편광에 무관한 1 x 8 InGaAsP/InP 다중모드간섭 광분배기의 설계 및 제작

Design and Fabrication of a Polarization-Independent 1 x 8 InGaAsP/InP MMI Optical Splitter

Jae Su Yu, Jeong Yi Moon, Seong Ju Bae, and Yong Tak Lee
Department of Information & Communications, Kwangju Institute of Science & Technology,
jsryu@geguri.kjist.ac.kr

Optical power splitters and/or couplers are important components for optical signal distribution between channels both in wavelength division multiplexing(WDM) systems and photonic integrated circuits(PICs). Since polarization is usually not known after propagation in an optical fiber, passive WDM components have to be polarization insensitivity. Compared to alternatives such as directional couplers or Y-junction splitters, splitters based on multimode interference(MMI) have found a growing interest in recent years because of their desirable characteristics, such as compact size, low excess loss, wide bandwidth, polarization independence, and relaxed fabrication tolerances[(1)]. These devices have been fabricated in polymers, silica, or III-V semiconductor materials. A 1 x 4 MMI power splitter on InP materials that were suitable for application in the 1.55-μm region[(2)]. However, the fabrication process of the structure is too complicated and the photolithography tolerance is very tight. Also, a 1 x 16 InGaAsP/InP MMI power splitter with an excess loss of 2.2dB and a splitting ratio of 1.5dB was demonstrated by using deep etching[(3)]. The deep etching of the sidewalls through the entire guide layer of the slab waveguide resulted in a number of drawbacks[(4)].

In this study, we have designed polarization-independent 1 x 8 MMI power splitters with a weakly guided ridge structure by using the effective index method(EIM) and a finite difference beam propagation method(FD-BPM) simulation. We fabricated them on InP materials by using an optimized CH_4/H_2 RIE process.

Figure 1 shows the excess loss and the splitting ratio at the output of the 1 x 8 MMI splitter as functions of the length and the width of the multimode waveguide, and the wavelength for TE and TM polarizations. The splitter exhibits a minimum excess loss of 0.29dB(0.36dB) and a splitting ratio of 0.34dB(0.49dB) at a wavelength of 1.55μm for TE(TM) polarization. For an excess loss and a splitting ratio below 1dB and 0.5dB, respectively, the fabrication tolerances for the length and the width of the multimode waveguide are 2445$\pm$15μm(20μm), 96$\pm$0.3μm(0.4μm), respectively, and the bandwidth is 20nm(35nm) for TE(TM) polarization. SEM micrographs of the fabricated 1 x 8 MMI splitter are shown in Fig. 2. All the input and output waveguides were 3-μm wide and supported the fundamental mode only. The epitaxial layer consisted of 350-nm-thick lattice-matched InGaAsP layer(λ_g=1.2μm) cladded by a 1.5-μm-thick InP layer and were grown by metalorganic vapor-phase epitaxy(MOVPE) on an InP substrate. The polarization dependence of the devices, both for TE and TM polarization, was investigated using a polarization controller and polarizer. The propagation loss was measured by the cutback(CB) method and found to be 2.91dB/cm at 1.55㎛ for the fabricated 3-㎛-wide straight waveguides. The IR camera image and the line scan of the 1 x 8 MMI splitter for TE polarization are shown in Fig. 3. Figure 4 shows insertion loss calculated and measured at each output port for a 1 x 8 MMI splitter both for TE and TM polarizations. For TE(TM) polarization, an excess loss of 1.02dB(1.95dB) and a splitting ratio of 0.68dB(1.13dB) were obtained for the fabricated 1 x 8 MMI power splitter. The measured excess loss was higher than the simulated one, which could be ascribed to device process errors.

In conclusions, we demonstrated theoretically and experimentally that a polarization-independent 1 x 8 MMI power splitter with a weakly guided ridge structure have the advantage of ease in manufacture and can be used to divide the power equally between the eight split output ports with low excess loss, low splitting ratio, and acceptable fabrication tolerance.

1. Pierre. A. Besse et al., J. Lightwave Technol. **12**, 1004 (1994).
2. A. Ferreras et al., IEEE Photon. Technol. Lett. 5, 1224 (1993).
3. L. H. Spiekman et al., in *Proceedings of ECOC* (firenze, Italy, 1994), paper We.C.2.3.
4. Tristan J. Tayag et al., IEEE Photon. Technol. Lett. 7, 896 (1995).

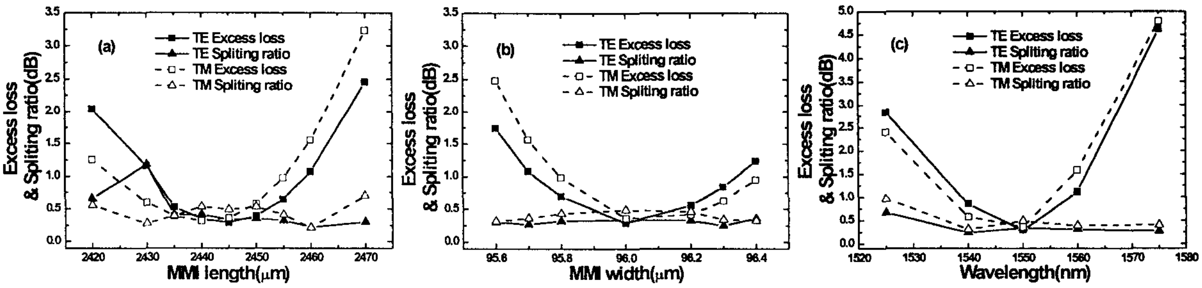

Fig. 1. Excess loss and splitting loss at the output ports of a 1 x 8 MMI splitter as function of (a) MMI length, (b) MMI width, and (c) wavelength.

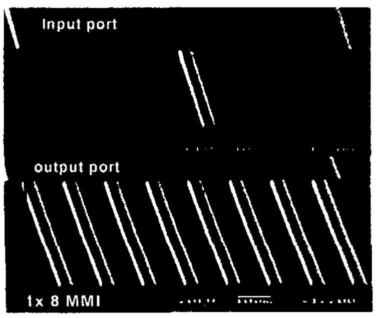

Fig. 2. SEM micrographs of the fabricated 1 x 8 InGaAsP/InP MMI splitter.

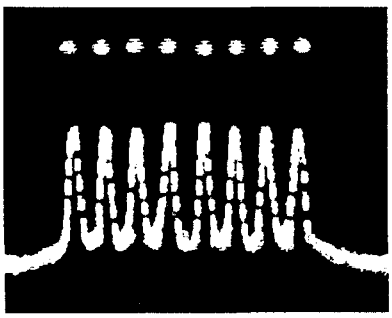

Fig. 3. IR camera image and line scan of the eight ouput beams of the 1 x 8 MMI splitter for TE polarization.

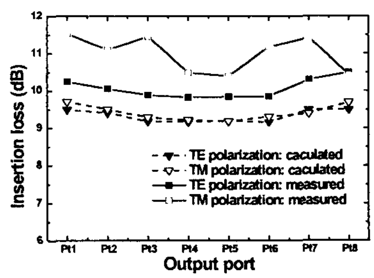

Fig. 4. Insertion loss calculated and measured at each output port for a 1 x 8 MMI splitter both for TE and TM polarizations.