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Bending insensitive single-mode fibre for FBT

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ABSTRACT: with the miniaturized development of optical passive devices and the increasing requirement of cost control, the problem of no compatibility between the FBT performance and macro-bending loss occurs when using the traditional single-mode optical fibre In this paper, an optimized single-mode fibre for FBT is presented. Not only for the excellent FBT performance, but also the macrobending loss is much better than G.657.A1. and properly solves above-mentioned pain points for the device customers.

Keywords: fused biconical FBT, bending insensitive, G.657.A1, fibre coupler

1 Created background of bending insensitive single-mode fibre for FBT

The optical fibre coupler is an optical device that realizes the distribution and combination of optical signal power between different fibres. With the development of "Internet+", cloud computing, , big data and other new technologies as well as the full launch of FTTX, 4G/5G network construction, the rapidly growing construction projects are in a blowout situation for the demand for optical fibre passive components, especially fibre couplers. In the fabrication process of fibre coupler, the fused biconical FBT method is favored by optical device manufacturers because of its simple operation, low fabrication cost and low device loss.

YOFC is an early supplier of optical fibre optimization design for fibre passive device applications. Prior to this, we have introduced the single-mode fibre for special device (PH1010-A), single-mode fibre for device FBT (PH1010-B), bending insensitive single-mode fibre for device (PH1011-A) and ultra-bending insensitive single-mode fibre for device (PH1012-A). This kind of optical fibre has strict optical and geometrical indexes as well as good mechanical performance. The MFD index is consistent with the corresponding single-mode fibre for communication, so it can be fully compatible with optical communication system.

With the miniaturization development of optical passive devices, the cost control requirements have increased and device customers have encountered some new problems when it was used in a small bending radius environment, such as narrow space, corner, wire distribution cabinet ,optical splitter and other small-sized devices, the macro-bending loss of optical fibre links is very large and it cannot meet the practical application requirements; Although the macro-bending losses of the normal G.657 series optical fibre are very low, but the trench structure with deep minus-delta sinking due to the increase of fluorine content in the outer cladding design. During the fabrication of the fused biconical FBT coupler, the mismatch in the material properties of the core cladding (expressed as a mismatch in viscosity and thermal diffusivity), the fibre waveguide structure changes are not synchronized, which will result in that no matter how to optimize the fused biconical FBT process, the splitting ratio required by the coupler cannot be achieved and the process loss is very large, so the coupler cannot be fabricated.

For above-mentioned reasons, based on the existing single-mode fibre for device FBT (PH010-B) and bending insensitive single-mode fibre for device (PH1011-A), a bending insensitive single-mode fibre for device FBT (PH1010-C) is newly developed by YOFC through optimizing the profile parameters and designing the reasonable v values. The fibre can meet the needs of fused biconical FBT and have certain bending insensitive characteristics, which can meet the customer demands of mainstream devices, especially micro-devices in the existing market.

2 Technical highlights of optical fibre

The bending insensitive single-mode fibre for device FBT (PH1010-C) has following technical highlights:

2.1 Macro-bending loss

The optical index of the bending insensitive single-mode fibre for device FBT (PH1010-C) fully meet the G.652.D standard and the macro-bending loss is better than the G.657.A1 standard issued by ITU-T, as shown in the following table

Table 1 Macro-bending Loss of Optical Index of the Bending Insensitive Single-mode Fibre for Device FBT (PH1010-C)

Bending Radius	Number of turns	Wave length (mm)	G.657.A1	PH1010-C	Internationally renowned business competitors
15 mm	10	1550	≤0.25	≤0.05	≤0.05
15 mm	10	1625	≤1.0	≤0.3	≤0.3
10 mm	1	1550	≤0.75	≤0.5	≤0.5
10 mm	1	1625	≤1.5	≤1.5	≤1.5

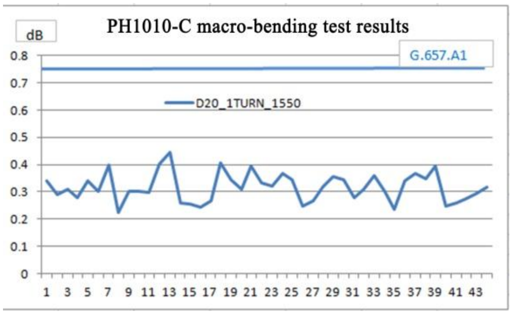

Figure 1. PH1010-C Macro-bending Test Results

The above figure shows the macro-bending test results of PH1010-C at 1550 nm band under φ 20 mm bending. It can be seen that the macro-bending loss is less than 0.5 dB in φ 20 mm and above bending diameters and is also far below the standard of G.657.A1 by issued by ITU-T.

2.2 Splicing loss

Sample 1	Sample2	splicing loss	
Fibre_ID	Fibre_ID	1310nm	1550nm
G.652.D	1	0.02	0.015
	2	0.02	0.01
	3	0.015	0.02
	4	0.015	0.015
	5	0.015	0.02
	6	0.01	0.02

The above table is samples of six disks of PH1010-C optical fibres and loss results of the single-mode fibre for communication in splicing. From the loss values, the results are very small and can fully meet the system requirements.

2.3 Fibre geometry

Compared with common G.652.D fibre, PH1010-C fibre has better geometrical properties, such as 124.5±0.5μm of cladding diameter, smaller fluctuation, stricter standard of non-circularity of cladding and concentricity of core-cladding than G.652.D. Moreover, many optical fibre devices have the need of core insertion, so the center value of fibre cladding diameter is set to be 124.5μm, which is slightly smaller than the standard fibre of 125μm in order to better meet the needs of device customers.

Table 2 PH1010-C Geometry

	G.652D	PH1010-C	Internationally renowned business competitors
Cladding diameter/μm	125.0±0.7	124.5±0.5	125.0±0.7
Core cladding concentricity/μm	≤0. 6	≤0.5	≤0.5
Non-circularity of cladding/%	≤1.0	≤0.7	≤0.7
Optical fibre outer diameter/μm	245±7	242±5	242±5

3 FBT verification

3.1 FBT **performance verification**

FBT performance verification: the material defects and waveguide structure changes will cause the optical power loss of device during the fused biconical FBT of optical fibre. This verification directly evaluates whether the fibre is suitable for fabrication of fused biconical FBT optical fibre device according to the optical power loss and stability of the device. The following figure shows the power/loss curves obtained by FBT of PH1010-C optical fibre, recording the change of power/loss with the stretching length of the fibre during the whole process from the start of stretching to the stop of fibre FBT machine (P1 is the output power of optical fibre, EL is the additional loss and CR is the splitting ratio). The loss fluctuation of PH1010-C fibre during FBT is very smooth and the loss is always lower than 0.1 dB by using 1310/1550 nm single-mode pump source in the verification.

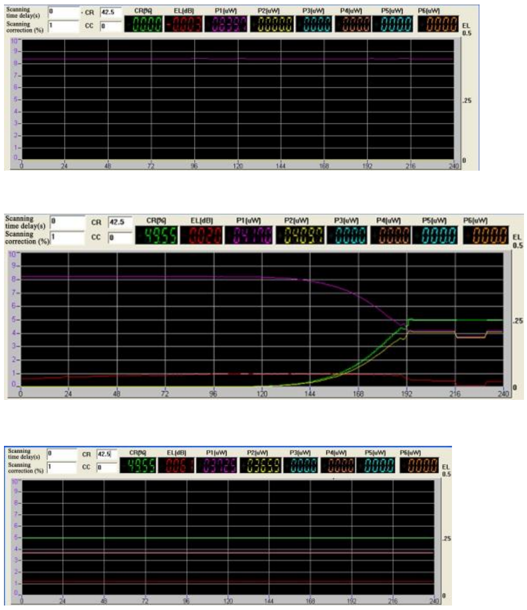

Figure 2 Change of Power/Loss with FBT Length in FBT Process of PH1010-C Fibre

(top: before FBT; middle: during FBT; bottom: stop of FBT)

According to the above FBT conditions, repeated double-window FBT tests were carried out on different batches of PH1010-C optical fibres and the test results are shown in the following table:

Table 3 Stability Test between Batches of PH1010-C

Samples	Wave length (mm)	Splitting ratio （50%±1%）	Process loss (dB)	Samples	Wave length (mm)	Splitting ratio (50%±1%)	Process loss (dB)

1	1310	49.55%	0.019	5	1310	49.59%	0.014
	1550	50.32%	0.061		1550	49.39%	0.017
2	1310	50.02%	0.016	6	1310	49.91%	0.055
	1550	50.81%	0.01		1550	50.24%	0.029
3	1310	49.26%	0.025	7	1310	50.01%	0.017
	1550	49.56%	0.011		1550	50.33%	0.023
4	1310	49.55%	0.02	8	1310	49.00%	0.016
	1550	49.85%	0.01		1550	49.14%	0.019

From the above verification results, it can be seen that PH1010-C can meet the requirements of FBT coupling both in the loss value of FBT process and in the fluctuation range of splitting ratio (i.e. FBT stability).

3.2 FBT reliability test

In order to get as close as possible to the practical application, we give the optical fibre to the famous domestic device company for making of the FBT coupler. After encapsulation, a series of reliability tests according to the optical device inspection standard were carried out: 1000h dry heat (DH), 800 times of temperature circuit (TC) and straight & side pull inspection. The polarization dependent loss change value (PDL) of the device is measured under the above conditions and the PDL is required to be less than 0.2 dB. Due to space limitation, we only enumerate four reliability test results as shown in the following figure.

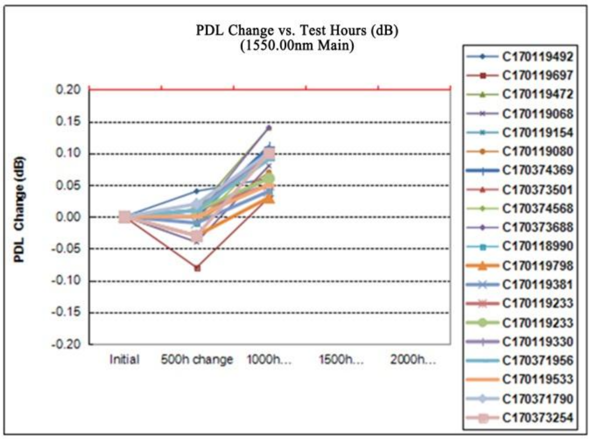

Figure 3 Variation of PDL in DH Test (Damp Heat (85 ℃/85% RH),1000 hours qualification (@ 25 ℃)

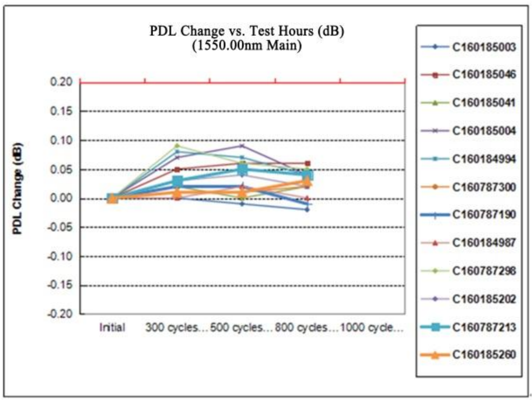

Figure 4 Variation of PDL in TC Test (Temperature cycle(-40 ℃~+85 ℃) ,800 cycles qualification)

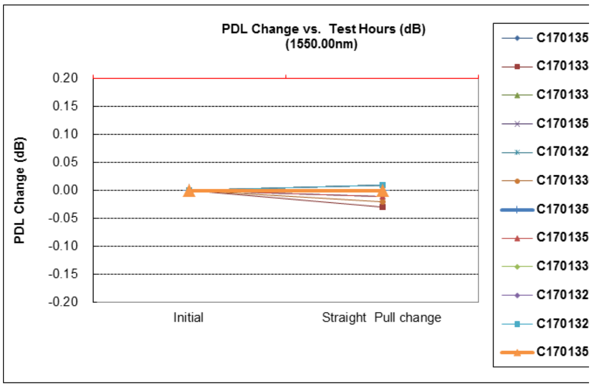

Figure 5 Variation of PDL in Straight Pull Test (0.45 kg, 60sec)

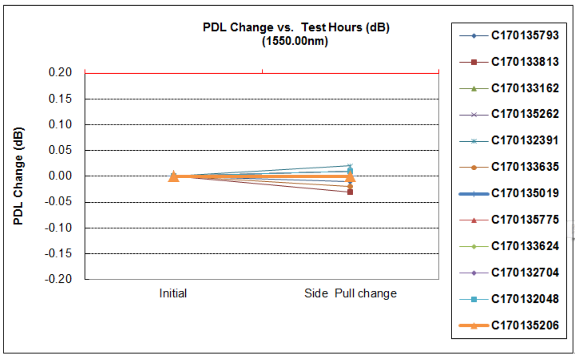

Figure 6 Variation of PDL in Side Pull Test (0.23kg, 90 °, 5sec)

For the test results from the above customer, it can be seen that all the FBT fabricated by PH1010-C can meet the requirements of device indexes. It is obtained by comprehensive information from customers that the PH1010-C fibre on the FBT loss is better than certain product provided by a famous foreign manufacturer, especially in the aspect of mini-size coupler control.

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