Analysis of Y-Branch with Substrate Prism on $LiNbO_3$

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Y-branches in optical waveguides are widely used as power divider/combiner in modulator, switches, interferometric devices, semiconductor lasers, etc. The conventional Y-junction (Fig. 1) couplers suffer severe radiation losses when the branching angle θ is larger than 2° [1]. Many efforts have been devoted to reduce the radiation losses [2]. Among them, the use of integrated prism is the most promising for practical applications [3]. When a Y-branch with an integrated prism is considered, regions of different refractive indices is then needed, which makes it difficult to be implemented on $LiNbO_3$. Recently, an abrupt bend with a bend angle of about 10° fabricated on $LiNbO_3$ by proton exchange has been reported [4]. The prism-like region of refractive index equal to that of the substrate (i.e. substrate prism) is placed at the corner of the bend to compensate the phase difference caused by bending. In this work, a novel Y-branch with a similar substrate prism and two tapered output waveguides (Fig. 2) is proposed and analyzed.

The substrate prism is designed by the rule as given by [4]

$$\left(n_f - n_s\right) \cdot L = n_{\mathrm{eff}} \cdot W \cdot \tan\left(\frac{\theta}{4}\right) \cdot \frac{n_s}{n_f} \qquad (1)$$

where n_f, n_{eff}, and n_s are waveguide, effective, and substrate indices, respectively, W is the waveguide width, and L is the prism height. For simplicity, proton exchanged waveguides on Z-cut $LiNbO_3$ are used for the simulation. Due to the inherent single-polarization property of the proton-exchanged waveguide, only the TM modes are considered. The normalized transmitted powers η of the proposed Y-branch is calculated by the semivectorial finite-difference beam propagation method [5]. Fig. 3 shows η versus the tapered length of the output waveguide S for n_f= 2.32, n_s=2.2, $n_{eff} \approx n_f$, and W = 4 μm, but with different values of θ. Obviously, η increases with S because that the optical field, after passing through the substrate prism, varies slowly in the tapered waveguides. Thus, the field mismatch losses can be much reduced. Moreover, the transmission power exhibits an oscillatory behavior. That's due to the interference of guided and leaky fields. In particular, $\eta \approx 90\%$ can be found when $\theta \approx 10°$ and S = 95 μm, which is close to that of the other prism design [6]. Fig. 4 shows that the normalized transmission power of the proposed Y-branch and the conventional one. As can be seen from the figure, the propagation loss of the proposed Y-branch is small within the limitation $\theta < 10°$, (the limitation of the beam propagation method) as compared to that of the conventional one. The proposed Y-branch does not involve any sophisticated process steps, hence it is believed to be more eligible for practical fabrication.

In conclusion, a novel Y-junction on $LiNbO_3$ with wide-angle and low-loss characteristics are proposed. Further application of the abrupt bend in the fabrication of

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waveguide devices such as Mach-Zehnder interferometer will be of great interest in the future.

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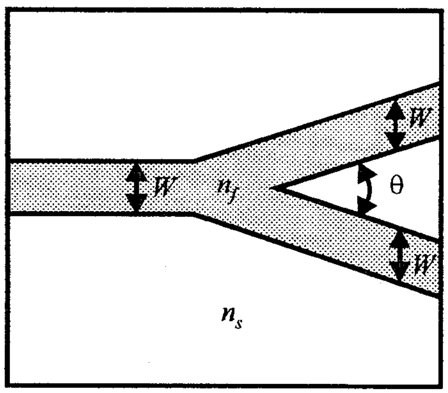

Fig. 1 The conventional Y-branch

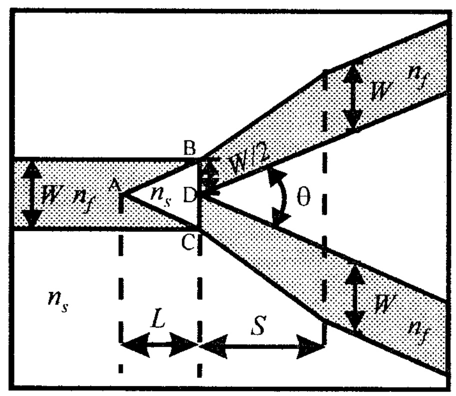

Fig. 2 The proposed Y-branch

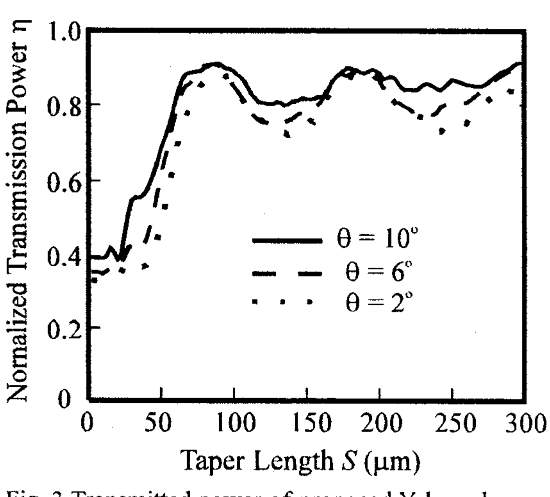

Fig. 3 Transmitted power of proposed Y-branch versus taper length with different branching angle

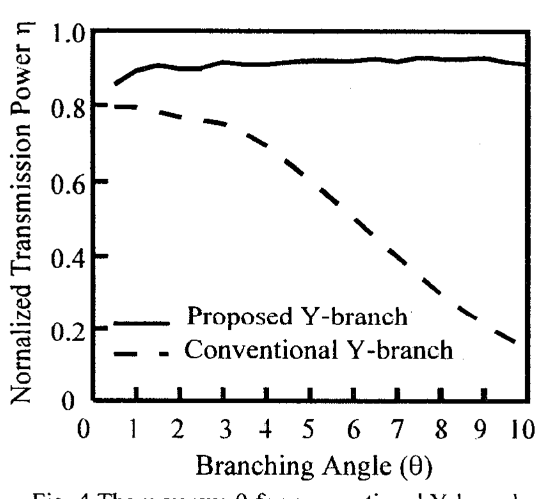

Fig. 4 The η versus θ for conventional Y-branch and proposed Y-branch with S=95μm.