FIBRE OPTICS BASED INTRUSION DETECTION SYSTEM

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Abstract

This research is aimed at development of fence mounted or buried optical fibre based intrusion detection system. Type and location of intrusion will be determined based on the principle of interferometry using counter propagating optical signals in the fibre. The system employs Mach-Zehnder interferometer through which counter propagated signals are launched. If there is some intrusion anywhere in the entire length of fibre the counter propagated signals are modified. The modified signals are detected on a photo detector. The type of intrusion i.e., touching, cutting, stepping over a fibre can be identified on the basis of modified signals. Time difference between receipts of modified counter propagated signals is used to determine the location of the event.

CERTIFICATE FOR CORRECTNESS AND APPROVAL

It is certified that the work contained in the thesis – Fibre Optics Based Intrusion Detection System carried out by Nisar Ali , Balaj Ahmad and Muhammad Faraz under the supervision of Lt Col Dr. Syed Amer Gillani for partial fulfilment of Degree of Bachelor of Telecommunication Engineering is correct and approved.

Approved by

Lt Col Dr. Syed AmerAhsan Gillani

EE DEPARTMENT
MCS

DECLARATION

No portion of the work presented in this dissertation has been submitted in support of another award or qualification either at this institution or elsewhere.

DEDICATION

In the name of Allah, the Most Merciful, the Most Beneficent.
To our parents who are always there supporting and praying for our success,
to our teachers who always assist us in the best way
&
to our friends.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter will give a brief overview of the problem statement and the identification of the solution to that problem through implementation of this project in addition to the important concepts about fibre optics and optical time domain interferometer (OTDR).

1.2 Overview

We have designed a hardware project that enables us to detect any intrusion across the perimeter of any desired area using optical fiber. The project is designed using optical hardware and Arduino Board uno. Using the principle of interferometry we have implemented Mach-Zehnder interferometry set up in this project and integrated the interferometer with the Arduino Board and visualized any attenuation of transmitted power due to any intrusion or disturbance of optical fibre on graphical user interface (GUI) of MATLAB.

1.3 Problem Statement

The security challenges are increasing day by day in our country, so our defence strategy demands the production of such systems which are reliable and qualitative and meet the modern standards of security measures. This project is one of the blocks of such a building which our research and development department is interested to build. The use of this system will ensure quick detection and locating the target more efficiently. This system would locate the target in real time. It has the following advantages

- It requires low power and can be implemented across long perimeter.
- Fibre optics intrusion detection system can detect any attempt to cut, lift, crawl or climb over a fence.
- Light weight and can easily be installed on a fence or buried in the ground.

1.4 Background

1.4.1 Optical Time Domain Interferometer (OTDR)

The optical time domain reflectometer (OTDR), initially demonstrated over two decades ago, is now widely used for locating breaks and other anomalies in fibre optic links and networks. In an OTDR system, light pulses from a semiconductor laser are injected into one end of a fibre, and Rayleigh backscattered light returned from the fibre is monitored with a photo detector. The system detects the presence and location of perturbations which affect the intensity of the light returned from the fibre, but does not in general respond to phase modulation of the light. The spectral width of the modulated laser is very broad (GHz to THz range), so that fluctuations in the return signal due to interference of backscattered components from different parts of the fibre are for the most part avoided. When present to a noticeable extent, coherent effects represent an undesirable source of noise in an OTDR trace.

OTDR SETUP

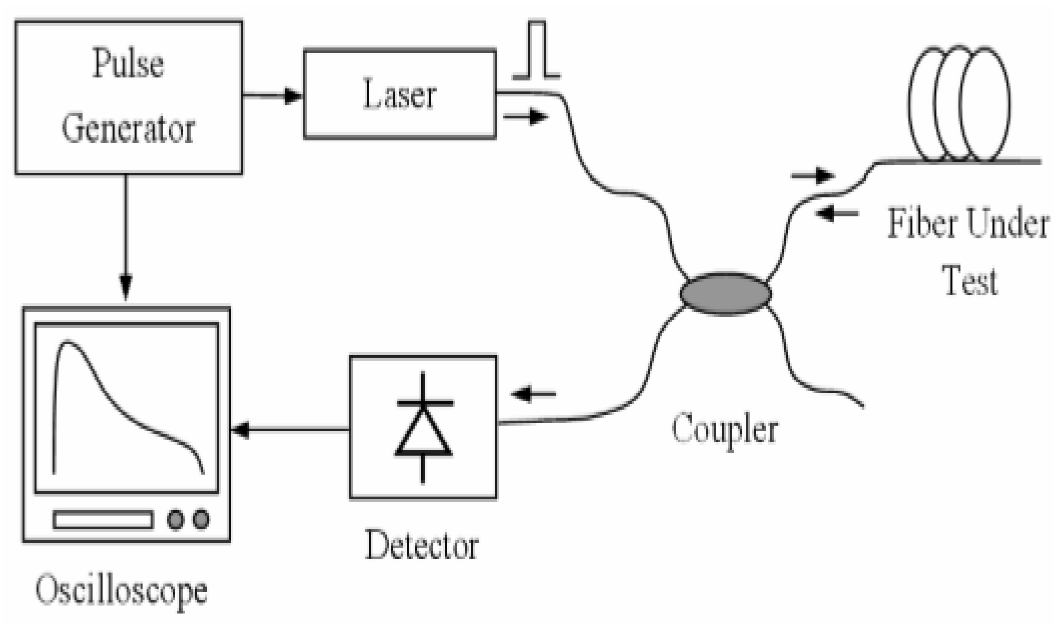


Figure 1 OTDR SETUP

OTDR WAVEFORM

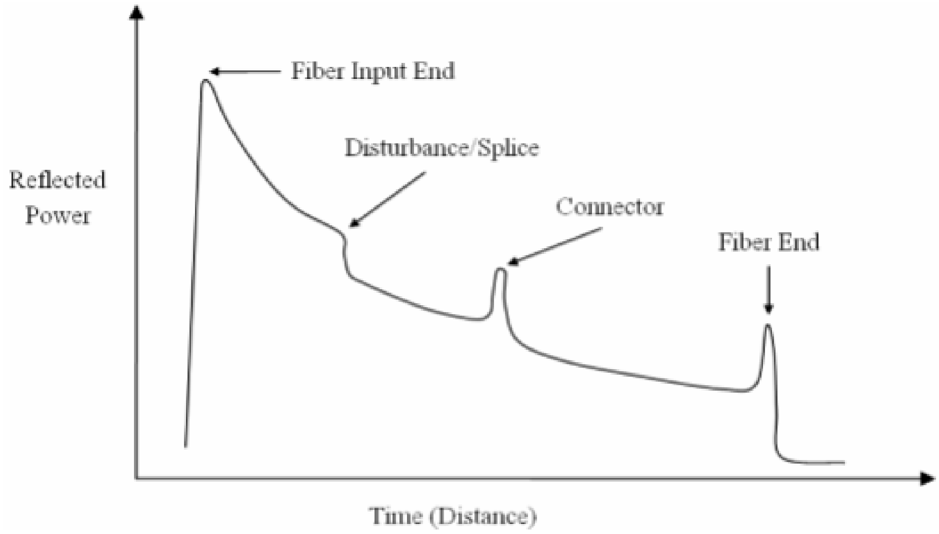


Figure 2 OTDR Waveform

1.4.2 Rayleigh Backscattering in single mode fibre

When optical fibre is drawn from its molten state, microscopic variations arise in the density of the material as it cools, which in turn produces variations in the index of refraction of the fibre. This causes scattering of optical power known as Rayleigh backscattering, which has become the dominant loss mechanism in single mode fibres accounting for nearly 96% of the attenuation in today's fibres . The inhomogeneities in the index of refraction of a fibre can be modelled as scattering centres embedded in a homogeneous material with sizes much smaller than those of the optical wavelengths . As an optical wave travels along the fibre, light will scatter in all directions, but a small fraction of the scattered light will couple into the fibre core and propagate in the reverse direction as shown in Figure . This phenomenon is commonly used in optical time domain reflectometry (OTDR) to monitor intensity attenuations throughout a fibre length. Rayleigh scattering loss is proportional to λ-4 with increasing wavelength throughout the visible and near-infrared spectral regions to a minimum of about 0.2 dB/km at 1550 nm. Beyond this wavelength the attenuation increases rapidly due to optical absorption resulting from the excitation of phonons in the fiber material .

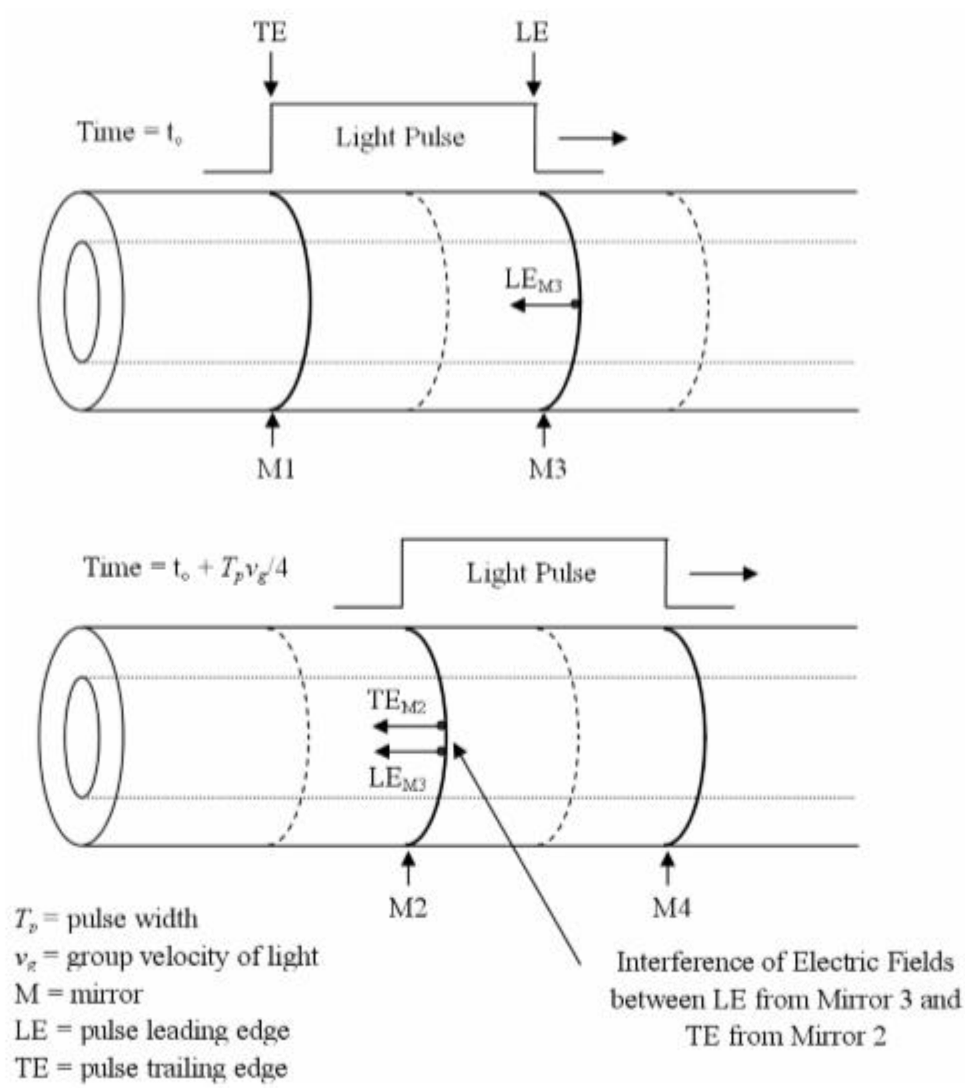


Figure 3 Rayleigh Backscattering

1.5 Literature Overview

1.5.1 Fibre Optics

An optical fiber is a cylindrical dielectric waveguide (non-conducting waveguide) that transmits light along its axis, by the process of total internal reflection. The fiber consists of a core surrounded by a cladding layer, both of which are made of dielectric materials. To confine the optical signal in the core, the refractive index of the core must be greater than that of the cladding.

1.5.2 Index of refraction

The index of refraction is a way of measuring the speed of light in a material. Light travels fastest in vacuum, such as in outer space. The speed of light in vacuum is 300,000 kilometers per second. The refractive index of a medium is calculated by dividing the speed of light in vacuum by the speed of light in that material. The refractive index of a vacuum is therefore 1 and the typical single mode fibre used for telecommunications has a cladding made of pure silica, with an index of 1.444 at 1500nm, and a core of doped silica with an index around 1.4475. The larger the refractive index the slower light travels in that medium. From this information, a simple rule of thumb is that a signal using optical fibre for communication will travel at around 200,000 kilometers per second.

1.5.3 Total internal reflection

When light travelling in an optically dense medium hits a boundary at an angle larger than the critical angle for the boundary, the light is completely reflected . This is called total internal reflection. This effect is used in fiber optics to confine the light in the core. Light travels through the fiber core, bouncing back and forth off the boundary between the core and cladding.

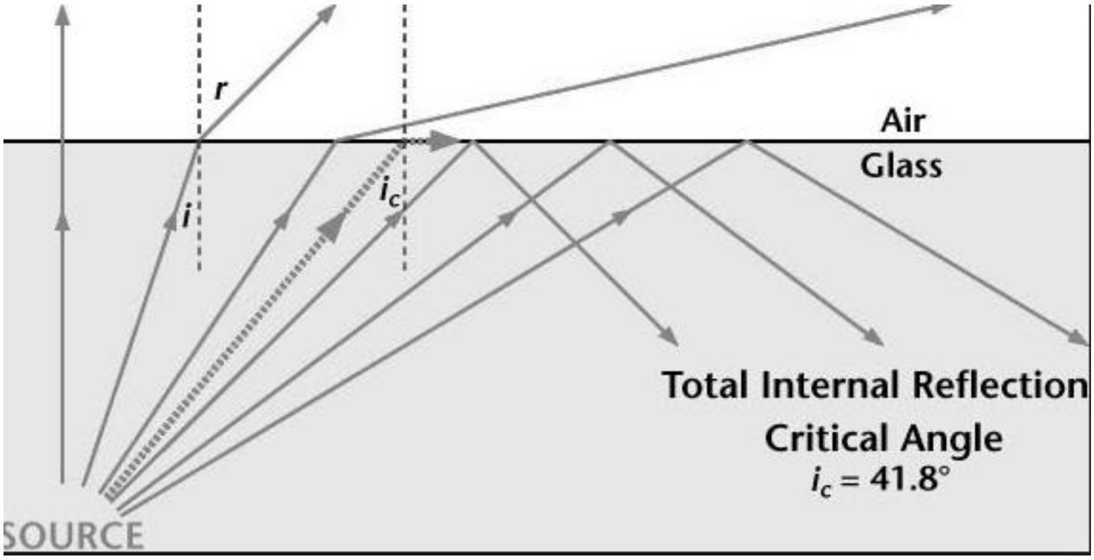


Figure 4 Total Internal Reflection

1.5.4 Multimode fibre

It is an optical fibre that has larger core diameter and designed to carry multiple light rays or modes concurrently, each at a slightly different reflection angle within the optical fibre core. Multimode fibre transmission is used for relatively short distances because the modes tend to disperse over longer lengths (called modal dispersion).

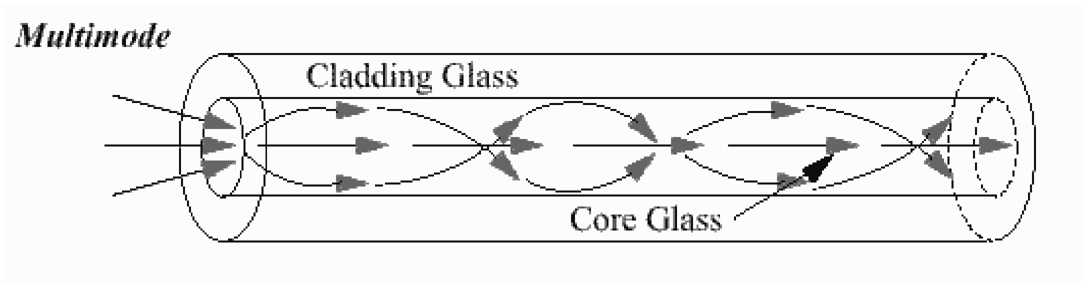


Figure 5 Multimode Fiber

1.5.5 Single mode fibre

Single mode fibre in optical fibre that is designed for the transmission of a single ray or mode of light as a carrier and is used for long distance signal transmission. Single mode fibre has much smaller core than multimode fibre.

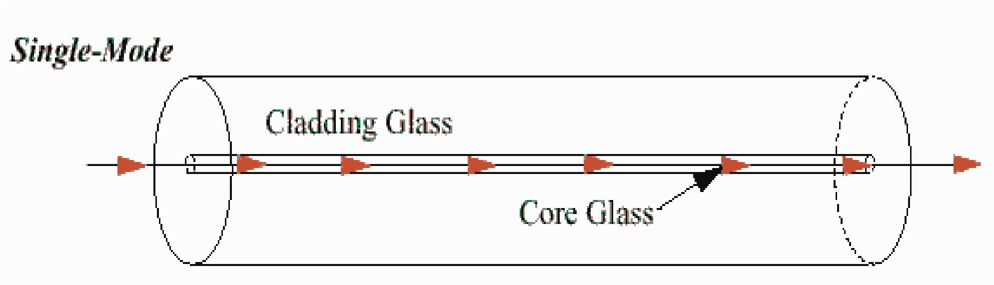


Figure 6 Singlemode Fiber

1.5.6 Special purpose fibre

Some special-purpose optical fiber is constructed with a non-cylindrical core and/or cladding layer, usually with an elliptical or rectangular cross-section. These include polarization-maintaining fiber and fiber designed to suppress whispering gallery mode propagation. Polarization-maintaining fiber is a unique type of fiber that is commonly used in fiber optic sensors due to its ability to maintain the polarization of the light inserted into it.

CHAPTER 2

PROJECT DESCRIPTION AND SALIENT FEATURES

2.1 Project description

Mach Zehnder interferometer set-up is formed using two couplers connected with two arms of different optical cable lengths. The light is divided in two arms of the input coupler of the MZ interferometer and they are later merged at the output coupler which is further connected with photo-detector integrated with a low noise amplifier and a signal processing system to observe the relative phase-shift and amplitude variation, as shown in figure.

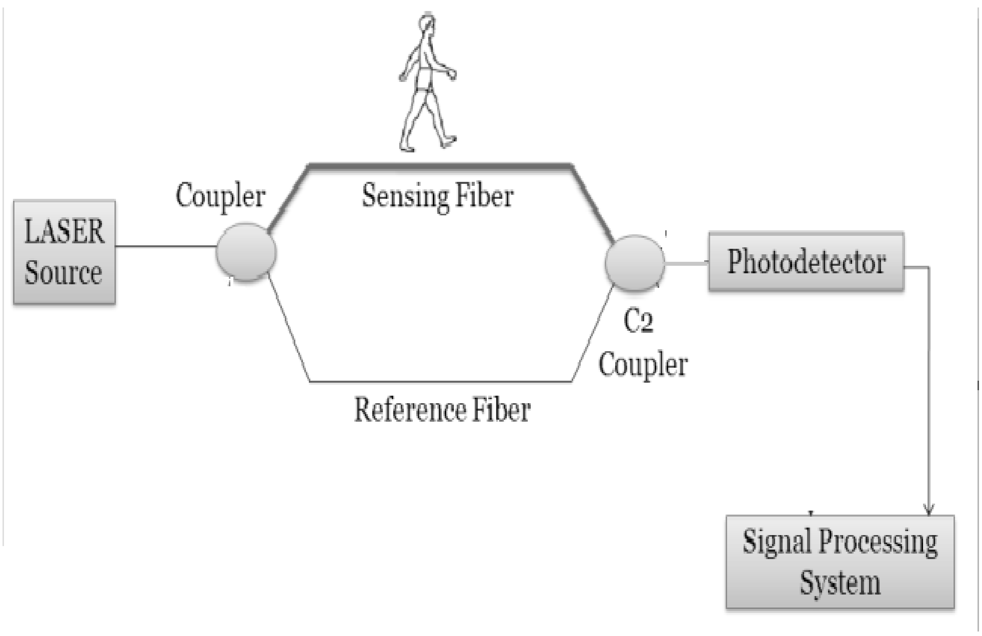


Figure 7 Mach Zehnder Test Setup

The above figure describes the acquisition and processing of the optical waves captured from the source and disturbed by the intruder. The optical pulses are injected into coupler via laser source and the acquired optical waves are then be processed on the Arduino and Matlab and the alarming system is to be activated if the power loss will be exceeded above the threshold level.

2.2 Application areas

The applications areas of the project are as under:

- **Perimeter Security Solution**

  The fibre optics based security system for intrusion detection and localization. The system can be installed on a fence or buried in the ground around a defended area, along perimeter boundaries and fences.

- **Security of borders**

  The fibre optics based system can be installed near borders to detect and prevent any illegal intrusion.

2.3 Scope

The scope of this project is to design a system which would enable accurate intrusion of a particular target source, enabling rapid and accurate reaction to assist our defence institutions for tackling wide range security challenges prevailing in the country .

- To develop a setup based on Mach Zhender interferometer technique.
- To implement the algorithm for setting up the threshold level and to detect intrusion.

- To detect any intrusion across perimeter installed fence in real time.

2.4 Objective

The main objective of this project is to create a setup for providing a fast and accurate means of detecting any intrusion using optical fibre. This system will be implemented using the principle of interferometer, where any disturbance of optical fibre changing the phase or amplitude of the transmitted optical wave will be detected at output. The time delay and the phase difference of two waveforms would be used to build an algorithm easy to be implemented on arduino to detect the intrusion. The main objectives are as below.

- Easy installation.
- Real time detection.

2.5 Requirements and Specifications

2.5.1 Hardware Requirements and Specifications

Following hardware components are required for our projects:

- Input Laser source source (coherent 1550nm).
- Polarization Controller (3 loops).
- Polarization maintaining Couplers
- Photo-detector (Inga As)
- Low Noise Amplifier (LM-324)
- Single Mode Fibre Spool

- Arduino board(Uno)
- Bluetooth module.
- Batteries (6 V).

2.5.2 Software Requirements and Specifications

- The main algorithm is implemented on matlab.
- Threshold level of signals captured through photodiode is set on arduino board.
- Arduino Software is used to set the threshold of the incoming signal on arduino board.

2.6 Deliverables

The deliverables are as:

- The intrusion detection system to monitor the sensitive premises of boundary.
- Easy to install and requires low power.
- Mach Zhender interferometery is implemented in real time.
- Platform for locating the intrusion.

CHAPTER 3

DESIGN AND DEVELOPMENT

3.1 Design and development

The project consists of two parts, the hardware implementation and software Development as shown in figure below:

Required Modules:

- Input source
- Polarization Controller
- Polarization maintaining couplers
- Photo-diodes
- Low Noise Amplifier
- Single Mode Fibre Spool
- Arduino board
- Bluetooth module

3.1.1 Input Source

The sources used for fiber optic transmitters need to meet several criteria; it has to be at the correct wavelength, be able to be modulated fast enough to transmit data and be efficiently coupled into fiber. Four types of sources are commonly used, LEDs, fabry-perot (FP) lasers, distributed feedback (DFB) lasers and vertical cavity surface-emitting lasers (VCSEL). All convert electrical signals into optical signals, but are otherwise quite different devices. All three are tiny semiconductor devices (chips). LEDs and VCSELs are fabricated on semiconductor wafers such that they emit light from the surface of the chip, while fabry-perot lasers emit from the side of the chip from a laser cavity created in the middle of the chip. LEDs have much lower power outputs than lasers and their larger, diverting light output pattern makes them harder to couple into fibers. Laser have smaller tighter light outputs and are easily coupled to single mode fibers, making them ideal for long distance high speed links. LEDs have much less bandwidth than lasers and are limited to systems operating up to about 250 MHz. Lasers have very high bandwidth capability, most being useful to well over 10 GHz.

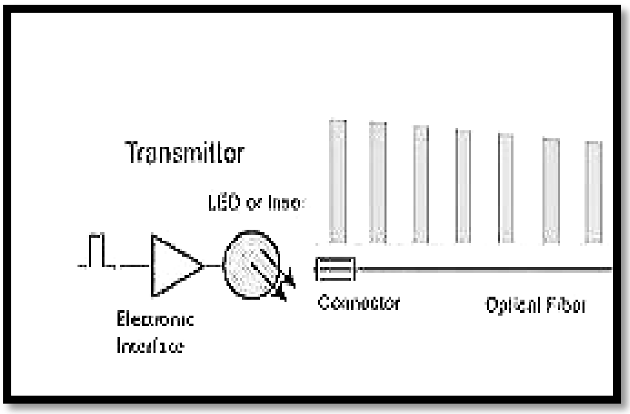


Figure 8 Transmitter

Typical fiber optics source specifications are as:

Device Type	Wavelength (nm)	Power into Fiber (dBm)	Bandwidth	Fiber Types
LED	850,1300	-30 to -10	<25MHZ	MM
FABRY - PEROT LASER	850,1300,1550	0 to +10	>10GHZ	MM, SM
DFB LASER	1550	0 to +25	>10 GHZ	SM

Spectral Output:

LEDs have a very broad spectral output which causes them to suffer chromatic dispersion in fibre, while lasers have a narrow spectral output that suffers very little chromatic dispersion. DFB lasers, which are used for long distance, and have the narrowest spectral width which minimizes chromatic dispersion on the longest links. DFB lasers are also highly linear (that is the light output directly follows the electrical input).so we chose DFB laser for our system.

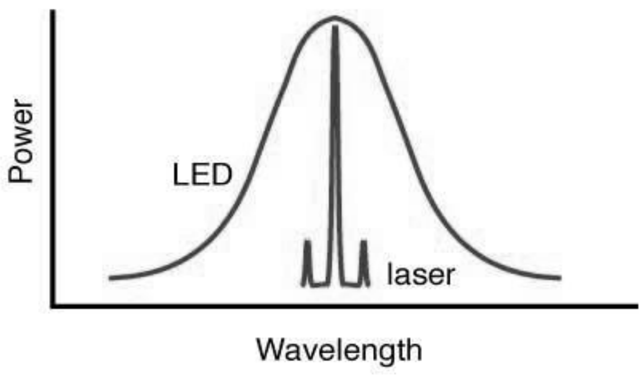


Figure 9 Wavelength Spectrums of LED and Laser

Coherent Nature of laser source:

The laser should be highly coherent so as to cause minimum drift in frequency and to achieve effective phase variation before combination of waves at the output couplers. As a result destructive or constructive interference takes place and intrusion (if any) is detected.

3.1.2 Polarization Controller

A simple polarization controller was designed by placing three wave plates in series , the radii of the wave plates should be multiple(2n.lamda) of the wavelength(1550nm) of the light , so that when the light passes through the wave plates the polarization is controlled by adjusting the wave plates position . The wave plates diameters and the adjustment of the wave plates to get the desired results needs perfection otherwise the polarization cannot be controlled and the fibre would be not sensitive enough.

Figure 10 polarization controller

3.1.3 Directional Couplers

The gated optical signal into the directional coupler is divided into two equal half power signals which are further gated into two separate fibres one is the reference line and the other is the sensing fibre. The reverse process is done on the other end of the fibres by combining the two signals by directional couplers or interferometers.

Figure 11 Directional Couplers

3.1.4 Photo-detector

The resultant signal from the interference (constructive or destructive) is allowed to fall on the photo detector made up of Indium Gallium Aresenide(InGaAs), the photo detector will change this electromagnetic signal into electrical signal, higher the intensity of the light more detectable the electrical signal will be.

Figure 12 Photo-Detector

3.1.5 Receiver

At the receiver end photodiode is coupled with the operational amplifier to convert the light into electrical signal and then amplify that signal to a certain level so that the signal is detected and processed easily.

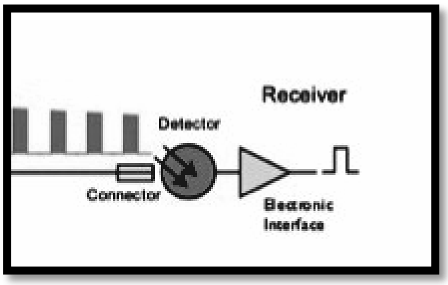


Figure 13 Receiver

Receivers use semiconductor detectors (photodiodes or photo detectors) to convert optical signals to electrical signals. Silicon photodiodes are used for short wavelength links (650 for POF and 850 for glass MM fiber). Long wavelength systems usually use InGaAs (indium gallium arsenide) detectors as they have lower noise than germanium which allows for more sensitive receivers.

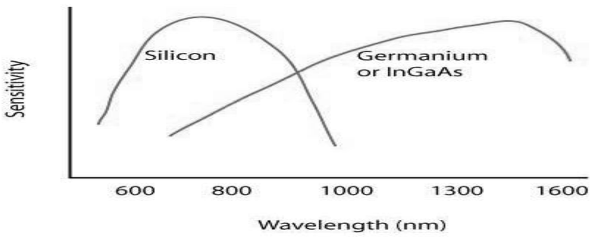


Figure 14 Sensitivity vs Waveform

Design of receiver:

The receiver is designed in such a way that the signals received by the photo-detector is introduced into LM 324 IC. Two stage amplification of the incoming signal is done by LM324 , its gain is 20.

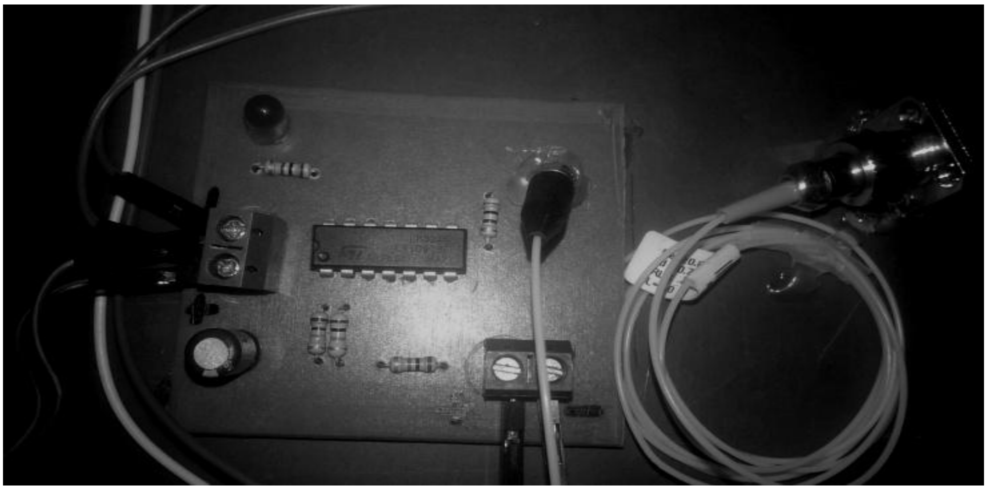


Figure 15 Receiver

PCB designed is as:

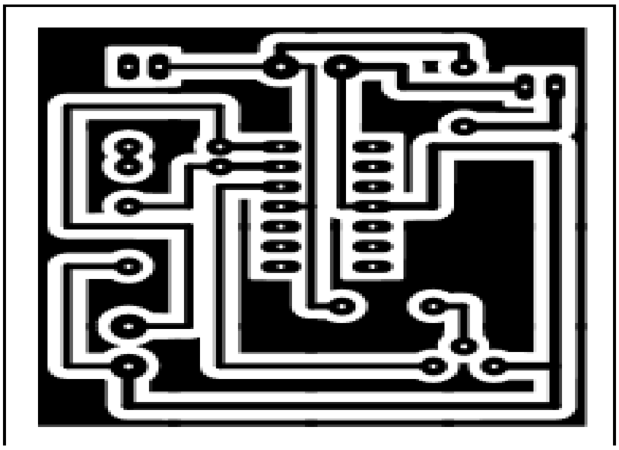


Figure 16 PCB design of the receiver

3.1.6 Arduino Board

Arduino is an open source prototyping platform based on easy-to-use software and hardware. Arduino boards are able to read inputs ; light on sensor , a finger on button ,or a twitter message and turn it into an output ,activating a motor , turning on LED , publishing something online . We can tell our board what to do by sending a set of instructions to the microcontroller on the board . To do so we use Arduino programming language (based on wiring), and the Arduino Software(IDE), based on processing.

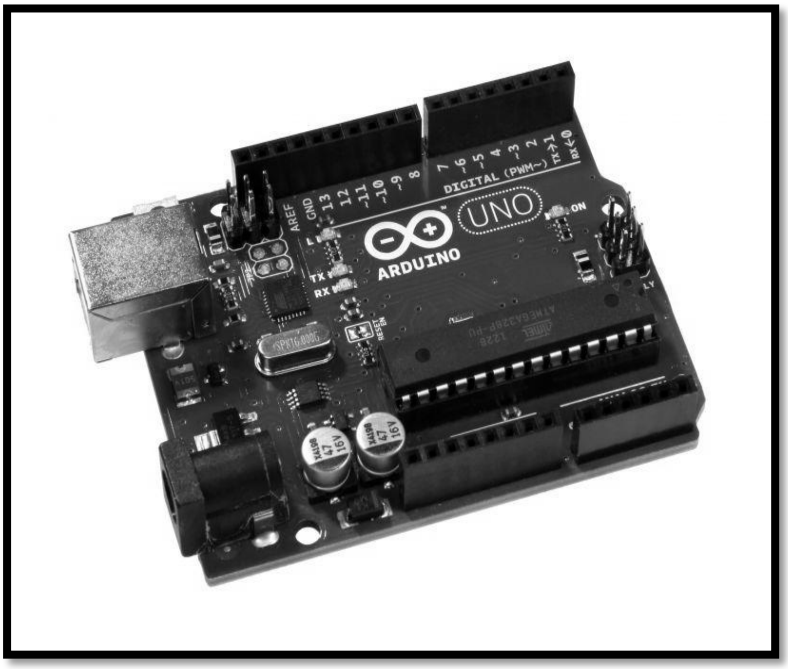


Figure 17 Arduino

The arduino in our project is used for two purposes which are as:

- To convert the analog signal into digital signals.
- To set a threshold level so that due to any disturbance of the optical fibre if the value of the signal strength is decreased and crossed the threshold the alarm system is activated.

3.2 Initial testing

The initial tests which were performed are as:

3.2.1 Experiment 1

The laser source DVP 1550nm was used the input source and Mach-Zehnder set-up was established and the output was achieved at the power meter, by pressing the optical fibre hard certain loss (0.1to 0.3dBmW) in the power was observed. The input power was 15dBmW and the output power without any disturbance was 12.43dBmW and after applying the pressure the power reduced to 12.1dBmW. Block diagram of the test is as.

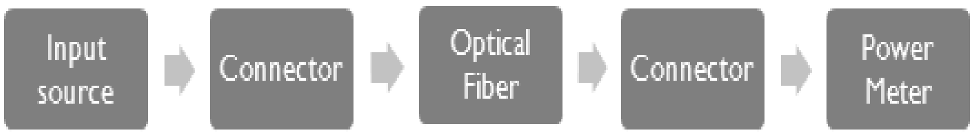


Figure 18 Initial Experiment 1

3.2.2 Experiment 2

The same set-up as in experiment was used and modified by introducing the Mach-Zehnder set up using the reference path and the fiber under test path . The fiber under test was longer than the reference power and couplers was used at both ends. The output at the power meter after was showing certain power loss (upto 9 dBmW) . The block diagram for this test is as:

Figure 19 Initial Experiment 2

3.2.3 Experiment 3

The establishment of the communication was done by designing a preliminary receiver and amplifier. The waveform was observed on the oscilloscope. The transmitter was given the input signal from the arduino and after receiving the output is amplified and fed to the oscilloscope for visual display. The overall receiving hardware is as given:

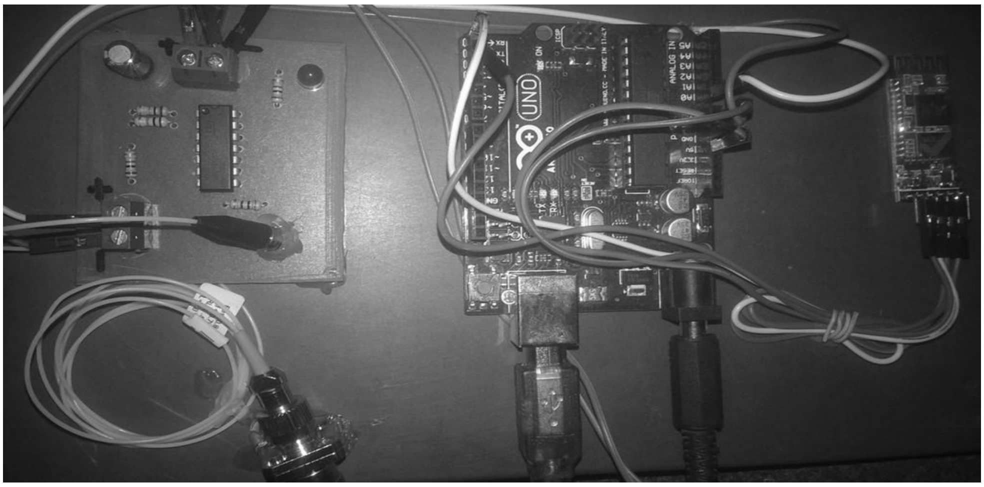


Figure 20 Complete Receiver Hardware

3.3 Simulations on Optisystem Software

The Mach-Zhender interferometer was designed and simulate on optisystem software and the power loss due to any perturbance was measured. The snapshot of that is as under.

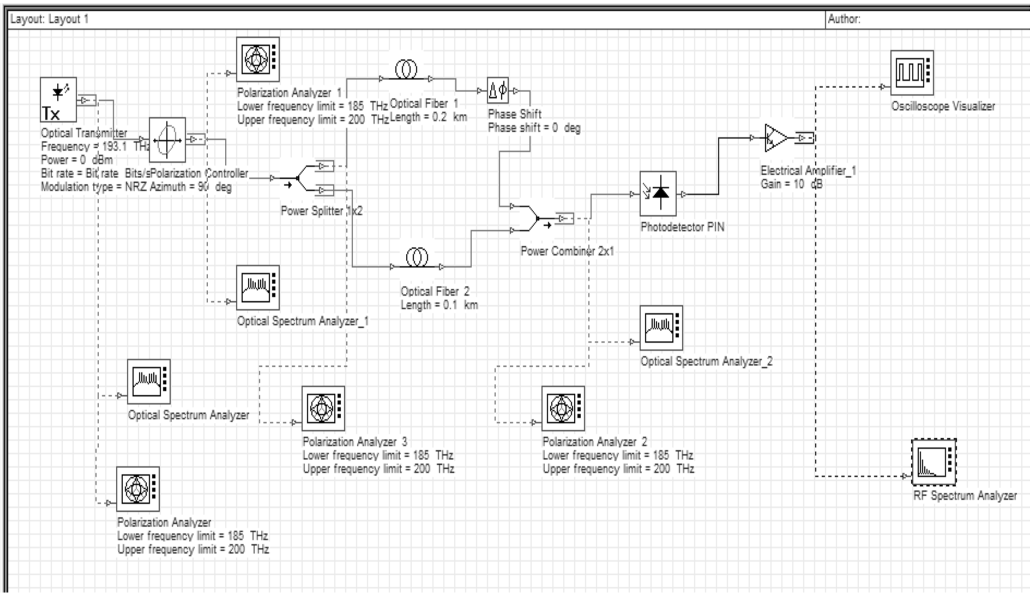


Figure 21 Set-up in optisystem software

After designing the set-up the power level was calculated keeping the phase shift as 0 degree as :

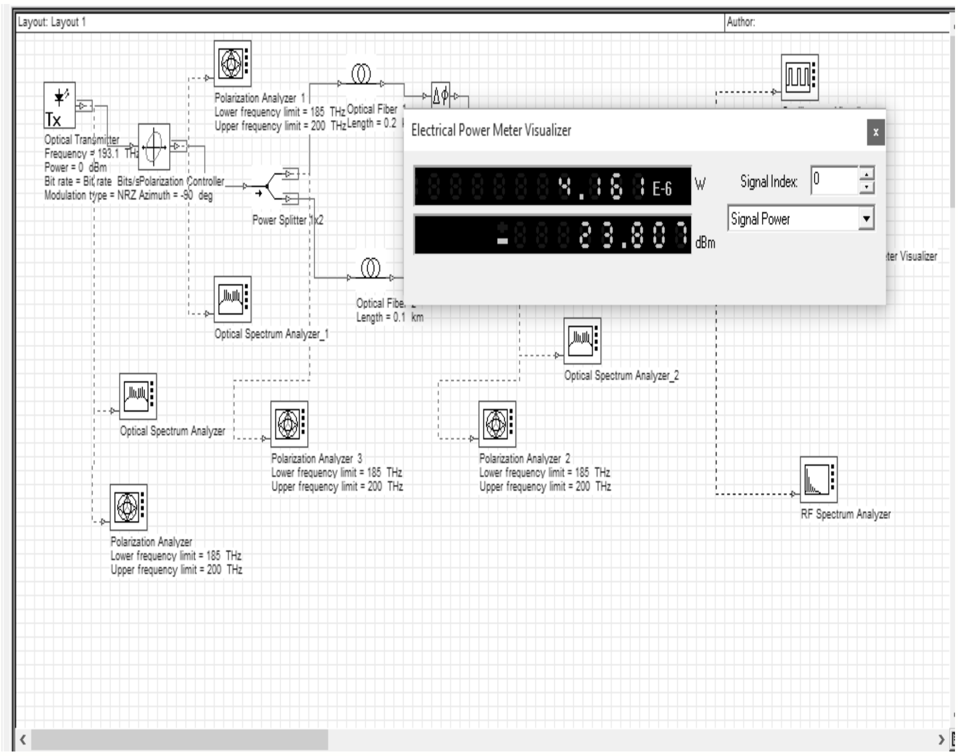


Figure 22 Power observed when there is no phase change

When the phase shift was changed to 45 degree the power level was reduced by 4dBm.

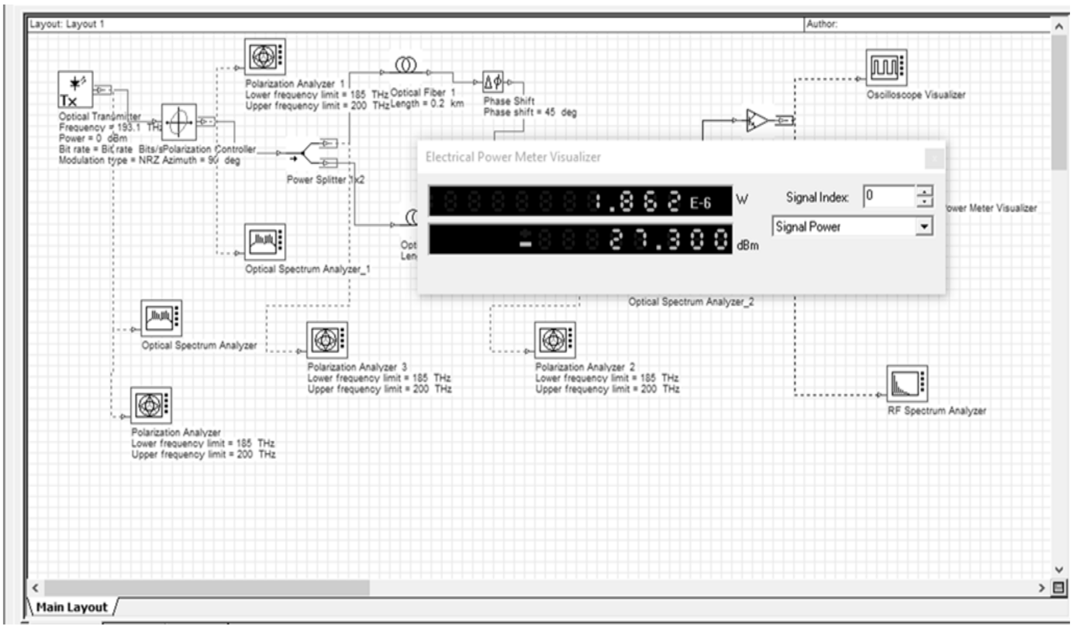


Figure 23 Power measure when phase change was 45 degree

The output of spectrum analyzer is as:

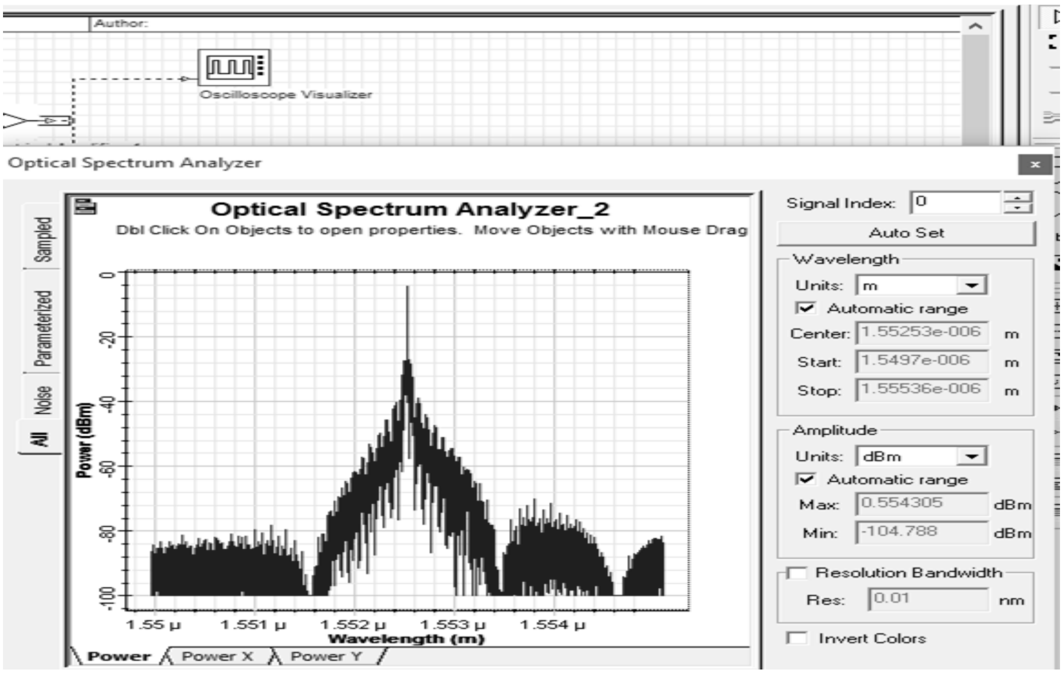


Figure 24 Spectrum Analyzer

The output of oscilloscope visualize is as:

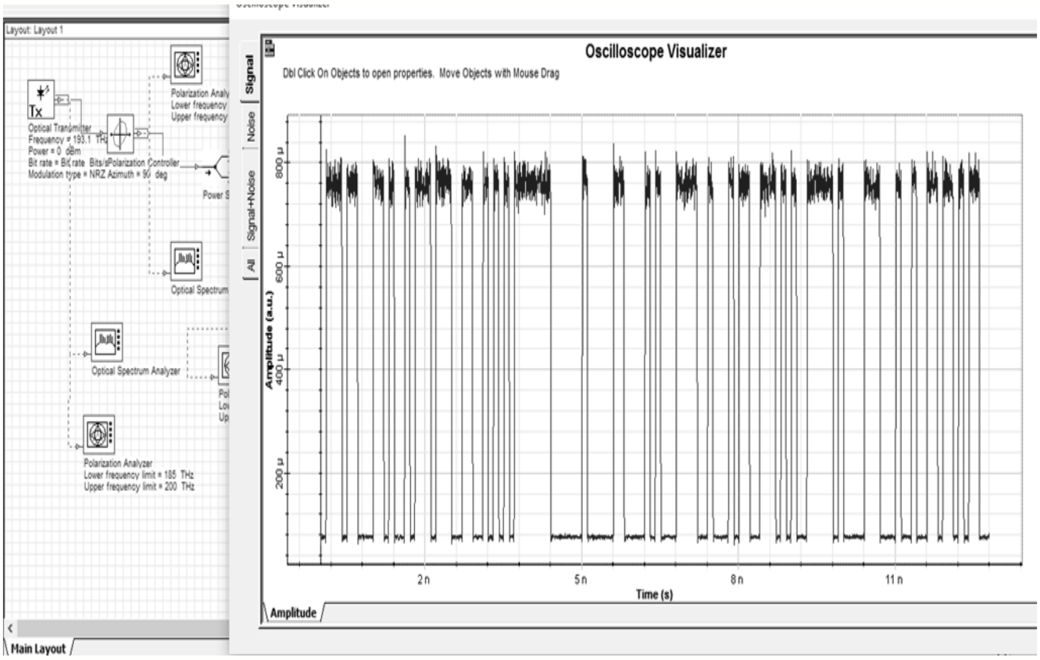


Figure 25 Oscilloscope Result

3.4 Final Experiment

The laser source is transmitting a light of 1550nm wavelength which is fed into the patch chord of 20 meters and received by the photo detector connected at the other side of the patch chord, where the light is converted into electrical signal by the photo detector and amplified by LM324. The output of the amplifier whose gain is 20 is supplied to the analogue pin A0 of the arduino Uno. The arduino is programmed in such a way that if the incoming signal has a voltage less than 3.83 volts then it communicates with the Bluetooth module by commanding the Bluetooth module to send an alert string to the computer by interfacing with mat lab, where this string is compared to another string in mat lab . If the strings are same then the alarm system is activated indicating that an intrusion has occurred.

When there is no intrusion:

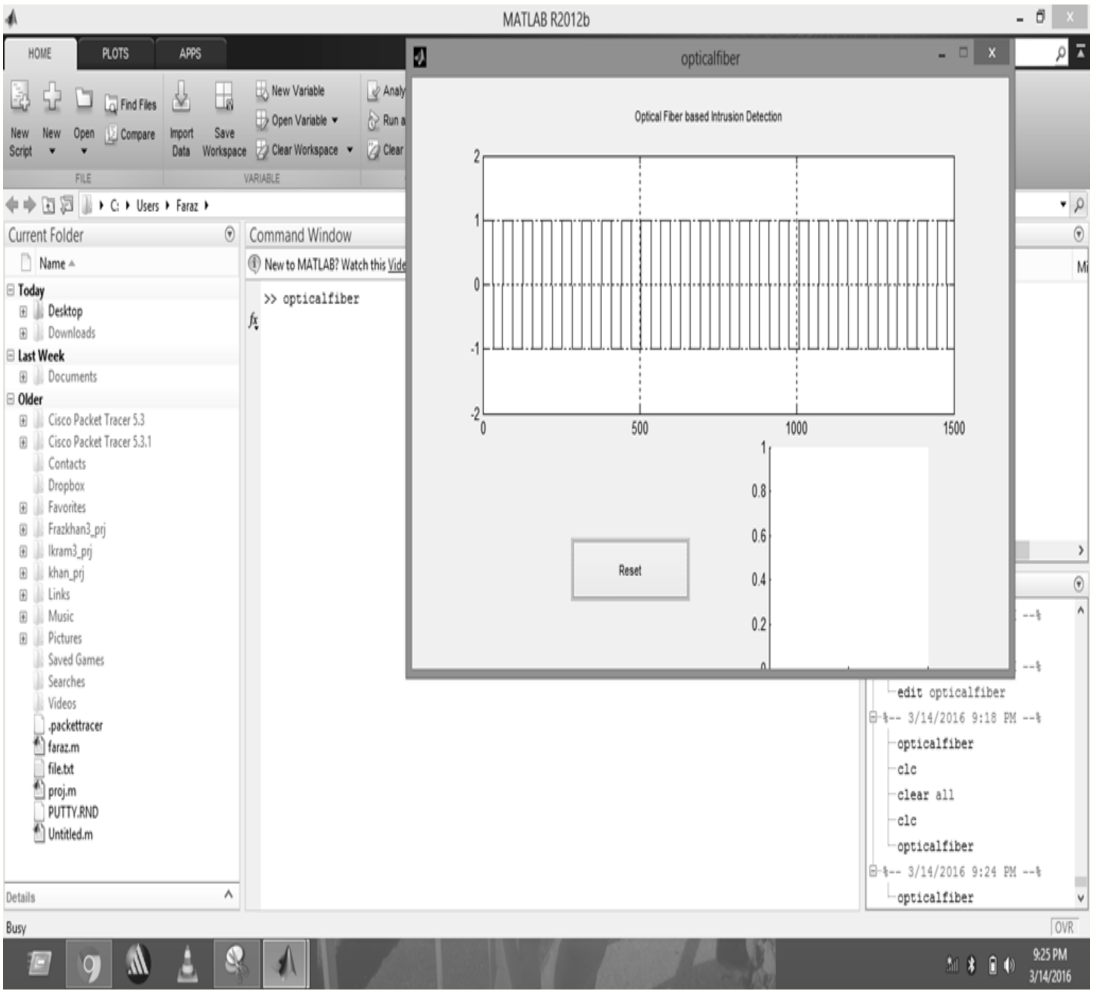


Figure 26 Matlab Output 1

When there is an intrusion the alarm is on:

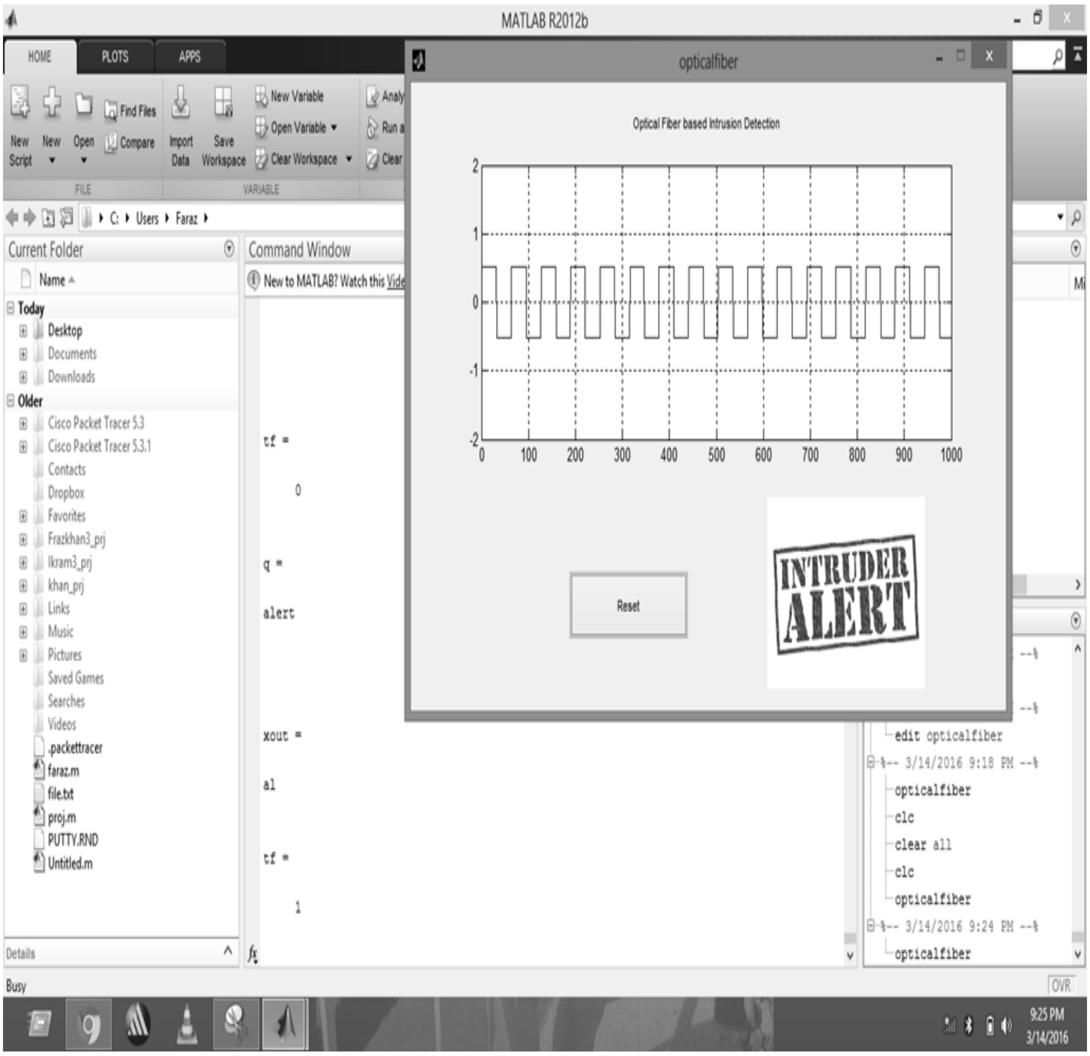


Figure 27 Matlab output 2

3.5 Algorithms and Methodologies

3.5.1 Detection of the intruder

After converting the light into electrical signals the arduino is programmed to set a threshold of 3.7 volt and transmit the alarming command to the Bluetooth module . The Bluetooth module sends the data to the PC via Bluetooth and the alarm system is activated which is programmed in matlab . The programming is done in GUI (graphical user interface) of matlab where a string in GUI is compared to the incoming string via Bluetooth . The sting to be compared is 'alert' and if the strings are same then the alarm system is activated.

The algorithm of arduino is as:

```
#include <Wire.h>

int x1=0;

int y1=0;
int sum[50]={0};
void setup()
 {
Serial.begin(9600);
pinMode(13,OUTPUT);
}
void loop()
 {
int i=0;
while(i<=50)
{
{int x=analogRead(A0);
sum[i]=x;
```

```
i=i+1;
}
  sum1=sum[i]+sum1;
  }
  int avgvalue=sum1/50;
digitalWrite(13,LOW);
//Serial.println(x);
if(avgvalue<=790)
{
  digitalWrite(13,HIGH);
  Serial.println("alert");
  delay(2000);}
else
{
  digitalWrite(13,LOW);
  Serial.println("");
  }
delay(100);
```

}

The algorithm of matlab is as:

```
guidata(hObject, handles);

x=1;

t=0:0.1:150;

sq=square(t);

axes(handles.axes2);

plot(sq);

axis([0 1000 -2 2]);

grid on;
guit1=wavread('alarm.wav');
guit=guit1(1:91000);
sound(guit,44100);
x1=imread('base4.bmp');
axes(handles.axes1)
imshow(x1);
```

% **--- Outputs from this function are returned to the command line.**

```
function varargout = opticalfiber_OutputFcn(hObject, eventdata, handles)
```

```
varargout{1} = handles.output;
```

% --- **Executes on button press in pushbutton1.**

```
function pushbutton1_Callback(hObject, eventdata, handles)

t=0:0.1:150;

sq=square(t);

axes(handles.axes2);

plot(sq);

axis([0 1000 -2 2]);

grid on;

b = Bluetooth('HC-05',1);

fopen(b);

x=0;

%s=serial('COM7','Baudrate',9600);

%fopen(s);

axis([0 1500 -2 2]);

guit1=wavread('alarm.wav');

guit=guit1(1:30300);

sound(guit,44100);

x1=imread('base4.bmp');

x2=imread('intruder.bmp');

p=0;
```

```
while(1)

q=fscanf(b)

xout=q(1:2)

tf=strcmp(xout,'al')

    if(tf==1)

     break;

    end

end

axes(handles.axes2);

sq=sq*0.7;

plot(sq);

axis([0 1000 -2 2]);

grid on;

axes(handles.axes1)

imshow(x1)

sound(guit,44100);

pause(0.6);

axes(handles.axes2);
```

```
sq=sq*0.5;

plot(sq);

axis([0 1000 -2 2]);

grid on;

axes(handles.axes1)

imshow(x2);

sound(guit,44100);

pause(0.6);

axes(handles.axes2);

sq=sq*1.5;

plot(sq);

axis([0 1000 -2 2]);

grid on;

axes(handles.axes1)

imshow(x1);

sound(guit,44100);

pause(0.6);

axes(handles.axes1)
```

```
imshow(x2)

sound(guit,44100);

pause(0.6);

axes(handles.axes1)

imshow(x1);

sound(guit,44100);

pause(0.6);

axes(handles.axes1)

imshow(x2);

sound(guit,44100);

pause(0.6);

axes(handles.axes1)

imshow(x1);

sound(guit,44100);

pause(0.6);



axes(handles.axes1)

imshow(x2);
```

```
sound(guit,44100);

pause(0.6);

delete(instrfindall)
```

CHAPTER 4

FUTURE WORK AND CONCLUSION

4.1 Future Work

Localization of the intruder:

4.1.1 Time Delay

The time delay, τ, between the gated light pulse and the received optical power determines the distance along the fibre from the input end where the reflected light originated, such that

$$\tau = \frac{2L}{v_g}$$

where L is the distance to the point of reflection and v_g the group velocity of the light in the fibre.

4.1.3 Backscattered Power

When the attenuation is constant for both directions of propagation, the

backscattered power, Ps, from a distance, L, can be calculated as :

$$P_s = \frac{F\alpha_s T_p v_g P_i e^{-2\alpha L}}{2}$$

where α_s is the Rayleigh scattering coefficient, α is the fiber loss coefficient, F is the capture coefficient, and Pi is the input power.

4.1.2 Minimum Resolvable Distance

The spatial resolution, Δz, which is the minimum resolvable distance, is determined by the width of the launched pulse.

$$\Delta z = \frac{T_p v_g}{2}$$

Where Tp is the pulse width, v_g is the group velocity.

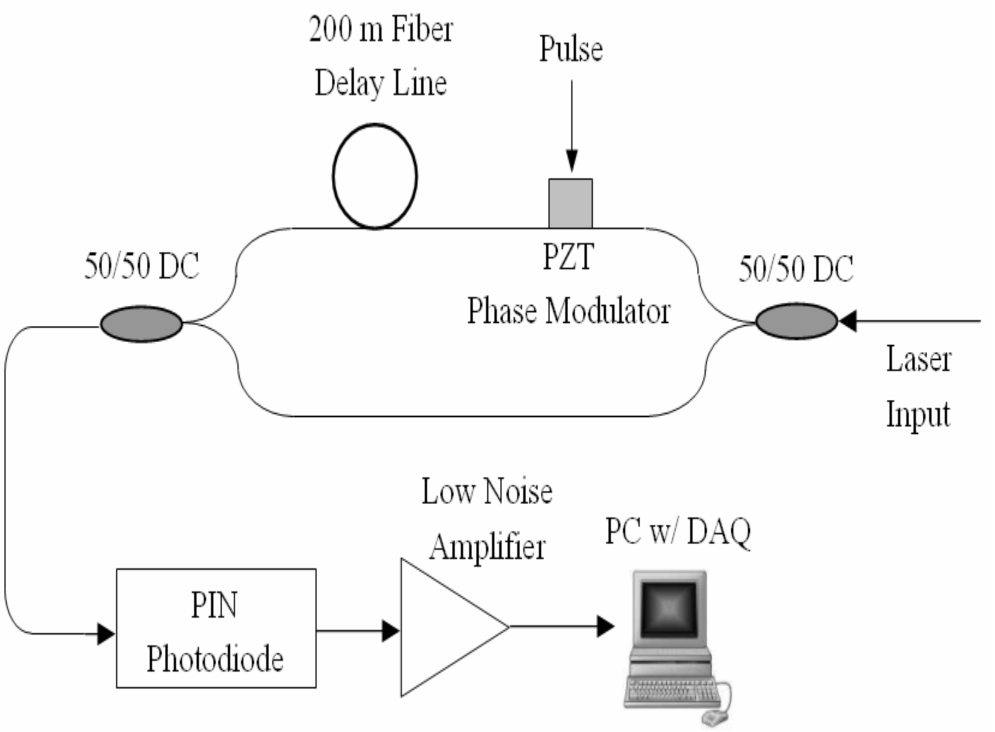


Figure 28 Mach Zhender test setup

4.3 Future Test Setup

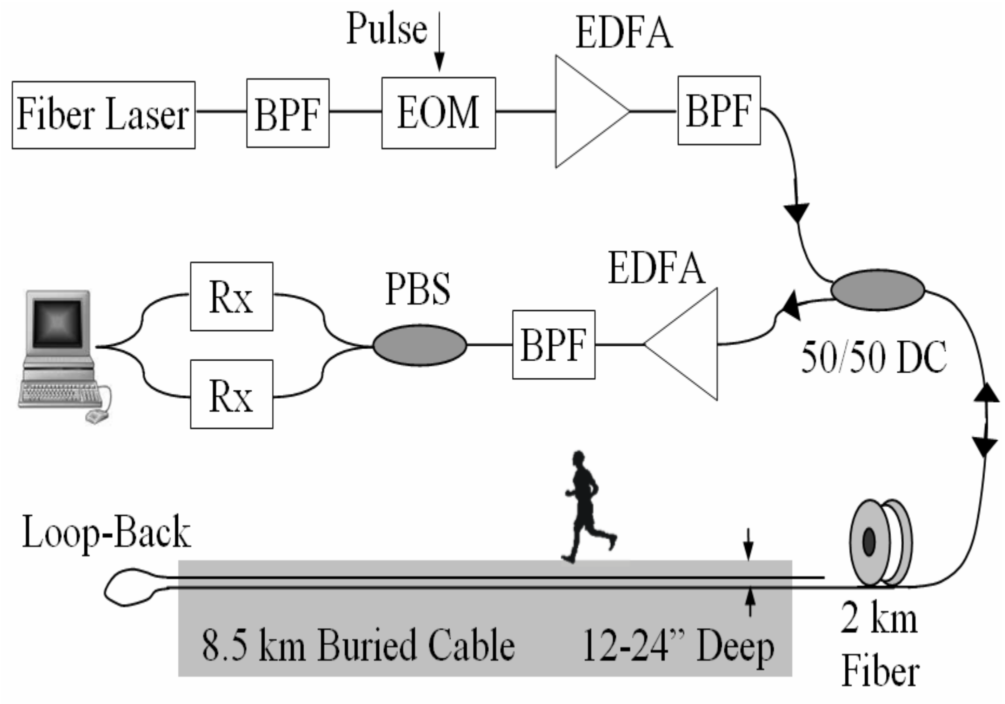


Figure 29 Future Test Setup Configuration

4.4 Conclusion

We can see that most of the existing implementations make use of the Interferometery principle. Substantial work has been done in the field of fibre optical based intrusion and localization. Most of the implementations take place on DSP kits as well as FPGA kits. To make the localization of intruder worthwhile and real-time and achieve better accuracy, the proposed techniques are the principles of OTDR and phase sensitive OTDR.

5 Reference

5.1 Bibliography

[1] Gri_ths, B, Developments in and applications of optic intrusion detection sensors, Security Technology, 1995. Proceedings. Institute of Electrical and Electronics Engineers 29th Annual 1995 International Carnahan Conference on, vol., no., pp.325-330, 18-20 Oct 1995.

[2] Fang, Nian; Wang, Lutang; Jia, Dongjian; Shang, Chao, Walking intrusion signal recognition method for _ber fence system, Communications and Photonics Conference and Exhibition (ACP), 2009 Asia, vol., no., pp.1-2, 2-6 Nov. 2009.

[3] Yannian Wang; Zhengmin Li; Zhuangde Jiang; , An improved distributed optical _ber sensor (DOFS) for monitoring long-distance buried oil pipeline leakage and intrusion, Industrial Electronics and Applica- tions, 2009. ICIEA 2009. 4th IEEE Conference on, vol., no., pp.318-320, 125-27 May 2009.

5.2 Reference

[1] M. K. Barnoski and S. M. Jensen, "Fiber waveguides: a novel technique for investigating attenuation characteristics," Appl. Opt., vol. 15, pp. 2112-2115, 1976.

[2] B. Costa and B. Sordo, "Experimental study of optical fiber attenuation by a modified backscattering technique," in Dig. of 3rd Eur. Conf. on Optical Communication (ECOC), 1977, pg. 69.

[3] M. K. Barnoski, M. D. Rourke, S. M. Jensen, and R. T. Melville, "Optical time domain reflectometer," Appl. Opt., vol. 16, pp. 2375-2380, 1977.

[4] H. F. Taylor and C. E. Lee, "Apparatus and method for fiber optic intrusion sensing," U. S. Patent # 5 194 847, issued Mar. 16, 1993.

[5] S. V. Shatalin, V. N. Treschikov, and A. J. Rogers, "Interferometric optical timedomain reflectometry for distributed optical-fiber sensing," Appl. Opt., vol. 37, pp. 5600-5604, 1998.

[6] W. Seo, "Fiber optic intrusion sensor investigation," Ph.D. dissertation, Dept. of Elect. Eng., Texas A&M University, College Station, TX, 1994.

[7] J. Park and H. F. Taylor, "Fiber optic intrusion sensor using coherent optical time domain reflectometer," Jpn. J. Appl. Phys., vol. 42, pp. 3481-3482, 2003.

[8] K. N. Choi and H. F. Taylor, "Spectrally stable Er:fiber laser for application in phase-sensitive optical time-domain reflectometry," IEEE Photon. Technol. Lett., vol. 15, pp. 386-389, Mar. 2003.

Appendix A

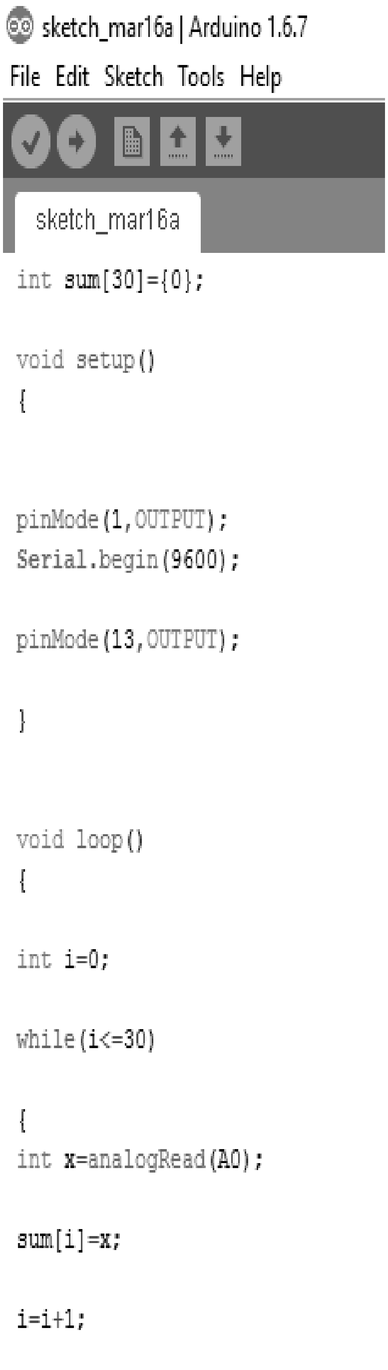
USER MANUAL

This User Manual applies to Arduino (IDE) and Matlab software for optical fibre based intrusion detection system. The purpose of this user manual is to assist the user in using project. Please read this manual thoroughly before using the project to ensure safe and proper use. Descriptions are based on the default settings.

Upload the arduino code

Select the code which needs to be upload after verification on arduino software.

Open the code in arduino software:

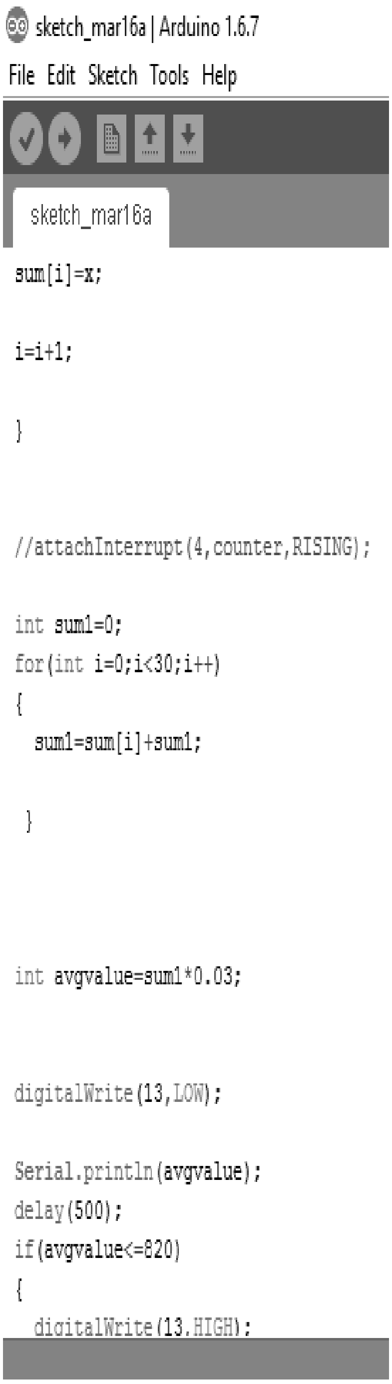


sketch_mar16a | Arduino 1.6.7

File Edit Sketch Tools Help

sketch_mar16a

```
int sum[30]={0};

void setup()
{


pinMode(1,OUTPUT);
Serial.begin(9600);

pinMode(13,OUTPUT);

}


void loop()
{

int i=0;

while(i<=30)

{
int x=analogRead(A0);

sum[i]=x;

i=i+1;
```



sketch_mar16a | Arduino 1.6.7

File Edit Sketch Tools Help

sketch_mar16a

```
sum[i]=x;

i=i+1;

}


//attachInterrupt(4,counter,RISING);

int sum1=0;
for(int i=0;i<30;i++)
{
  sum1=sum[i]+sum1;

 }



int avgvalue=sum1*0.03;


digitalWrite(13,LOW);

Serial.println(avgvalue);
delay(500);
if(avgvalue<=820)
{
  digitalWrite(13,HIGH);
```

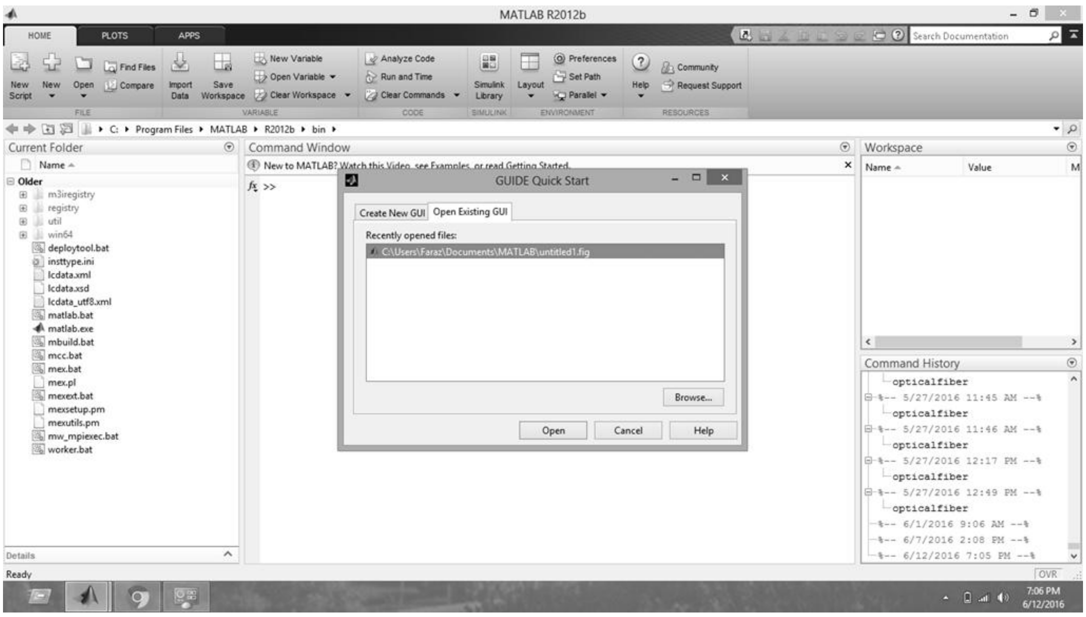
Verify the code

Upload the code

Open the serial monitor and check out the signal level.

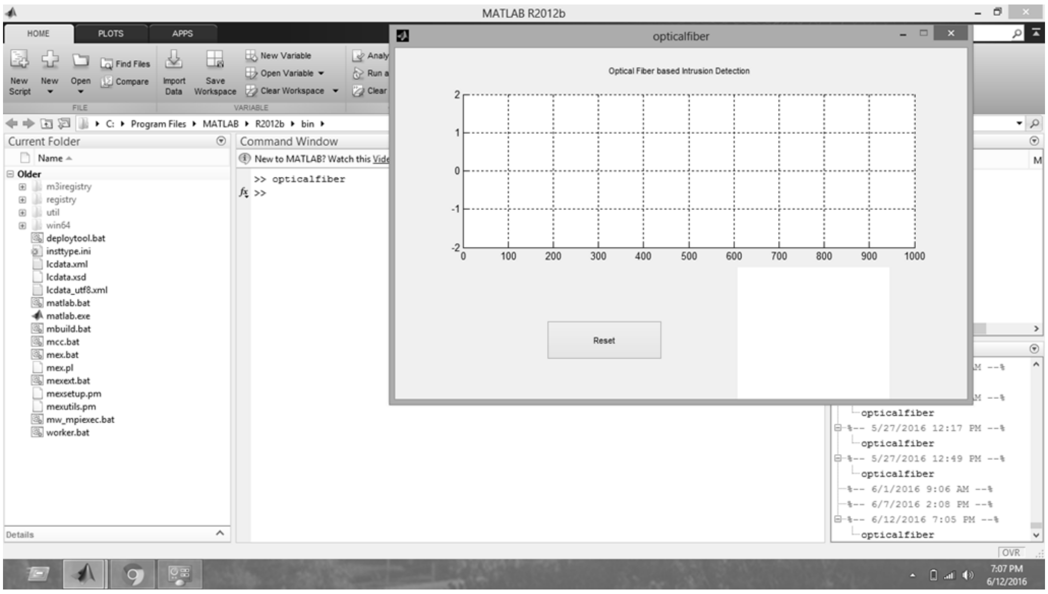
According to the signal level adjust the threshold level.

Open the Matlab and upload all the required files on GUI.

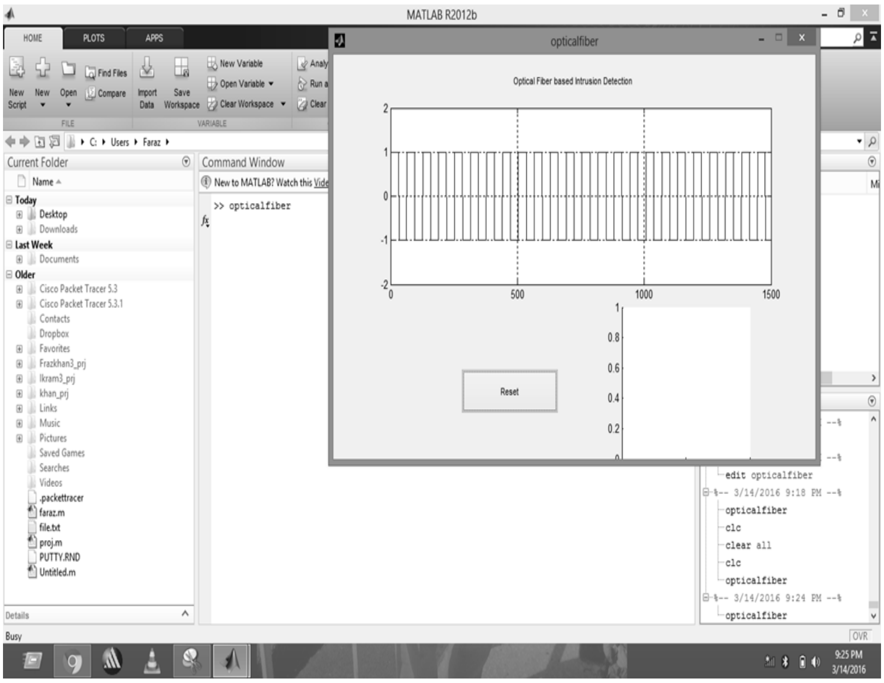


Connect the Bluetooth module with the aruino on Rx Tx ports.

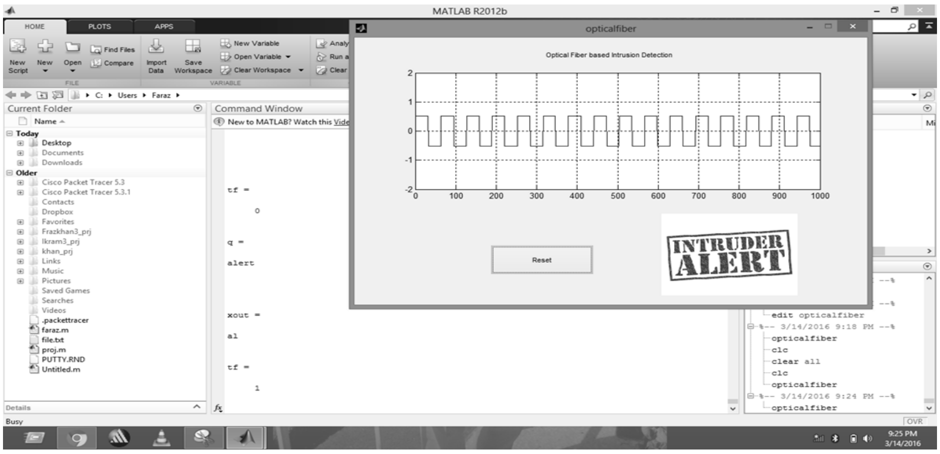
Write the name of the program in the command window the gui will appear.



Before any intrusion the screen will show the waveform.



After the intrusion the screen will show the variation in waveform along with warn



Click the reset button on GUI .