INTERNSHIP REPORT:

Laser Communication and Vibrometer System

Submitted to :

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I will strive to use the skills and knowledge I have gained, and work hard for their improvement.

Ajay Ramesh Ranganathan

Summer Internship Certificate

This is to certify that Mr./Ms. Ajay Ramesh Ranganathan of IIIT, Bangalore has participated in the ***Summer Internship Program*** under my guidance at the Centre for Nano Science and Engineering (CeNSE), Indian Institute of Science, Bangalore, during 20/5/2019 to 02/07/2019 20....

Title: Laser Communication and Vibrometer System Supervised by Mr. Rakesh, TF32, CeNSE

Prosenjit Sen

Centre for Nano Science and Engineering
IISc, Bangalore

CONTENTS

1. Abstract 1
2. Introduction 2
3. Working 3
4. Grazing Laser Vibrometer 6
5. Results 7
6. References 8
7. Appendix 1 9
8. Appendix 2 10

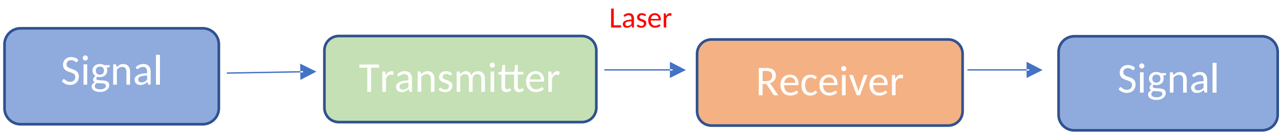
ABSTRACT

Optical communication is a form of communication that uses light as a transmission medium. Laser communication is one kind of optical communication. An analog laser communication system works with the process of 'Amplitude Modulation'. In this process, the amplitude of the carrier wave varies according to the instantaneous amplitude of the modulating signal (input signal). Here, amplitude refers to the intensity of the laser beam. It is a lightweight, high bandwidth and low cost communication method. Its various applications include space communication, military/combat zones etc.

Laser vibrometer is a system used to detect the vibrational frequency of an object/surface using a laser beam in a non-contact manner. Since the reflected laser beam is intensity modulated as a result of vibration of the surface, the vibrational frequency of a surface can be detected by analysing a laser beam that is reflected from the surface. Its applications include automotive industry, space technology, security etc.

INTRODUCTION

A simple laser communication system consists of a transmitter, which encodes a message into an optical signal, a channel, which carries the signal, and a receiver which decodes and reproduces the message.



A 5mW 650 nm Laser diode (Class 3A) is used for transmission. Laser is an acronym for "Light Amplification by Stimulated Emission of Radiation". It is a device that stimulates atoms to emit light of a particular wavelength. The three principles of the working of a laser are –

- Absorption - Electrons in the ground state absorb energy and jump to a higher energy level.
- Spontaneous emission - Electrons can stay in the excited state only for a short period. They thus return to ground state emitting photons.
- Stimulated emission – Incident photons force the excited electrons to return to the ground state. Unlike spontaneous emission, it is an artificial process.

High directionality and low beam divergence properties of a laser beam enable it to travel long distances without spreading. Hence, they are useful for communication purposes.

A solar cell is used to receive the transmitted signal. Solar cell is a device that converts incident light energy into electric current by the photovoltaic effect. The photovoltaic effect is the phenomenon of creation of voltage and electric current in a material upon exposure to light.

A transimpedance amplifier, which is a current to voltage converter is used to convert the current generated by the solar cell, due to incident laser beam, to a usable voltage.

WORKING

The **transmitter** circuit is shown below :

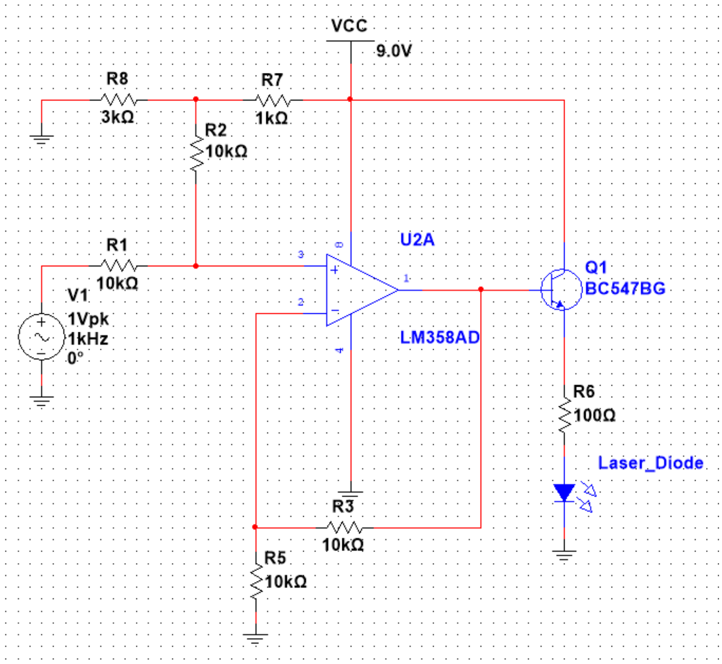
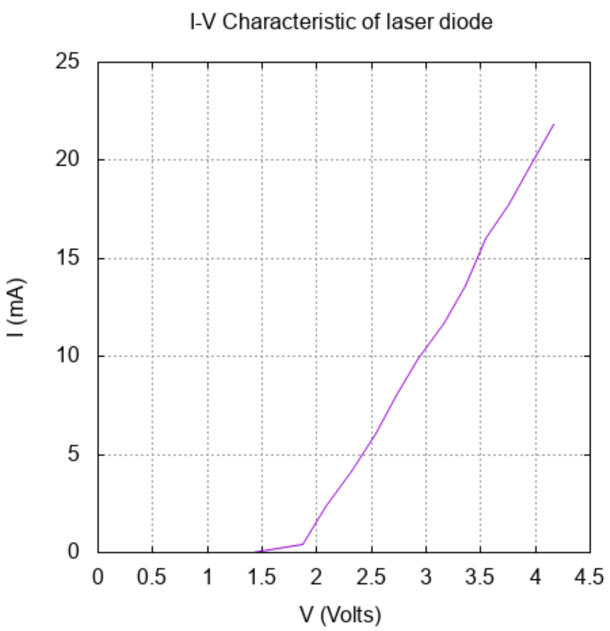


Figure 1

The first part of the circuit is an adder, which adds a DC offset of 6.75 V to the input signal. The DC offset is added to ensure that the laser diode does not turn off during analog modulation. The value of offset was decided on grounds of the knee voltage of the laser diode and that the output voltage from an aux pin is a maximum of 2 Vpp. It is also required to maintain sufficient intensity. The laser is driven by a transistor as the op amp cannot provide for the required current.



The IV characteristic of the laser diode was plotted and the knee voltage obtained –

Knee voltage = 1.9 V

Threshold current = 0.4 mA

Maximum output power = 9 mW (practical)

Intensity = Power/Area = 9mW/3.14 * 5mm*5mm = 11.46mw/cm^2

Figure 2

The Laser modulation current is shown below –

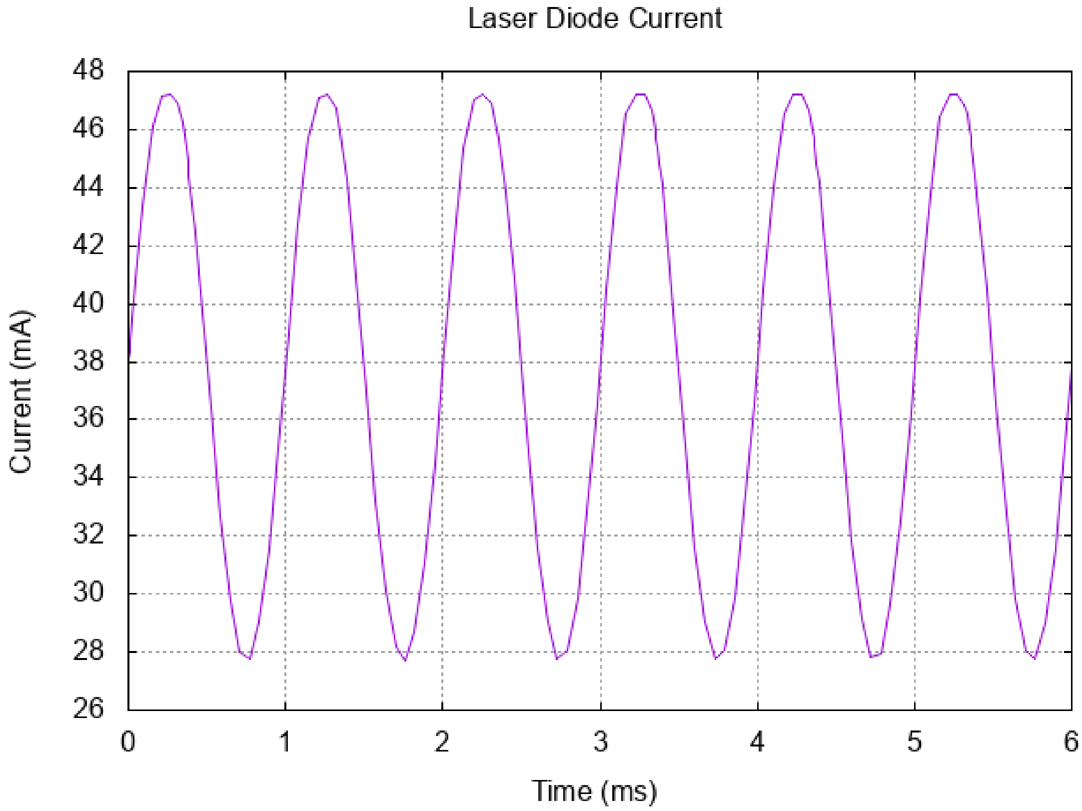


Figure 3

As expected, the frequency of current is equal to the frequency of input signal (1KHz). It is known that the Intensity of light emitted by a laser is linearly proportional to the current through it. Thus, the laser light is modulated accordingly.

The **receiver circuit** is shown below :

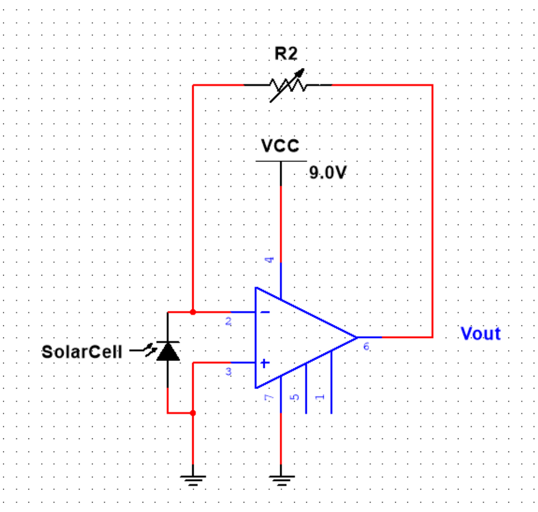


Figure 4

The current generated by the solar cell is provided as input to a transimpedance amplifier. Transimpedance amplifier is a current to voltage converter. It is used because the solar cell has a more linear current response than voltage, with respect to incident light intensity. The output voltage is thus determined by the equation

$V = -IR$

Short circuit current of solar cell = -2.75 mA

Open circuit voltage = -0.5 V

Quantum efficiency is defined as the ratio of number of carriers collected by the solar cell to the number of photons of a given energy incident on the solar cell. The quantum efficiency of the solar cell used is 80% at 650 nm wavelength.

The laser current vs solar cell current is shown below –

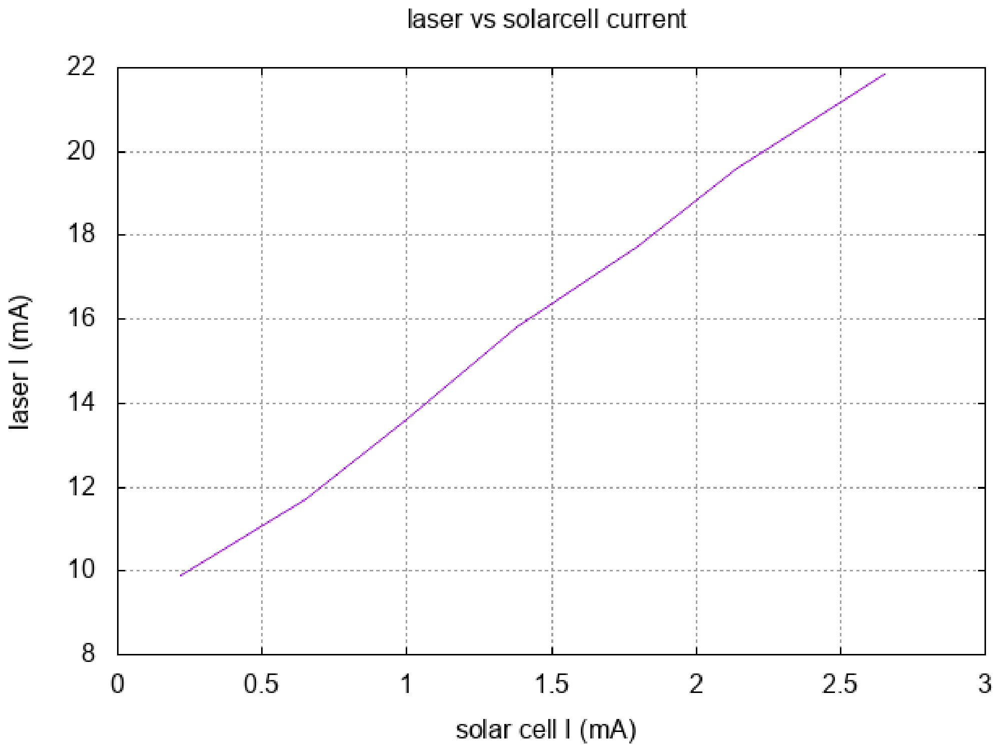


Figure 5

The fact that the exact signal that is transmitted can be recovered, is a consequence of the linearity of the above plot.

Thus, audio was transmitted successfully using this system.

GRAZING LASER VIBROMETER

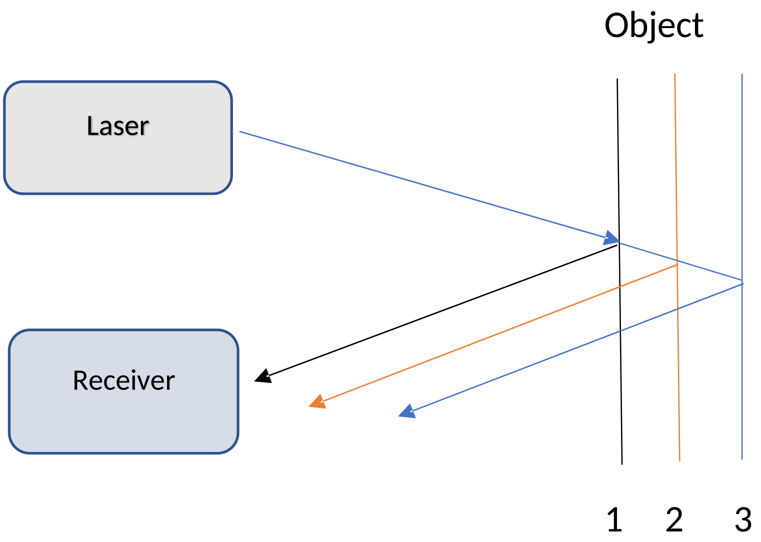


Figure 6

A grazing laser vibrometer is a system used to detect the vibrational frequency of a surface. When a laser beam is reflected off the surface of the vibrating object, the reflected rays reach the receiver at different instants of time as shown in the figure. The light reflected when the object is in position 1 reaches faster than the light reflected when the object is in position 2. Intensity of light varies inversely with square of distance. Thus, an intensity variation with the same frequency as that of the vibrating object is observed at the receiver.

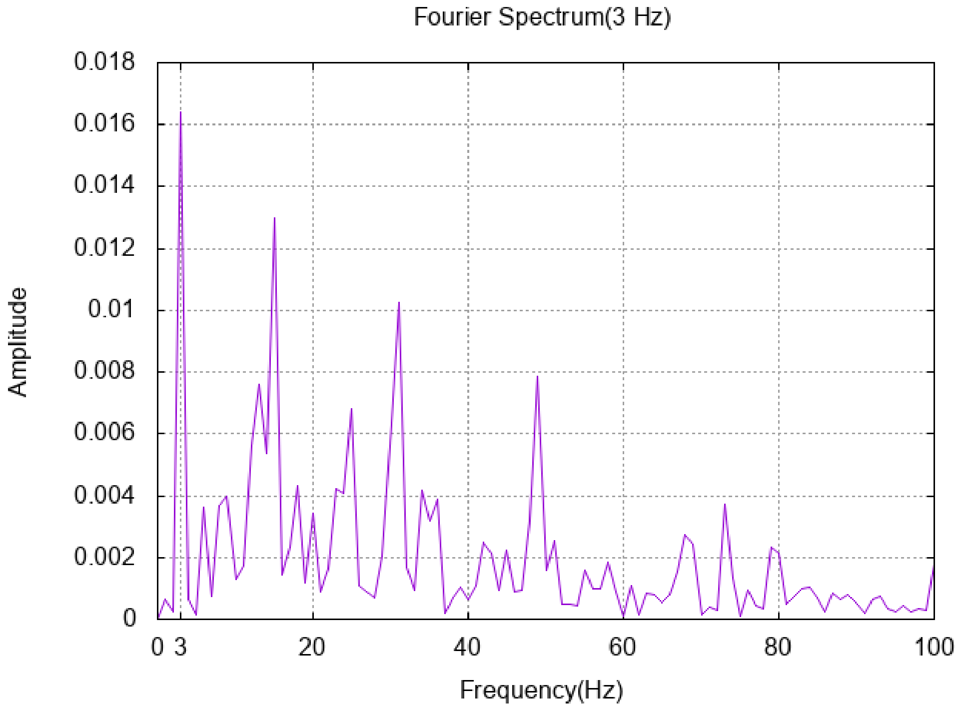
EXPERIMENTAL SETUP –

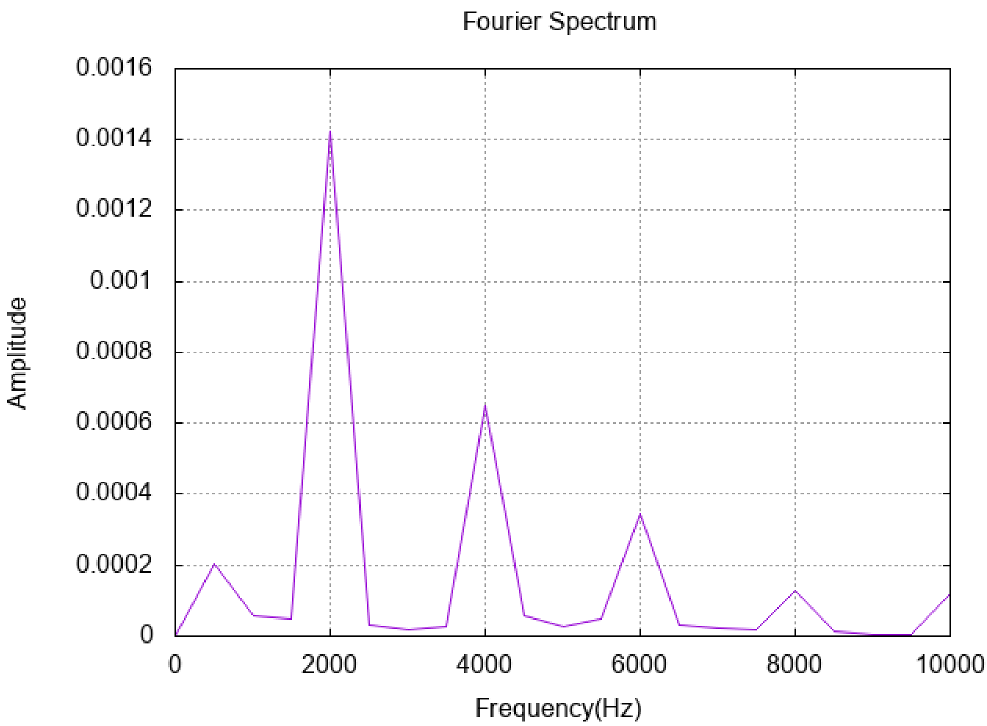
AN 8 ohm 0.5W speaker was tightly covered with elastic material to allow for maximum pressure build up. A piece of aluminium foil was glued to the elastic material.

Sound waves travel in air as compressions and rarefactions. Hence, the sound emitted by the speaker causes vibrations in the aluminium foil. The laser was reflected off the aluminium foil and the speaker was driven by a function generator to test the system. The receiver signal was captured and processed to detect the vibrational frequency.

RESULTS

The vibrometer system can detect frequencies from 3Hz to 2KHz. Fourier analysis of the signals is shown below –





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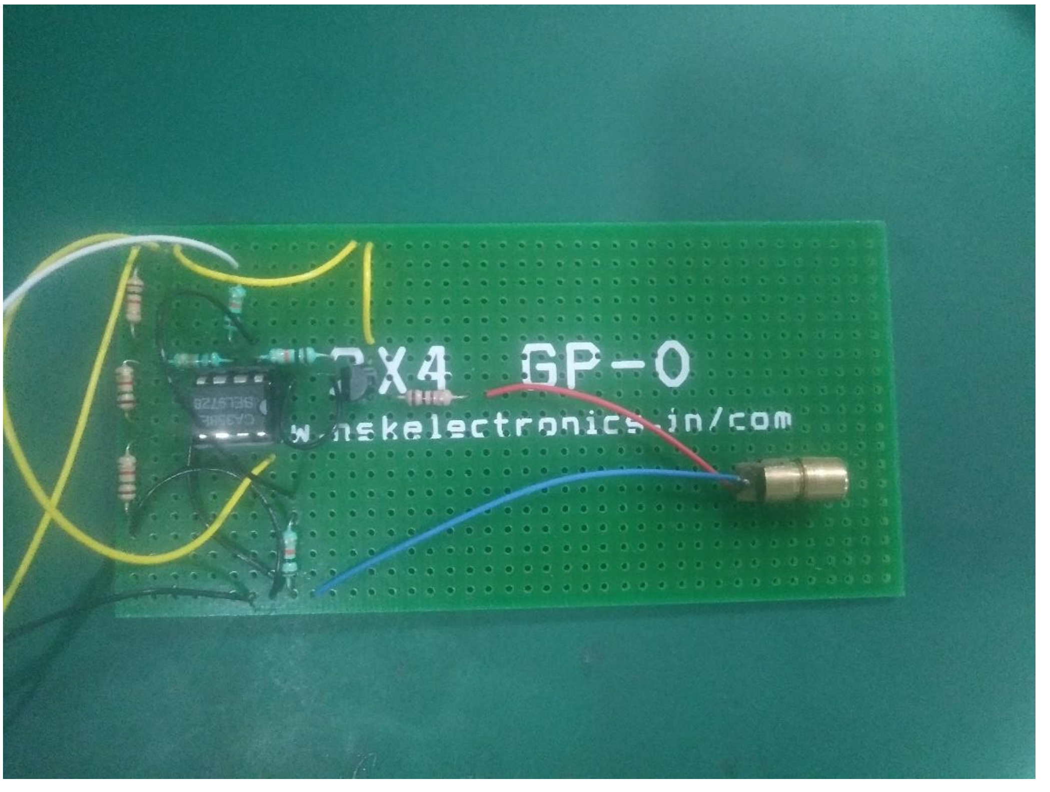
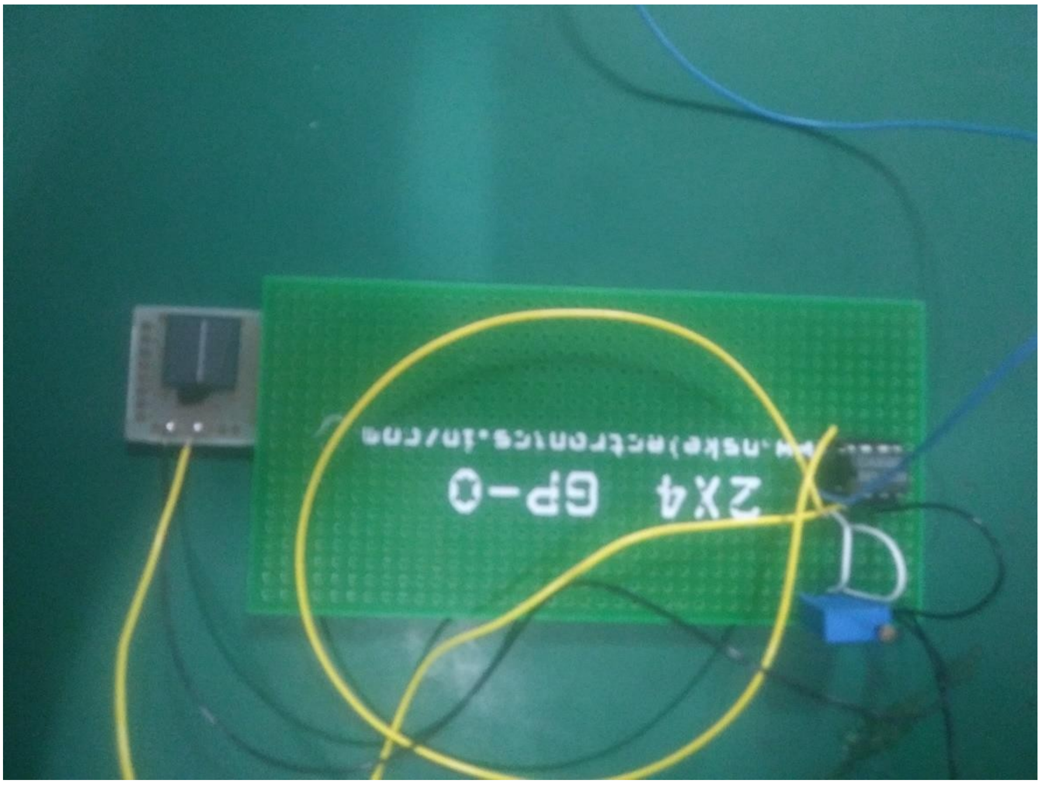
APPENDIX 1

Transmitter –



Receiver -

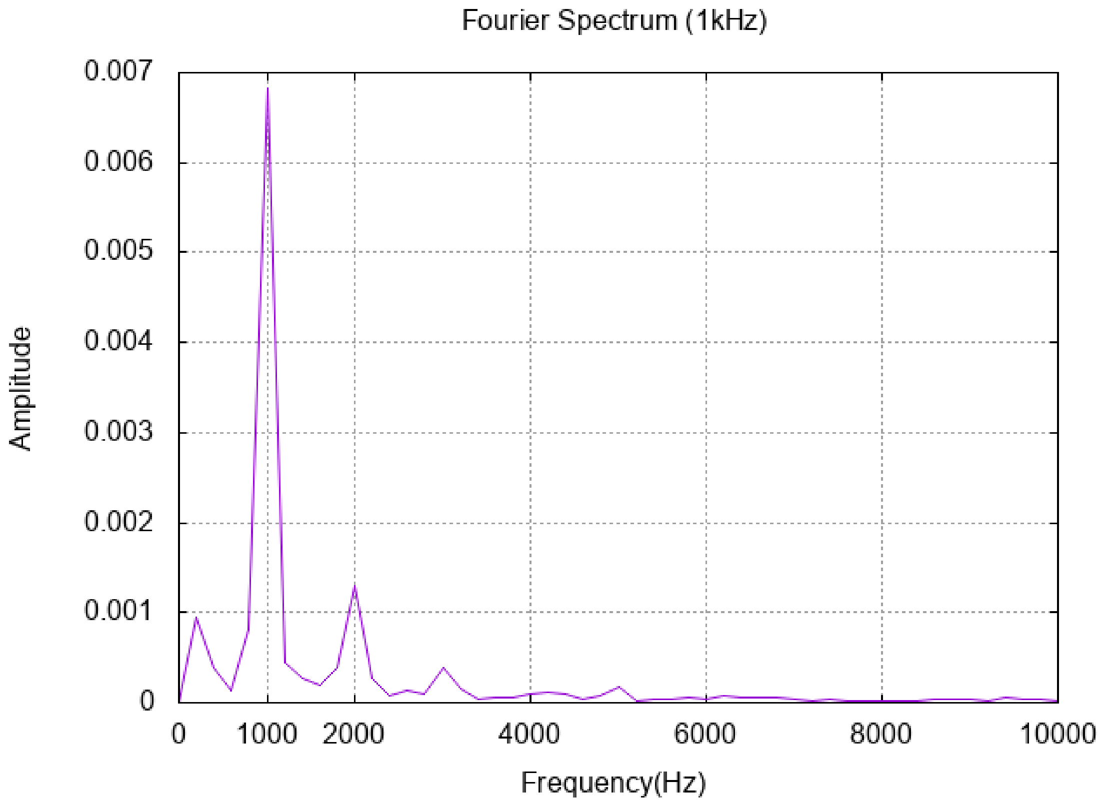


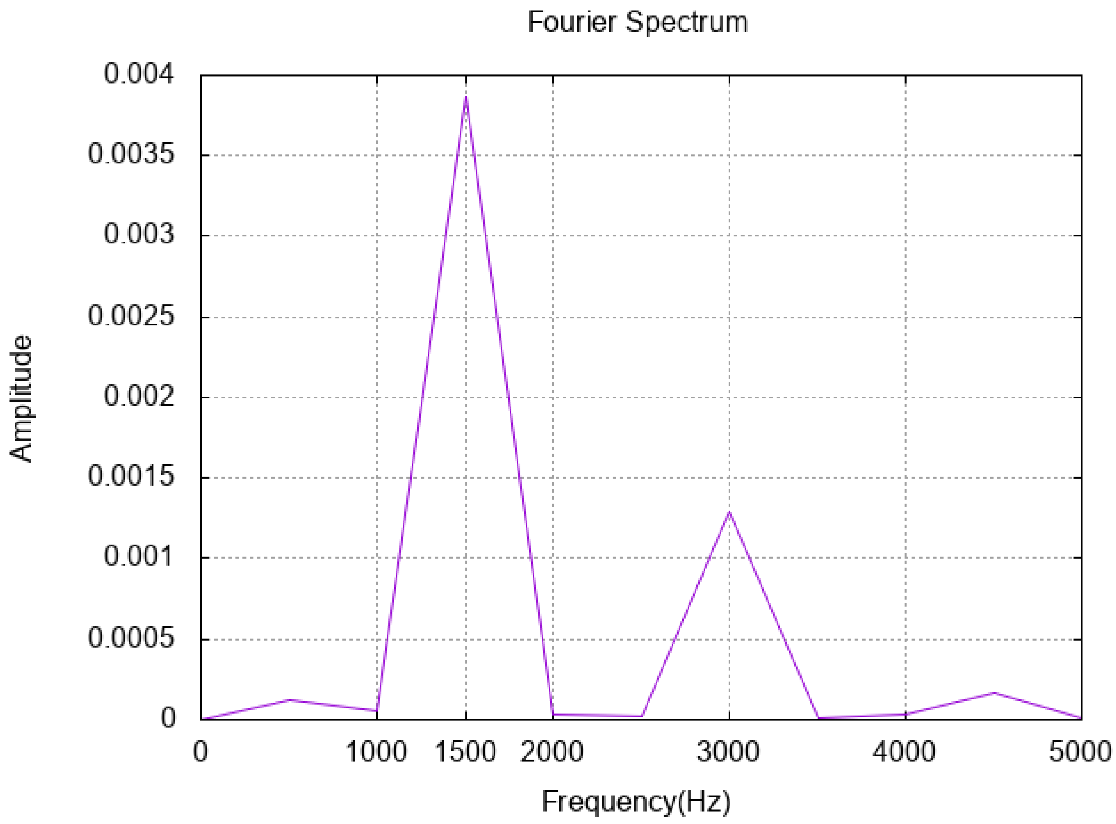
APPENDIX 2

Octave code to obtain the Fourier spectrum –

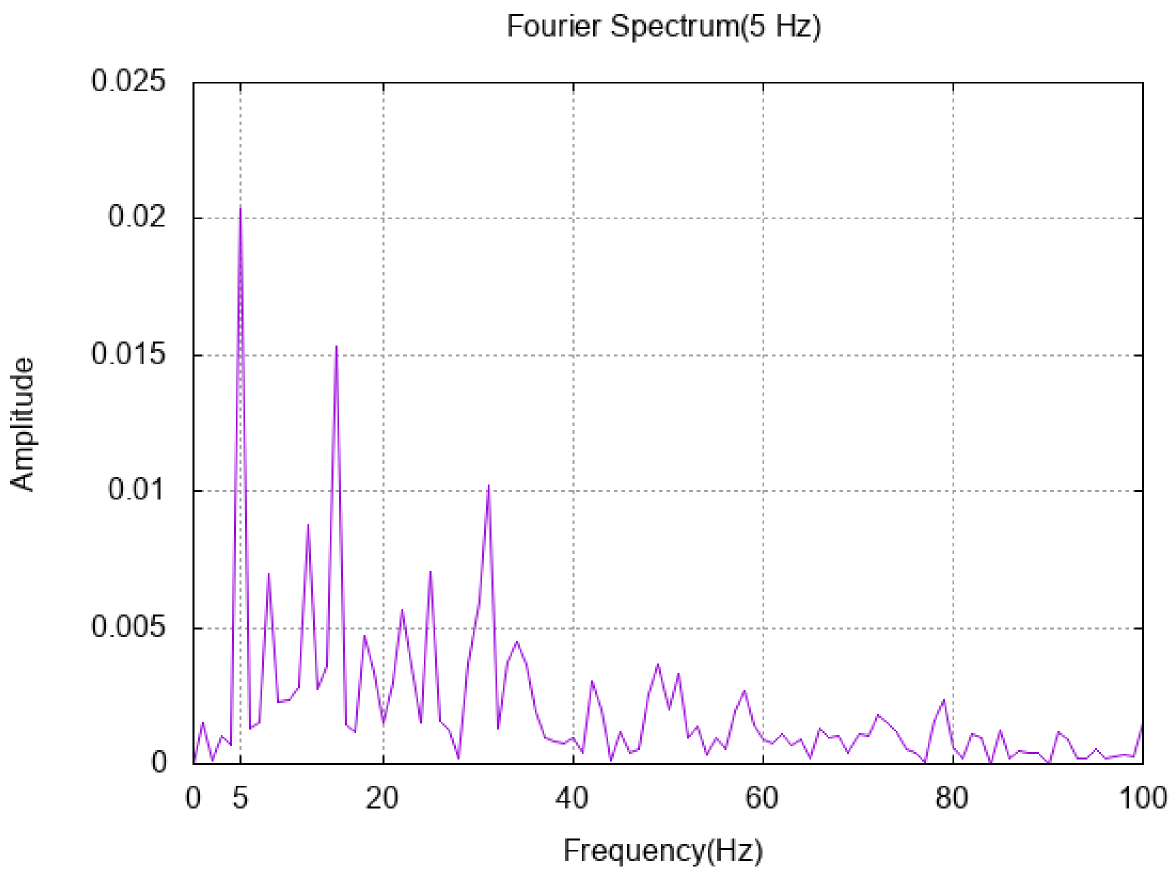
```
filename = 'DS0019.csv'  #file to read
M = csvread(filename);
time = M(:,1);
voltage = M(:,2) - mean(M(:,2));  #remove DC
plot(time,voltage);
T = 2.00E-04;  #sampling period
Fs = 1/T;
disp(Fs);
N = length(time);
F = fft(voltage);
F2 = abs(F/N);
F1 = F2(1:N/2 + 1);
F1(2:end - 1) = 2*F1(2:end - 1);
freq = Fs*(0:N/2)/N; #frequency axis
figure;plot(freq,F1);
freq = freq';
output = [freq,F1];
output_filename = 'output6.csv'; #write to file
csvwrite(output_filename,output);
```

Few other results -





Fourier Spectrum
Amplitude
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
1000
1500
2000
3000
4000
5000
Frequency(Hz)



Fourier Spectrum(5 Hz)
Amplitude
0.025
0.02
0.015
0.01
0.005
0
0
5
20
40
60
80
100
Frequency(Hz)