iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL
FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: XII Month of publication: December 2021

DOI: https://doi.org/10.22214/ijraset.2021.39284

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue XII Dec 2021- Available at www.ijraset.com

Comparison of Several Characteristics of Single Mode Step-Index (SMSI), Multimode Step-Index (MMSI), and Multimode Graded-Index (MMGI) Fibers for Optical Communication Systems

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Abstract: Optical fiber is a medium that made by silica or plastic, and widely used in transmitting information over longer distance especially in communication system. There are three types of fiber optic used in this project which are single mode step-index (SMSI), multimode step-index (MMSI), and multimode graded-index (MMGI) in optical communication system. There are three objectives in this project in order to get the suitable optical fibers in the communication system. First objective is to simulate the result by using Excel and Origin software. The data and the formula of fiber optics will be key in through Excel software while the graph will be analyzed by using Origin software. The second objective is to compare the different types of fiber optics in communication system by comparing the several of their characteristics such as numerical aperture (NA), acceptance angle ($\theta_{(a)}$) and propagation constant (β). The performance of all types fiber optics are analyzed from the result using the standard communication wavelength of 1550 nm. The core diameter for SMSI, MMSI, and MMGI are 9, 200 and 50 µm respectively while the cladding diameter for SMSI and MMGI is 125 µm and 240 µm for MMSI. This diameter also been analyzed by using the standard value for optical communication system. Then, the comparison between SMSI, MMSI and MMGI will be made to choose the more suitable for optical communication system based on their characteristics. From the results, MMSI and MMGI give best performance compared to SMSI. After that, the third objective is to make the comparison between MMSI and MMGI in term of intermodal dispersion to compare the efficiencies of fiber optics. MMGI give the better result in terms of efficiencies for communication system compared to MMSI.
Keyword: Single Mode Step-Index (SMSI), Multimode Step-Index (MMSI), Multimode Graded-Index (MMGI), Communication System, Excel and Origin Software

I. INTRODUCTION

For over 40 years, sensing via fiber optics has been occupied by R&D groups and some important transitions into commercial sector have been achieved. In the mid of 1960s, the photonic sensor was based on bifurcated fiber bundles to illuminate a surface and reflection. One example the photonic concept is known as extrinsic sensors. [1]. Then, the first single mode for optical fiber exist to give benefits to immense engineering. The communication system was one of vital principle stimulus and fiber sensors is rely on communication technology to provide a basic component set. Other than that, fiber sensors also rely on communication technology to facilitate specialist technologies through which slightly different versions of optical fibers can be fabricated purely for the sensing community. Today, a variety of industries including the medical, military, telecommunication, industrial, data storage, networking, and broadcast industries are able to apply and use fiber optic technology in a variety of applications. Fiber optic had many advantages. Some of them are bandwidth, low power loss, interference, size, lighter weight, safety, secured medium for carrying sensitive data, flexibility and low cost than copper.

II. EXPERIMENT

In order to make one optical communication system that can reduce the courses or materials especially fiber optic, the approached or method that been used is using simulation. The software that are involved in this simulation is Excel and Origin. There are three types of fiber optic which are single mode step-index (SMSI), multimode step-index (MMSI) and multimode graded-index (MMGI). The main purpose of this study is to compare the characteristics and efficiency of them. By using Excel software, the parameter of each fiber optic can be measured.

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A. Simulation Tools

1) Excel Software

The formula and data for each characteristic were inserted into the spreadsheet of Excel software.

2) Origin Software

III. RESULTS AND DISCUSSION

A. Parameter Measurement

Table 1: Standard values of core/cladding refractive index for SMSI, MMSI and MMGI

Types of Fiber	Standard Values of Core/Cladding Refractive Index (µm)
Single Mode Step-Index (SMSI)	9/125
Multimode Step-Index (MMSI)	200/240
Multimode Graded-Index (MMGI)	50/125

B. Data of SMSI, MMSI and MMGI

For each type of fiber, the standard value are used to measure each of characteristic which is stated in table 1. Other than that, there are two constant values that been used in this simulation method which are light wavelength, 1550 nm and core refractive index, 1.5 µm. The manipulated variable is cladding reflective index and responding variable is the characteristics itself.

Single Mode Step-Index (SMSI), Multimode step-index (MMSI) and Multimode Graded-Index (MMGI)

Table 2: Result of all characteristics for SMSI, MMSI and MMGI by using simulation method.

Core Refractive Index, N_1 (µm)	Cladding Refractive Index, N_2 (µm)	Numerical aperture, NA	Acceptance Angle, $\theta_{(a)}$ (°)	Propagation constant, β (°/µm)
1.50	1.00	1.1180	1.3660	1236998
1.50	1.05	1.0712	1.2882	1695973
1.50	1.10	1.0198	1.2060	2169597
1.50	1.15	0.9630	1.1190	2654980
1.50	1.20	0.9000	1.0265	3148904
1.50	1.25	0.8292	0.9275	3647858
1.50	1.30	0.7483	0.8202	4148084
1.50	1.35	0.6538	0.7014	4645634
1.50	1.40	0.5385	0.5649	5136433

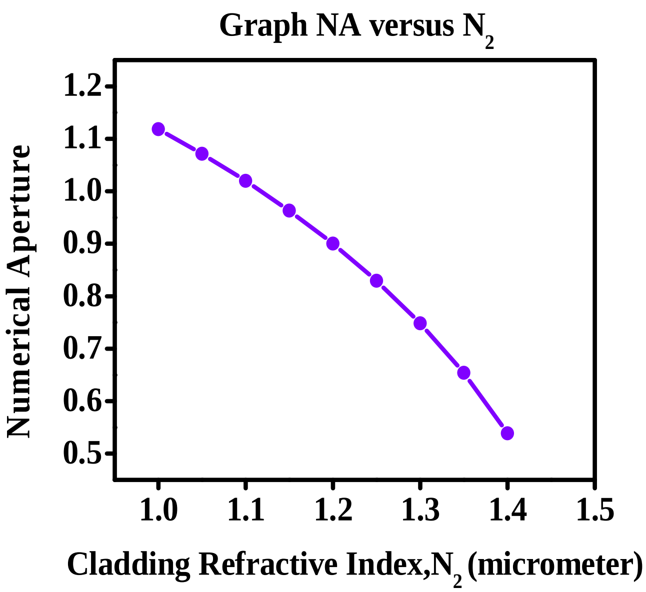


Figure 1 Graph numerical aperture (NA) versus cladding refractive index (N_2).

Table 2 and Figure 1 show the values of cladding refractive index, N_2 and numerical aperture in SMSI, MMSI and MMGI fiber optic. The figure shows the numerical aperture, NA decrease exponentially as the increasing of cladding refractive index, N_2. As the value of cladding refractive index decrease, the ability of an optical fiber to capture the light is lower. Other than that, the experimental result for SMSI, MMSI and MMGI are 0.14, 0.2 – 0.4 and 0.5 respectively. From the graph, the value of numerical aperture for SMSI do not suitable for optical communication system because the value of numerical aperture from the result is bigger than the value from the experimental result. Meanwhile for MMSI, the numerical aperture value from the result also lower than existing result but higher compared to SMSI. The suitable value for numerical aperture value for optical communication system is MMGI.

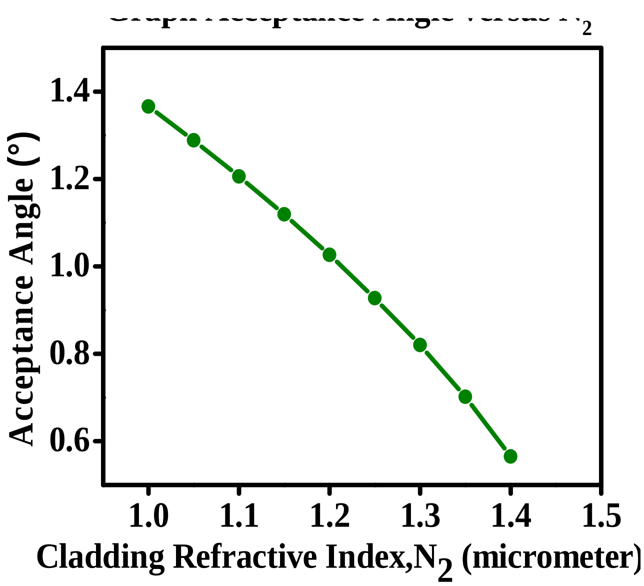


Figure 2: Graph Acceptance Angle, $\theta_{(a)}$ versus N_2.

Table 2 and Figure 2 show the values of cladding refractive index, N_2 and acceptance angle, $\theta_{(a)}$. The value of acceptance angle depends on the value of cladding refractive index. It shows the acceptance angle, $\theta_{(a)}$ also decrease exponentially with the increasing of cladding refractive index, N_2. It can be conclude that, as the value of N_2 increase, the maximum angle of a ray that hitting the fiber core decrease. For acceptance angle, if it is exceed, the internal incident angles less than the critical angle. Since the acceptance angle is lower, so the TIR in SMSI, MMSI and MMGI occur.

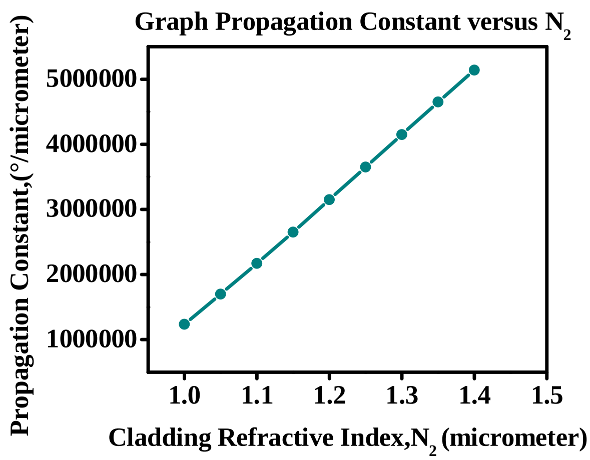


Figure 3 Graph Propagation Constant, β versus Cladding Refractive Index, N_2.

Table 2 and Figure 3 show the values of cladding refractive index, N_2 and propagation constant, β. This characteristic differ from others above because it is increase directly proportional to the cladding refractive index. As the N_2 increase, the phase change also increase.

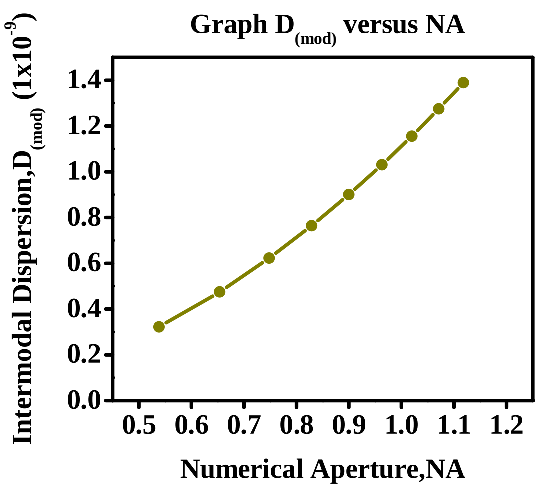
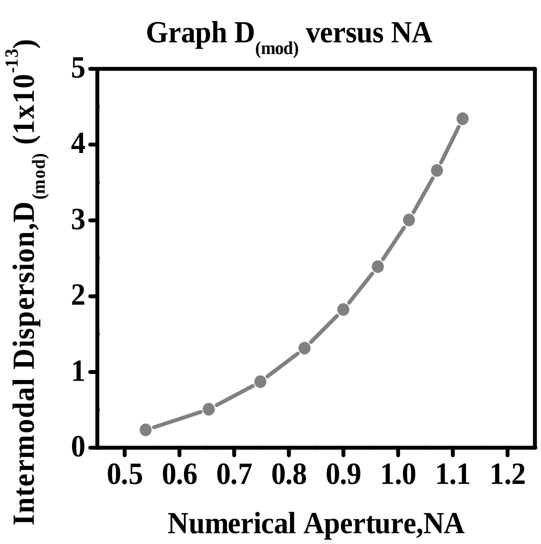


Figure 4 Graph $D_{(mod)}$ versus NA for MMSI.

Figure 4 show the values of numerical aperture, NA and intermodal dispersion, $D_{(mod)}$ of MMSI. The value intermodal dispersion increase exponentially as the value numerical aperture increase. The value for intermodal dispersion depends on the value of numerical aperture. Since the value of difference between higher and fundamental modes time propagation, $\delta t_{(mod)}$ bigger, value of intermodal dispersion also bigger. In this MMSI, the intermodal value is still higher compared to MMGI.



Graph 5 Graph $D_{(mod)}$ versus NA for MMGI.

Figure 5 show the values of numerical aperture, NA and intermodal dispersion, $D_{(mod)}$ of MMGI. The value intermodal dispersion increase highly exponentially as the value numerical aperture increase compared to MMSI. The value of intermodal dispersion in MMGI lower, so that is mean the intermodal dispersion been reduced by using a graded refractive index itself. In this MMGI, the intermodal value is lower compared to MMGI.

IV. CONCLUSIONS

As a conclusion, this project have achieved the objectives and the scope of study. The capability to simulate the optical communication system by using Excel and Origin software that using formula from several characteristics of fiber optic. The characteristics were analyzed from the results using the standard telecommunication wavelength of 1550 nm. The performance of fiber optic in term of characteristics and intermodal dispersion were investigated. As we increase the value of numerical aperture, the intermodal dispersion value of each multimode fiber optic also increase. The efficiency between multimode fibers in optical communication system were identified. Multimode graded-index (MMGI) shown the best performance and efficiency compared to other fiber optic.

V. ACKNOWLEDGEMENTS

The author would like to thank the Ministry of Higher Education of Malaysia (MOHE) and Universiti Teknologi Malaysia, UTM for providing GUP (2020/2021) grants in order to conduct this research and developing the paper. The author report no conflicts of interest in this work.

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