UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FIBER OPTIC SENSOR OF TEMPERATURE MEASUREMENT FOR TUNNEL APPLICATION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Electronic Engineering Technology (Telecommunications) with Honours

by

NAJWA SYAFIQAH BT SAMHUDI

B071210315

900411086202

FACULTY OF ENGINEERING TECHNOLOGY

2015

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Fiber Optic Sensor of Temperature Measurement for Tunnel Application**

SESI PENGAJIAN: **2015/16 Semester 1**

Saya **NAJWA SYAFIQAH BT SAMHUDI**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐ SULIT (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TERHAD (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TIDAK TERHAD

Disahkan oleh:

(____________________) (____________________)

Alamat Tetap:

Kampong Telok Batu,

33400 Lenggong,

Perak.

Cop Rasmi:

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled 'Fiber Optic Sensor of Temperature Measurement for Tunnel Application' is the result of my own research except as cited in references.

Signature	: ....
Author's Name	: Najwa Syafiqah Bt. Samhudi
Matric Number	: B071210315
Date	: ....

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor's Degree in Electronics Engineering Technology (Telecommunications) with Honours. The members of the supervisory committee as are follow:

Signature	: ....
Name of Supervisor	: Mr MD Ashadi Bin MD Johari
Position	: Senior Lecturer
Date	: ....

ABSTRACT

This project entitled 'Fiber Optic Sensor of Temperature Measurement for Tunnel Application'. Fiber-optica sensor has been one of the most successful and powerful applications of both fiber optics and sensing technology. Recently, along with the rapid progress in micro/nanotechnology and increasing demands on optical sensors with higher performances and versatilities, spatial miniaturization has been one of the current trends of fiber-optic sensors. This project is to analyze the temperature in the tunnel with the different temperature.

ABSTRAK

Projek ini bertajuk ‘Fiber Optic Sensor of Temperature Measurement for Tunnel Application’. Gentian optik penderiaan telah menjadi salah satu aplikasi yang paling berjaya dan berkuasa kedua-dua gentian optik dan teknologi penderiaan. Baru-baru ini, bersama-sama dengan kemajuan yang pesat dalam mikro / nanoteknologi dan tuntutan ke atas sensor optik dengan persembahan yang lebih tinggi dan versatilities meningkat, pengecilan ruang telah menjadi salah satu trend semasa sensor gentian optik. Projek ini adalah untuk menganalisis sensitiviti sensor gentian optik dalam menentukan suhu di dalam terowong dengan haba yang berbeza.

DEDICATIONS

This research was dedicated to:

My parent:

SAMHUDI BIN TALIB

TAYIBAH BT. HJ. ISMAIL

Who are always praying and support for my success, always be my side, struggle to give me enough education and always loving me with full of their hearts.

Special thanks to my sibling and friends from 4BETT

Who are always support me in everything that I did, giving me meaningful advice and also help me through the easiness and hardness tune.

ACKNOWLEDGEMENTS

In the name of Allah S.W.T, The most Merciful and The most Passionate, I am thankful to Allah for enabling me to complete this report.

First and foremost, I would like to thanks to my supervisor Mr. Md Ashadi Bin Md Johari, lecturer of Faculty Technology Engineering for giving me a full cooperation and supervision during the making of this final year report. Not to be forgotten, I would like to thanks my family and my friends for contributing their ideas and also encourage me by giving moral support in completing this report.

Last but not least, I would like to thanks for those who are directly or indirectly involved during completion of this project. All of your kindness are very much appreciated.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

LIST OF SYMBOLS AND ABBREVIATIONS

ASE	=	Amplified Spontaneous Emission
OSA	=	Optical Spectrum Analyzer
dB	=	decibel
V	=	voltage
WSS	=	Wavelength Selective Switch
LIF	=	Laser Induced Fluorescence
SVEA	=	slowly varying envelope approximation
FBG	=	Fiber Bragg grating

CHAPTER 1

INTRODUCTION

1.1 Background

For more than a century now, an optical fiber is a glass or plastic fiber designed to guide light along its length. Fiber optics is the overlap of applied science and engineering concerned with the design and application of optical fibers. Optical fibers are widely used in fiber-optic communication, which permits transmission over longer distances and at higher data rates than other forms of communications. Fibers are used instead of metal wires because signals travel along them with less loss, and they are immune to electromagnetic interference. Optical fibers are also used to form sensors, and in a variety of other applications.

Optical fibers can be used as sensors to measure strain, temperature, pressure and other parameters. The small size and the fact that no electrical power is needed at the remote location gives the fiber optic sensor an advantage over a conventional electrical sensor in certain applications. This study will make to produce a simple of temperature measurement for tunnel application..

1.2 Project objectives

The objectives of this project are to:

1. To study of fiber optic works.
2. To develop of fiber optic sensor.
3. To analyze sensor using fiber optic for temperature measurement.

1.3 Problem statement

Nowadays, a lot of technology that are used to measure temperature in the tunnel. But, some technology are used is not durable and easy to damage because of some factors. For example, the already existing temperature sensor is thermistor. This research are made to produce a sensor that can sense a temperature in the tunnel by fiber optic sensor because temperature in the tunnel cannot be expected. Fiber optic are used in this research because it is highly resistant to temperature changes. Besides, this research are made is to see the capability of fiber optic functional.

1.4 Scope of Study

i. To achieve the objectives of project. In this project, we are create a fiber optic sensor of temperature measurement for tunnel.

ii. This sensor are made for detect temperature in the tunnel because some technology are used is not durable and easy to damage.

iii. The scope also shows the capability of this sensor. Other than that, the scope is to understanding of a fiber optic and its properties.

CHAPTER 2

THEORITICAL BACKGROUND

2.1 Introductions

This research are made to analyse the temperature level in tunnel by using fiber optic sensor.

2.2 Fiber Optic

2.2.1 Evaluating Efficiency of Multi-Layer Switching in Future Optical Transport Networks (Soumya Roy, 2013)

Introduction

Network bandwidth is growing significantly at approximately 40% year over year mainly driven by mobile, cloud and video. As a result there is an increasing requirement from optical transport networks for additional capacity, higher spectral efficiency and lower cost per bit.

To cope up with the increasing high capacity demands, next generation DWDM systems would require line rates greater than 100 Gb/s. Super-channels are the next-generation technology to increase spectral efficiency and maximize fiber capacity [1]. This will be complimented by the introduction of flexible grid WDM channel plan, to the existing CDC (colorless, directionless and contentionless) architecture of the multi-degree reconfigurable optical add drop multiplexer (ROADM) to become the fundamental building blocks of the next generation DWDM photonic layer.

While advances in optical transport technologies enable the network capacity scale to multi Tb/s per fiber pair, network planners need to consider not just fiber capacity, but also what mix of service types are expected to traverse the transport network. Prior studies have indicated that even in 2017, 90% of the client services would be 10G or below, while the network line rate has reached 100G and beyond. A digital switching architecture enables the integrated sub-wavelength grooming capability at every add/drop node can provide up to 4x greater bandwidth efficiency in typical long-haul networks.

The proposed multi-layer switching architecture in the next generation optical network nodes integrates the digital OTN switching with ODU0 granularity and super-channel based reconfigurable optical switching. It combines the benefits of digital switching architecture for sub-wavelength grooming leaving no stranded line side capacity and super-channel based optical switching for operational simplicity and greater degree of flexibility for express traffic.

In this paper, we present the results of a network architecture analysis showing the cost savings in the optical transport networks with multi-layer bandwidth management in the network node.

Methodology: Node Switching Architectures

While analyzing the multi-layer switching architecture, three principal node architectures in the optical transport network can be described as:

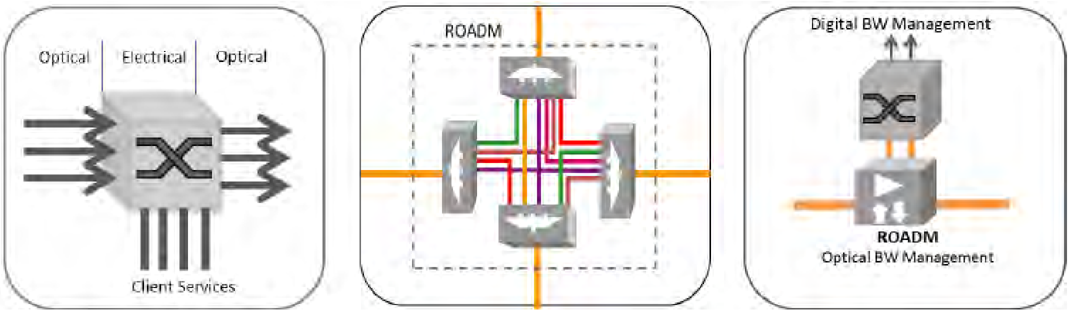

Figure 2.1: Node Switching Architectures

As shown in Fig 2.1, digital switching architecture enables grooming available at every node by integrating the DWDM line modules and digital switching in a single digital transport chassis. This architecture uses OTN standard and provides digital wrapper and OTN multiplexing technologies for an efficient mapping of clients onto line side bandwidth. The benefit of integrated switching architecture is the elimination of extra interconnects between DWDM and any external grooming device in addition to removing the need for manual grooming.

In all optical switching architecture, Fig 1(b), the client services are groomed using a muxponder and mapped to a DWDM wavelength. Once the client signals are groomed on the wavelength, the node uses Wavelength Selective Switch (WSS) based optical switching. There are various versions of muxponder providing variety of client services ranging from 10Gb/s to 100Gb/s. The client signals cannot be individually accessed at intermediate nodes without terminating the entire wavelength and manually re-grooming the client signals onto the wavelengths as needed.

As shown in Fig 2.1, multi-layer switching architecture has integrated optical and digital bandwidth management. It provides flexible ROADM layer with super-channel based optical switching and ODU0 level OTN digital switching. This gives reconfigurable super-channel based optical switching for high flexibility and unconstrained sub-wavelength digital switching for efficiently filling the client services in the line waves.

Results

Comparison – Multi Layer vs. Optical vs. Digital Switching

In the first part of our study (Figure 3), we compared the total number of 100G ports required for each of the switching architectures. With digital switching, grooming is done at every node. Therefore, when there are fewer demands, it maximally fills the 100G waves. However, when the demand increases, all-optical switching becomes much more efficient than all-digital switching because demands can fully-fill the wavelengths. Penalty for digital regeneration for grooming can outweigh the benefits of grooming under those circumstances.

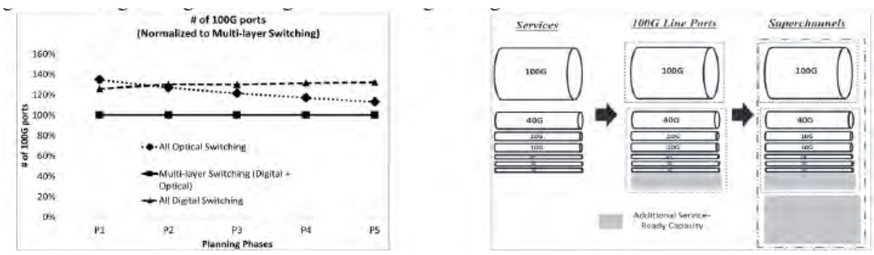

Figure 2.2: Multi Layer vs. Optical vs. Digital Switching

Multi-layer switching combines the benefits of both types of switching and uses minimum number of 100G waves under both situations: (1) when the demand is low and the wavelengths are not filled (2) demand is high and the wavelengths can get well filled. The result shows multi-layer switching uses 13-22% less number of 100G ports than the best performance of either all-optical or all-digital switching architectures. Multi-layer switching uses digital grooming for better-filling of the wavelengths, while for fully-filled wavelengths, it optically expresses through the nodes without regenerations for grooming purposes. Therefore, from network planning perspective, network planners should consider multi-layer switching architectures right from the initial planning phase to deploy the lowest cost networks.

Super-Channel based Multi-Layer Switching

In the results presented above, granularity of optical transport has been 100G. With rising network bandwidth demand, super-channels will be the next-generation technology to increase spectral efficiency and maximize fiber capacity. Flex-grid based super-channels, in simple terms, pack more 100G channels in a given spectrum by removing guard bands and get transported in Nx100G granularity. As explained in Figure 4, 100G line ports are filled using digital grooming of sub-100G services with similar path characteristics. With super-channels, Nx100G demands having similar path characteristics are packed together as a super-channel and that become the granularity of optical transport. With approximately 40% demand growth, this becomes the more efficient mode of transport compared to 100G transport. Our results with 500G (i.e. 5x100G) super-channels show (Figure 5) that there is 7-29% additional service-ready network capacity and service providers can monetize this capacity as and when needed without additional truck-rolls. This significantly reduces the OPEX as with super-channels, there are fewer line-cards, implying less install time, less maintenance and improved reliability. Therefore, with the increase in demands, multi-layer switching combined with super-channels can provide the most logical way to scale the network capacity.

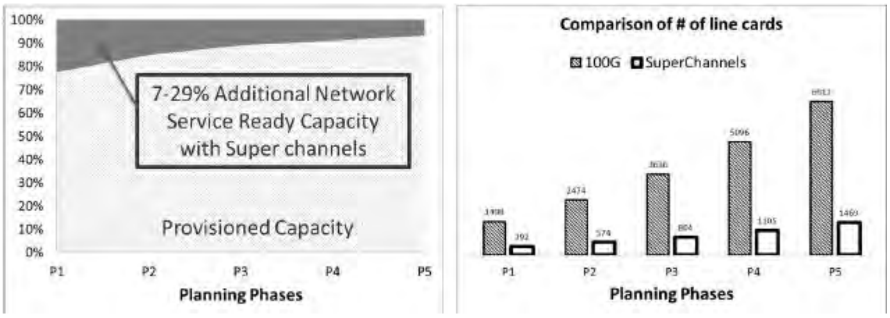

Figure 2.3: Benefit of Using Super Channels

2.3 Fiber Optic Sensor

2.3.1 Advances on Optical Fiber Sensors (Luciano Mescia, 2013)

Introduction

Almost four decades have passed since the research on optical fiber sensors began in earnest. Various approaches and technologies have been utilized for measuring a number of different physical parameters, but only some types of optical fiber sensors are commercially interesting. In fact, in many cases, optical fiber sensor systems are not available in a complete form, *i.e.*, including both detecting and signal-processing electronics. However, their future is very promising because they exhibit well known advantages such as compactness, immunity to electromagnetic interference and to ionizing radiation (γ-ray, X-ray *etc*.), high sensitivity, large bandwidth, and minimum weight. These properties, make optical fiber sensors key photonic devices in radiative environments, like nuclear power plants, where the detection and evaluation of radiation levels and temperature changes are very important, especially in case of accidental constraints. Optical fiber sensors have been developed to measure strain, temperature, pressure, current, voltage, gas, chemical contaminant, rotation, vibration, acceleration, bending, torsion, displacement, and biomolecules.

Chemical optical fiber sensors for the detection of polluting substances in water, soil, and air, such as the biological sensors, optimized for medicine applications, have attracted noticeable interest because they are directly related to the quality of human life. They have been investigated as key elements of environmental monitoring systems, with the aim of preventing environmental catastrophes, and also as novel techniques for medical diagnosis. In particular, optical fiber sensor systems can avoid the collection of samples to be investigated in appositely equipped laboratories. They provide means of overcoming the drawbacks exhibited by *ex-situ* techniques which are invasive, time consuming and expensive. In fact, optical fiber chemical/biological sensors, enable pollution detection and/or medical diagnostic monitoring via an *in-situ* and slightly invasive technique.

Optical spectroscopy of water, atmosphere, soil or biological samples, is commonly performed in chemical laboratories and is based on Laser Induced Fluorescence (LIF) or Raman effects. LIF or Raman equipment is generally expensive due to both the utilized light sources (and related optical components) and to the sophisticated processing electronics. In order to develop low-cost pollution and bio-medical monitoring, a promising approach concerns the optimization of microstructured optical fibers (MOFs) for sensing. In fact, in recent years, a number of sensors made of suitable MOFs have been theoretically and experimentally investigated for the measurement of a large variety of physical and chemical parameters .

Both conventional fiber optic and MOF sensors can be based on fiber gratings, interferometers, scattering/reflecting, Faraday rotation, fiber-optic gyroscopes, fluorescence, luminescence, and interaction of evanescent electromagnetic field structures.

Method of Optical Fiber Gratings as Key Elements of Sensors

The core refractive index perturbation $\Delta n(z)$ along the fiber longitudinal direction z, constituting a grating, can be expressed as reported in [31]:

$$\Delta n(z) = n_1(z) - n_1 = n_1\sigma(z)\left[1 + m\sin\left(\frac{2\pi z}{\Lambda}\right)\right]$$

where $n1$ is the core refractive index, Λ is the grating period, m is the induced-index fringe modulation, and $\sigma(z)$ is the slowly varying envelope of the grating.

The well-known coupled mode theory CMT can be employed to find the equations describing the electromagnetic field propagation along the grating, by considering the slowly varying envelope approximation (SVEA). Coupled equations can be correctly written when grating inscription induces a weak perturbation on the propagation modes and the electromagnetic field amplitudes of the forward and backward modes can be calculated.

A strong mode interaction can be obtained in the grating at the wavelength where both mode phase matching (phase synchronism) and a sufficient mode overlap occur. Therefore, different modes can exchange power between them. The local reflectivity is the complex ratio of the forward and backward wave amplitudes. FBGs, characterized by a short period, typically couple the forward propagating core mode to the backward propagating one. Chirped fiber gratings exhibit a large reflection spectrum. They are generally utilized when the phenomenon that each wavelength component is reflected at different positions in different delay times must be exploited for the fabrication of specific devices. Tilted fiber gratings exhibit different characteristics and they can be used to couple the forward propagating core mode to the backward one and to a backward propagating cladding mode. LPGs, characterized by a long period, are generally designed to allow the power exchange of a forward.

When a core mode is coupled with a cladding mode the transferred electromagnetic energy is affected by the mode phase mismatch (displacement from the phase matching condition) which can be due to a variation of a number of different measurands such as wavelength, temperature, stress, fiber bending *etc*. Therefore optical sensors can be obtained.

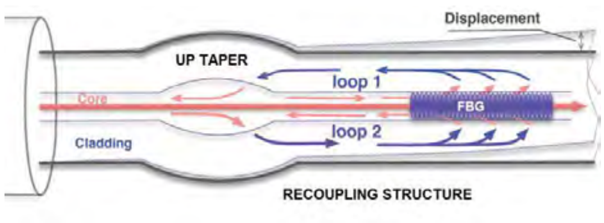

Figure 2.4 :Schematic of cladding-mode backward recoupling structure including the up taper and the fiber Bragg grating proposed in.