What is a mode in few mode fibers?: Proposal of MIMO-free mode division multiplexing using true eigenmodes

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Abstract: The evolution of electromagnetic field profile of LP modes along with the propagation owing to the difference of propagation constants between constituent true eigenmodes is accurately analyzed. It is shown that the mode demultiplexer can't accurately discriminate the LP mode at the output end and so the MIMO-DSP is inevitable for the mode division multiplexed transmission using LP modes. From the accurate analysis, a transform matrix between LP modes and constituent true eigenmodes is derived and a novel method to configure true eigenmode multi/demultiplexer is proposed to realize MIMO-free transmission.

Keywords: few mode fiber, mode division multiplexing, true eigenmode, LP mode, mode multiplexer

Classification: Optical systems

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1 Introduction

The true eigenmodes of round optical fiber are known as HE_{ℓ_m} and EH_{ℓ_m} (TE_{0_m} and TM_{0_m} when ℓ = 0) modes [1]. Since the propagation constants of HE_{ℓ+1,_m} and EH_{ℓ−1,_m} modes are quasi-degenerated, however, weakly guiding approximation and linearly polarized (LP) mode were proposed [2]. The linear combination of HE_{ℓ+1,_m} and EH_{ℓ−1,_m} quasi-degenerate modes can constitute a linearly polarized field profile, and this synthesized field profile is defined as LP_{ℓ,_m} mode. The polarization state of laser source used for the optical fiber transmission is linearly polarized, and so the excited electromagnetic field profile of optical fiber is also linearly polarized. Therefore, the LP mode is excited at the input end of few-mode fiber. Since the propagation constants of eigenmodes constituting an LP mode are not identical to each other [3], however, the electromagnetic field profile varies along with the propagation and is no longer the linear-polarized (LP) mode at the output end. In addition, the modal dispersion between true eigenmodes constituting an LP mode is as large as 1 ns for 100 km transmission [3]. Since the fundamental mode defined by LP₀₁ mode is identical to HE₁₁ mode, which is intrinsic linearly polarized mode, the single mode optical fiber transmission has been quit of the complexity of LP mode approximation.

On the other hand, after the recent rapid development of mode division multiplexing transmission, LP mode notation has been widely used in many ultra-large capacity long distance transmission experiments [4, 5, 6]. This is because the MIMO-DSP can reproduce the input channel by iterative numerical calculation, even though the output channels are mixed together. Therefore, the MIMO-DSP is inevitable for the mode division multiplexing using LP modes even when the transmission distance is short, e.g. less than 1 km. The load of calculation of MIMO-DSP and the latency, however, will increase with the increase of the number of modes.

To realize an MIMO-free mode division multiplexed transmission, an accurate analysis of behaviour of LP modes along with the propagation is needed, and there have been several reports that the intensity profile of LP_{11}^{even} mode evolves to become LP_{11}^{odd} mode along with the propagation and vice versa [7, 8, 9]. The period (beat length) of such evolution due to modal birefringence has been analyzed [3]. However, there has been no report on the accurate analysis of the evolution of electric field vector of LP modes.

In this study, we analyze accurately the evolution of electromagnetic field of LP modes along with the propagation and show that the field can be expressed by the localized elliptical polarization. Next the transform matrix between LP modes and true eigenmodes is derived and a novel method to constitute “true eigenmode multi/demultiplexer” by the combination of in-phase/reversed-phase 2×2 circuit and the conventional LP-mode multi/demultiplexer.

2 Transform matrix between LP modes and true eigenmodes

The eigenmode of round dielectric waveguide was first analyzed by Carton et al. [10], and the definition of HE, EH, TE, and TM modes was given by Snitzer [1]. In the following analysis, we use the definition and notation of true eigenmodes by Snitzer. Although Snitzer used the time and z dependent term as $\exp[i(\beta z - \omega t)]$, however, we use the notation $\exp[j(\omega t - \beta z)]$.

2.1 Electromagnetic field of LP mode consisting of true eigenmodes

Let us assume a step-index round optical fiber of which index profile is given by

$$n^2(r) = \begin{cases} n_1^2 & (r \leq a) \\ n_2^2 = n_1^2[1 - 2\Delta] & (r > a) \end{cases} \quad (1)$$

where n_1 and n_2 are the refractive indexes of core and cladding, respectively, a is the core radius, and Δ is the relative index difference. The solution E_z and H_z of vector wave equation in the cylindrical coordinate system is expressed in terms of Bessel function inside the core as follows.

$$E_z = A_\ell J_\ell(\kappa r) \cos(\ell\theta + \varphi_\ell) \exp[j(\omega t - \beta z)] \quad (2)$$

$$H_z = B_\ell J_\ell(\kappa r) \cos(\ell\theta + \psi_\ell) \exp[j(\omega t - \beta z)] \quad (3)$$

where A_ℓ and B_ℓ are the amplitudes, ℓ is the mode number in the azimuth direction, and φ_ℓ and ψ_ℓ are azimuth phases, which represent even and odd modes for degenerate modes. Here κ is given by $\kappa = \sqrt{k_0^2 n_1^2 - \beta^2}$, and $\varphi_\ell - \psi_\ell = \pm \frac{\pi}{2}$ [1]. Since E_z and H_z in the cladding are obtained by replacing $J_\ell(\kappa r)$ by $\frac{J_\ell(\kappa a)}{K_\ell(\gamma a)} K_\ell(\gamma r)$, where $\gamma = \sqrt{\beta^2 - k_0^2 n_2^2}$ and $K_\ell(x)$ is the modified Bessel function of second kind, we discuss only the field profile inside the core.

The transverse components E_r , E_θ , H_r and H_θ are derived from the longitudinal components E_z and H_z . Since only the electric components E_r and E_θ are required to describe the polarization state of modes, we derive E_r and E_θ from Eq. (2) as follows.

$$E_r^{(\ell)} = -j \frac{\beta}{\kappa} \left[\frac{1-P}{2} J_{\ell-1}(\kappa r) - \frac{1+P}{2} J_{\ell+1}(\kappa r) \right] F_c \quad (4)$$

$$E_\theta^{(\ell)} = -j \frac{\beta}{\kappa} \left[-\frac{1-P}{2} J_{\ell-1}(\kappa r) - \frac{1+P}{2} J_{\ell+1}(\kappa r) \right] F_s \quad (5)$$

where F_c and F_s are defined by

$$F_c = A_\ell \cos(\ell\theta + \varphi_\ell) \exp[j(\omega t - \beta z)] \quad (6)$$

$$F_s = A_\ell \sin(\ell\theta + \varphi_\ell) \exp[j(\omega t - \beta z)] \quad (7)$$

The parameter P was introduced by Snitzer [1] and is defined by

$$P = -\frac{\omega\mu_0}{\beta} \frac{H_z}{E_z} = -\frac{\omega\mu_0}{\beta} \frac{B_\ell \cos(\ell\theta + \psi_\ell)}{A_\ell \sin(\ell\theta + \varphi_\ell)} \quad (8)$$

The true eigenmodes are classified into HE and EH modes in terms of the parameter P as shown in Table I.

Table I. Classification of true eigenmodes in terms of P [1]

Mode label	At cutoff	Far from cutoff
HE _{ℓm} ($\ell > 1$)	$P = -1$	$P = -1$
EH _{ℓm} ($\ell > 1$)	$P = \frac{n_1^2}{n_2^2} \simeq 1$	$P = 1$
TM _{0m}	$P = 0$	$P = 0$
TE _{0m}	$P = \infty$	$P = \infty$

On the other hand, LP _{μm} mode consists of HE _{$\mu+1m$} and EH _{$\mu-1m$} modes (TE_{0m} and TM_{0m} modes when $\mu = 1$), and the electric fields of HE and EH modes are superimposed to form a linearly polarized electric field by regulating the azimuth phases φ_ℓ and ψ_ℓ [2]. The x and y components of electric field of true eigenmode are derived from Eqs. (4) and (5) to be

$$E_x^{(\ell)} = -j \frac{\beta}{\kappa} A_\ell e^{j(\omega t - \beta z)} \times \left[\frac{1-P}{2} J_{\ell-1}(\kappa r) \cos\{(\ell-1)\theta + \varphi_\ell\} - \frac{1+P}{2} J_{\ell+1}(\kappa r) \cos\{(\ell+1)\theta + \varphi_\ell\} \right] \quad (9)$$

$$E_y^{(\ell)} = -j \frac{\beta}{\kappa} A_\ell e^{j(\omega t - \beta z)} \times \left[-\frac{1-P}{2} J_{\ell-1}(\kappa r) \sin\{(\ell-1)\theta + \varphi_\ell\} - \frac{1+P}{2} J_{\ell+1}(\kappa r) \sin\{(\ell+1)\theta + \varphi_\ell\} \right] \quad (10)$$

using the coordinate transform matrix. Then by substituting the value of P given in Table I into Eqs. (9) and (10), the x and y components of electric field of HE, EH, TE, and TM modes are derived as follows.

a. $HE_{\mu+1,m}$ mode (component of $LP_{\mu,m}$ mode, $P = -1$)

$$E_x^{(\mu+1)} = -j \frac{\beta}{\kappa} A_{\mu+1} e^{j(\omega t - \beta_{\mu+1} z)} J_{\mu}(\kappa r) \cos(\mu\theta + \varphi_{\mu+1}) \quad (11)$$

$$E_y^{(\mu+1)} = j \frac{\beta}{\kappa} A_{\mu+1} e^{j(\omega t - \beta_{\mu+1} z)} J_{\mu}(\kappa r) \sin(\mu\theta + \varphi_{\mu+1}) \quad (12)$$

b. $EH_{\mu-1,m}$ mode (component of $LP_{\mu,m}$ mode, $P = +1$)

$$E_x^{(\mu-1)} = j \frac{\beta}{\kappa} A_{\mu-1} e^{j(\omega t - \beta_{\mu-1} z)} J_{\mu}(\kappa r) \cos(\mu\theta + \varphi_{\mu-1}) \quad (13)$$

$$E_y^{(\mu-1)} = j \frac{\beta}{\kappa} A_{\mu-1} e^{j(\omega t - \beta_{\mu-1} z)} J_{\mu}(\kappa r) \sin(\mu\theta + \varphi_{\mu-1}) \quad (14)$$

c. $TM_{0,m}$ mode (component of $LP_{1,m}$ mode, $P = 0$)

d. $TE_{0,m}$ mode (component of $LP_{1,m}$ mode, $P = \infty$)

In the case of TE and TM modes, since $P \neq \pm 1$, Eqs. (9) and (10) can not be used and we need to derive the expressions before reaching Eqs. (4) and (5) in Ref. [1]. Then the derived equations are

$$E_x^{(0)} = j \frac{\beta}{\kappa} A_0 e^{j(\omega t - \beta_0 z)} J_1(\kappa r) \cos(\theta + \varphi_0) \quad (15)$$

$$E_y^{(0)} = j \frac{\beta}{\kappa} A_0 e^{j(\omega t - \beta_0 z)} J_1(\kappa r) \sin(\theta + \varphi_0) \quad (16)$$

where $\varphi_0 = 0$ and $\varphi_0 = \frac{\pi}{2}$ correspond to $TM_{0,m}$ and $TE_{0,m}$ modes, respectively, and it should be noted that the propagation constant β_0 differs for TM and TE modes, i.e. $TE_{0,m}$ and $TM_{0,m}$ modes are not degenerated [3].

2.2 Synthesis of electric field of LP mode in terms of true eigenmodes

Let us suppose the two mode region of step-index fiber corresponding to $V \leq 3.81$, supporting LP_{01} and LP_{11} modes. Since there are two orthogonal polarizations (x and y polarizations) and two orthogonal field profiles, i.e. even and odd modes for LP_{11} modes, six orthogonal modes are actually supported as summarized in Table II. The fundamental LP_{01} mode corresponds to HE_{11} mode, and the first order LP_{11} mode consists of HE_{21}^{even} , HE_{21}^{odd} , TM_{01} , and TE_{01} modes.

Table II. Definition of degenerated LP_{01} , LP_{11}^{even} , and LP_{11}^{odd} modes

LP_{01}	LP_{11}^{even}	LP_{11}^{odd}
x - polarization
y - polarization

2.2.1 x polarized LP_{11}^{even} mode input (TMH group)

The sum of Eq. (11) for HE_{21} mode with $\varphi_2 = 0$ (corresponding to HE_{21}^{even} mode) and Eq. (15) for TM_{01} mode with $\varphi_0 = 0$ gives the x component of electric field of LP_{11}^{even} mode at the input end. In the same way, the sum of Eq. (12) and Eq. (16) gives the y component of electric field of LP_{11}^{even} mode at the input end. These relations can be seen from the vectorial summation of the electric field profiles as illustrated in Figs. 6.7(a) and (b) in Reference [11]. When the polarization of input beam is x polarization, $-A_2 = A_0 = A_{LP11}^e$ should be satisfied to make y component zero. In this case, the x and y components of electric field at the propagation distance z is expressed by

$$E_x^{\text{LP11-e}} = j \frac{\beta_{aM}}{\kappa} A_{LP11}^e e^{j(\omega t - \beta_{aM} \cdot z)} J_1(\kappa r) \cos(\theta) [2 \cos(\delta\beta_M \cdot z)] \quad (17)$$

$$E_y^{\text{LP11-e}} = j \frac{\beta_{aM}}{\kappa} A_{LP11}^e e^{j(\omega t - \beta_{aM} \cdot z)} J_1(\kappa r) \sin(\theta) [2j \sin(\delta\beta_M \cdot z)] \quad (18)$$

Here β_{aM} is the average of propagation constants of HE_{21} and TM_{01} modes and $\delta\beta_M$ is the half of the difference of these propagation constants, which are defined by

$$\beta_{aM} = \frac{\beta_{HE21} + \beta_{TM01}}{2} \quad (19)$$

$$\delta\beta_M = \frac{\beta_{HE21} - \beta_{TM01}}{2} \quad (20)$$

The intensity profile (z component of complex Poynting vector) is derived from Eqs. (17) and (18) and is expressed by

$$\begin{aligned} \tilde{S}_z &= \frac{2\beta_{aM}^3}{\omega\mu_0\kappa^2} (A_{LP11}^e)^2 J_1^2(\kappa r) \\ &\times [\cos^2(\delta\beta_M \cdot z) \cos^2(\theta) + \sin^2(\delta\beta_M \cdot z) \sin^2(\theta)] \end{aligned} \quad (21)$$

It can be seen from Eqs. (17) and (18) that the electric field profile is expressed by a locally elliptical polarization of which ellipticity and the direction of rotation of polarization depend on position in the transverse cross section, because the phase of y component in Eq. (18) differs from that of x component in Eq. (17) by $\pm \frac{\pi}{2}$. This fact has not been shown in References [3] and [7, 8, 9].

On the other hand, the intensity profile of LP_{11-x}^{even} mode evolves into that of LP_{11-y}^{odd} mode via a torus-shape intensity profile, and this change is periodic with respect to the propagation distance. Therefore, LP_{11-x}^{even} mode and LP_{11-y}^{odd} mode belong to the same mode group called TMH mode group [3], of which constituent true eigenmodes are HE_{21}^{even} and TM_{01} modes. Fig. 1 shows the evolution of intensity profile of LP_{11-x}^{even} mode to LP_{11-y}^{odd} mode, and Fig. 2 illustrates the detailed polarization state distribution together with the intensity profile at the propagation distance satisfying $\delta\beta_M \cdot z = \frac{\pi}{4} + 2\pi N$ ($N = \text{integer}$).

The following conclusions are derived from these facts.

- (a) The electromagnetic field profile at the output end of FMF is not any longer that of the LP mode even if the linearly polarized light is incident on the input end of FMF.
- (b) When LP_{11-x}^{even} mode is excited at the input end of FMF, the field profile evolves into LP_{11-y}^{odd} mode at the propagation distance given by

Fig. 1. Evolution of field profile of LP_{11-x}^{even} mode to LP_{11-y}^{odd} mode

Fig. 2. Polarization state distribution of TMH mode group at the middle point of evolution from LP_{11-x}^{even} mode to LP_{11-y}^{odd} mode

$$\frac{L_b^{TMH}}{2} = \frac{\pi}{\delta\beta_M}, \quad (22)$$

and this change is repeated with the period of L_b^{TMH} , even if the fiber is ideally straight and circular.

- (c) Therefore, the analysis and measurement of modal characteristics of FMFs without any information on the polarization state don't make any sense. The crosstalk analysis due to the offset splicing also should take into account this modal evolution [12].

2.2.2 x polarized LP_{11}^{odd} mode input (TEH group)

In the same way as subsection 2.2.1, the sum of Eq. (11) for HE_{21} mode with $\varphi_2 = \frac{\pi}{2}$ (corresponding to HE_{21}^{odd} mode) and Eq. (15) for TE_{01} mode with $\varphi_0 = \frac{\pi}{2}$ gives the x component of electric field of LP_{11}^{odd} mode at the input end. On the other hand, the sum of Eq. (12) and Eq. (16) gives the y component of electric field of LP_{11}^{odd} mode at the input end. When the polarization of input beam is x polarization, $A_2 = -A_0 = A_{LP11}^0$ should be satisfied to make y component zero. In this case, the x and y components of electric field at the propagation distance z is expressed by

$$E_x^{\text{LP}_{11-\text{o}}} = j \frac{\beta_{aE}}{\kappa} A_{\text{LP}_{11}}^{\text{o}} e^{j(\omega t - \beta_{aE} \cdot z)} J_1(\kappa r) \sin(\theta) [2 \cos(\delta\beta_E \cdot z)] \quad (23)$$

$$E_y^{\text{LP}_{11-\text{o}}} = j \frac{\beta_{aE}}{\kappa} A_{\text{LP}_{11}}^{\text{o}} e^{j(\omega t - \beta_{aE} \cdot z)} J_1(\kappa r) \cos(\theta) [-2j \sin(\delta\beta_E \cdot z)] \quad (24)$$

where β_{aE} and $\delta\beta_E$ are defined by

$$\beta_{aE} = \frac{\beta_{\text{HE}_{21}} + \beta_{\text{TE}_{01}}}{2} \quad (25)$$

$$\delta\beta_E = \frac{\beta_{\text{HE}_{21}} - \beta_{\text{TE}_{01}}}{2} \quad (26)$$

The evolution of intensity profile is shown in Fig. 3, and the detailed polarization state distribution together with the intensity profile at the propagation distance satisfying $\delta\beta_E \cdot z = \frac{\pi}{4} + 2\pi N$ ($N = \text{integer}$) is illustrated in Fig. 4.

Fig. 3. Evolution of field profile of $\text{LP}_{11-x}^{\text{odd}}$ to $\text{LP}_{11-y}^{\text{even}}$ mode

The transform matrix between LP_{11} modes and true eigenmodes is derived from Eqs. (11), (12), (15), (16), (17), (18), (23), and (24) as follows.

$$\begin{bmatrix} \text{LP}_{11-x}^{\text{even}} \\ \text{LP}_{11-y}^{\text{odd}} \\ \text{LP}_{11-x}^{\text{odd}} \\ \text{LP}_{11-y}^{\text{even}} \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & -1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & -1 \\ 0 & 0 & 1 & 1 \end{bmatrix} \cdot \begin{bmatrix} \text{TM}_{01} \\ \text{HE}_{21}^{\text{even}} \\ \text{HE}_{21}^{\text{odd}} \\ \text{TE}_{01} \end{bmatrix} \quad (27)$$

2.2.3 Period of modal evolution

The period of modal evolution between $\text{LP}_{11-x}^{\text{even}}$ and $\text{LP}_{11-y}^{\text{odd}}$ is greater by one order than that between $\text{LP}_{11-x}^{\text{odd}}$ and $\text{LP}_{11-y}^{\text{even}}$, because the values of $\delta\beta_M$ and $\delta\beta_E$ are very different [3, 8]. The period of modal evolution (beat length) is given by [3]

$$L_b^{(v)} = \frac{n_{\text{eq}} \lambda}{n_1^2 \Delta^2 B_v(V)}, \quad (v = \text{TMH or TEH}) \quad (28)$$

where $B_{\text{TMH}}(V)$ and $B_{\text{TEH}}(V)$ are normalized differences of propagation constants which are related to $\delta\beta_M$ and $\delta\beta_E$ by

Fig. 4. Polarization state distribution of TEH mode group at the middle point of evolution from LP_{11-x}^{odd} mode to LP_{11-y}^{even} mode

$$B_{TMH}(V) = \frac{2n_{eq}}{n_1^2 \Delta^2} \delta\beta_M, \quad B_{TEH}(V) = \frac{2n_{eq}}{n_1^2 \Delta^2} \delta\beta_E. \quad (29)$$

Since the formulas for calculating $\delta\beta_M$ and $\delta\beta_E$ have been derived in Ref. [3] in detail, only the calculated results are shown here. The normalized difference of propagation constant and the period of mode evolution are plotted as a function of V parameter as shown in Fig. 5 and Fig. 6, respectively. It can be seen from Fig. 6 that the period of mode evolution of TMH mode group depends strongly on V and varies from several tens centimeters to several meters, while that of TEH mode group is in the order of several tens centimeters. Therefore, the behavior of field profile is also quite different for TMH and TEH mode groups, because the wavelength (frequency) dependence of modal evolution is quite different.

Fig. 5. V dependence of normalized difference of propagation constant

Fig. 6. V dependence of period of mode evolution ($\Delta = 0.4\%$)

3 Proposal of mode multiplexed transmission using true eigenmodes

Since the transmission channels using LP modes are mixed together as described above, the MIMO-DSP is inevitable for the mode division multiplexing using LP modes even when the transmission distance is short, e.g. less than 10 m. In addition, the modal dispersion between true eigenmodes constituting an LP mode is as large as 1 ns for 100 km transmission [3]. To overcome these problems and to realize a MIMO-free transmission, a novel mode multiplexed transmission using true eigenmodes is needed. It has been difficult, however, to excite selectively true eigenmodes except the fundamental mode because higher order modes like TE_{01} , TM_{01} , HE_{21}^{even} , and HE_{21}^{odd} modes have complex field profiles such as azimuth, radial, and bent looped electric field [1]. Although a TE and TM modes exciter has been proposed [13], this device can not excite HE_{21} modes and has a problem of strong wavelength dependence because of the microring resonator structure with corrugated side-wall.

Instead of exciting directly higher order true eigenmodes, we can utilize the relation between LP modes and true eigenmodes expressed by the transform matrix Eq. (27). The inverse matrix of Eq. (27) is given by

$$\begin{bmatrix} TM_{01} \\ HE_{21}^{\text{even}} \\ HE_{21}^{\text{odd}} \\ TE_{01} \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & -1 & 1 \end{bmatrix} \cdot \begin{bmatrix} LP_{11-x}^{\text{even}} \\ LP_{11-y}^{\text{odd}} \\ LP_{11-x}^{\text{odd}} \\ LP_{11-y}^{\text{even}} \end{bmatrix} \quad (30)$$

It can be seen from the first and second lines of Eq. (30) that TM_{01} mode can be synthesized by adding LP_{11-x}^{even} and LP_{11-y}^{odd} modes in-phase, and HE_{21}^{even} mode can be synthesized by adding LP_{11-x}^{even} and LP_{11-y}^{odd} with reversed phase. As for the TEH mode group, the similar synthesis is possible by adding LP_{11-x}^{odd} and LP_{11-y}^{even} modes in-phase and reversed phase to excite HE_{21}^{odd} mode and TE_{01} mode, respectively.

Utilizing the above relationship, a novel true eigenmode multi/demultiplexer can be configured by the combination of in-phase/reversed-phase 2×2 circuit and the conventional LP-mode multi/demultiplexer as shown in Fig. 7. Asymmetric X-shaped mixing and branching circuit and/or asymmetric directional coupler can be used as the in-phase/reversed-phase 2×2 circuit as shown in Fig. 7. As the LP-mode multi/demultiplexer, a PLC-type mode multi/demultiplexer with mode rotator [14] can be used. The mode rotator can act as the polarization rotator as well as the mode rotator. True eigenmode multi/demultiplexer for higher order modes will be possible because the transform matrix between higher order LP modes and constituent true eigenmodes is similar to that expressed in Eq. (30).

Fig. 7. True eigenmode multi/demultiplexer

4 Conclusion

In contrast to LP modes, the true eigenmodes don't change their electromagnetic field profile along with the propagation, and so they are hardly mixed up during the propagation. Therefore, the MDM using true eigenmode is expected to realize

MIMO-free transmission as long as the mode mixing is negligible. The true eigenmode multi/demultiplexer will enable such MIMO-free MDM transmission.

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