Power Propagation On Linear Mxn Fiber Couplers Using Matrix Transfer

SAKTIOTO
Plasma and Photonics Reserach Laboratory
Department of Physics, Faculty of Mathematics and Natural Sciences,
University of Riau, Pekanbaru, Indonesia, email: saktioto@yahoo.com

ABSTRACT

Coupling power propagation on MXN monolithic fiber coupler has been calculated by using matrix transfer based on coupled-mode theory. Launching input power to one fiber on linear 1X7 monolithic fiber coupler shows that power is distributed to the other fibers with different coupling velocity. It is found that the outer fiber has the slowest coupling velocity and high transferred power. The measurement of output power of 1X7 fiber coupler as fiber combiner has been theoretically and experimentally done. The experimental result is compared to the theoretical model. A small different peak at certain distance occurs due to the coupling velocity. This MXN multi fiber coupler is applied for various optical power circuits.

Keyword: coupling power, matrix transfer

INTRODUCTION

Fiber coupler is main devices in optical communication system. It is used to split, to combine, and to switch the optical signal. The fiber coupler is commonly fabricated by fusion process. The analysis and fabrication of 2X2 SMF-28 fiber couplers has been clearly investigated [1]. It describes how the light intensity can be transferred from fiber one to fiber two. The coupling coefficient is a parameter that affected by refractive index, separation between fibers, and radius of fibers. The fabrication of MXN fiber couplers will be benefit and interesting phenomena where multi fibers with many junction fibers are not much investigated due to difficulties in controlling fiber coupling parameters [2,3]. Launching input power to the different input ports gives different coupling velocity profile. The 1X7 monolithic fiber coupler and 7X1 are purposed.

DESIGN AND SIMULATION

By launching input power to the fiber 1, the coupling velocity will vary for each fiber in Fig.1.

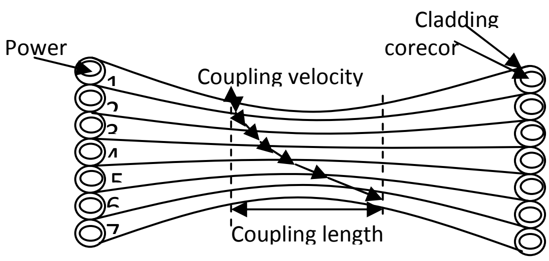

Figure 1.Illustration of cross section and coupling velocity of linear 1X7 fiber coupler.

The transfer of light in fiber couplers was determined by coupling-mode theory, where it much depend on coupling coefficient and propagation constant of the fibers.

$$\frac{dA_m(z)}{dz} = -j\beta_m A_m(z) - j\kappa_{m(m-1)}A_{m-1}(z) - j\kappa_{m(m+1)}A_{m+1}(z) \tag{1a}$$

$$\frac{dA_n(z)}{dz} = -j\beta_n A_n(z) - j\kappa_{n(n-1)}A_{n-1}(z) \tag{1b}$$

The value of β denotes propagation constants, and κ is the coupling coefficient. The solution of inner matrix is determined by eigenvalue and eigenvector that describes transformation of power where $M_{pq} = \sum_{p,q=1}^{n} \sin\left(\frac{pm\pi}{n+1}\right)\sin\left(\frac{qm\pi}{n+1}\right) e^{\lambda_m z}$ is the transfer matrix and,

$$\beta = \left[\left(\frac{2\pi n_1}{\lambda}\right)^2 - \frac{U^2}{\rho^2}\right]^{1/2} \quad (4) \text{ and, } \kappa = \frac{\sqrt{\delta}U^2 K_0\left[W\left(d/\rho\right)\right]}{\rho V^3 K_1^2(W)} \quad (5)$$

where λ is the wavelength, K 's are modified Hankel function, the value of $\delta = 1 - \left(\frac{n_2}{n_1}\right)^2$, $V = \frac{2\pi\rho n_1\sqrt{\delta}}{\lambda} = U^2 + W^2$ is a normalized frequency, $U \cong 2.405\mathrm{e}^{-\left(1-\delta/2\right)V}$ is the progression of phase, and W is the transverse decay of amplitude. Assuming the cross section, separation of the fibers, and propagation constant held to be constant, then

$$P_N(z) = \left[A_N(z)\right]^2 = \sum_{m=1}^{n}\sum_{q=1}^{n}\sum_{s=1}^{n}\sum_{t=1}^{n} \sin\left(\frac{is\pi}{n+1}\right)\sin\left(\frac{ms\pi}{n+1}\right)\sin\left(\frac{it\pi}{n+1}\right)\sin\left(\frac{qt\pi}{n+1}\right) e^{(\lambda_s+\lambda_c)z}\sqrt{P_q(0)P_m(0)} \quad (6)$$

where $\lambda_m = -2jK\cos\left(\frac{m}{n+1}\pi\right)$, $m,q,s,t = 1,2,3,....n$

RESULT AND DISCUSSION

The simulation of power propagation on fiber with single input power is gradually transferred to the other fibers as a function of length of the interaction region or phase. The input power is transferred to fiber two, three until fiber seven.

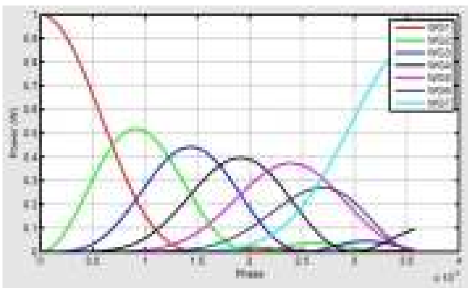

Fig. 3. Coupling power (simulation)

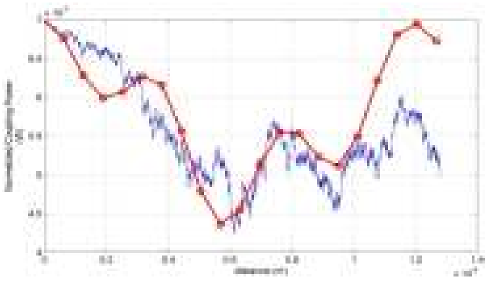

Fig. 4. Coupling power (experiment)

In Fig. 3, power is transferred with different coupling velocity. The coupling velocity follows the profile given in Figure 1, where it is slower for the outer fiber. If power is launched to fiber 1, the fiber 7 has the slower coupling velocity, and has the higher transferred power. Comparison of power propagation for coupling power model to experiment can be seen in Fig. 4showing good agreement. When all input powers are launched to the input ports, the output power is maximum or equal to 7mw.Simulation result decreases sharply from 7mW to 6mW at distance around 20 nm. Power is absorbed by the silicon dioxide fiber structure, and some energy is transferred to mechanical heating and radiation. As the distance increases, power increases gradually with small decrease at around 0.9. The experimental result remains not many changes power amplitude in the range of $\approx$0-10nm, the simulation result follows the experiment with the small discrepancydue to the fiber geometry, where the coupling velocity no longer transfers all power to the center of fiber. For distance more than 10 nm, power could not increase as high as simulation results.

CONCLUSION

Power is transferred to others fiber with different coupling velocity. The test for linear 1X7 fiber, the fiber 7 has the slowest coupling velocity and has the higher transferred power for input of fiber 1. Comparison between simulation and experimental results has shown good agreement. There is different normalized power by factor fiber geometry where the coupling velocity no longer transfers to others fiber.

REFERENCE

Amir Hosseini, David N. Kwong, Yang Zhang, Yazhao Liu, and Ray T. Chen, On the Optimum Design for 1xN Multimode Interference Coupler based Beam Splitters. *Microelectronics Research Center, Electrical and Computer Engineering Department,* University of Texas at Austin, Austin, TX, 78758, USA. 2010.

Daniel, H. S, Moore, D.R, and Tekippe, V.J, Broad Band of MXN Fiber and Method for Making.*United States Patent*, Patent number.5,355,426, Millersville 1994.

Saktioto, Jalil Ali, Mohamed Fadhali, "Simplified coupling power model for fiber fusion"**,** *Journal of Opto-electronic Review.*Springler Link Journal, Vol. 17, No.3, pp.193-199, (2009).

Snyder, A.W and Love. J. D, Optical Waveguide Theory, *Institute of Advanced Studies Australian National University*, Canberra, Australia 1983

Stove, D. W and Corke, M.Fiber Optic Power Combiner.*United States Patent,* Patent number. 5,121,452, Medfield 1992.

Wang, Y., Xue, D., Lu, X., Power transfer characteristics among N parallel single-mode optical fibers, *Science Direct.* Zhejiang University (2007)

Dedi Irawan, Saktioto, and Jalil Ali, "Linear and triangle order of NX3 optical directional couplers: variationcoupling coefficient. *SPIE Proceeding 7781, 77810J (2010).*