

Sudan University of Science and Technology

College of Graduate Studies



Wavelengths Calibration of some Laser systems

معايرة الأطوال الموجية لبعض المنظومات الليزرية

**A thesis Submitted as partial fulfillment for the
requirement of the Degree of Master Science
(M.Sc.) in Laser Application in Physics**

By

Mohamed Ahmed Abd Elkareem

Supervisor:

Dr: Abd elmoneim M. Awadelgied

2014

Dedication

I dedicated this study to:-

My Parents

My Family

My Teachers

My Friends

Mohamed

Acknowledgment

First of all , I would like to express my deepest thanks to Allah who give me power and care to create this work.

*Thanks are due to my supervisor Dr. **Abd Elmoneim M Awadelgied** for his encouragement, support and supervision of this study.*

I would like to thanks the staff of institute of laser , Sudan University of Science and Technology, and the staff of medical laser center for his help and support.

*Also I would like to thanks **Dr.Abd Alfatah Mohammed** and Ustaz **Abd Alsakhi Suliman**, at Elneelain University.*

I would like thanks to my family members for their great support and encouragement.

Abstract

In this research calibration of some laser equipment in the clinic of the laser institute of the university of Sudan(Omega xp and Orillia) was performed together with some other devices (diode laser second harmonic, He- Ne ,diode).some laser parameters like (wavelength and FWHM)were calculated. The accuracy of each equipment was determined. The International method of calibration was used and the device USB 2000 with computer software Origin6 was also used to find the Gaussian configuration and then calculation of some laser parameters. the results showed reduction in wavelength for all calibration devices compare to the standard wavelengths (1.65, 3.35,10.18,10.38,16.87)the calculation showed the high accuracy of some lasers equipment .

مستخلص البحث

في هذا البحث تمت معايرة بعض أجهزة الليزر الموجودة في عيادة (وأجهزة أخرى ((Omega xp and Orillia)) معهد الليزر جامعة السودان كما تم حساب (diode laser second harmonic He- Ne ,diode) تم أيضا تحديد دقة كل (FWHM) بعض معاملات الليزر (الطول الموجي و جهاز على حدة .استخدمت طريقة المعايرة العلمية العالمية بالإضافة إلي Origin مصحوبا ببرنامج الحاسب الآلي USB 2000 استخدام جهاز لإيجاد الشكل القاروسي ومن ثم حساب بعض معاملات الليزر 6.1.

أظهرت النتائج تغير في الطول الموجي لجميع الأجهزة المعايرة مقارنة بالأطوال القياسية، كما أوضحت الحسابات الدقة العالية لبعض الأجهزة

List of contents

Article	Page No.
Dedication	I
Acknowledgment	II
Abstract (E)	III
مستخلص البحث	IV
List of Contents	V
Chapter One: Basic concept of Lasers	1
1-1 Definition of laser	2
1-2 Basic elements of a Laser	2
1-2-1 Laser medium	3
1-2-2 Pumping source	3
1-2-3 Feedback mechanism	3
1-3 Laser physical concept	4
1-3-1 Induced absorption	5
1-3-2 Spontaneous emissions	5
1-3-3 Stimulated emissions	6
1-4 Types of lasers	8
1-4-1 Solid state laser	8
1-4-2 Gas lasers	8
1-4-3 Dye lasers	8
1-4-4-Semiconductor lasers	9
1-5 Applications of lasers	9
1-6 Literature review	10
1-7-Thesis layout	11
1-8-Aim of the work	11
Chapter Two: Calibration	
12	
2-1 Introduction	13
2-2-Types of calibration	14
2-2-1 Primary standard	16
2-2-2 Transfer standard	16
2-2-3 Field transfer standard	17
2-3 The principle subsystems of the calibration set up	17
2-4-Analysis Capabilities	18
Chapter Three: Experimental part	
19	
3-1 Instruments and apparatus	19
3-1-1 laser sources	19
3-1-2 USB 2000 fiber optics spectrometer	25
3-1-3 Laser safety goggles	28
3.2 Methodology	
29	

Chapter Four: Results and Discussion

30

4-1 The results	31
4-1-1 Results of calibration diode laser second harmonic	31
4-1-2 Results of calibration He-Ne laser	32
4-1-3 Results of calibration ORALIA laser	33
4-1-4 Results of calibration Omega 820 nm laser	34
4-1-5 Results of calibration Omega 675 nm laser	35
4-1-6 Results of calibration diode laser	36
4-2 Calculations	37
4-3 Dissection	39
4-4 Conclusion	39
4-5 Future work	39
References	41

Chapter One

Chapter One

Basic concepts of lasers

1.1 Definition of laser

The word (laser) is an acronym derived from Light Amplification by Stimulated Emission of Radiation. The light emitted by laser is different from that produced by more conventional light sources. laser is a device that generates or amplifies coherent radiation at frequencies in the infrared, visible or ultraviolet and other regions of the electromagnetic spectrum [1].

Lasers are distinguished from other light sources by their [coherence](#). Spatial coherence is typically expressed through the output being a narrow beam which is [diffraction-limited](#), often a so-called "pencil beam." Laser beams can be focused to very tiny spots, achieving a very high [irradiance](#), or they can be launched into beams of very low divergence in order to concentrate their power at a large distance. temporal (or longitudinal) coherence implies a [polarized](#) wave at a single frequency whose phase is correlated over a relatively large distance (the [coherence length](#)) along the beam. a beam produced by a thermal or other incoherent light source has an instantaneous amplitude and [phase](#) which vary randomly with respect to time and position, and thus a very short coherence length. most so-called "single wavelength" lasers actually produce radiation in several modes having slightly different frequencies (wavelengths), often not in a

single polarization. and although temporal coherence implies monochromaticity , there are even lasers that emit a broad spectrum of light, or emit different wavelengths of light simultaneously. there are some lasers which are not single spatial mode and consequently their light beams [diverge](#) more than required by the [diffraction](#) limit. However all such devices are classified as "lasers" based on their method of producing that light: stimulated emission, lasers are employed in applications where light of the required spatial or temporal coherence could not be produced using simpler technologies [2].

1.2 Basic elements of a laser:

Any laser system is composed of three main components, laser medium, pumping source and feedback mechanism (optical resonator and output coupler) as shown in figure (1.1).

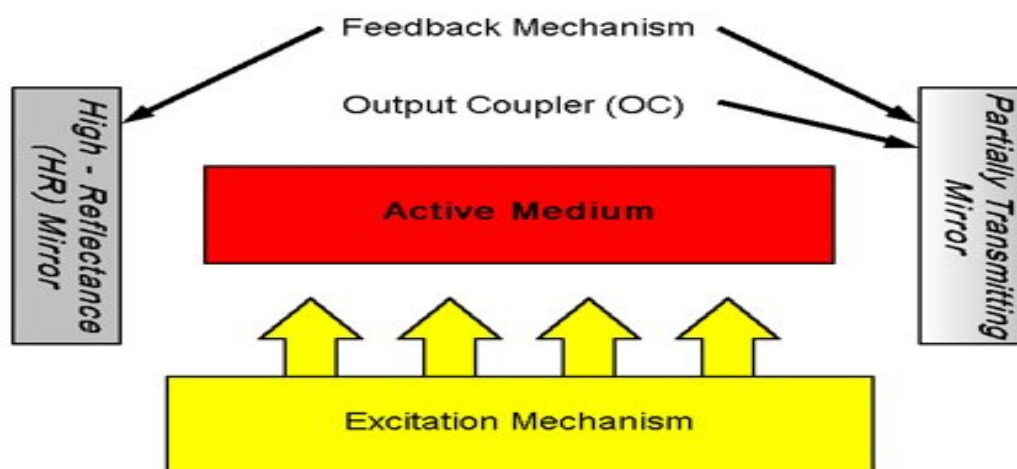


Figure (1.1) Basic Element of laser

1.2.1-Laser medium:

The laser medium could be gas such as atoms, molecules, and ions, liquid such as dyes or solids such as dielectric crystals and electron beams such as free electron laser. This medium interacts with electromagnetic radiation in such a way that radiation is amplified [3].

1.2.2- Pumping source:

In order to achieve amplification in laser, population inversion in the energy levels of the laser medium has to be achieved. The process that realizes this population is called the pumping process. there are several pumping source such as electrical (gas-discharge, injection current) , optical(flash lamp or laser)and chemical($H+F=HF$).

1.2.3- Feedback mechanism:

The feedback mechanism (optical resonator and output coupler) returns a portion of the coherent light originally produced in the active medium back to the active medium for further amplification by stimulated emission. The amount of coherent light produced by stimulated emission depends upon both the degree of population inversion and the strength of the stimulating signal. The feedback mechanism usually consists of two

mirrors--one at each end of the active medium--aligned in such a manner that they reflect the coherent light back and forth through the active medium. One of the mirrors of the feedback mechanism allows some light to be transmitted through it at the laser wavelength. The fraction of the coherent light allowed to escape varies greatly from one laser to another--from less than one percent for some helium-neon lasers to more than 80 percent for many solid-state lasers [4].

1.3 Laser physical concept:

The Einstein rate equation is necessary to understand the basics of laser action. In quantum-mechanic (Einstein treatment) the interaction between the energy levels in active medium and the photon of electromagnetic field. If we consider transitions between two energy levels, ground state at energy E_m to an excited state at energy E_n we can see the three different processes occur as figure (1.2)[5].

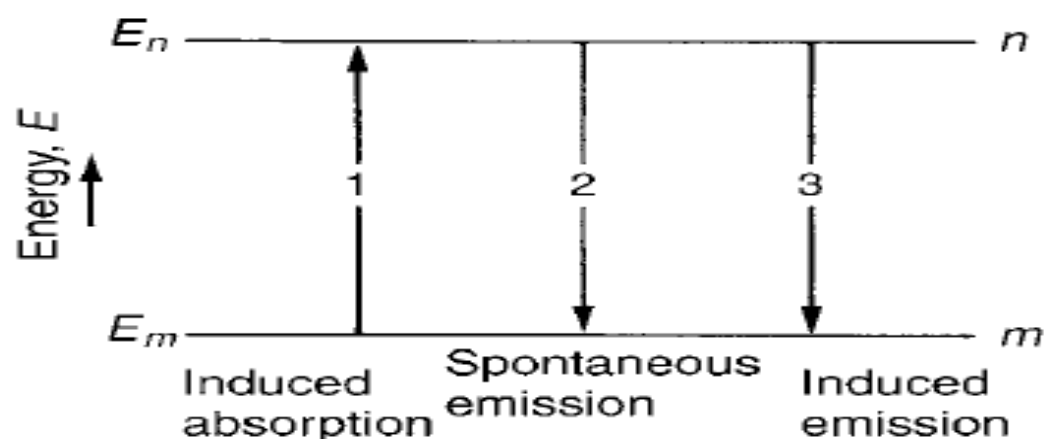


Figure (1.2) present three process

1.3.1 Induced Absorption:

$E_3 E_2$ Photon strikes an atom in energy state E_2 and is absorbed by that atom. The photon ceases to exist; and its energy appears as increased in the atom, which moves to the E_3 energy level energy. The process of absorption removes energy from the laser beam and reduces laser output. as shown in Figur (1.3)

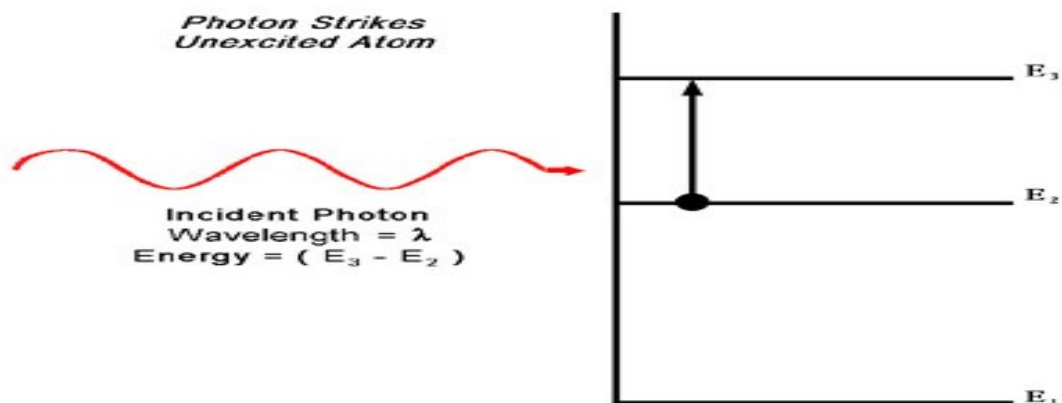


Figure (1.3) present Induced Absorption:

1.3.2 Spontaneous Emission:

An atom in an excited state is unstable and will release spontaneously its excess energy and return to the ground state. This energy release may occur in a single transition or in a series of transitions that involve intermediate energy levels as shown in figure (1.4)

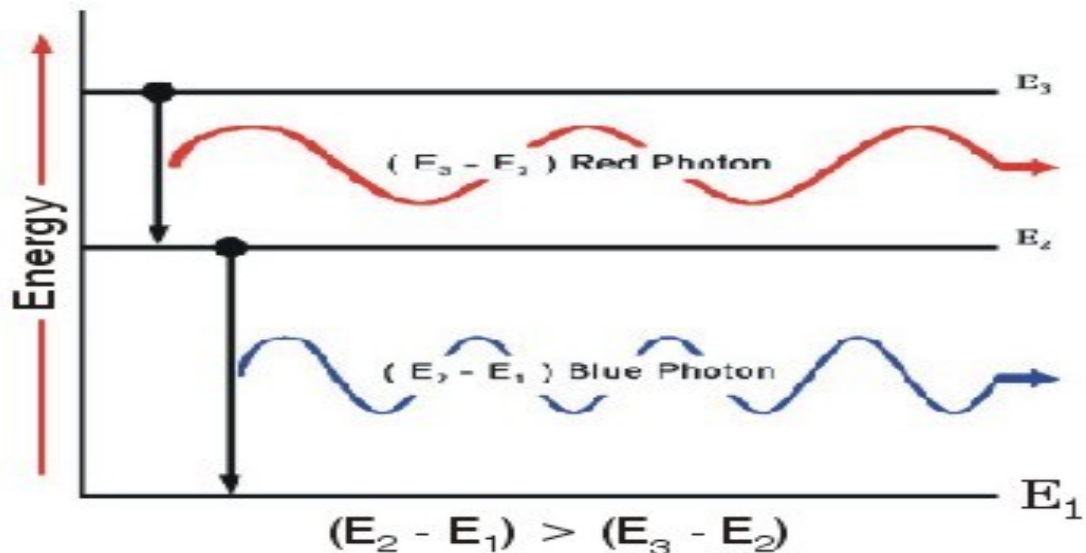


Figure (1.4) present Spontaneous Emission:-

$E_3 E_3 E_2$

In this case, the excited atom is stimulated by an outside influence to emit its energy (photon) in a particular way. The stimulating agent is a photon whose energy ($E_3 - E_2$) is exactly equal to the energy difference between the present energy state of the atom, E_3 and some lower energy state, E_2 . This photon stimulates the atom to make a downward transition and emit, in phase, a photon identical to the stimulating photon. The emitted photon has the same energy, same wavelength, and same direction of travel as the stimulating photon; and the two are exactly in phase. Thus, stimulated emission produces light that is monochromatic, directional, and coherent. This light appears as the output beam of the laser.

$$\frac{dN_n}{dt} = N_m B_{mn} \rho(\nu) - N_n B_{nm} \rho(\nu) - A_{nm} N_n$$

The rate of change of population of state n due to induced absorption is given by:

$$B_{mn}$$

Where B_{mn} is called Einstein coefficient and the spectral radiation density, $\rho(\nu)$, is given by:

$$\rho(\tilde{\nu}) = \frac{8\pi h c \tilde{\nu}^3}{\exp(hc\tilde{\nu}/kT) - 1}$$

$$\frac{dN_n}{dt} = -N_n B_{nm} \rho(\nu) - A_{nm} N_n$$

Similarly, induced emission changes the population by:

$$B_{nm}$$

$$\frac{dN_n}{dt} = -N_n A_{nm}$$

Where A_{nm} is the Einstein coefficient for this process and is equal to A_{nm} . For spontaneous Emission, we have:

Where A_{nm} is another Einstein coefficient and the absence of radiation indicates a spontaneous process. In the presence of radiation of wave number, all three processes are going on at once and when the populations have reached their equilibrium values we have:

$$\frac{dN_n}{dt} = (N_m - N_n)B_{nm}\rho(\tilde{\nu}) - N_n A_{nm} = 0$$

$$N_n N_m$$

At equilibrium N_n and N_m are related, through the Boltzmann distribution law by:

$$\frac{N_n}{N_m} = \frac{g_n}{g_m} \exp\left(-\frac{\Delta E}{kT}\right) = \exp\left(-\frac{\Delta E}{kT}\right)$$

If the degrees of degeneracy g_n and g_m of states n and m are the same. Putting this relationship as:

$$A_{nm} = 8\pi h c \tilde{\nu}^3 B_{nm}$$

1.4 Types of laser:

Laser can be classified according to their type of active medium, excitation method, output wavelength, and output power characteristic. The major classification according to their state of matter is into some types, as follows:

1.4.1 Solid-state laser:

. A large and important family of lasers contains solid crystalline or glass material as an active medium. Ruby and neodymium are two common examples of solid lasers with widespread industrial applications. Ruby is crystalline aluminum oxide in which some of the aluminum ions in the crystal lattice have been replaced by chromium ions. These chromium ions are the active elements in the ruby laser. Yttrium aluminum garnet (YAG) is the crystal host for

Nd:YAG lasers; some of the aluminum in the YAG is replaced by triply-ionized neodymium (Nd^{3+}), a rare earth element. Glass is also used as a host for neodymium lasers.

1.4.2 Gas lasers:

Another important family of lasers utilizes a gas or gas mixture as the active medium. Excitation usually is achieved by current flow through the gas. Gas lasers may be operated in either CW or pulsed modes.

One popular type of gas laser contains a mixture of helium (He) and neon (Ne) gases. The gas mixture is contained at a low pressure within a sealed glass tube called the "plasma tube." The excitation mechanism of the He-Ne laser is a direct-current discharge through the gas; the current pumps the helium atoms to an excited atomic state. The energy of the excited helium atoms is transferred to neon atoms through collisions, and the neon atoms then undergo a transition to a lower energy state that results in lasing. The feedback mechanism consists of a pair of mirrors sealed to the ends of the plasma tube. One of these mirrors, the output coupler.

1.4.3 Dye laser:

The most common laser dyes belong to specific classes of chemical compounds e.g. Rhodamine6G, Co marine and most of them dissolved in alcohol solutions. One of the most important features that dye lasers offer is tunability, that is, the color of the output beam can be varied by adjusting the internal tuning element and also by

changing the type of dye that is used. The monochromatic output of available dye lasers can be turned over a broad range, from the ultraviolet, to the near infrared. Liquid dye lasers that can be tuned to any visible wavelength, and to portions of the infrared and ultraviolet, are commercially available in both pulsed and continuous models. Dye lasers are chosen for applications, like spectroscopy, in which tunability is important.

1.4.4 Semiconductor laser:

The active medium of a semiconductor (injection) laser is the junction between two types of semiconductor materials. A semiconductor is a material whose electrical conductivity is greater than that of an insulator, such as glass or plastic, but less than that of a good conductor, such as silver or copper. Gallium arsenide (GaAs) is an example of a material used in the manufacture of a semiconductor laser. A p-type semiconductor material has a deficiency of negatively-charged free electrons in the crystal structure. This deficiency exists in the form of positions in the crystal that can accept an electron if one were available. These positively-charged "holes" are the carriers of electric current in p-type semiconductors. By contrast, an n-type semiconductor material has a surplus of electrons that act as current carriers. If two slabs, one of p-type and one of n-type semiconductor material, are joined together, the result is called a pn junction. When current flows across a pn junction, free electrons from the n-type material combine with holes in the p-type material

and release energy. This energy may appear as visible light as in the light-emitting-diode (LED) displays of electronic calculators[6].

1.5 Applications of laser:

The laser has a large number of applications in various fields, such as communication, engineering, measurement, medical, industry, agriculture, science, military and other new applications. Any of these applications is depend of one or more than one of the laser parameter such as power, energy, wavelength and pulse duration [7].

1.6 Literature review:

David J. Livigni National Institute of Standards and Technology

Boulder, CO 80303, high-accuracy laser power and energy meter calibration service. This document describes the high-accuracy laser power and energy meter calibration service provided by the National Institute of Standards and Technology (NIST). Calibrations are performed by direct substitution of a test detector with a cryogenic laser radiometer, traceable to NIST electrical standard the service currently supports measurements with lasers wavelengths in the range from 458 to 1550 nm.

Thesis layout:

In chapter one fundamental of laser, in chapter two is theoretical background about calibration and laser systems calibration, the third chapter represents

experimental setup of the lasers calibration (lasers, optics element ,fiber, detector and computer program).Results, discussion, conclusions are in the fourth chapter.

Aim of the work:

The aim of this work is calibrated of some laser systems, determine some of laser parameters (Spot size and beam waist) and determine the accuracy of all laser systems calibrated.

Chapter Two

Chapter Two

Calibration

2.1 Introduction:

The importance of laser calibration comes from the wide range of wavelengths and wide application of the laser systems in many different types. The laser system calibration was founded to meet the industry's need for very high-accuracy measurements of laser power and energy, at various selected wavelengths [8].

The most fundamental method of checking the performance of laser is to measure its power or energy output. Laser output directly affects a laser's ability to perform a process. Measuring and monitoring this parameter is often very important from the time a laser is first manufactured, through system integration, and on to the final end customer who will be using the laser system in applications as far-ranging as medical, scientific, biomedical, and industrial applications. The different of weather, made, and condition of uses laser systems from country to another affect to the laser output power and lead to shift in result. For detection and measurement of the laser output the specialized institutes for measurement and calibration had built [9].

The first one and famous of this institutes is built in U S A and called the National Institute of Standards and Technology(NIST),after that many of industrial country

built same institutes such as France, South Africa and Egypt.

Since 1967, NIST has built and maintained room-temperature, electrically calibrated laser calorimeters for the calibration of laser power and energy meters for customers. A number of standard laser calorimeters have been developed to provide measurements over a wide range of laser wavelengths (ultraviolet to far-infrared), power levels (nanowatts to kilowatts), and energy levels (few to joules to mega joules). The combined standard uncertainty of measurements with these calorimeters is usually limited to about 0.25 %, primarily due to their operation at room temperature. Their performance is limited primarily by in equivalence between electrical and optical heating, due to factors such as: radioactive and convective cooling of the optical receiver, and its limited diffusivity, which result in the formation of temperature gradients, and parasitic heating in the electrical heater leads. Commercial laser power and energy meters have significantly improved over the last 10 years and customers now require lower uncertainties. The LOCR calibration service was developed by NIST's Optoelectronics Division to meet select customers' needs for higher accuracy. The goal of the high-accuracy calibration service is to provide laser power and energy meter calibrations for the most demanding customers, with low uncertainty (< 0.1 %), performed in a stable and fully documented environment, at an affordable

cost and in a timely manner. The calibration system achieves the goal by offering calibrations based on the highly accurate laser optimized cryogenic radiometer (LOCR) primary standard, using a stabilized laser source, in an automated calibration system that allows quick calibration of multiple detectors at the same time.

2.2 Types of calibration:

There are many types or ways to calibrate the laser system, the main is the primary standards, secondary standard and field transfer standard. Each type of standard has specific performance requirements that make it useful for a particular application. The primary standards emphasize accuracy and low uncertainty at the sacrifice of speed and convenience. The laboratory reference standard must be able to provide traceability between the primary standard and the low-level requirements of the field instruments. The field transfer standards feature sensitivity, speed, and rugged operation, but are not as accurate. Low-level instruments are based on semiconductor detectors in order to provide the sensitivity and portability necessary for an effective field transfer standard.

Table (2.1) Types of lasers calibration.

Nist electrical Standards



National Standard calorimeter(primary standard)



Laboratory reference Standard(Secondary
Transfer Standard)



Filed Transfer Standard(pulsed-laser radiometer)

2.2.1 Primary standard:

Laser power and energy meters are calibrated without specific knowledge of many of the DUT's parameters. However, evaluation of many of the uncertainties associated with the DUT's calibration does require specific knowledge of some of the DUT's parameters. Some examples are the DUT's spectral responsivity, power linearity, temperature coefficient, spatial uniformity, and sensitivity to beam parameters such as polarization, incidence and divergence angles. Similarly, the uncertainty in the DUT's Gain is unknown. To

avoid having to gather the information from the customer or measure the DUT's Properties ourselves, we specify in the calibration report the conditions present at the time of the calibration.

Figure (2.1) shows the Current configuration of the high-accuracy calibration system [10].

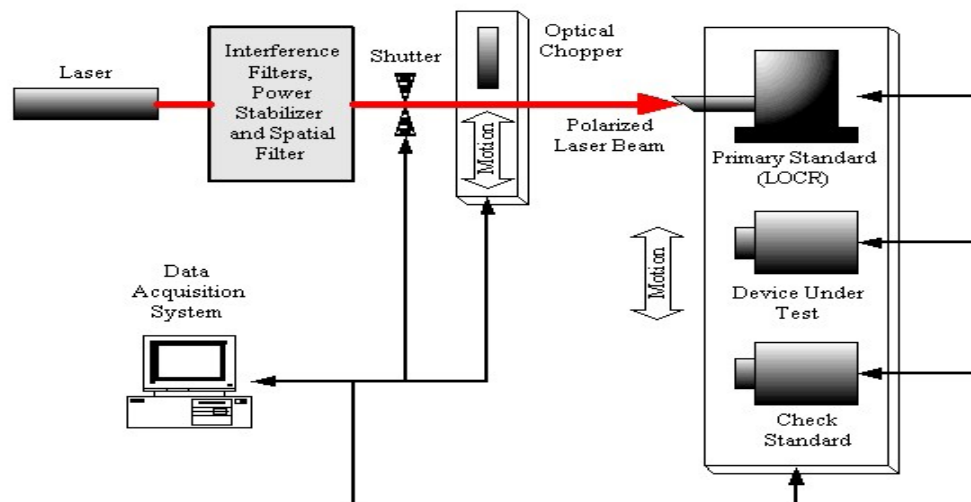


Figure (2.1) diagram of primary standard

2.2.2 Transfer-Standard Definitions:

A laboratory reference standard or secondary transfer standard is a device that is calibrated against a primary standard, and then used in a secondary calibration system to serve as the standard.

2.2.3 Field transfer standard:

A field transfer standard is an instrument that is calibrated against the laboratory standard, and is used at

remote locations away from the NIST site to continue the calibration chain. For the purposes of this document, field transfer standards are pulsed-laser radiometers whose response is calibrated in terms of irradiance or fluency [11].

Figure (2.2) shows the system used for calibrating laser pulse energy or peak power at 1.06 μm . Dashed line represents first-order diffracted beam, which has been modulated into pulses.

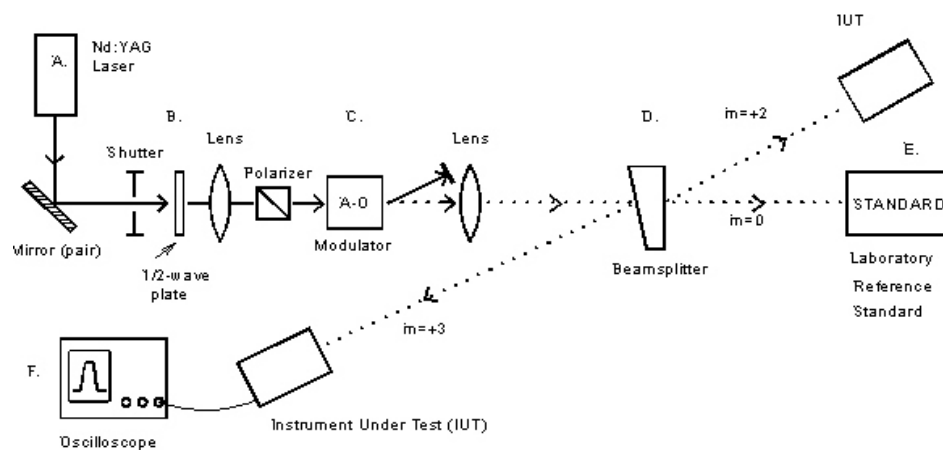


Figure (2.2) diagram of field transfer standard

2.3 The principal subsystems of the calibration set-up are:

- A . Laser Source.
- B. Beam-steering and polarizing optics
- C. Collimating lenses and modulator
- D. Multiple-reflection beam splitter/attenuator if need
- E. Laboratory reference standard if found.
- F. Waveform measuring instrument: oscilloscope, spectrometer.

Most laser power and energy sensors and meters sold on the markets are calibrated and traceable to national standards laboratory and are sold with a traceable calibration certificate.

2.4 Analysis Capabilities:

Some meters have built in capabilities for logging data and performing various statistical calculations on stored entries, averaging and wavelength correction. More sophisticated energy meters can provide values for irradiance, fluency, radiometric calculations and other parameters.

Chapter Three

Chapter Three

The Experimental Part

3.1 Instruments and Apparatus:

In this chapter is presented all the systems and optical set used in the experimental part.

3.1.1 Laser sources:

Diode laser second harmonic 532nm:

In the first presents the items of the Laser diode second harmonic (532nm) instrument which was calibrated and its specifications in details. The instrument was form Lambda Scientific Pty Ltd. Its specifications are listed in table [3.1].

Table (3.1) Specifications of diode laser second harmonic 532nm

Specifications	
1-Wavelength Range	532 nm
2-Wavelength Accuracy	≤ 0.4 nm
Output power	$\geq 40mW$

The schematic diagram of the LIRA - 300 Laser Raman Spectrometer structure is shown in figure (3.1)[13]

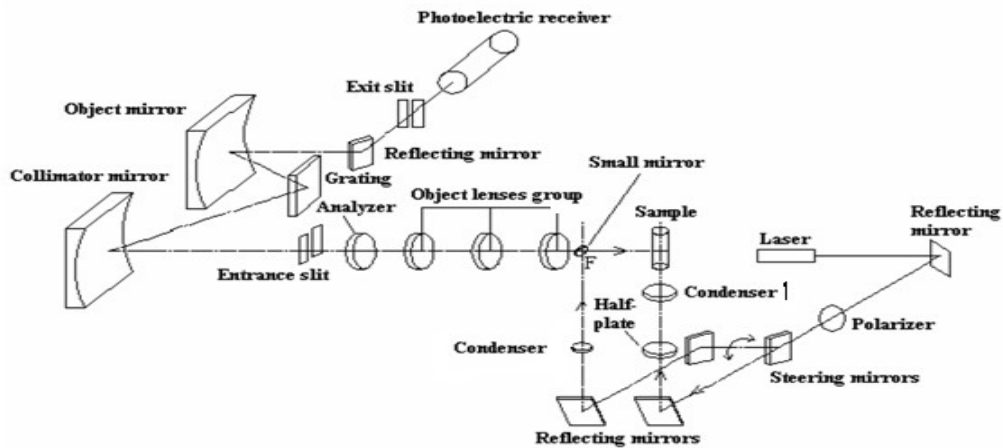


Figure 3.1 shows the system schematic of the LIRA - 300 Laser Raman Spectrometer.

He-Ne laser Multi-function cure instrument:

He-Ne Kx---350-IB is founded in laser laboratory of al Neelain University is uses in many type of training students. it is have wavelength 632.8nm,laser output power >6mw,date of produce 5 / 2000 ,date of uses 2/ 2003, It has two working modes: continuous and pulsed, which can be chosen according to requirement of the treatments. from Guilin Kangxing Medical Instrument Co.,Ltd The specification of He- Ne laser is listed in table(3.2) [14]

Table (3.2) Specifications of He- Ne

632.8nm	Wavelength
6 mw	Output power
110V/220V and 50/60Hz.	Power Source
Kx-350-IB	Model
456*307*175(mm)	Size

The He Ne schematic is shown in figure 3.2.



Figure (3.2) He Ne laser

ORALIA system:

ORALIA system 810 nm is founded in laser clinic Sudan university, uses in many medical applications. Its specifications are listed in table (3.3). [15]

Table (3.3) specification of laser ORALIA.

Wavelength	810nm
Out put power	20 watt
Serial number	04-040352
Laser class	4
Prduce	2004

The ORALIA laser schematic is shown in figure 3.3.



Figure (3.3) ORALIA laser

Omega xp:

Also Omega xp (675nm,820nm) , model XP serine number (2199) is founded in laser clinic. it uses in many medical applications, the specification of omega laser listed in table3.4 [16].

Table 3.4 is specification of laser Omega xp.

820nm, 675nm	Wavelength
30 ~ 300 mW	Out put power
3B Laser	Classification
H:190 x D:300 x W:260mm Ga AIAs	Size Medium

The schematic of Omega XP:



Figure (3.4) omega xp laser

Diode laser 808:

This device model: L D C d . serial number A2027-290.founded in laser Institute of Sudan University. It uses in many type of applications such as Solid-state Laser Pumping, Materials Processing and Medical Therapeutics. The specification in table3.5 [17]

Table (3.5) is specification of laser diode 808.

808nm	Wavelength
500~5000mW	Output power
4	Class
CW	Mode

The schematic of diode laser.



figure(3.5) The structure of laser diode 808

3.1.2 USB 2000 fiber optics spectrometer:

The USB2000 spectrometer from ocean Optics Company, It automatically reads the wavelength calibration coefficient of the spectrometer and configures operating software. We use with it light sources, collimating lenses, sampling holders, filter holders, flow cell, fiber optic probes and sensors, and optical fibers to create the optimal system for their application. We used it to detect the florescence, emission and laser output. It can detect wavelength from 400-1100nm The specifications of USB 2000 spectrometer is listed in table(3.6) [18].

Table (3.6) is specification of USB 2000 spectrometer:

Wave length optimization	200 -1100nm
Numerical aperture	0.22 +/-0.02 (24.8°)
Fiber core	Pure silica
Cladding	Doped fused silica
Fiber profile	Step-index multi-mode
Jacketing	Silicone Monocoil
Resolution	0.01nm

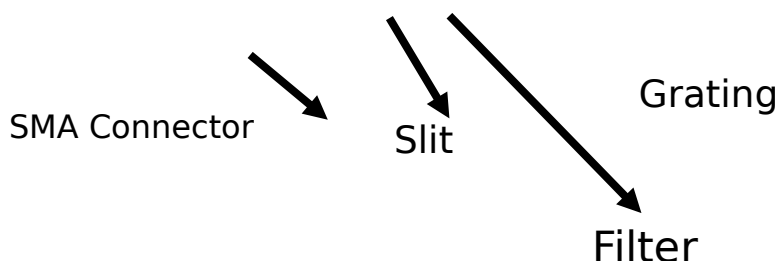
Collimating Mirror

The components of USB fiber optics spectrometer is shown in. . Fig.(3.6)

Focusing Mirror

L2 Detector

CCD detector (UV or VIS)



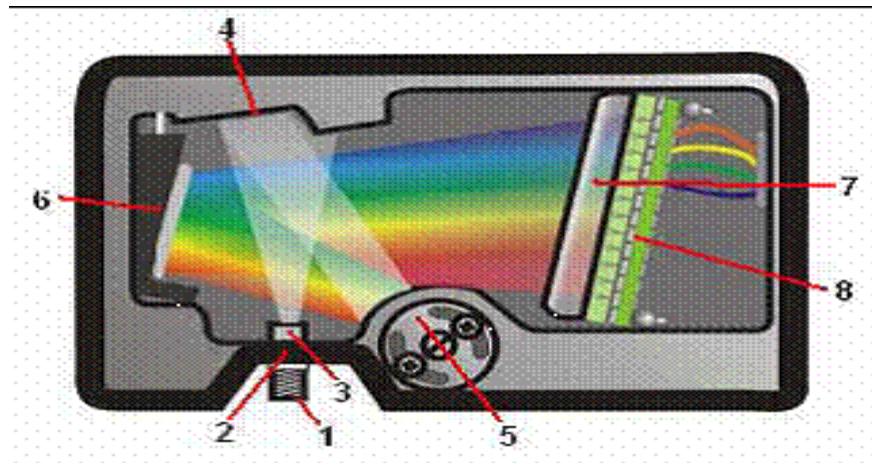


Fig.(3.6)components of USB fiber optics spectrometer

1. SMA Connector: The **SMA Connector** secures the input fiber to the spectrometer. Light from the input fiber enters the optical bench through this connector.

2. Slit: The Slit is a dark piece of material containing a rectangular aperture, which is mounted directly behind the SMA Connector. The size of the aperture regulates the amount of light that enters the optical bench and controls spectral resolution.

3. Filter: The Filter is a device that restricts optical radiation to pre-determined wavelength regions(400 -1100nm).

4. Collimating Mirror: The Collimating Mirror focuses light entering the optical bench towards the Grating of the spectrometer.

5. Grating: The Grating diffracts light from the Collimating Mirror and directs the diffracted light onto the Focusing

Mirror.

6. Focusing Mirror: The Focusing Mirror receives light reflected from the Grating and focuses the light onto the Detector.

7. L2 Detector Collection Lens: The L2 Detector Collection Lens (optional) is attached to the CCD Detector. It focuses light from a tall slit onto the shorter CCD Detector elements. The L2 Detector Collection Lens should be used with large diameter slits or in applications with low light levels.

8. CCD Detector (UV or VIS): The CCD Detector collects the light received from the Focusing Mirror or L2 Detector Collection Lens and converts the optical signal to a digital signal. The spectrometer then transmits the digital signal to the OOIBase32 application.

OOIBase32 is an operating software for all Ocean Optics spectrometers; OOIBase32 is a user-customizable, advanced acquisition and display program that provides a real-time interface to a variety of signal-processing functions. With OOIBase32, user has the ability to perform spectroscopic measurements (such as absorbance, reflectance, and emission), control all system parameters, collect and display data in real time, and perform reference monitoring and time acquisition experiments.

The **CUV-ALL 4-WAY** is a cuvette holder for 1 cm cuvettes that has fiber optic couplings at four collimators, the cuvette holder that attaches directly to light sources. When combined with the spectrometers and light sources, it can

measure absorbance, fluorescence, scattering, or any combination of these optical phenomena.

3.1.3 Laser safety goggles:

Laser safety goggles are the most important, yet inexpensive protective measure against laser radiation. They offer protection against direct, reflected or diffusely scattered laser radiation. Nevertheless, even when wearing safety goggles, it should be avoided to look directly into the laser beam.



Figure (3.7) laser safety goggles diagram.

3.2 Methodology:

$\bar{\omega}_0 \omega \nabla \lambda$
In this research we used direct measurement. Laser source connected to power supply then the fiber optics to obtain Gaussian shape to determined laser parameter as different in wavelength , spot size , beam waist and efficiency.

Chapter Four

Chapter four

Results and discussions

In this chapter it presented and discusses the result of calibration laser systems .First we present the result.

4.1 The results:

4.1.1 The result of calibration diode laser second harmonic 532nm:

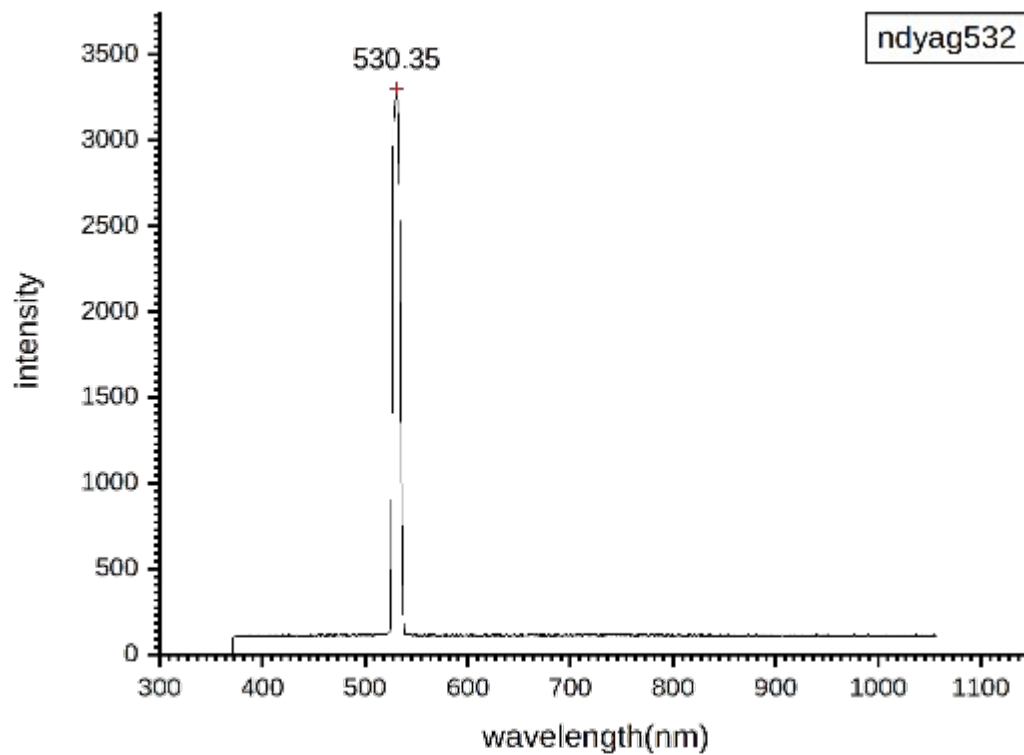


Figure (4.1) represent relationship between wavelength (nm) and intensity (a.u) for second harmonic laser.

4.1.2 The result of calibration of He Ne laser:

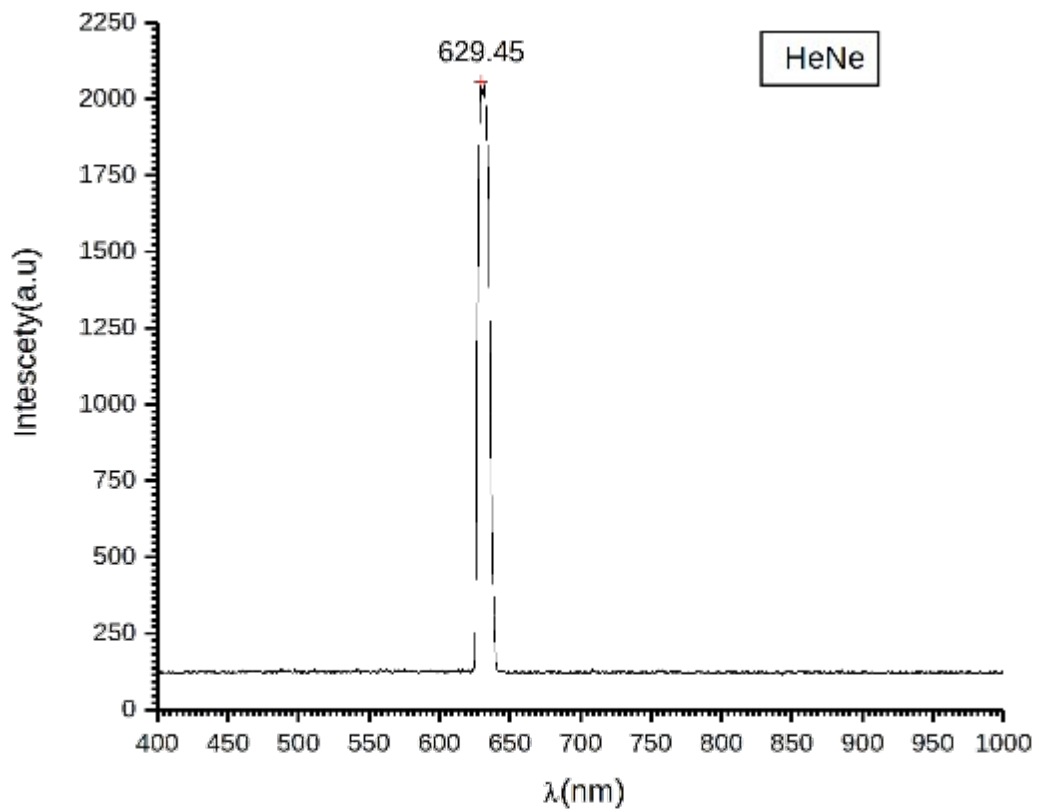


Figure (4.2) represent relationship between wavelength (nm) and intensity (a.u) for He Ne laser.

4.1.3 The result of calibrated laser ORALIA:

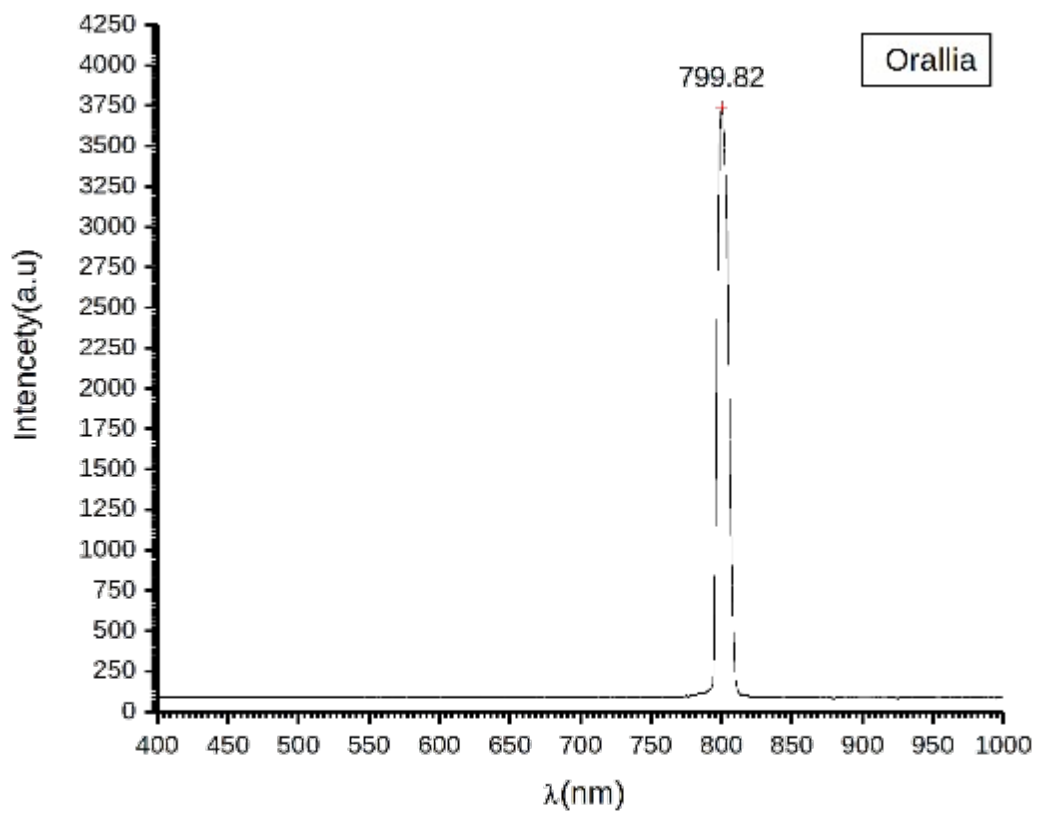
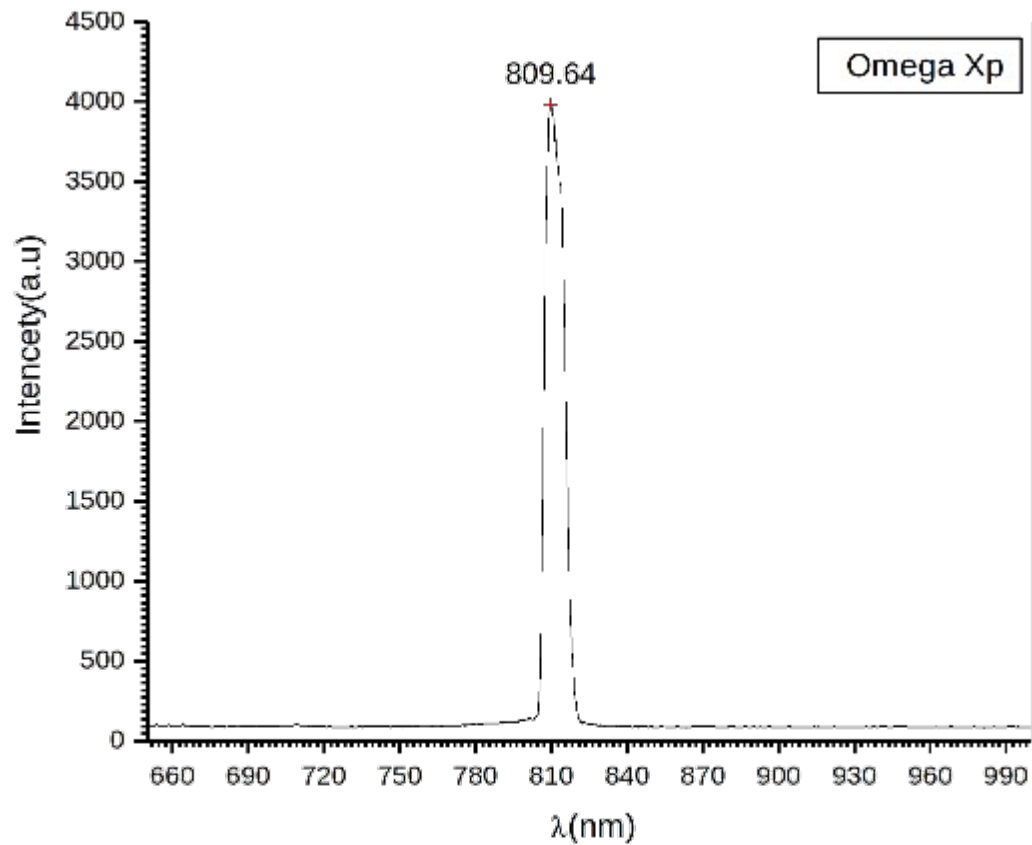


Figure (4.3) represent relationship between wavelength(nm) and intensity(a.u)for ORALIA laser.

4.1.4 The result of calibrated laser omega XP820 nm :



Figure(4.4)represent relationship between wavelength(nm) and intensity(a.u)for Omega xp laser.

4.1.5 The result of calibrated omega XP 675nm:

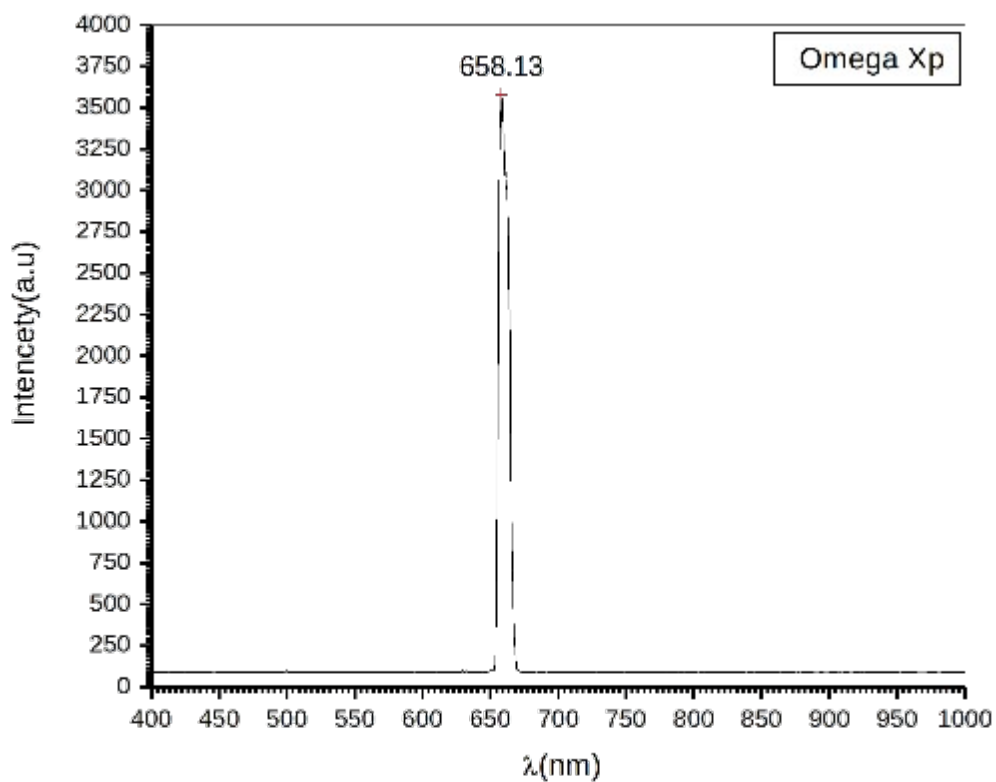
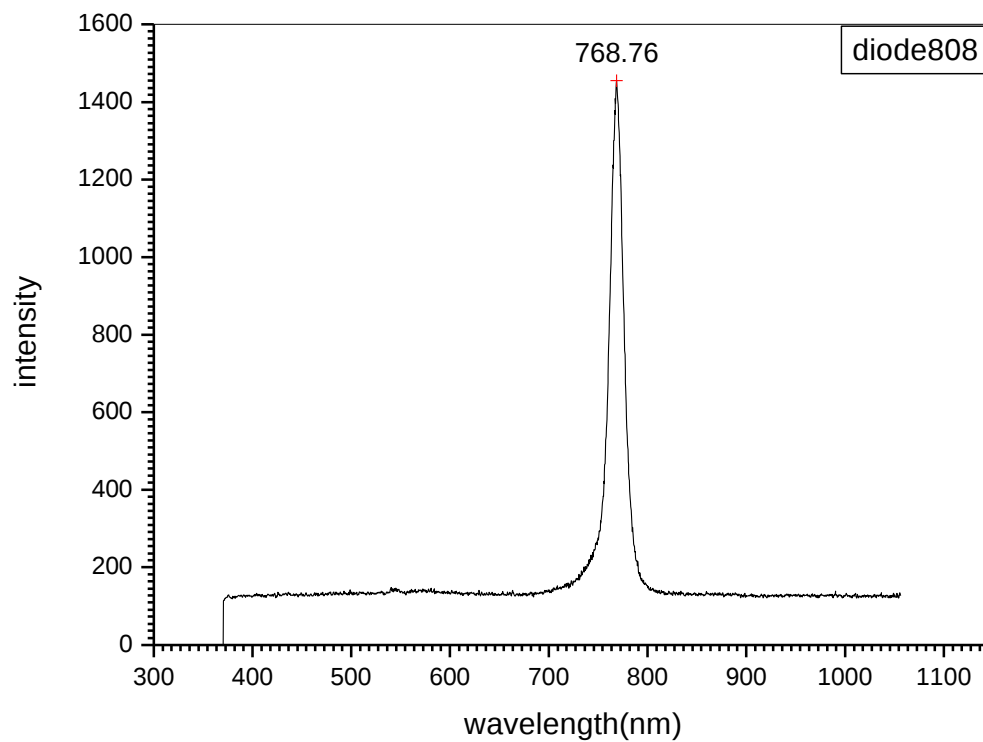


Figure (4.5) represent relationship between wavelength(nm) and intensity(a.u)for Omega laser.

4.1.6 The diode laser calibrated result:



figure(4.6) Represent relationship between wavelength (nm) and intensity(a.u)for diode laser.

4.2 Calculation:

$$\Delta(\lambda) \Delta\lambda = \lambda_2 - \lambda_1 \text{ (}\lambda_1 \text{ and } \lambda_2\text{)}$$

The Gaussian graph that was shown represented relationship between intensity (a.u) in y axis and wavelength (nm) X axis from it calculated () by measured the maximum intensity and divided by 2 so marked two position then

$$\frac{\lambda_m}{\lambda_s}$$

From maximum intensity after divided was taken FWHM (full width half maximum).then calculated the accuracy for any laser systems calibrated.

Accuracy =

$$\lambda$$

Refers to as wavelength of laser in nanometer.

$$\lambda_1$$

Refers to as wavelength at first position in nanometer.

$$\lambda_2$$

Refers to as wavelength at second position in nanometer.

$$\nabla\lambda \Delta\lambda$$

Difference in wavelength in nanometer.

λ_s λ_m Refers to as wavelength measurement in nanometer.

Refers to as wavelength standard in nanometer.

.

From Gaussian shape calculated the parameter:

Table(4.1)
Represent some parameters of laser

Source	λ S/nm	$\lambda \lambda$ M/nm	<i>FWHM</i> nm	accuracy
Nd yag	532	530.35	10.66	%100
He _ Ne	632.8	629.45	8.2	%100
ORLIA	810	799.82	9.06	%99
OmegaX P	820	809.62	8.79	%99
OmegaX P	675	658.13	9.21	%98
Diode	808	768.76	17.1	%95

4.3 Discussion:

- From the above result and calculation there are founded error in wavelengths for (Nd-Yag ,He-Ne, ORILLA, Omegaxp (675, 820) and diode) about (1.65,3.35,10.18,10.38,16.87&39.24) respectively, compare with standard. And this shift is acceptable when is small and not change in other parameters (FWHM),this errors comes from many factors affected to measurement such as condition of measurement is not perfect condition and more accuracy need to sensitive and special characteristic condition. The large shift in wavelength diode system according to affected high temperature and time of calibration, otherwise uses U S B spectrometer in calibration is good and high speed. From result and calculation we can say all systems calibrated are proper to give good result in many applications.

4.4 Conclusions:

- All laser systems calibrated have a different accuracy (He-Ne, Nd Yag, ORIIA , Omega and diode) (%100, %100, %99, %95) and small shift in one or more parameters refer to many factor.
- The error in results come from receiver of optical signal in fiber optic connected USB spectrometer detector and this is one of the main factor affected to exact measurement.

- The computerize program give a simply and high speed.
- Laser systems in special lab give protection long time with high accuracy.
- Professional technical for laser lab help to uses and measurement.

4.5 **future works:**

Require and exist stander Lab and detector have a large rang to measure all wavelength and power. Predict all laser systems to circle test in lab stander. For more accuracy it calibrated more laser specification and use the mechanic wave and acoustic sound in the calibration.

Reference:

- (1) Louis Baltimore, laser second edition, Lewis center Ohio(1998) .
- (2) Conceptual physics, Paul Hewitt, 2002.
- (3) J.P Woerdman, laser physics, fifth addition (1995)
- (4) W. H. Freeman, lasers and Light - Readings from Scientific American. San Francisco (1969).
- (5) karlo ayuel, laser quantum optics lecture note Al nelain university (2004).
- (6) Orazio svelte , Principles of laser Fifth edition, springer science business media (2010) .
- (7) Leon J.Radziemski, laser spectroscopy and applications (2004).
- (8) David J. Livigni, High-Accuracy Laser Power and Energy Meter Calibration Service (2009).
- (9) Rodney W. Leonhard Pulsed-Laser Radiometers, Calibration Service for Low-level (2011).
- (10) WWW National Institute of Standards and Technology.com (2013)
- (11) Measuring Laser Power and Energy Output, paper from coherent company,(2011).
- (12) WWW.powertechnology.com (agust2004) & Electus Distribution (2001).
- (13) WWW. Lambda Scientific Pty Ltd.(2013)
- (14) WWW.Guilin Kangxing Medical Instrument Co.,Ltd(2010).
- (15) www.orila medical instrument co ,ltd (2004).
- (16) WWW.Omega XP Quantum Healing Lasers(2013).
- (17) WWW.Changchun new industries optoelectronics technologies CO.Ltd(2011)

- (18) Mandel, Leonard and Wolf, Emil (1995). Optical Coherence and Quantum Optics. Cambridge: Cambridge University Press. [ISBN 0-521-41711-2](#). Chapter 5, "Optical Beams," pp. 267
- (19) Ocean Optics, Inc. (Copyright 2001-2005), USB2000 Fiber Optic Spectrometer, Installation and Operation Manual Document Number 170-00000-000-022-1005.