Sudan University of Science and Technology

College of graduate studies

Usage of Laser Induced Emission to Distinguish Between Dental Caries and Sound Teeth

استخدام الإنبعاث المنتج بالليزر للتمييز بين الأسنان المتسوسة والأسنان السليمة

A thesis submitted in partial fulfillment for the requirements

Of M .Sc. in physics

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2016

الآية

بسم الله الرحمن الرحيم

قال تعالى : وَضَرَبَ لَنَا مَثَلًا وَنَسِيَ خَلْقَهُ ۖ قَالَ مَن يُحْيِي الْعِظَامَ وَهِيَ رَمِيمٌ (78)

صدق الله العظيم

يس:78

Dedication

This work is dedicated to the person who gives my life meaning and who I love, my mother.

To my lovely father

To my lovely brothers and lovely sisters

To my doctors and teachers

To my family

To my best friends

And my colleagues

Acknowledgements

Before of all, I render my praise to God who offered me the health to perform this work.

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Abstract

In this research Nitrogen laser (N_2) was used to induce emission to distinguish between the dental caries and sound teeth.

Three samples of dental caries and one sample of sound teeth has been used to determine absorbance of the dental caries and sound teeth using UV-Vis spectrophotometer then it irradiated by nitrogen laser (N_2) with wavelength of 337.8nm, pulse energy 0.04mJ, and pulse time 100msec, interaction between laser and the teeth was happened, teeth absorbed some of these ultraviolet rays induce visible spectrum carried out by a USB spectrophotometer.

The result showed an emission of broad band (363 t0 627nm) and sharp peak (673nm) in the visible region and one sharp peak in the infrared region (1013nm) in all samples, the intensity of this band and peaks is low in dental caries spectra while it was high in the sound tooth spectrum.

المستخلص

في هذا البحث تم إستخدام ليزر النيتروجين (N_2)لإنتاج الإنبعاث المستحث لليزرللتمييز بين الأسنان المتسوسة والأسنان السليمة.

أخذت ثلاث عينات من الأسنان المتسوسة وعينة واحدة من الأسنان السليمة لتحديد طيف الإمتصاص لمادتها باستخدام جهاز مطيافية الأشعة فوق البنفسجية والمرئية. ثم شُعِعت بواسطة ليزر النيتروجين ذي الطول الموجي 337.8نانومتر بطاقة نبضية قدرها 0.04ملي جول,و بزمن نبضي 100 ملي ثانية وحدث تفاعل بين الليزر والأسنان ومنه إمتصت الأسنان بعضا من هذه الأشعة وانتجت أطياف في مدى الطيف المرئي والذي تم الحصول عليه بمنظار طيف موصل عموديا على المسجل

أظهرت النتائج انبعاث حزمة عريضة (363-627 نانومتر) و قمة حادة (673 نانومتر) في منطقة الطيف المرئي وقمة حادة في مدى الأشعة تحت الحمراء (1013 نانومتر) في جميع العينات, كانت الشدة في طيف عينات الأسنان المتسوسة منخفضة, بينما كانت الشدة عالية في طيف عينة السن السليمة.

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Chapter One

Introduction and Literature Review

1.1 Introduction

Dental caries is a disease in which enamel and dentin are gradually eroded, due to the elimination of minerals by acid excreted from bacteria in tooth surface plaque. Dental caries is a chronic disease that occurs frequently. Dental caries is a disease, which leads to destruction of the tooth structure and eventually to infection of the dental pulp and even surrounding tissues. Factors contributing to the progression of the disease include diet (mainly fermentable carbohydrates), microbes, and the host (amount and constituents of the saliva, habits). The progression of dental caries lesions needs time. Fluoride protects the teeth from dental caries by influencing the tooth structure.

Dental caries is usually performed using a tool called explorer that catches as it moves across a tooth with a cavity. This method of detection has many limitations, including the instrumentation (Vuokko Anttonen, 2007).

1.2 Objectives

The basic goal of this research is to use laser induced emission to distinguish the dental caries compared with sound teeth

1.3 Literature Review

Laura, DDS, et al in (2001), reviewed current knowledge concerning conventional and new diagnostic methods for occlusal caries. These methods have several limitations, particularly in their ability to diagnose early carious lesions. Part II examines new and emerging technologies that are being developed for the diagnosis of occlusal decay. Electrical conductance measurements and quantitative laser- or light-induced fluorescence represent significant improvements over conventional diagnostic methods, especially for in vitro applications and particularly with regard to sensitivity and reproducibility.

Iain A. Pretty, BDS, and Gerardo Maupomé, in (2004) examined some of the diagnostic tools supporting a philosophical shift in mainstream dental practice from concern with extensively decayed teeth to a focus on detecting incipient dematerialized tissues.

Ana Maria COSTA, Lillian Marley de PAULA, Ana Cristina Barreto BEZER in (2007), Evaluated the use of a laser fluorescence device for detection of occlusal caries in permanent, was found that the laser detection method produced high values of sensitivity (0.93) and specificity (0.75) and a moderate positive predictive value (0.63).The laser device showed the lowest value of likelihood ratio (3.68). Kappa coefficient showed good repeatability for all methods. Although the laser device had an acceptable performance, this equipment should be used as an adjunct method to visual inspection to avoid false positive results.

Anttonen , Vuokko in (2007), used Laser fluorescence in detecting and monitoring the progression of occlusal dental caries lesions and for screening persons with un favorable dieter habits This study focused on the clinical use of laser fluorescence compared to visual inspection (VI) for detecting and monitoring the progress of caries lesions during a one-year follow-up period and for screening subjects with unfavourable dietary habits causing demineralization of teeth.

Roxana Ranga1et al in (2007), has attempted to emphasize the efficiency of laser induced fluorescence (LIF) and fiber optic trans-illumination (FOTI) as complementary methods in diagnosing the early caries lesion.It has also demonstrated interactive and didactic role of the Diagnodent pen.

Bennett T. Amaechia in (2009), described the various technologies available to aid the dental practitioners in detecting dental caries at the earliest stage of its formation, assessing the activities of the detected carious lesion, and quantitatively or qualitatively monitoring of the lesion over time. The need and the importance of these technologies were also discussed. The data discussed are primarily based on published scientific studies and reviews from case reports, clinical trials, and in vitro and in vivo studies.

Zangooei booshehry et al, in (2010), evaluated different caries diagnostic methods, Clinical Visual Inspection, Fiber Optic Transillimination, Caries Indicter Dyes, Fluorescent Methods.

Fardad Shakibaie, Roy George, L.J.Walsh, in (2011), proposed the principle of the fluorescent phenomenon, then explore the scientific background of fluorescent studies on dental tissue. The laser-induced fluorescence can be used to detect and diagnose dental caries, calculus and bacterial biofilms in dental applications. Pini et al. used laser fluorescence to detect residual pulp tissue within the root canal, using a 308 nm wavelength ultraviolet laser, while Sarkissian and Le used 366, 405, and 440 nm wavelengths to distinguish remaining pulp tissue and bacteria from normal hard tissue in root canals. Most work using fluorescence in dentistry has employed visible light as the excitation source.

Yao-Sheng Hsieh and et al in (2013), described the applications of dental optical coherence tomography (OCT) in oral tissue images, caries, periodontal disease and oral cancer. The background of OCT, including basic theory, system setup, light sources, spatial resolution and system provided. The comparisons between OCT and other clinical oral diagnostic methods are also discussed.

1.4 Research problem

The use of laser induced emission to determined the absorbance of dental caries and to distinguish between emission from dental caries and sound tooth.

1.5 Thesis Layout

This thesis consist of four chapters, chapter one covers the Introduction, literature review, objectives of this research, and thesis layout. chapter two presents the Basic concepts of laser, human tooth**,** laser interaction with tissue, spectroscopy and laser induced fluorescence. chapter three covers the Experimental part (The materials, devices and method) while chapter four presents the results **,** discussion, conclusion, recommendation and references.

Chapter Two

Basic Concepts

2.1 Lasers:

2.1.1 Definition of Lasers

The word **LASER** is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

Lasers are devices that amplify or increase the intensity of light to produce a highly directional, high-intensity beam that typically has a very pure frequency or wavelength. They produce wavelengths or frequencies ranging from the microwave region and infrared to the visible, ultraviolet, vacuum ultraviolet, and into the soft-X-ray spectral regions. They generate the shortest bursts of light that man has yet produced, or approximately five million-billionths of a second (5×10^{-15} sec). (William T. Silfvast , 2003)

Lasers are a primary component of some of our most modern communication systems and are the probes that generate the audio signals from our compact disk players. They are used for cutting, heat treating, cleaning, and removing materials in both the industrial and medical worlds. They are the targeting element of laser-guided bombs and are the optical source in both supermarket checkout scanners and tools (steppers) that print our microchips.

Because of the special stimulated nature of the laser light source, and the apparatus needed to produce laser light, laser photons are generally not as cheap to produce or to operate as are other light sources of comparable power. We presently do not use them to light our rooms, as lamp bulbs for our flashlights, as headlights for our automobiles, or as street lamps. Lasers also don't generally provide "white light" but instead produce a specific "color" or wavelength, depend in up on the laser used.(William T. Silf Vast , 2003).

Stimulated emission of radiation is a natural process first identified by Einstein. It occurs when a beam of light passes through a specially prepared medium and initiates or stimulates the atoms within that medium to emit light in exactly the same direction and exactly at the same wave length as that of the original beam. A typical laser device consists of an amplifying or gain medium, a pumping source to input energy into the device, and an optical cavity or mirror arrangement that reflects the beam of light back and forth through the gain medium for further amplification. A useful laser beam is obtained by allowing a small portion of the light to escape by passing through one of the mirrors that is partially transmitting. (William T. Silfvast , 2003)

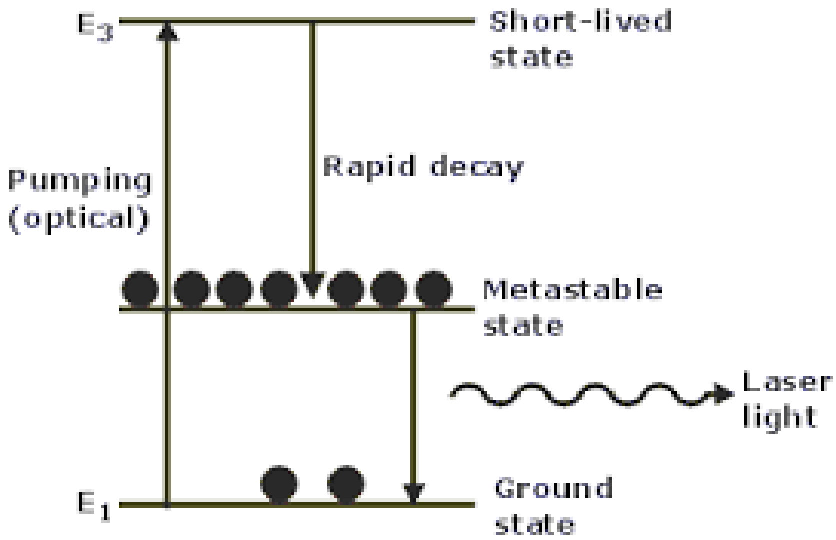

Fig 2.1 The general figure of laser

2.1.2 Properties of Lasers Radiation

The use of a laser for various applications depends upon the beam properties of laser, such as direction, divergence, and wavelength or frequency characteristics, which can be adjusted by the laser components. The features affecting the beam properties of laser include: size of the gain medium, location, separation and reflectivity of the mirrors of the optical cavity, and presence of losses in the beam path within the cavity (William T. Silf Vast, 2004).

Light produced from the lasers have several valuable characteristics not shown by light obtained from other conventional light sources, which make them suitable for a variety of scientific and technological applications. Their monochromaticity, directionality, brightness, and coherence of laser light make them highly important for various materials processing and characterization applications.

These properties are discussed separately in the following subsections (Subhash Chandra Singh, Haibo Zeng, Chunlei Guo, and Weiping Cai**,** 2012).

2.1.2.1 Monochromaticity

Theoretically, waves of light with single frequency ν or single wavelength λ is termed as *single color* or *monochromatic* light source.

Practically, no source of light including laser is ideally monochromatic. Monochromaticity is a relative term. One source of light may be more monochromatic than others. Quantitatively, degree of mono chromaticity is characterized by the spread in frequency of a line by $\Delta\nu$, line width of the light source, or corresponding spread in wavelength $\Delta\lambda$. For small value of $\Delta\lambda$, frequency spreading $\Delta\nu$, is given as $\Delta\nu = -(c/\lambda^2)\ \Delta\lambda$ and $\Delta\lambda = (c/\nu^2)$. The most important property of laser is its spectacular mono chromaticity. Based on the type of laser media, solid, liquid, or gas and molecular, atomic, or ions, and the type of excitation, produced laser line consists of color bands that range from broad (as dye laser $\Delta\lambda \approx 200$ nm) to narrow (for gas discharge lines, $\Delta\lambda \approx 0.01$ nm). A single line also contains a set of closely spaced lines of discrete frequencies, known as laser modes. (Subhash Chandra Singh, Haibo Zeng, Chunlei Guo, and Weiping Cai, 2012).

2.1.2.2 Directionality

One of the most striking properties of laser is its directionality, that is, its output is in the form of an almost parallel beam. Owing to its directional nature it can carry energy and data to very long distances for remote diagnosis and communication purposes. In contrast, conventional light sources emit radiation isotropically; ThereFore, very small amount of energy can be collected using lens. Beam of an ideal laser is perfectly parallel, and its diameter at the exit window should be same to that after traveling very long distances, although in reality, it is impossible to achieve. The beam radius at any point inside and outside the cavity is determined by the distance from the cavity axis where intensity reduces $1/e$ times of its maximum value (Subhash Chandra Singh, Haibo Zeng, Chunlei Guo, and Weiping Cai, 2012).

2.1.2.3 Coherence

Coherence is one of the striking properties of the lasers, over other conventional sources, which makes them useful for several scientific and technological applications. The basic meaning of coherence is that all the waves in the laser beam remain spatially and temporarily in the same phase. Photons generated through stimulated emission are in phase with the stimulating photons. For an ideal laser system, electric field of light waves at every point in the cross section of beam follows the same trend with time. Such a beam is called spatially coherent. The length of the beam up to which this statement is true is called coherence length (CL) of the beam. Another type of coherence of the laser beam is temporal

coherence, which defines uniformity in the rate of change in the phase of laser light wave at any point on the beam. The length of time frame up to which rate of phase change at any point on the laser beam remains constant is known as coherence time (Ct).
The coherence time of the laser beam is almost inverse of the width *v*, of the laser transition. The lasers operating in the single mode (well-stabilized lasers) have narrow linewidth, therefore Spatial and temporal coherences of continuous laser beams are much higher compared to those of pulsed laser systems because temporal coherence in the pulse lasers are limited by the presence of spikes within the pulse or fluctuation in the frequency of emission (Subhash Chandra Singh, Haibo Zeng, Chunlei Guo, and Weiping Cai, 2012).

2.1.2.4 Brightness

Lasers are more intense and brighter sources compared to other conventional sources such as the sun. A 1mW He–Ne laser, which is a highly directional low divergence laser source, is brighter than the sun, which is emitting radiation isotropically. Brightness is defined as power emitted per unit area per unit solid angle (Subhash Chandra Singh, Haibo Zeng, Chunlei Guo, and Weiping Cai, 2012)

2.1.3 Laser Construction

A laser system is constructed from three main parts:-

2.1.3.1 Pumping source

It can provide energy to the laser system for example electrical discharge, flash lamp, light from another laser, chemical reactions and even explosive devices. The type of pumping source uses principally depends on the gain medium, and this also determines how the energy is transmitted to the medium.

2.1.3.2 Laser Gain medium

Also called lasing medium results from stimulated emission of electronic or molecular transition from higher to lower energy state populated by a pump source (Kay A .Ball, 1995).

2.1.3.3 The Optical Resonator or Optical cavity

In its simplest form is two parallel mirrors placed around the gain medium which provide feedback of the light. Cavity designed to internally reflect infrared, visible, And Ultra-violet. It contains gases, liquids and solids, Cavity materials can determine the wavelength of the output (Kay A.Ball, 1995).

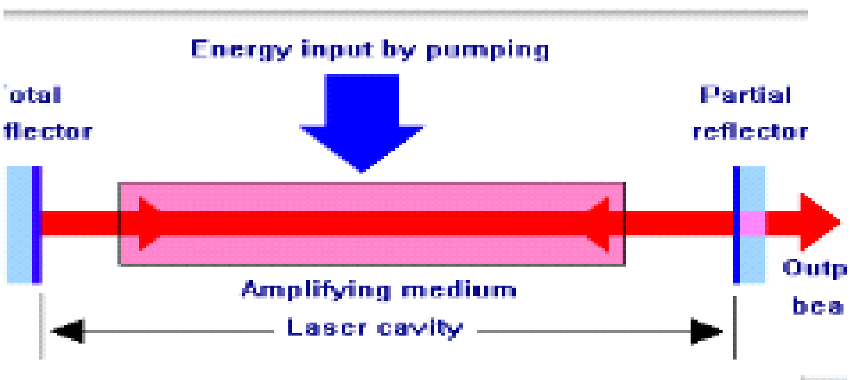

Fig 2.2 the laser construction

2.1.4 Types of lasers

2.1.4.1 Helium-Neon (He-Ne) laser

He-Ne Laser is the most widely used noble gas laser. Lasing can be achieved at wavelength 632.8 nm (Rao M.C. 2013).

He Ne lasers can also be operated at the 543.5nm green wavelength and several infrared wavelengths. Initiation of a relatively low electrical current through a low-pressure gas discharge tube containing a mixture of helium and neon gases produces the population inversion. With this gas mixture, helium meta stable atoms are first excited by electron collisions with helium ground-state atoms. This energy is then transferred to the desired neon excited energy levels, thereby producing the required population inversion with lower-lying helium energy levels (William T. Silf Vast, 2004).

2.1.4.2 Argon and Krypton ion laser

Similar to the He-Ne laser the Argon ion gas laser is pumped by electric discharge and emits light at wavelength: 488.0nm, 514.5nm, 351nm, 465.8nm, 472.7nm, 528.7nm.It is used in applications ranging from retinal phototherapy for diabetes, lithography and pumping of other lasers. The Krypton ion gas laser is analogous to the Argon gas laser with wavelength: 416nm, 530.9nm, 568.2nm, 647.1nm, 676.4nm, 752.5nm, 799.3nm. Applications range from scientific research. When mixed with argon it can be used as "white-light" lasers for light shows (Rao M.C. 2013).

2.1.4.3 Carbon dioxide laser

In the carbon dioxide (CO_2) Gas laser the laser transitions are related to Vibrational-Rotational excitations.
CO_2 lasers are highly efficient approaching 30%. The main emission wavelengths are 10.6μm and 9.4μm. They are pumped by transverse or longitudinal electrical discharge. It is heavily used in the material processing industry for cutting and welding of steel and in the medical area for surgery. Carbon monoxide (CO) gas laser are having wavelength range 2.6 - 4μm, 4.8 - 8.3μm and they are pumped by electrical discharge. They are used in material processing such as engraving, welding and in photo acoustic spectroscopy. Output powers as high as 100kW have been demonstrated (Rao M.C.2013)

2.1.4.4 Nitrogen laser

Lasing transition in N_2 laser takes place between two electronic Energy Levels; therefore this laser operates in the ultraviolet region at 337nm wavelength. Here, upper electronic level has a shorter lifetime compared to the lower one, hence CW operation cannot be achieved, but pulsed operation with narrow pulse width is possible. The pulse width is narrow because as soon as lasing starts, population of the lower state increases, while that at upper state decreases and rapidly a state at which no lasing is possible is rapidly achieved (Subhash Chandra Singh, Haibo Zeng, Chunlei Guo, and Weiping Cai, 2012).
Nitrogen lasers (N_2) are mainly used for pumping compact tunable dye lasers. These lasers can be fabricated in comparatively small size and can have a sealed-off laser tube, which has a long operating life. They can be used in combination with a compact dye Laser Scheme, which also is

coupled with diffraction grating, which gives out pulsed tunable Laser outPut totally covering the visible region of the spectrum (K.R. Nambiar, 2004)

2.1.4.5 Excimer laser

Excimer Lasers are of great interest because they provide a source of ultraviolet laser light. The laser medium of an Excimer Laser is a volume of gas the atoms of which are able to form diatomic molecules only in an excited state. The molecules immediately dissociate, releasing high-energy ultraviolet photons on entering the ground state. A population inversion between excited and ground states and consequent laser action at ultraviolet wavelengths is therefore possible.
The word "excimer" is a contraction of the words "excited dimer", but often the active molecule is a rare gas atom combined in the excited state with a halogen atom. Strictly speaking these combinations should not be called Excimers since they involve dissimilar atoms.
Specific examples of rare gas/halide excimer lasers are argon fluoride (193 nm), krypton fluoride (248 nm), xenon chloride (308 nm) and xenon fluoride (351 nm). They may be pumped either by an electron beam or by an electrical discharge. The output is pulsed. The length of each pulse being of the order of a few tens of nanoseconds (T.A. Mcnicholas, 1990)

2.1.4.6 Dye Lasers (liquid lasers)

The laser gain medium is organic dyes in solution of ethyl, methyl alcohol, glycerol or water. These dyes can be excited optically with Argon lasers for example and emit at 390-435nm, 460-515nm, 570-640 nm and many others. These lasers have been widely used in research and spectroscopy because of their wide tuning ranges. Unfortunately, dyes are carcinogenic and as soon as tunable solid state laser media became available dye laser became extinct (Rao M.C. 2013).

2.1.4.7 Ruby Laser

The first laser was indeed a solid- state laser Ruby and it is emitting at 694.3nm8. Ruby consists of naturally formed crystal of aluminum oxide (Al_2O_3) called corundum. In that crystal some of Al^{3+} ions are replaced by Cr^{3+} ions. Its chromium ions that give Ruby the pinkish color, i.e. its fluorescence, which is related to the laser transitions. Today, for the manufacturing of ruby as a laser material, artificially grown crystals from molten material which crystallizes in the form of sapphire is used. The lifetime of the upper laser level is 3ms. Pumping is usually achieved with flash lamps (Rao M.C. 2013).

2.1.4.8 Neodymium YAG laser

Neodymium YAG consists of Yttrium-Aluminum-Garnet (YAG) $Y_3A_{15}O_{12}$ in which some of the Y^{3+} ions are replaced by Nd^{3+} ions. Neodymium is a rare earth element, where the active electronic states are shielded inner 4f states. Nd: YAG is a four level laser. The main emission of N d: YAG is at 1.064μm.

The properties of Nd:YAG are the most widely studied and best understood of all solid state laser media. Its energy level diagram, optical arrangements for Q-switching and stable and unstable resonators are depicted. The active medium is triply ionized neodymium, which is optically pumped by a flash lamp whose output matches principle absorption bands in the red and near infrared (NIR). Excited electrons quickly drop to the $F_{3/2}$ level, the upper level of the lasing transition, where they remain for a relatively longer time (230 μs). The strongest transition is $F_{3/2} \rightarrow I1_{11/2}$, emitting a photon in NIR region (1064 nm) (Subhash Chandra Singh, Haibo Zeng, Chunlei Guo, and Weiping Cai, 2012).

2.1.4.9 Semiconductor lasers or diode laser

Semiconductor, as the name implies, is half-way between a conductor and an insulator (non-metal), so far as its electrical conductivity is concerned. The semiconducting materials containing gallium and arsenic compounds have been found to generate infrared rays when the current is passed through them. This implies that these semiconductors convert electrical energy into photons. But, these were ordinary incoherent light rays and were not produced by the' laser action, However, when the gallium arsenide crystal is through it, the laser action does take place. Many semiconductors serve as laser materials and they have been made to 'laser' under the stimulation of electricity instead of light which is used for the other solid-state lasers.There are two types of semiconductors, n-type and p-type. To understand the functioning of these devices, it is necessary to know the nature of the electronic energy states in a semiconductor. A typical semiconductor has bands of allowed energy levels separated by forbidden energy gap region. In an intrinsic semiconductor, there are just enough electrons present to fill the uppermost occupied energy band (valence band) leaving the next higher band (conduction band) empty. In an n-type semiconductor, a small amount of impurity is added intentionally so that the material is made to have an excess of electrons, which thus becomes negative. On the other hand, by adding a different type of impurity in a p-type semiconductor, the material can be made to have an excess of holes (vacancy of electrons) ,which thus becomes positive.The semiconductor laser consists of a tiny block (about one square millimetre in area) of galliu arsenide . When the p- and n-type layers are formed in an intimate contact, the interface becomes a p-n junction. When direct current is applied across the block, the electrons move ii across the junction region from the n-type material to the ptype material, having excess of holes. In this process of dropping of the electrons into the holes, recombination takes place leading to the emission of radiation. The photons travelling through the junction region stimulate more electrons during the transition, releasing more photons in the process. The laser action takes place along the line of the junction. Due to the polished ends of the block, the stimulated emission grows enormously and a beam of coherent light is emitted from one of the two ends.With a gallium arsenide laser, a continuous beam of a few militates power is easily obtained (William T. silf Vast,2004).

2.1.4.10 Free Electron Lasers

Free-electron lasers, discovered recently, are significantly different from any other type of laser in that the laser radiation is not obtained by discreet transitions in atoms or molecules of a material. Instead, a high-energy beam of electrons (of the order of one million electron volts (meV) is directed to pass through a spatially varying magnetic field that causes the electrons to oscillate back and forth in a direction transverse to the direction of their beam, at a frequency related to the energy of the electron beam (William T. Silf Vast , 2003).

This oscillation causes the electrons to radiate at the oscillation frequency and to stimulate other electrons also to oscillate and radiate at the same frequency, in phase with the original oscillating electrons thereby producing an intense beam of light emerging from one end of the device. Mirrors can be placed at the ends of the magnetic region to feed the optical beam back through the amplifier to stimulate more radiation and cause the beam to grow. The frequency is tunable by variation of electron energy and the laser radiation can be generated at any wavelength from the ultraviolet to infrared regions.

A great advantage of the free-electron laser is that a high average output power of the range of a few kilowatts can be obtained in the continuous mode. Although still more of a laboratory curiosity, it shows good promise of high energy applications especially in the medical field (William T. Silf Vast, 2004).

2.1.4.11 X-Ray Lasers

In contrast to teasers operating in the visible and infrared regions, the x-ray lasers offer a considerable challenge to the present day technology. In the x-ray region, i.e., below a few nanometers (10^{-9}m) wavelengths, the transmission and reflection properties of materials are very poor and as a result severe constraints are imposed on the cavity design. Also, there are limitations to achieve sufficient laser action from the medium. For a visible laser, the characteristic energies are of the order of electron volts with excitation time of 10^{-9} s, so that a moderately fast electrical circuitry feeding a weakly ionized discharge can be used as a lasing medium. In contrast, in the x-ray region energies of the order of kilo electron volts (keV) and time scales of the order of 10^{-15} s require inner shell electronic transitions of some materials or highly stripped ions as medium, pumped by a source of time duration much less than a picoseconds (10^{-12} s). In particular, very high energy densities are required to achieve the stimulated emission from the medium. For these reasons, the x-ray lasers use a subsidiary laser or a particle beam to excite the medium. A multi-joule visible laser can directly pump the gain medium through inversion produced in the laser-heated plasma or indirectly by using the x-rays from laser plasma to pump a separate x-ray laser medium. Thus x-ray laser action has been achieved in selenium at about 21 nm (William T. silf vast, 2004).

2.1.5 Applications of laser

Laser radiation in various applications was made use of immediately after the first laser became operational. The ruby laser was designed and constructed by TEODOR MAIMAN in 1960 and as early as 1961 its radiation was used to treat eye and skin diseases. As a device, it is now used in medicine, astronomy, geodesy, metrology, chemistry, biology, spectroscopy, holography, power engineering, in various processes in engineering, as well as in communication technology, automation and remote control, in military technology, entertainment industry (Rao M.C. 2013).

The ruby laser was verified in practice immediately after it had become operational, namely in ophthalmology and in dermatology. Monochromaticity and coherence, two properties of laser radiation, are utilized mainly in medical diagnostics. Due to further advances in laser physics and to new types of laser devices, the laser has gradually entered many new branches of medicine, namely ophthalmology, dermatology, general, plastic and cardiovascular surgery, neurosurgery, otolaryngology, urology, gynecology, dentistry, oncology, gastroenterology, orthopedics and others.

Industrial applications now include many new procedures, such as laser welding, drilling, cutting, annealing, sputtering and others; Laser welding makes use of optical radiation to melt the material to a desired depth, minimizing at the same time the surface vaporization. In practice, this process utilizes mostly the continuous lasers of the infrared CO_2 spectrum and the Nd: YAG lasers, of a wavelength of 10.6 nm and 1.06 nm, respectively. Welding, as against some other processes, uses a lower intensity optical beam and a longer laser pulse (Rao M.C. 2013)

Ground laser radars are used in ecology to measure air pollution. They are also used in meteorology. In this case it is both reflection and scattering that are made use of in measurements. LIDAR serves to monitor the distribution and direction of smoke trails; to measure the bottom level and profile of clouds of atmospheric turbulence, distribution and areas of various imissions in the atmosphere.

Computer field of applications requires small-size lasers, so semiconductor or He-Ne low-power lasers seem to be the best.

Thus the laser printer, used in a device that makes use of laser radiation to obtain the image of what is to be printed, i.e., transferred from the rotating drum to paper. The information to be printed, including the intended graphical layout, is encoded into the computer from which it is transferred to the modulator of optical radiation, which, according to the codes, interrupts the laser beam impinging upon the reflection part of the deflection disc. Every single segment on the deflection disc deflects the beam across the drum which is covered with a layer of photosensitive material of specific property, namely that after laser radiation has impinged upon it, its electric resistance at the irradiated dot will decrease by several orders. If this layer prior to receiving the relevant information carries a constant potential, then, upon the incidence of laser beam, in agreement with the code, it will produce an image composed of dots whose potential differs from the original one. The matrix thus created on the drum is then electro statically covered with a toning medium.

Lasers appear also in various military applications, the most widely utilized being the so called laser range finders, an analogy to the ground laser radar that can measure with great accuracy the target's distance and thus obtain the optimal trajectory of a missile and higher reliability of the hit. Purpose, the Nd: YAG lasers seem to be best. However, much less sophisticated are the laser markers used in, e.g., guns, to identify the target at a distance of up to 20 m. In this case small diode lasers are used. On the other hand, for intercontinental ballistic missiles to be destroyed, it is necessary to use a high power laser, i.e., of the CO_2 or chemical type and mirrors placed in space (Rao M.C., 2013).

2.1.6 Medical Applications

Lasers have many varied applications in dentistry, acardio vascular medicine, dermatology, gastroenterology, gynecology, neurosurgery, ophthalmology and otolaryngology.

Applications of Lasers in modern medicine: The first section concerned with laser applications in ophthalmology. Even today, the majority of medical lasers sold are applied in this field. Dentistry was the second clinical discipline to which lasers were introduced. Laser applications were found in dermatology and orthopedics laser medicine is not restricted to one or a few disciplines. Instead, it has meanwhile been introduced to almost all of them, and it is expected that additional clinical applications will be developed in the near future.

2.1.7 Laser in Dentistry

Dentistry is one of the disciplines to explore the use of laser technology.

New applications are being discovered because the laser affects all aspect of the dentists' modalities of care.

The CO_2, Nd:YAG, argon, holmium and erbium lasers are the most used lasers today in dentistry. These wavelengths are being used on soft tissue to excise tumors and lesions, vaporize excess tissue, control bleeding of vascular lesions and remove or reduce hyper plastic tissue.

Hard-tissue application include vaporizing dental cavities, desensitizing exposed root surface, glazing teeth, smoothing rough surfaces in preparation for bonding procedures, stopping demineralization of enamel surfaces, promoting remineralization and debonding ceramicorthodontic.

Aphthous ulcers are being treated with laser energy.

The Co_2 laser beam is defocused and debrides the necrotic tissue.

The procedure can be performed without an anesthetic. The results are remarkable as painful symptoms are minimized; almost immediately after the procedure, the pain is relieved.
Herpetic lesions are also being treated with laser applications. The Pain relief is just as significant as with Phthous ulcers. The Laser also being used in exposing implants. The contact Nd:YAG laser should not be used because it could damage titanium implants. The laser energy is used to vaporize the overlying tissue until the implant is visualized (Kay A.Ball, 1995).

2.2 The Human Tooth

The anatomy of the human tooth as well as its physiology and pathology shall be given. In principle, the human tooth consists of mainly three distinct segments called enamel, dentin, and pulp. A schematic cross-section of a human tooth is shown in Fig 2.4

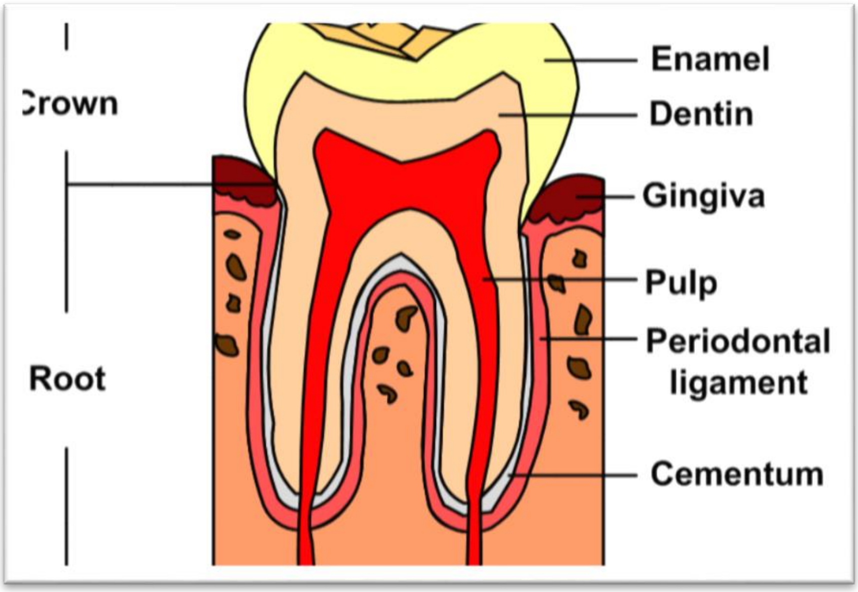

Fig 2.4 Schematic diagram of a tooth structure

The enamel is the hardest substance of the human body. It is made of approximately 95% (by weight) hydroxyl apatite, 4% water, and 1% organic matter. Hydroxy apatite is a mineralized compound with the chemical formula Ca_{10} $(PO4)_6(OH)_2$ Its substructure consists of tiny crystallites which form socalled enamel prisms with diameters ranging from 4 µm to 6µm. The crystal lattice itself is intruded by several impurities, especially Cl^-, F^-, Na^+, K^+, and Mg^2 The dentin, on the other hand, is much softer. Only 70% of its volume consists of hydroxylapatite, whereas 20% is organic matter – mainly collagen fibers – and 10% is

water. The internal structure of dentin is characterized by small tubuli which measure up to a few millimeters in length, and between 100nm and 3 μm in diameter. These tubuli are essential for the growth of the tooth.
The pulp, finally, is not mineralized at all. It contains the supplying blood vessels, nerve fibers, and different types of cells, particularly odontoblasts and fibroblasts. Odontoblasts are in charge of producing the dentin, whereas fibroblasts contribute to both stability and regulation mechanisms. The pulp is connected to peripheral blood vessels by a small channel called the root canal. The tooth itself is embedded into soft tissue called the gingiva which keeps the tooth in place and prevents bacteria from attacking the root.
The most frequent pathologic condition of teeth is called decay or caries.
Its origin lies in both cariogeneous nourishment and insufficient oral hygiene.
Microorganisms multiply at the tooth surface and form a layer of plaque.
These microorganisms produce lactic and acetic acid, thereby reducing the pH down to values of approximately 3.5. The pH and the solubility of hydroxy apatite are strongly related by

$$Ca_{10}\,(PO_4)_6(OH)_2 + 8H^+ \longleftrightarrow 10\,Ca^{2+} + 6HPO^{2-} + 2\,H_2O$$

By means of this reaction, the enamel can be demineralized within a few days only. Calcium bound to the hydroxyl apatite is ionized and washed out by saliva. This process turns the hard enamel into a very porous and permeable structure. Usually, this kind of decay is associated with a darkening in color. Sometimes, however, carious lesions appear bright at the surface and are thus difficult to detect. At an advanced stage, the dentin is demineralized, as well. In this case, microorganisms can even infect the pulp and its interior which often induces severe pain. Then, at the latest, must the dentist remove all infected substance and refill the tooth with suitable alloys, gold, ceramics, or composites. Among alloys, amalgam has been a very popular choice of the past. Recently, though, a new controversy has arisen concerning the toxicity of this filling material, since it contains a significant amount of mercury.
The removal of infected substance is usually accomplished with conventional mechanical drills. These drills do evoke additional pain for two reasons (Dr. Markolf H. Nemz, 2007).
First, tooth nerves are very sensitive to induced vibrations tooth nerves also detect sudden increases in temperature which are induced by friction during the drilling process. Pain relief without injection of an anaesthetic was the basic ulterior motive when looking for laser applications in caries therapy. However, it turned out that not all types of lasers fulfill this task.

Although vibrations are avoided due to the contactless technique, thermal side effects are not always eliminated when using lasers. CW and long-pulse lasers, in particular, induce extremely high temperatures in the pulp Even air cooling does not reduce this temperature to a tolerable value. Thermal damage is negligible only when using ultra short pulses according to the statements .

Meanwhile, other advantages are being discussed which could even be more significant than just pain relief . Very important among these are the so-called conditioning of dental substance and a possibly more precise procedure of caries removal. Conditioning provides additional protection of the tooth by means of sealing its surface. Thereby, the occurrence of caries can be significantly delayed. Improved control of caries removal, e.g. by a spectroscopic analysis of laser-induced plasma could minimize the amount of healthy substance to be removed. Then, indications for expensive dental crowns or bridges are effectively reduced (Dr. Markolf H.Niemz, 2007).

2.3 Laser Tissue Interaction

Laser energy can interact in one of four ways with the target tissue, depending on the optical properties of that tissue.

It is transmission of the laser energy, reflection, scattering and absorption.

Three types of reactions occur when laser light interacts with tissue: photochemical, photothermal, and photomechanical.

In photochemical reactions, very low-power irradiation inactivates cell function by means of induced toxic chemical processes: temperature increase is indiscernible.

In photothermal reactions, laser light is absorbed by tissue chromophores and is converted to heat; this process is accompanied by a local temperature increase, and the heat is conducted to cooler regions.

Greater degrees of heat result in denaturization, necrosis, and even vaporization and spallation (that is, splintering of the tissue). This is the type reaction that occurs in laser angioplasty.

In photomechanical reactions within the chromophores occur when extremely high energies get absorbed at short pulse duration, which lead to extremely rapid thermal expansion of the target and subsequent photomechanical destruction (Donald J. Coluzzi, DDS, 2008).

2.4 Spectroscopy

Spectroscopy is the branch of science dealing with the study of interaction of electromagnetic radiation with matter (Dr.H.Kaur, 2011). The various branches of spectroscopy generally involve measurements of two experimental parameters,

(a) The energy of the radiation absorbed or emitted by the system.
(b) Intensity of the spectral lines (Dr.H.Kaur, 2011).

The study of spectroscopy can be carried out under the following

2.4.1 Atomic spectroscopy

It deals with the interaction of electromagnetic radiation with atoms which are most commonly in their lowest energy state.

2.4.2 Molecular Spectroscopy

It deals with the interaction of electromagnetic radiation with molecules. The result in transition between rotational and vibrational energy levels in addition to electronic transitions.Molecular spectra extend from the visible through infrared in to the microwave region (Dr.H.Kaur, 2011).

2.4.3 Raman Spectroscopy

The Raman effect is a light-scattering effect. The exciting monochromatic beam has to be of high intensity (laser beam) in order to induce in the molecule a virtual energy state. Raman scattering is always of very low intensity, its investigation requires high-quality instrumentation. The Raman Effect can be excited in the UV region, the visible region or in the NIR region. Raman spectroscopy is the study of inelastic scattering of light. The inelasticity stems from a transfer of energy between the incident radiation field and the material under investigation. The technique provides, amongst other things, important information about the vibrational state of matter. One of the most influential early investigations into light scattering was undertaken by Lord Rayleigh (1899). It was shown that the intensity of elastically scattered light is strongly dependent on its wavelength. In fact an inverse fourth power dependence on wavelength was proved, and was subsequently called the Rayleigh law (Kluwer A cademic / Plenum publishers, 2002)

2.4.4 Fluorescence phenomena

Fluorescence is the emission of light by a substance that has a bsorb light or other electromagnetic radiation. Fluorescence occurs if the transition is between states of the same electron spin and phosphorescence if the transition occurs between states of different spin. Luminescence is a general term used to describe the emission of radiation, which incorporates both fluorescence (short lived) and phosphorescence (long lived), as well as other phenomena such as bioluminescence in living organisms in which chemical reactions generate light. Many naturally occurring substances fluoresce, including minerals, fungi, bacteria, keratin, collagens and other components of body tissue; this is termed primary fluorescence or auto fluorescence.

The molecule absorbs energy from lower ground singlet state (S_0) to one of vibrational level at excited single state S_n (n=1, 2…) the excited molecule positions itself in an unstable level therefore vibrates and loses energy partly through internal conversion (Red arrow) without photon emission. After that the molecule at excited singlet state will spontaneously return back to one of vibrational level of ground singlet state (Pink arrow) to fluorescence a lower energy photon (Fardad Shakibaie, RoyGeorge , L.J Walsh, 2011)

In fluorescence, energy levels transitions do not involve changes in electron spin. If light emission occurs within one microsecond (one millionth of a second) of light exposure, the luminescence is fluorescence, whereas if light emission takes longer than this, the luminescence is phosphorescence.

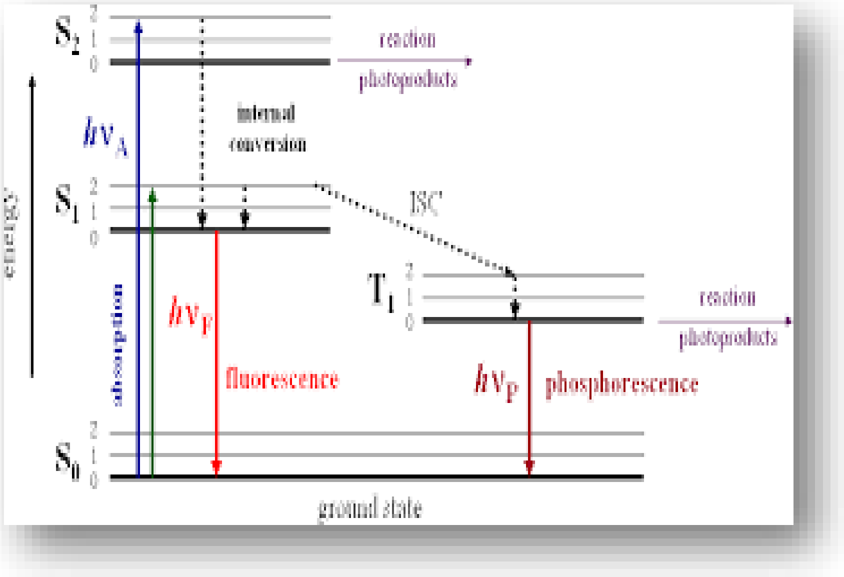

Fig 2.5 Jablonski diagram of fluorescence and phosphorescence

2.4.5 Laser-induced fluorescence

Laser-induced fluorescence (LIF) spectroscopy is a method developed for tissue diagnostics. Laser-induced fluorescence (LIF) has a large range of applications in spectroscopy. An important application is to find tumors and delineate its borders. The method is non-invasive and can perform in real-time. The method makes it possible to investigate inner hollow organs by using optical fibers compatible with endoscopes. The tissue is irradiated with a laser of a specific wavelength that induces fluorescence from the present fluorophores (Jenny Svensson, 2007).

To study tissue auto fluorescence, UV or blue lasers are primarily used as excitation sources. Only superficial lesions can be detected following excitation in the violet to the blue wavelength region, as the penetration depth is very shallow. By using longer wavelengths, the light can penetrate several millimeters inside the tissue and deeper lying lesions can be detected. The fluorescence light will be attenuated as it propagates through tissue, especially for light with long path lengths. It is not only the wavelength though that can influence the recorded fluorescence spectrum, but also the illumination-detection geometries used.
Using LIF as a guide, more precise biopsies could be taken.
The goal when using LIF as a guiding tool is to avoid unnecessary biopsies and only sampling biopsies where LIF finds something suspicious (Jenny Svensson , 2007).

First, LIF serves as a sensitive monitor for the absorption of laser photons in fluorescence excitation spectroscopy. In this case, the
undispersed total fluorescence from the excited level is generally monitored.
Second, it is well suited to gain information on molecular states if the fluorescence spectrum excited by a laser on a selected absorption transition is dispersed by a monochromator.
Third aspect of LIF is the spectroscopic study of collision processes. Another aspect of LIF concerns its application to the determination of the internal-state distribution in molecular reaction products of chemical reaction (Waflong DemtOrder , 2003).

Chapter Three

Experimental Part

3.1 Introduction

This chapter include with the materials, devices and method.

3.2 The materials

3.2.1: The dental caries and sound teeth

Dental caries is a disease in which enamel and dentin are gradually eroded, due to the elimination of minerals by acid excreted from bacteria in tooth surface plaque.

Fig 3.1 The Dental Caries.

Fig 3.2 The Sound Teeth.

3.3 The Devices

3.3.1 The Nitrogen (N_2) laser

Nitrogen laser is an example of molecular laser, using transitions between vibrionic state. This laser oscillates at wavelength of 337 nm, in ultraviolet region.

Fig 3.3 The device of Nitrogen laser(N_2) at Alneelain universit

3.3.2 The Vibratory Disc Mill RS 200

The Dental caries and Sound teeth were ground to fine powder using the Vibratory Disc Mill RS 200, shown blow:

Fig 3.4 The vibratory Disc Mill RS 200.

3.3.3 UV- Vis spectrophotometer

UV- Vis mini 1240 spectrophotometer was used in this study to measure the absorption spectrum of these samples.

Fig 3.5 UV-Vis mini 1240 spectrophotometer.

3.4 The Method of Experiment

To distinguish between dental caries and sound tooth:

These teeth were ground to fine powder using the Vibratory Disc Mill RS 200, shown in fig 3.4

The powder samples were dispersed in distill water. The absorption spectrum of these samples were carried out using UV-Vis mini 1240 spectrophotometer, shown in fig 3.5

PL properties was determined using nitrogen (N2) laser with wavelength about 337.8 nm, power 0.04 mw, and repetition rate 100 msec , shown in fig 3.6

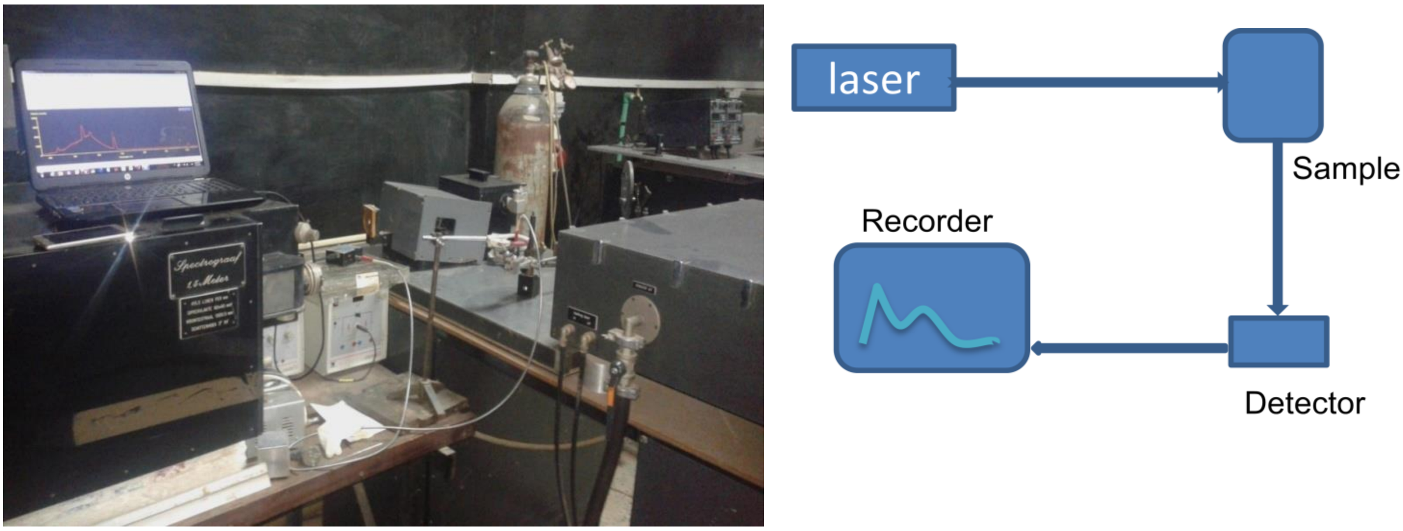

Fig 3.6 PE system

Chapter Four

Results and Discussion

4.1 Introduction

The chapter four Include results, discussion, and conclusion.Results which obtained during the work and included spectra and table as shown below.

4.2 The Results

4.2.1 Absorbance spectra of Dental Caries

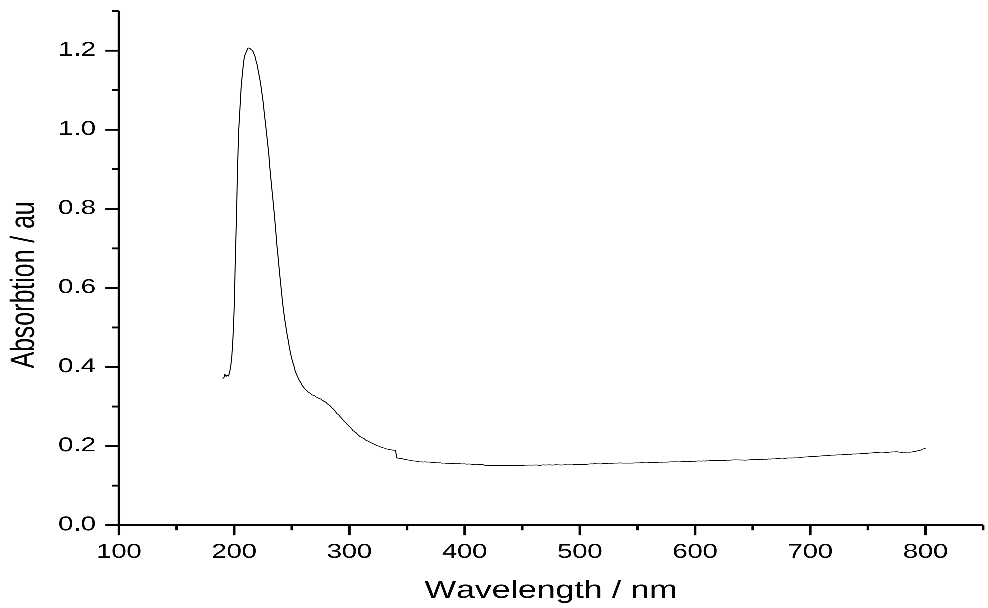

Fig 4.1: Absorbance spectra of dental caries

4.2.2 Spectra of the Dental Caries

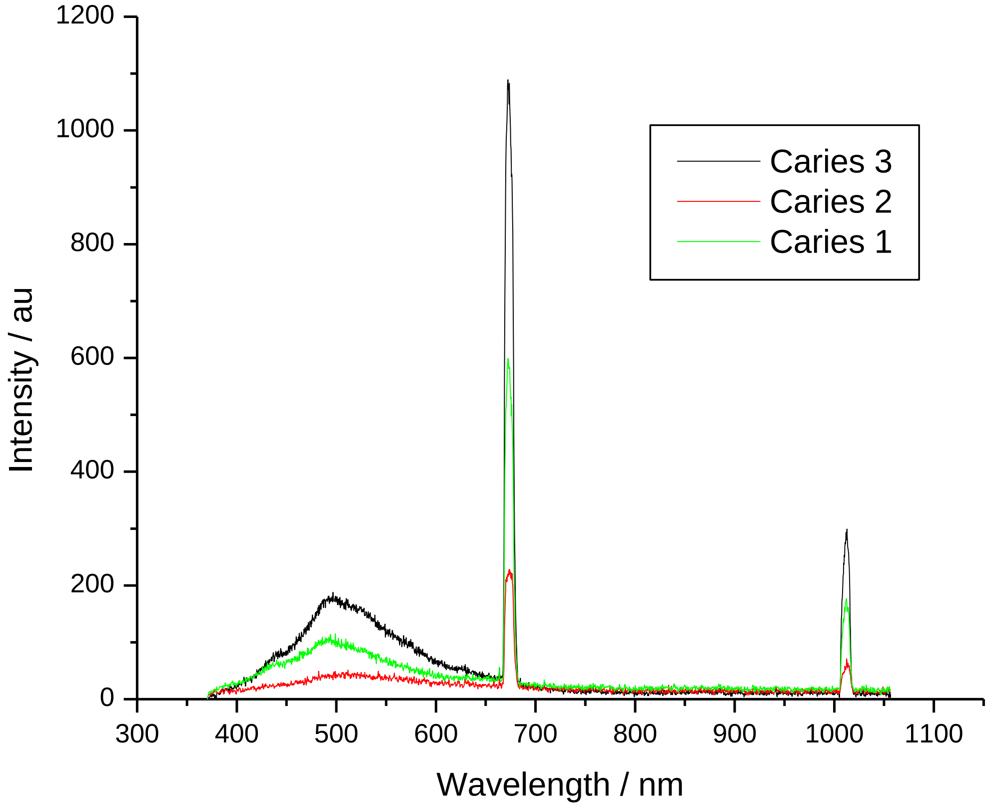

Fig 4.2 Spectra of the Dental Caries (Excitation at 337.8 nm)

4.2.3 Spectra of the Dental Caries and Sound Tooth

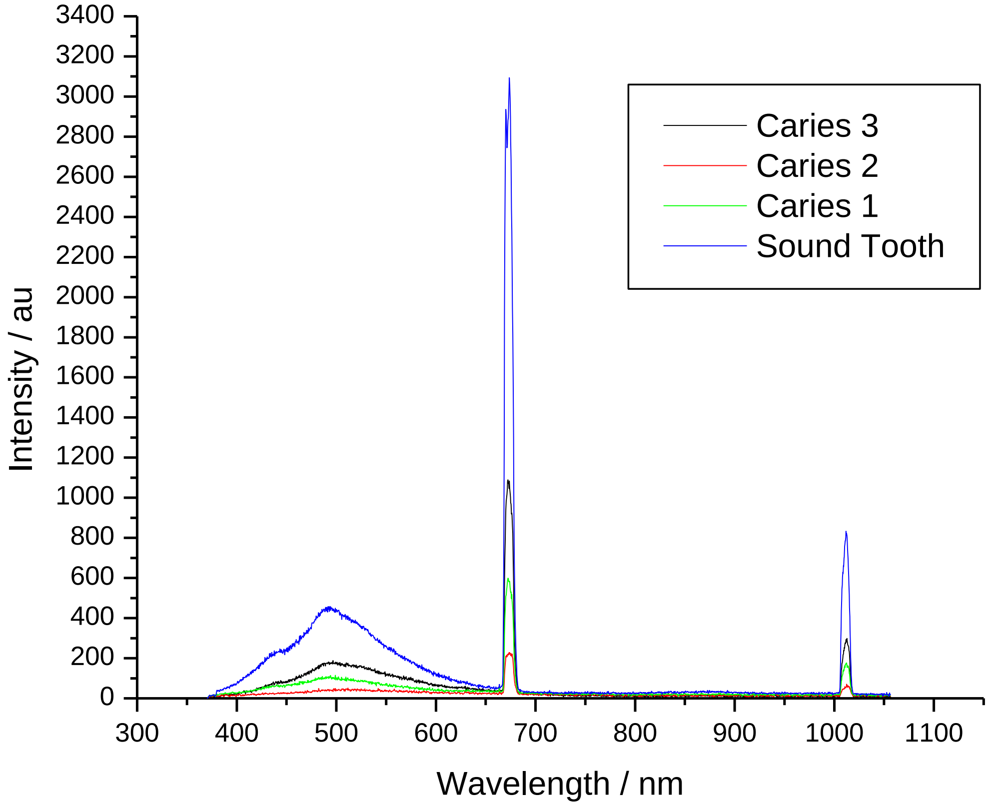

Fig 4.3 Spectra of the Dental Caries and Sound Tooth (Excitation at 337.8 nm)

4.3 The Discussion

Spectra in fig 3.2 shows that the spectrum of the three samples of the dental caries, in second and third spectra were sharp peaks (673, 1013) nm and in first spectrum was broad peak (500) nm

The intensities of the sharp peak of the dental caries at 1013nm of the sample caries $_2$ is 190 au, the sample caries$_3$ is 425.4 au and sample caries$_1$ is 290 au.

The intensities of the sharp peak of the dental caries at (673) nm of the sample caries $_3$ is 1215 au, the sample of caries $_2$ is 345.8 au and sample caries$_1$ is 713au.

Spectra in fig 4.3 there are three samples of dental caries and one is sound tooth, this spectra shows that when the dental caries and sound tooth irradiated to laser, the intensity of the sharp peak of sound tooth at 1013 nm is 969 au, at the sharp peak 673 nm the intensity is 3227 au and the intensity at the broad peak is around 597 au.

The intensity of the broad peak at (500) nm of the caries$_3$ is 312.4au, the caries$_1$ is 230.5au, and the intensity of the caries$_2$ is 166au This spectra shows that the intensity in sound tooth is very high (364.42) au while in dental caries$_3$ the intensity is low (144.62) au in caries$_1$the intensity is lower (69.6) au than caries$_3$ and in caries$_2$ the intensity is the lowest (52.47) au.

The caries proportional inverse to intensity of induced emission.

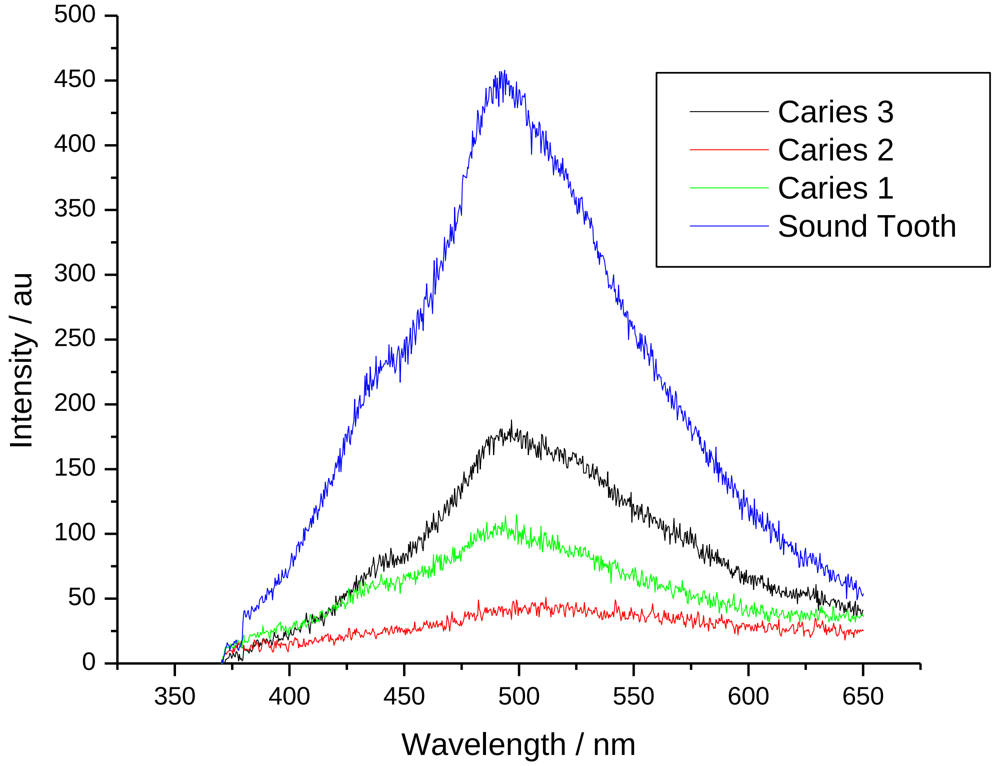

Fig 4.4 Broad Band of the Dental Caries and Sound Tooth (Excitation at 337.8 nm)

Table 4.1 comparative of the dental caries and sound tooth

No of sample	λ (nm)	A	Fw.HM	I (a.u.)
Sample1	502.9	8460.86	114.24	69.6
Sample2	531.79	15295.38	273.81	52.47
Sample3	513.28	11917.71	124.19	144.62
Sample4	501.78	44938.24	115.58	364.42

The results show that there is a different in the intensities of the emission peaks from the Luminescence of dental caries and sound tooth.

Conclusions

PE (photoemission) spectra from dental caries and sound tooth has been obtained and investigated.

All samples produce abroad band and sharp peak in the visible region and sharp peak in the infrared region

The obtained results show different PE spectra from all samples. Comparing the PL spectra from sound tooth with dental caries, we found that the intensity is decrease in the caries tooth which indicates that the intensity is depending on the amount of caries.

Recommendation

Future studies could be done using another UV laser because the absorbance of the dental material falls around this wavelength.

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