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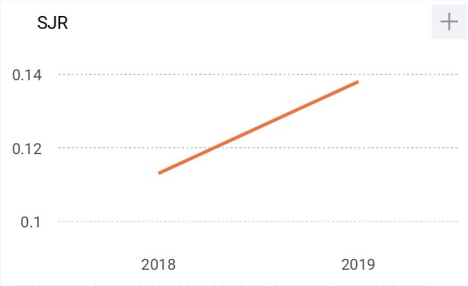
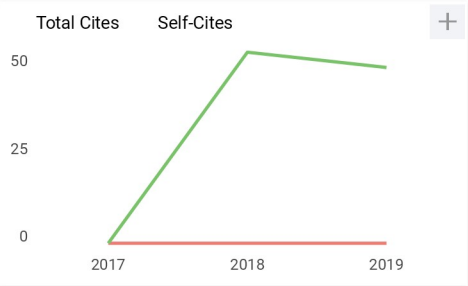
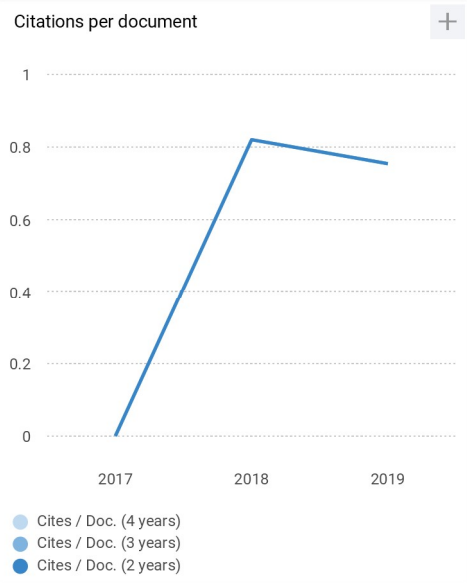
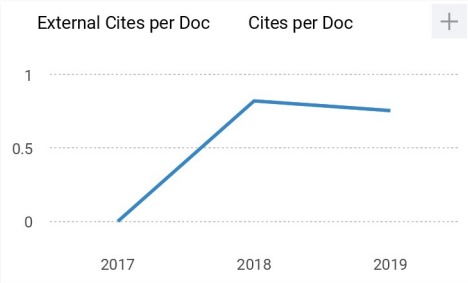
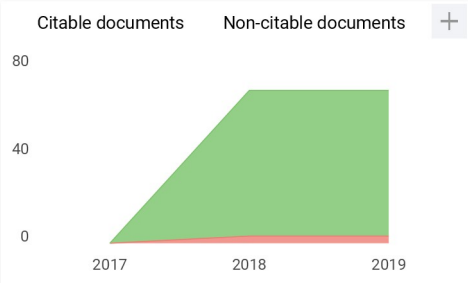
H Index

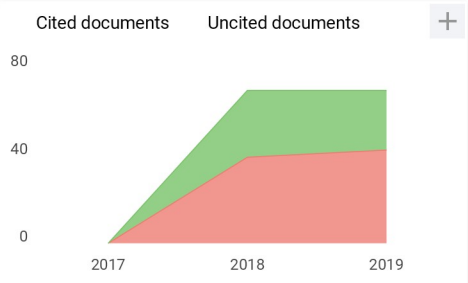












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I hereby certify that **Mr./Ms. Ary Syahriar** attended the *2016 International Seminar on Application for Technology of Information and Communication (ISEMANTIC 2016)*, held at Universitas Dian Nuswantoro (Indonesia) from 5th to 6th August 2016

Dr. Pulung Nurtantio Andono, S.T., M.Kom.
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Title : Analysis of Three Paralel Waveguides Using Coupled Mode Theory and the Method of Lines

Authors : Ary Syahriar

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International Seminar on Application for Technology of Information and Communication

PROCEEDINGS

Science and Technology for a Better Future

1st International Seminar on Application for Technology of Information and Communication

August 5th – 6th, 2016
Universitas Dian Nuswantoro
Semarang, Indonesia

2016 International Seminar on Application for Technology of Information and Communication

(ISEMANTIC)

PROCEEDING

August 5th – 6th, 2016

Universitas Dian Nuswantoro

Semarang, Indonesia

Table of Contents

GREETINGS FROM THE GENERAL CHAIR

Greeting, conference participants!

Welcome to the 2016 International Seminar on Application for Technology of Information and Communication (ISEMANTIC 2016). On behalf of the conference committee, I would like to convey my appreciation to all authors for participating and contributing valuable works and efforts in this conference.

ISEMANTIC 2016 aimed to meet the demands of the academia, researcher and industrial society regarding the application of information technology and communication. Where I believe it is the most comprehensive conferences focused on science and technology for the better future. Furthermore, future ISEMANTIC will constitute a unique opportunity for academics and industry professionals to discuss the latest update and progress in the area of science and information technology. Therefore, we expect ISEMANTIC to become a significant milestone for further related research and technology improvements. Based on the results of the rigorous review process, 64 papers have been accepted out of 112 submitted papers, which constitutes acceptance rate of 57.14%

I would like to extend my special gratitude to the Keynote Speakers who have kindly agreed to support ISEMANTIC 2016.

- Prof. Nasir as a minister of research and higher education of republic Indonesia,
- Prof. Adang Suandi Ahmad from Institut Teknologi Bandung (ITB) Indonesia,
- Prof. Taufik from California Polytechnic State University USA
- Dr. Hector Sances Lopez from Universitas Dian nuswantoro Semarang Indonesia
- Also we would like special thanks to IEEE Indonesia Section for their technically support to our conference.

Furthermore, I would like to thank all oragnizer, supporters, and organizing committee members of ISEMANTIC 2016. The success of ISEMANTIC 2016 would not have been possible without their support and contribution, as I strongly believe their collaboration and support was invaluable to making this International Conference fruitful and insightful.

Lastly, I would like to thank you all and it would be my great honor and pleasure to have your continued contribution in future ISEMANTIC.

With warm regard

Dr. Pulung Nurtantio Andono, M.Kom

Vice Rector for Research & Collaboration

Universitas Dian Nuswantoro

GREETINGS FROM RECTOR

Greeting, conference participants!

Welcome to the 2016 International Seminar on Application for Technology of Information and Communication (ISEMANTIC 2016). In this beautiful day I welcome you to semarang Indonesia the greatest city of central java. As a rector of Universitas Dian NuswantoroI am extremely impressed with the dedication and enthusiasm of the conference organizing committee member .I congratulate all of them for the team effort that is adding to the success of the conference.

We couldn't be happier to have Prof. Nasir as a minister of research and higher education of republic Indonesia, Prof. Adang Suandi Ahmad from Institut Teknologi Bandung (ITB) Indonesia, Prof. Taufik from California Polytechnic State University USA and Dr. Hector Sances Lopez from Universitas Dian nuswantoro Semarang Indonesia

Also I would like to deliver my best greeting to all authors and participants of 2016 international seminar on application for technology of information and communication. The 2016 ISEMANTIC focuses on science and technology for a better future. Since science, information technology and communication develops rapidly in present day. I believe it could be the indicator of the glory of the humankind.

Therefore, personally I put my best wises to all of you as academia, researchers and industrial society to inspire and take a look closer to the real world through research in science and technology application.I hope all of us could aim for our best future and God bless us!

Lastly I would like to thank you all and it would be my great honor and pleasure to have your continued contribution in future ISEMANTIC. I sincerely hope that you will have a memorable experience in 2016 ISEMANTIC and have a good time in Semarang Indonesia.

With warm regard,

Dr. Ir. Edi Noersasongko, M.Kom.

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GENERAL INFORMATION

VENUE

Conference Venue

ISEMANTIC 2016 will be held in Universitas Dian Nuswantoro, Semarang, Indonesia. It is placed on Building E (Gedung E) 3th Floor of the University Campus.

All sessions will take place in the Faculty of Computer Science that are at the fourth (4th) Floor of Building D (Gedung D).

Address

Building E (Gedung E), 3th Floor, Kampus II Universitas Dian Nuswantoro

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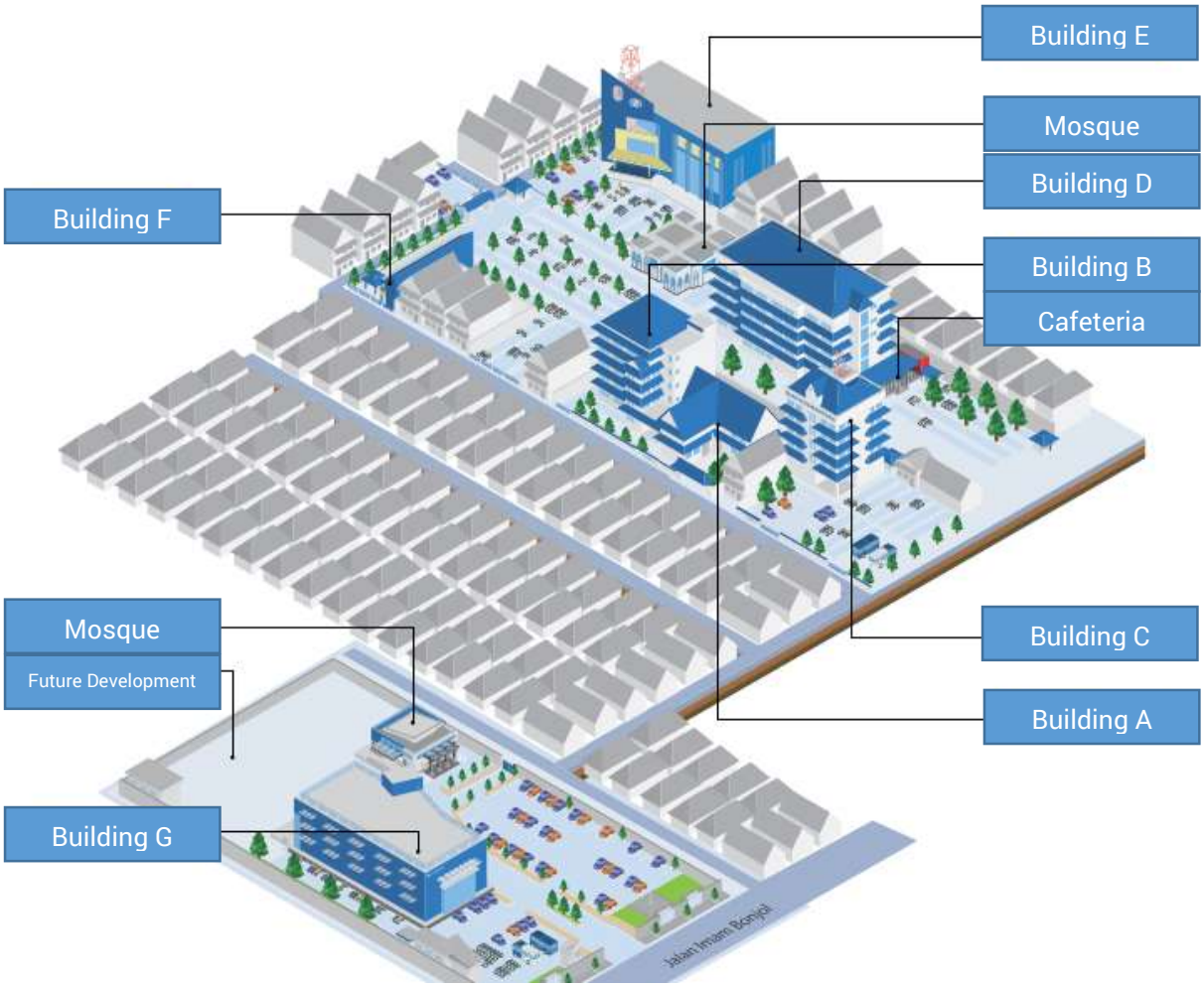


KEYNOTE SPEAKER 1

Prof. M Nasir, PhD

Minister of Research and Technology and Higher Education of Republic of Indonesia

Biography

Prof. M Nasir, PhD is a minister of research and higher education of Republic Indonesia. He is former rector of Universitas Diponegoro in Semarang, Indonesia. He leads the new ministry which is a combination of the Ministry of Research and Technology and Directorate General of Higher Education. He achieved his doctoral degree in University of science in Penang, Malaysia. As the Minister of Higher Education Research and Technology, he was committed to make Indonesian higher education research able to competes with advanced nations in the world. The president of Republic Indonesia has been appoint him as Minister of Research and Technology and Higher Education for 2014-2019 period.

KEYNOTE SPEAKER 2

Prof. Adang Suwandi Ahmad

Professor at Sekolah Teknik Elektro dan Informatika (STEI), Institut Teknologi Bandung Indonesia

Keynote Title:

Brain Inspired Soft Computing for Advancement of Artificial Intelligence

Biography

Dr. Adang Suwandi Ahmad is a Professor of Intelligent Electronics Instrumentation System in the School of Electrical Engineering and Informatics at Institut Teknologi Bandung (ITB), Indonesia. He received his BS in Electrical Engineering from Institut Teknologi Bandung in 1976, Diplome Etude Approfondi Signaux et Bruits (DEA) option Electronique in 1978, and Docteur Ingenieur Signaux et Bruits option Electronique (Dr.-ing) from Universite des Sciences du Languedoc Montpellier in July 1980. Professor Adang areas of expertise are in intelligent electronic instrumentation for instrumentation devices and computational intelligence. His research activity currently focuses on Bioinformatics Computation, Information Sciences, and Intelligent-based Systems.

KEYNOTE SPEAKER 3

Prof. Taufik

Director of Electric Power Institute at California Polytechnic State University, San Luis Obispo,

Keynote Title:

Intelligent Systems In DC House For Residential Electricity

Biography

Educational Background:

- Bachelor of Science, Electrical Engineering & Minor in Computer Science
  Northern Arizona University, May 1993
  Graduated with Honors (Cum Laude, Tau Beta Phi, Phi Kappa Phi)
  Final Project: Piezoelectric Amplifier for Telescope Viewing Stabilization
- Master of Science, Electrical Engineering and Computer Science
  University of Illinois at Chicago, May 1995
  Thesis: Theory of Rectangular Waveguide Filled with Bianisotropic Material
- Doctor of Engineering, Electrical Engineering
  Cleveland State University, May 1999
  Emphasis: Power Electronics, Power Systems, and Controls
  Dissertation: Parallel AC-AC Converters with Master/Slave Control

Research Background:

Dr. Taufik is a Professor of Electrical Engineering and the Director of Electric Power Institute at California Polytechnic State University, San Luis Obispo, USA. He received his BS from Northern Arizona University, MS from University of Illinois at Chicago, and Doctor of Engineering from Cleveland State University, all in Electrical Engineering. Since joining Cal Poly he has received numerous teaching awards, most notably the 2012 Outstanding Teaching Award from the American Society of Engineering Education (ASEE). He is a senior member of the Institute of Electrical and Electronics Engineering (IEEE) with expertise in power electronics, power systems, and renewable energy. He has work and consulting experience with several world-class companies. His current project is the DC House Project for rural electrification which has received supports from several partners in Indonesia, Philippines, and Malaysia.

Major Concerns:

Power Electronics, Power Systems and Protection, Smart Grid, Renewable Energy, Power Quality

KEYNOTE SPEAKER 4

Dr. Hector Sanchez Lopez

Gradient Coil Architect,
Lecturer in Biomedical Engineering at
Universitas Dian Nuswantoro

Keynote Title:

Electromagnetic and Therapy for Alternative Medicine

Biography

Dr. Hector Sanchez Lopez has expertise in the Biomedical Engineering field with specialty in MRI (Magnetic Resonance Imaging) Gradient Coils. He achieved his PhD in Biomedical Engineering from University Claude Bernard Lyon1, France. Presently, he is a Managing Director in Nanjing Cichen Medical Technology in Nanjing, China. He has published more than 30 papers in international journals and 49 in conference proceedings, and has been awarded 5 patents in biomedical engineering. Tesla and General Electric Health care are among world class companies that invited him for collaboration for his work in biomedical engineering. He is currently a lecturer in Biomedical Engineering at Universitas Dian Nuswantoro, Semarang, Indonesia.

Analysis of Three Paralel Waveguides Using Coupled Mode Theory and the Method of Lines

Ary Syahriar
[1] Electrical Engineering Departement, University Al-Azhar Indonesia
Jakarta
Indonesia

[1] Helmi Adam , Dwi Astharini, Ahmad Husin Lubis, Danny M. Gandana
Electrical Engineering Departement, University Al-Azhar Indonesia
Jakarta
Indonesia

Abstract—**We present a numerical comparison of three parallel waveguides coupler characteristics by using the coupled mode theory and the method of lines. We analyzed for cases where a beam is launched into an input waveguide at the center and an outer input in the three waveguide arrangements. The output is then calculated using two methods. In the coupled mode theory we use an analytical solution and compare the results with semi numerical method of lines. The results show that both analytical and numerical scheme give similar result for simple three waveguide coupler structures.**

***Index Terms* --- Three paralel waveguide, coupled mode theory, method of lines.**

I. Introduction

Optical waveguide couplers play an important role in the construction of flexible and highly reliable optical communication networks. Directional couplers are widely used as passive and active optical devices in fibre and integrated optics [1], and form the basis of components such as switches, modulators and wavelength filters. In its simple arrangements a directional couplers consists of two or more evanescently coupled waveguides place in close proximity, whose separation is sufficiently small that power may be transferred between the modes propagating in the two or more guides through an interaction involving their evanescent fields.

In a conventional coupler, light exchanges sinusoidally between the two or more guides guides as it propagates. The required coupling coefficient is determined by the propagation constant difference between the two lowest order modes. However, all directional couplers have an intrinsic wavelength dependence in their coupling ratio, which is very sensitive to parameters such as guide width, guide separation, refractive index difference and coupling length [2]. Changes in these parameters can cause a large change in the power splitting ratio. To analyze this three-core coupled waveguide system, usually a coupled-mode formulation is used. In this calculation all waveguide parameters are assumed to be identical

The method of lines (MoL) has been proved to be a very useful tool for the analysis of general waveguide systems [5]. It is a semi analytical method, in which the wave equation is discretized as far as necessary in the transverse direction and solved analytically in the longitudinal direction, which results in less computational effort. An accurate result can be obtained since the MoL behaves in a stationary fashion and convergence is monotonic [6]. Discontinuous fields can be described accurately because the interface conditions are included in the calculation. Furthermore, the MoL is relatively easy to implement using computer numerical methods.

In this paper we present an analysis of power exchange along the propagation path of three coupled optical couplers, with parameters suitable for silica-on-silicon waveguides. The initial analysis is performed using weak coupled mode theory, in which the physical device shapes are abstracted into suitable variations of the input beam at different input arm. A comparison between the prediction of the coupled mode theory and a beam propagation scheme based on the method of lines is then used to determine the validity of the method of lines approach.

II. Theoretical Background

A. Coupled Mode Theory

To analyse the structure, we first construct a suitable theoretical model. In the geometry studied here, we shall consider a coupler consisting of three waveguides with constant width and gap as shown in Figure 1.

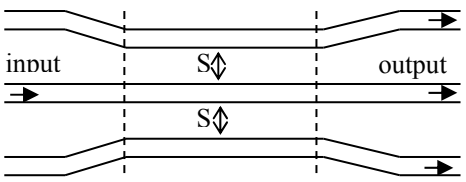


Figure 1. Three paralel waveguide sructure

The coupled-mode equations for a three-waveguide system are described as follows [3]:

$$\frac{d}{dz}\begin{bmatrix} a_1(z) \\ a_2(z) \\ a_3(z) \end{bmatrix} = -j \begin{bmatrix} \Delta\beta_1 & K & 0 \\ K & 0 & K \\ 0 & K & \Delta\beta_3 \end{bmatrix} \begin{bmatrix} a_1(z) \\ a_2(z) \\ a_3(z) \end{bmatrix} \quad (1)$$

where :

$\Delta\beta_1 = \beta_1 - \beta_2$

$\Delta\beta_3 = \beta_3 - \beta_2$

β_1 , β_2 and β_3 are the propagation constant of each waveguide, and K_1 , K_3 is the coupling coefficients.

Since all waveguides are symmetry, $\Delta\beta_1 = \Delta\beta_3 = 0$, then the solution for Equation (1) is [3]:

$$\begin{bmatrix} a_1(z) \\ a_2(z) \\ a_3(z) \end{bmatrix} = \begin{bmatrix} c_1 + \frac{1}{2} & c_2 & c_1 - \frac{1}{2} \\ c_2 & 2c_1 & c_2 \\ c_1 - \frac{1}{2} & c_2 & c_1 + \frac{1}{2} \end{bmatrix} \begin{bmatrix} a_1(0) \\ a_2(0) \\ a_3(0) \end{bmatrix} \quad (2)$$

where

$$c_1 = \frac{1}{2}\cos\sqrt{2}\,Kz$$

$$c_2 = -j\frac{1}{\sqrt{2}}\sin\sqrt{2}\,Kz$$

In three parallel waveguide we have two ways to launch the input input. First an input beam is launched into central waveguides, and secondly we can launch the input beam into one of the outer waveguide. For the first category the initial conditions become:

$$a_1(0) = a_3(0) = 0, \quad a_2(0) = 1 \quad (3)$$

Then the solution for Equation (2) is :

$$a_1(z) = a_3(z) = c_2, \; a_2(z) = 2c_1 \quad (4)$$

The output power on each waveguide become :

$$P_1 = |a_1(z)|^2 = \frac{1}{2}\sin^2\sqrt{2}\,Kz \quad (5)$$

$$P_2 = |a_2(z)|^2 = \cos^2\sqrt{2}\,Kz \quad (6)$$

$$P_3 = |a_3(z)|^2 = \frac{1}{2}\sin^2\sqrt{2}\,Kz \quad (7)$$

For the second category, a beam is launched into one of the outer waveguide (eg waveguide 1), the initial conditions are :

$$a_1(0) = 1, \quad a_2(0) = a_3(0) = 0 \quad (8)$$

Then the solution for Equation (2) is :

$$a_1(z) = c_1 + \frac{1}{2}, \quad a_2(z) = c_2, \quad a_3(z) = c_1 - \frac{1}{2} \quad (9)$$

In this case the output power become:

$$P_1 = |a_1(z)|^2 = \frac{1}{4}\cos^2\sqrt{2}\,Kz + \frac{1}{2}\cos\sqrt{2}\,Kz + \frac{1}{4} \quad (10)$$

$$P_2 = |a_2(z)|^2 = \frac{1}{2}\sin^2\sqrt{2}\,Kz \quad (11)$$

$$P_3 = |a_3(z)|^2 = \frac{1}{4}\cos^2\sqrt{2}\,Kz - \frac{1}{2}\cos\sqrt{2}\,Kz + \frac{1}{4} \quad (12)$$

B. The Method of Lines

To solve three parallel waveguides coupler by the method of lines, the region under analysis is broken into a large number of small elements Δx in the x direction as shown in Figure 2.

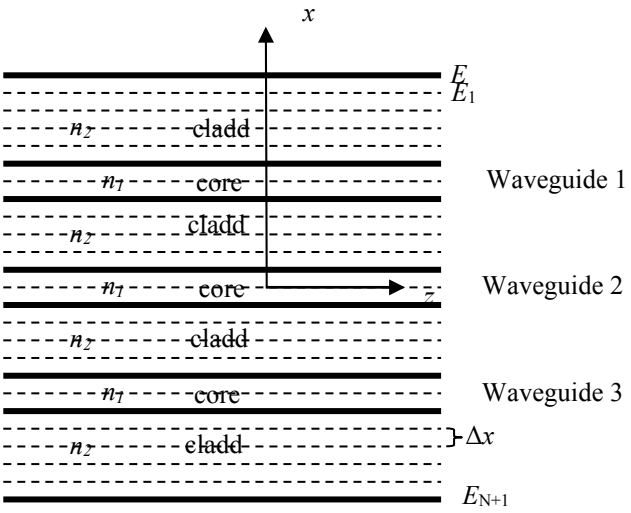


Figure 2. Discritization of three parallel waveguide structure

We begin by using Helmholtz equation for TE modes as [5-6],

$$\frac{\partial^2 E_y}{\partial x^2} + \frac{\partial^2 E_y}{\partial z^2} + k^2 E_y = 0 \quad (13)$$

A central difference approximation is then assumed for the second derivative term d^2E/dx^2, so that:

$$\frac{d^2 E_y}{dx^2} = \frac{E_{i+1} + 2E_1 + E_{i\ 1}}{\Delta x^2} \quad (14)$$

If this is done, Equation (23) reduces to a matrix differential equation:

$$\frac{d^2\vec{E}_y}{dz^2} + \vec{Q}^2\ \vec{E} = 0 \qquad (15)$$

where $\vec{E} = [E_1, E_2, E_3, ..., E_N]^t$ is a column vector containing discretised values of the field $E(x)$, at the points x_1, x_2, ... x_N, and t on the bracket stands for transpose. The matrix $\vec{Q}$ can be written as [5-6]:

$$\vec{Q}^2 = \frac{1}{\Delta x^2}\begin{bmatrix} -2 & 1 & 0 & .. & 0 \\ 1 & -2 & .. & .. & .. \\ 0 & .. & .. & .. & 0 \\ .. & .. & .. & -2 & 1 \\ 0 & .. & 0 & 1 & -2 \end{bmatrix} + k_o^2 \begin{bmatrix} n_{x1} & 0 & .. & .. & 0 \\ 0 & n_{x2} & .. & .. & .. \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & 0 \\ 0 & .. & .. & 0 & n_{xN} \end{bmatrix} \qquad (16)$$

In this equation there are always three components that are coupled with each other because of the tridiagonal structure of a matrix, so that a direct solution is not possible. A matrix transformation is therefore introduced such that,

$$\vec{\beta} = \vec{T}\ \vec{Q}\ \vec{T}^{\ 1} \qquad (17)$$

Where $\vec{\beta}$ is diagonalization result from $\vec{Q}^2$ that consist Eigen value, and $\vec{T}$ consist Eigen vector from $\vec{Q}^2$.

Then, equation (25) can rewrite as :

$$\frac{d^2 E_y}{dz^2} + \vec{\beta}^2\ \vec{E} = 0 \qquad (18)$$

Equation (18) is wave equation that propagate in z direction If we assume that no reflected waves occur (in, say, the particular example of a straight loss-less waveguide), therefore, Equation (18) has a solution as [5] :

$$\vec{E} = e^{-i\vec{B}z} \qquad (19)$$

Therefore, total solution of wave that propagates along z direction can be written as:

$$\vec{E} = \vec{T}\ e^{\ i\beta z}\ \vec{T}^{-1}\ \vec{E}_{inp} \qquad (20)$$

One of the most important parameters associated with the waveguide is the fractional power that remains in the core at point z. This power is approximately given by the overlap integral:

$$P(z) = \left| \int_{\infty}^{\infty} E(x,0)E(x,z)dx \right|^2 \qquad (21)$$

where $E(x,0)$ is the input field and $E(x,z)$ is the field at point z.

III. Numerical Results

The light propagation at the coupling region significantly depends on the waveguide geometry such as propagation constant, refractive index and diameters of core and cladding.

Figure 3 shows wave propagation in three parallel waveguide as shown in Figure 1. In this simulation we use parameters such as core refractive index of 1.457, cladding refractive index of 1.463, wavelength of 1.52 μm, core width is 5 μm, and separation distance between waveguides is 5 μm.

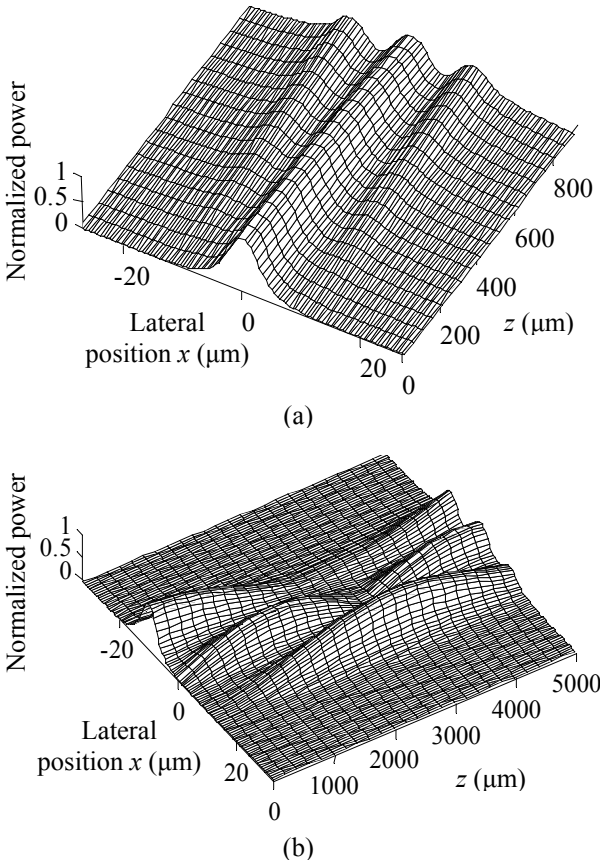


Figure 3. Wave propagation in three parallel waveguide (a) Input launched into central waveguide (b) Input launched into outer waveguide

If input launched into center waveguide, the light will coupled to two of outer waveguide, and the power is transferred. We see that the power of each waveguide become equal at z = 940 μm. In this case it can be used to design a directional coupler with equal output. However, if the input is launched into one of the outer waveguide, then the equal power output cannot be achieved.

Figure 4 show the mode profile of input and output. The input is launched into a center waveguide can be divided into three equal output power and happen at a distance z = 940 μm.

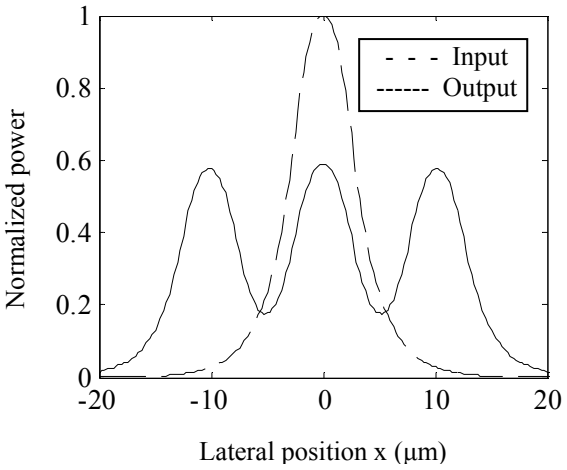
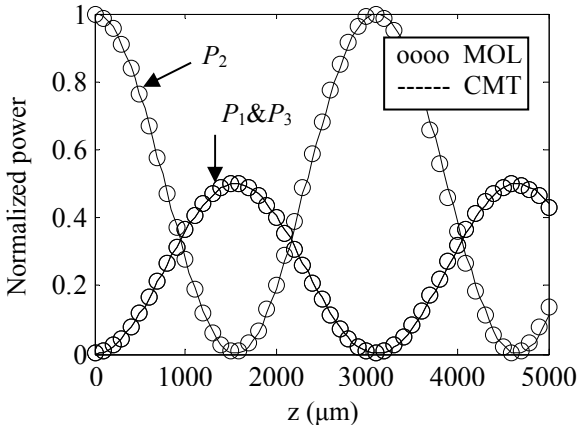


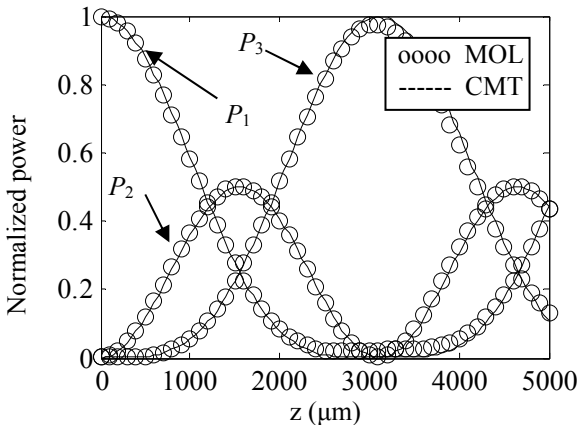
Figure 4. Power distribution in three parallel waveguide

5. Comparison between Coupled Mode Theory and Method of Lines

Figure 5 shows power along the propagation in three parallel waveguide. In this simulation we use two method. First coupled mode theory, the power in each waveguide can calculated by using Equation (15)-(17), (20)-(22). And second, the power were calculated by using the method of lines, where the output power were calculated by integrating field in each waveguide in along the distance z as in Figure 3.



(a)



(b)

Figure 5. Power along the propagation in three parallel waveguide (a) Input launched into central waveguide (b) Input launched into outer waveguide

In the figure 5(a) all power of three waveguide meet periodically, it mean each waveguide have equal power. In figure 5(b) we don't find any meet point between three waveguide it means the power is never equal each other along the propagation.

As we see both methods produce similar results. The coupled mode theory as an analytical method is assumed to give the correct answer. Since the result of method of lines is similar to the coupled mode theory, this method has been proven to have good accuracy for simple three waveguides structures. However in term of calculation speed and simplicity, the coupled mode theory is simpler and easy to handle, meanwhile the calculation speed in the method of lines depends on discretization number of lines and hence bigger matrix size.

6. Conclusion

The analysis of three waveguide optical power splitter with identical and equally spaced waveguide has been done using two methods. We have demonstrated that in three parallel waveguide, if the wave was launched into the center waveguide it will coupled to two of outer waveguides and equal power output can be achieved. However if the light is launched into one of two outer waveguides, the power splitting will not be equal. These characteristics have been proven by the two methods. It shows that for simple three waveguides coupler both methods can be applied and produce similar results.

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References

1. Gines Lifante. Integrated Photonics: Fundamentals. Wiley, New Jersey, 2003.
2. H.A Haus, W. Huang, "Coupled mode theory", Proceeding of the IEEE, vol. 79, 1505-1518, 1998.
3. C.M. Kim and Y.J. Im, "Switching operations of three-waveguide optical switches," IEEE Journal of Quantum Electronics, vol 6, 170-174, 2000.
4. Emmanuel Paspalakis, Adiabatic three-waveguide directional coupler, Optics Communications 258, 30–34, 2006)
5. R. Pregla, Analysis of Electromagnetic Fields and Waves, The Method of Lines, John Wiley & Sons Ltd, 2008
6. U. Rogge, R. Pregla, "Method of lines for the analysis of dielectric waveguides", IEEE journal of lightwave technology, vol. LT-11, 2015-2020, 1993.