Analysis Of Linearly Polarized Modes

Ioana Moldovean (Avram), Ioan G. Tarnovan, Bogdan Tebrean
Introduction

• This paper is an analysis of the propagation mode of step index fiber optic

• To obtain the propagation modes of electromagnetic waves the characteristics of the optical fiber has been changed

• Analytical method of this analysis is based on finite element method

• This study is required for further investigation of states of polarization and analysis of electric field distribution
Basic equations

- Snell’s law: \( n_1 \sin \phi_1 = n_2 \sin \phi_2 \)

- Wave equation: \( A(r, t) = \text{Re}\{\bar{A}(r) \exp(j \omega t)\} \)

- The equation of electric field: \( \nabla^2 E + \nabla \left( \frac{\nabla \varepsilon}{\varepsilon_r} \cdot E \right) + k^2 E = 0 \)
  \[ \nabla^2 E + k^2 E = 0 \]

- The equation for magnetic field: \( \nabla^2 H + \frac{\nabla \varepsilon}{\varepsilon_r} \times (\nabla \times H) + k^2 H = 0 \)
  \[ \nabla^2 H + \varepsilon n^2 k^2_0 H = 0 \]

- The Helmholtz’s equation for the electric and magnetic fields can be summarized as
  \[ \nabla_\perp^2 E + (k^2 - \beta^2) E = 0 \]
  \[ \nabla_\perp^2 H + (k^2 - \beta^2) H = 0 \]
  \[ \nabla_\perp^2 E + k^2_0 (\varepsilon - n^2_{eff}) E = 0 \]
  \[ \nabla_\perp^2 H + k^2_0 (\varepsilon - n^2_{eff}) H = 0 \]
The propagation of electromagnetic field

- Optical fibers
  - core- $8 \, \mu m$ and $50 \, \mu m$
  - cladding - $125 \, \mu m$
  - Refractive index of core – 1.4457
  - Refractive index of cladding – 1.4378
  - Core – pure silica
  - Cladding – doped silica

Finite element mesh for single mode and multimode fiber optic
Classification of $\text{LP}_{nm}$ modes for single mode optical fiber and the distribution of electric and magnetic field

- Fundamental mode
- $\text{LP}_{02}$ mode
- $\text{LP}_{01}$ Electric transverse mode
- $\text{LP}_{01}$ Magnetic transverse mode
Classification of $\text{LP}_{nm}$ modes and distribution of electric field for multimode optical fiber

LP$_{01}$, LP$_{11}$, LP$_{21}$
LP$_{52}$, LP$_{62}$, LP$_{72}$
LP$_{12}$, LP$_{32}$, LP$_{42}$
LP$_{13}$, LP$_{23}$, LP$_{33}$
The propagation of electromagnetic wave through a transversal optical fiber.

The 3-D optical fiber

The electrical field distribution
One fundamental mode

The electrical field distribution.
Three fundamental modes

Line graph for electric field distribution along the z axis
The propagation of electromagnetic wave through a curved optical fiber.

Eigenvalue - 2
Wavelength - 1.55 µm

The electric field.
One fundamental LP

Eigenvalue - 2
Wavelength - 2.2 µm

The electric field.
Six fundamental LP

The mesh for the multimode curved optical fiber
The propagation of electromagnetic wave through a junction optical fiber

The mesh of optical fiber junction

First step of electrical field distribution along z axis

Second step of electrical field distribution along z axis

Last step of electrical field distribution along z axis
Conclusion

• According to the simulation through the single-mode fiber, the wave is transmitted in one linearly polarized mode

• Through the multimode fiber more light waves can pass, but each with its particular linearly polarized mode

• These simulations will be developed to simulate Faraday Effect, Kerr Effect and Pockels Effect