1×4 Fused Taper Star Couplers

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Optical splitters are important devices for the Passive Optical Network (PON). We propose two types of fused taper 1×4 couplers; low excess loss, dual window 1×4 couplers for the current PON system, and high uniformity type 1×4 couplers for BPON full-band operation. Wavelength flattened characteristics and excellent branching uniformity less than 0.4dB have been achieved in wavelength range from 1,200nm to 1,700nm. Their high reliability is also demonstrated.

1. Introduction

Fiber-To-The-Home (FTTH) services are becoming widespread in Japan. According to the Japanese government publication, the number of subscribers is estimated to be more than 7.7 million in 2005.

Passive Optical Networks (PON) are usually applied to FTTH services, as shown in Fig. 1. Wavelengths of 1,310nm and 1,550nm are used for up and down stream, respectively. Optical splitters are important devices for the PON system. They are categorized into two types; fused taper star couplers[1)] and PLCs (Planner Lightwave Circuit). The conventional star couplers have advantages of low manufacturing cost, low excess loss and high reliability, compared with the PLCs. However, they are not applicable to the PON system, because their optical properties, such as wavelength dependence of insertion loss and branching uniformity, are not sufficient for the 1,310/1,550nm dual-window operation[1)]. Moreover, Broadband Passive Optical Network (BPON) system (ITU-T 983.3), which utilizes 1,310nm for upstream, 1,490nm for downstream and 1,550nm for additional services such as video distribution service or data service, is expected to become commonplace in the future. In this case, high branching uniformity is required in 1,310nm, 1,490nm and 1,550nm band.

In this report, we propose low excess loss, dual window 1×4 fused taper couplers for the current PON system, and high branching uniformity type 1×4 fused taper couplers for BPON full-band operation. Wavelength flattened characteristics and excellent branching uniformity less than 0.4dB has been achieved in wavelength range from 1,200nm to 1,700nm.

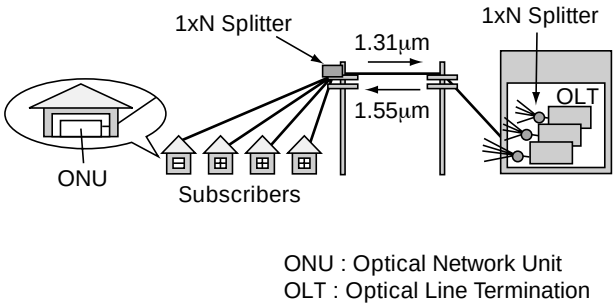


Fig. 1. Typical Passive Double Star Architecture.

2. Structure and Optical Characteristics of the Dual Window 1×4 Fused Taper Star Couplers (Type-1)

Detail structure of the type-1 1×4 coupler is shown in Fig. 2. Four fibers are arranged so that three fibers

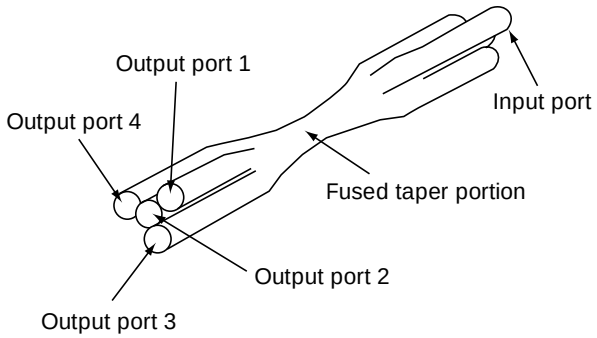


Fig. 2. Detailed Structure of the Dual Window 1×4 Fused Taper Coupler (Type 1).

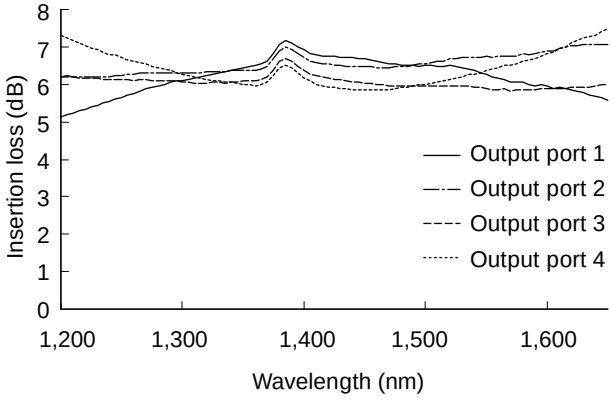


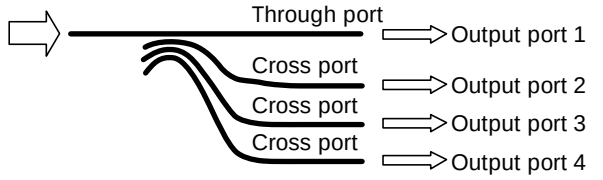
Fig. 3. Wavelength Dependence of Insertion Loss of the Dual Window 1×4 Coupler (Type 2).

surround a center fiber. The four fibers are elongated to induce the desired coupling, under precisely controlled condition.

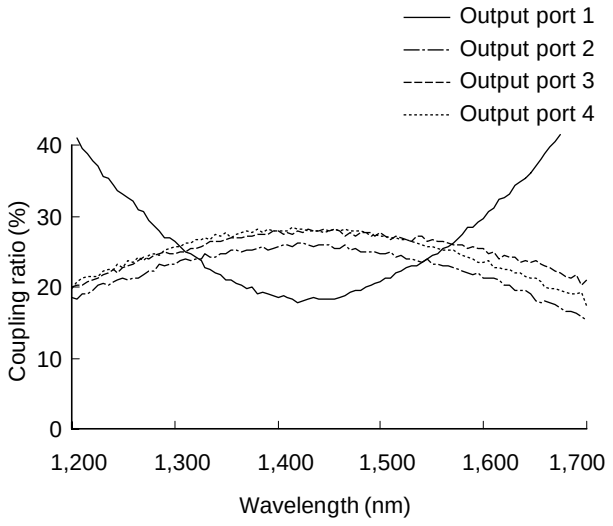
Insertion loss spectra of the type-1 1×4 coupler are shown in Fig. 3. Low insertion loss and high branching uniformity has been achieved in 1,310nm and 1,550nm band. Therefore, the type-1 1×4 coupler is applicable to the current PON system. Its size is as small as 3mm in diameter and 58mm in length.

3. High Branching Uniformity Type 1×4 Fused Taper Star Couplers (Type-2)

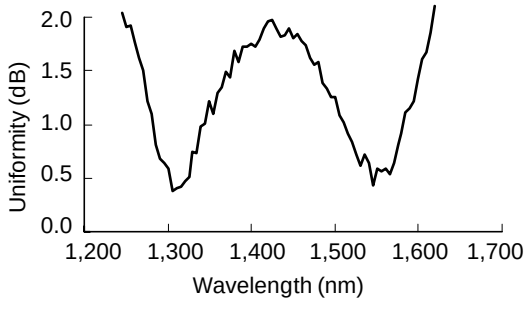
When 1×4 coupler is applied to the BPON system, it is necessary to keep branching uniformity high not only in 1,310nm and 1,550nm band, but also 1,490 nm band. However, the type-1 1×4 coupler does not show sufficient branching uniformity in 1,490nm band (see Fig. 3). To solve this problem, we developed high branching uniformity type 1×4 coupler for BPON full-band operation (Type-2). 0.4dB of branching uniformity has been achieved in wavelength range in 1,200nm to 1,700nm [2) 3)].



(a) A schematic illustration of the type-1 1×4 coupler



(b) Wavelength dependence of coupling ratio



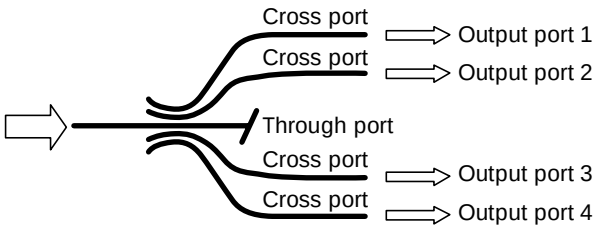
(c) Wavelength dependence of branching uniformity

Fig. 4. A Schematic Illustration and Optical Characteristics of the Type-1 Coupler.

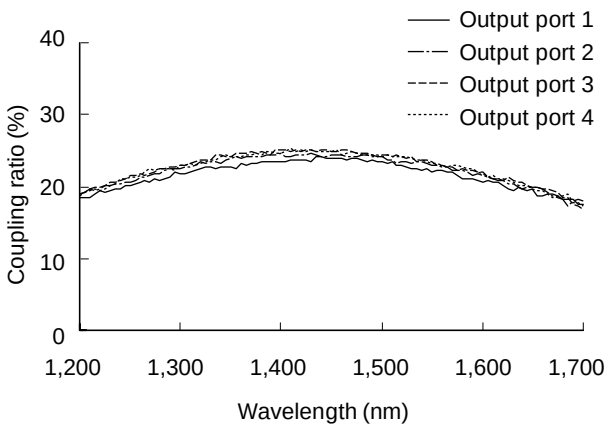
4. Structure and Optical Characteristics of High Branching Uniformity Type 1×4 Couplers (Type-2)

Schematic illustrations and optical characteristics of the dual window 1×4 coupler (Type-1) and the high branching uniformity 1×4 coupler (Type-2) are shown in Fig. 4 and Fig. 5.

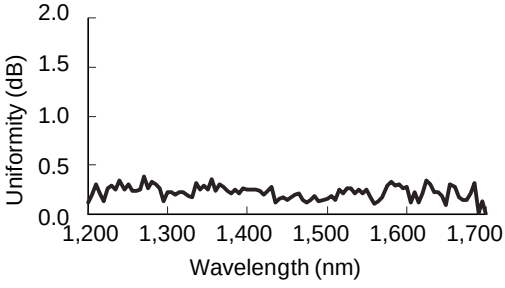
The type-1 coupler has one through port (power remaining port) and three cross ports (power coupling ports) (see Fig. 4(a)). Since the through port



(a) A schematic illustration of the type-2 1×4 coupler



(b) Wavelength dependence of coupling ratio



(c) Wavelength dependence of branching uniformity

Fig. 5. A Schematic Illustration and Optical Characteristics of the Type-2 Coupler.

and the cross ports show different wavelength dependence of coupling ratio, the type-1 coupler cannot keep high branching uniformity in wide wavelength range (see Fig. 4(c)). On the other hand, in the case of the type-2 coupler such as Fig. 5(a), all the launched power couples entirely to the four cross ports (no power appears on through ports) (see Fig. 5(a)). Therefore, the four output ports show the same wavelength dependence of coupling ratio (see Fig. 5(b)). As a result, the proposed type-2 coupler shows excellent branching uniformity less than 0.4dB in wide wavelength range (see Fig. 5(C)).

Detailed structure of the type-2 1×4 fused taper coupler is shown in Fig. 6. Five fibers are arranged so that four fibers surround a center fiber symmetrically (face-centered square structure), in contrast to the type-1 coupler, which are produced by tapering four fibers. The five fibers are elongated to induce the desired coupling, under precisely controlled condition.

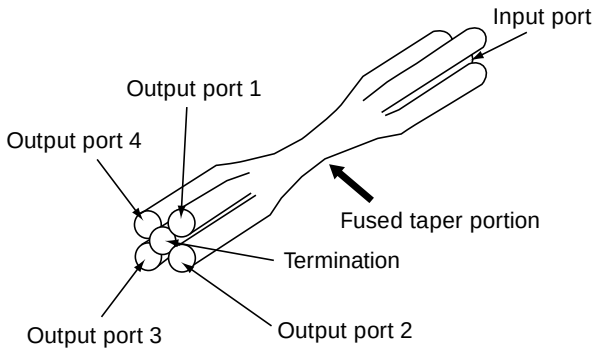


Fig. 6. Detailed Structure of the High Branching Uniformity 1×4 Coupler (Type-2).

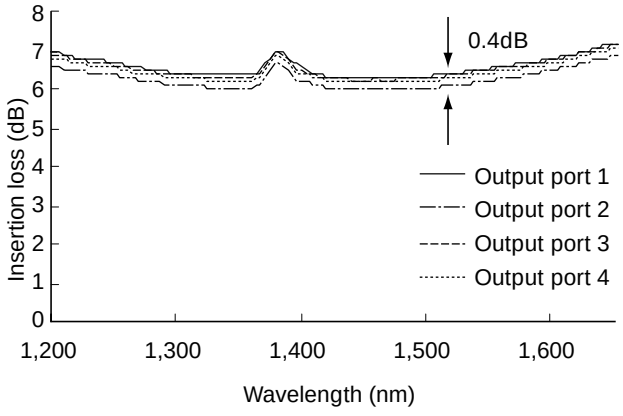


Fig. 7. Wavelength Dependence of Insertion Loss of the Type-2 1×4 Coupler.

Table 1. The Insertion Loss and Branching Uniformity at the Wavelength Defined in ITU-T G.983.1

Wavelength (nm)	Proposed 1×4 star coupler (Type-2)		Conventional 1×4 star coupler (Type-1)	
	Insertion loss (Max.) (dB)	Unifomity (dB)	Insertion loss (Max.) (dB)	Unifomity (dB)
1,310	6.9	0.2	6.4	0.4
1,490	6.7	0.1	-	1.3
1,550	6.9	0.3	6.4	0.6
1,625	7.4	0.3	-	2.1

Insertion loss spectra of the fabricated 1×4 coupler are shown in Fig. 7. The insertion losses and the branching uniformity at the wavelength defined in ITU-T G.983.3 are summarized in Table 1. Wavelength flattened characteristics and high branching uniformity less than 0.4dB have been achieved not only in 1,310nm and 1,550nm window but also in 1,490nm region and U-band (>1,625nm). Its size is the same as the type-1 1×4 coupler, 3mm in diameter and 58mm in length with stainless steel tube packaging.

5. Long Term Reliability

Since the 1×4 couplers are based on the fused taper technology, their reliability is expected to be high as the conventional fused taper couplers. In order to confirm this, the following tests, which were based on Telcordia GR-1209-CORE were performed on each type of the fused taper 1×4 coupler.

(1) Temperature-Humidity Aging, 75°C/90% RH, 7 days (168H)
(2) Temperature Cycling, –40/75°C, 10 cycles

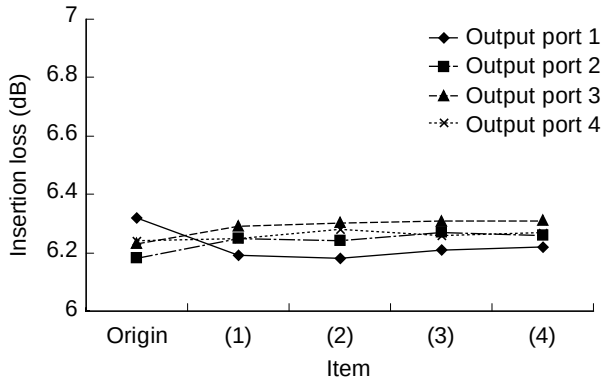


Fig. 8. Insertion Losses Changes of the Type-1 Coupler before and after Each Test.

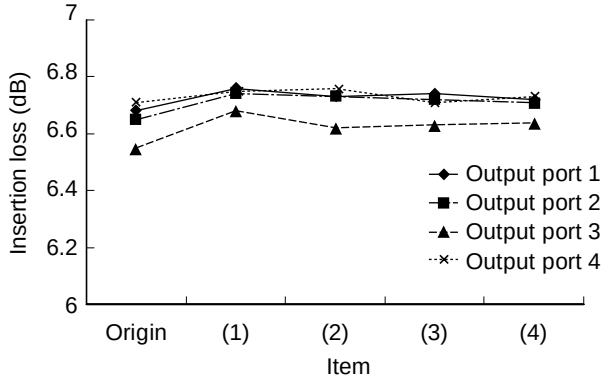


Fig. 9. Insertion Losses Changes of the Type-2 Coupler before and after Each Test.

Table 2. Insertion Losses Changes before and after Each Test

Item	Type-1				Type-2			
	Output port1	Output port2	Output port3	Output port4	Output port1	Output port2	Output port3	Output port4
ORIGIN	6.32	6.18	6.23	6.24	6.68	6.65	6.55	6.71
(1) after Temperature-Humidity Aging	6.19	6.25	6.29	6.25	6.76	6.74	6.68	6.75
(2) after Temperature Cycling	6.18	6.24	6.3	6.28	6.73	6.73	6.62	6.76
(3) after Vibration Test	6.21	6.27	6.31	6.26	6.74	6.72	6.63	6.71
(4) after Impact Test	6.22	6.26	6.31	6.27	6.72	6.71	6.64	6.73

(unit : dB)

(3) Vibration Test, 10-55Hz, 1.52mm amplitude, 3 axes, 1H each
(4) Impact Test, 500g, 3 axes, 2 impacts/direction

The insertion losses of each 1×4 coupler were measured before and after each test. Fig. 8 and Fig. 9 show test results. Also, Table 2 summarizes change of insertion loss. Observed insertion losses changes were small in the both types of the 1×4 couplers.

6. Conclusion

We proposed the low excess loss, dual window fused taper 1×4 coupler for the current PON system. We also proposed the high branching uniformity type 1×4 coupler for BPON full-band operation. Wavelength flattened characteristics and excellent branching uniformity less than 0.4dB has been achieved in wavelength range from 1,200nm to 1,700 nm. Their high reliability was also demonstrated.

References

1) N.Kawakami, et.al.: Fused-taper single mode fiber 32×32 star coupler supported by low-refractive-index glass rod, ECOC'91, Vol.1, pp.321-324, 1991
2) M.Ohashi, et.al.: Novel fused taper 1×4 star coupler for full-band operation, to be published.
3) M.Ohashi et.al.: Novel 1×4 Fused Fiber Coupler with Ultra Wide Band High Branching Uniformity, NFOEC 2003, Vol.3, pp.795-800, 2003