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COMPARISON OF OPTICAL PROPERTIES OF 1 × 8 SPLITTERS BASED ON Y-BRANCH AND MMI APPROACHES

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Abstract. 1 × 8 Y-branch and MMI splitters were designed, simulated and the obtained results of both approaches were studies and compared with each other for such splitters. The core size of the used waveguides is usually 6 × 6 µm^2 to match the diameter of the single mode input/output fibers, *i.e.* to keep the coupling loses as low as possible. In this work we show that the used waveguide core size supports not only propagation of the single mode but of the first mode too, leading to an asymmetric splitting ratio (increasing non-uniformity of the split power over all the output waveguides). Decreasing waveguide core size it is possible to suppress presence of the first mode and this way to reduce non-uniformity, nearly to one half of the original value.

Key words: Y-branch splitter, optical splitting, integrated optics, multimode interference splitter, MMI splitter.

1. INTRODUCTION

Splitting and combining of multiple optical beams plays an important role in the integrated optics [1] allowing the several customers to share the same connection, bringing high-speed networking, digital television and telephone services to residences using fiber-optic cables. There are two main approaches used to split one optical signal into *N* output signals. A simpler possibility to split an optical signal is to make it as a cascade of 1-by-two waveguide branches called Y-branch splitting. Such splitters are the key components in FTTx networks because they are polarization and wavelength independent, *i.e.* one device can be used to split optical signals in the whole operating wavelength window. However, the processing of branching points where two waveguides start to separate, is technologically very difficult leading to an asymmetric splitting ratio of the split power over all the output waveguides.

In multimode interference (MMI) splitters the splitting of the optical signal is based on a self-imaging effect (superposition of modes with different propagation velocities) appearing inside of the multi-mode section [2]. The MMI splitters feature a large splitting number and stable splitting ratio [3], ensuring good uniformity over all the output signals. Another advantage is their good fabrication tolerance because the splitting is performed in multimode section. Furthermore, MMI splitters are potentially shorter compared to Y-branch splitters [4]. However, the length of the multimode section is wavelength dependent, *i.e.* the MMI splitters are designed solely for one wavelength and can only operate in a narrow wavelength band. They are also polarization dependent. However, it has been shown that for strong guidance waveguide structures this dependence is negligible [5].

In this paper we will design and simulate 1 × 8 Y-branch and MMI splitters to show the advantages and disadvantages of both approaches. We will also show that not only technology but also the waveguide core size has strong influence on the non-uniformity of the split power.

2. 1 × 8 Y-BRANCH AND MMI SPLITTERS

1 × 8 Y-branch and 1 × 8 MMI splitters were designed and simulated using Optiwave photonic tool. We concentrated on weakly guiding glass waveguides, *i.e*. the refractive index of the waveguide core was n_c = 1.456 and of the cladding, n_{cl} = 1.445 with a typical refractive index-contrast Δn = 0.75%. The core size of the waveguides was set to (6 × 6) μm^2. The structures were simulated at operating wavelength λ = 1550 nm.

2.1. DESIGN OF STANDARD 1 × 8 Y-BRANCH AND MMI SPLITTERS

1 × 8 Y-branch splitter. For the design of 1 × 8 Y-branch splitter we used the Y-branch structure of 1 × 4 optical splitter as shown in Fig. 1. The branches of this splitter were designed using a predefined “s-bend-arc” shape (OptiBPM tool) because this shape provides the lowest losses [3]. The design of 1 × 8 Y-branch splitter is constructed from two 1 × 4 Y-branch splitters connected by an additional branch. As can be seen from its geometry the splitter consists of a linear input port set to 1000 μm, 8 linear outputs and 7 branches, which are distributed into 3 layers. The port pitch of the output branches, required for the connection with the fibres, was set to 127 μm. Based on this the length of the 1st branch layer, L(1st) = 5000 μm and the 2nd branch layer is doubled, L(2st) = 10000 μm. To keep further the constant bending shape the next branch layer was also doubled *i.e.* L(3rd) = 20000 μm. The pitch between the waveguide in each branch layer was automatically doubled, *i.e.* in the 1st branch layer W(1st) = 127 μm, in the 2nd branch layer W(2nd) = 254 μm and in the 3th branch layer W(3th) = 508 μm. Thereby the whole length of the

1 × 8 Y-branch splitter reached 38000 µm and the width of the splitter was 889 µm (= 7 × 127 µm).

1 × 8 Y-MMI splitter. As a next step a conventional MMI splitter with eight outputs was designed as presented in Fig. 1 – right. The width of the multimode section was tested and finally set to 200 µm and the length was accordingly set to 4843 µm. The waveguide pitch was expanded to 127 µm port pitch by adding a s-bend-arc part to each output. After, the length of s-bend-arc part was set to 10000 µm. The whole length of the 1×8 MMI reached 16023 µm.

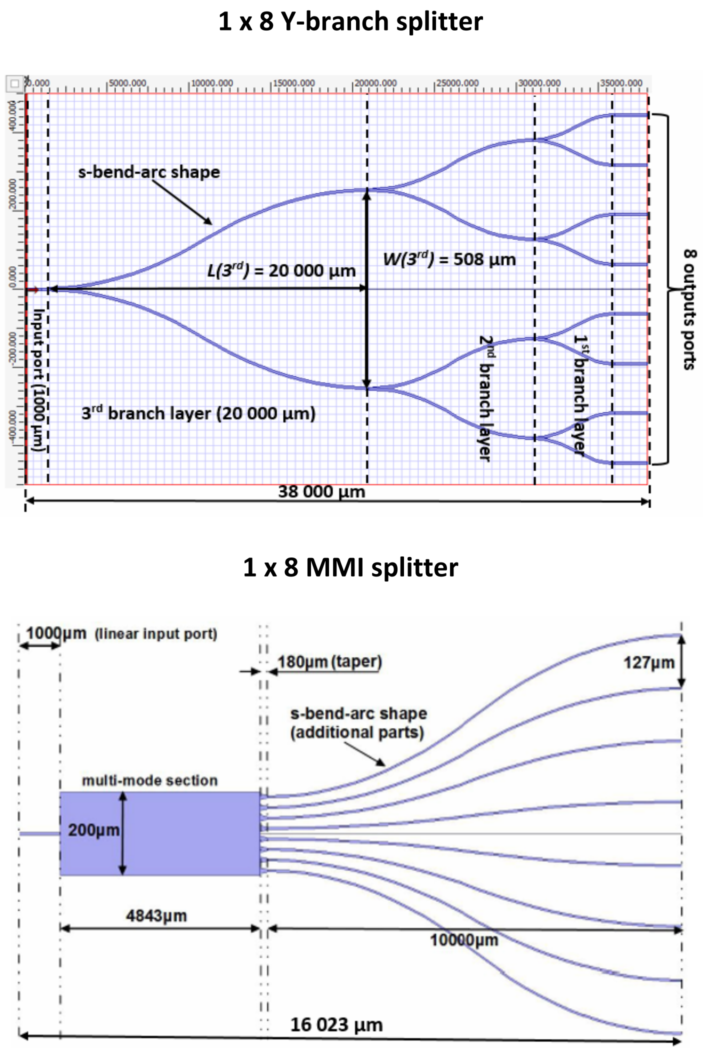


Fig. 1 – Layouts of standard 1 × 8 Y-branch (left)
and 1×8 MMI (right) splitters using OptiBPM tool.

2.2. SIMULATION OF STANDARD 1×8 Y-BRANCH AND MMI SPLITTERS

Figure 2 – top presents the top view of the simulated 1 × 8 Y-branch and MMI splitters using Optiwave tool. As can be seen Y-branch features much lower background noise than MMI splitter. Figure 2 – middle shows the corresponding field distribution at the end of the structures. In both approaches, all eight outputs are well separated. The background noise of Y-branch splitter, *BX* = = –46.81 dB (Fig. 2 – middle-left) and for MMI splitter is higher, *BX* = –35.63 dB (Fig. 2 – middle-right), confirming the results presented in Fig. 2 – top. The uniformity of the split power over all the output channels (also called insertion loss non-uniformity), *ILu* = 1.41 dB and the insertion loss (worst peak) *IL* = –10.01 dB for Y-branch approach (Fig. 2 – bottom-left). For MMI splitter the non-uniformity reached value, *ILu* = 0.51 dB as shown in Fig. 2 – bottom-right. Insertion loss is similar to Y-branch splitter, *IL* = –9.91 dB.

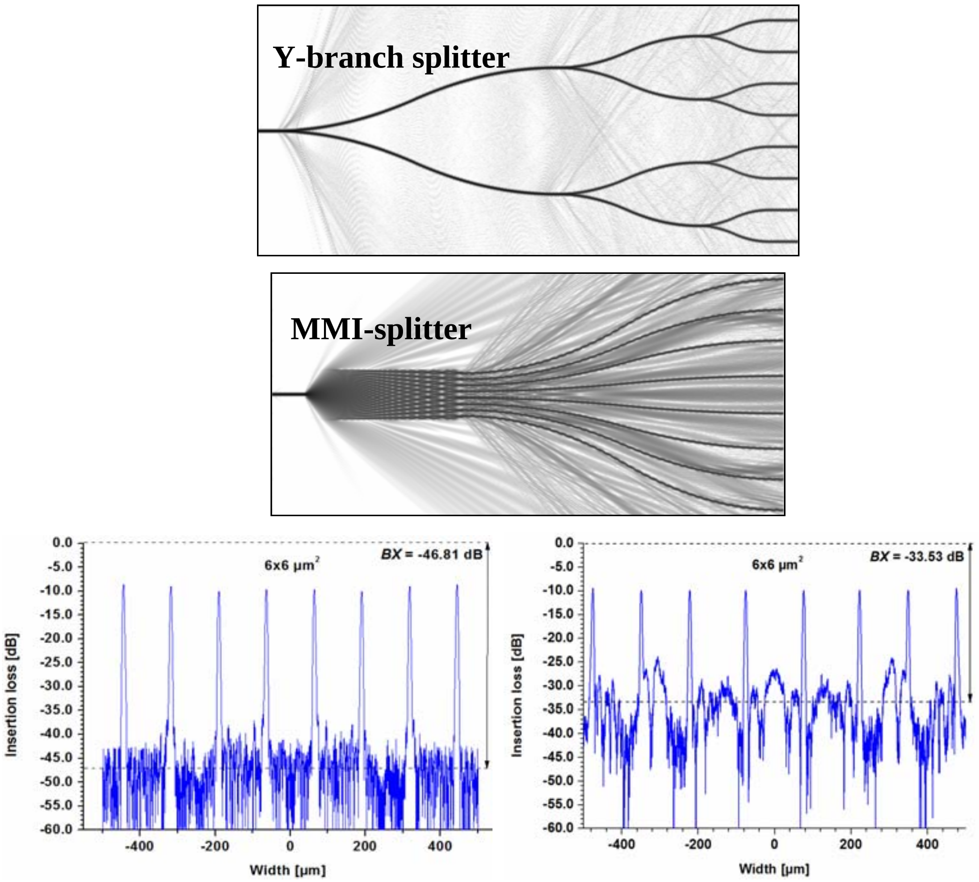
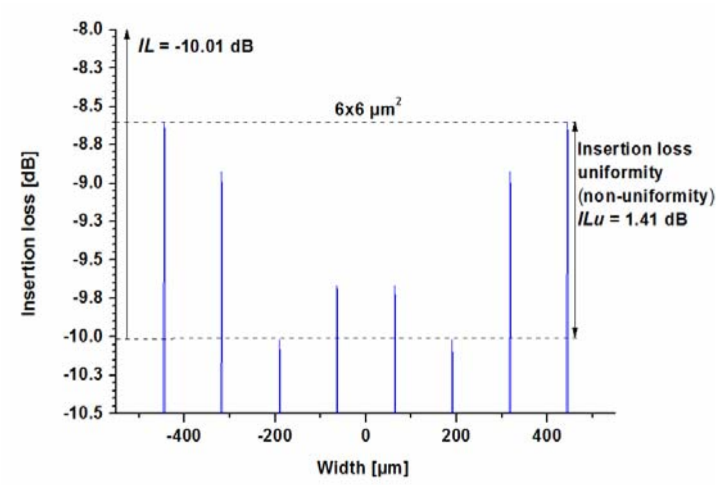


Fig. 2



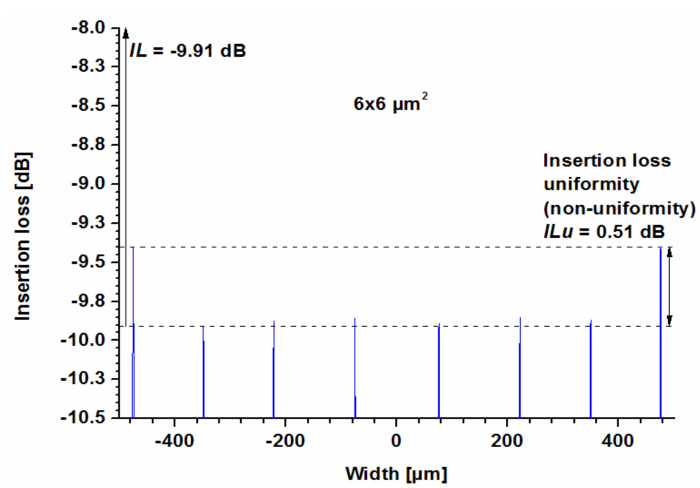


Fig. 2 – Top view of the simulated 1 × 8 Y-branch (top-left) and MMI (top-right) structures. Field distribution at the end of 1 × 8 Y-branch (middle-left) and 1 × 8 MMI (middle-right) splitters. Non-uniformity and insertion loss of 1 × 8 Y-branch (bottom-left) and 1 × 8 MMI (bottom-right) splitters.

3. COMPARISON OF OPTICAL PROPERTIES OF BOTH APPROACHES

The deep study of the achieved simulation results presented in Fig. 2 showed that in the standard 6×6 μm^2 waveguide not only propagation of the single mode is supported but also the presence of the first mode is already so strong that it causes additional asymmetric splitting of the optical signal at the branching points in Y-branch splitters. This becomes a dominant factor particularly when reducing the length of the high channel Y-branch splitters [6]. To show this influence we reduced the waveguide core size from 6 × 6 μm^2 to 5.5 × 5.5 μm^2 and 5 × 5 μm^2 in both splitters keeping the same size of the structures. The simulated results are shown in Fig. 3. It can be seen that the splitting parameters of the MMI splitter compared to the splitting parameters of Y-branch splitter are again much better. While the non-uniformity of MMI splitter reached only *ILu* = 0.25 dB, the non-uniformity of Y-branch splitter, *ILu* = 0.73 dB for the waveguide core size of 5.5 × 5.5 μm^2. For the waveguide core size of 5 × 5 μm^2 the non-uniformity, *ILu* is again much smaller for the MMI splitter, namely 0.82 dB while the non-uniformity of the Y-branch splitter, *ILu* = 1.2 dB. Also the insertion loss is slightly lower for MMI splitters. Only the maximum background noise is much better for Y-branch splitters. This confirms that a large splitting number features a stable splitting ratio only for MMI splitters.

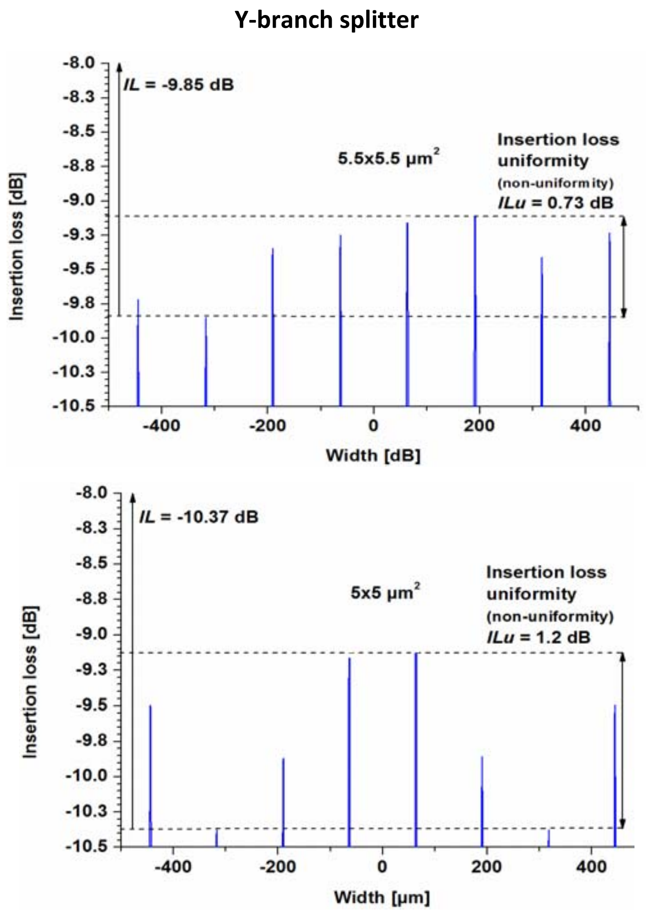


Fig. 3

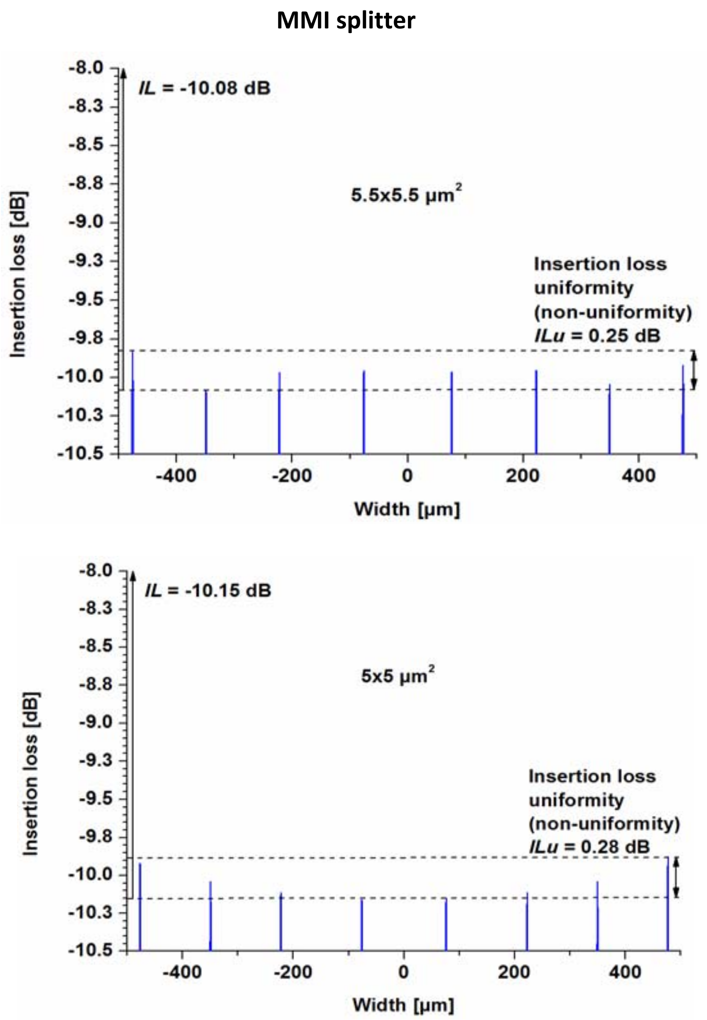


Fig. 3 – Detailed view of splitting parameters of 1 × 8 Y-branch (left) and 1 × 8 MMI (right) splitters with the waveguide core sizes of 5.5×5.5 μm^2 (top) and 5×5 μm^2 (bottom).

4. DISCUSSION AND CONCLUSIONS

As shown in Fig. 3 keeping the same Y-branch layout and decreasing the waveguide core size from (6×6) μm^2 to (5.5×5.5) μm^2 and (5×5) μm^2 the splitting parameters of the Y-branch splitter were strongly improved. From the simulated results, we can conclude that optimizing the waveguide core size of both splitters could lead to strong improvement of splitting parameters. Particularly, decreasing the waveguide core it is possible to suppress presence of the first mode and in this way to reduce the non-uniformity to approximately half of the original value.

In Table 1, the splitting parameters as well as the length of the 1 × 8 Y-branch and 1 × 8 MMI splitters are presented.

Table 1

Comparison of splitting parameters of standard 1 × 8 Y-branch and 1 × 64 MMI splitters

		Non-uniformity, *ILu*	Insertion loss, *IL*	Background noise, *BX*	Length of splitter
Y-branch	6×6 μm^2	1.41 dB	–10.01 dB	–46.81 dB	38 000 μm
	5.5×5.5 μm^2	0.73 dB	–9.85 dB	–47.67 dB	38 000 μm
	5×5 μm^2	1.2 dB	–10.37 dB	–45.89 dB	38 000 μm
MMI	6×6 μm^2	0.51 dB	–9.91 dB	–33.53 dB	16 023 μm
	5.5×5.5 μm^2	0.21 dB	–10.08 dB	–32.08 dB	16 023 μm
	5×5 μm^2	0.82 dB	–10.82 dB	–31.97 dB	16 023 μm

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