OPTICAL POWER SPLITTER BASED ON MULTIMODE INTERFERENCE (MMI)

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DEDICATION

Especially dedicated to my beloved parents, my wife, my daughters Aya and Doa'a, *and all my family members for their support.*

ACKNOWLEDGEMENT

In the name of ALLAH, the Most Beneficent, the Merciful. Foremost, all praise to ALLAH for the incredible gift endowed upon me and for give me the health and strength to pursue with this study and enable me to prepare this thesis.

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ABSTRACT

The challenge in optical access networking is to bring optical fibers as close to the end-users as possible. One way to realize this economically is to employ the passive devices. Therefore, it is necessary to use plenty of passive optical power splitters in the central office for distribution purposes. Some of the important characteristics of such splitter are low loss, compactness, and a low price. To achieve this description fully, Multimode Interference (MMI) optical power splitters based on self-imaging meet all these requirements, with considering the ability to optimize the performance of optoelectronic device over range of operational parameters. These parameters are important to reduce device length and provide increase component density. Mathematical model was used in MATLAB software and verified it by BPM-CAD to design and optimize 1X2, 1X4, 1X8, 1X16 and 1X32 power splitter based on MMI.

ABSTRAK

Cabaran rangkaian laluan optik adalah di dalam pendekatan gentian optik dengan pengguna. Satu daripada cara ekonomi untuk merealisasikannya adalah dengan menggunakan peranti pasif. Oleh itu, adalah perlu untuk menggunakan banyak pemisah punca kuasa optik di dalam pejabat utama bagi tujuan penyebaran Sebahagian daripada ciri-ciri penting pemisah tersebut adalah sedikit kehilangan, padat dan harga yang murah. Untuk memenuhi apa yang dinyatakan di atas, pemisah punca kuasa optic gangguan pelbagai mod (MMI) berasaskan gambaran diri perlu memenuhi semua keperluan, dengan mengambil kira pengoptimuman keupayaan peranti optoelektronik alam julat parameter operasi. Parameter ini adalah penting untuk mengurangkan panjang peranti dan menyediakan peningkatan ketumpatan komponen. Suatu model matematik yang menggunakan perisian MATLAB dan telah disahkan oleh BPM-CAD untuk mencipta dan mengoptimumkan penggunaan IX2, IX4, IX8, IX16 dan IX32 pemisah punca kuasa berdasarkan MMI.

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LIST OF SYMBOLS

SYMBOL		DESCRIPTION
β	-	Propagation coefficient
ε_r	-	Relative permittivity
ε_o	-	Free space permittivity
μ_0	-	Free space permeability
λ_0	-	Optical wavelength in free space
c	-	Speed of light in free space
γ	-	Attenuation coefficient
K	-	Transverse wavevector
E	-	Electric field
H	-	Magnetic field
P	-	Power carrier in waveguide
n_f	-	Refractive index for the core
n_c	-	Refractive index for the clad
n_{eff}	-	Effective refractive index
k_o	-	Vacuum wavevector
R_c	-	Curvature radius
O	-	S-bend offset
ω	-	Angular frequency

h_e	-	Effective width of the multimode region
h	-	Physical width of the multimode region
L_π	-	The beat length

LIST OF ABBREVIATIONS

1D	-	One-Dimensional
2D	-	Two-Dimensional
3D	-	Three-Dimensional
AlGaAs	-	Aluminium Gallium Arsenide
BPM	-	Beam Propagation Method
EIM	-	Effective index method
FTTH	-	Fiber to the home
GaAs	-	Gallium arsenide
InGaAsP	-	Indium Gallium Arsenide Phosphide
InP	-	Indium Phosphide
MMI	-	Multi-mode interference
PDS	-	Passive double star
PICs	-	Photonic integrated circuits
PL	-	Propagation Loss
SiO_2	-	Silica- Silicon Dioxide
TE	-	Transverse Electric
TM	-	Transverse Magnetic
WDM	-	Wavelength divisions multiplex

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CHAPTER 1

INTRODUCTION

1.1 Background

The world we live in today requires communication on many levels, the most basic of which is human to human. Indeed invention of the telegraph and the telephone were the answers to this need that changed our world and resulted in the creation of widespread telecommunication network. A similar revolution has occurred in electronics computing devices that have resulted in the need for communication from computer to computer. An ever increasing demand for the acquisition, processing and sharing of information concerning the world and its future course, today, these needs are echoed in the demand for higher bandwidth in telecommunication network and similarly in computing as a demand for higher processing speeds.

Today's evolving telecommunication networks are increasingly focusing on flexibility and reconfigurability, which requires enhanced functionality of photonic integrated circuits (PICs) for optical communications. In addition, modem wavelength demultiplexing (WDM) systems will require signal routing and coupling devices to have large optical bandwidth and to be polarization insensitive. Also small device dimensions and improved fabrication tolerances are required in order to reduce process costs and contribute to large-scale PIC production.

The challenge in optical access networking is to bring optical fibers as close to the end-users as possible that called Fiber to the home (FTTH). One way to realize this economically is to employ the passive double star (PDS) topology [I]. Therefore, it is necessary to use plenty of passive optical power splitters in the central office for distribution purposes as depicted in Figure 1.1. Some of the important characteristics of such splitter are low loss, compactness, compatibility with optical single-mode fibers, uniform distribution of the output power on the output waveguides and a low price.

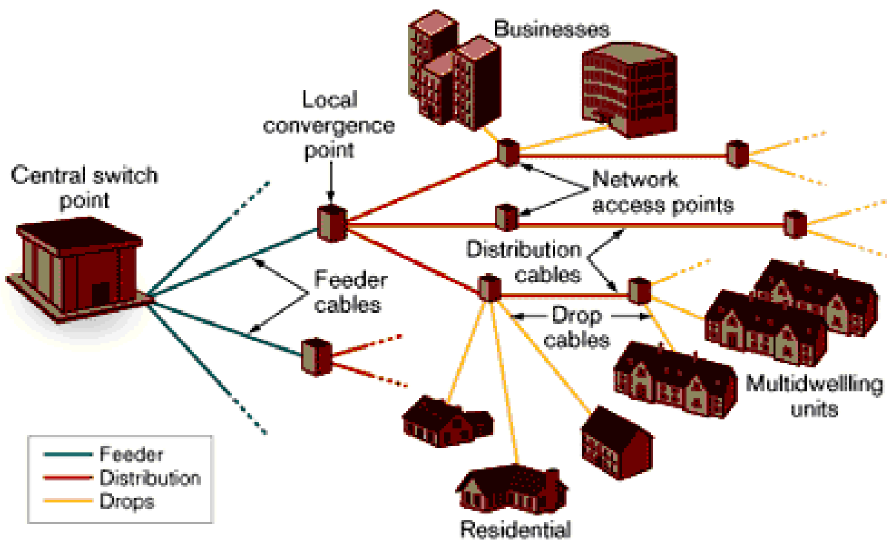

Figure 1.1: Distribution the fiber to the home.

A power splitter 1×2 is usually a symmetric element which equally divides power from a straight waveguide between two output waveguides. The simplest version of a power splitter is the Y-branch, which is easy to design and relatively insensitive to fabrication tolerances. Nevertheless, the curvature radii of the two branches, as well as the junction, must be carefully designed in order to avoid power losses. Also, if the two branches are separated by tilted straight waveguides, the tilt angle must be small, typically a few degrees [2].

A different version of a power splitter is the multi-mode interference element (MMI. This name comes from the multi-modal character of the wide waveguide region where the power split takes place. The advantage of this design is the short length of the MMI compared to that of the Y-branch. Although the dimensions of the MMI are not critical, allowing wide tolerances, this element must be designed for a particular wavelength. The two power splitters which have been described are symmetric, and thus 50% of the input power was carried by each output waveguide. Nevertheless, asymmetric splitters can also be designed for specific purposes. In addition, it is possible to fabricate splitters with N output waveguides, and in that case the element is called a 1 × N splitter.

MMI devices are important components for photonic and optoelectronic integrated circuits due to their simple structure, low loss, and large optical bandwidth. These structures provide power splitting or combining.

1.2 Problem Statements

Power splitting is a basic function of the integrated optics. It plays a central role in passive optical distribution networks. Furthermore, the device should meet practical requirement such as type of material, small size and wavelength dependency.

1.3 Objective of the Project:

The main objective of this project is to determine the specification of the optical power splitter based on MMI coupler to achieve acceptable power splitter design.

1.4 Scope of the project

In order to achieve the objective of this project, the following scope of work has been identified which comprises of:

- A mathematical model using numerical analysis was formulated to calculate the optimum width and length of the 1x2, 1x4, 1x8, 1x16, and 1x32 power splitter based on MMI and plot electric field intensity for input and each output signal.
- Simulate of the 1x2, 1x4, 1x8, 1x16, and 1x32 power splitter based on MMI by BPM-CAD.

1.4 Methodology of the Project

To carry out this project, the following methodology is designed:

- Build up the our mathematical model in Matlab software to design 1X2, 1X4, 1X8, 1X16, and 1X32 power splitter based on multimode interference(MMI), which includes the following tasks:
  - Get the eingenvalues for propagation coefficient.

- Find the electrical field intensity for each mode inside the waveguide.
- Determine the dimension of the device according to:
  - The numbers of output port.
  - Type of materials.
  - Wavelength.

- Find the output optical power for each port and mention of the Excess loss and Imbalance.

- Use the approximate formula (Soldano's formula) to get propagation constant and find all parameters as previous point.
  - Get the eigenvalues for propagation coefficient.
  - Find the electrical field intensity for each mode inside the waveguide.
  - Determine the dimension of the device according to:
    - The numbers of output port.
    - Type of materials.
    - Wavelength.

  - Find the output optical power for each port and mention of the Excess loss and Imbalance.
- Simulate all those devices by BPM-CAD to verify our mathematical model and compare with approximate formula.