PC474 Lab Manual[1]

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February 3, 2016

[1]Much of this information is taken from OptoSci documentation
[2]with much original material byAdam Prescott

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Chapter 1

Power Measurements

1.1 Purpose

The purpose of the this exercise is to familiarize yourself with fibre optic measurements and measurement equipment.

1.2 Introduction

This exercise is intended to introduce basic concepts of measurement related to optical fibre networks.

1.3 Theory

$$P(dBm) = 10\log_{10}\left(\frac{P_s}{1mW}\right) \tag{1.1}$$

$$P(dB) = 10\log_{10}\left(\frac{P_A}{P_B}\right) \tag{1.2}$$

1.4 Procedure

1.4.1 Experimentation

Apparatus

- various meters
- various single mode cables
- various fibre light sources

Method

PROTECT EYES!!!!

- always keep sources capped unless in use
- never point at eyes (yours or anyone else's!)

PROTECT Equipment

- most pieces few to 10's of thousand dollars. (even used!)
- take your time
- don't move equipment unless absolutely necesary

Power is measured in three ways:

1. absolute, in **Watts**
2. relative, in **dB** (See Equation 1.2.)
3. absolute, in **dBm** (See Equation 1.1.)

This exercise will cover the following concepts:

1. Conversion between power units:

   - dBm to W
   - W to dBm

   Note that difference in dBm = difference in dB

2. Comparing sources:

   Which is most dangerous?

3. Comparing meters:

   How consistent are they?

In-lab Tasks

IT1: Measure the power of a single source in dBm using a single meter, and convert it to mW. Do this with it connected properly and improperly so you can see the difference. Use the results to fill in Table 1.1. *Demonstate general results to the lab instructor.*

IT2: Measure the power through a single cable with a single meter using 3 different sources to determine the power of each source. Note any indications about what class of laser each source represents. (If a source produces two wavelengths, measure both.) Use the results to fill in the dBm columns of Table 1.1. (You'll convert to mW later.) *Demonstate general results to the lab instructor.*

IT3: Measure the power through a single cable with a single source with 3 different meters to see how well the meters agree. Repeat the measurement with the first meter after the others to see how consistent it is. Use the results to fill in the dBm columns of Table 1.3. (You'll convert to mW later.) Will the different powers of the different sources affect this? Explain. *Demonstate general results to the lab instructor.*

1.4.2 Analysis

Post-lab Discussion Questions

Q1: What is a class I laser? Do your power measurements agree for the ones which identify themselves as such?

Q2: What is the dB value of

1. 10 % loss?
2. 50 % loss?
3. 90 % loss?

Q3: What percentage of the input power is lost if the cable is improperly connected?

Q4: What is the advantage of measuring power in dB over mW?

Post-lab Tasks

T1: Fill in the conversions from dBm to mW in Tables 1.2 and 1.3.

1.5 Recap

By the end of this exercise, you should know how to :

- Connect optical fibre components properly.
- Measure optical power in
  - dBm
  - Watts

  and convert between both units.

1.6 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	0	________	0
In-lab Questions	0	________	0
Post-lab Questions	4	________	30
Pre-lab Tasks	0	________	0
In-lab Tasks	3	________	60
Post-lab Tasks	1	________	10

1.7 Template

Source:			
Meter:			
Properly connected		Improperly connected	
dBm	mW	dBm	mW

Table 1.1: Power conversion

Meter:				
Source	1550nm		1310nm	
	dBm	mW	dBm	mW

Table 1.2: Source variation

Source:				
Meter	1550nm		1310nm	
	dBm	mW	dBm	mW

Table 1.3: Meter variation

Chapter 2

Insertion Loss

2.1 Purpose

The purpose of the this experimentation is to practice taking measurements of insertion loss.

2.2 Theory

Insertion loss is the loss of transmitted light power when optical devices are inserted into the light path. An example of this would be the use of a patch cord, a fibre connector, imperfections in the fibre itself such as a bad splice, or an unclean fibre end. The total loss of light energy in the system is called the **insertion loss**.

Light traveling in the core of the fibre remains within the core due to the refractive index ratio of the core and cladding. This is due to the total internal reflection (TIR) relation. If the angle of the propagating light wave reflecting off of the cladding back into the core becomes less than the TIR angle, often called the critical angle, some of the light will escape into the cladding, and thus reduce the optical power of the signal.

2.3 Procedure

2.3.1 Preparation

Pre-lab Questions

PQ1: In order for the calculations below to work, should power be measured in mW or dBm? Explain.

2.3.2 Experimentation

Apparatus

- 2 patch cords
- patch cord adapter (connector)
- power meter
- 1550 nm laser source

Method

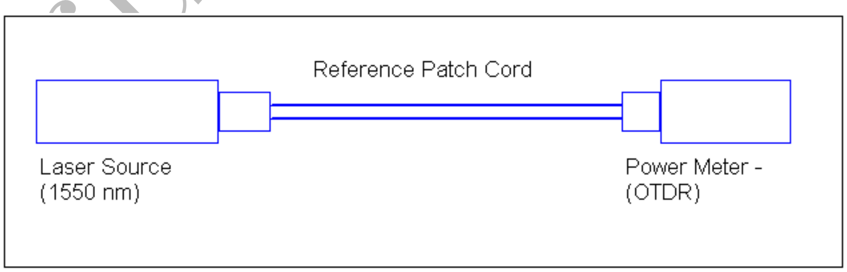

Figure 2.1: Simple Patch cord

Note: For all of the discussion following, power is assumed to be in dBm; otherwise power loss will be represented by multiplication by a factor less than one. Subraction only makes sense in logarithmic terms.

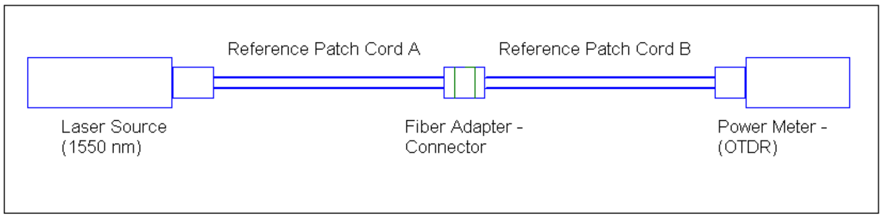

Figure 2.2: Two Patch Cords and Adapter

1. Measure the output power (P_A) of the 1550 nm laser diode or laser source with a power meter through one patch cord to be used as a reference. Actually, P_A is the output power of the source, *minus* the loss due to the cable. We could write this as:

$$P_A = P_0 - P_{c1}$$

where P_0 is the source power and P_{c1} is the loss in the cable. The reference patch cord should then be marked, for this will be the used as the reference to measure the loss of other devices and cords. (See Figure 2.1). Repeat with a 1310 nm source.

2. Repeat the above, though this time use another patch cord of a defined length and measure the output power again (P_B). Similar to what was said above, P_B is the output power of the source, *minus* the loss due to the cable. We could write this as:

$$P_B = P_0 - P_{c2}$$

where P_0 is the source power, (as before), and P_{c2} is the loss in the cable.

3. Connect the two patch cords together via the provided adapter and take the power output (P_{total}) reading of the system. (See Figure 2.2).

4. The overall loss should be noted as such; $P_{total} = P_A + P_B + P_{(adapter)}$. In this case, P_{total} is the output power of the source, *minus* the loss due to both cables *and the adapter*. We could write this as:

$$P_{total} = P_0 - P_{c1} - P_{c2} - P_{adapter}$$

where $P_{adapter}$ is the loss in the adapter. We can calculate the insertion loss in the second cable (almost) by subtracting $P_A - P_{total} = P_B + P_{(adapter)}$. Note that we can't get the adapter loss by itself. In this case

$$P_A - P_{total} = P_0 - P_{c1} - (P_0 - P_{c1} - P_{c2} - P_{adapter}) = P_{c2} + P_{adapter}$$

Note that this will give losses as positive values. Calculate the insertion loss due to cable 2 and the adapter.

5. Now that the power loss of the separate components of the system is known we are able to determine the loss due to other components used in the system if the original references are used. For instance, if we take $P_A + P_B - P_{total}$ then we should be able to *almost* get the output power of the source itself since:

$$P_A + P_B - P_{total} = P_0 + P_{adapter}$$

Calculate the output power of the source and the adapter.

6. Keeping the first patch cord and the adapter, replace the second patch cord with cord 3, measure the output and calculate the insertion loss for cable 3 and the adapter.

7. Keeping the first patch cord and the adapter, replace the second patch cord with cord 4, measure the output and calculate the insertion loss for cable 3 and the adapter.

In-lab Tasks

IT1: Fill in the dBm columns of Table 2.1. (You'll fill in the mW columns later.) *Demonstrate general results to the lab instructor.*

In-lab Questions

IQ1: Can you ever determine the insertion loss of the adapter itself? Explain.

2.3.3 Analysis

Post-lab Discussion Questions

Q1: If a device has an insertion loss of 3 dB, what percentage of the input power is being absorbed by the device?

Q2: Are the insertion losses for different cables in the same ballpark? If not, is there something which might explain the discrepancy?

Q3: What percentage of the incoming light is lost in each cable? Does that seem reasonable?

Post-lab Tasks

T1: Fill in the mW columns of Table 2.1.

2.4 Recap

By the end of this exercise, you should know how to :

- Measure the insertion loss of any component in a fibre optic system.

2.5 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	1	________	10
In-lab Questions	1	________	20
Post-lab Questions	3	________	10
Pre-lab Tasks	0	________	0
In-lab Tasks	1	________	40
Post-lab Tasks	1	________	20

2.6 Template

Source:				
Meter:				
cord	1550 nm		1310 nm	
	dBm	mW	dBm	mW
1				
2				
series				
1 and 3				
1 and 4				

Table 2.1: Cable variation

Chapter 3

Bending Loss

3.1 Purpose

The purpose of the this exercise is to study bending loss in optical fibres.

3.2 Theory

Over bending the optical fibre such that the bend radius decreases leads to signal attenuation, referred to as **bend radius attenuation**.

See sections 2.3, 11.3.3.7, and 15.4 in the text.

3.3 Procedure

3.3.1 Preparation

Pre-lab Questions

PQ1: From the webpage, read the description of **Backreflection** (BR) on page 12 of the *JDS RM3750B Backreflection/Power Meter* (which I'll refer to from now on as the RM3), and read the description of **Return loss** on pages 11 and 12 of the *JDS PS3 Polarization Dependent Loss Meter* (which I'll refer to from now on as the PS3), and explain how the two quantities are related.

PQ2: Is the term *Return loss* in PQ 1 the same as the term defined in section 3.3.2 of the text?

PQ3: Read section 3.4.1.2 of the textbook and determine how to identify **SC**, **ST**, and **FC** connectors. (These are the ones we'll be using in the lab.) Which is the most common one in our lab?

3.3.2 Experimentation

Apparatus

- various meters
- various single mode cables
- various fibre light sources

Method

Never bend the fibre around anything with a diameter less than 10 mm, for this will permanently damage the fibre.

1. For three different diameters of spindles, do the following:

   (a) Measure the power through a cable.

   (b) Wind one turn of cable around the spindle, and measure power again.
   (c) Add a turn and repeat the measurement, up to 5 turns.

2. Measure the spindle diameters.
3. Find how big the diameter has to be to produce no noticeable loss with one turn. Record this diameter.
4. Repeat the measurement for a different cable.

In-lab Tasks

IT1: Explain general results to the lab instructor:

- how loss varies with diameter
- how loss varies with the number of turns
- how the above losses vary between cables

3.3.3 Analysis

- Plot loss versus diameter.
- Plot loss versus number of turns.
- Plot the above for both cables.

  You can put any or all of them on a single graph if it's not too cluttered.

Post-lab Discussion Questions

Q1: Is the relationship between loss and diameter linear? Would you expect it to be linear? Explain.

Q2: Is the relationship between loss and number of turns linear? If so, how much loss is there per turn for each diameter? Would you expect it to be linear? Explain.

Q3: Is the loss the same for both cables? Would you expect it to be? Explain.

Post-lab Tasks

T1: Photocopy your data, and hand in the graphs and question answers.

3.4 Recap

By the end of this exercise, you should know how bending affects optical fibres.

3.5 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	3	________	10
In-lab Questions	0	________	0
Post-lab Questions	3	________	30
Pre-lab Tasks	0	________	0
In-lab Tasks	1	________	40
Post-lab Tasks	1	________	20

3.6 Template

Source:				
Meter:				
diameter (mm)	turns			
	1	2	3	4
Cable one:				
Cable two:				

Table 3.1: Loss (dBm) measurements

Chapter 4

OTDR (Optical Time Domain Reflectometry) Basic Operational Introduction

4.1 Purpose

The purpose of this experiment is to become comfortable with the OTDR as well as determining fibre length, attenuation, and ghosts in a network.

4.2 Theory

4.2.1 Turning the OTDR On

Be sure that the OTDR is lying flat with the LCD screen facing up. Plug the designated power key into the OTDR in its designated location. (See Figure A.2 .) Push the **Power** Button. (See Figure A.1 .) Allow a few moments for the OTDR to power up.

4.2.2 Basics of the Top Menu

The OTDR has many features, but the main features, which will be used in the OTDR experimentation, will be outlined, further investigation of the OTDR capabilities will be left to the student.

Once the OTDR is powered up a **Top Menu** screen will come up. The user will be able to bring up the screen at any time by pushing the **Top Menu** button. (See Figure A.1 .) The **Top Menu** gives the user the option to

1. Adjust backlighting
2. Locate faults
3. Do a trace analysis
4. Use the OTDR as an optical power meter
5. Use the OTDR as a light source
6. Open a previous file
7. Change the system settings

These seven options can be activated using the keypad. (See Figure A.1 .)

Most of the experiments outlined in the lab manual will be using the OTDR trace analysis. At any time the user is able to get back to the top menu via the **top menu** button on the OTDR, as shown in Figure A.1 .

4.2.3 OTDR Trace Analysis

The trace analysis option in basis sends a signal down the optical fibre and due to back scattering receives an attenuated signal back to the OTDR. The system then does an analysis on the back signal and a data plot is displayed. It is the responsibility of the student to analyze the displayed graph as well as determine what is happening at various points on the graph.

Measurement Conditions

The measurement conditions for the trace analysis are used to create a more specified trace depending on the specific conditions of the network being analyzed. In the measurement conditions settings mode the user is able to adjust settings parameters, measurement parameters, and detailed parameters. Using the arrow up ($\bigwedge$) and arrow down ($\bigvee$)key Figure A.1 highlight the condition to be adjusted; once the condition is highlighted (i.e. wavelength) press the **Enter** key and a separate window will appear with options. Again choose the desired option by pressing the **Enter** key and this will activate the chosen option.

The main conditions that will be altered will be the measurement conditions. The wavelength condition can be chosen to be 1310nm or 1550nm. The distance range can be automatic or various distance such as 0.5km $\rightarrow$ 200km if the user knows the length of the network line being analyzed. Using the distance range enables the user to get a more contained reading (i.e. if the fibre is 0.47km long why analyze as though the fibre is 2.5 km long). Pulse width can be set as auto or incremental times from 3n$\rightarrow$100ns. The pulse width determines at what time increment the OTDR will be able to determine various network anomalies. If the time is set low the OTDR will be able to distinguish and analyze events which are much closer together in distance that if the pulse width is set to 10ns. At 50ns the OTDR is able to distinguish events which are 5m apart. The IOR is the reflective index setting of the fibre being used. Often this number will be given to the student. The reflective index is able to be set from 1.000000$\rightarrow$ 1.999999. The next measurement setting is the averaging. This setting allows the user to determine how many traces of the network will be done before an averaged graphical representation is shown. The higher the averaging the more accurate the output will be, though running 100 analysis runs can take a lot of time. For student purposes 5 times is sufficient unless otherwise directed.

The detailed parameters allow the user to change the internal attenuation level of the OTDR. Also the backscatter level can be changed, as well as the sampling mode. Though for most experiments students will not be required to make adjustments to the detailed parameters. Once the measurement conditions have been set up the next step is to measure.

Measuring

Once the settings have been properly defined, the measure is taken by simply pressing the **F4** button at the bottom the OTDR. The measurement process will take a few seconds to go through but once completed a graphical analysis will be displayed. Once the graph has been displayed the student can analyze the graph either on the OTDR or by using the OTDR software. The student is encouraged to analyze the data via the software, for it is more user friendly than the OTDR itself. From the measure, the OTDR will also display the fibre length in km, the total loss in dB, the fibre loss in dB/km, and the total R.Loss in dB, which will be displayed below the graph displayed by the

OTDR.

Analyzing Measurements

Once the measurements have been taken by the OTDR the graphical data needs to be analyzed by the student. One method is to look at the graphical data on the OTDR and manipulate the curve using **F3** *(Zoom and Shift)*, that allows the user to manipulate the curve in order to zoom into a desired location. The reasoning for this is to allow the user to look for fine details in the graph. The best way to analyze the data is to save the data and then analyze it via the OTDR software. The software allows the user to zoom in and out on both the horizontal and vertical axis as well as shift the curve vertically, and give the curve a vertical offset. This allows the user to measure the attenuation in dB of a specific drop in the curve due to a splice for example. The software also allows the user to set markers, moves the distance marker and determine the dB difference from the two points, as well as showing the distance from the beginning to the specific point being analyzed. Though the software takes some time to get used to, it is quite intuitive and simple as far as the scope of this lab course goes.

4.2.4 Saving a File

The user has both the options to save a file directly onto the OTDR internal drive or to save the file to a USB key. To save the file pressing the **3**-key, as shown in Figure A.1 , will allow the user to save a file. Choosing the **USB Memory** will save the file to the USB key. The user can change the filename by pressing **f2** while in the save option window. The user can then vary the name of the file by manipulating the **F1**→**F4** keys to choose letters and number for the file name. When the desired name has been created, hitting **Enter** saves the file. If the user chooses to close the save window pressing **f6** will close the window.

4.2.5 OTDR as Optical Power Meter

If the OTDR is not on the **Top Menu**, press the **Top Menu** button to get to main menu. Press number **5** in order to use the OTDR as an optical power meter. When the OTDR is being used as an optical power meter it is capable of reading four wavelengths, being 1310nm, and 1550nm, 1625nm, and 1650nm. Change the wavelength to the appropriate value by pressing **f1** until the desired wavelength is displayed. It is important to correlate the OTDR wavelength to that being output by the optical light source. If the wavelengths do not correspond the OTDR will not read appropriately. The OTDR will measure the power of the light source in dBm, which are easily converted to Watts. The OTDR will measure the light source through a fibre patch cord connected to the OTDR input (G in Figure A.2) .

4.2.6 OTDR as Light Source

Choosing **Light source** or number **6** from the **Top Menu**, shown in Figure A.1 , allows for the OTDR to be used as a light source. The light source capabilities of the OTDR allow for wavelengths of 1310nm, and 1550nm as well as modulations of 270Hz, 1kHz, and 2kHz. Once the desired wavelength and modulation are chosen the light source can be activated via **f5** and deactivated via **f6** in Figure A.1 . The light source is output through an optical fibre through the OTDR Input (G in Figure A.2) .

4.2.7 OTDR System Settings

The OTDR system setting fund on the **Top Menu** is made available by pressing **0** (See Figure A.1 .) Under the **General** system setting one is able to change the date, time, time difference, and the language setting. Also under the **General** settings the buzzer option can also be activated or deactivated. Under the **Print** setting a printer is able to be chosen as well as paper feed option. Students will generally not be required to manipulate the **General** settings.

The **display** settings can be activated via **f2**. Under the **display** settings the distance unit can be varied as well as various formats for the date, time, and name on the title bar. The colour pallet can also be changed in the **display** settings.

Power savings settings can be viewed from **f3**, and the *measurement* settings from **f4**. Students will not be required to vary any of the system setting form any experimentation, and students are asked to not manipulate the current settings of the OTDR.

4.2.8 Becoming Comfortable with the OTDR and the OTDR Software

Students are asked to take some time and go through

1. Turning the OTDR On
2. OTDR as Light Source

to become comfortable with the various capabilities of the OTDR. A simple patch cord should be connected to the OTDR Input (G in Figure A.2) . This will ensure an output from the OTDR. Take note of the fibre to OTDR connection as there are lips on both the fibre connector as well as the OTDR connector which need to be aligned correctly in order to ensure a good connection. (See Figure A.3 .) No actual data will be recorded though this exercise is important to ensure a basic skill level in operating the OTDR.

4.2.9 Basic Theoretical Principles of OTDR

Rayleigh Backscatter

One of the mechanisms that cause loss in optical fibres arises from **Rayleigh scattering**, which is a resultant of interacting sinusoidal varying electric field in the light wave with the electron clouds of the atoms in the glass to generate oscillating dipoles. The dipoles scatter (re-radiate) a fraction of power from the guided wave in all directions. A small portion of the scattered power is collected by the fibre and propagates in a backward direction towards the OTDR. The backscatter power is coupled out of the fibre and measured by a photodiode. The OTDR, in operation, launches pulses of light into the fibre of an optical network and monitors the backscatter signal as a function of time in relevance to the launch time. The received backscatter power, P_s, as a function of distance,d, down an uninterrupted fibre is given by

$$P_s = P_o S \alpha \Delta L \times 10^{-0.2\alpha d} \tag{4.1}$$

where P_o is the launched power, α is the fibre attenuation coefficient in dB/km, ΔL is the normalized spatial pulse width in the fibre and S is the fraction of the scattered power collected by the fibre in the backwards direction. Taking $10\log_{10}$[1] of both sides of Equation 4.1 and then dividing it by 2

[1] The factor of 10 is due to the fact that we're measuring in **deci**bels; if we were simply using bels we wouldn't need the 10.

gives the formula for the OTDR output.

$$\frac{10\log_{10}\left(\frac{P_s}{P_o}\right)}{2} = -\alpha d + C \tag{4.2}$$

where C is a constant and

$$C = \frac{10\log_{10}\left(S\alpha\Delta L\right)}{2} \tag{4.3}$$

Plotting $\frac{10\log_{10}\left(\frac{P_s}{P_o}\right)}{2}$ against distance we get an OTDR trace with a straight line of gradient $-\alpha$ for the line fibre.

4.2.10 OTDR Trace Variances

The OTDR trace of a simple fibre will appear as a straight line with a slight negative gradient due to the basic attenuation in a fibre optic line. Anything other than a gradual slope in the trace is due to non-reflective elements such as fused coupler components, bends of small diameters, or bad fibre splices. These elements will appear on the trace as an abrupt drop in the backscatter signal. Also noted is that both the forward propagating pulse and the returning backscatter pulse will experience loss and attenuation due to the fibre and the features of the network. The loss is hence be divided by 2 by the OTDR in order to compensate for this.

4.2.11 Fresnel Reflections, Dead Zones, and Ghosts

Large **Fresnel reflections** can cause problems to the detection systems often leading to transient but strong saturation of the front end receiver which will require time to recover. The bandwidth should be as small as possible to maximize SNR without compromising the instrument resolution. This means that the receiver bandwidth should be about equal to the pulse width used. The dead zones arising from the large Fresnel reflection signals from the fibre input and output(s) are referred to as **near** and **far end dead zones** respectively. The Fresnel reflections arising from connectors or interruptions in the fibre line are referred to as **event dead zones**. The larger the Fresnel reflection signal, the longer it takes the detector to recover, hence the near end dead zone and event dead zones in shorter networks present greater problems. If the signal strength is sufficiently high, as in short networks, these multiply reflected pulses will be detected and will appear on the OTDR trace as what is referred to as **ghosts**. The ghosts are smaller than the detected pulses from the primary Fresnel reflections and appear at exact integer multiple distances relative to the primary reflected pulse. The ghosts usually appear in the noise region beyond the maximum length of the network as large spikes.

4.2.12 SNR, Signal Recovery, and Loss Measurement Resolution

For good spatial resolution of 10m or less, a 50ns pulse must be used, and the receiver bandwidth must be greater than 20MHz which sets the level of thermal noise in the system. Being that Rayleigh backscattering in an optical fibre is weak and the returned signal is buried in the noise from the front-end receiver, this causes a great deal of averaging to be required to achieve a useful SNR. To do this we divide the photodiode output followed by each pulse by a large number of time slots (2048, 4096 or 8192), the number depending on the range addressed and the required range resolution. For example, for a 4km range, the use of 4096 samples provides a range resolution of about 1m. The signals from the individual time slots are fed into samples and hold memories, which then store up and add up the signals from many pulses. This causes the signal to increase linearly with the number of additions (pulses), though the noise, which is un-correlated from trace to trace, increases with the square root of the number of additions. This means that each time we double the number of additions, the SNR increases by a factor of root 2 or 1.5dB.

4.2.13 Spatial and Range Resolution and Event Location

One of the important features of the OTDR is the **spatial resolution**, which is the minimum separation at which two events can be distinguished. The spatial resolution is determined by the pulse width. The length in the fibre is directly related to time via

$$L = v_g t \tag{4.4}$$

where v_g is the group velocity of the propagating pulse, which is given by $\frac{c}{n_e}$, where n_e is the fibre's refractive index usually between 1.45→1.47 and c is the speed of light in a vacuum. With Equation 4.4 we can estimate that the pulse travels approximately 1m in 5ns. This also signifies that a pulse width of 5ns in time has a spectral width of 1m. This means that depending on the resolution, there is varied accuracy in events. Hence lower spatial resolution will give a more exact location of an event than that of a higher spatial resolution.

4.3 Procedure

4.3.1 Experimentation

Apparatus

- OTDR
- long fibre reel

Method

Investigation of a Single Point to Point Link

1. Connect the long reel of fibre to the OTDR and switch the OTDR on. Set up the OTDR to be in *Trace* mode. Under the trace mode set the system to operate at 1550nm, with the distance range between 3km and 5km. Set the pulse width to 50ns and the fibre refractive index (n_e) to be 1.4685. Why??
2. Acquire an average OTDR trace of the long reel of fibre for a wavelength of 1550nm.
3. Measure the length of the trace directly from the OTDR screen or later in the OTDR software. Using the zoom feature will be beneficial to examine the Fresnel reflection, being sure to place the cursor at the beginning of the Fresnel reflection. Save "button 3"?
4. What is the difference if the wavelength is reset to be 1310nm?
5. Determine the attenuation coefficients of the fibre for the wavelengths of 1550nm and 1310nm, using the cursors and screen readouts. Comment on any variances between the two wavelengths trials.
6. Expand the range setting to be at least double of the actual trace length (fibre length). Does the ghost appear at an integer multiple of the actual fibre length? If so determine the distance of the ghost. The ghost will appear as a large spike beyond the trace in the noise.

In-lab Tasks

IT1: Fill in Table 4.1 with the results .

IT2: Explain general results to the lab instructor:

- What was the length of the fibre reel?
- How did the attenuation vary with wavelength?

IT3: Demonstrate a trace which shows a ghost, and one which doesn't.

4.3.2 Analysis

Post-lab Discussion Questions

Q1: Which wavelength could be used over longer distances with this fibre? Explain.

4.4 Recap

By the end of this exercise, you should know how to :

- use the OTDR to identify features in a fibre optic network by
  - location
  - power (loss or reflection)

4.5 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	0	________	0
In-lab Questions	0	________	0
Post-lab Questions	1	________	10
Pre-lab Tasks	0	________	0
In-lab Tasks	3	________	90
Post-lab Tasks	0	________	0

4.6 Template

Wavelength	1550nm	1310nm
Length of Fibre (from OTDR trace) (km)		
Pulse Propagation Velocity (m/s) $V_p = c/n_e$		
Time of Flight of Fresnel Reflected Pulse (μs) $T = Length/V_p$		
Attenuation (From OTDR Trace) (dB/km)		
Ghost Distance (km)		

Table 4.1: Single Point to Point Link

Chapter 5

Fibre Couplers (4 Port)

5.1 Purpose

The purpose for experimentation with fibre couplers is to understand the structure of a common four port fibre coupler as well as to be able to measure the characteristics of these couplers. Also, it is important to learn some of the applications of the couplers, mainly with relevance to optical networking, such that the couplers are often used as **multiplexers** (MUX) and **de-multiplexers** (DeMUX).

5.2 Theory

One of the most widely used components is the **fibre coupler**. The coupler allows two or more optical signals to be combined into one signal. The coupler can also be used to split the signals apart again. The fused coupler is the most common of the fibre couplers and the principle behind the fused couplers is that when two or more fibre cores are brought to within a wavelength apart some of the light in one core will leak into the other core or cores. The amount of coupling, or power transfer, between the cores is dependent upon the distance at which the core are apart, as well as the interaction length. Also, the coupling properties are very dependent upon wavelength I that operation of a coupler at 1310nm will distinctly vary in relation to a 1550nm wavelength. This experimentation will only cover couplers, which operate at the same wavelengths. In this case the amplitude of the signal has been combined or split, and a network built with couplers of this sort usually employs **T**ime **D**ivision **M**ultiplexing (TDM) for signal processing. In the fused fibre technology, two fibres are twisted then fused together to produce a fibre coupler. The amount of twists and the length of the fusion will determine coupling characteristics of the device, such that the coupling ratio can be between $0 \rightarrow 100\%$. This is a transmission device in that light travels from an input port to an output port on the opposite side of the device, with little reflection back from the input port. Since the main function of the fibre coupler is to transfer light power from one port to another, the key parameters are the coupling ratio, insertion loss, spectral response, and directivity. The 3-port coupler (See Figure B.3). is a 50/50 coupler at 1550nm. The 50/50 means that half of the signal will be directed to each output port. The 4-port coupler (See Figure B.4). is also a 50/50 coupler and will split the signal from the incoming ports 1 or 4 to the outgoing ports 2 and 3. The transfer of light power across ports is not a perfect process and there are considerable losses that occur in the coupling region. This is a major contributing factor in the device's insertion loss figure.

5.3 Procedure

5.3.1 Preparation

Pre-lab Questions

PQ1: Directivity is defined as $10 \log (P_a/P_b)$. How would you compute this knowing P_a in dBm and P_b in dBm?

5.3.2 Experimentation

Apparatus

- 4-port coupler
- power meter
- patch cord
- 1310nm, 1550nm laser source

Method

1. Record the power level, P_a, of the source at 1550nm in Table 5.1.
2. Send a signal into one input port of the 4-port coupler.
3. Measure the output power P_1 from output port 1, P_2 from output port 2, and P_b, the other input port, respectively. Fill in the dB column of Table 5.1.
4. Determine the directivity of this coupler. (This is also referred to as **near-end crosstalk**.)
5. Feed the input into the other input port and repeat the measurements.
6. Repeat with a 1310nm signal.

In-lab Tasks

IT1: Explain general results to the lab instructor:

- power distribution from each input port between output ports
- variation with wavelength
- directivity

5.3.3 Analysis

- For both wavelengths, calculate the power, in watts,
  - of the source going into input port a of the coupler
  - of the source going into input port b of the coupler
  - out of output port 1
  - out of output port 2
- Determine the coupling ratio at both wavelengths, for both inputs.
- Determine how much signal is lost in the coupler for both inputs at both wavelengths, in mW and dBm.

Post-lab Discussion Questions

Q1: Summarize the information above, to describe the coupling ratios and internal losses at both wavelengths.

Post-lab Tasks

T1: Fill in the mW and % columns in Table 5.1.

5.4 Recap

By the end of this exercise, you should know how to :

- measure coupling coefficients
- measure near-end crosstalk

5.5 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	1	________	10
In-lab Questions	0	________	0
Post-lab Questions	1	________	10
Pre-lab Tasks	0	________	0
In-lab Tasks	1	________	60
Post-lab Tasks	1	________	20

5.6 Template

Meter:						
	1550nm			1310nm		
	Source power (dBm):			Source power (dBm):		
	dBm	mW	%	dBm	mW	%
$P_a \to P_1$						
$P_a \to P_2$						
$P_a \to P_b$						
loss						
$P_b \to P_1$						
$P_b \to P_2$						
$P_b \to P_a$						
loss						

Table 5.1: Coupling data

Chapter 6

Fibre Couplers (3 Port)

6.1 Purpose

The purpose for experimentation with fibre couplers is to understand the structure of a common three port fibre coupler as well as to be able to measure the characteristics of these couplers. Also, it is important to learn some of the applications of the couplers, mainly with relevance to optical networking, such that the couplers are often used as **multiplexers** (MUX) and **de-multiplexers** (DeMUX).

6.2 Theory

The theory is covered in Chapter 5, *"Fibre Couplers (4 Port)"*.

6.3 Procedure

6.3.1 Preparation

Pre-lab Questions

PQ1: Can you calculate the directivity of this coupler? Explain with reference to the 4 port coupler.

6.3.2 Experimentation

Apparatus

- 3-port coupler
- power meter
- patch cord
- 1310nm, 1550nm laser source

Method

1. Record the power level of the source at 1550nm in Table 6.1.
2. Using one of the previously measured reference fibre cords, measure the insertion loss of the 3-port coupler for each output. Fill in the dB column of Table 6.1.
3. Determine if it is in fact a 50/50 ratio. Explain the observations. Repeat with a 1310nm signal.
4. Does this give a 50/50 ratio, and how do the outputs from the two wavelengths differ?

In-lab Tasks

IT1: Explain general results to the lab instructor:

- power distribution between output ports
- variation with wavelength

6.3.3 Analysis

- For both wavelengths, calculate the power, in watts,
  - of the source going into port 1 of the coupler
  - out of port 2
  - out of port 3

- Determine the coupling ratio at both wavelengths.
- Determine how much signal is lost in the coupler at both wavelengths, in mW and dBm.

Post-lab Discussion Questions

Q1: Summarize the information above, to describe the coupling ratio and internal loss at both wavelengths.

Post-lab Tasks

T1: Fill in the mW and % columns in Table 6.1.

6.4 Recap

By the end of this exercise, you should know how to :

- measure coupling coefficients

6.5 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	1	________	10
In-lab Questions	0	________	0
Post-lab Questions	1	________	10
Pre-lab Tasks	0	________	0
In-lab Tasks	1	________	60
Post-lab Tasks	1	________	20

6.6 Template

Meter:						
	1550nm			1310nm		
	Source power (dBm):			Source power (dBm):		
	dBm	mW	%	dBm	mW	%
$P_a \rightarrow P_1$						
$P_a \rightarrow P_2$						
loss						

Table 6.1: Coupling data

Chapter 7

WDM Couplers (Station 1)

7.1 Purpose

The purpose of this module is to further understand the wavelength separation properties of a WDM coupler. Another purpose of this experimentation is to explore applications of WDM technology in optical amplifiers and in WDM networks.

7.2 Theory

Wavelength **D**ivision **M**ultiplexing or **WDM** couplers are couplers that are optimized for combining or separating two or more wavelengths that are from different input ports. WDM couplers are therefore important components in WDM optical networks. WDM couplers are also used to combine pump lasers of different wavelengths, as well as optical signals in applications such as optical fibre amplifiers and fibre lasers.

The most widely used technology for making WDM couplers are fused fibre and thin-film filter for separating or combining several wavelengths. Diffraction gratings are becoming more popular for making WDM couplers, mainly in the line of **D**ense **W**avelength **D**ivision **M**ultiplexing (DWDM). DWDM allows for multiple wavelengths to be multiplexed along a single fibre, expanding the available capacity of a single fibre to that of several virtual fibres along a single core. The main focus of this module however is on the most widely used fused fibre type WDM coupler.

The basis of operation behind a WDM fibre coupler is shown in Figure B.6. This figure depicts two wavelengths traveling along the same fibre core, though not interacting. The objective of WDM is to multiplex two signals such that the two or more fibres are in the core, or de-multiplex the signal. De-multiplexing consists of separating the signals in the single fibre into two fibres so that the signals are no longer propagating along the same fibre.

Characteristics of WDM couplers are highly dependant on the specific application required for the WDM. For example, WDM pump amplifiers accept signals that vary up to ± 10nm. In contrast a DWDM used in an optical network is much more specific and the channel range may be as small as 0.2nm (25 GHz). As well some WDM will accept only specific wavelengths such as the 1550nm and 1310nm.

7.3 Procedure

7.3.1 Preparation

Pre-lab Questions

PQ1: How is a WDM coupler different from a normal fibre coupler?

7.3.2 Experimentation

Apparatus

- WDM coupler
- 980nm pump laser
- 1550nm laser source
- power meter

Method

1. Measure the power of the 980 nm pump laser and record it in Table 7.1.
2. Connect the 980 nm pump laser to the input port of the WDM and record the power at each of the output ports. Fill in the dB column of Table 7.1.

3. Connect the 1550nm laser to the input port of the WDM and record the power at each of the output ports. Fill in the dB column of Table 7.1.

4. What is the difference in the measured optical power in the values in 2 and 3? Is this what you expect? Explain.

In-lab Tasks

IT1: Explain general results to the lab instructor:

- Power transmitted to each port as a function of wavelength.

7.3.3 Analysis

- Calculate the percentage of the signal that is transmitted through each output port for each frequency.

- Calculate the power lost in the coupler for each frequency.

Post-lab Discussion Questions

Q1: What percentage of power is transmitted through each output at each input frequency?

Post-lab Tasks

T1: Fill in the mW and % columns in Table 7.1.

7.4 Recap

By the end of this exercise, you should know how to :

- distinguish a WDM coupler from a normal fibre coupler

7.5 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	1	________	10
In-lab Questions	0	________	0
Post-lab Questions	1	________	10
Pre-lab Tasks	0	________	0
In-lab Tasks	1	________	60
Post-lab Tasks	1	________	20

7.6 Template

Meter:						
	1550nm			980nm		
	Source power (dBm):			Source power (dBm):		
	dBm	mW	%	dBm	mW	%
$P_a \rightarrow P_1$						
$P_a \rightarrow P_2$						
loss						

Table 7.1: Coupling data

Chapter 8

WDM Couplers (Station 2)

8.1 Purpose

The purpose of this module is to further understand the wavelength separation properties of a WDM coupler. Another purpose of this experimentation is to explore applications of WDM technology in optical amplifiers and in WDM networks.

8.2 Theory

The theory is covered in Chapter 7, *"WDM Couplers (Station 1)"*.

8.3 Procedure

8.3.1 Preparation

8.3.2 Experimentation

Apparatus

- WDM coupler
- 1310nm laser source
- 1550nm laser source
- power meter

Method

1. Measure the power of the 1310 nm laser and record it in Table 8.1.
2. Connect the 1310 nm laser to the input port of the WDM and record the power at each output port. Fill in the dB columns of Table 8.1.
3. Connect the 1550nm laser to the input port of the WDM and record the power at each output port.
4. What is the difference in the measured optical power in the above values in 2 and 3? Is this what you expect? Explain.

In-lab Tasks

IT1: Explain general results to the lab instructor:

- Power transmitted to each port as a function of wavelength.

8.3.3 Analysis

- Calculate the percentage of the signal that is transmitted through each output port for each frequency.
- Calculate the power lost in the coupler for each frequency.

Post-lab Discussion Questions

Q1: What percentage of power is transmitted through each output at each input frequency?

Post-lab Tasks

T1: Fill in the mW and % columns in Table 8.1.

8.4 Recap

By the end of this exercise, you should know how to :

- distinguish a WDM coupler from a normal fibre coupler

8.5 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	0	________	0
In-lab Questions	0	________	0
Post-lab Questions	1	________	20
Pre-lab Tasks	0	________	0
In-lab Tasks	1	________	60
Post-lab Tasks	1	________	20

8.6 Template

Meter:						
	1550nm			1310nm		
	Source power (dBm):			Source power (dBm):		
	dBm	mW	%	dBm	mW	%
$P_a \to P_1$						
$P_a \to P_2$						
loss						

Table 8.1: Coupling data

Chapter 9

Add-Drop (ADM) Couplers

9.1 Purpose

The purpose of this module is to further understand the wavelength separation properties of an add-drop ADM coupler. Another purpose of this experimentation is to explore applications of add-drop couplers in optical networks.

9.2 Theory

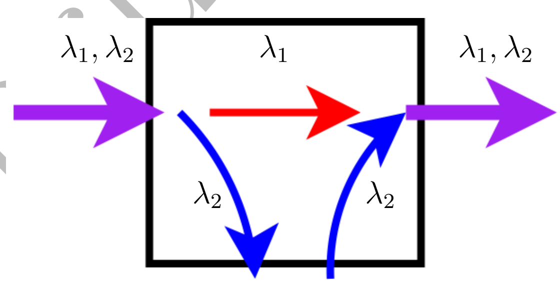

Figure 9.1: Add-drop multiplexer operation

The basis of operation behind an add-drop multiplexer is shown in Figure 9.1. This figure depicts two wavelengths traveling along the same fibre core, though not interacting. The objective of add-drop multiplexer is to allow one signal to pass through unchanged, while allowing the other to be replaced with a different one. *Note: The signal being "dropped" and the signal being "added" will be of the same wavelength.*

9.3 Procedure

9.3.1 Preparation

Pre-lab Questions

PQ1: How is an add-drop WDM coupler different from a WDM coupler?

9.3.2 Experimentation

Apparatus

- add-drop WDM coupler
- power meter
- 1310nm laser source
- 1550nm laser source

Method

1. Connect the 1550 nm laser to the *common input* port of the multiplexer and record the power at the *common output* port.
2. Record the power at the *drop* port.
3. Connect the 1310 nm laser to the *common input* port of the multiplexer and record the power at the *common output* port.
4. Record the power at the *drop* port.
5. Connect the 1550 nm laser to the *add* port of the multiplexer and record the power at the *common output* port.

6. Connect the 1310 nm laser to the *add* port of the multiplexer and record the power at the *common output* port.

7. What is the difference in the measured optical power in the above values recorded in 1 and 2? Explain why.

8. What is the difference in the measured optical power in the above values recorded in 3 and 4? Explain why.

9. What is the difference in the measured optical power in the above values recorded in 5 and 6? Explain why.

10. If time permits, try using the other add-drop multiplexer where the wavelengths are reversed. Do the changes in the results make sense?

In-lab Tasks

IT1: Explain general results to the lab instructor.

In-lab Questions

IQ1: Is the operation of the ADM consistent with what you expect?

9.3.3 Analysis

- Calculate the percentage of the signal that is transmitted through each output port for each frequency.

- Calculate the power lost in the coupler for each frequency.

Post-lab Discussion Questions

Q1: What percentage of power is transmitted through each output at each input frequency, for input at each different input port?

Post-lab Tasks

T1: Fill in the mW and % columns in Table 9.1.

9.4 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	1	________	0
In-lab Questions	1	________	0
Post-lab Questions	1	________	20
Pre-lab Tasks	0	________	0
In-lab Tasks	1	________	60
Post-lab Tasks	1	________	20

9.5 Template

Meter:						
1550nm source:						
	Drop port			Common output		
	Source power (dBm):			Source power (dBm):		
	dBm	mW	%	dBm	mW	%
at common input						
at add input						
1310nm source:						
	Drop port			Common output		
	Source power (dBm):			Source power (dBm):		
	dBm	mW	%	dBm	mW	%
at common input						
at add input						

Table 9.1: Coupling data

<table>
<tr><td colspan="7">Meter:</td></tr>
<tr><td colspan="7">1550nm source:</td></tr>
<tr><td rowspan="3"></td><td colspan="3">Drop port</td><td colspan="3">Common output</td></tr>
<tr><td colspan="3">Source power (dBm):</td><td colspan="3">Source power (dBm):</td></tr>
<tr><td>dBm</td><td>mW</td><td>%</td><td>dBm</td><td>mW</td><td>%</td></tr>
<tr><td>at common input</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>at add input</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">1310nm source:</td></tr>
<tr><td rowspan="3"></td><td colspan="3">Drop port</td><td colspan="3">Common output</td></tr>
<tr><td colspan="3">Source power (dBm):</td><td colspan="3">Source power (dBm):</td></tr>
<tr><td>dBm</td><td>mW</td><td>%</td><td>dBm</td><td>mW</td><td>%</td></tr>
<tr><td>at common input</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>at add input</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 9.2: Coupling data for other coupler

Chapter 10

Optical Isolators

10.1 Purpose

The purpose of this exercise is to understand how an optical isolator works as well as to gain an appreciation for the importance of optical isolators in specific applications.

10.1.1 Theory

An **optical isolator** has three main components. The first component is a magnetic garnet crystal having the **Faraday Effect**, the second a permanent magnet for applying a specific magnetic field, and finally polarization elements which allow only forward light to pass. The isolator acts as a valve, which only allows the flow of light in one direction.

The function of an optical isolator is to stop undesirable reflection from getting back into the light source. By stopping back reflection, the laser source becomes a more stable light source, because back reflection into the laser cavity is known to cause interference inside the laser and leads to noise in the system. In optical networks, connectors and other optical components often cause back-reflection. The optical isolator inhibits this back reflection and will stop a network from having poor performance due to noise and interference. However, the uni-directional isolator, since it only allows light to travel in one direction along the system, inhibits its use in a WDM system because many of todays WDM networks have virtual fibres which are bi-directional. Also, isolators are most often designed and optimized for few wavelengths, 1550nm being one of them. This means that an isolator designed for 1550nm operation will not produce good results if a 1310nm laser source is used.

There are two main types of optical isolator, one being **polarization dependant**, and the other **polarization independent**. Most polarization dependant optical isolators are used with traditional lasers and bulk optics and polarization independent isolators are used more with fibre optic devices. The optical isolators that we will be using are polarization independent. The details of the polarization independent optical isolator can be seen in Figure B.7. Though the picture is slightly blurry, the top is light traveling in forward direction and the bottom is light traveling in the backwards direction.

In the forward direction, a 45° Faraday rotator is interposed between two wedge-shaped birefringent plates, and a lens is placed at both ends of the isolator for focusing and coupling light into optical fibres. Though polarization-dependant optical isolators only allow the light to be polarized in specific directions, polarization-independent isolators transmit all polarized light. This is the reason why these isolators are often used in optical networks. In the forward direction, a forward incident light is separated into ordinary and extraordinary rays by the No.1 birefringent plate, with the polarization planes indicated by a horizontal and a vertical arrow. Next, the polarization plates are rotated by 45° anti-clockwise by the faraday crystal. Third, the ordinary and extraordinary rays pass through the No.2 birefringent plate, which has an optical axis that holds a constant relation between the two types of maintained rays. This causes both rays to be refracted in a parallel direction when they exit the No.2 birefringent plate. Last, the calumniated beams converge into a downstream optical fibre through a lens. The light signal from the input fibre to the output fibre is now complete with minimum insertion loss.

The backward light incident on the same optical isolator is separated by the No.2 birefringent plate into ordinary and extraordinary rays, as shown by the arrows in Figure B.7. These two rotated rays will diverge when they travel across the No.1 birefringent plate, due to the setting of the optical axis of the No.1 birefringent plate. The resultant backwards traveling rays is divergent and thus cannot be focused into the upstream (input) fibre.

Most single stage optical isolators provide approximately 30dB of isolation at the designated wavelength. This means that the maximum amount of backward traveling light that can be reflected back into the device is around -30 dB or about 1% of the original intensity. A dual stage isolator can provide about 45 dB of isolation, and is a crucial component for stabilizing high power lasers.

10.2 Procedure

10.2.1 Preparation

Pre-lab Questions

PQ1: What is the definition of isolation?

10.2.2 Experimentation

Apparatus

- Single stage optical isolator
- Dual stage optical isolator
- 1550nm laser source
- 1310nm laser source
- 980nm laser source (optional)
- power meter (OTDR)

Method

1. Send the 1550nm light along the “arrow” direction of the single stage optical isolator and measure the output power. Fill in the dB column in Table 10.1.

2. Send the 1550nm light against the “arrow” direction of the single stage isolator and measure the output power.

3. Calculate the optical isolation of the single stage isolator from the measured powers of 1 and 2. Compare to *Isolation* marked on the isolator.

4. Repeat the above steps from 1 to 3 with the dual stage optical isolator, and find the optical isolation. Compare to *Isolation* marked on the isolator.

5. What is the optical isolation if the two isolators are cascaded?

6. Repeat 1, 2 and 3 using the 1310nm laser. What is observed?

7. If avialable, repeat 1 to 3 using the 980nm laser. Does the result follow a consistent pattern with the 1310nm source? Explain the observations.

In-lab Questions

IQ1: Calculate the isolation for each wavelength in both dB and as percentages. Is the isolation wavelength specific? Is this what you expect?

In-lab Tasks

IT1: Explain general results to the lab instructor:

- how much isolation is achieved; both in db and as percentages
- how the isolation varies with wavelength

10.2.3 Analysis

Post-lab Discussion Questions

Q1: Summarize your results in a table and a brief sentence or two.

Post-lab Tasks

T1: Fill in the mW and % columns in Table 10.1.

10.3 Recap

By the end of this exercise, you should know how to :

- measure the isolation of an optical isolator

10.4 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	1	________	10
In-lab Questions	1	________	20
Post-lab Questions	1	________	10
Pre-lab Tasks	0	________	0
In-lab Tasks	1	________	40
Post-lab Tasks	1	________	20

10.5 Template

Meter:						
	1550nm			1310nm		
	Source power (dBm):			Source power (dBm):		
	dBm	W	%	dBm	W	%
single stage			expected isolation (dBm):			
$P_a \to P_1$						
$P_1 \to P_a$						
isolation						
dual stage			expected isolation (dBm):			
$P_a \to P_1$						
$P_1 \to P_a$						
isolation						
cascaded			expected isolation (dBm):			
$P_a \to P_1$						
$P_1 \to P_a$						
isolation						

Table 10.1: Isolator data

Chapter 11

Fibre Bandwidth

11.1 Purpose

The purpose of the this exercise is to study the bandwidth limits of a fibre optical system.

11.2 Theory

The bandwidth of a fibre optic system depends on the

- transmitters
- cables
- receivers

and all other components in the system.

11.3 Procedure

11.3.1 Preparation

Pre-lab Questions

PQ1:

11.3.2 Experimentation

Apparatus

- various meters
- modulated source
- demodulating receiver
- wave generator

Method

1. Determine the limits of amplitude and offset which can be transmitted undistorted for a low frequency (e.g. 1 kHz) signal. Use a sine wave.
   (a) Measure both input and output signal, and determine gain.
2. Increase frequency, and measure input and output amplitude to determine gain.
3. Do Bode plot.

In-lab Tasks

IT1:

In-lab Questions

IQ1: Why is it important to use a sine wave when determining bandwidth?

IQ2: From previous measurements of the cable, how much of the observed attentuation is due to the cable?

11.3.3 Analysis

- ??

Post-lab Discussion Questions

Q1: Since digital signals are *not* sinusoidal, why is it that transmission of digital signals is preferable? (Explain with reference to IQ1.)

Post-lab Tasks

T1:

11.4 Recap

By the end of this exercise, you should know how to test bandwidth.

11.5 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	1	________	10
In-lab Questions	2	________	0
Post-lab Questions	1	________	30
Pre-lab Tasks	0	________	0
In-lab Tasks	1	________	40
Post-lab Tasks	1	________	20

11.6 Template

Source:				
Meter:				
diameter (mm)	turns			
	1	2	3	4
??				
??				

Table 11.1: ??

Chapter 12

OTDR Network Analysis

12.1 Purpose

The purpose of this investigation is to familiarize students with finding important features in OTDR traces.

12.2 Theory

In an OTDR trace, a Fresnel backreflection from a fibre end shows up as a spike. A splice or coupler joint will show up as a drop. The positions of these features can be measured, and the degree of coupling can be determined by the size of the drop. WDM couplers can be distinguished from ordinary couplers by the responses at different wavelengths.

12.3 Procedure

12.3.1 Method

In-lab Tasks

The inlab tasks are included with each part.

Connector and Splice Losses

1. Connect the long 2km reel to the OTDR and to Port 1 of the network box. The schematic for port 1 is outlined in Figure 12.1.
2. Set the OTDR to *Trace* to obtain a trace of the link for a wavelength of 1550nm. Save the file and analyze. Print out the trace as needed.
3. Estimate the length of the fibre.
4. Measure the distances from the input to the two splices and to the end of the link. The first splice is of very low loss and may be difficult to find. (Be creative here.)
5. Measure the loss induced by the connector and the splices. One should be able to determine these values from the OTDR screen or from the software.
6. Measure the total link loss at 1550nm.
7. Switch the OTDR to 1310nm and repeat the above procedure.
8. Fill in the data in Table 12.1.

IT1: Summarize your findings to the lab instructor.

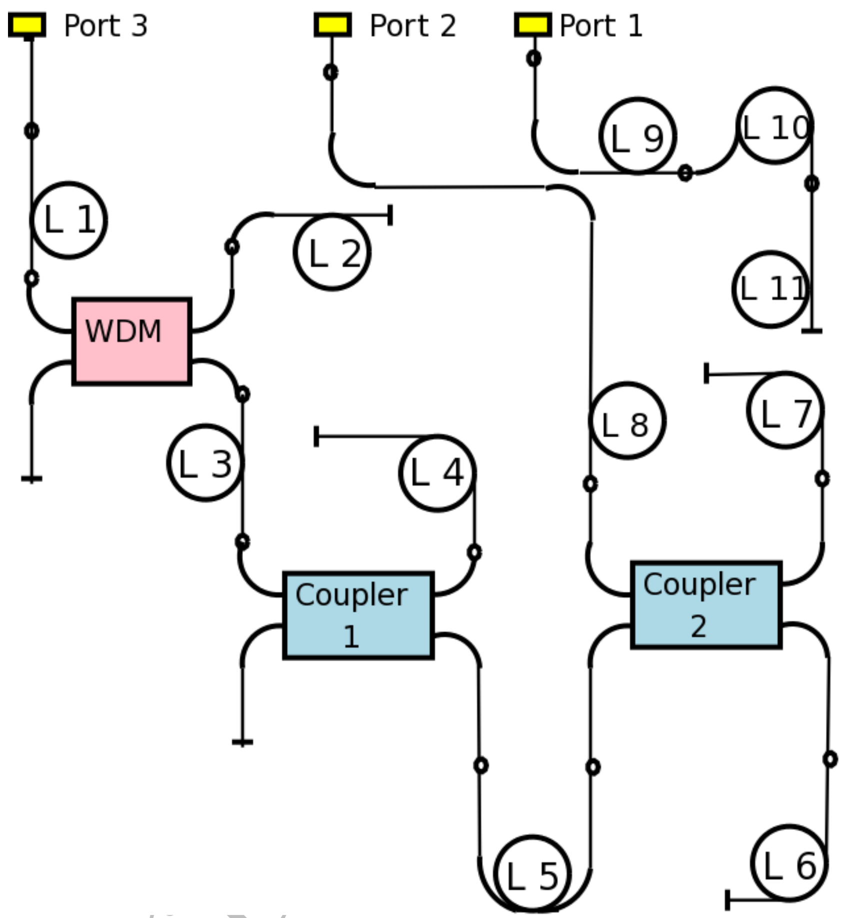

Figure 12.1: Schematic Diagram of Network

Network Section with Fused Fibre Coupler

1. Connect port two of the network box via a patch cord to the OTDR. The network schematic of port 2 can be noted in Figure 12.1.

2. The patch cord to be used should be one of the short patch cords and not the long spool.

3. Set the OTDR to operate at 1550nm and acquire a trace of the network,

making note of the distances to the coupler and to each terminal as well as labeling each component on the trace.

4. Measure the total loss at the end of the longest branch arm.
5. Reset the OTDR under trace mode for 1310nm operation and repeat the above procedure.
6. Fill in the data in Table 12.2.

IT2: Summarize your findings to the lab instructor.

Simple Network Investigation

1. Connect the OTDR to port 3 of the network using a short patch cord.
2. Set the OTDR to measure a trace at 1310nm
3. Label the trace as of all points on the trace using the OTDR or the OTDR software. Print out the plot is required
4. Fill in the data in Table 12.3.
5. Repeat the above procedure with a wavelength of 1550nm.
6. Fill in the data in Table 12.4.

IT3: Summarize your findings to the lab instructor.

12.3.2 Analysis

Post-lab Discussion Questions

Q1: Sketch in approximate lengths for the loops in Figure 12.2 and indicate coupling information for the couplers, as much as you are able.

Q2: Can you distinguish between loops 6 and 7 in the diagram? Explain.

Post-lab Tasks

T1: Write the distances from the fibre end to each feature in Figure 12.2, and in some other way (i.e. different colour, highlighted, etc.) show the change in dBm for the feature.

12.4 Recap

By the end of this exercise, you should know how to :

- identify and characterize comoponents in an optical fibre network using OTDR analysis, including
  - using OTDR software

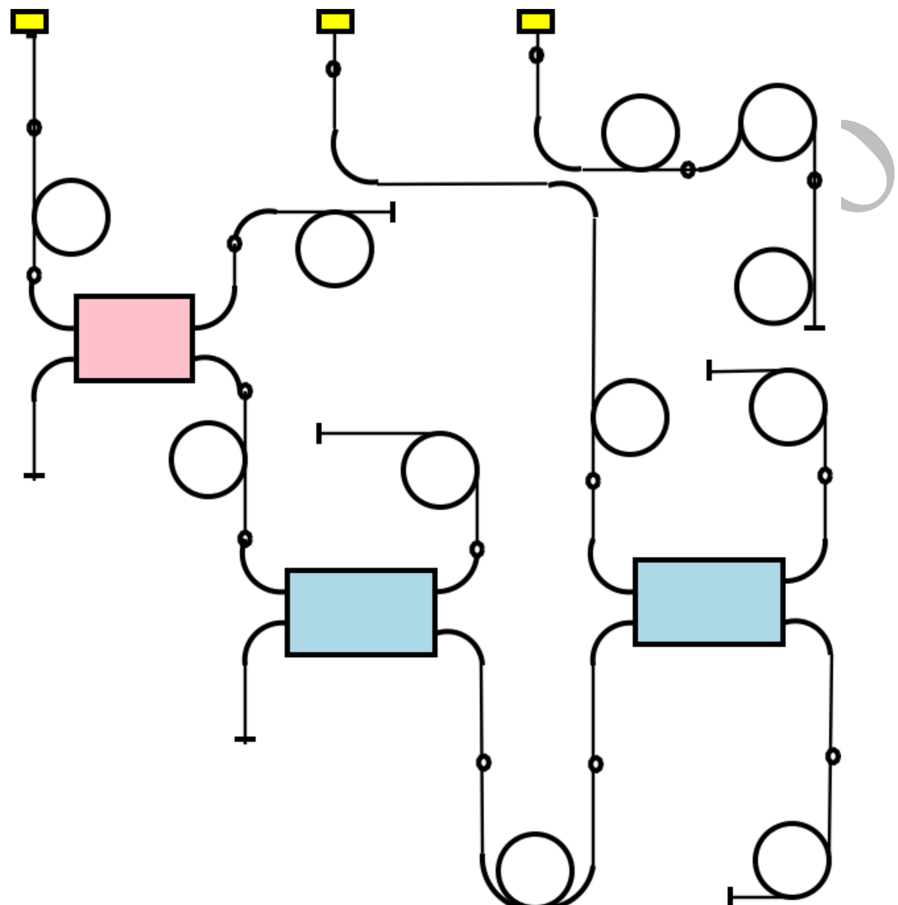

Figure 12.2: Schematic Diagram of Network (no text)

12.5 Summary

Item	Number	Received	weight (%)
Pre-lab Questions	0	________	0
In-lab Questions	0	________	0
Post-lab Questions	2	________	20
Pre-lab Tasks	0	________	0
In-lab Tasks	3	________	60
Post-lab Tasks	1	________	20

12.6 Template

Wavelength	1550nm	1310nm
Length Estimation from Trace (km)		
Distance Splice 1 (km)		
Distance Splice 2 (km)		
Connectors Loss (db)		
Splice 1 Loss (dB)		
Splice 2 Loss (dB)		
Total loss (dB)		
Average attenuation coefficient (dB/km)		

Table 12.1: Connector and Splice Losses

	1310nm			1550nm		
	Event		Total Link	Event		Total Link
	1	2		1	2	
Loss (dB)						
Distance (m)						
α Loss Longer Arm (dB) (Loss 1 + Loss 2)						
Transmitted Signal % $1 - (\frac{Loss1}{\alpha})$						

Table 12.2: Fibre Coupler Summary

1310nm		
	Loss (dB)	Distance (m)
WDM		
Total		
After 1310nm WDM		

Table 12.3: Simple Network Data for 1310nm

1550 nm		
	Loss (dB)	Distance (m)
WDM		
Coupler 1		
Arm End Reflection 1		
Coupler 2		
Arm End Reflection 2		
Total		
After 1550nm WDM		

Table 12.4: Simple Network Data for 1550nm

Appendix A

OTDR Schematic Figures

The following diagrams illustrate features of the OTDR.

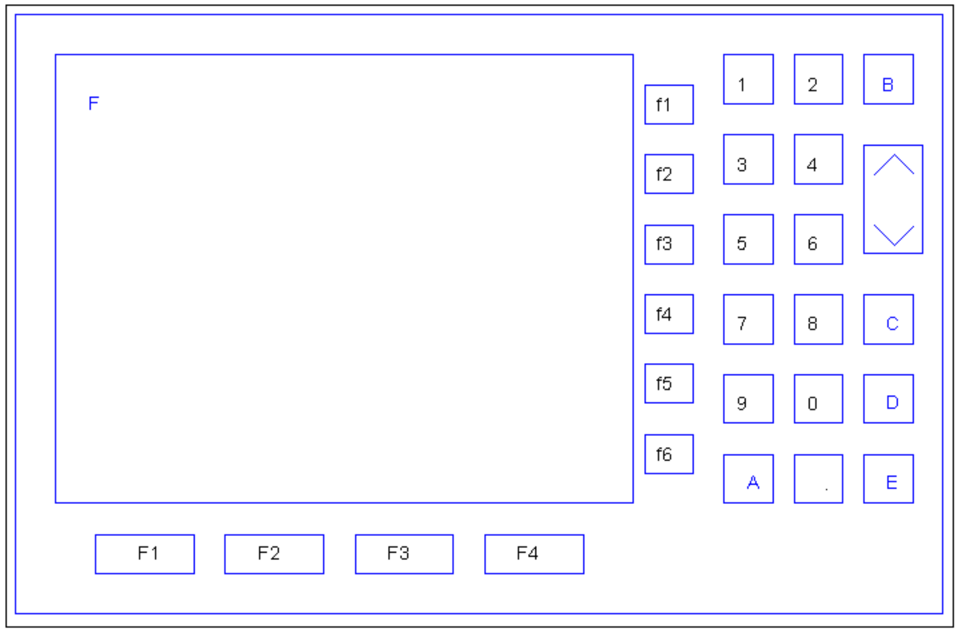

Figure A.1: OTDR Front View

A.1 Legend of Front View

A: Power

B: ESC

C: Enter

D: Back Space

E: Top Menu

F: LCD Screen

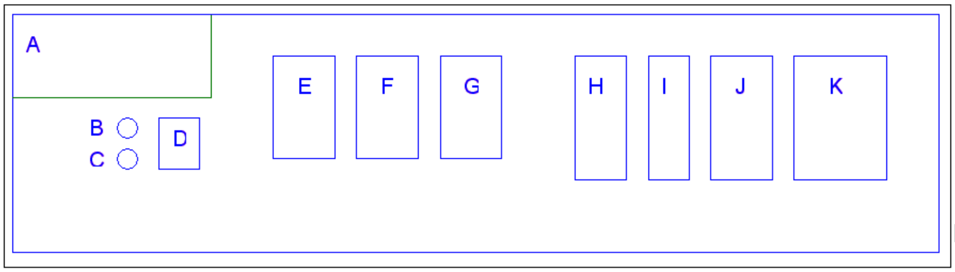

Figure A.2: OTDR Top View

A.2 Legend of Top View

A: Battery

B: Battery Charging LED

C: External Power LED

D: DC Input

E: Open Space

F: Open Space

G: OTDR Input (Fiber Input) Max +10dBm

H: USB Down (Save Attribute)

I: Open Space

J: USB Up (To PC)

K: Open Space

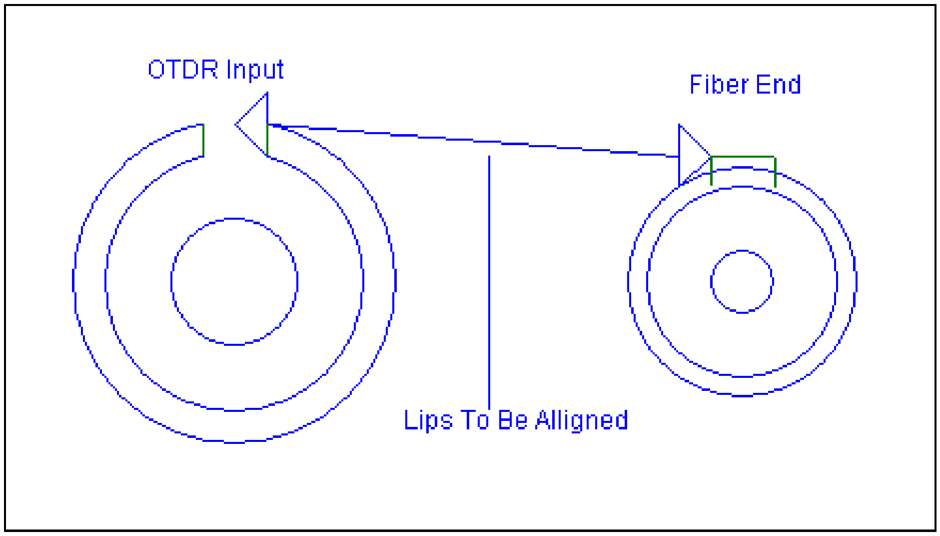

Figure A.3: Fiber Optic Cable Head and OTDR Input

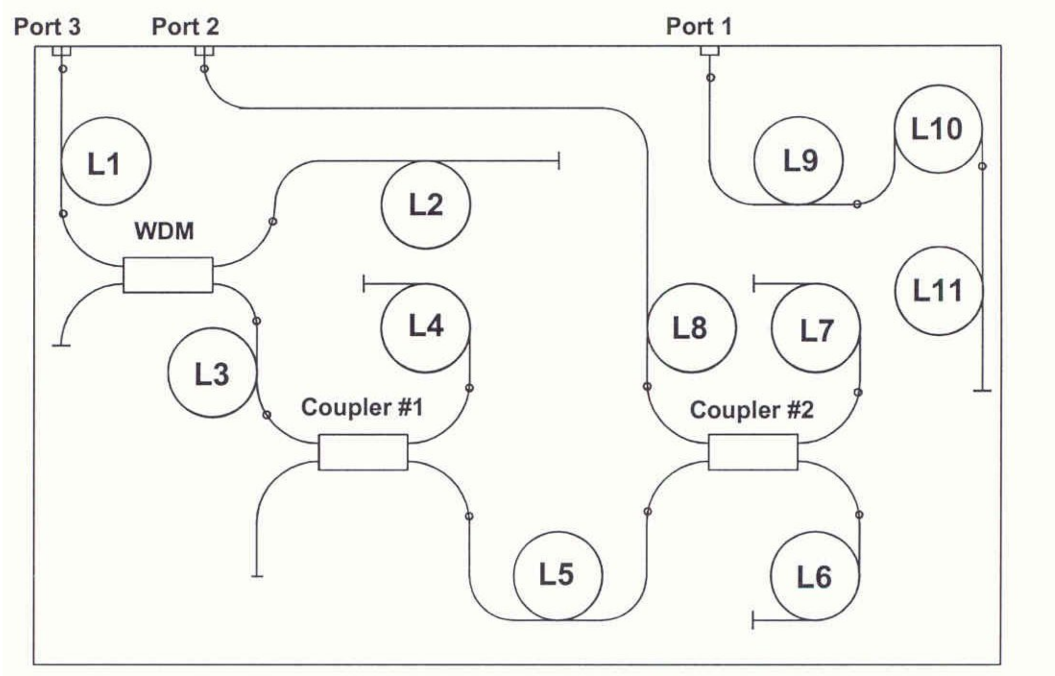

Figure A.4: Schematic Diagram of Network

A.3 Legend

WDM Wavelength Division Multiplexer

L1→L11 Loops of Fiber to Lengthen the Network

∘ Splices

Appendix B

Components and Devices

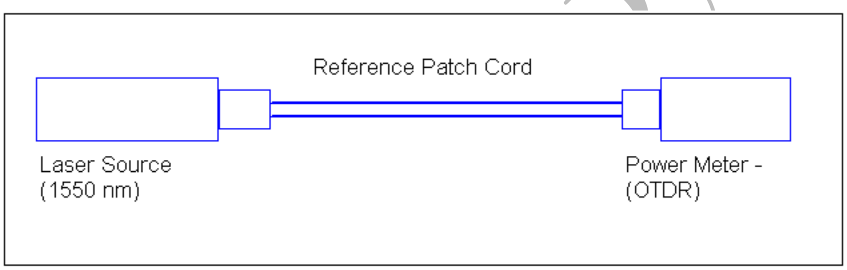

Figure B.1: Simple Patch cord

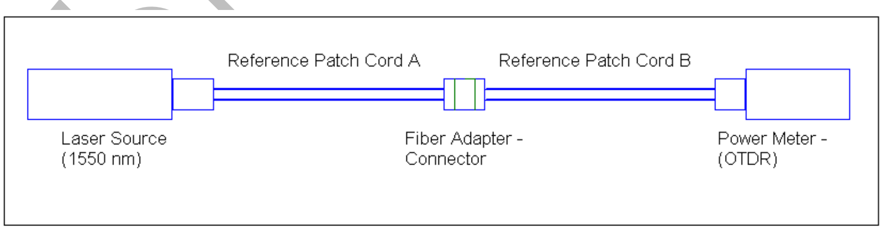

Figure B.2: Two Patch Cords and Adapter

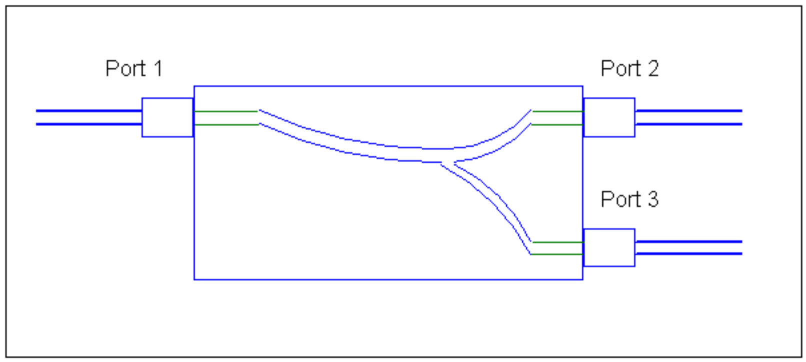

Figure B.3: 3-Port Fused Coupler

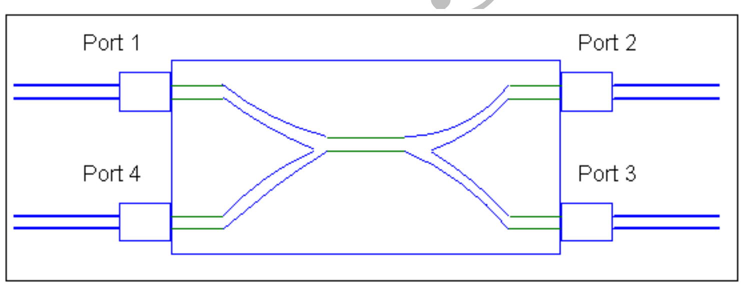

Figure B.4: 4-Port Fused Coupler

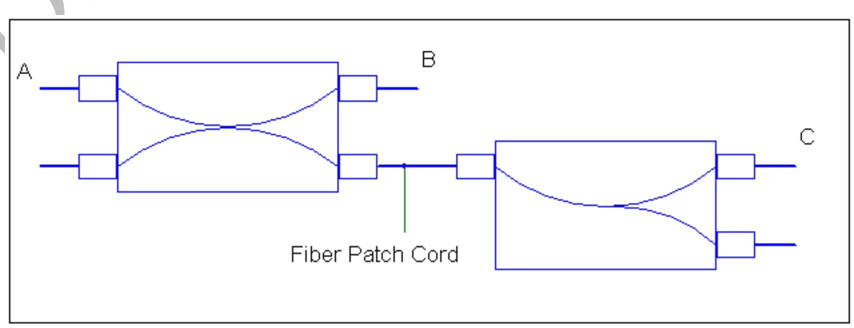

Figure B.5: 4-Port / 3-Port Simple Network

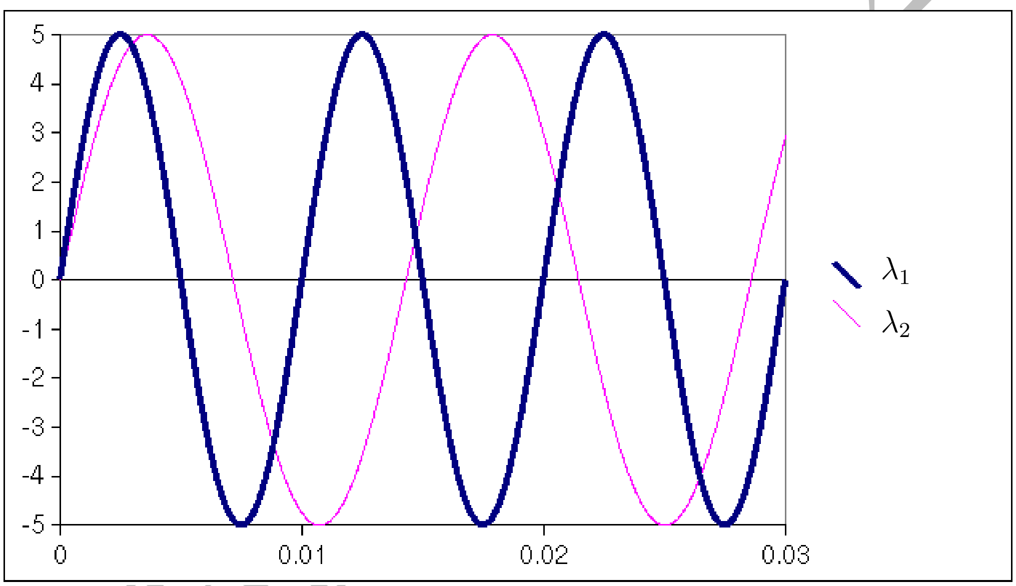

Figure B.6: Principles of WDM Inside Fiber Core

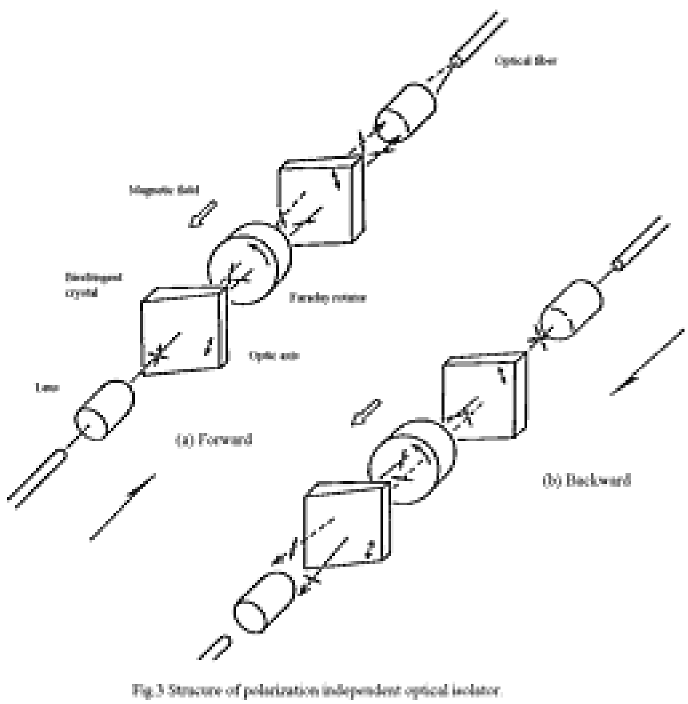

Figure B.7: Polarization Independent Optical Isolator

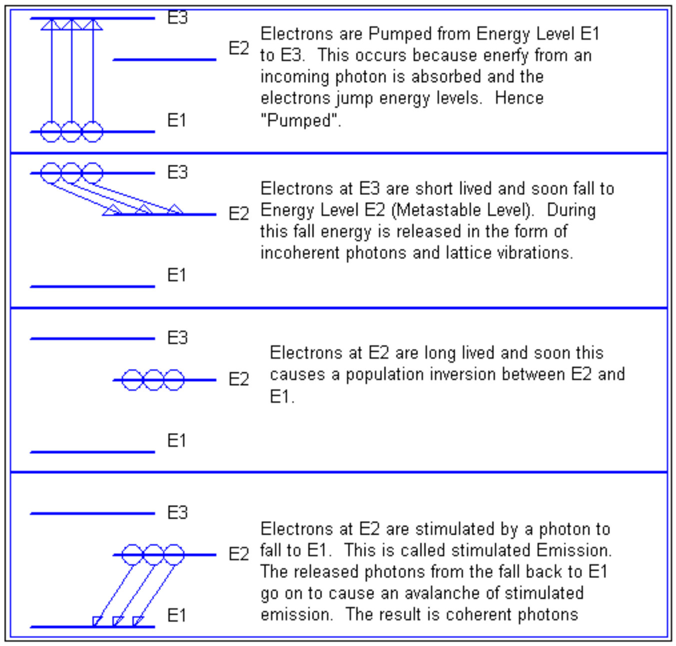

Figure B.8: Basic Principle Operation of a Laser

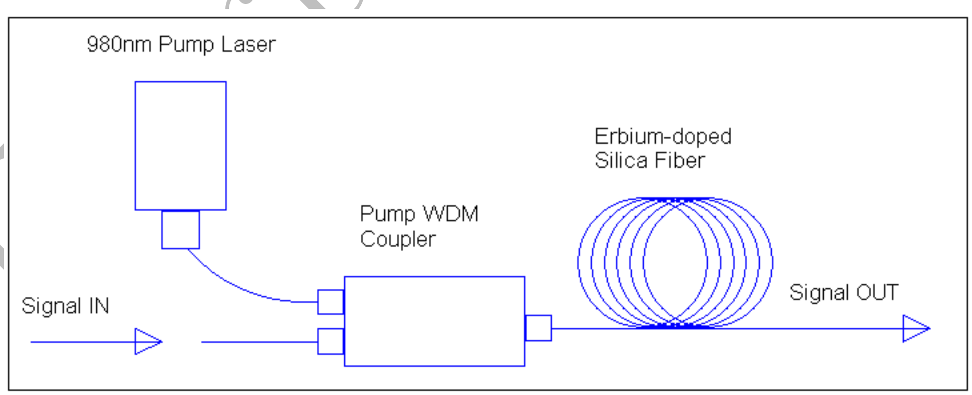

Figure B.9: EDFA Design

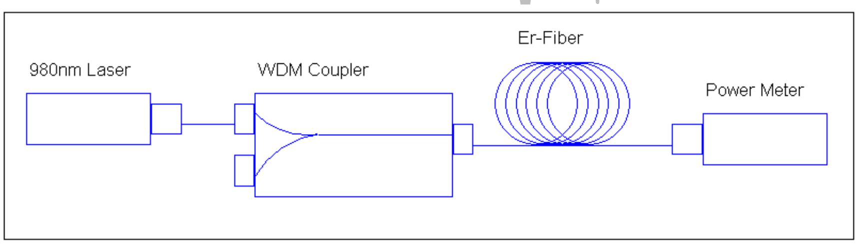

Figure B.10: Fiber Laser Design

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