	0.3	0.7

Shrinkage

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Test Conditions

Temperature	T1	=	85 ℃ (dry)
	T2	=	95 ℃ (dry)
	T3	=	105 ℃ (dry)
Annealing Time	h1	=	24 hours
Sample Length	L1	=	2 m

Measuring Method

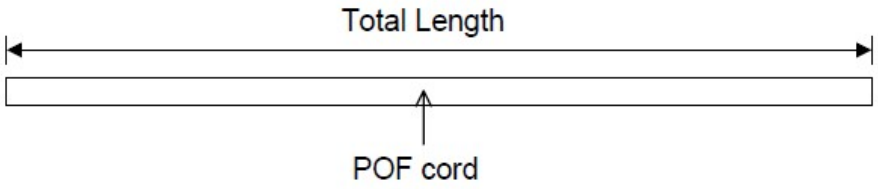

Fig. Sample

1. Before annealing, the total length (L0) is measured.
2. After annealing, the total length (L1) is measured.
3. Shrinkage (%) is (L0-L1) / L0 × 100.

Results

Temp. (℃)	Shrinkage (%)		
	Mean	Min.	Max.
85	0.6	0.6	0.7
95	0.7	0.6	0.8
105	0.8	0.7	0.9

Pistoning

Test Conditions

Temperature	T	=	90 ℃ (dry)
Annealing Time	H	=	24 hours
Sample Length	L	=	0.5 m

Measuring Procedure

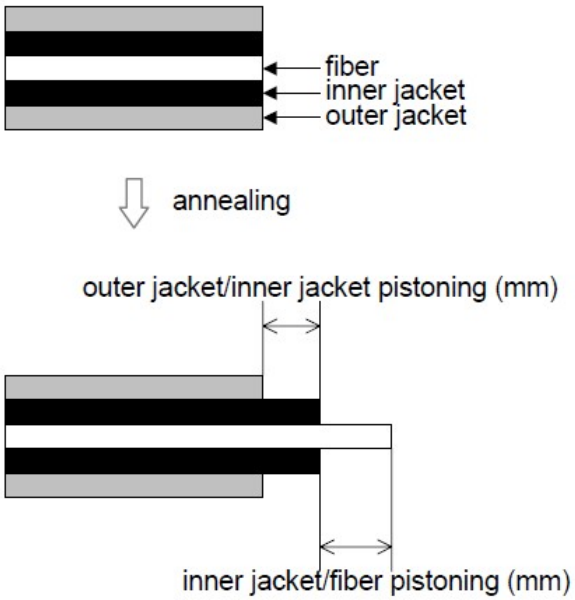

Fig. Pistoning of samples

Results

	Pistoning (mm)		
	Mean	Min.	Max.
outer jacket / inner jacket	-0.01	-0.02	-0.01
Inner jacket / fiber	-0.01	-0.01	0.00

Durability against Hydrolysis

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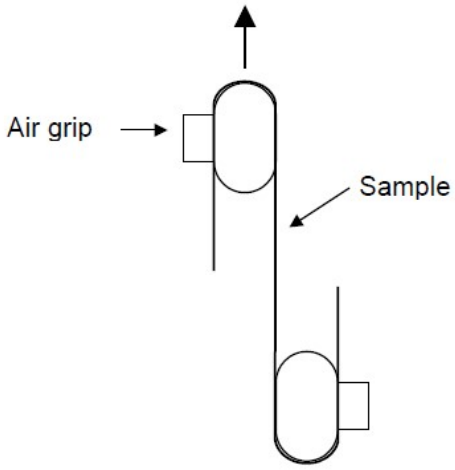
Test Conditions

Temperature	T	=	R.T. (23 ℃)
Strain Length	LB	=	200 mm
Tensile Speed	v	=	100 mm/min

Device setup



Sample prepareation

Temperature	T	=	80 ℃
Relative Humidity	RH	=	85 %
Aging Time	t	=	720 hours

Results

The sample didn't become brittle.

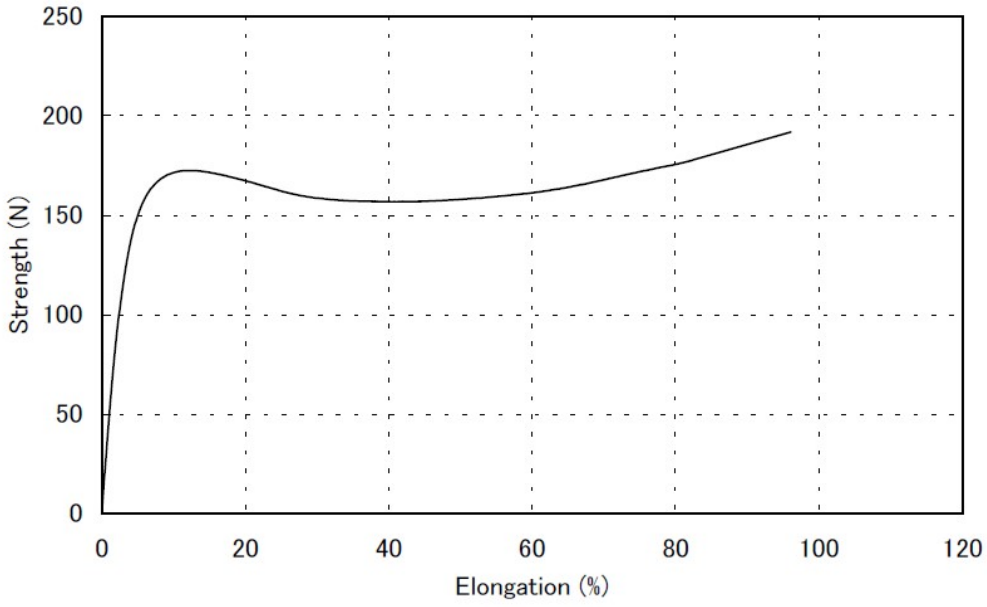


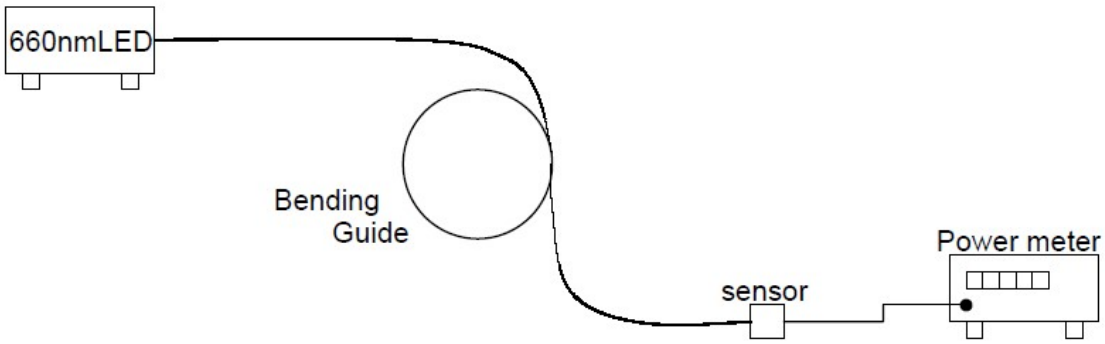
Fig. Strain-Strength Curve after conditioning of 80℃, 85% and 720h

Static Bending

Test Conditions

Temperature	T	= R.T. (23 ℃)
Wavelength	λ	= 660 nm (LED)
Spectrum FWHM	Δ λ	≦ 25 nm
Sample Length	L	= 3 m
Bending Angle		= 360 °
Bending Radius	R	= 10, 15, 20, 25, 30 mm
Reference Radius	Rr	= 100 mm
Strain Position		= Middle of Sample

Device setup



Test Result

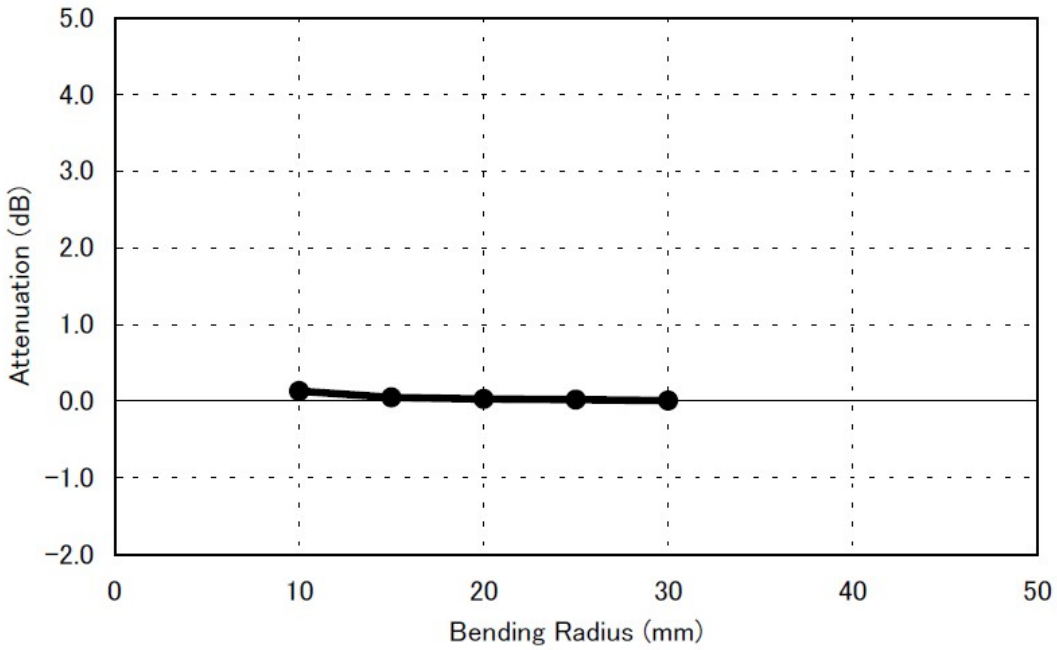


Fig.1 Attenuation over the bending radius

Table 1 Attenuation over bending radius

Bending radius (mm)	Attenuation (dB)		
	Mean	Min.	Max.
10	0.12	0.08	0.18
15	0.04	0.03	0.07
20	0.02	0.02	0.04
25	0.01	0.01	0.02
30	0.00	0.00	0.01

Table 2 Irreversible attenuation after bending over bending radius

Bending radius (mm)	Attenuation (dB)		
	Mean	Min.	Max.
10	0.01	0.01	0.01
15	0.00	0.00	0.01
20	0.00	0.00	0.01
25	0.00	0.00	0.01
30	0.00	0.00	0.01

Impact

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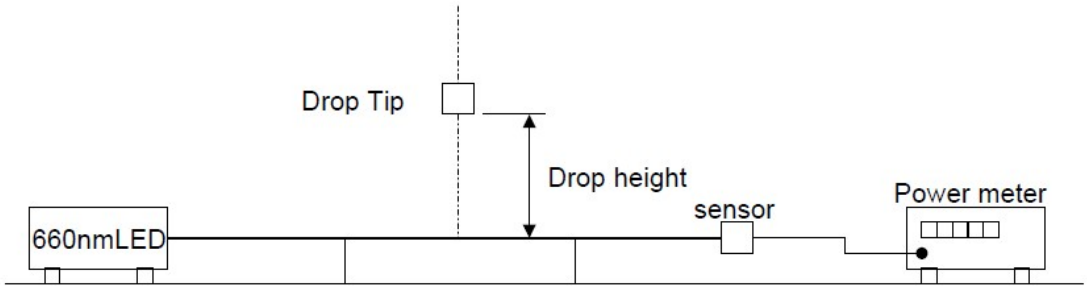
Test Conditions

Temperature	T	=	R.T. (23 ℃)
Wavelength	λ	=	660 nm (LED)
Spectrum FWHM	Δ λ	≦	25 nm
Sample Length	L	=	3 m
Tip Weight	m	=	100 g
Tip R	R	=	300 mm
Height	h	=	100 mm
Stress Position		=	Middle of sample

Device setup



Test Result

No. of impact (turns)		0	1	2	3	4	5	6	7	8	9	10
Attenuation (dB)	Mean	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Max.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Static Torsion

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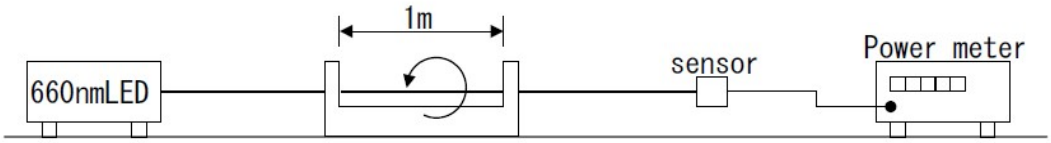
Test Conditions

Temperature	T	=	R.T.(23 ℃)
Wavelength	λ	=	660 nm (LED)
Spectrum FWHM	Δ λ	≦	25 nm
Sample Length	L	=	3 m
Load	N	=	10 N
Strain Length	LB	=	1 mm
Turning Speed	f	=	0, 5…2 s/roud
Maximum Torsion		=	10 rounds
Holding Time		=	60 minutes

Device setup



Results

Temp.(℃)	Attenuation (dB) After 60 min with held		
	Mean	Min.	Max.
23	0.0	0.0	0.0

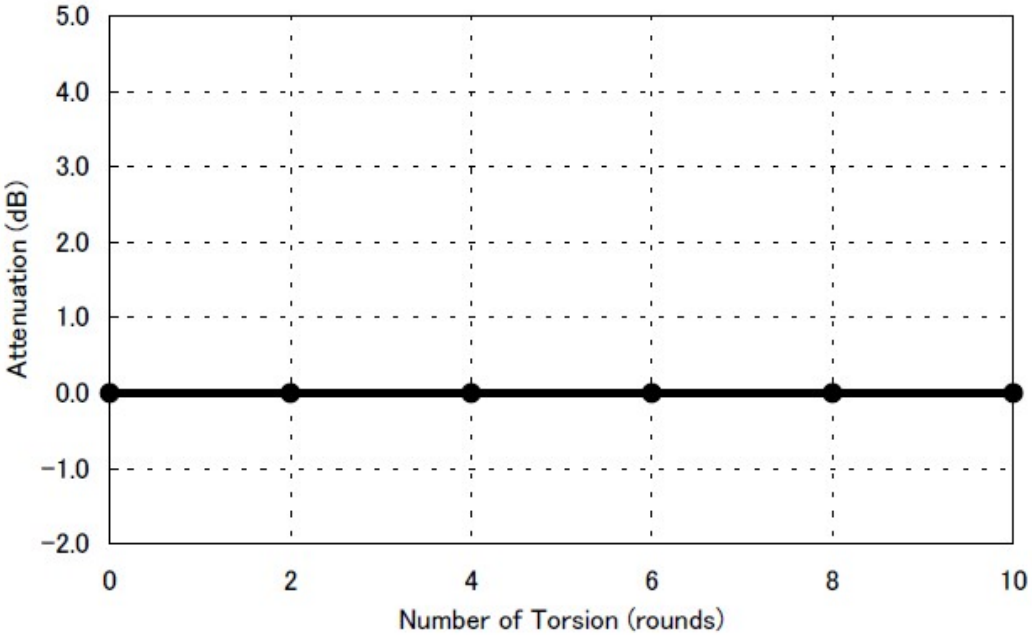


Fig.1 Attenuation over number of torsion at 23℃

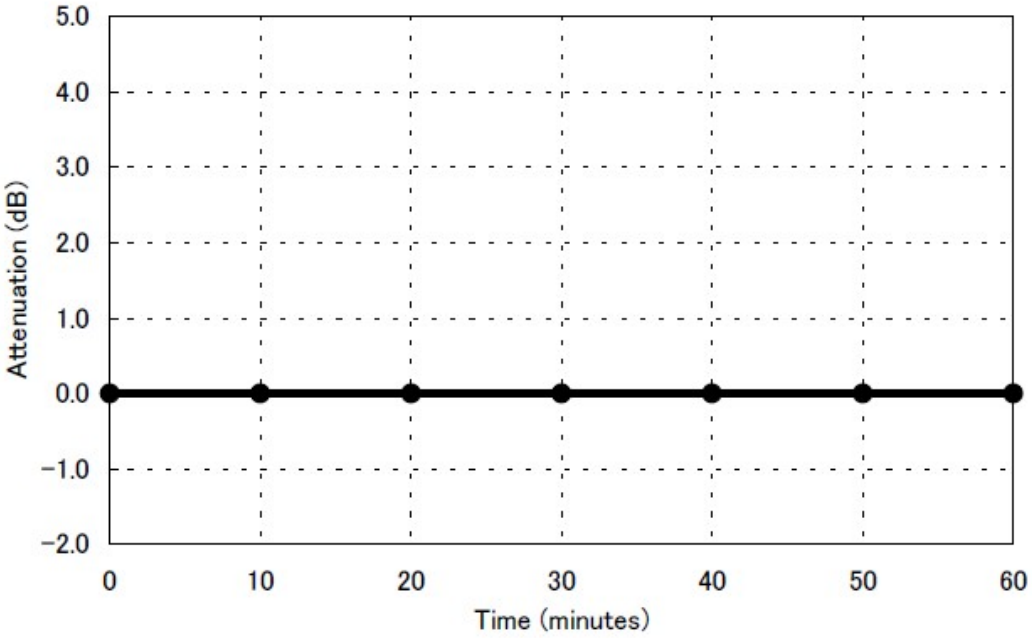


Fig.2 Attenuation over time with holding maximum torsion at 23℃.

Repeated Bending

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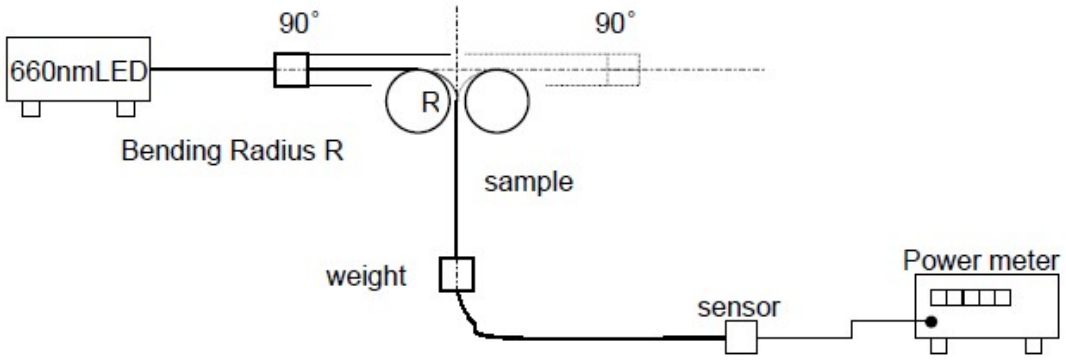
Test Conditions

Wavelength	λ	=	660 nm (LED)
Spectrum FWHM	Δ λ	≦	25 nm
Sample Length	L	=	3 m
Bending radius	mm	=	40 mm
Bending angle		=	±90°
Bending speed	V	=	0.5 bending / sec
Load	F	=	5 N (500g weight)
Stress Position		=	Middle of Sample
Temperature	T	=	R.T.(23℃)
Bending cycle	N	=	10000

Device setup



Test Result

Table Attenuation in 23℃

Bending Cycles	Attenuation (dB)		
	Mean	Min.	Max.
10000	0.0	0.0	0.1

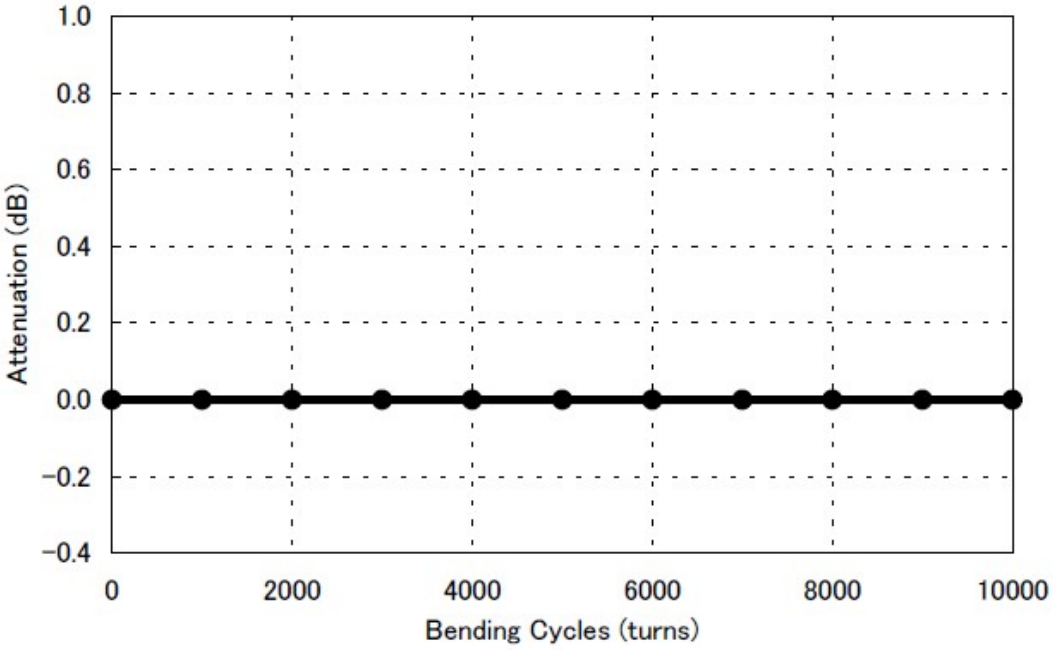


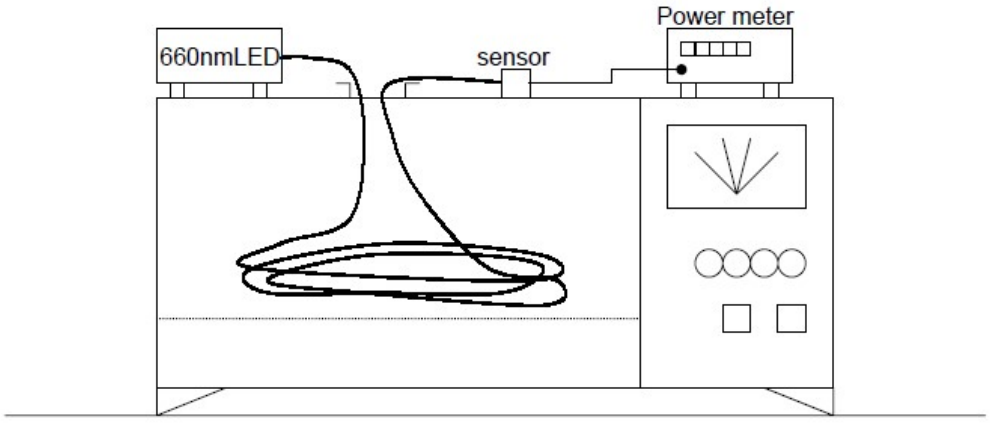
Fig.1 Attenuation in 23℃ over bending cycles

Durability of High Temparature

Test Conditions

Temperature	T1	= 85 ℃
Relative Humidity	RH	= 0 % (dry)
Wavelength	λ	= 660 nm (LED)
Spectrum FWHM	Δ λ	≦ 25 nm
Sample Length	L	= 10 m

Device setup



Test Result

Table Attenuation over temperature after 1000 hours

Aging time (h)	Attenuation (dB)		
	Mean	Min.	Max.
1000	-0.1	-0.2	0.0

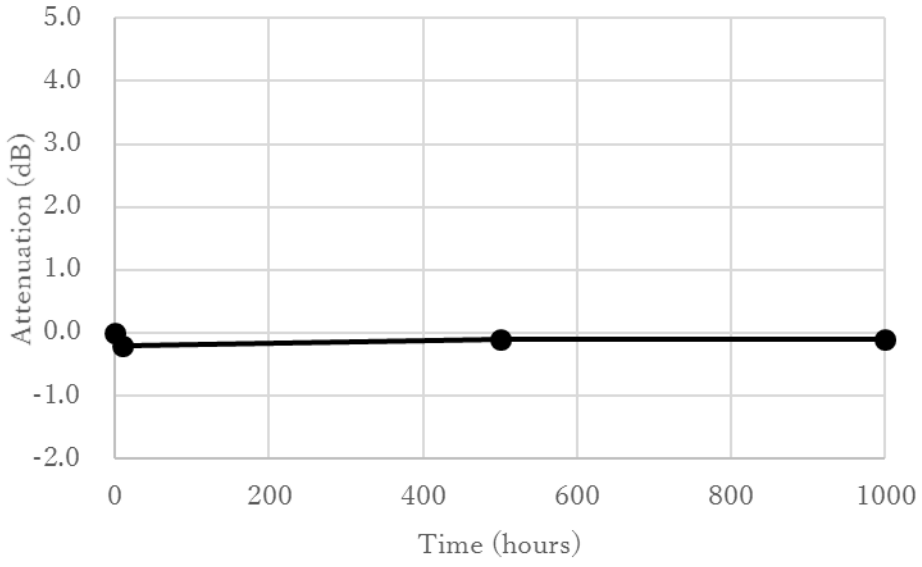


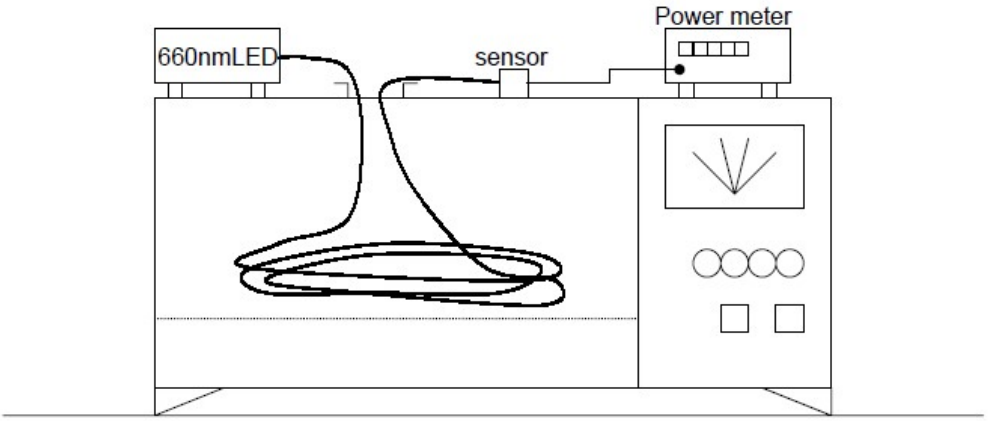
Fig. Attenuation over time at 85℃

Durability of Low Temparature

Test Conditions

Temperature	T1	= -40 ℃
Wavelength	λ	= 660 nm (LED)
Spectrum FWHM	Δ λ	≦ 25 nm
Sample Length	L	= 10 m

Device setup



Test Result

Table Attenuation after 1000 hours

Aging time (h)	Attenuation (dB)		
	Mean	Min.	Max.
1000	0.04	0.00	0.05

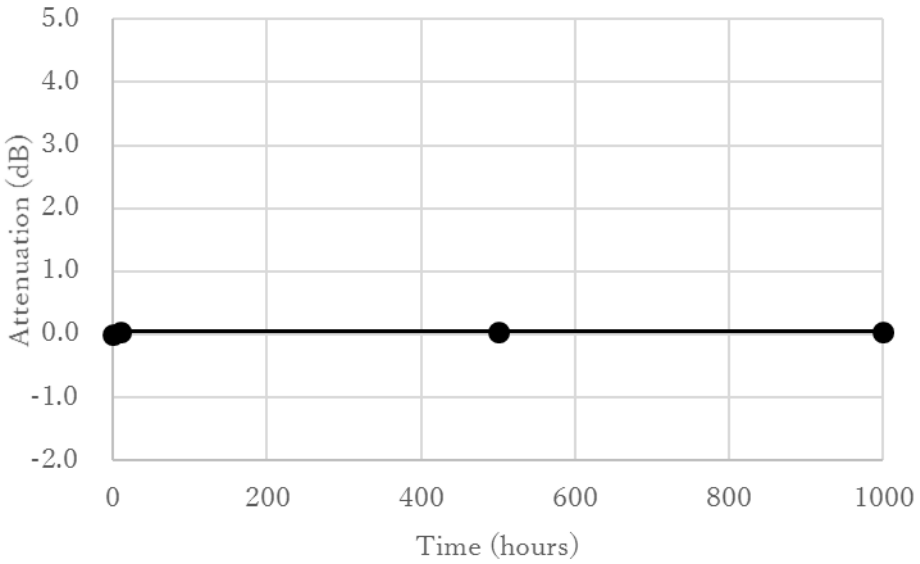


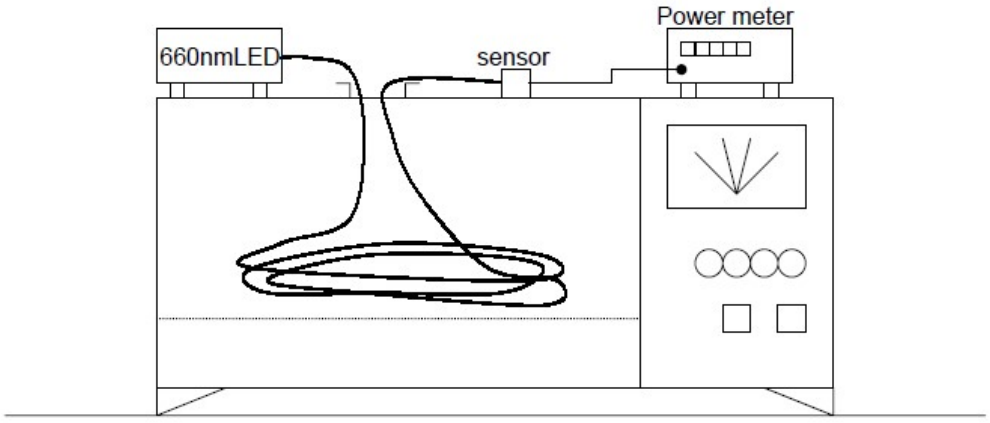
Fig. Attenuation over time at -40℃

Durability to Heating with Moisture

Test Conditions

Temperature	T1	= 85 ℃
Relative Humidity	RH	= 95 %
Wavelength	λ	= 660 nm (LED)
Spectrum FWHM	Δ λ	≦ 25 nm
Sample Length	L	= 10 m

Device setup



Test Result

Table 1 Attenuation after 1000 hours

Aging time (h)	Attenuation (dB)		
	Mean	Min.	Max.
3000	0.2	0	0.3

Table 2 Attenuation in dry air after conditioning of 85 95%R.H. and 1000 hours

Time (h) In dry air	Attenuation (dB)		
	Mean	Min.	Max.
24	0.2	0	0.3

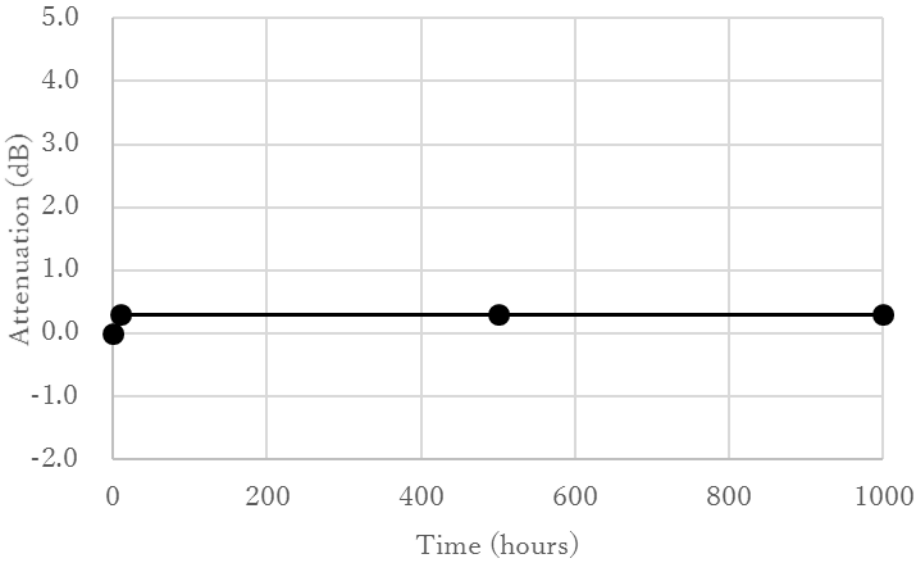


Fig. Attenuation over time at -40°C