MATERIALS OF SILICA FOR SINGLE MODE OPTICAL FIBRE (SMF) DESIGN BASED ON DISPERSION

FINAL PROJECT

In partial fufillment of the requirements for the degree of Bachelor of Engineering

By :

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MATERIALS OF SILICA FOR SINGLE MODE OPTICAL FIBRE (SMF) DESIGN BASED ON DISPERSION

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Submitted to the Department of Electrical Engineering on February, 2017, in partial fullfillment of the requirment for the degree of Bacheloor Engineering.

Abstract

Loss or attenuation and pulse dispersion represent the two characteristics of an optical fiber most important in determine the information-carrying capacity of a optical fiber communication system. Optical loss or attenuation in optical fiber is limiting factor as it reduces the average optical power reaching the reciever. In addition, dispersion is an effect responsible for spreading of a signal in time when the signal propagates.

Attenuation in optical fiber have many factors, such as intrinsic loss, absorption, rayleigh scattering, waveguide loss, bendig loss, microbending loss, joint or splice loss, and attenuation coefficient. Based on literature studies, there are three main types of dispersion are material dispersion, Waveguide dispersion, and modal dispersion.

This project will analyze the characteristic of optical fibers cable based the dispersion factor,Material dispersion and Waveguide dispersion to design the best Single Mode Fiber (SMF) cable. Sellemeire's equation is used to determine dispersion.

In this study the effect of the dipersion were conducted on the folowing nine material SiO_2, SiO_2 doped germanium 3.1% , SiO_2 doped germanium 5.8%, SiO_2 doped germanium 7.9% , 86.5SiO_2 : 13.5GeO_2, 90,0SiO_2 : 9.1P_2O_5, 86.7SiO_2 : 13.3B_2O_3, 99.0SiO_2 : 1.0F, 50,6SiO_2 : 16,2Na_2O : 32.5B_2O_3. Then data of Sellemeire's coefficient obtained from literature were used to determine the total dispersion which include material and waveguide dispersion.

The analysis of the simulation of the total dispersion resulted in the increasing of refractive index of the material due to increasing dopant, it was also observed that the increasing refractive indeks.Value and the type of material could give an effect to increase the curve of the total dispersion.

Fom this study it was also resulted in that the material of 86.5SiO_2 : 13.5GeO_2 is the best material for design Single Mode Fiber based dispersion due to its small dispersion value.

Keyword : Optical Fiber Cable, Sellemeire's Equation, Material Dispersion, Waveguide Dispersion, Refractive Index

Characteristic of Cascaded Mach-Zehnder Interferometers

with Different Arm Length

FINAL PROJECT

In partial fulfillment of the requirements for the degree of Bachelor of Engineering

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Characteristic of Cascaded Mach-Zehnder Interferometers with Different Arm Length

Fauzan Al-Ayyubi

0103512004

Submitted to the Department of Electrical Engineering on March, 2017, in partial fulfillment of the requirement for the degree of Bachelor of Engineering.

ABSTRACT

Mach-Zehnder Interferometers (MZI) are devices that use several couplers linked together at both of their arms. The outputs of MZI are determined by the coupler's coupling coefficient, the coupler's coupling length, and the coulpler's arm length difference. In MZI, the coupling coefficient and coupling length are fixed, the only parameter that can be freely manipulated is the length difference. The length difference will cause the power output phase to shift. This phase shift can be utilized to design a filter by changing the length difference.

This final project will talk about the characteristic of Cascaded MZI with different arm length. The power output phase shift in MZI is calculated by using transfer matrix obtained from the derivation of Maxwell's Equations and the Couple Mode Equation.

The characteristic Cascaded MZI with different arm length and one input will be analyzed and compared from the simulation of the transfer matrix of Cascaded MZI with two configurations: the same length difference of every arm between the couplers and the same total length difference for every arm between the couplers.

For the first configuration, three couplers MZI have FSR = 5 nm, while four couplers MZI will have FSR = 6 nm. For the second configuration, the FSR of three couplers MZI is double of the first configuration, while the FSR of four couplers MZI is triple of the first configuration. Because the input used is only at one port, the power outputs are divided into two, where one of the output port's minimum amplitude does not reach zero. The maximum and minimum amplitude for three couplers MZI is in the opposite port of Single MZI, while the maximum and minimum amplitude for four couplers MZI is at the same port as Single MZI. The four couplers MZI can be used as a better filter than the Single MZI and the three couplers MZI because it has flat top.

Keyword: Optical fibers, optical fiber couplers, transfer matrix method, length differences, spectral response.

CHARACTERISTICS OF THREE WAVEGUIDE DIRECTIONAL COUPLERS : SWITCHING OPERATION AND THERMO-OPTICS EFFECTS

FINAL PROJECT

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CHARACTERISTICS OF THREE WAVEGUIDE DIRECTIONAL COUPLERS : SWITCHING OPERATION AND THERMO-OPTICS EFFECTS

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Abstract

The two waveguide directional coupler is the common optical coupler components. It has two input ports and two output ports, and is composed of two closely spaced waveguides. By placing a third waveguide between the two waveguides is what this final project analyzed. One advantage of this scheme is that it can reduce the physical length of the device significantly.

Assuming that three proximate waveguides of an optical switch are identical and equally spaced, we examine the switching mechanism for cases where an initial power/beam is launched into an outer waveguide and into a middle waveguide. For each power-launched case, switching voltage is applied so that the overall index is detuned symmetrically or antisymmetrically. After the new system is compare with the conventional system, we add a temperature parameter where the cases are heated 10^0C from the initial temperature. Based on this research, it concluded that the system with three identical waveguides which the beam launched into middle waveguide has smaller minimum coupling length about 30% less from two waveguide system, and better system to withstand cross state condition while the value of propagation constant mismatch is changes at raising temperature due to thermo-optic effect compared to others. Note that the system's limit changes of propagation constant mismatch which can keep the cross state performance is $\Delta\beta$ = -0.4 – 0.4 before heated, and $\Delta\beta$ = -1.4 – 1.4 after heated.

Keywords : three directional coupler, detuned symmetrically, detuned antisymmetrically, cross state condition, thermo-optic effect.

LOSS CHARACTERISTICS OF ASYMMETRY AND SYMMETRY CURVED OPTICAL WAVEGUIDE

FINAL PROJECT

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LOSS CHARACTERISTICS OF ASYMMETRY AND SYMMETRY CURVED OPTICAL WAVEGUIDE

Indah Juningtiaz Devayani
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Submitted to the Department of Electrical Engineering on October, 2014, in partial fulfillment of the requirement for the degree of Bachelor of Engineering.

Abstract

Bending waveguide is used to connect two separated optical waveguides. But the bend will produce a high loss. The bending loss can be reduced by designing the geometry structure, and value of effective refrative index for the core and cladding. In this final project, we will compute the bend loss between two slabs waveguide structure, asymmetry and symmetry. In asymmetry, we only calculate the curved loss and compare it with the curved loss at symmetry slab waveguide in the same parameters. Then, we calculate the S-shaped bend geometry structures at symmetry slab waveguide; back-to-back and sinusoidal bends. From the simulation result, we can obtain that the bend loss depends on the value of Δn, and geometry structure of bend in slab waveguide. The bend loss decrease when Δn is increased. The comparisons result of curved loss at asymmetry is lower than symmetry slab waveguide structure, because there is a difference at the refractive index cladding (n_3). To get the lower curved loss we use the minimum curvature (r) > 3mm for asymmetry, and (r) > 4mm for symmetry slab waveguide. Then, the bend loss back-to-back is higher than sinusoidal bend at the same parameters. It may caused of the sinusoidal bend geometry structure is more smooth than back-to-back because the bend on sinusoidal S-shaped bend is a function of transition length. The bend loss will occur at the range tansition length (L) is 1-3.8mm for back-to-back, and (L) is 1-1.6mm at sinusoidal bend.

Keywords: Back-to-back bend, sinusoidal bend, curved bend, asymmetry slab waveguide

OPTICAL CHARACTERIZATION OF ONE DIMENSION PHOTONIC CRYSTAL

FINAL PROJECT

In partial fulfillment of the requirements for the degree of Bachelor of Engineering

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OPTICAL CHARACTERIZATION OF ONE DIMENSION PHOTONIC CRYSTAL

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Submitted to the Department of Electrical Engineering on October, 2014, in partial fulfillment of the requirement for the degree of Bachelor of Engineering.

Abstract

Photonic crystal is a periodic dielectric material that affect the propagation of light. That produces a photonic bandgap. Photonic bandgap is a phenomena where a range of frequency cannot propagate through the structure.

We use Plane Wave and Transfer Matrix method to analyze the dispersion relation that produce the photonic bandgap. In the simulation we try to compare both results and show them in graph of wavevector *k* vs frequency, with unit cell consisting GaAS as material of the dielectric and air as the gap.

If we increase the width of the dielectric medium, the bandgap will shift into higher frequency value. The proof of the bandgap is reflectance coefficients. Comparing both TMM and PWM method resulting an error of calculation. The length of error on each bandgap increased as the normalized frequency increased. In the first bandgap, it has length of differences 0.0072 in normalized frequency. And is increasing when we analyze the second and third photonic bandgap, with length of differences 0.0136 and 0.0195, respectively. The fourth and fifth photonic bandgap occured above the normalized region so was not a valid results.

Keyword : Photonic crystal, plane wave method, transfer matrix method, GaAS, photonic bandgap

TEMPERATURE EFFECT ON FIBER BRAGG GRATINGS BASED ON THERMO-OPTIC COEFFICIENTS AND OPTIMIZATION BY USING APODIZATION PROFILE

Universitas Al Azhar Indonesia

FINAL PROJECT

In partial fulfillment of the requirements for the Bachelor degree of Engineering

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TEMPERATURE EFFECT ON FIBER BRAGG GRATINGS BASED ON THERMO-OPTIC COEFFICIENTS AND OPTIMIZATION BY USING APODIZATION PROFILE

Rumadi

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Submitted to the Department of Electrical Engineering on February 2015, in partial fulfilment of the requirements for the degree of Bachelor of Engineering

Abstract

The FBGs temperature sensor offer a high sensitivity, as well as other important advantages, such as real-time processing, long-term stability, electromagnetic interference immunity, and multiplexing capability [1]. The basic principle of FBGs sensor is the measurement of an induced shift in the wavelengthof an optical source due to a measured, such as temperature. Changes in temperature affect both the effective refractive index and grating period of an FBGs, which results in a shift in the reflected wavelength. Effect on the effective index is called the thermo-optical effect, while the effect on the grating period is called the thermal expansion effect. Compared to the thermo-optical effect, the thermal expansion effect can be ignored. In this work, we assume only thermo-optic coefficient influencing temperature effect on fiber Bragg gratings (FBGs).

Based on the thermo-optic coefficients, we analyze the effect of temperature on fiber Bragg gratings. The design of fiber Bragg gratings used Coupled Mode Theory (CMT). The coupled mode equations were solved by the Transfer Matrix Method (TMM) since it was considered as good approximation to calculate the spectral response of fiber Bragg gratings. Apodization techniques are used to get optimized reflection spectrum.

The simulated reflection of FBGs with different grating lengths and index change were described. The influence of index change and grating length on the full width half maximum (FWHM) of the reflected spectrum at the Bragg wavelength and the maximum reflectivity of the reflected spectrum were investigated. The increasing of index change and grating length causes the increasing of FWHM and maximum reflectivity. Temperature versus wavelength shift graph was plotted. The temperature sensitivity for silica fiber at 1550 nm was found to be 12.5 pm/^{0}C on uniform FBGs and 13.1 pm/^{0}C on linearly chirped FBGs. The FBGs with several types of apodization were modeled in this project. It was proven that apodization profile could be reduced the sidelobes.

Keyword: FBGs, thermo-optic coefficient, index change, grating length, apodization, CMT, TMM, temperature sensitivity, sidelobes.

CHARACTERISTIC OF DOUBLE MICRORING RESONATOR ON SERIES CONFIGURATION

FINAL PROJECT

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ABSTRACT

Optical microring resonator waveguides is set with a closed-loop feedback plus some sort of light and output. The microring resonator filter is narrow band, and thus is suited for Wavelength Division Multiplexing (WDM) systems. They can be implemented for such diverse of applications such as lasers, sensor, and optical add/drop filter. In the double microring resonator, there are two ring waveguides are used, instead of one, and arranged in series or parallel configuration. When using two rings in a series configuration, the output of the double ring resonator will be in the same direction as the input. The second ring will be combined with the first ring brings to light that is passed to the second ring. By the same method, the light would then eventually be transferred to the output.

In this research the characteristic of single microring resonator and double microring resonator on series configuration including Free Spectral Range (FSR), Full Width Half Maximum (FWHM), temperature effect and wavelength shifted by using computer simulation. The simulation result in investigating the effect of temperature indicates that wavelength shifted by changing the temperature from 27 ^{o}C to 627 ^{o}C with difference value is 200 ^{o}C. The value of FSR-FWHM in single is 53.556 nm and 3.717 nm and for the value of FSR-FWHM in the double of microring resonator is 53.556 nm and 42.6 nm.

Keyword : Microring resonator, series configuration, temperature effect, wavelength shifted.

CHARACTERISTIC OF BRIGHT AND DARK SOLITON

Universitas Al Azhar Indonesia

FINAL PROJECT

In partial fufillment of the requirements for the degree of Bachelor of Engineering

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CHARACTERISTIC OF BRIGHT AND DARK SOLITON

By:

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Submitted to the Department of Electrical Engineering on July, 2013, in partial fulfillment of the requirements for the degree of Bachelor of Engineering

ABSTRACT

This final project discusses the declines formula of nonlinear Schrödinger equations (NLSE) Maxwell that is affected by the linear response of the dielectric material and the nonlinear response of dielectric material. NLSE is a general equation which is used to describe the propagation of soliton waves in the field of nonlinear optics. However, for pulses of order femtoseconds NLSE is not able to give a good overview.

Bright soliton pulse profile is influenced by the effects of self-phase modulation (β), self-steepening (δ) and group velocity dispersion (V). By changing the value parameter of β, δ, and V used obtain a characteristic of soliton profile, where β value has a small hole before the increasing pulses and the resulting large bandwidth. When there is a change in the value of δ, the pulse profile is formed when there is a hole large δ value and has greater bandwidth too. The changing of the following pulse profile changes also occurs because of the influence from GVD, the effects of these changes are evident in the resulted bandwidth. When the value of V is bigger than the previous parameter, and the bandwidth is narrower, it will make the resulting hole is deeper. The pulse profile forms a shape hole in the negative area and to be unstable. On the dark soliton, the pulse profile is very sharp hole formed in the region tend to be negative and unstable.

To get the pulse of bright solitons are stable, the parameter β must be between 5 to 11, the value of δ between 1 - 1.75, and the value of the V parameter ranges

between 0 - 3. If the value of the parameter is smaller or larger, it will have an impact on the shape of the pulse tends to be unstable. As for the dark soliton pulses with parameter values $A = 1$, $\beta = 11$, $\delta = 1$ and $V = 1.51$ pulses generated unstable.

Keyword : Soliton, nonlinear Schrödinger equation, self-phase modulation, self-steepening, group velocity dispersion.

Temperature Effects in Optical Fiber Interleaver Based on Cascaded MZI Structures

FINAL PROJECT

In partial fulfillment of the requirements for the degree of Bachelor of Engineering

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Temperature Effects in Optical Fiber Interleaver Based on Cascaded MZI Strucutres

ABSTRAK

Optical Interleaver adalah perangkat serat optik pasif yang digunakan untuk menggabungkan dua set saluran DWDM ke dalam aliran sinyal komposit dengan cara interleaving ataupun sebaliknya. Interleaver optik biasanya dibuat berdasarkan struktur Mach Zehnder Interferometer (MZI). Optical Interleaver semacam ini biasanya digunakan di lingkungan ekstrem dengan suhu yang cukup tinggi dan tidak stabil. Oleh karena itu dalam tugas akhir ini, efek suhu pada perangkat optical interleaver disimulasikan dan dianalisis berdasarkan struktur Cascaded MZI (CMZI).

Metode transfer matriks digunakan untuk mendapatkan persamaan matriks pada CMZI dan efek suhu dihitung menggunakan persamaan indeks bias efektif dalam serat silika sebagai akibat dari perubahan suhu. Simulasi dan analisis difokuskan pada struktur CMZI dua tahap dan tiga tahap pada rentang suhu dari 30ºC hingga 430ºC dan kisaran panjang gelombang dari 1530 nm hingga 1565 nm (rentang C-Band).

Pemanasan mengubah karakteristik sinyal keluaran pada CMZI. Pemanasan pada lengan CMZI menyebabkan perubahan nilai indeks bias sehingga menyebabkan pergeseran panjang gelombang. Nilai pergeseran panjang gelombang pada CMZI dua tahap dan tiga tahap memiliki nilai pergeseran yang sama yaitu 1,209 nm pada setiap perubahan suhu 100ºC. Nilai pergeseran panjang gelombang diekspresikan oleh persamaan wavelength shift CMZI yang dibuat menggunakan persamaan linear. Pemanasan sampai 430ºC pada CMZI coupler menyebabkan perubahan nilai coupling ratio sehingga menyebabkan perubahan karakteristik output daya. Peningkatan daya isolasi dan daya crosstalk pada CMZI dua tahap masing-masing sekitar 4-dB dan 3,5-dB. Sementara peningkatan daya isolasi dan crosstalk power pada CMZI tiga tahap masing-masing sekitar 5-dB dan 4-dB.

Kata kunci: Indeks bias efektif, Efek Suhu, Koefisien Kopling, Teori Mode Kopling, Metode Transfer Matriks, Cascaded MZI

Wavelength Shift in Single MZI as a Function of Arm Length Differences

FINAL PROJECT

In partial fulfillment of the requirements for the degree of Bachelor of Engineering

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DEPARTMENT OF ELECTRICAL ENGINEERING

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Final Exam Date : August 13th, 2018

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Wavelength Shift in Single MZI as a Function of Arm Length Differences

Abstract

Optical communication is curently using DWDM technology as multiplexing method. Mach-Zehnder interferometer (MZI) as a filter application has an important role in this multiplexing technology. MZI is device that use several couplers linked together at both of their arms. The work principle of MZI is divide the input signal into 2 parts when pass through the first coupler, then the signal is re-integrated in the next couplers. The output depends on the coupler's coupling coefficient, the coupler's coupling length, and the coupler's arm length difference (ΔL). Length difference will cause wavelength shift on the output. This wavelength shift can be utilized to desain a filter by changing the value of ΔL.

This final project will performed experiments about the chracacterstic of single MZI with one input port. The characteristics discussed include the work principle on single MZI, different ΔL value between experiment and simulation result, increasing the output power peak as a function of input power, and wavelength shift as a function of arm length differences.

The arm length different on single MZI experiment will be analyzed and fitted with the ΔL value on simulation using Mathcad. From the fitting experiment obtained relative error. The changes of output power peak are obtained by inputting different input power values. The wavelength shifts are obtained by cutting one of arm on single MZI which produces variations value of ΔL.

The results of transmission output power experiment can be used for power budget calculation. From fitting experiment result is obtained relative error of ΔL value is 0.00137%. The length of ΔL that can be used to meets the standard ITU grid of 0.8 nm in the C Band window (1550 nm) is 2.2172 mm, it can be used as direct function for practical fabrication of the filter devices.

Keyword: Optical fibers, optical fiber couplers, arm length differences, wavelength shift.

CHARACTERISTIC OF THERMO-OPTIC EFFECT ON CASCADED MACH ZEHNDER INTERFEROMETER FOR L-BAND RANGE

FINAL PROJECT

In partial fufillment of the requirements for the degree of Bachelor of Engineering

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CHARACTERISTIC OF THERMO-OPTIC EFFECT ON CASCADED MACH ZEHNDER INTERFEROMETER FOR L-BAND RANGE

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Submitted to the Department of Electrical Engineering on June, 2013, in partial fulfillment of the requirement for the degree of Bachelor of Engineering.

Abstract

Optical device based on Mach Zehnder Interferometer is usually used as the optical switching, modulator and many applications in telecommunication networks. The subject of this work is to analyze the characteristic of thermo-optic effect on cascaded Mach Zehnder Interferometer (MZI). Effect of Temperature is calculated by using sellmeier equation which causes the changing of effective refractive index material with the temperature varied from 28^0C to 300^0C.

The central wavelength used in all chapter is 1575nm which this wavelength are commonly used L-Band in optical communication. The transfer matrix methode are used to obtain the formula of couple mode theory and the Mach Zehnder Interferometer equation.

Based on simulation result and analysis, the changing temperature influence the refractive index and the coupling coefficient value. Heating effect in arms side of Single and Cascaded MZI causes the wavelength shifting about 1.08nm for every 100^0C temperature changing. Heating on couplers causes the changing in coupling coefficient which lead to the increasing of the isolation power and crosstalk. Higher temperature produce the higher isolation power and crosstalk. When the MZI is heated until 327^0C, the increasing of crosstalk power is about 23.4dB and the increasing of isolation power is up to 35dB.

Keyword : Cascaded Mach Zehnder Interferometer, Thermo-optic effect, Sellmeier equation, transfer matrix methode.

ANALYSIS OF FIBER BRAGG GRATINGS FOR ONE DIMENSIONAL PHOTONIC CRYSTAL BAND GAP

FINAL PROJECT

In partial fulfillment of the requirements for the Bachelor degree of Engineering

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ANALYSIS OF FIBER BRAGG GRATINGS FOR ONE DIMENSIONAL PHOTONIC CRYSTAL BAND GAP

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Submitted to the Department of Electrical Engineering on August, 2012, in partial fulfillment of the requirements for the degree of Bachelor of Engineering

Abstract

The subject of this work is to analyze the characteristics of fiber Bragg grating with their properties to continued about studying one dimensional photonic crystal band gap. Uniform fiber Bragg grating are simulated to better understanding about the characteristics of uniform fiber Bragg grating. Defect structure, strain, temperature and pressure sensitivity in fiber Bragg grating as the properties of fiber Bragg gratings are simulated. Characteristics of one dimensional photonic crystals band gap are explained in a small scope.

The aim of this project is to better understand about filtering properties and versality of fiber Bragg gratings as in fiber devices has large aplication in optical telecommunication, laser and sensor fields. The characteristics of fiber Bragg grating in reflection and transmission power tends to happen close to Bragg wavelength in fiber Bragg grating. The sensitivity of fiber Bragg gratings to the grating length, number of elementary cells, refractive index, defect fraction and other properties will be laid as the foundation for a variety of important optical component in telecommunication aplication.

All of chapter use the central wavelength of 1550 nm which this wavelength are commonly used in optical communication. Couple mode theory are used to describing such phenomenon in optical fiber then integrated with transfer matrix method to understand the formula of fiber Bragg grating.

Keyword : Fiber Bragg grating, one dimensional photonic crystal band gap, transfer matrix method, power reflection, power transmission.

Comparison of Semiconductor Laser at Wavelength 980nm & 1480nm for EDFA Pumping Scheme

FINAL PROJECT

In partial fulfillment of the requirements for the degree of Bachelor of Engineering

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ABSTRACT

Comparison of Semiconductor Laser at Wavelength 980nm & 1480nm for EDFA Pumping Scheme

Satyo Pradana

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Submitted to Department of Electrical Engineering on November, 2017, in partial fulfillment of requirement of the requirement for the degree of Bachelor of Engineering.

Optical Communication are affected by many problem, loss of signal is one of them. Erbium Doped Fiber Amplifier (EDFA) is the key to solve it. By using Semiconductor Laser as pump for EDFA, can bring back the signal to normal condition. EDFA have a good wavelength operation at 980nm and 1480nm. To achieve selected wavelength, we must construct the Semiconductor Laser that suitable for 980nm and 1480nm. In that case, *InGaAs* and *InGaAsP* are the based material to construct the Semiconductor Laser. At wavelength 980nm the material that used is *InGaAs* and at wavelength 1480nm the material that used are *InGaAs* and *InGaAsP*. The reason material choose is suitable for selected wavelength. By using selected wavelength and material, the Semiconductor Laser can be produced properly. Also, determining the parameter is the important things to construct the Laser. By using Rate Equation, it can be obtained four result for Semiconductor Laser such as Injection Current vs Voltage, Carrier Density, Photon Density and Output Power vs Injection Current. By comparing output power of three Laser, *InGaAs* at 980nm has the largest output power and slope efficiency compared to *InGaAs* at 1480nm and *InGaAsP* at 1480nm. *InGaAs* at 1480nm is the most efficient Laser since have smallest threshold current compared to *InGaAs* at 1480nm and *InGaAsP* at 1480nm, even though have smallest output power.

Keywords: Semiconductor Laser, Fabry-Perot, Wavelength at 980nm and 1480nm, Materials *InGaAs* and *InGaAsP*