AUTOMATED WAVEGUIDE ALIGNMENT AND DIRECT UV WRITING SYSTEMS FOR INTEGRATED OPTICAL DEVICES FABRICATION AND CHARACTERIZATION

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FACULTY OF SCIENCE

UNIVERSITY OF MALAYA

KUALA LUMPUR

2010

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DISSERTATION SUBMITTED IN FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREEOF

MASTER OF SCIENCE

FACULTY OF SCIENCE

UNIVERSITY OF MALAYA

KUALA LUMPUR

2010

UNIVERSITI MALAYA

ORIGINAL LITERARY WORK DECLARATION

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Name of Degree: **Master of Science**

Title of Project Paper/Research Report/Dissertation/Thesis ("this Work"):
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Sir/Mdm,

Response to Examiner's Comments for the Degree of Master of Science (Research Mode) for Student SGR 080136

As refer to the subject above, below are my answers of response to the reviewer's comments.

1. **What is the difference between the developed algorithm/systems as compared to commercial ones? Is the performance better?**

   In general, the developed algorithm in this work particularly provides a solution for rapid waveguide slab detection compared to commercial point-by-point detection technique. Observation on the interference pattern change enables fast pre-alignment of fiber to waveguide prior to the onset of fine alignment. The is believed to be superior to conventional point-by-point (spiral, etc) alignment algorithm as fiber alignment to the waveguide slab can be achieved in a relatively short duration at very high confidence level.

2. **Theoretically, how do you relate the interference pattern with the location of the clad, boundary and core?**
   The occurrence of the interference fringes is similar to the interference pattern demonstrated by Lloyd's mirror. In general, the underlying fundamental of this phenomenon originated from the interference fringes from a double source (Young's experiment). Hence, a modified formula from Young's experiment, replacing the Young's double slit source with a single fibre output can be used in this case. As the spacing between light source and the slab waveguide reduces, the order (number) of fringes reduces too. Whenever only one fringe is observed, the light has been coupled into the slab waveguide. The effect of light propagating in the cladding layers to the interference fringes is observed to be minimal.

3. **What are the steps taken to improve the output uniformity and repeatability?**
   Uniformity of the output is an inherent characteristic of the device under test and therefore can only be improved in the fabrication process. On the other hand, a motorized stage equipped with 5 motorized axes and the optimization on communication time between computer and instruments will increase the repeatability and speed of the alignment.

Thank you.

Yours sincerely,
Tan Chin Chong

Abstract

This dissertation reports the studies on the development of waveguide alignment techniques as well as the UV writing coding structures for optical circuitries through a programming platform, LabVIEW. In the first part of the work, 1-by-4 silica splitter was pigtailed with a single mode fiber which placed on a stepper motorized stage. The developed alignment techniques are image analysis for waveguide alignment, initial light seeking from interference fringes, manual alignment of launch fiber for waveguide's input, and peak power detection. These waveguide alignment techniques covered from the search of input channel within waveguide to the performance test. While, in the part of developing UV writing coding architectures, two types of optical circuitries have been designed and transferred onto card which was placed on a stepper motorized stage. The designed optical circuitries are the simple 1-by-2 optical splitter and Mach Zehnder Interferometer. Each of the corresponding architecture was tested from the aspect of processing time at different driving speed.

Abstrak

Disertasi ini melaporkan kajian tentang pembangunan teknik susunan komponen pandu gelombang cahaya serta pengekodan untuk penghasilan litar optik secara UV laser melalui satu platform pengaturcaraan yang bernama LabVIEW. Pada bahagian pertama kajian ini, silika splitter jenis 1-kepada-4 telah disusun dengan fiber jenis mode tunggal dimana splitter tersebut diletak atas “stepper motorized stage”. Antara teknik susunan yang telah dibangunkan adalah analisis terhadap imej yang mengadungi komponen pandu gelombang cahaya yang perlu disusun, carian saluran panduan cahaya dengan teknik interferensi cahaya, susunan fiber ke komponen panduan cahaya secara manual, dan pengesanan puncak kuasa. Teknik-teknik ini merangkumi teknik mencari saluran panduan cahaya sehingga ke teknik pencirian komponen. Untuk bahagian pembangunan pengekodan pula, litar optik splitter jenis 1-kepada-2 dan litar optik Mach Zehnder Interferometer telahpun dihasilkan diatas kad yang diletak pada “stepper motorized stage”. Pengekodan yang bertanggunjawab terhadap setiap litar optik yang dihasilkan telah diuji dari segi masa pemprosessan dengan kelajuan “stepper motorized stage” yang berlainan.

Acknowledgements

Within the two years life in Master studies, progress on the research will not went smoothly without the encouragements and advices from them. My deepest appreciation will give to my family members especially my parents for their understanding and continuous support when the decision of continue studies has been made.

My sincere gratitude also goes to my supervisor, Prof. Harith Ahmad for his advices and supports throughout the studies. A special thanks to my co-supervisor, Dr. Faisal Rafiq Mahamd Adikan for the offer of research assistant, and all the efforts he had put on my work.

Lastly, thank you to Mr. Chong Wu Yi, Dr. Nizam Tamchek, Mr. Alvin Law and others for the contribution of ideas and assistances.

Tan Chin Chong

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Chapter 2: Integrated Optics

Chapter 3: Principle of Optical Waveguide Alignment and UV Writing

Chapter 5: Result and Discussion

Abbreviations:

CVD	Chemical Vapor Deposition
dB	Decibel
DOF	Degree of freedom
FBGs	Fiber Bragg Gratings
FHD	Flame Hydrolysis Deposition
GHz	Giga- Hertz
GPIB	General Purpose Interface Bus
IL	Insertion Loss
IO	Integrated Optics
LabVIEW	Laboratory Virtual Instrument Engineering Workbench
LSI	Large Scale Integration
NTT	Nippon Telegraph and Telephone
OS	Operating System
PECVD	Plasma Enhanced Chemical Vapor Deposition
PLC	Planar Lightwave Circuit
PLD	Pulsed Laser Deposition
PON	Passive Optical Network
RIE	Reactive Ion Etching
SiOB	Silicon Optical Bench
SMF	Single Mode Fiber
SMP	Surface Mount Photonics
USB	Universal Serial Bus
UV	Ultra violet
VAD	Vapor Axial Deposition
VD	Vapor Deposition
VI	Virtual Instrument

Chemical Names:

Ar	Argon
Cl_2	Chlorine
D	Deuterium
Ge	Germanium
$GeCl_4$	Germanium Tetrachloride
GeO_2	Germanium dioxide
H_2	Hydrogen
H_2O	Water vapor
HCl	Hydrochloric acid
$LiNbO_3$	Lithium niobate
O_2	Oxygen
P_2O_5	Phosphorus pentoxide
PMMA	Poly-methyl-methacrylate
$POCl_3$	Phosphorus Oxychloride
$SiCl_4$	Silicon Tetrachloride
SiO_2: Si	Silica on Silicon
TiO_2	Titanium dioxide

Symbols:

E	Field distribution of waveguide field
e	Exponential
P_E	Transmitted optical power from waveguide field
P_ε	Optical power from excitation
r	Distance from Germanium site
Γ	Coupling efficiency
ε	Field distribution of the incident beam
η	Coupling efficiency
η*	Coupling ratio
κ	Loss ratio
ω_0	Beam waist of evenly distributed fundamental mode field distribution of circular beam input