CHARACTERIZATION OF OPTICAL MECHANICAL SWITCH (OMS)

WONG YIN LENG

UNIVERSITI TEKNOLOGI MALAYSIA

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Specially dedicated to my father, mother, brother and my friends for their loving, understanding, cares and support.

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ABSTRACT

This new generation network nowadays needs to fulfill the demands of the new information age, which requires improved scalability, flexibility, and dynamic delivery of communication services. An evolution of the network is underway to meet this demand. The evolution introduces new network elements supporting an architecture that is better suited for the dynamic global distribution of broadband based services. As such, the next major step in the progression is the wide scale deployment of intelligent optical switches. The purpose of this study was to investigate the characteristics and behavior of an optical mechanical switch (OMS) in order to implement efficiently into optical communication system. Extensive simulations based on Mathlab were performed and measurement based on physical connection is set up. Evaluation was based on various expressions like crosstalk, isolation, insertion loss and control signals to OMS. Practical channel separation of spacing and bandwidth needs to be determined to meet crosstalk and other parameters. The measurement is carried out by implying 2 x 2 Newport Optical Switch, TLS and OSA. Two input wavelengths of 1550.12 nm (Channel 1) and 1549.32 nm (Channel 2) are used to carry out the measurement in the system. Results are made from comparison between the simulation and measurement data. These results showed significant improvement in overall performance especially in Channel 1. The framework used for this measurement is general enough for further investigation by either evaluating other parameters of the switch or by extending its application in the optical communication network.

ABSTRAK

Rangkaian telekomunikasi yang wujud masa kini perlu memenuhi permintaan teknologi maklumat baru yang merangkumi peningkatan terhadap pengukuran, flexibilitinya, dan juga kemudahan dalam penghantaran telekomunikasi. Adalah penting bagi perubahan rangkaian ini supaya ia dapat memenuhi permintaan sejagat. Perubahan ini memperkenalkan satu teknologi baru yang mampu menyokong kemudahan teknologi maklumat luas yang lebih dinamik dalam globalisasi. Oleh itu, langkah penting seterusnya adalah penggunaaan suis optik dalam rangkaian secara meluas. Tujuan penyelidikan ini adalah untuk menyiasat perwatakan dan fungsi suis optik supaya dapat implemantasikan secara efektif ke atas sistem rangkaian optik. Kajian simulasi dilaksanakan menggunakan perisian Mathlab dan pengukuran data adalah berdasarkan kepada kelengkapan perkakasan. Keberkesanan telah dinilai terhadap beberapa kebolehan parameter seperti pertindihan saluran(crosstalk), pengasingan (isolation), kehilangan sisipan(insertion loss) dan isyarat kawalan dari suis optik. Aspek pemisahan saluran dan kelebaran gelombang perlu diambilkira untuk menentukan pertindihan saluran dan parameter lain. Pengukuran memerlukan 2 x 2 Newport suis optik, TLS dan OSA. Dua input panjang gelombang iaitu 1550.12 nm (Saluran 1) dan 1549.32 nm (Saluran 2) telah digunakan dalam sistem pengukuran. Keputusan diambil dari perbandingan antara data simulasi dan data pengukuran. Keputusan ini menunjukkan penghasilan yang signifikan kepada prestasi keseluruhan terutamanya dari Saluran 1. Rangka pengukuran adalah bersifat umum dan boleh digunakan untuk kajian lanjut samada bagi menguji parameter lain bagi suis optik atau meluaskan penggunaannya dalam rangkaian telekomunikasi optik.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADM	-	Add/ Drop Multiplexer
APS	-	Automatic Protection Switching
BER	-	Bit Error Rate
DC	-	Direct Current
DWDM	-	Dense Wavelength Division Multiplexing
ITU-G	-	International Telecommunications Union Grid
LED	-	Light Emitting Diodes
MEMS	-	Micro Electro Mechanical Switch
MOS	-	Metal Oxide Silicon
OADM	-	Optical Add/Drop Multiplexer
O-E-O	-	Optical-Electrical-Optical
O-O-O	-	Optical-Optical-Optical
OMS	-	Optical Mechanical Switch
OSA	-	Optical Spectrum Analyzer
OSNR	-	Optical Signal to Noise Ratio
OTDR	-	Optical Time Domain Reflectometer
SNR	-	Signal to Noise Ratio
SOA	-	Semiconductor Optical Amplifier
SONET	-	Synchronous Optical Network
TLS	-	Tunable Laser Source
WDM	-	Wavelength Division Multiplexing
WM	-	Wavelength Multimeter

LISTS OF SYMBOLS

λ	-	wavelength channel
λ_i	-	wavelength channel *i*
λ_j	-	wavelength channel *j*
λ_1	-	wavelength of 1550.12 nm
λ_2	-	wavelength of 1549.32 nm
σ	-	channel pass band
°C	-	celcius
C_i	-	crosstalk at channel *i*
dB	-	decibel
GHz	-	gigahertz
Hz	-	hertz
I_i	-	isolation at channel *i*
IL	-	insertion loss
m	-	number of channel
mA	-	miliAmpere
ms	-	miliseconds
nm	-	nanometer
nW	-	nano watt
N_i	-	noise at channel *i*
P_i	-	received power at channel *i*
P_o	-	input power at channel *i*
P_{oj}	-	input power at channel *j*
P_{out}	-	output power
pW	-	pico watt

μm	-	micro meter
μW	-	micro watt
V	-	volt

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION OF PROJECT

1.1 Introduction

Network service providers are seeking a new class of equipment that will expand their reach while reducing provisioning time, increasing accuracy and improving revenue. Customers of today want fast turn up capacity and the ability to utilize only the bandwidth they need as their demand varies.

The metro core, access network are evolving rapidly into all optical DWDM based networks designed to facilitate applications [1]. High speed fiber optic links are increasingly being used to connect network nodes located only a few kilometers a part. To ensure the continuous rapid and widespread deployment of fiber in metro area networks, it is imperative that the optical components used in these networks be available in low power consuming compact packages and at economical prices. An important component for metro area networks will be low port optical switches for protection switching and network configuration.

With recent technologies, many optical switches actually are optoelectronic with input optical signals converted to electronic form for switching, and the switched electronic signals then driving an optical transmitter. All optical switches manipulate signals in the form of light, either by redirecting all signals in a fiber or by selecting signal at certain wavelengths in wavelength division multiplexing (WDM) systems. Some switches can isolate individual wavelengths but typically their input is individual optical channels separated by demultiplexing optics. It means it can operate at the optical channel level without regard to what data the optical channel is carrying. Electronic or optoelectronic switches are still required to manipulate the data stream transmitted on each optical channel [1] [2].

Current technologies do provide all optical switches, which are considered transparent because they transmit the original input light without converting into some other form. One simple example is a moving mirror switch, which reflects the input photons in different directions. Opaque optical switches convert the input photons into some other form and thus do not transmit them. It includes optoelectronic types and others that convert the signal to a different wavelength using optical or electronic techniques.

1.2 Objectives

The main objectives of this project is to study and investigate the characteristics on optical mechanical switch (OMS) in order to implement efficiently into network router system for broadband application. In order to determine the switch measurement being carried out successfully, a proper physical connection between optical mechanical switch, tunable laser source and an optical spectrum analyzer is being set up to observed the switch behavior and its application in optical communication system.

Besides, this project is carried out by implementing and evaluating an optical mechanical switch capable of switching two wavelengths through Mathlab software simulation. By monitoring two independent input and output power signal continuously from the switch, results gathered based on parameters like insertion loss, crosstalk and isolation are analyzed to determine the optimized usage of OMS. Finally, this research is revised and at the same time, conclusions and suggestions are made for future expansion.

1.3 Scope Of Work

Architecture for optical mechanical switch is developed based on an optical switching core and electrical buffering. I intend to continue the studies on this switch architecture, focusing on:

1.3.1 Switch's fixture and selection of switches

i. Selection of optical switch where the data measurement will be carried out. Fiber optic switch from Newport 2x2 Single Mode is chosen.
ii. Investigate the behavior and the characteristics of the particular OMS.
iii. To measure the characterization of an optical mechanical switch where all the relevant parameters will be included. Other characteristics to take into consideration are the range of wavelength tuning, minimum and maximum voltage switching, maximum switching time, and safety precautions to handle the switch.

1.3.2 Signal conditioning to OMS

i. Light projection with constant wavelength is input into OMS in order to produce efficient switching and also with low loss output.
ii. Light with different range of wavelength between 1290nm to 1570nm will be input to OMS and output of OMS will be monitor and loss in the system will be analyzed. Two wavelengths have been chosen for the measurement which is 1550.12nm and 1549.32nm.
iii. Tunable Laser Source used as the input source to the system and Optical Spectrum Analyzer is used to display the output power from OMS. Switch performance will be further analyzed.

1.3.3 Investigation on switch insertion loss, crosstalk and isolation

i. In addition to the system measurement, individual components may be tested for insertion loss, crosstalk and isolation.
ii. Optical sources such as TLS and OSA can be used to carry out such tests. Output power from the OMS can be measured and viewed in power spectrum.

1.3.4 Verification of the simulated results based on hardware implementation

i. Mathlab 5.1 is used to generate the simulation results of the expected parameters obtained from the measurement of OMS. These simulations are based on equations of parameters like crosstalk, insertion loss and isolation.

1.3.5 Determination of an optimum characteristics of OMS and implementation in the network

1.4 Methodology

This research project is mainly divided into two parts, which during the first part of the project is to understand and investigate the behavior and characteristics of an optical mechanical switch (Newport model). Optical switching systems provide a means of interconnecting test equipment and various DWDM modules in a reconfigurable manner. It is imperative that a switching system guarantees repeatable low loss and excellent return loss across all wavelengths. In this research, there are several device will be use in the measurement. The devices involved are Tunable Laser Source, Optical Mechanical Switch and Optical Spectrum Analyzer.

The characteristics of the OMS must be determined before any measurement process takes place. Some of the parameters are very important to take note such as the minimum and maximum switching voltage in the device. A control signal apply to the switch must be under 6V according to the speculation of the fiber optic switch. This is to avoid any breakdown due to high power voltage input to the device. Operating switching current to allow the switch to work safely is between 36mA to 48mA. An optical switch suppose to provide fast switching, therefore the switching time in the device must be always less than 15ms so that the OMS can produce ideal switching and less loss in the transmission.

The Tunable Laser Source (TLS) will work as an input to the OMS. TLS will provide wavelength as the light sources into OMS. But only wavelengths between 1290nm - 1570 nm can be able to input into OMS because the 2x2 single mode switch only operates at those particular wavelengths. With a value of wavelength chosen from

TLS, this light source will travel through the optical switch and switch to the desired output port. With 2x2 fiber optic switch, meaning there are two inputs and two outputs. Switching process will be done mechanically in the switch itself.

In order to capture the results of the switching, Optical Spectrum Analyzer (OSA) device will interface with the output port of the OMS. Through the switching process, light signal that emerged from the switch will be capture on the OSA. OSA is a device to capture and display the results in a power spectrum waveform. Losses due to switching interference, insertion loss and crosstalk will be measured at the other port. These output spectrums can be seen on OSA and its losses can be calculated.

Measurement will be carried out with two chosen input wavelength (1550.12nm and 1549.32nm) and these data measured will be analyzed to select the best characteristics that best fit a router in its application. The control signal from OMS will be used as guidance to make sure the switch is working under the desired condition. Mathlab is chosen as the programming platform due to the popularity, fast processing time and it also support variety of simulation function.

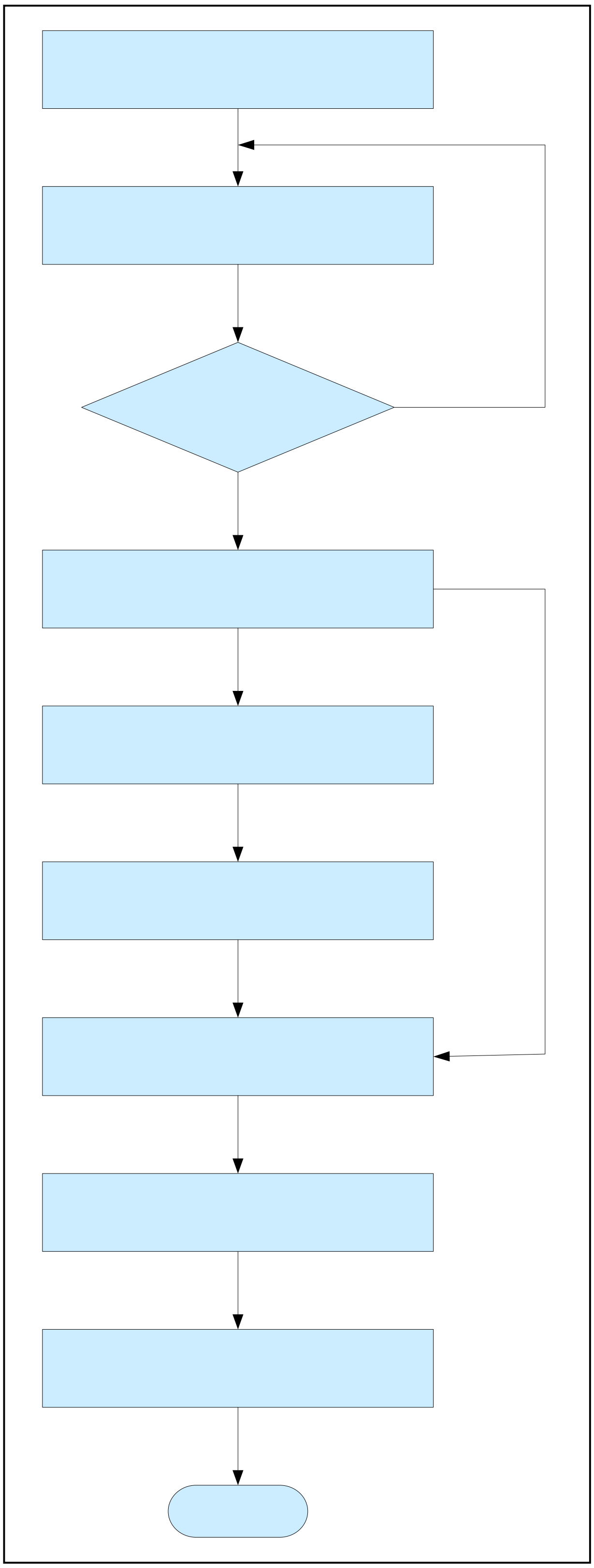

Figure 1.1: Research Step On Optical Mechanical Switch

1.4.1 Determine Newport 2x2 Single Mode Switch Specification

i. Determined switch model to be used.
ii. Obtained switch specification and its datasheet.
iii. Understand its operation and safety precautions to handle switch.

1.4.2 Do simulation of switch parameter with Mathlab 6.1

i. Using Mathlab as the simulation tool.
ii. Analyze the configuration required.

1.4.3 Compare simulation result with switch specification

i. Crosstalk, insertion loss and isolation result of simulation will compare with the switch specification written on datasheet.

1.4.4 Physical connection of hardware implementation

i. Physical connection involves 2x2 single mode optical mechanical switch, tunable laser source, optical spectrum analyzer, and DC power supply.
ii. Measurement is being carried out.

1.4.5 Result Analysis

i. Results obtained from process measurement will be analyzed.
ii. Insertion loss should be less than 1 dB and value of maximum crosstalk should be -80dB.

As shown in Figure 1.2, there are some essential process and steps that should be bear in mind in order for the whole process measurement work successfully. Firstly, the DC power supply must supply at least 4.5V to the switch. This control signal from OMS will be used as guidance to make sure the switch is working under the desired condition. DC power supply is being increased slowly from 4.5 V to 4.6V until it reaches 5.0V for measurement purposes, and therefore it is represents with value $i = 6$. Besides, input power to TLS will be supplied with 100uW to 1mW in order to obtain output power at the output port. This input power will increase slowly from 100uw to 200uW until reaches 1mW. Therefore, there are 10 values of input power to TLS and it is represents in $j = 10$. However, there are only two wavelengths being chosen in this project which are 1549.32nm and 1550.12nm. All output power will be measured, compared and analyze throughout the whole process measurement. It is also important to realize that many of the data from the output power spectrum may be tested and measured several times, as to get values to be more accurate.

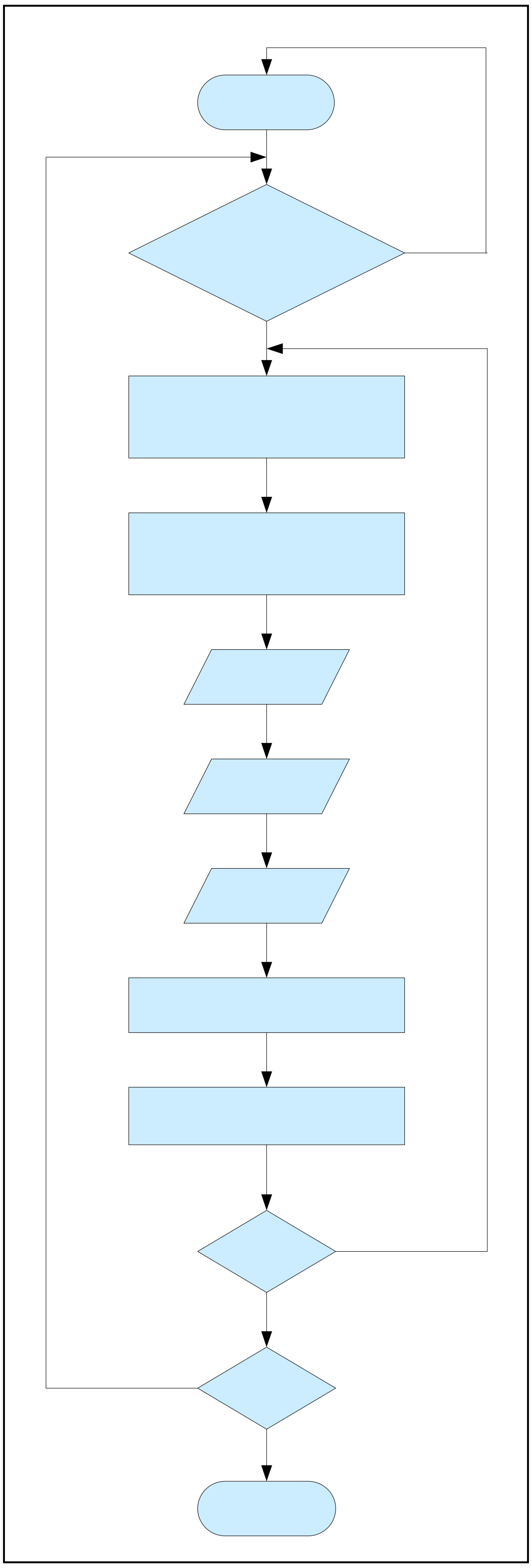

Figure 1.2: Process Measurement Of OMS

1.5 Test Requirements

The most common optical layer parameters being tested are:

1.5.1 Channel centre wavelength an channel spacing

The ITU-T specifies the emission wavelengths to be used in DWDM systems [6]. To avoid interference between channels it is vital that the wavelengths of individual transmitter are set and measured accurately along with the channel spacing. Individual lasers will have a preset ITU-T wavelength is used to tune the emission wavelength so that it complies precisely with a specific ITU-T wavelength. The emission wavelength must be checked and tuned and an OSA or wavelength meter can be used for this task. A WM will be more accurate for such tests than an OSA as the typical WM wavelength accuracy is ±3 pm compared to ±50 pm for an OSA. However an OSA may be used where it is also check the levels of spurious laser side modes. Side modes arise because lasers not only generate light at one main wavelength or mode but also at adjacent wavelengths. These spurious side modes are normally at very low level. An OSA has an advantage over a WM for such tests because of its superior dynamic range.

1.5.2 Wavelength drift

Drift in the operating wavelength of laser sources with time is very undesirable, because with narrow channel spacing down to 0.8nm, drift can cause interference between adjacent channels. Drifts in the parameters can be cause by factors such as temperature change, back reflection, and aging [7]. The laser source is analyzed to ensure signals remain within their assigned wavelength limits, under all operating conditions. Even with tight control the wavelength of the each channel is slightly temperature sensitive. Temperature cycling of the completed system will be carried out to determine the level of unwanted temperature induced drift for each channel, measured in pm/°C.

1.5.3 Per channel power level

The ITU specifies the acceptable power channel power levels. If the optical power level of an individual channel is too high it may cause crosstalk problems, while if it is too low the bit error probability for that channel will be degraded. The per channel power level are measured in dBm. The OSA also estimates spectral flatness parameters from the per channel power measured.

1.5.4 Optical signal to noise ratio

Noise and interference builds up on a system over the total system span as a combination of crosstalk and optical amplifier noise. At present a distance limitation of about 700 km between full electronic regeneration points is imposed on systems by noise and it is thus a critical measurement parameter [6]. An OSA is used to measure the optical signal to noise ratio on a per channel basis as the difference in dB between a channel's power and the noise floor level in the vicinity of the channel.

1.5.5 Spectral flatness

Ideally the power levels of all of the channels should be equal at all points in the system, in effect leading to a flat spectrum. In practice this is not so due to variations in transmitter power levels, variations in the spectral response of components such as multiplexers and amplifiers, as well as the normal variations in fiber attenuation. Gain tilt is the difference in dB between the highest channel power and the lowest channel power for a given wavelength range. Gain slope represents the rate of change of channel power with wavelength over a given number of channels. Its units are dB/nm and it may be positive or negative.

1.6 Hardware and Software required

Equipments and tools that are needed such as Tunable Laser Source, Optical Spectrum Analyzer, Newport 2x2 optical switch and Mathlab software to accomplish this project are briefly described here. All equipments are available in the Photonic Laboratory of Faculty of Electrical Engineering.

1.6.1 Tunable Laser Source (TLS)

The Agilent 8163A Light wave Multimeter is a high performance optical multimeter for the characterization and evaluation of optical components. It is flexible enough to meet changing needs when measuring optical power, power loss or return loss for single or multimode components. As single slot plug-in modules for Agilent's 8163A mainframes, they are a flexible and cost effective stimulus for single channel and DWDM test applications.

A tunable laser is a laser source for which the wavelength can be varied through specified range. The Agilent Tunable Laser allows setting the output power and choosing between continuous wave or modulated power. Laser source is chosen in this measurement because it can provide a stable light wavelength into the optical mechanical switch as the input source.

1.6.2 Optical Spectrum Analyzer (OSA)

The MS9710B provides excellent wavelength accuracy, waveform shape and new features. This OSA features improved wavelength accuracy, resolution bandwidth and signal to noise averaging. The diffraction grating spectrum analyzer covers a wide range from 600 to 1750nm with –90 dBm guaranteed optical reception sensitivity. The MS9710B features high power level accuracy, wide dynamic range and high reception sensitivity.

In addition to its basic features, the superior stability and reliability of the diffraction grating easily pass the severe specifications required for precise measurement of WDM communications methods, particularly in the 1.55 μm band. This Anritsu OSA has features such as to improved signal to noise measurement, tracking function with tunable laser source, built in attenuator for high power optical input, and optional built in light source and reference wavelength.

OSA is use in several occasions such as spectrum analysis for WDM communication system. The MS9710B permits extremely quick and simple waveform analysis of up to 300 spectra. Another application of OSA is the convenient light source where MS9710B calibrated automatically by inputting the reference light for the wavelength, post-calibration wavelength accuracy in the 1.52 to 1.57 μm range is better than ±0.05 nm. It is very useful in precision absolute measurement of the wavelengths of light sources used in WDM systems.

1.6.3 2 X 2 Newport Fiber Optic Switch

An optical mechanical switch from Newport manufacturer has been used in this project to carry out most of the measurement. This switch requires a trigger voltage from +4.5 VDC to 6 VDC to switch into position. When the switch is OFF, it is in the BAR state and when the switch is ON, then it is in CROSS state. The input to the switch is a light source from tunable laser source.

1.6.4 Software

There are two software's being used in this project. There are MATHLAB 6.1 and LABVIEW programming. Most of the project requirement of simulation is done by using Mathlab 6.1 because it can support the requirement of this project. On the hand Labview programming is perform to interface with Tunable Laser Source so that measurement with optical mechanical switch can be carried out successfully.

1.7 Specification Of 2 x 2 Newport Optical Switch

Below is the Table 1.1 showing data specification of the optical switch used in measurement analysis.

Table 1.1: 2 x 2 Newport Optical Switch Specifications

Parameter	Specification	Unit	Description
Switch Type	2 X 2 SM		
Wavelength Tuning Range	1290 - 1570	nm	
Insertion Loss	0.6 1	dB dB	Typical Maximum
Back Reflection	-55	dB	Maximum
Switching Time	15	msec	Maximum
Isolation/Crosstalk	-80	dB	Maximum
Durability	> 10 million cycles		
Repeatability Polarization	± 0.01	dB	Maximum
Dependant Loss	0.05	dB	Maximum
Fiber Type	9/125	µm	
Switching Voltage	4.5 6	VDC VDC	Minimum Maximum
Switching Current	36 48	mA mA	Minimum Maximum
Coil Resistant Operating	125 ± 10%	ohm	
Temperature Range Storage	-20°C to +65°C	celcius	
Temperature Range	-40°C to +80°C	celcius	
Humidity	60°C / 90% RH / 5 days		

1.8 Outline Of Thesis

This thesis contains of seven chapters. Description of each chapter is discussed below.

In Chapter 1, it includes the introduction, objectives, scope of work and methodology of this entire project. It also explains briefly on what mechanism and equipments are being used to do the optical mechanical switch measurement. Chapter 2 practically involves all kind of literature review on optical switches. Literature review is done through reading on other people's work, research paper and serving the online network. It practically discussed the theory and operation of an optical mechanical switch in this chapter. Also the importance of characteristics and performance parameters are being introduces as well.

Chapter 3 thoroughly explained the performance parameters involved in an optical switching. Theory of each term of parameters such as crosstalk, isolation, insertion loss and switching time involved in an optical switching are being explained. In Chapter 4, Mathlab is used to do the simulation of a model switch. Simulation covers the crosstalk, isolation and insertion loss of an optical mechanical switch.

Results of measurement from the hardware implementation of optical mechanical switch with TLS and OSA are presented in Chapter 5. Measurement is taken when optical switch is operating under BAR state and CROSS state. All other experimental setup will also be discussed in this chapter. Result obtained from data measurement experimentally and data from simulation will be compared and analyze in Chapter 6. Overall results of multiple parameters gathered in this project are presented and work of analysis is presented throughout the whole project. Chapter 7 included all the suggestion to improve the efficiency of optical switches and conclusion is made based on the measurement result obtained from hardware implementation.

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