Int. J. Nanoelectronics and Materials **6** (2013) 9-16

The response of a window glass to the frequencies of sound

Nathera A. A. Al-Tememee[1*], Salwan K. J. Al-Ani[2], Dhefaf Y. S. Al- Mashhadani[3]

[1] *Department of Physics, College of Science, Baghdad University*
[2] *NCPW, P.O. Box (25777), Doha, Qatar*
[3] *Department of Physics, College of Science, Nahrain University*

Received 3 Jan. 2012; Revised 14 Jan. 2012; Accepted 6 March 2012

Abstract

There are a several methods for detecting sound inside a building. In research a method of a beam splitter is used for detecting sound and therefore reflectance and transmittance of windows to the sound have been studied. The response of the window glass to the frequencies of sound has been studied by using laser diode (λ=630nm; P=1mW) and a silicon detector is being used to measure the intensity of the modulated beam. The design of the experimental setup used in this work is reported.

It is found that the vibrations of the glass are low at frequencies from 20-200 Hz and much of the sound energy falls within the frequency range 200 -500 Hz where the resonance frequency is detected at 400Hz.

Keywords: Vibration; Acoustical properties; Laser diodes; Modulation.
PACS: 62.30.+d; 62.65.+k; 42.55.Px; 42.60.Fc.

1. Introduction

The voice of a human sends out energy. This energy makes the air molecules to vibrate and the vibration hit a window glass, the molecules of the glass window start to vibrate in fixed positions. When a laser beam is aimed toward the window, this vibrations cause instantaneous change in the angle of incidence of the laser beam, therefore the angle of reflected beam on the detector will be changed, which cause a change in the intensity of the current passes through the detector. The change in the laser beam intensity with angles of the incident and reflected rays from the detector within the glass vibration, indicates that the sound waves had been modulated on the laser beam [1].

Modulation is defined as the process of varying the amplitude, phase, frequency, intensity, and, polarization of a carrier to convey an information signal [2,3]. There are two distinct methods where optical waves have been modulated for communication purpose:

1. Direct Modulation; in which the source itself is caused to vary its output power [4].
2. External Modulation; in general consists of an optical waveguide in which the incident light pass through and the refractive index of the medium is modulated by the information signal [5, 6].

*) For correspondence, E-mail: nathera_2007@yahoo.com

The aim of this research is the design of the experimental setup to study the response of a window glass to the sound frequencies in the range 200-500 Hz.

2. Experimental Part

The system components consist of the transmitter, receiver circuits, reflective object and the variable function generator.

Our design depends on some calculation regarding the electronic components such as detector; transistor and laser diode. These considerations are illustrated in Table (1).

Table 1: The experimental values of the transmitter and the receiver circuits

Transmitter circuit		Receiver circuit	
V_{base}	0.405 V	$I_{det.}$	1.2mA
I_T	0.01A	V_{base}	2.16V
Regulator(7805)	5V, 0.5A	Voltage amplification	100
R_{diode}	0.32Ω		
		Cutoff frequency	3KHz
		R_{filter}	53Ω
		Current gain	250

2.1 Transmitter Circuit

The circuit used in this work consist of a light source; power supply, capacitor, transistor, resistor and regulator [7] which is illustrated in Figure 1.

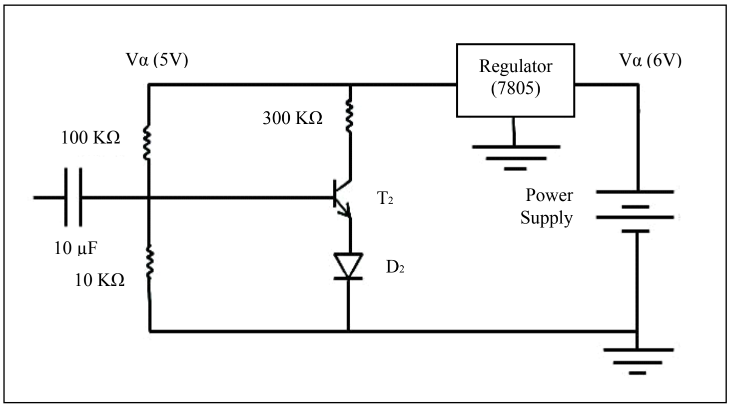

Figure 1: The design of the transmitter circuit.

2.2 Receiver Circuit

Receiver circuit used in this work consists of optical detector (PIN silicon photo diode), power supply, preamplifier circuit, low pass filter and oscilloscope [7] illustrated in Figure 2.

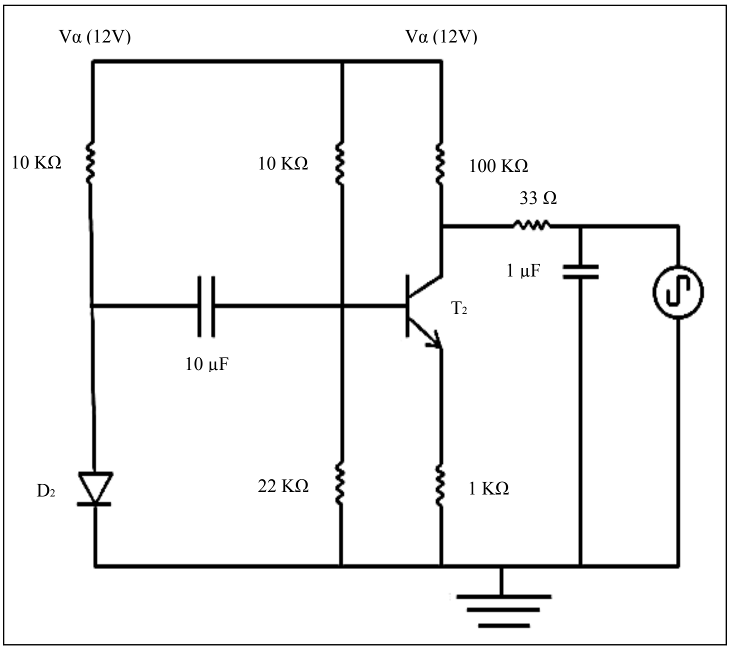

Figure 2: The design of the receiver circuit.

2.3 Reflective Object

Window glass silica (SiO_2) type of different thickness and colors is used as a reflector. This glass placed on the vibrating surface (speaker) to vibrate.

2.4 Variable Function Generator

Variable function generator (501A, 2MHz) is used to generate frequency. It is connected directly in order to select the required frequencies.

The laser beam is obtained by using LD of wavelength 630nm. This beam is modulated separately by different sound waves obtained from an oscillator. After its incidence and reflection from a window glass; the silicon photodiode detector receives the modulated beam, which connected to the channel one of oscilloscope on which a sine wave representing the received beam will be shown.

The resonance represents the largest vibration of the glass, and, the process has been carried out to all thicknesses in order to obtain the maximum response for each glass to the sound frequencies. The setup of the system is illustrated in Figures 3 and 4.

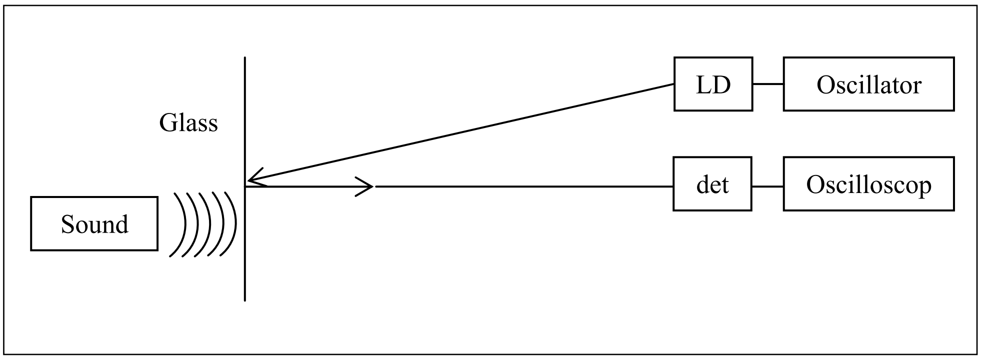

Figure 3: The resonance effect.

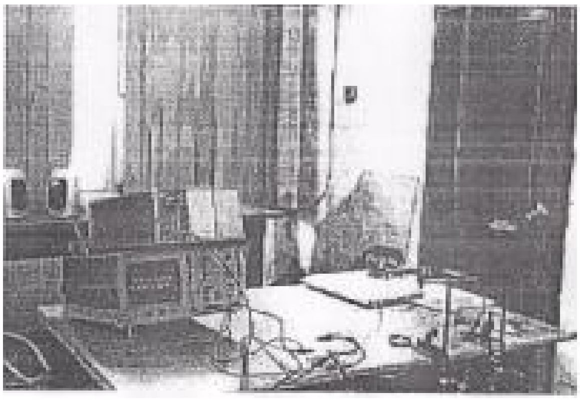

Figure 4: The set up of the system.

3. Result and Discussion

3.1 Merits of Circuit Design

The designed receiver and transmitter circuits have the properties given in Table 1. The transmitter circuit consist of common emitter transistor with high gains and voltage divider consist of two resistors connected in series with the base of a transistor in order to obtain small value of voltage. This assembly has connected to a regulator to fix the voltage in order to achieve a safe circuit work.

While the receiver circuit consists of preamplifier circuit consist of common emitter transistor with high voltage amplification and low pass filter with cutoff frequency equal to 3 KHz is calculated according to the cutoff equation.

The capacitance value is chosen to be 1μF, and the required resistance was 53Ω as listed in Table 1. These values are essential to run two circuits with voltage amplification 100 and current gains 250, which enable us to use the laser and silicon detector.

3.2 The Relation Between the Amplitude and Frequency of Sound

Once the laser beam modulated by different frequencies is aimed towards the window glass, the molecules (atoms) start to vibrate. The first molecule strikes the second and the second strikes the third, and then the first molecule starts slowly back to the original position [8].

Figures 5-10 display the amplitude of the reflected beam versus frequency of a window glass of different thicknesses and colors. It is found that the vibrations of a glass are low at frequencies from 20-200 Hz. Then the height of the peak indicates the strength of oscillation [9]. Results from the application of harmonic component are located at frequency called resonance. At this frequency the vibration of windows reaches its maximum value. Much of sound energy, the source falls within the frequency of range 200-500 Hz, the resonance frequency appears at 400 Hz. Resonance frequency depends on the material of the glass [10]. Each glass that is used in this work has the same dimensions. Above these frequencies the energy of sound decays and the oscillation of glass begins to decrease until it reaches frequency in the range 1000 -3000 Hz (the vibration of these windows does not appeared at higher frequencies).

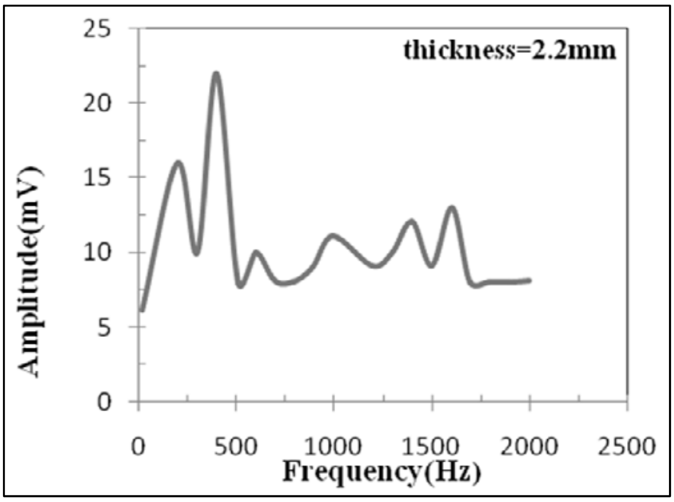

Figure 5: Amplitude of reflected beam (mV) vs. frequency (Hz) for glass thickness 2.2mm.

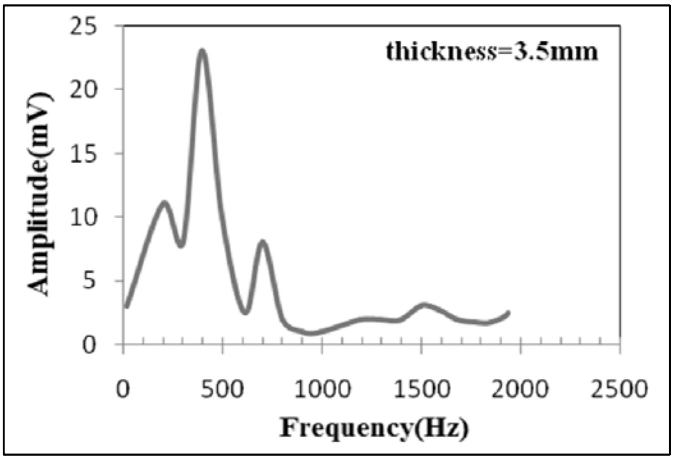

Figure 6: Amplitude of reflected beam (mV) vs. frequency (Hz) for glass thickness 3.5mm.

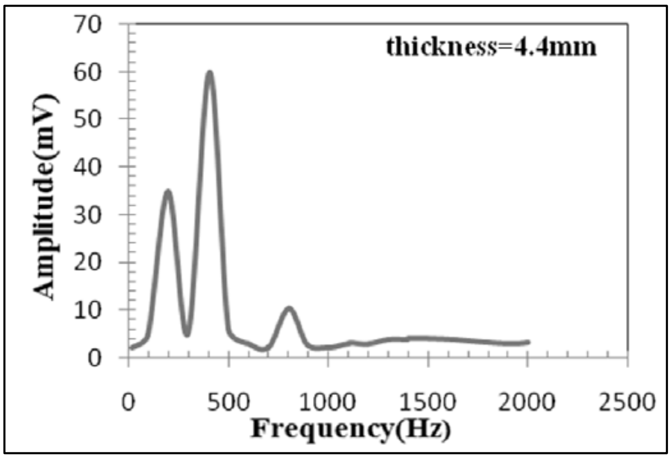

Figure 7: Amplitude of reflected beam (mV) vs. frequency (Hz) for glass thickness 4.4mm.

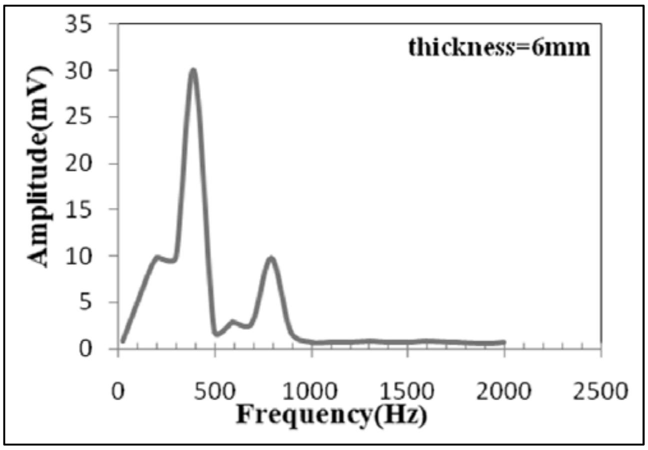

Figure 8: Amplitude of reflected beam (mV) vs. frequency (Hz) for glass thickness 6mm.

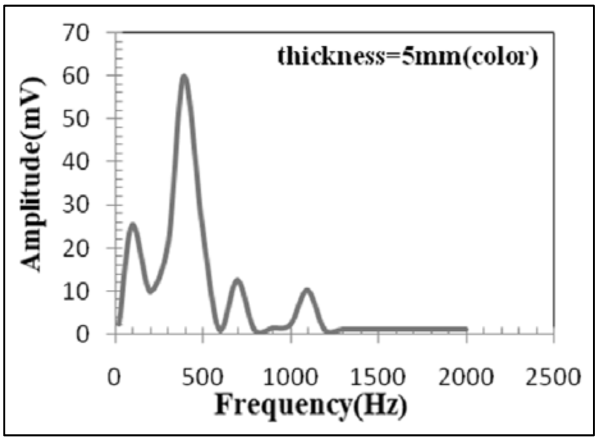

Figure 9: Amplitude of reflected beam (mV) vs. frequency (Hz) for colored glass thickness 5mm.

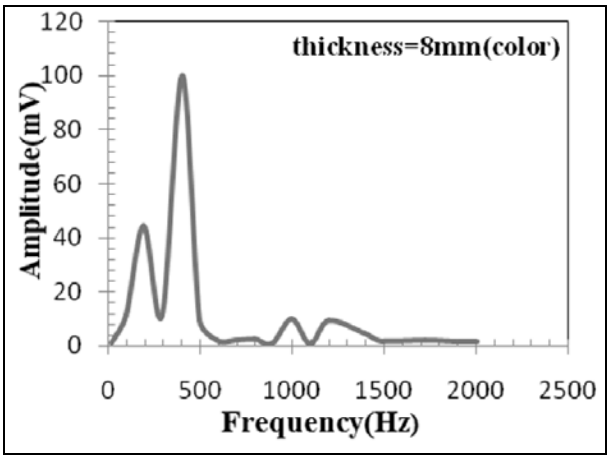

Figure 10: Amplitude of reflected beam (mV) vs. frequency (Hz) for colored glass thickness 8mm.

Figure 11 shows the highest amplitude versus the thickness of the window glass at the resonance frequency (400Hz) for uncolored and colors glass windows. From this figure it is found that in order to reduce the reflected laser beam from the windows, a glass of high thickness and dark color must be used because it is difficult to vibrate and transmit sound as the vibration depends on the number of atoms (as well as its mass of the color window).

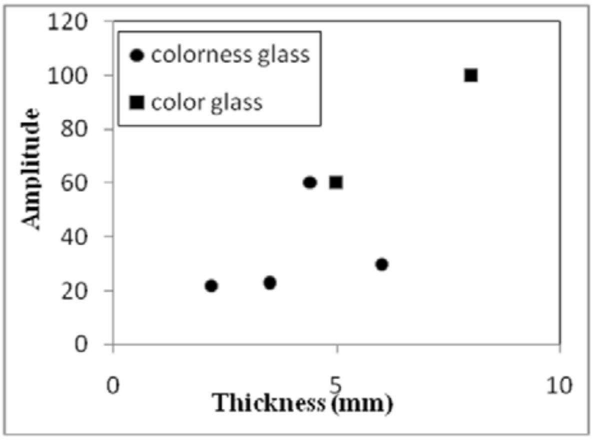

Figure 11: Height's amplitude of reflected beam (mV) vs. thickness (mm) of different glasses at the resonance frequency.

4. Conclusion

Once the laser beam is applied towards the window glass of different thicknesses and colors and the sound generated near the windows, the following conclusions have been drawn from this work:

- The aim of this work is to detect a sound within a room having outside windows, by using incident laser aimed toward a window glass of different thicknesses and colors.
- The molecules of glass start to vibrate and then modulated with the laser beam. The incident beam on the receiver converts this modulation into conversation.
- The circuits of the receiver and transmitter have been designed for this purpose.
- The reproducibility and reliability of our design was very high, when repeating the experiment in different occasions and circumstances.
- Maximum response to the windows in the range of frequencies 200-500 Hz, and the resonance frequency is 400Hz.
- The incident beam on the colored glass will not penetrate, there isn't a transmitted ray and all energy is reflected i.e. The vibrations of dark windows are very weak. Thus this glass may be used in buildings to minimize detection of sound and the information that will be obtained from these windows is very little.

The results show the modulated laser beam that reflected from colored glasses is higher than the uncolored glass suggesting its suitability and utility in closed rooms.

References

[1] M. S. Mahdi, *Infrared Laser Window Detection System*, the Military College of Engineering, Baghdad, Iraq (2000)

[2] M. Kang and M. Liu, *Principles and Application of Optical Communication*, Mc Graw-Hill (1996)

[3] W. E. Veritt and G. E. Aneer, *Communication Engineering*, 3rd Ed Mc Graw-Hill, New York (1956)

[4] M. J. Beesley, *Laser and Their Applications*, Taylor & Farancis Ltd. London (1976)

[5] Qing Wang and Jianping Yao, Optical Society of America, Vol. **15** (25) (2007) 16500-16505

[6] R. W. Dixon and E. I. Gordon, The Bell System Technical Journal, (1967) 367-389
[7] Sensors Magazine, *A New Detector For IR LED Light* Report (1996)
[8] L. F. Yerges, *Sound Noise, and, Vibration Control*, New York; Van-Nostrand (1969)
[9] K. Furuya, Y. Suematsu and T. Hong, Applied Optics, Vol. **17**(12) (1978) 1949-1952
[10] J. D. Quirt, http:// irc, nrc. Gc. Ca/pubs/cbd 240_ehtml (2007)