# 具有改良式基板稜鏡及漸變波導之Y形分岔之設計

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## 摘　要

本論文係提出一種具有改良式基板稜鏡及兩漸變輸出波導之對稱式 Y 形分岔。研究結果顯示，即使在 30 度分岔角度下，所模擬之正規化傳輸率可高達約 70%。

**關鍵詞**：Y 形分岔、漸變波導、基板稜鏡

# The Design of Y-branch with Improved Substrate Prism and Tapered Waveguides

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## Abstract

The symmetric Y-branch with a improved substrate prism and two tapered output waveguides are proposed. The simulated normalized transmission power is about 70% even with a branching angle of $30^o$. 。

**Key Words**：Y-branch, tapered waveguides, substrate prism

# I. Introduction

Y-branches in optical waveguides are widely used as power divider and combiner in modulator, switches, interferometric devices, semiconductor lasers, etc. However, devices using conventional Y-branches suffer from severe radiation losses, particularly with a branching angle larger than 2 degree [1]. To find a large-angle low-loss bend configuration for increasing packing density is then quite important. Many efforts have been devoted to reduce the radiation losses [2]-[7]. Hung et al. proposed a Y-junction with a low refractive index region, called the phase-front accelerator, at the central region between the two branches. Although the radiation loss is reduced, the branching angles are not large enough, and no simple rule is available for the design of the device. Lin et al. designed one pair of high-index integrated microprisms on a single mode Y-junction to compensate the phase mismatch caused by waveguide branching. Recently, a symmetric Y-branch with a substrate prism and two tapered output waveguides on $LiNbO_3$ has been reported. The prism-like region of refractive index equal to that of the substrate (i.e. substrate prism), also known as the phase-front accelerator region, is placed at the the junction of the Y-branch to compensate the phase difference caused by bending. Two tapered output waveguides are used to reduce the field mismatch caused by the substrate prism. Because of not requiring extra regions of indices different from those of waveguide and substrate, the proposed structure can be easily fabricated.

In this paper, we propose the novel wide-angle low-loss symmetric Y-branches with improved substrate prism and tapered waveguides. We use optic-wave propagation simulation propagation program 'BeamPROP' to simulate the output results.

# II. Design and Results

Fig. 1 shows the proposed Y-branch with a improved substrate prism and two tapered arms. We apply the substrate prism to compensate the phase difference. In this Fig., *W* is the width of the input waveguide, $\theta$ is the branch angle of the proposed Y-branch. The arms is varied from $W_b$ to *W* with a taper length *S* to reduce the field mismatch. Consider a Y-branch of width *W* with type II substrate prism and branching angle $\theta$ as shown in Fig. 2. We examine the interface $\overline{AB}$ between the waveguide region and the substrate prism region. A laser light of wavelength λ is incident to the left end of the junction and then directed to two branching waveguides. The angles of incidence and refraction, $\theta_i$ and $\theta_r$, are measured with respect to the normals to the interface planes. From Snell's law

$$n_s \sin\theta_i = n_f \sin\theta_r \quad , \tag{1}$$

and

$$\theta_r = \theta_i - \frac{\theta}{2} \quad . \tag{2}$$

Combining (1) and (2) leads to

$$\tan\theta_i = \frac{n_f \cdot \sin\left(\frac{\theta}{2}\right)}{n_f \cdot \cos\left(\frac{\theta}{2}\right) - n_s} \quad . \tag{3}$$

The length L of the type II substrate prism can be given by

$$L = \frac{W}{2}\cdot\tan\theta_i = \frac{W}{2}\cdot\frac{n_f \cdot \sin\left(\frac{\theta}{2}\right)}{n_f \cdot \cos\left(\frac{\theta}{2}\right) - n_s} \quad . \tag{4}$$

where $n_f$ and $n_s$ are waveguide and substrate indices, respectively, and *L* is the prism length.

To demonstrate the operation of the improved Y-branches, the normalized transmission power $\eta$ is calculated for a 2-D slab waveguide. The device parameters are chosen as $n_f = 2.32$, $n_s = 2.2$, and $W = 4$ μm. Assume the input end is excited by the fundamental transverse magnetic (TM) mode of a straight waveguide at $\lambda = 0.6328$ μm. The field passing through the substrate prism region is distorted and suffers from some loss due to field mismatch. Fig. 3 shows the normalized transmission power $\eta$ versus *S* for the proposed Y-branch. As can be seen from the figure, $\eta$ increases with *S* for the proposed Y-branches. That is because the optical field, after passing through the substrate prism, varies slowly in the tapered waveguides. Consequenly, the loss from field mismatch can be reduced. Moreover, the transmission power exhibits an oscillatory behavior. That is due to the interference of guided and leaky fields.

Fig. 4 shows the normalized transmission power $h$ versus the substrate prism length variation for $q = 10^{o}$, $20^{o}$ and $30^{o}$. The corrected $L$ ($L_c$) and the $L$ obtained directly from (4) versus $q$ are both shown in Fig. 5. The corrected $L_c$ is very approximate to the $L$ obtained from (4). Fig. 6 shows $h$ versus $q$ for the conventional Y-branch and the proposed Y-branch with corrected prism length $L_c$. As shown in the figure, the transmission loss is small with a relatively wide branching angle by compared with the conventional Y-branch. The normalized transmission power of the proposed Y-branches can be greater than 70 % even with $\theta = 30^{o}$.

## III. Conclusions

The novel Y-branch with a improved substrate prism and two tapered output waveguides are proposed. The losses from the phase mismatch and field mismatch are considered. The calculated transmitted power ratio is about 70% at the branching angle of $30^{o}$. The complete and advance details is under research.

## Acknowledgment

This research was supported by the National Science Council, Taiwan, ROC, under Grant NSC 90-2215-E-231-001.

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91 年 08 月 26 日投稿
91 年 09 月 28 日接受

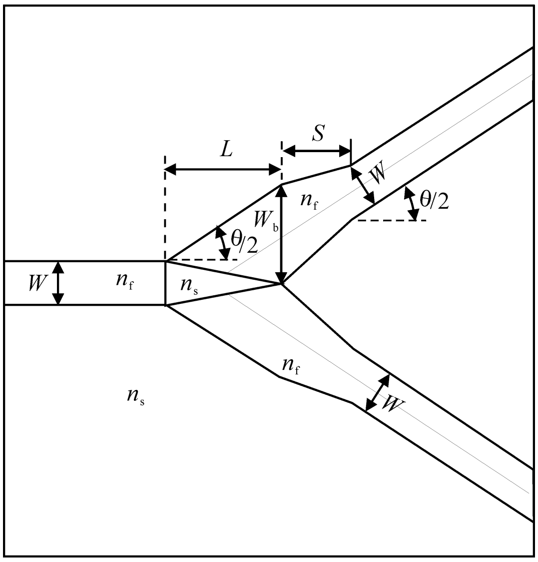

Fig 1　The proposed Y-branch with a improved substrate prism and two tapered arms.

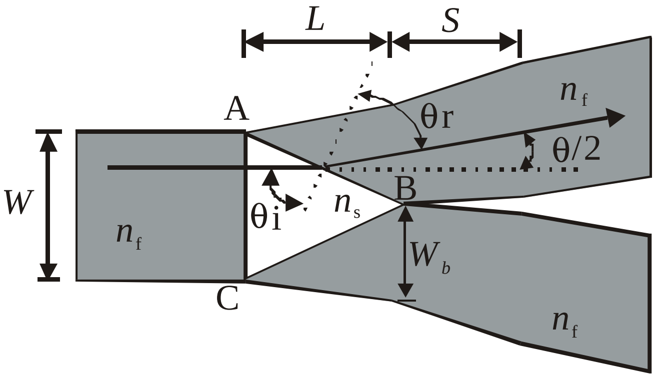

Fig 2　The ray tracing of the proposed Y-branch.

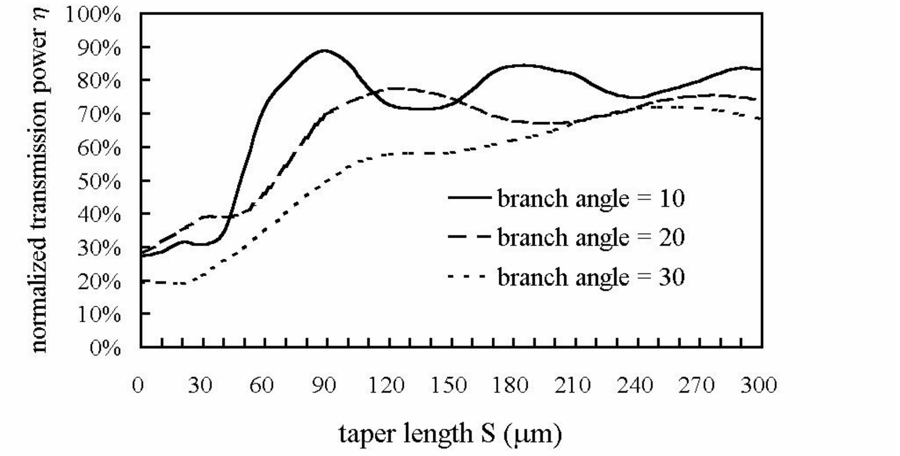

Fig 3　The normalized transmission power ***h*** versus *S* for the proposed Y-branch.

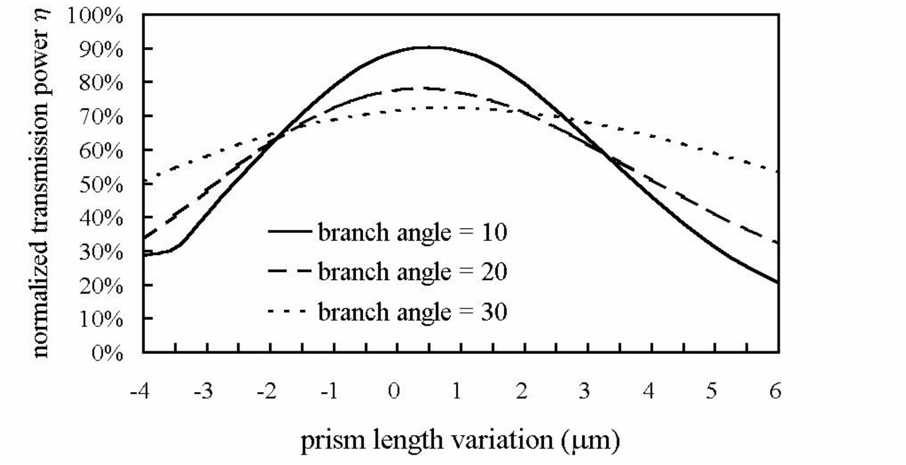

Fig 4 The normalized transmission power $h$ versus the substrate prism length variation for $q$ = $10^{o}$, $20^{o}$ and $30^{o}$.

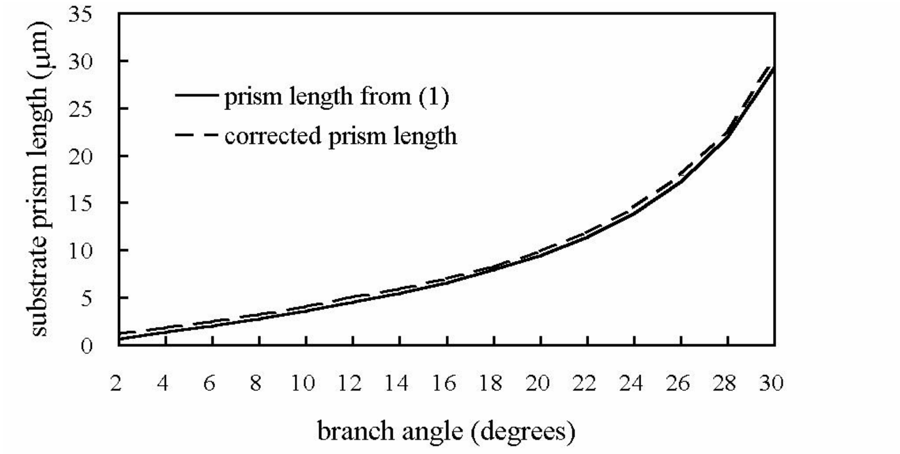

Fig 5 The corrected $L$ ($L$c$)$ and the $L$ obtained directly from (1) versus $q$.

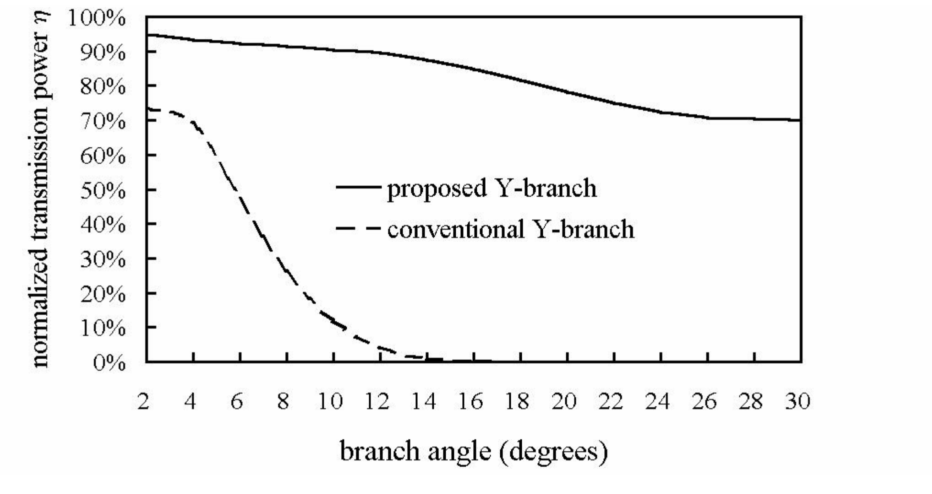

Fig 6 shows $h$ versus $q$ for the conventional Y-branch and the proposed Y-branch with corrected prism length $L_c$.