Sudan University of Science and Technology

Collage of Graduate Studies

Detection of Chemical Bonds for Some Plant Leaves in Shadow and Sun Using Assembled Ultrasound Spectrometer

الكشف عن الروابط الكيميائية لبعض أوراق النباتات في الظل و الشمس بإستخدام المطياف فوق السمعي المجمع

A Thesis Submitted for the Fulfillment of the Award of PhD in Physics

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الاية

بسم الله الرحمن الرحيم

قال تعالى:

وَتَرَى الْأَرْضَ هَامِدَةً فَإِذَا أَنْزَلْنَا عَلَيْهَا الْمَاءَ اهْتَزَّتْ وَرَبَتْ وَأَنْبَتَتْ مِنْ كُلِّ زَوْجٍ بَهِيجٍ

صدق الله العظيم

سورة الحج الآية 5

Dedication

To my family, especially to my parents, who gave me self-confident, happiness, knowledge and education? To my kids, to those who guided and supported me to achieve goals.

ACKNOWLEDEMENTS

First of all , thanks to god for guiding me to conduct this study. I am profound grateful to express my appreciation and thanks to my supervisor prof. Mubarak Dirar Abd-Alla for his continuous guidance, advising and encouraging during preparing the thesis. Thanks extend to Sudan University of science and technology, graduate college, faculty of science, department of physics, for enabling me to do this work. I would like to extend thanks also to those who help me in doing practical work specially Abdu alsakhi Suleiman Hamid and T. Abdu Alazeez Gasim .

Abstract:

New ultrasonic spectrometer was assembled using laser to generate ultrasound from molecules and atoms in addition to USP 2000 spectrometer connected to a computer. Apiezoelectric sensor is also used. The function of piezoelectric is to receipt the ultrasound generated. The spectrometer receipt the diffraction laser beam by sound waves to give its wavelength.

This spectrometer was used to determine the chemical bonds of Bougainvillea SPP1, Citrus Sanseis, Canna Indicia ,Ixora Coccinnia, Bougainvillea SPP2, Citrus paradisi, leaves which grow in shadow and grow in regions exposed to the sun directly. Two approaches
were used for bond characterization.

One is named the pulsed regime which determine the bonds from the ultrasound pulse directly. The other regime is called Bragg regime which determine the bonds due to Bragg diffraction of the laser deflected beam using USP 2000 spectrometer connected to a computer.

The results obtained showed that the exposure of the plants to the sun change the strength of the chemical bonds as well as the crystal spacing and sometimes generates new bonds in the sun.

The results obtained indicates existence of S-S, C-S,C-H, Stretching in all samples.

However Ixora Coccinnia and Bougainvillea SPP2 has extra S=0 bond in the sun, while citrus has additional N- H and, O-H bonds in shadow and sun. The fact that extra bonds can be formed in the sun can be used in herbal drugs to produce new effective ingradient.

مستخلص البحث

تم تجميع مقياس جديد للطيف بالموجات فوق الصوتية بإستخدام الليزر لتوليد الموجات فوق السمعية من الجزيئات والذرات بالإضافة إلى مقياس USP 2000 المتصل بجهاز كمبيوتر.أستخدم كاشف كهروضغطي أيضاً. وظيفة الكاشف الكهروضغطي هي إستقبال الموجات فوق الصوتية المتولدة. أما المطياف وهو يستقبل شعاع الليزر الذي عانى من الحيود بالموجات فوق الصوتية ليعطينا طولها الموجي. تم إستخدام هذا المقياس لتحديد الروابط الكيميائية لـ Bougainvillea spp و Canna Indica و Bougainvillea spp2 Ixora Coccinnia و Leaves Citrus Paradisi التي تنمو في الظل وفي نظام معرض للشمس مباشرة.

أستخدم نظامان لتوصيف الروابط ، أحدهما يسمى: النظام النبضي الذي يحدد الروابط من نبض الموجات فوق الصوتية مباشرة. ويسمى النظام الآخر نظام براغ الذي يحدد الروابط بسبب حيود براغ لشعاع الليزر بإستخدام مقياس الطيف USP2000 المتصل بجهاز كمبيوتر.

أظهرت النتائج التي تم الحصول عليها أن تعرض النباتات للشمس يغير من قوة الروابط الكيميائية وكذلك التباعد البلوري ويولد في بعض الأحيان روابط جديدة في الشمس. كما تشير النتيجة التي تم الحصول عليها إلى وجود تمدد S-S و C-H في جميع العينات. ومع ذلك ، فإن Bougainvillea spp2 Ixora I Coccinnia لديها روابط S = O إضافية في الشمس والتي تحتوي الحمضيات على روابط N-H و O-H إضافية في الظل والشمس ويمكن إستخدام حقيقة نشوء روابط جديدة قي الشمس في العقاقير العشبية لصنع مواد فعالة جديدة.

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Chapter One

Introduction

1.1 Introduction

Sound is one of the phenomena that humans and animals use for planning and understanding through the sense of hearing. Sound waves coming from a source, will pass through matter to the ear and brain, it turns into understandable information. Sound waves are able to move in several forms of materials such as solid bodies, liquids, gas, but it does not diffused in vacuum. The speed of sound waves varies according to the mediator in which they travelled and the temperature. It always becomes the highest speed in solid materials, less in liquids and much less in gas. Regarding the spread of the sound in the air, it depends on the pressure which means that sound speed reduces according to its height over the surface of the ground [1]. The sound spreads (diffuses) in different directions. The occurrence of sound depends on the vibrations of the source which works on generating sound waves and its spread depends on the source geometry. The sound can be gendered by mechanical or thermal means; it can also be generated by laser [2]. Laser is an electro-magnetic beam that has photons which are equal in frequency and are in phase. Laser waves overlap constructively to form a pulse of light with high energy and strong cohesion in terms of time and place. Laser is used in different domains and it is also used as an analytical tool that is classified into two groups [3]: Light detection method and Non-light detection method. Sound can be generated with laser when laser pulses are shed on metal or material which absorbs laser light and transforms it into oscillating kinetic energy for the atoms of the substance that collide with neighboring air atoms and makes them oscillate with the same laser frequency. The kinetic energy so produced is spread over the used material as sound waves [4,]. Sound has many applications in different domains as explained below: A team of scientists were able to make a device which uses the sound to penetrate the very part of vision in the mind. Some of the scientists have mentioned that the laser produced sounds can activate the vision spot in the mind of blind people and can then restore their vision. Sound is also used by physicians to detect what is happening in the body of patients and it is a mean of determining the position with

echo. It sends sound waves in the body of patient and provides digital image of what happen [5]. In this study used Acoustic optic modulation that generated from leaves of plant that growth in sun and shadow in different bonds vibration position, and generate traveling acoustic waves on the surface of some plant that growth in sun and shadow by the Photoacoustic spectroscopy.

1. 2 Problem Statement

The high price and complexity of spectra treatment system in Sudan and proportion of the scarcity of advanced search services in Sudan such as advanced interactive devices make doing research in spectroscopy very expensive. The use of ultrasound in spectroscopy is also rare.

1.3 General Objectives

The aim of work is to generate acoustic waves as nondestructive test technique, by generating waves on the surface of a plant so as to detect chemical bonds using spectrometer.

1.3.1 Spicific Objectives

- To generate traveling acoustic waves on the surface of sun and shadow plant
- To detect vibration bonds on the sun and shadow Plant using non-destructive test by Photoacoustic Spectroscopy.
- To find the different bonds vibration position according to the plant leaves (sun or shadow).
- To find the frequency of acoustic optic modulation by Bragg regime model.
- To compere different frequencies and wavenumbers for the plant that growth in sun and shadow.

1.4 Theses Layout

This thesis consists of five chapters. Chapter one and two are concerned with introduction and theoretical background, while chapter three included materials and methods. Chapter four displayed the results Finally, chapter five contains conclusion and recommendations.

Chapter Tow

Theoretical Background

2.1Introduction

This chapter is concerned with studying the nature of laser and sound.

2-2 Sound Waves:

Sound waves are the almost common example of the longitudinal waves.

They travel through any material medium with a speed that depends on the properties of the medium. As the waves travel through air, the element of the air vibrate to produce changes in the density and pressure along the directions of the motion of the wave if the source of the sound waves vibrates sinusoidal, the pressure vibrates are also sinusoidal. The mathematical description of the sinusoidal sound waves is very similar to that of the sinusoidal string waves. The two conditions that are required for the generation of a sound wave are vibratory disturbance and an elastic medium.

In the most general sense, sound is the propagation of density waves through some medium. In fact most homogeneous substances conduct sound. The density waves are typically created by vibration of some object immersed in the medium, such as a string, membrane or chamber[6]

The waves propagate outwards from their point of origin. Sound waves are divided into three categories that cover different frequency ranges.

(1) Audible waves.

(2) Infrasonic waves.

(3) Ultrasonic waves.

2-2-1 Ultrasonic:

Ultrasonic is simply sound that are above the frequency range of the human hearing. When a disturbance occurs at a portion in an elastic medium, it propagates through the medium in a finite time as a medical sound wave by the vibrations of molecules, atoms or any particles present.

Ultrasound waves or ultrasonic waves are the terms used to describe elastic waves with frequency greater than 20,000 Hz and normally exist in solids, liquids and gases.

Ultrasonic is define as acoustic waves at frequencies greater than 20khz and infrasound can interact with biological tissues by medical and thermal processes. Ultrasound has been widely used in medical practice for at least 50 years diagnostic examinations include obstetric, abdominal, pelvic and cardiac imaging. Therapeutic uses include promotion of bone and soft tissue regeneration, destruction of kidney stones and tumor ablation.

Industrial application include son chemistry, emulsification, welding, cleaning and nondestructive testing; and ultrasound has been used in consumer products such as range finders, movement detectors and pest repellents. Naturalsources of ultrasound include bats, dolphins and other species that use it for echolocation.

Human exposures to ultrasound have not been well quantified except for those from medical devices. At high level of exposure ultrasound is capable of causing permanent damage to biological tissues, including teratogen effect, through heating, acoustic cavitation and radiation force.

At lower levels, such as those used for diagnostic cause heating beyond the normal physiological range. Studies of the effects of ultrasound in humans have largely concerned in utero exposure to diagnostic ultrasound

there is no consistent evidence of any physiological or behavioral effect of acute exposure to infrasound in humans. There is, however little good quality research and interpretation is complicated because low frequency noise often includes audible as well as infrasonic frequencies.

Ultrasonic sensing techniques have become mature and are widely used in the various fields of the engineering and basic science. Actually, many types of conventional ultrasonic instruments, devices and sophisticate software are commercialized and used for both industrial and medical applications. One of advantages of ultrasound sensing is its outstanding capability to probe inside objectives nondestructively because ultrasound can propagate through any kinds of medium including solids, liquids, and gases except vacuum. In typical ultrasonic sensing the ultrasonic waves are travelling in a medium and often fussed on evaluating objects so that a useful information on the interaction of ultrasonic energy with the objects are acquired as ultrasonic signals that are wave forms variations with transit time. Such ultrasonic data provides the fundamental basic for describing the outputs of ultrasonic sensing and evaluating systems.

2-2-2 infrasonic waves:

Infrasonic or infrasound is widespread in modern society, being generated by cars, trains and many machines and applications. It is also produced by various natural phenomena, such as earthquakes and volcanic eruptions.

Health effect associated with exposure to infrasound are less well understood than for ultrasound. It is important to establish if exposure below hearing thresholds at these low frequencies can cause adverse effects. Infrasound and ultrasound refer to the three frequency bands in an overall spectrum of acoustic waves.

There is some confusion over the meaning of the terms infrasound. A popular interpretation is that is sound such low frequency that it is below the lower frequency limit of hearing generally taken to be around 20Hz. The international electrotechnical commission and the British standards institution define infrasound as acoustic oscillations whose frequency is below the low frequency limit of audible sound.

Infrasound may be generated through natural geological and weather processes or as the results of manmade activates, infrasound is created whenever a surface moves periodically with a motion that includes frequency components below 20Hz. Such sources may be natural or article and in both cases a wide range of know or putative sources have been reported.

A range of natural environmental source contributes to the complex infrasonic background. Measurements of background infrasound have shown that it's acoustic pressure increase with decreasing frequency and most natural sources generate infrasound predominantly in the far infrasound.

The nuclear test ban treaty has created a need to monitor nuclear explosions and the associated infrasound forms one of the criteria for such monitoring. Similarly, other explosive devices cause infrasound, as do other ordinance and rocket launches.

The industrial sector, low frequency vibrated of some industrial machinery may cause infrasound, especially in association with air compressors and ventilation systems. The major application of ultrasound lies in medicine where, over a period of 50 years, diagnostic imaging has developed into a key modality for the identification and management of disease. Additionally almost all developing fetus within the UK are the

subject of at least one obstetric examination. It has become well stabilized that ultrasound can have an effect on tissue primarily through its heating effect arising from absorption by tissue.

The potential of an ultrasonic field to disrupt or modify a material, primarily though acoustic cavitation, has found extensive and growing applications in cleaning, son chemistry and processing of water. Many of the sources of infrasound are natural, resulting from geological or meteorological conditions[7].

2-2-3 Audible waves:

Audible waves lie within the range of sensitivity of the human ear. The human ear responds to sounds with frequencies in the range from 20Hz to 20,000Hz.

This is called the audible range of human ear; examples of vibrating sources that produce sound in the audible range of frequencies are drums, guitar strings, tuning fork, human vocal cords and diaphragms of loudspeakers.

In audible sound wave whose frequencies are less than 20Hz are in the infrasonic range. Source of infrasonic waves include earthquakes, thunder, volcanoes and waves produced by vibrating heavy machinery.

Frequencies above 20,000Hz are in the ultrasonic range. The audible range of dogs, cats, moths and mice extends into ultrasound frequencies they can hear very high frequencies that human cannot.[8].

2.3 speed of sound:

The speed of sound in the air is considered constant; it has scientific value, particularly 331 m/sec at zero temperature.

The general equation of sound wave velocity can be derived from differential laws:

$$\frac{dy}{dt} = \frac{dy}{dx}\frac{dy}{dt} = C\frac{dy}{dx} \quad (2.3.1)$$

$$\frac{d}{dt}\frac{dy}{dt} = C\frac{d}{dt}\frac{dy}{dt} \quad (2.3.2)$$

So:

$$\frac{d}{dt}\frac{dy}{dt} = C\frac{d^2y}{dx^2}\frac{dx}{dt} = C^2\frac{d^2y}{dx^2} \quad (2.3.3)$$

$$\frac{d^2y}{dt^2} = C^2\frac{d^2y}{dx^2} \quad (2.3.4)$$

This is an equation of wave moving in x-direction.

Newton‘s laws of mechanics can be utilized to deduce the velocity of transverse wave of stretched string, in a line element Δx with linear densityρ. Therefore there are two forces exerts on the string. So the resultant force is given by

$$F_x = T\cos(\theta + \Delta\theta) - T\cos\theta \quad (2.3.5)$$

Since the angles (θ and $\Delta\theta$) are very small then

$$\cos(\theta + \Delta\theta) \approx \cos\theta = 1$$

Therefore the resultant force in y axes is

$$F_y = T\,\Delta\theta \quad (2.3.6)$$

And from second Newton law, the force is

$$F_y = ma \quad (2.3.7)$$

$$F_y = \rho \Delta x \frac{d^2y}{dt^2} \quad (2.3.8)$$

Since m is equal:

$$m = \rho \Delta x \quad (2.3.9)$$

$$a = \frac{d^2y}{dt^2} \quad (2.3.10)$$

According to Newton equation:

$$\rho \Delta x = \frac{d^2y}{dt^2} = T \Delta \theta \quad (2.3.11)$$

$$\frac{d^2y}{dt^2} = \frac{T}{\rho} \frac{\Delta \theta}{\Delta x} = \frac{T}{\rho} \frac{d\theta}{dx} \quad (2.3.12)$$

Then:

$$\Theta = \tan \theta = \frac{dy}{dx} \quad (2.3.13)$$

$$\frac{\Delta \theta}{\Delta x} = \frac{d\theta}{dx} = \frac{d^2y}{dx^2} \quad (2.3.14)$$

From (2.3.12) we find:

$$\frac{d^2y}{dt^2} = \frac{T}{\rho} \frac{d^2y}{dx^2} \quad (2.3.15)$$

Comparing equation (2.3.15) to equation (2.3.5) it is clear that speed of light c is equal:

$$C^2 = \frac{T}{\rho} \quad (2.3.16)$$

Hence

$$c = \sqrt{\frac{T}{\rho}} \quad (2.3.17)$$

2.4 Sound power and Intensity

The strength of sound wave is as the energy contained in the sound wave per second in the unit area which is perpendicularly in the plane of the sound wave. Therefore

$$I = \frac{power}{area}$$

$$\mathrm{I} = \frac{pr}{4\pi r^2}$$

$$\mathrm{I} = \frac{\pi\varpi y_m^2 Tf}{cx4\pi r^2} = \frac{\pi\omega y_m^2 c^2 Tf\rho}{c4\pi r^2}$$

Substitute:

$\omega = 2\pi f$

Thus:

$$I = \left(\frac{\pi y_m^2 c^2 \rho f}{c4\pi r^2}\right) = \frac{2\pi^2 y_m^2\, cf^2\rho}{4\pi r^2} = \frac{\pi y_m^2 f^2 c\rho}{2r^2}$$

Since

$$I = \frac{\pi y_m^2 f^2 c\rho}{2r^2}$$

2.5 Energy transfer in sound wave

$$F_y = \omega\frac{y_m T}{C}\cos\omega\,(t - \frac{x}{c}) = \omega\frac{y_m T}{C}\cos\phi$$

Work done to generate one wave since

$$E = \int_c^T F_y \text{ dy} = \omega\frac{y_m T}{C}\int_c^T cos\phi y_m cos\phi\, d\phi = \frac{\omega {y_m}^2}{C} T\int_0^T \cos^2\phi\, d\phi$$

$$\cos^2\phi = \frac{1}{2}(1 + \cos 2\phi)$$

$$E = \frac{T\omega y_m^2}{c} \int_0^T \frac{1}{2}(1 + \cos 2\phi)\, d\phi$$

$$\phi = \omega\left(1 - \frac{x}{c}\right) \ , E = \frac{T\omega y_m^2}{2c}[\phi + \frac{\sin 2\phi}{2}]_0^T$$

But: T=$\frac{1}{f}$, $\omega = 2\pi f$

So: $E = \frac{T\omega y_{m(2\pi)}^2}{2c}$

$$\rho = \frac{\Pi T\omega y_m^2}{c} Xf = \frac{T\omega^2 Y_m}{2c}$$

2-6 Sound impedance

When the sound wave incident on an area between two different mediums then its velocity and pressure will change from V_2 to V_1 and P to P_1 respectively.

$V = \frac{P}{Z}$

$V_{i=P_t/Z_1}$

$V_{r=-P_r/Z_1}$

$V_{t=P_t/Z_2}$ (3.3.3..3)

The pressure obey

$P_i + P_r = P_t$

Since the displacements of incident, reflection and transmitted wave are

$\check{S}_i$= Si sin (kx- ωt)

$\check{S}_r$ =Sr sin (kx- ωt)

$\check{S}_t$= St sin(kx- ωt)

So their velocities reads

V_i= -$\omega\ Si \cos(\mathrm{kx} - \ \omega t)$

=vi cos (kx- ωt)

V_r = -$\omega\ Sr \cos(\mathrm{kx} - \ \omega t)$

= Vr cos (kx- ωt)

V_t = -$\omega\ St \cos(\mathrm{kx} - \ \omega t)$

= Vt cos (kx- ωt)

Then we find

Vi = -$\omega\ Si$

Vr = -$\omega\ Sr$

Vt = -$\omega\ St$

Since the resultant displacement of transmitted wave is equal to the sum of incident and reflectance wave displacements. So

$\check{S}t$= $\check{S}i$+$\check{S}r$

St = Si+ Sr

Multiply the above equation by –ω yield

$-\omega\ St = \ \omega\ Si - \omega\ Sr$

Vt = Vi + Vr

Substitute these into equation (3.3.3..)

$\frac{pt}{z2} = \frac{pi}{z1} - \frac{pr}{z1}$

Pi – Pr = $\frac{z1}{z2}$Pt

Using

Pi + Pr = Pt, we get

Pi – Pr = $\frac{z1}{z2}$ (Pi + Pr)

Z2 Pi – z2 Pr = z1 Pi + z1 Pr

-(z1 +z2) Pr = (z1- z2) Pi

$\frac{pr}{pi} = \frac{z2-z1}{z2-z1}$

Pr =$\frac{z2-z1}{z2-z1}$ pi

After a little algebra we get

Pt = Pr +Pi =$\frac{z2-z1}{z2-z1}$ Pi + Pi = ($\frac{2z2}{z2+z1}$) Pi

2.7 The Free and Forced Vibrations of Crystal

$$m\ddot{U}n = -(F1 + F2) = C\,(2Un - un - 1 - un + 1)$$

$$m\ddot{U}n = C\,(Un + 1 + un - 1 - 2un)$$

The most general solution is

$$U = Acoskx = Acos\,(na + ct)$$

$$= Acos\,(kna + \omega t) = Ae^{i\,(kna+\omega t)}$$

$$Kc = \frac{2\pi}{\lambda}\lambda f = \omega$$

$$X = na$$

$$Un = Aeiknae^{i\omega t}$$
$$Un + 1 = Ae^{i(n+1)a}e^{i\omega t}$$

$$Un - 1 = Ae^{i(n-1)a}e^{i\omega t}$$

Plug the above equation into the first equation we get

$$-m\omega^2 Ae^{ikna}oe^{i\omega t} = CAe^{i\omega t}e^{ikna}\left[e^{ikna} + e^{-ika} - 2\right]$$
$$-\omega^2 m = C\left(e^{ika} + e^{-ika} - 2\right)$$
$$-\omega^2 m = C(cos\ ka + i\sin ka)$$
$$C(\cos ka + i\sin ka - 2)$$
$$-\omega^2 m = C(cos\ ka - 1)$$

But $c = constant$

$$\cos 2x = cos^2 x - sin^2 = 1 - 2\ sin^2 x$$

$sin^2 x = \frac{1}{2}(1 - \cos 2x)$, $- sin^2 x = \frac{1}{2}(\cos x - 1)$

$$-\omega^2 m = -4\ c\ sin^2\frac{ka}{2}$$

Divided both side by $-m$ we get

$$\omega^2 = \frac{4c}{m}sin^2\frac{ka}{2}$$
$$\omega = 2\sqrt{\frac{c}{m}\sin\frac{ka}{2}}$$

When the distance between two atoms are very small $0 \rightarrow$ which means a

$$ka << 1$$

$$\sin\frac{ka}{2} \approx \frac{ka}{2}$$

the frequency is:

$$\omega = \sqrt{\frac{c}{m}}\frac{ka}{2}$$

When crystals are forced to vibrate by the force F then:

$$F = F_0 e^{iwt} e^{ikna}$$

The equations of motion thus become:

$$m\ddot{U}n = -(F_1 F_2) - F$$

Substitution for F_1'F2 yield:

$$-\omega^2 mA = +C\left(e^{ika} + e^{-ika} - 2\right)A - Fo$$

$$-\omega^2 mA = 2C(1 - \cos ka)A - Fo$$

$$-\omega^2 A = \frac{2c}{m}\left(2sin^2\frac{ka}{2}\right)A + \frac{Fo}{m}$$

SETTING

$$\omega o^2 = \frac{4c}{m}sin^2\frac{ka}{2}$$

WHERE ωo THE NATURAL FREQUENCY EQUATION BECAME

$$(\omega^2 - \omega o^2)A = \frac{F_0}{m}$$

$$A = \frac{F_0}{m(\omega^2 - \omega o^2)}$$

$$T = \frac{1}{2}mv^2 = \frac{1}{2}m[un]^2$$

$$un = Ae^{i\omega t}e^{ikna} \qquad |un| = A$$

$$T = {}^1\!/_2\, m\omega^2 A^2 = \frac{m\omega^2 F_0^2}{2m^2(\omega^2 - \omega_0^2)^2}$$

$$V = -\int cun\, dun = -{}^1\!/_2\, cu_n^2$$

$$V = -{}^{1}/_{2}\, c|un|^2 = {}^{1}/_{2}\, CA^2$$

$$E = T + V = {}^{1}/_{2}\, m\omega^2 A^2 - {}^{1}/_{2}\, CA^2$$

$$= {}^{1}/_{2}\, (m\omega^2 - C)A^2$$

$$E = \frac{(m\omega^2 - c)F_0^2}{2m^2(\omega - \omega_0)^2(\omega + \omega_0)^2}$$

The vibrational energy:

According to the lows of quantum mechanics the vibrational energy is given by [9].

$E_n = (n+\frac{1}{2})\, \hbar\omega$

The quantum number n is given by n= 0,1,2,3 ….

The vibrational energy takes the form:

$E = \hbar^2 L\, \frac{(L+1)}{2I}$

The orbital quantum number:

L=0,1,2,3,….

I= moment of Inertia

2.8 Laser Physic's

The acronym LASER stands for Light Amplification by Stimulated Emission of Radiation. It is beyond the scope of this paper to cover in depth the physics of laser operation; for more detailed information, the reader is directed to the many excellent textbooks on the subject [10]. They are of interest because the light emitted from a laser has several distinctive features that separates it from that from other sources. For example, laser light is distinctly monochromatic compared to say, a lightbulb or the sun. It is directional, rather than being radiated isotopically, and importantly, spatially

and temporally coherent to a much higher degree than other light sources. The basic principle of lasing action is the stimulated transition of an electron in a high energy level to a lower one, emitting a photon with the same properties as the incident photon that initiated the transition. This requires that there are more electrons in the upper state than the lower, or the incident photon would be absorbed. This is called a 'population inversion' and is an unusual state, as a thermal Boltzmann distribution of population in an atom (where 'atom' can be taken to include ions and molecules) would be for there to be more electrons in the lower energy level. Imagining the simplest case of a two level atom, we can see that it is impossible to establish a population inversion in this closed case. The rates of absorption and stimulated emission are proportional to the populations in the lower and upper levels respectively and to the strength of the applied field. In the steady state this means no net change in the population of either level and at most half the total population can be in the upper state. Therefore a population inversion cannot be created in a two level system and lasers need at least three participating energy levels. Three and four level lasers, first one is the three level laser is illustrated schematically in fig. 1. Here incident pump light is absorbed on the transition from the ground state level 0 → level 2. The population in level 2 relaxes into level 1 via a non-radiative transition. If more than half the population can be moved from the ground state by the pump, then it is possible to establish a population inversion between levels 1 and 0 which constitute the upper and lower laser levels. Clearly, it requires considerable pump energy to move enough population from the ground state to make a population inversion in a three level laser system and a more efficient arrangement is a four level laser also shown in fig (2.1). Here, the pump transition is from level 0 (the ground state) to level 3, which then decays to level 2. If level 1 is sufficiently far above the ground state that it is not thermally populated then a single electron in level 2 constitutes a population inversion clearly requires much less pump energy to establish than for a three level system. It is also advantageous for population in level 1 to rapidly decay back down to the ground state so that it remains effectively empty These are of course simplified versions of real atomic or molecular systems, and not all laser media can be so neatly categorized; some media can be more three or four level like for different lasing wavelengths, and the lasing levels themselves are not infinitely sharp but are broadened in energy. Depending on the exact properties of a particular laser medium, it may be possible to create a population inversion in the steady state and for the laser to operate continuous wave (cw). In some cases it is only

possible to achieve population inversion temporarily and the laser emits pulses of light at a specific repetition rate. Some lasers are deliberately made to operate in pulsed mode to achieve higher peak powers than can be achieved using cw systems[11].

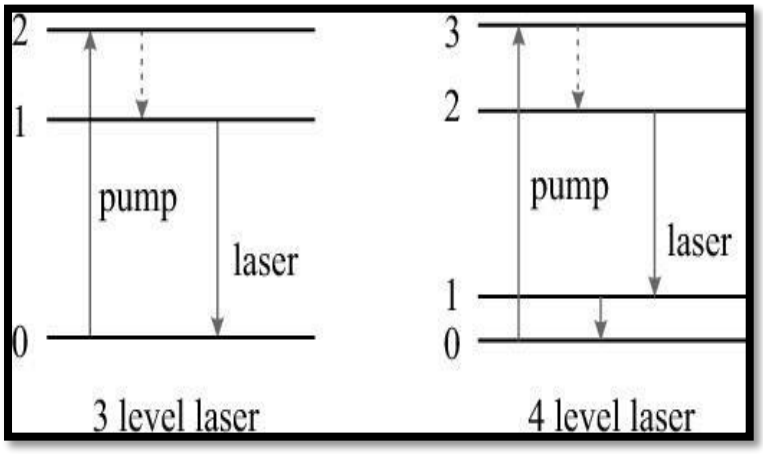
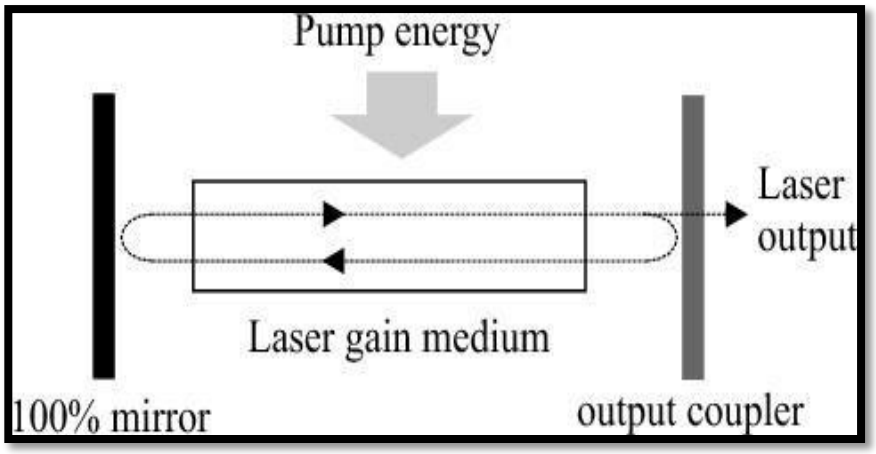


Fig (2.1) Schematic illustration of three and four level lasers

The transition on which a laser operates is by no means totally monochromatic, as implied by the narrow energy levels drawn in schematic representations of lasers such as fig. 1. In fact, one or both levels of a laser transition are subject to broadening by a number of different mechanisms and so the laser output will have a finite spectral width (its linewidth), with a characteristic spectral shape depending on the dominant broadening mechanism. These can be divided into two classes, homogeneous and inhomogeneous broadening. Homogeneous broadening includes the fundamental lifetime broadening which is a consequence of the finite lifetimes of the upper and lower lasing levels – essentially the uncertainty principle dictates that there must be an uncertainty in the energy of an excited state with a certain radiative lifetime and this causes the energy levels have a finite spectral width. So the lasing transition has an intrinsic linewidth that is the sum of the widths of the upper and lower levels, which is the fundamental minimum achievable and has a Lorentzian spectral distribution. However, there are many additional broadening mechanisms that can act to increase the linewidth of a laser transition and it rare to find a laser linewidth as narrow as simply given by the lifetime broadening component. A major homogenous broadening mechanism is pressure broadening where collisions between the radiating atoms lead to changes in the spectral output of the emitted light and thus broadening of the emission across the macroscopic

ensemble, which also gives a Lorentzian line shape. Some important broadening mechanisms are inhomogeneous i.e. they do not affect all atoms in the laser in the same way. One of these is Doppler broadening, which is important for gas lasers and is caused by the Doppler shift of the emitted laser light from the thermal motion of the atoms. Doppler broadening leads to a Gaussian output linewidth. Inhomogeneous broadening also often arises in solid state lasers, where the local environment of each lasing ion within a crystalline host or amorphous medium such as glass might be quite different, leading to significant spectral broadening of the laser output.

Establishing a population inversion in a laser medium is not enough to ensure lasing action. The basic form of a laser oscillator (a system that produces laser light with the properties outlined in section 1) consists of a laser gain medium, a pump source and a cavity, shown schematically in fig (2.2). The pump source (which may be a flash lamp, electrical discharge, other laser etc.) creates a population inversion in the laser medium. Some of the upper state population decays via spontaneous emission and photons emitted close to the optical axis of the cavity are trapped between the mirrors and recirculate through the gain medium. These photons then stimulate further transitions from the upper state and the light field is amplified on every pass through the gain medium. Thus a large circulating body of photons builds up in the optical cavity. One of the cavity mirrors is partially transmissivity, so some of the photons are emitted from this mirror (the ‘output coupler’) forming the laser beam. Once the round trip gain of the laser exceeds the cavity losses (through the output coupler, from absorption or diffraction loss) the laser is said to have reached threshold and it lases



2.8.1 Types of laser

Lasers are normally categorized as gas, liquid or solid state, depending on the lasing medium. Of these, the most important are the solid state lasers, although there are significant systems in each of the other categories. In the following subsections, representative examples of each type of laser are described. More details about these lasers can be found in refs.[11,12].].

Gas lasers: These use a gas as the laser medium, generally with the source of excitation (the pump) being an electrical discharge through the gas, creating ions and electrons. Some examples of gas lasers include:

- ***The helium-neon laser (HeNe)*** :This uses a mixture of helium and neon as the lasing medium and lases in the red at 632.8nm, although other wavelengths are possible. Helium-neon lasers are often found in optics labs for testing and alignment, owing to their relatively low cost and small footprint.
- ***The carbon dioxide (CO_2) laser:*** These systems lase in the infrared at 10.6μm and have found particular use in industry for applications such as cutting and welding as they can achieve extremely high powers. CO_2 lasers are also used for some medical applications.

Excimer lasers: This is a general term for gas lasers where the gain medium is a mix of a noble gas, such as argon or krypton, and a reactive gas such as chlorine or fluorine. These lasers are useful because they lase in the ultraviolet (~126 – 350nm)

where there are few other available laser sources. These lasers have important applications in photolithography and medicine.

Liquid lasers: These use a liquid as the lasing medium, usually an organic dye in a solvent. One of the most well-known is rhodamine 6G, which can lase from ~560 – 630nm, producing light in the orange/yellow range of the visible spectrum where there are few other sources. Dye lasers have been important as the earliest tunable laser sources, which has been hugely influential in modern spectroscopy. The broad lasing bandwidth also allows dye lasers to support ultrashort pulsed operation. In general, although dye and other liquid lasers have been very important historically, the difficulty of handling a liquid gain medium means other laser sources are preferred if available.

Solid state lasers: This is perhaps the broadest category of laser, ranging from lasing ions doped into glass, crystal, or ceramic host materials with form factors ranging from building size large high power glass systems to optical fiber lasers and semiconductor diode systems.

Semiconductor diode lasers: These are perhaps the most important class of laser in terms of the numbers produced per year, being deployed in large numbers in CD and DVD players, optical telecommunications systems and barcode readers. The semiconductor lasing medium typically has dimensions of only a few tens of microns. The large reflection coefficient at the surfaces and high gain of these lasers mean they do not require external mirrors to create an oscillator cavity so they can be very small indeed, contributing to their widespread use. These lasers can operate on a variety of wavelengths across the visible and near infrared spectrum depending on the exact semiconductor material used. The pump source for semiconductor lasers is electrical current, which means they have a high electrical to optical (wall plug) efficiency. Semiconductor diodes are important in high power laser science as pump sources for other lasers.

Optical fiber lasers: This term refers to the structure of the laser, rather than the specific gain medium. Optical fibres are waveguides, typically constructed of glass with a core surrounded by a cladding of lower refractive index, which can guide light over long distances. These passive fibres are well known for their use in high speed data communications but it is also possible to dope lasing ions into the core to create an

active, i.e. amplifying, optical fibre laser. Some examples are erbium doped fibre amplifiers (EDFAs), which are vital component of long distance optical telecommunications, and ytterbium doped fibres which can operate at very high average powers with important applications in industry.

Nd:YAG doped lasers : Neodymium (Nd) is one of the most common lasing ions, and has been successfully used in a number of hosts, of which yttrium aluminum garnet (Nd:YAG) and glass are the best known. Nd:YAG is a widely used laser, operating at 1064nm and pumped using flash lamps or near infrared semiconductor laser diodes. It can operate in either cw or pulsed mode, typically producing pulses of tens of nanoseconds in Q-switched mode. Nd:YAG lasers have many applications in medicine and science but an important application for accelerator science is the use of the green frequency doubled output [13] at 532nm as pump light for titanium sapphire lasers.

2.8.2 Laser properties

Directionality: The laser beam emerging from the output mirror of the cavity is highly parallel, which is a consequence of the strict requirements for the alignment of the cavity mirrors. Divergence of the beam is typically a few mill radians parallel, which is a consequence of the strict requirements for the alignment of the cavity mirrors. Divergence of the beam is typically a few mill radians [13].

Monochromaticity:

Brightness: This is denned as the power emitted per unit area of the output mirror per unit solid angle and is extremely high compared with that of a conventional source. The reason for this is that, although the power may be only modest, as in, for example, a0.5 m helium–neon gas laser, the solid angle over which it is distributed is very small[12,13]..

Coherence: Conventional sources of radiation are incoherent, which means that the electromagnetic waves associated with any two photons of the same wavelength are, in general, out of phase. The coherence of laser radiation is both temporal and spatial, the coherence lasting for a relatively long time and extending over a relatively large

distance Coherence of laser radiation is responsible for its use as a source of intense local heating, as in metal cutting and welding, and for holography]

2-9 Electromagnetic radiation

Molecules and their energy levels are one main ingredient of spectroscopy. The other main ingredient is the electromagnetic radiation that induces transitions between different energy levels. Let us therefore briefly recall what electromagnetic radiation is. There are two general ways of describing electromagnetic radiation: as a wave and as a particle. Some aspects of an experiment are best explained by the to explain the interaction of matter with radiation.

In some experiments and often in the interaction with molecules, electromagnetic radiation behaves particlelike. The particles are called photons. Each photon has a defined energy, which only depends on the frequency f (color) of radiation.

$E = hf$ (2.3.1)

Where h is Planck´s constant ($h = 6.63 \times 10^{-34}$ J s). The intensity (brightness) of radiation depends on the number of photons.

If radiation shows its wave face, electromagnetic radiation has two components: and electric field E and a magnetic field B. Both oscillate with the same frequency and are oriented perpendicular to each other and to the direction of propagation at all times. For the phenomena we will describe, it is often sufficient to consider only one of the two components.

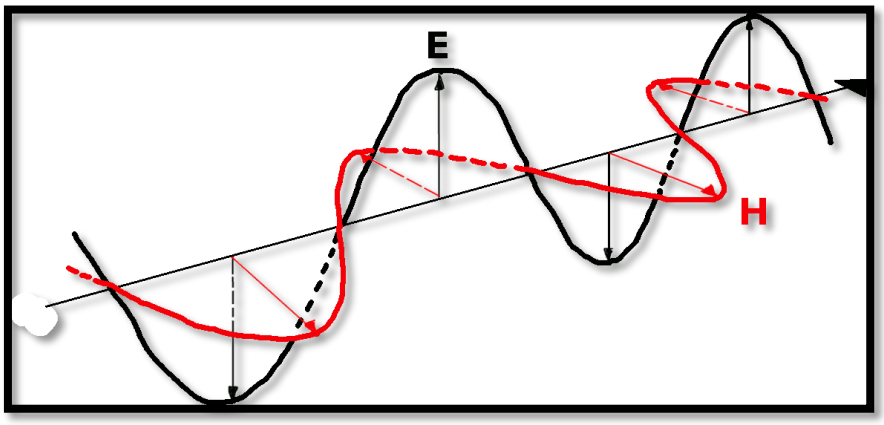
Light can be polarized, that is the electric and magnetic field oscillate each in one particular direction. In unpolarized light, the electric and magnetic field oscillate in all directions perpendicular to the direction of propagation.

Frequency f of a wave and wavelength λ are related by

$\lambda = c/f$ (2.3.2).

Where c is the velocity of propagation of the wave. For electromagnetic radiation in a vacuum, $c = 3 \times 10^8$ m s^{-1}. Frequency and wavelength are often used to characterize electromagnetic radiation. Another quantity is the wavenumber $\tilde{\nu}$ measured in reciprocal centimeters. The wavenumber is the inverse of the wavelength.

Wavenumber is mainly used in vibrational spectroscopy. Its advantage is that is conveys the information about the wavelength (just calculate the inverse) and is also proportional to the energy or frequency.



2.9.1 Interaction of electromagnetic radiation with matter

We will now discuss the interaction between electromagnetic radiation and matter and start with a simple classical model for this interaction before discussing the different phenomena that take place when matter interacts with electromagnetic radiation.

Our classical model is a mass on a spring that is subjected to an oscillating driving force and to damping, which is another word for friction. We will apply this model to describe the interaction between electromagnetic radiation and matter when we discuss the different spectroscopic methods in the following lectures. Then it will be important to identify what is the driving force and what corresponds to the mass on a spring. In most cases the driving force corresponds to the electric field of the radiation and the mass to the electrons or to the nuclei in the interacting molecules.

When a spring with attached weight is extended and released, it will oscillate at its intrinsic frequency f_0 which is determined by the spring force constant. However, when it is driven by a sinusoid ally time-varying driving force, $F_0 \cos \theta t$, it will eventually oscillate with the external

frequency f (the frequency of light). When there is friction (= interaction with the environment), then the spring does not immediately follow the driving force, it lags behind. One says that there is a phase delay between driving force and spring movement. The phase delay occurs because friction/resistance has to be overcome. One can separate the resulting spring movement in a part that is in phase (0 or 180° phase difference between spring and driving force) and one which is 90° out of phase. The amplitude of these two components depends on the driving frequency and on the intrinsic frequency of the spring (panel e). The components are called dispersion and absorption because their frequency dependencies resemble those for the refractive index and the absorption of energy by the spring respectively. We are interested in the absorption curve in the following[13,14].

2.10 What is diffraction

When a light passes through a small aperture whose dimensions are (comparable with the 'λ' (wavelength).

of light then light deviates from its rectilinear path and bends round the corner of the placed aperture of its

Geometrical shadow, this phenomenon is called diffraction[15,16].

2.11 Bragg's law:

Bragg's law means that the diffraction can occur only when the following equation is satisfied

$$.n\lambda = 2dsin\theta$$

Where:

n is a positive integer,

λ is the wavelength of the X-ray,

d is the distance between the lattice plane,

ɵ is the incident glancing angle (supplement of the incident angle).

One may think: “isn’t the “incident angle?”..., but the “incident angle” is defined as the angle between the normal direction of a reflection plane and the incident ray (or more generally quantum beam), in a traditional theory of optics.

The Bragg’s law is often expressed in another way:

Λ=2d sinɵ, (1.2)

and this expression may be more popular than that of Eq. (1.1). Be sure that the left side of Eq. (1.) does not include “ n.”

Why can there be different expressions? Don’t you think one of those equations should be wrong? Actually, both of them are correct. The definition of d in Eq. (1.2) is different from the definition of d in Eq. (1.1), and it is equivalent with(d /n) for the definition of d in Eq. (1.2). In the following sections in this chapter, the expression by Eq. (1.1) will be used, because it looks a little easier to be understood[17,18].

2.12 Spectroscopy

Seeing is spectroscopy: we perceive the world via the interaction of visible light with the light receptors in our eyes. The light is emitted from the sun or from other light sources. It is then reflected from (or transmitted through) the objects in our surroundings. In these processes, the color changes because some of the light is absorbed by the objects. How much and what spectral regions are absorbed depends on the atoms and

molecules in these objects. The light not absorbed reaches our eyes. It carries the information of the molecular structure of our surroundings with it. In our eyes its color is analyzed by 3 different types of photoreceptors which absorb different light in spectral regions. In this way we perform a spectroscopic experiment every time we look at things. There is a light source, and object that reflects, transmits, scatters and absorbs light and a wavelength dependent detector in our eyes. An apparatus for spectroscopic studies is called spectrometer and a plot of a particular property of matter against wavelength, frequency or energy of radiation is called spectrum .wave-particle dualism of matter, spectroscopy includes the related study of the interaction between matter and particles - like electrons and neutrons. With this definition X-ray diffraction, neutron scattering, electron microscopy, and NMR are spectroscopic methods. However, we will not discuss these techniques here, because they are covered in the structural biochemistry course. This course deals instead with the following techniques: UV/vis (ultraviolet/visible) spectroscopy, fluorescence, circular dichroism, Raman spectroscopy, Infrared spectroscopy, and electron spin resonance. Most of these use light in the UV/vis spectral range, infrared spectroscopy uses infrared light and electron spin resonance microwave radiation. In addition to explaining the fundamentals of these techniques, we will also discuss some of their applications to biological systems and biological processes. The methods that we will discuss are very versatile. In the life sciences they are used to study the structure and dynamics of biomolecules. Apart from the spectroscopy of biological molecules, another impressive example of the power of spectroscopy is at the other extreme of dimensions: the study of space with astronomy. Nearly the only information that we have from outer space reaches us in form of electromagnetic radiation. One example is the recent discovery of water on Mars by the European Mars mission using the

infrared spectral region. Other more exotic applications are named in the video. This should not give the impression that spectroscopy is a series of niche techniques[20].

Most of our knowledge about the structure of atoms and molecules is based on spectroscopic investigations. Thus spectroscopy has made an outstanding contribution to the present state of atomic and molecular physics, to chemistry, and to molecular biology. Information on molecular structure and on the interaction of molecules with their surroundings may be derived in various ways from the absorption or emission spectra generated when electromagnetic radiation interacts with matter. Wavelength measurements of spectral lines allow the determination of energy levels of the atomic or molecular system. The line intensity is proportional to the transition probability, which measures how strongly the two levels of a molecular transition are coupled. Since the transition probability depends on the wave functions of both levels, intensity measurements are useful to verify the spatial charge distribution of excited electrons, which can only be roughly calculated from approximate solutions of the Schrödinger equation. The natural line width of a spectral line may be resolved by special techniques, allowing mean lifetimes of excited molecular states to be undetermined. Measurements of the Doppler width yield the velocity distribution of the emitting or absorbing molecules and with it the temperature of the sample. From pressure broadening and pressure shifts of spectral lines, information about collision processes and interatomic potentials can be extracted. Zeeman and Stark splitting by external magnetic or electric field sare important means of measuring magnetic or electric moments and elucidating the coupling of the different angular moment in atoms or molecules, even with complex electron configrations.The hyperons structure of spectral lines yields information

about the interaction between the nuclei and the electron cloud and allows nuclear magnetic dipole moments, electric quadruple [21].

2.12.1 The spectroscopic method:

The spectroscopic methods can be classified as follows:

- Rotational spectroscopy
- Vibration spectroscopy
- Electronic spectroscopy
- Photoelectron and related spectroscopes
- laser spectroscopy [20,22].

Laser spectroscopy is still a very intense field of research which has expanded with remarkable progress into many areas of science, medicine and technology, and has provided an ever-increasing number of applications. The importance of laser spectroscopy and its appreciation by many people is, for instance, proved by the fact that over the last ten years three Nobel Prizes have been awarded to nine scientists in the field of laser spectroscopy and quantum optics[23].

This positive development is partly based on new experimental techniques ,such as improvements of existing lasers and the invention of new laser types, the realization of optical parametric oscillators and appliers in the fem to second range, the generation of at to second pulses, the revolution in the measurements of absolute optical frequencies and phases of optical waves using the optical frequency comb, or the different methods developed for the generation of Bose–Einstein condensates of atoms and molecules and the demonstration of atom lasers as a particle equivalent to photon lasers. These technical developments have stimulated numerous applications in chemistry, biology, medicine, atmospheric research,

materials science, metrology, optical communication networks, and many other industries[24,25].

2.13 Photoacoustic Theory

The mathematical analysis of a photo acoustic signal can be understood on the basis of radiation matter interaction. When a sample absorbs intensity-modulated optical radiation, the sample will undergo periodic heating. This periodic heating results in a periodic heat flow from the sample to the gas at the sample-gas boundary. A thin layer of gas near the boundary is then cyclically heated by this heat flow. The thickness of the boundary layer is determined by the thermal diffusion length in the gas, p.', which is given by

$$\mu^{-} = (\frac{2\alpha}{\omega})^{\frac{1}{2}} \qquad (2\text{-}5\text{-}1)$$

where (oJ) is the radial frequency at which the light is emitted- where tc is the thermal conductivity, p the density and C the specific modulated and a is the thermal diffusivity defined as

$$a = \frac{t_c}{pC^2} \qquad (2\text{-}5\text{-}2)$$

heat. Generally, the thermal diffusion length for most gases runs in the range of 25-500 p.m for the frequencies usually used in photoacoustic spectroscopy (1000 Hz-5 H_z). The thermal diffusion length represents the distance where the temperature rise due to conduction is e-1 that at the origin of the heating, which for our case is the sample surface .The localized heating of a layer of fluid or gas can be viewed as producing a localized stress that is then rapidly transmitted through the rest of the enclosed gas in the photoacoustic

cell. The local pressure or stress that is generated within a thermal diffusion length of the sample surface can be approximated by the expression

$$3p_{\mu} \cong B^{-}\alpha_{t}^{-}({}^{1}/_{2\Theta_{0}}) \qquad (2\text{-}5\text{-}3)$$

where B' is the bulk modulus and a; the volume expansion coefficient of the gas, and where 1/280 is approximated as the average temperature within this thermal diffusion length, if 80 is taken as the temperature at the sample-fluid interface. The pressure at the microphone, a distance l

$$p = p_{\mu}\left(\frac{\mu^{-}}{t^{-}}\right) = \frac{1}{2\beta^{-}}\,\alpha^{-}{}_{t}\Theta_{O}\left(\frac{\mu^{-}}{l^{-}}\right) = \frac{\Upsilon P_{O}}{2T_{O}a^{-}l^{-}}\Theta_{O} \qquad (2\text{-}5\text{-}4)$$

since for a gas, B' = yPo where y is the ratio of specific heats and Po is the pressure, and a; = 1/ To where To is the temperature and a' = 1/ p'. When the gas or fluid is completely constrained at its borders, then the pressure p is the same everywhere in the cell, as long as the cell dimensions are much smaller than the acoustic wavelength . The temperature 90 at the sample-gas interface can be approximated By

$$\Theta_{O} \simeq \frac{H_{abs}}{M_{th}} \qquad (2\text{-}5\text{-}5)$$

where H_{abs} is the amount of heat absorbed per unit time within the first thermal diffusion length p. in the sample and Mlh is the thermal mass of this region of the sample. For the case where the thermal diffusion length in the sample is smaller than the sample thickness (p. < /) and where A is the area illuminated by the ligh[26].,

$$H_{abs} = \frac{I_{O}A(1-e^{-\beta\mu})}{\omega} \qquad (2\text{-}5\text{-}6).$$

with I_O being the light intensity and β the optical absorption coefficient

$$M_{th} = \rho C_{\mu} A \qquad (2\text{-}5\text{-}7)$$

This gives

$$\Theta_0 = \frac{I_0(1-e^{-\beta\mu})}{\rho C \omega \mu}.$$

Similarly, when $\mu > l$,then

$$H_{abs} \square \frac{I_0(1-e^{-\beta l})}{\omega}$$

and

$$M_{th} \square \rho^{"} C^{"} \mu^{"} A$$

where the unprimed symbols represent the sample and the double-primed symbols represent the parameters of the material directly behind the sample . Thermal conduction introduces a phase lag in the PAS signal. There is a 7T / 4 phase lag due to conduction in the gas and an additional phase lag due to conduction in the sample. The sample phase lag is approxi- mated by 4>= 1 / pJL. When JL < 1/ p, 4> reaches a maximum value of 7T / 4 as well . Combining these expressions for the magnitude of the PAS signal with the above remarks on phase, we can reconstruct all six of the special photoacollstic cases treated in the more detailed Rosencwaig- Gresho theory [8]We find that aside from a factor of 1/2, all six cases are properly given by the above arguments[26].

2.14 Photoacoustic spectroscopy:

The photo acoustic (PA) (formerly also known as opto acoustic effect consisting in sound generation from the interaction of light and matter was discovered by Alexander Graham Bell .He noticed that focused intensity-modulated light (chopped sunlight) falling on an optically absorbing solid substance produced an audible sound. In the next year, light absorption was detected through its accompanying acoustic effect not only in solids, but also in liquids and gases by Bell[9] .Tyndall, Röntgen , and Preece . They found the sound was stronger when the substance was placed in a sample cell (then called "photo phone" and later "spectrophone .("It was Bell again that first described the resonant amplification of the PA signal . The PA effect was also investigated at different light wavelengths. Bell and Preece were among the first to notice a PA signal for an aerosol when they experimented with cigar smoke. During the past few years, another optical technique has been developed to study those materials that are unsuitable for the conventional transmission or reflection method[10]. Photo acoustic spectroscopy (PAS), is distinguished from the conven-tional techniques chiefly by the fact that, even though the incident energy is in the form of optical photons, the interaction of these photons with the sample under investigation is studied not through subsequent detection and analysis of some of these photons but rather through a direct measure of the energy absorbed by the material because of its interaction with the photonIt was not until 1973 that photoacoustic spectroscopy started to be used in a wide range of different applications. This "rediscovered" technique provides the following main advantages over the conventional types of spectroscopy. It allows the characterization and analysis of substances in highly light-scattering and opaque materials such as powders (drugs, insulators, \and metals), amorphous solids (glasses), gels (films), suspensions (bacteria, algae, cell organelles) and tissues (leaves, skin). Non-destructive and in

vivo studies at different subsurface levels of a material (depth profile analysis), studies of the optical and energy properties of the sample, gathering information about the de-excitation states of molecules (e.g. energy state, quantum yield) and about the lifetime of the intermediates of chemical reactions.[27].

2.15 Application of Photo Acoustic Spectroscopy in Plant matter

The unique capabilities of photo acoustic spectroscopy enable it to be used to obtain optical absorption data on even more complex biological system such as green leaf. Photo acoustic spectroscopy can used to study intact plant matter and to obtain valuable information about normal and up normal plant process and pathology [24].

2.15.1 Application in photosynthesis

The photoacoustic effect measures the nonradioactive deexcitation processes that occur in a system after it has been optically excited. This selective sensitivity of the PAS technique to the nonradioactive deexcita tion channel can be used to great advantage in the study of biologi cal systems that exhibit photochemistry. In biology, one of the most important manifestations of photochemistry is the process of photosyn thesis, both in green plants and in certain bacterial organisms. Photo chemical processes like photosynthesis compete with the photoacousticprocess and thus can be studied with PAS[24].

2.16 Acousto-optic modulators (AOMs):

Acousto-optic modulators (AOMs) are useful devices which allow the frequency, intensity and direction of a laser beam to be modulated. Within these devices incoming light Bragg diffracts off acoustic wave fronts which

propagate through a crystal. Modulation of this incoming light can be achieved by varying the amplitude and frequency of the acoustic waves travelling through the crystal. In an acousto-optic modulator (AOM) a laser beam is caused to interact with a high frequency ultrasonic sound wave inside an optically polished block of crystal or glass (the interaction medium). By carefully orientating the laser with respect to the sound waves the beam can be made to reflect off the acoustic wave fronts (Bragg diffraction). Therefore, when the sound field is present the beam is deflected and when it is absent the beam passes through undeviated. By switching the sound field on and off very rapidly the deflected beam appears and disappears in response (digital modulation). By varying the amplitude of the acoustic waves the intensity of the deflected beam can similarly be modulated (analogue modulation). An acousto-optic modulator (AOM), also called a Bragg cell, uses the acousto-optic effect to diffract and shift the frequency of light using sound waves (usually at radio-frequency). They are used in lasers for Q-switching, telecommunications for signal modulation, and in spectroscopy for frequency control. A piezoelectric transducer is attached to a material such as glass. An oscillating electric signal drives the transducer to vibrate, which creates sound waves in the glass. These can be thought of as moving periodic planes of expansion and compression that change the index of refraction. Incoming light scatters (see Brillion scattering) off the resulting periodic index modulation and interference occurs similar to in Bragg diffraction. The interaction can be thought of as four-wave mixing between phonons and photons. The properties of the light exiting the AOM can be controlled in five ways:

- ***Deflection :*** A diffracted beam emerges at an angle θ that depends on the wavelength of the light λ relative to the wavelength of the sound Λ in the Bragg regime.

$$\sin\theta = \left(\frac{m\lambda}{2\Lambda}\right) \text{in the Bragg regime}$$

And

$$\sin\theta = \left(\frac{m\lambda_0}{n\Lambda}\right) \text{with the light normal to}$$

the sound waves where : m = ...-2,-1,0,1,2,... is the order of diffraction. Diffraction from a sinusoidal modulation in a thin crystal solely results in the m = -1,0,+1 diffraction rders. Cascaded diffraction in medium thickness crystals leads to higher orders of diffraction. In thick crystals with weak modulation, only phase matched orders are diffracted, this is called Bragg diffraction. The angular deflection can range from 1 to 5000 beam widths (the number of resolvable spots). Consequently, the deflection is typically limited to tens of mill radians.

- ***Intensity:*** The amount of light diffracted by the sound wave depends on the intensity of the sound. Hence, the intensity of the sound can be used to modulate the intensity of the light in the diffracted beam. Typically, the intensity that is diffracted into m=0 order can be varied between 15% to 99% of the input light intensity. Likewise, the intensity of the m=1 order can be varied between 0% and 80%.
- ***Frequency :*** One difference from Bragg diffraction is that the light is scattering from moving planes. A consequence of this is the frequency of the diffracted beam f in order m will be Doppler-shifted by an amount equal to the frequency of the sound wave F This

frequency shift is also required by the fact that energy and momentum (of the photons and phonons) are conserved in the process. A typical frequency shift varies from 27 MHz, for a less-expensive AOM, to 400 MHz, for a state-of-the-art commercial device. In some AOMs, two acoustic waves travel in opposite directions in the material, creating a standing wave. Diffraction from the standing wave does not shift the frequency of the diffracted light.

- ***Phase:*** In addition, the phase of the diffracted beam will also be shifted by the phase of the sound wave. The phase can be changed by an arbitrary amount.
- ***Polarization :*** Collinear transverse acoustic waves or perpendicular longitudinal waves can change the polarization. The acoustic waves induce a birefringent phase-shift, much like in a Pockets cell. The acousto-optic tunable filter, especially the dazzler, which can generate variable pulse shapes, is based on this pWhen faster control is necessary electro-optic modulators are used. However, these require very high voltages[28]. .

2.17 Piezoelectric effect:

When mechanical pressure or stress has been applied on some crystals, it causes positive and negative charges in atoms or compounds to form electric dipoles. These electric dipoles form an internal field and generate electric potential between two sides and parallel surfaces of the crystal. This effect is known as a piezoelectric effect. The reverse effect can also be observed, where the application of electric field and voltage produces mechanical pressure or stress. When the voltage is in the form of a sine wave sound or ultrasound sound waves can be generated[29].

2.18 Literature Review

KVeeranjanayulu and V.S.R Das (1983), applied photo acoustic spectroscopy to Compare the acoustic spectra of ad axial surface of green leaves and observing higher signal intensities .they found that the intensities of signals at 545nmand 675nm in purple pigmented leaf decrease with increase in acoustic frequency from 20 HZ to 50 HZ. However the signal Ratio at 545 nm to 675 nm was found to increase with increase in frequency[30].

Jietlui etal, [2016]. Able to convert molecular vibration into acoustic waves following bond selective photo acoustic spectroscopy imaging technique in which away of detecting specific molecule in complex tissue environment [31]

Kveeranjaneyulu and V.S.R DAS [1982] utilized [PAS] technique to characterize purple pigmentation in leaves of species of euphorbia by observing a peak at 545nm .They recorded the maximum absorption peak in vivo chlorophyll at 675nm as against 665nm of the in vivo chlorophyll The intensity in leaves of Euphorbia are inversely correlated to the soil moisture level, leaf water content and leaf water portioned[32]

Hong-PenWang,etal;(2019).use photo acoustic spectroscopy and spectral imaging to characterize the effects and mechanism of biological and physiological to solve basic biological problems such as adaptation in special environment .They obtained that there was great significance for analyzing optical and acoustic signals of living tissues.[33].

R. C Mesquite et al;(2006).reviewed the application of open photo acoustic technique to study photosynthetic activity in plant leaves. This study reviewed that the photo acoustic spectroscopy could be applied to determine the action of spectrum from oxygen evaluation measurement

and photo synthetic parameters such as temperature and nutrient availability[34]..

Stephen et al;(2001). evaluate interpretation of the most useful of photo acoustic signals applied to photo synthetic with an emphasis on the resolution of uncertain ties in the interpretation of photo acoustic signal in plant tissue including the storage of energy and oxygen evaluation by leaf tissue[35]. .

Sang Joon Lee,etal;[2018] used photo acoustic to investigate the effect of surface acoustic wave frequency on plant transpiration to understand the acoustic activated leaf transpiration and utilized the advantage of surface acoustic wave to enhance water transport in the test plant using differ rent frequencies [10.15.20] **MHZ** Study revealed that the transpiration rates of water transportation in the leaves gave the heights value at 15 MHZ. **Crestina popa [2019]**studied the detection of ethylene released by cherry flowers ,apple flowers and straw berry flowers using photo acoustic spectroscopy and get the result that the ethylene can be a measure of flowers growth regulator and nitrogen has substantial control on ethylene [36]..

C.Bushmann(1989) applied photo acoustic in plant science such as photo synthesis. The study revealed that this can allow the detection of gross oxygen evaluation and information about the energy balance of photo synthetic reaction[37]..

Metron and Kurt Schoffner (1985) applied pulse laser induse opto acoustic and recorded the response of leaves of several plant.The result showed that there was spectra resemble the absorption spectra of leaves and that the result is wavelength dependent. Under the condition of application the opto acoustic signals it was found to be increased by a

factor of approximaitly by two over the signal measured without background illumination and the authors reported that this application provide basis for countitative evaluation for photo physical and photo chemical prosses in photo synthetic system[38].

E.A.Zakhidov et al;(2018),designed photo acoustic spectrometer based on three wavelength (465,525,640)nm to determine the intensity of photo synthesis in different layers of plant leaves and they reported that the proposed spectro photo meter can be employed for quantitative evaluation of heat dissipation and photo chemical assimilation of the absorped light energy in this medium.[39].

A.K.Rai and J.P.Singh (2007) reported the importance of photo acoustic spectro scopy in agricultural and life science and discussed the benifets of photo acoustic spectroscopy as a tool to diagnose diseases in plants.[40].

Jietlui etal, [2016] able to convert molecular vibration into acoustic waves following bond selective photo acoustic spectroscopy imaging technique in which away of detecting specific molecule in complex tissue environment[41].

Kveeran janeyulu and V.S.R DAS [1981] utilized [PAS] technique to characterize purple pigmentation in leaves of species of euphorbia by observing a peak at 545nm .They recorded the maximum absorption peak in vivo chlorophyll at 675nm as against 665nm of the in vivo chlorophyll. The intensity in leaves of Euphorbia are inversely correlated to the soil moisture level, leaf water content and leaf water portioned.

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special environment .They obtained that there was great significance for analyzing optical and acoustic signals of living tissues.

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Crestina popa [2019]studied the detection of ethylene released by cherry flowers ,apple flowers and straw berry flowers using photo acoustic spectroscopy and get the result that the ethylene can be a measure of flowers growth regulator and nitrogen has substantial control on ethylene[42].

Summary and critique : Different attempts were made to study the atomic structure of atoms using different techniques [43,44].The spectral techniques are the most popular powerful tools[45,46,47].These include the UV spectrum of elements [48].In the laser technique light spectrum is displayed [49].The Fourier transform infra red spectrometer utilizes the infra red spectrum [50,51,52]].The XRF spectrometer utilizes the X-ray fluoresece spectrum of atoms [53].The XRD device is utilized to determine the nano and crystal structure of the specimen [54].But recently ultrasound is used as a probe for determining the chemical bonds and atomic structure [55,56].This new technique is based on the Bragg refletion phenomenon [57].This new technique is widely used in many applications [58].It is used in material science[59],as well as medicine [60,61].

Chapter Three

Materials and Methods

3.1 Introduction

This chapter contains the materials (plant leaves) showing the equipment which are used to generate and detect photo acoustic spectrum.

3.2 Materials and Equipment

Six samples of different plant leaves were prepared which live under the sun light and other six samples for the same plants which are living in the shadow were also prepared. The samples which grow in sun and shadow are : *Bougainvillea spp1, Sitrus sanseis , Canna indicia, Ixora, Coccinnia, Bougainvillea spp2, and Citrus paradisi.*

3.3 The Equipment's:

The equipment's used in work are:

3.2.1 Light source

The light source is diode laser, having power of (4,4Mw) and wavelength of 450nm.The importance of using this specific wavelength light source is due to the possibility of its absorption by Chlorophyll of the plants.

3.2.2 Chopped light

The Chopped Light mode is used:

1. To increase measurement level sensitivity by cutting the high frequency noise.
2. To detect only the light that the LS emitted, effective for free space measurement. In free space measurement, the detector can also receive ambient light, e.g. sunlight and ceiling light. If the LS emits chopped light, then the OPM measures only the chopped signal at the same frequency.

3. To remove power measurement error due to the drift of the electrical amplifier's offset, effective for long term measurement. Since the amplifier's offset is temperature dependent, AC detection (CHOP mode) is ideal for long term measurement.
4. In field testing, chopped light is commonly used for fiber identification.

3.2.3 Samples:

The Samples used are six plant leaves growth in sun and same as growth in shadow. These plants are:

3.2.3.1 Bougainvillea is a genus of thorny ornamental vines, bushes, and trees with flower-like spring leaves near its flowers. Bougainvillea are popular ornamental plants in most areas with warm climates. Although it is frost-sensitive, bougainvillea can be used as a houseplant or hanging basket in cooler climates. In the landscape, it makes an excellent hot season plant, and its drought tolerance makes it ideal for warm climates year-round. Its high salt tolerance makes it a natural choice for color in coastal regions. It can be pruned into a standard, but is also grown along fence lines, on walls, in containers and hanging baskets, and as a hedge or an accent plant. Its long arching thorny branches bear heart-shaped leaves and masses of papery bracts in white, pink, orange, purple, and burgundy.

Bougainvillea are popular ornamental plants in most areas with warm climates, such as Florida and South Carolina, and across the Mediterranean Basin.

3.2 3.2(*Citrus sinensis* (L.) Osbeck) is the most important. Fruits are characterized by sweet and pleasant taste and a fine aroma that is much appreciated by consumers. Sucrose is the main

carbohydrate, and citric acid the dominant organic acid in the juice. It is considered as a rich source of antioxidants, such as ascorbic acid and phenolic compounds (mainly hesperidin and narirutin). It is quite rich in carotenoids (mainly violaxanthin, β-cryptoxanthin, and lutein). In pigmented oranges the color is due to the presence of anthocyanins, except in a few cultivars in which lycopene is the main pigment.

3.2.3.3 Canna indica is a perennial growing to between 0.5 m and 2.5 m, depending on the variety. It is hardy to zone 10 and is frost tender. The flowers are hermaphrodite. *Canna indica* sps. can be used for the treatment of industrial waste waters through constructed wetlands. It is effective for the removal of high organic load, color and chlorinated organic compounds from paper mill wastewater.

a species of flowering plant in the family Rubiaceae. It is a common flowering shrub native to Southern India, The flowers, leaves, roots, and the stem are used to treat various ailments in the Indian traditional system of medicine, the Ayurveda, and in various folk medicines, in traditional Indian medicine the fusion of juice leaves and the fruit of Ixora coccinea is used to care for dysentery, ulcers and gonorrhea.

3.2.3.4 The grapefruit (*Citrus* × *paradisi*) is a subtropical citrus tree known for its relatively large, sour to semisweet, somewhat bitter fruit. The interior flesh is segmented and varies in color from pale yellow to dark pink.

3.2 3.5 Grapefruit is a citrus hybrid originating in Barbados as an accidental cross between the sweet orange (*C. sinensis*) and the pomelo or shaddock (*C. maxima*), both of which were introduced from Asia in the 17th century. When found, it was called the *forbidden fruit*. In the past it was referred to as the *pomelo*, but that term is now the common name for *Citrus maxima*.

(Bougainvillea spp 1l in shadow, Bougainvillea spp 1 in sun, Citrus Sanseis in sun, Citrus Sanseis in shadow, Canna Indicia in sun, Canna Indicia in shadow, Ixora Coccinnia in sun, Ixora Coccinnia in shadow, Bougainvillea Spp2 in sun, Bougainvillea Spp2 in sun, Citrus Paradisi in shadow and Citrus Paradisi in sun.

3.2.4 piezoelectric sensor

3.2.5 USB-2000 spectrometer (detection sensors).

3.2.6Computer:

Having a programmer that can enable to display sound spectrum on the screen.

3.3 Methodology:

1. Each leave is exposed 0.0125 second to laser beam. The photons of laser were absorped by leaves atoms which cause them to vibrate .The vibration atoms emit ultrasound waves to the surrounding.
2. The transducer unit which is the piezoelectric sensor receipts the emitted sound and produces an electric pulse.
3. The vibration bond which generates acoustic waves can be characterized throw it is special pulse frequency.

Experimental schemes for photoacoustic studies on solid sample includes the measurement of the generated vibration bonds in samples wave either directly with a piezoelectric sensor for the pulse regime, or indirectly in the

USB 2000 spectrometer which is in contact with the sample by a computer as shown in fig (31) .for the Bragg regime.

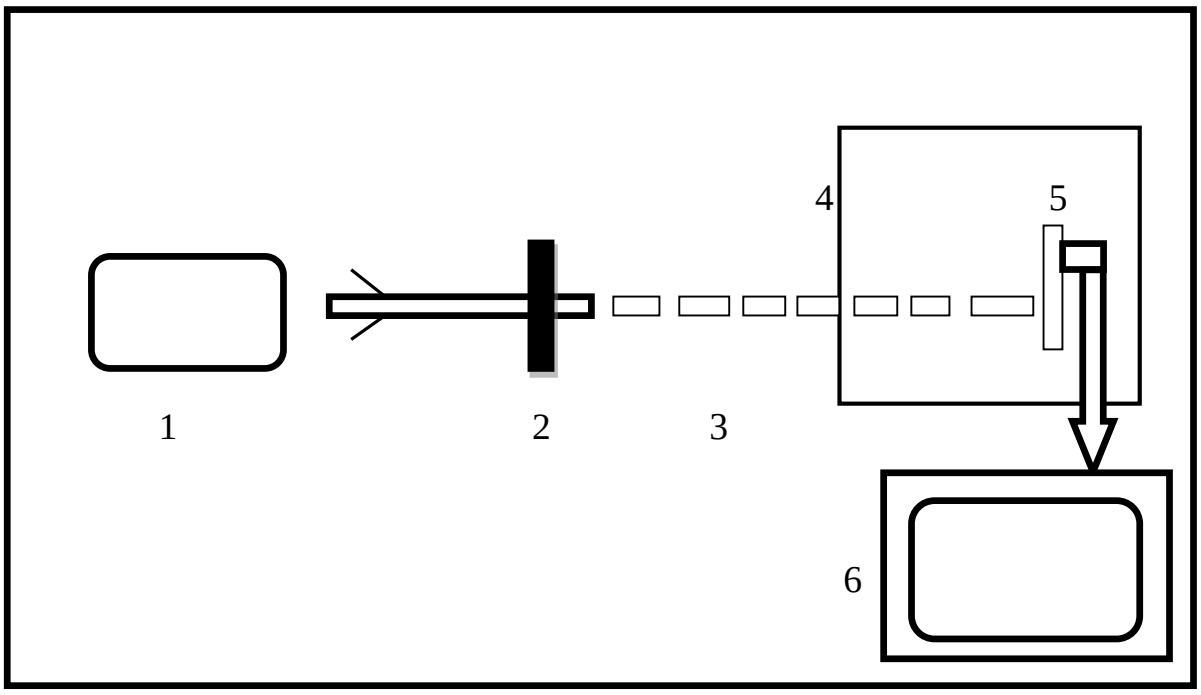


Fig (3.1): setup of experiment

1= light source, 2 = sample, 3 = laser beam ,4 = piezoelectric sensor ,
5 = USB 2000 spectrometer , 6 = computer.

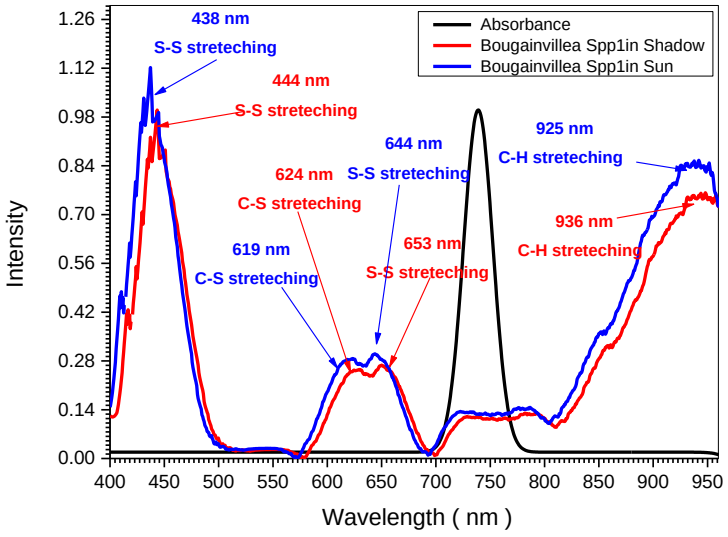
Chapter Four

Results and Discussion

4.1 Introduction:

In this chapter the main results that have been obtained from the experiments made to generate travelling acoustic waves on the surface of sun and shadow plant and non-destructive test by Photo acoustic Spectroscopy. The generated travelling acoustic waves and vibration bonds (Non-Destructive test) of five samples plant growth in sun and shadow were measured by the Photoacoustic spectroscopy (PAS) and the results as shown in this chapter.

4.2.1 The results of Photo acoustic spectroscopy (PAS)



Fig(4.1)The experimental acousto-optic modulators curve relation between wavelength and acousto-optic modulators intensity of Bougainvillea Spp1 samples growth in sun and same plant `growth in shadow.

Fig(4.1) shows the relation between the wavelength and the intensity of acoustic optic modulation that generated from leaves of Bougainvillea Spp1 growth in sun and same plant growth in shadow which exposed with diode laser 450nm at range (400 - 960) nm . Also fig(4.1) shows spectra of the diode laser of power 2.76 eV due to the plant absorbance 1.6757 eV. Due to sucked energy , the bonds that shown are (S-S stretching at (438,644) nm for sun and(444, 653) nm f or shadow, C-H stretching at 619 nm for sun and 624nm f or shadow and C-S stretching at 925 nm for sun and 936 nm for shadow). The reason of different position vibration bonds between the sun and shadow plant come from the concentration of components which consist of the plant leaves.

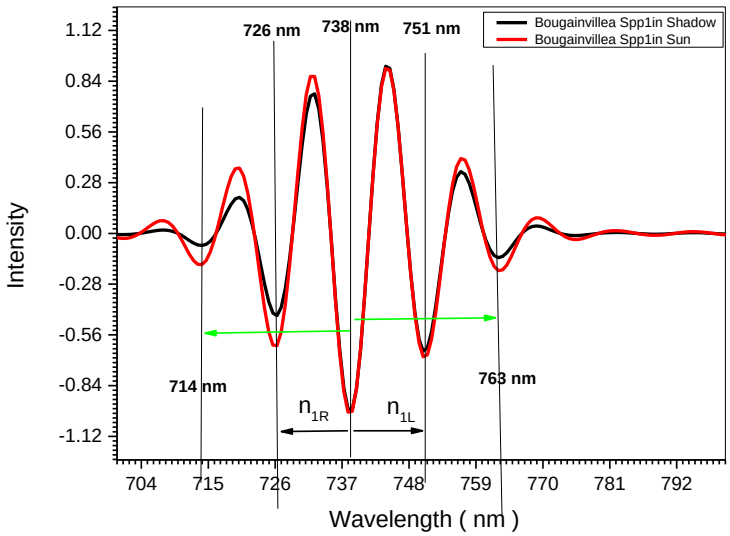


Fig (4.2) Bragg regime of Bougainvillea Spp1 samples growth in sun and shadow.

Fig(4.2) show the Bragg regime of Bougainvillea Spp1 samples growth in sun and in shadow. The main wavelength of bragg regime modal is at 738nm.The first order diffraction to the left at (751) nm and first right is at (726)nm. The second order diffraction left is at(763)nm. and second right is at (714) nm. The results of Bragg regime of Bougainvillea Spp1 samples growth in sun in shadow was tabulated in table (2).

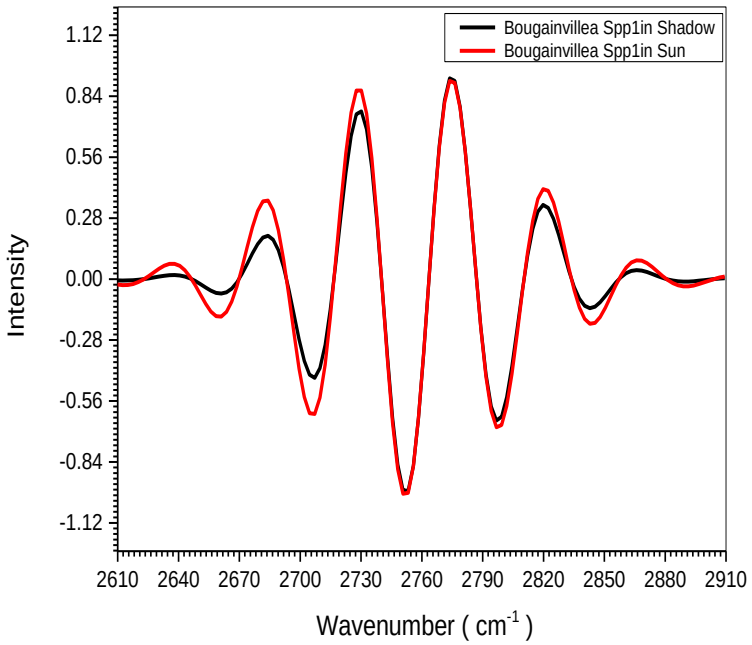


Fig (4.3) The frequency of acoustic optic modulation of Bougainvillea Spp1 growth in sun and in shadow.

Fig(4.3) shows the curve of relation between wavenumber and the intensity of acoustic optic modulation that made from Bragg regime of Bougainvillea Spp1 growth in sun and in shadow.The frequency of acoustic optic modulation is equal $\frac{1}{\lambda}$, the first average order equal (6 nm) and the second average order equal (12 nm) as shown in table (4.2). The

frequency of acoustic optic wave of samples Bougainvillea Spp1 growth in sun and same plant in shadow equal 46 cm^{-1} are shown fig (4.3).

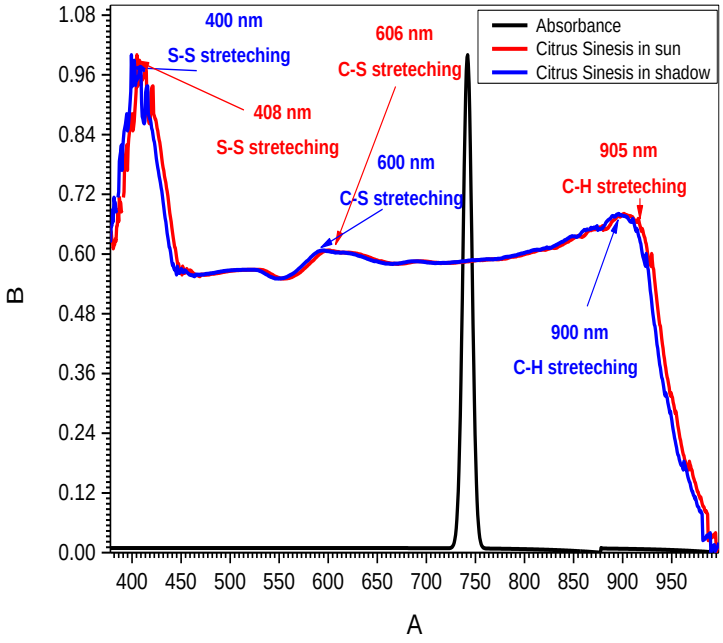


Fig (4.4) the experimental acousto-optic Modulators curve relation between wavelength and acousto-optic modulators intensity of Citrus Sinesis samples growth in sun and shadow

Fig(4.4) shows the relation between the wavelength the intensity of acoustic optic modulation that generated from leaves of Citrus Sinesis growth in sun and shadow which are exposed with diode laser 450nm at range (400 - 960) nm . Also one used diode laser of power 2.76 eV. The plant absorbance is 1.6644 eV. Due to sucked energy ,the bonds shown are (S-S stretching at (408) nm for sun and(400) nm f or shadow, C-H stretching at 906 nm for sun and 900nm for shadow and C-S stretching at 606 nm for sun and 600 nm for shadow) as shown in fig (4.4) . The reason of different

position vibration bonds between the sun and shadow plant come from the concentration of components in the plant leaves.

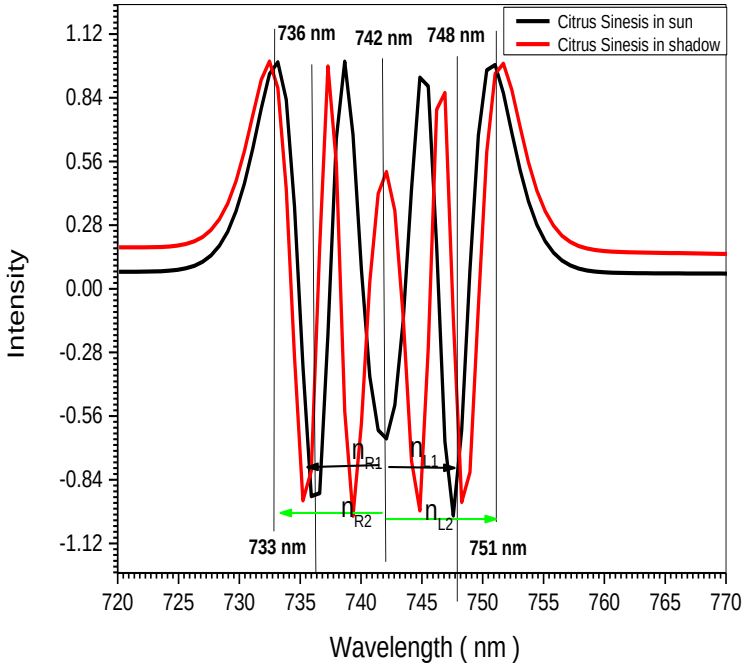


Fig (4.5) Bragg regime of Citrus Sinesis samples growth in sun and shadow.

Fig (4.5) shows the Bragg regime of Citrus Sinesis samples grown in sun and shadow. The main wavelengths of Bragg regime modal are at 742nm. The first order diffraction to the left is at (748) nm and the first right is at (736)nm. The second order diffraction left is at (751) nm, and second right is at (733) nm. The results of Bragg regime of Citrus Sinesis samples growth in sun and in shadow was tabulated in table (4.2).

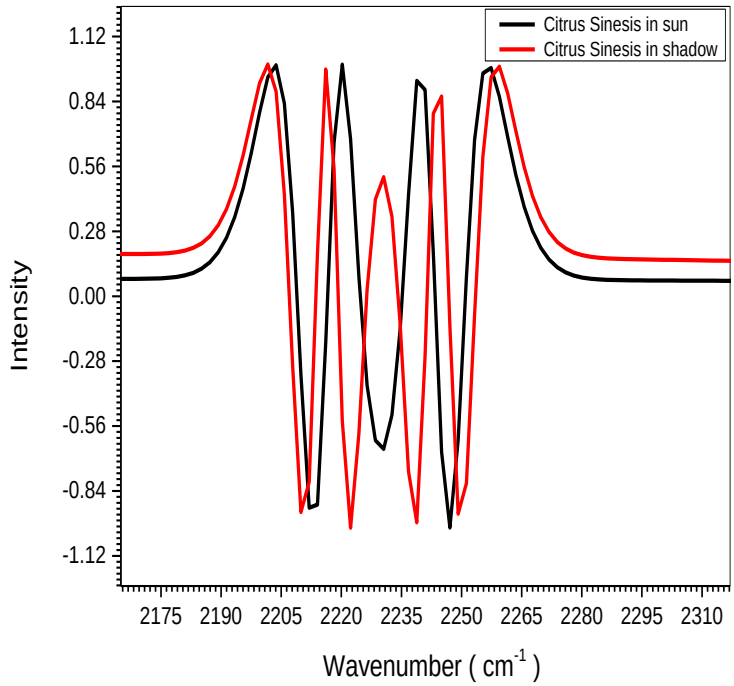
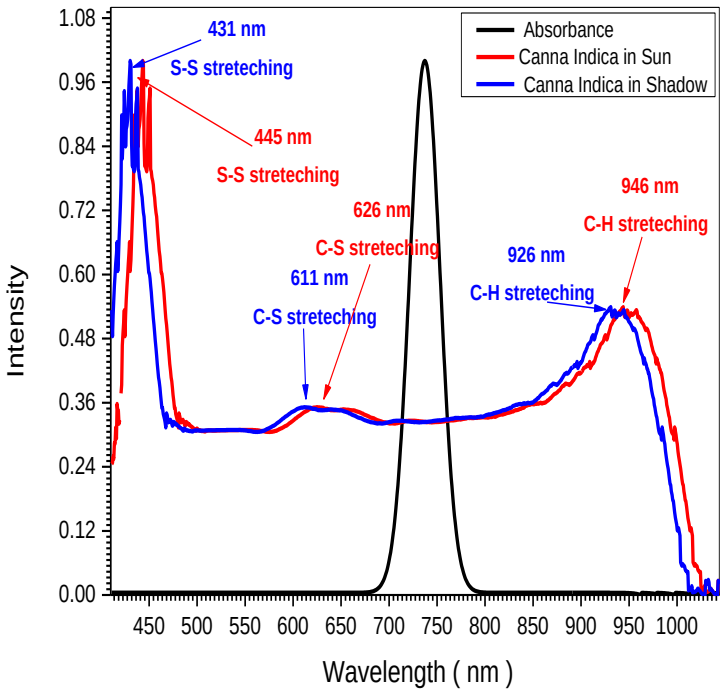


Fig (4.6) The frequency of acoustic optic modulation of Citrus Senisis growth in sun and same plant in shadow.

Fig(4.6) shows the curve of relation between wavenumber and the intensity of acoustic optic modulation that made from Bragg regime of Citrus Senisis growth in sun and shadow the frequency of acoustic optic modulation is equal $\frac{1}{\lambda}$. The first average order is equal (6 nm) and the second average order is equal (9 nm) as shown in table (4.2). The average frequency of acoustic optic wave of Bougainvillea Spp1 growth in sun and in shadow are equal 17 cm^{-1} as shown in fig (4.5).



Fig(4.7). The experimental acousto-optic Modulators curve relation between wavelength and acousto-optic modulators intensity of Canna Indica samples growth in sun and shadow.

Fig(4.7) shows the relation between the wavelength and the intensity of acoustic optic modulation that generated from leaves of Canna Indica growth in sun and shadow which is exposed with diode laser 450nm at range (400 - 960) nm. When used the diode laser of power 2.76 eV the plant absorbance is at 1.6847 eV. Due to sucked energy , bonds that are shown (S-S stretching at (445) nm for sun and(431) nm for shadow, C-H stretching at 946 nm for sun and 926 nm for shadow, and C-S stretching at 925 nm for sun and 936 nm for shadow).

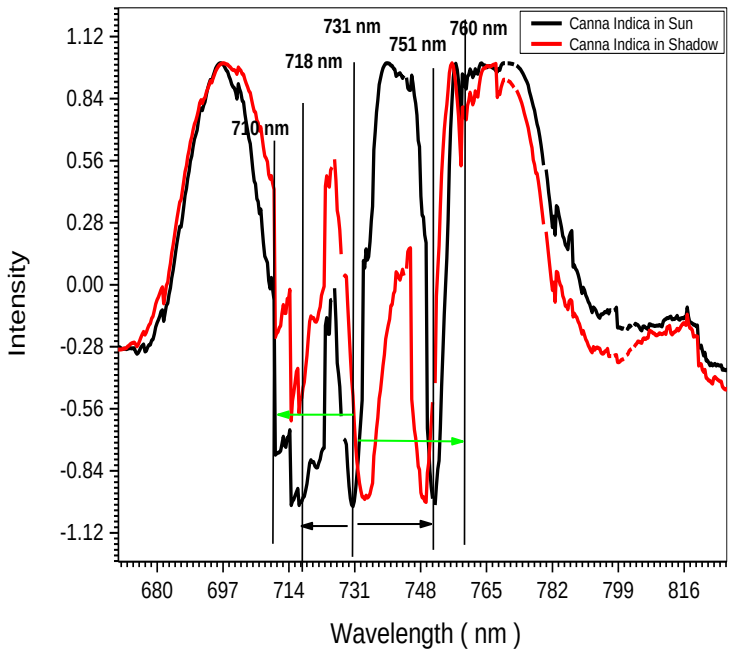


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Fig (4.8) Bragg regime of Canna Indica samples growth in sun and same plant `growth in shadow

Fig(4.8) show the Bragg regime of Canna Indica samples growth in sun and shadow. The main wavelength of Bragg regime modal is at 731 nm, the first order diffraction left is at (751)nm and first right is at (718) nm. The second order diffraction left is at (700) nm, and second right is at (710) nm. The result are shown in table (4.2).

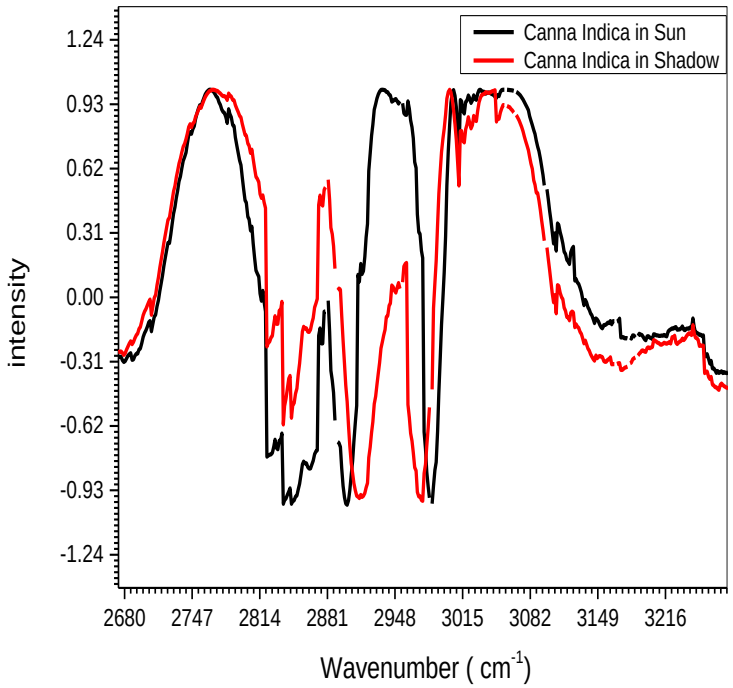

Fig (4.9) The frequency of acoustic optic modulation of Cannaq Indica growth in sun and shadow.

Fig(4.9) shows the relation between wavenumber and the intensity of acoustic optic modulation that made from Bragg regime of Canna Indica growth in sun and shadow the frequency of acoustic optic modulation is equal $\frac{1}{\lambda}$. The first average order is equal (16.5 nm) and the second average order is equal (25 nm) as shown in table (4.2).

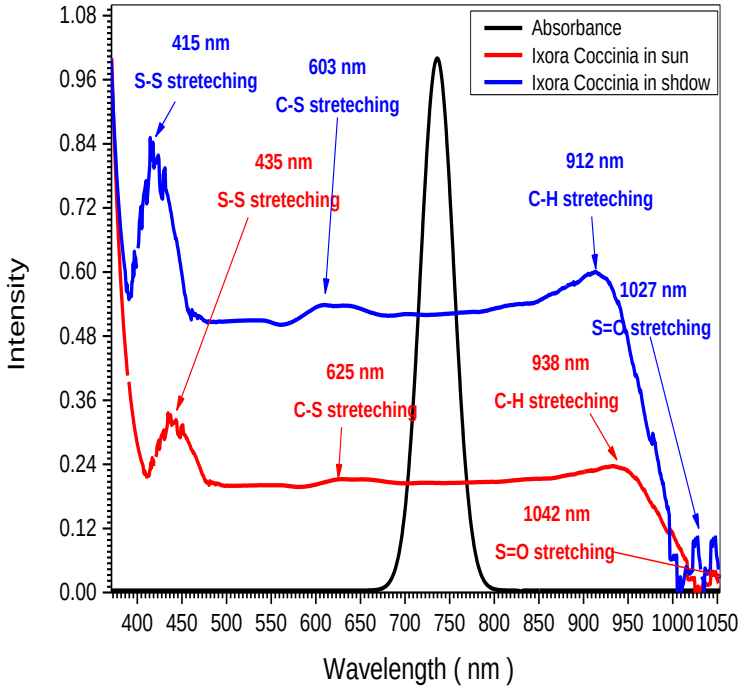

Fig (4.10) the experimental acousto-optic Modulators curve relation between wavelength and acousto-optic modulators intensity of Ixora Coccinia samples growth in sun and shadow.

Fig (4.10) shows the relation between the wavelength and the intensity of acoustic optic modulation that generated from leaves of Ixora Coccinia growth in sun and shadow which exposed with diode laser 450nm at ranged (400 - 960) nm. for the diode laser of power 2.76 eV the plant absorbance is 1.6824 eV, Due to sucked energy. Bonds that are shown are (S-S stretching at (435) nm for sun and(415) nm f or shadow, C-H stretching at 938 nm for sun and 912 nm f or shadow and C-S stretching at 625 nm

for sun and 603 nm f or shadow and S=O stretching at1042nm for sun and 1027nm for shadow).

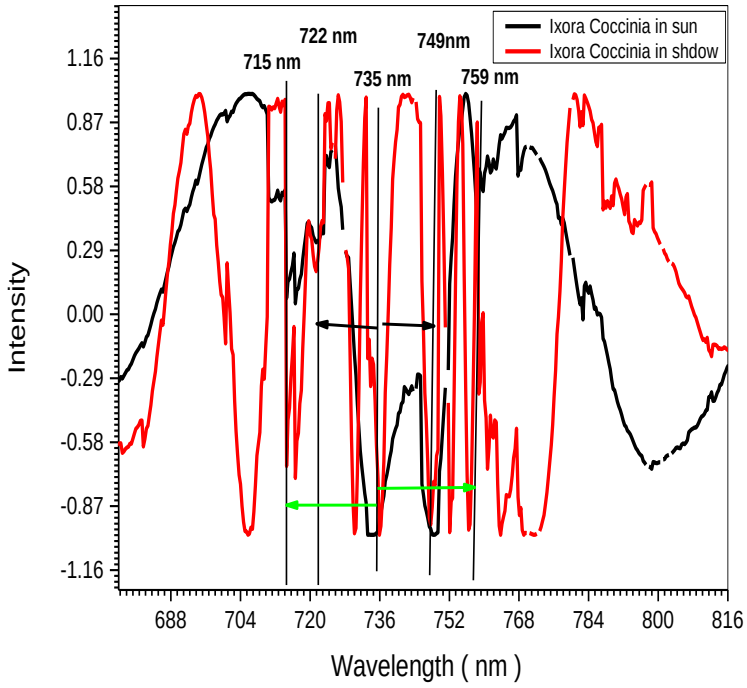

Fig (4.11) Bragg regime of Ixora Coccinia samples growth in sun and same plant `growth in shadow

Fig (4.11) shows the Bragg regime of Ixora Coccinia samples growth in sun and shadow. The main wavelength of Bragg regime modal is at 735nm.The first order diffraction left is at (749) nm and first right is at (722) nm. The second order diffraction left at (759) nm, and second right at (715) nm. The all results of Bragg regime of Ixora Coccinia samples growth in sun and shadow was shown in table (2).

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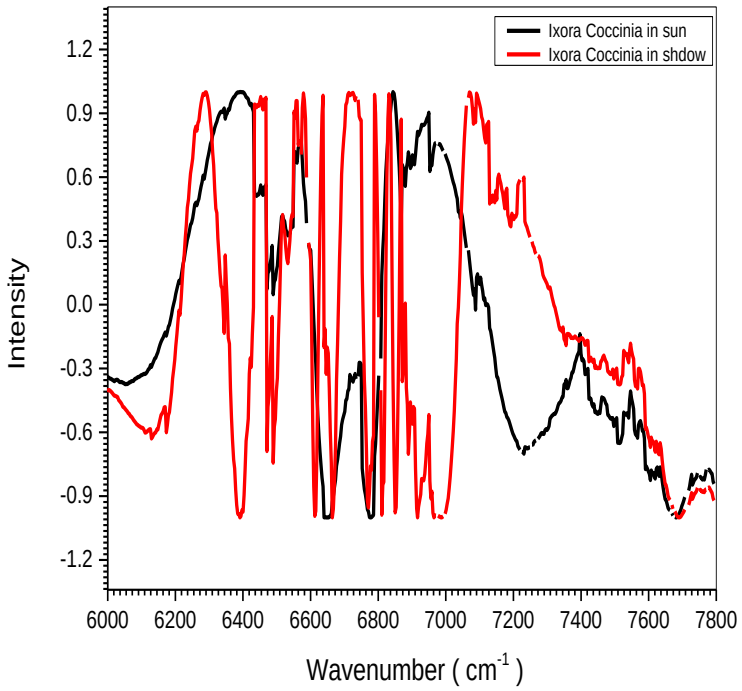


Fig (4.12) the frequency of acoustic optic modulation of Ixora Coccinia growth in sun and in shadow.

Fig(4.12) shows the relation between wavenumber and the intensity of acoustic optic modulation that made from Bragg regime of Ixora Coccinia growth in sun and the same plant growth in shadow, where n is the average order is taken from fig (4.11),and the frequency of acoustic optic modulation is equal $\frac{1}{\lambda}$, the first average order equal (13.5 nm) and the second average order equal (22 nm) as shown in table (4.2). The average frequency of acoustic optic wave of samples Ixora Coccinia growth in sun and in shadow are equal to 290 cm^{-1} as shown in fig (4.11).

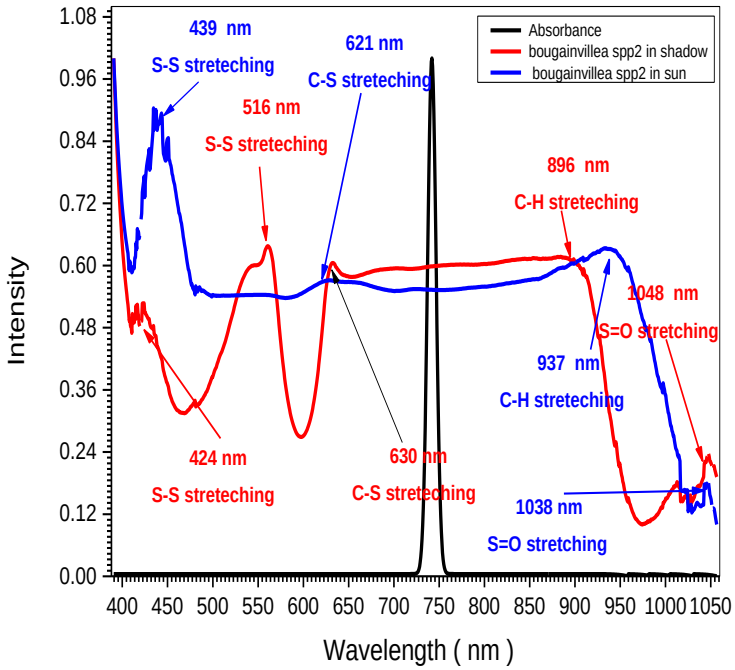


Fig (4.13) The experimental acousto-optic Modulators curve relation between wavelength and acousto-optic modulators intensity of Bougainvillea Spp2 samples growth in sun and `growth in shadow

Fig(4.13) the relation between the wavelength and the intensity of acoustic optic modulation that generated from leaves of Bougainvillea Spp2 growth in sun and in shadow which was exposed with diode laser 450nm at ranged (400 - 960) nm .For the diode laser of power 2.76 eV the plant absorbance is 1.6779 eV , due to sucked energy. The bonds that are shown are (S-S stretching at (439) nm for sun and(516-424) nm f or shadow, C-H stretching at 937 nm for sun and 896 nm f or shadow and C-S stretching at 621 nm for sun , 630 nm f or shadow and S=O stretching at 1038nm for sun and 1048nm for shadow

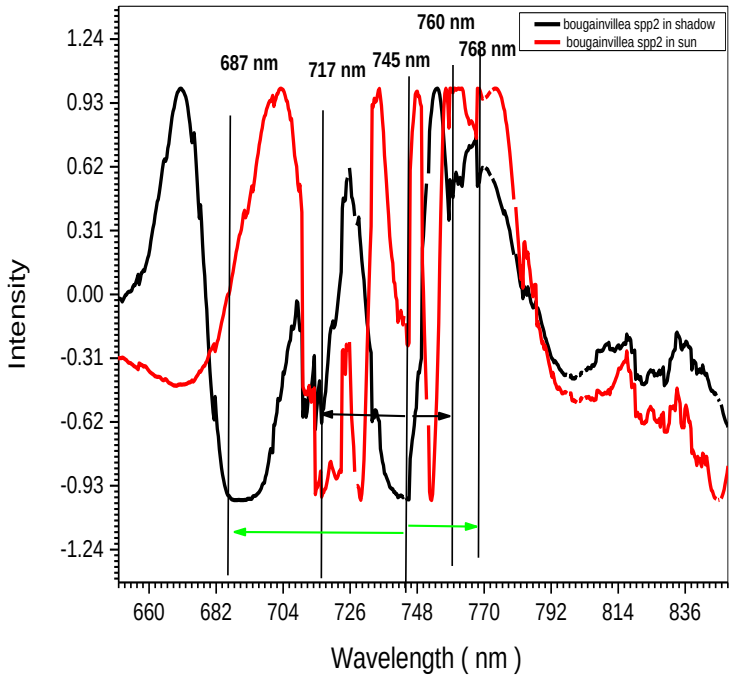


Fig (4.14) Bragg regime of Bougainvillea Spp2 samples growth in sun and `growth in shadow

Fig(4.14) show the Bragg regime of Bougainvillea Spp2 samples growth in sun and ` in shadow .The main wavelength of Bragg regime modal is at 745 nm, the first order diffraction left at (760) nm and first right at (717)nm. The second order diffraction left at (768) nm,and second right at (687) nm. The results of Bragg regime of Bougainvillea Spp2 was exhibited table (2) .

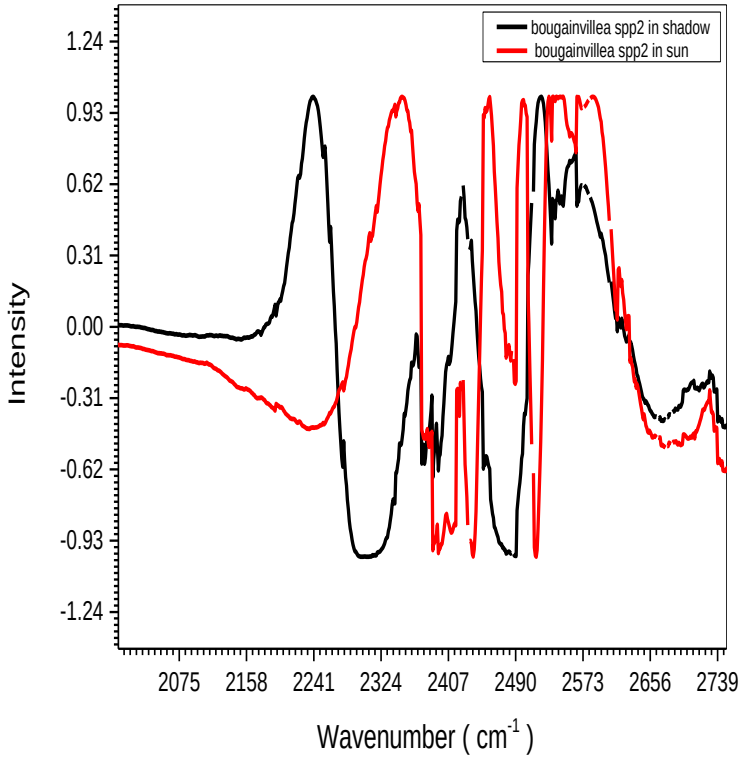


Fig (4.15) The frequency of acoustic optic modulation of Bougainvillea Spp2 growth in sun and in shadow.

Fig(4.15) show the relation between wavenumber and the intensity of acoustic optic modulation that made from Bragg regime of Bougainvillea Spp2 growth in sun and the same plant growth in shadow, where n is the average order is taken from fig (4.14),and the frequency of acoustic optic modulation is equal $\frac{1}{\lambda}$, the first average order equal (21.5 nm) and the second average order equal (35.5 nm) as showing in table (4.2). The average frequency of acoustic optic wave of samples Bougainvillea Spp2 growth in sun and in shadow is equal 127 cm^{-1} as shown in fig (4.3).

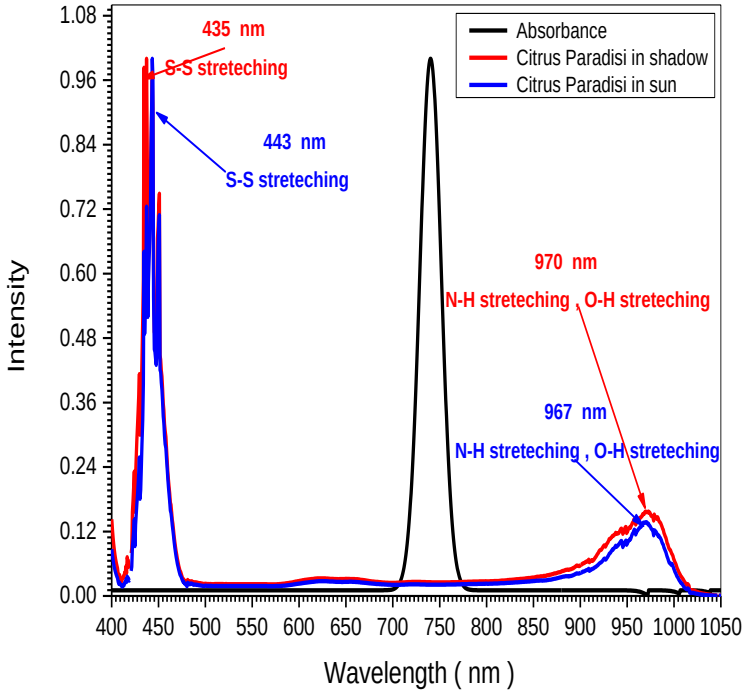


Fig (4.16) The experimental acousto-optic Modulators curve relation between wavelength and acousto-optic modulators intensity of Citrus Paradisi samples growth in sun and in shadow

Fig(4.16) shows the relation between the wavelength hand the intensity of acoustic optic modulation that generated from leaves of Citrus Paradisi growth in sun and in shadow which are exposed to diode laser 450nm at ranged (400 - 960) nm when using the diode laser of power 2.76 eV the plant absorbance is 1.6824 eV , due to sucked energy , The bonds that are shown are (S-S stretching at (443) nm for sun and(435) nm f or shadow, N-H stretching O-H stretching at 967 nm for sun and 970 nm f or shadow).

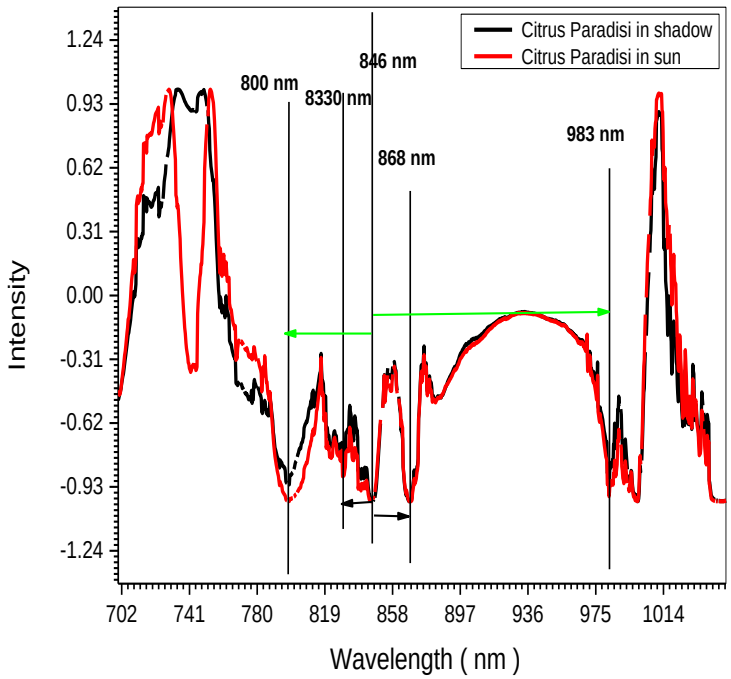
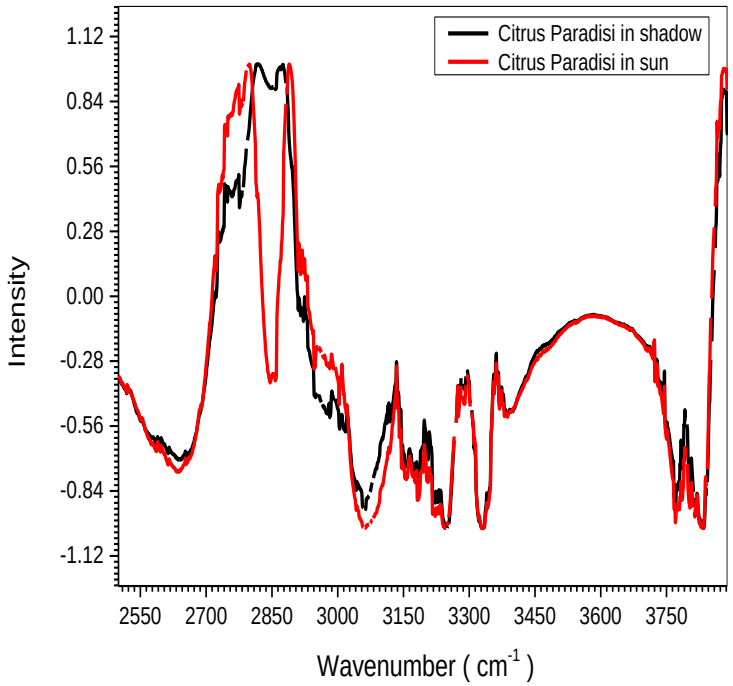


Fig (4.17) Bragg regime of Citrus Paradisi samples growth in sun and in shadow

Fig(4.17) shows the Bragg regime of Citrus Paradisi samples growth in sun and in shadow was applied .The main wavelength of Bragg regime modal is at 846 nm, the first order diffraction left at (868) nm and first right at (830)nm. The second order diffraction left at (983) nm,and second right at (800) nm. The esults of Bragg regime of Citrus Paradisi samples growth in sun and same plant `growth in shadow has been shown in table (4.2) .



Fig(4.18) The frequency of acoustic optic modulation of Citrus Paradisi growth in sun and in shadow.

Fig(4.18) shows the relation between wavenumber and the intensity of acoustic optic modulation that made from Bragg regime of Citrus Paradisi growth in sun and the in shadow, where n is the average order is taken from fig (4.17),and the frequency of acoustic optic modulation is equal $\frac{1}{\lambda}$, the first average order equal (19 nm) and the second average order equal (41.5 nm) as shown in table (4.2). The average frequency of acoustic optic wave of samples of Citrus Paradisi growth in sun and in shadow is equal 77 cm^{-1}

Table (4.1) the samples and Wavelength of some bands organic compounds (nm) using pluse regime

No	Samples	Wavelength of some bands organic compounds (nm)				
		S-S stretching	C-S stretching	C-H stretching	S= O stretching	N-H and O-H
1	Bougainvillea spp 1 in sun	438nm 644nm	619nm		925nm	
2	Bougainvillea spp 1in shoadow	444nm 653nm	624nm	936nm		
3	Citrus Sanseis in sun	408nm	606nm	905nm		
4	Citrus Sanseis in shadow	400nm	600nm	900nm		
5	Canna Indicia in sun	445nm	606nm	946nm		
6	Canna Indicia in shadow	431nm	611nm	926nm		
7	Ixora Coccinnia in sun	435nm	625nm	938nm	1042nm	
8	Ixora Coccinnia in shadow	415nm	603nm	912nm		
9	Bougainvillea Spp2 in sun	516nm 424nm	630nm	896nm	1048nm	
10	Bougainvillea Spp2 in sun	439nm	621nm	937nm	1038nm	
11	Citrus Paradisi in sun	443nm				970nm
12	Citrus Paradisi in shadow	435nm				967nm

Table (4.2) The samples and the order diffraction of Bragg regime

No	**samples**	Order Diffraction of Bragg Regime **(nm)**					
		$n_{L=2}$	$n_{L=1}$	$n_{R=1}$	$n_{R=2}$	n-1	n-2
1	Bougainvillea spp 1l in shadow	12	6	6	12	6	12
2	Bougainvillea spp 1 in sun	11	5	7	13	6	12
3	Citrus Sanseis in sun	9	6	6	9	6	9
4	Citrus Sanseis in shadow	8	7	5	10	6	9
5	Canna Indicia in sun	29	20	13	21	16.5	25
6	Canna Indicia in shadow	30	19	14	20	16.5	25
7	Ixora Coccinnia in sun	24	14	13	20	13.5	22
8	Ixora Coccinnia in shadow	23	15	12	21	13.5	22
9	Bougainvillea Spp2 in shadow	23	15	28	42	21.5	35.5
10	Bougainvillea Spp2 in sun	22	16	27	43	21.5	35.5
11	Citrus Paradisi in shadow	37	22	16	46	19	41.5
12	Citrus Paradisi in sun	36	23	15	47	19	41.5

Chapter Five

Discussion and Recommendation

5.1 Discussion:

In view of figures (4.1, 4.2……4.18) and table (4.1).All plants have S_S,C_S,C_H stretching .However Ixora Coccinia and Bougainvillea SPP2 have extra S=0 Stretching in the sun. The plant citrus paradisi has N_H and O_H stretching in both Shadow and sun. The bond wave lengths for each plant is different from all other plants. The bond wave length for any specific plant in sun is different from that in shadow but no regular pattern is observed where the change looks random. A change in the D number of absorbed photon is also observed. Table (4.2) shows that for all plants the exposure to sun change the position of the diffraction order which reflect change of atomic distances. The atomic distances changes also from plant to plant. It is very interesting to note that the discovery of formation of new bonds in plants exposed to sun by ultrasound technique is very important for herbal medicine. This enable forming the desired bonds which contribute to the effective ingredient of a certain plant by exposing it to the sun. It also enables discarding the bods that contribute to toxic compounds.

In the work of K.Veeranjaneyulu and V.Das[30] ,the spectra of green leavesis in the range of 545 nm to 675nm,where the intensity decreases upon increasing US spectra. The wavelength range is in a agreement of that found in this work. The paper of Kveeranjaneyulu [32] showed the existence of chlorophyll peak at 675 nm,the intensity is inversely correlated to the moisture and water leaf content. This conforms with our study as far as shadow leaves is more rich in water compared to that exposed to sun. Thus the change of intensity means change in the number of formed bonds. In our work the strength of the bond it self changes. The study of Matron [38] indicate that the back ground illumination affect the acoustic signal intensity. The signal intensity without back ground is higher. This agrees with our study which also

indicates the effect of environment .The work of E.A.Zakhidov [39] designed photo acoustic spectrometer for (465,576,640nm) to evaluate absorbed light energy. This means that light affect the spectra in complete agreement with our study .A.K.Rai [40] used photo acoustic spectroscopy to diagnose plant diseases agrees with our study as far as plant diseases affect light absorption of leaves.

5.2 Conclusion:

The new assembled laser induced ultrasound spectrometer is found to be useful in discovering the chemical bonds in plants as well as their crystal structure. It shows that the bonds of plants are different from each other is wave length spectra. It also shows that the bonds of plants in shadow have different strengths form that exposed to sun more over some plants form new bonds in the sun.

5.3 Future work:

1-The ultrasound spectrometer can be extended to be useful in mineral exploration.

2-The part of the spectrometer that utilize Bragg reflection can be prompted to determine the nano sizes.

3-The detection of atom mechanical vibration can be promoted infra-red and temperature detection

Recommendations

1-These tests can be extended to other plant leaves.

2-The laser induced ultrasound spectrometer role in studying the crystal structure can be extended for thin films also.

3-The laser induced ultrasound spectrometer should be tested for the Nano size.

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