Digest of Tech. Papers The 11th Conf. (1979 International) on Solid State Devices, Tokyo

B—4—3

A Coupled-Waveguide TE/TM Mode Splitter

Osamu Mikami

Musashino Electrical Communication Laboratory,

Nippon Telegraph and Telephone Public Corporation

3-9-11, Midoricho, Musashino-shi, Tokyo, 180, Japan

A guided-wave optical TE/TM mode splitter is one of the basic components for integrated optical circuits. This paper proposes a novel channel waveguided TE/TM mode splitter, which spatially separates the TE and TM mode components, and which is compatible with single mode fiber systems.

The device configuration is shown in Fig. 1. Two straight waveguides are formed closely parallel to each other on an electro-optic c-plate $LiNbO_3$ substrate by preferential Ti diffusion. The interaction length is denoted by L_1. An Al metal strip is loaded on waveguide 2. Two planar electrodes, whose lengths L_2 are equal to $L_1/2$, are formed on waveguide 1 with an in-between Al_2O_3 buffer layer. The following condition is assumed to be satisfied for the TE mode :

$$L_o \leq L_1 \leq 3L_o \ , \qquad (1)$$

where L_o is 0 dB coupling length. This condition is not required for the TM mode. From coupled wave equations,[1] light coupling between two adjacent waveguides can be made negligibly small, if $L_o|\beta_1 - \beta_2| \gg 1$ is satisfied, where β_1 and β_2 are propagation constants for the two waveguides. A metal film loaded on a waveguide markedly reduces the TM mode propagation constant.[2] A simple calculation for an Al loaded slab waveguide shows that the TM mode propagation constant changes by nearly 0.03 %, which is large enough to reduce TM mode light coupling to zero and realize 20 dB crosstalk for $L_o \gtrsim 10$ mm. On the other hand, the TE mode propagation constant change, due to the loaded metal film, is much smaller, so that light coupling takes place. From the condition of Eq. (1), a complete 0 dB coupling can be realized by applying external voltages V_1 and V_2 to the two electrodes.[3] Applied voltages V_1 and V_2 have an opposite sign with respect to each other. As a result, when a laser beam is fed into waveguide 1, the TM mode component passes through the waveguide (" straight-through state "). On the other hand, the TE mode component is coupled to waveguide 2 (" crossover state ").

The device structure was as follows : Each waveguide was 8 μm wide, the gap width was 5 μm and the interaction length L_1 was 15 mm. 0 dB coupling lengths for the TM and TE modes were measured, at 1.15 μm wavelength, to be about 10 mm and 7.5 mm, respectively. The loaded Al strip on waveguide 2 was about 2000 Å thick. After depositing about 1700 Å thick Al_2O_3 fim on waveguide 1, two planar Al electrodes, with 7.5 mm length L_2, were provided. The gap between these electrodes and the metal strip on waveguide 2 was 5 μm.

The 1.15 μm He-Ne laser beam was coupled into waveguide 1 with a single mode fiber. Only fundamental TM and TE modes propagated in the waveguides. At zero applied voltages $V_1=V_2=0$, light coupling for the TM mode was almost completely reduced to zero, and more than 20 dB crosstalk was realized. This was due to sufficiently large propagation constant difference induced by the loaded Al strip. On the other hand, nearly 25 % coupling occured for the TE mode at $V_1=V_2=0$. Next, the V_1 and V_2 values were adjusted so that the TE mode output power from waveguide 2 became a maximum. In this sample, the " crossover state " was realized at V_1=20 V and V_2=-15 V. The obtained TE mode crosstalk was about 20 dB. The " straight-through state " for the TM mode was hardly affected by the applied voltage. The near-field patterns of the waveguides were measured by using a galvano-mirror. As shown in Fig. 2, " straight-through state " for the TM mode and " crossover state " for the TE mode were simultaneously realized. Optical insertion loss, excluding fiber to waveguide connecting loss and Fresnel reflection loss at the device end faces, was 1.7 dB.

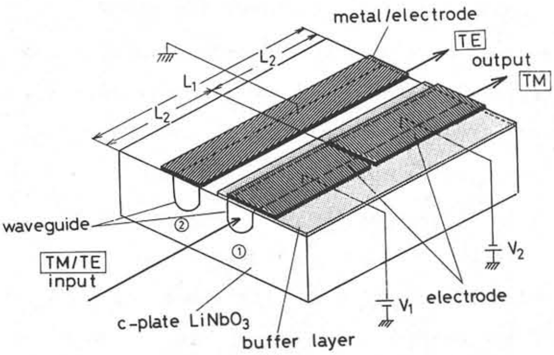

Fig. 1 Principal configuration of the proposed TE/TM mode splitter.

References

1)S.E.Miller,BSTJ,33,661(1954).

2)O.Mikami et al.,APL,33,856(1978).

3)R.V.Schmidt et al.,APL,28,503(1976).

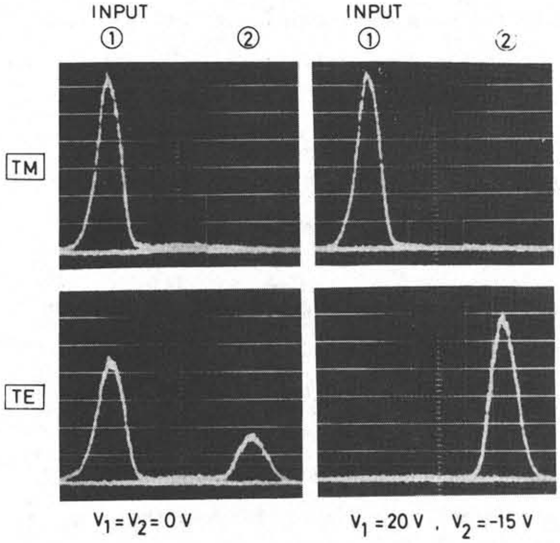

Fig. 2 Observed near-field patterns for TM and TE modes at $V_1=V_2=0$, and V_1=20 V, V_2=-15 V. The laser beam was coupled into waveguide 1.