LASERS AND IT'S APPLICATIONS

PROJECT REPORT

Submitted for the course: Engineering Physics (PHY1003)

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CERTIFICATE

This is to certify that the project work entitled " **Laser and its applications**" that is being submitted by " **Medha Shruti , Mohammed Affan, Gayathri Jayaraj, Gokul Prasad G ,Samreen Naqvi, Soobarnikaa S V, Samaja M S** " for Engineering Physics (PHY1003) is a record of bonafide work done under my supervision. The contents of this Project work, in full or in parts, have neither been taken from any other source nor have been submitted for any other CAL course.

Place : Vellore

Date : 18th June 2021

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ABSTRACT

This project report entitled “Laser and its applications” aims to study the principle of laser operation and the various applications of laser. It focuses to work on the introduction and working principle of laser, highlighting its importance in various fields. The details regarding each subtopic were collected through discussion with the team members.

Additionally a model has been prepared to demonstrate the working of a laser security system and study its functions. By the end of this report we shall be able to learn a lot about laser physics.

1. INTRODUCTION

1.1 Objective and goal of the project

The project objectives are to discuss what are lasers, what is the working principle, and the various applications of lasers used in different fields. By this project our goal is to dive into the world of laser physics and explore how interesting the concept of laser is and how this technology has positively impacted the world. We aim to make this journey of laser physics very much mesmerizing by the demonstration of a laser security system and its functions.

1.2 Literature

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The first laser was built in 1960 by Theodore H. Maiman at Hughes Research Laboratories, based on theoretical work by Charles Hard Townes and Arthur Leonard Schawlow. The enormous growth of laser technology has stimulated a broad range of scientific and engineering applications that exploit some of the unique properties of laser light.

In 1917, Albert Einstein established the theoretical foundations for the laser and the maser in the paper Zur Quantentheorie der Strahlung (On the Quantum Theory of Radiation) via a re-derivation of Max Planck's law of radiation, conceptually based upon probability coefficients (Einstein coefficients) for the absorption, spontaneous emission, and stimulated emission of electromagnetic radiation. In 1928, Rudolf W. Ladenburg confirmed the existence of the phenomena of stimulated emission and negative absorption. In 1939, Valentin A. Fabrikant predicted the use of stimulated emission to amplify "short" waves. In 1947, Willis E. Lamb and R.C. Retherford found apparent stimulated emission in hydrogen spectra and effected the first demonstration of stimulated emission. In 1950, Alfred Kastler (Nobel Prize for Physics 1966) proposed the method of optical pumping, experimentally confirmed, two years later, by Brossel, Kastler, and Winter.

On May 16, 1960, Theodore H. Maiman operated the first functioning laser at Hughes Research Laboratories, Malibu, California, ahead of several research teams, including those of Townes, at Columbia University, Arthur Schawlow, at Bell Labs, and Gould, at the TRG (Technical Research Group) company. Maiman's functional laser used a flashlamp-pumped synthetic ruby crystal to produce red laser light at 694 nanometers wavelength. The device was only capable of pulsed operation, due to its three-level pumping design scheme. Later that year, the Iranian physicist Ali Javan, and William R. Bennett, and Donald Herriott, constructed the first gas laser, using helium and neon that was capable of continuous operation in the infrared (U.S. Patent 3,149,290); later, Javan received the Albert Einstein Award in 1993. Basov and Javan proposed the semiconductor laser diode concept. In 1962, Robert N. Hall demonstrated the first laser diode device, which was made of gallium arsenide and emitted in the near-infrared band of the spectrum at 850 nm. Later that year, Nick Holonyak, Jr. demonstrated the first semiconductor laser with a visible emission. This first semiconductor laser could only be used in pulsed-beam operation, and when cooled to liquid nitrogen temperatures (77 K). In 1970, Zhores Alferov, in the USSR, and Izuo Hayashi and Morton Panish of Bell Telephone Laboratories also independently developed room-temperature, continual-operation diode lasers, using the hetero junction structure.

The earliest security system comes from the early 1990's. They were very expansive at that time and hard to monitor an intrusion. Now the technology has developed very much more than the old days. Laser security system are also known as burglar alarm systems. In most common security system laser and light dependent resistor are used. This system is easy to construct and install. Now a days lots of advance security system such as PIR based security system, temperature detecting based security system, infrared security system, etc. have come into existence. Among them this system is simple and effective too.

2. Methodology : Experimental/Simulation

2.1 Laser

Laser stands for light amplification by stimulated emission of radiation. Lasers are essentially highly directional , highly intense highly monochromatic and highly coherent optional sources . Stimulated emission was postulated by Einstein as early as in 1917. In 1960 , a solid state ruby laser is developed by maiman on the principle .In 1961 , a gas state He-Ne laser is developed by alijavan and others in bell telephone laboratory.

2.2 Principle of Laser

(a) Absorption
(b) Spontaneous emission
(c) Stimulated emission

Absorption - The process of exciting the atom to higher level by absorbing the stimulating incident photon is known as stimulated absorbtion of radiation .

Spontaneous emission - The transition of an excited atom by itself to lower energy level is known as spontaneous emission of radiation .

Stimulated emission - The excited atom after getting stimulated by the incident photon tansits to lower energy level by emitting photon is known as stimulated emission of radiation .

2.3 Laser Fundamentals

- The light emitted from a Laser is MONOCHROMATIC , that is it is of one color/wavelength . In contrast , ordinary white light is a combination of many colors (or wave length)of light.

- Lasers emit light that is highly DIRECTIONAL, that is , laser light is emitted as a relatively narrow beam in a specific direction .ordinary light, such as from a light bulb , emitted many directions away from the source .
- The light from a laser is said to be COHERENT , which means that wavelengths of the laser light are In phase In space and time . ordinary light can be mixture of many wave lengths

2.4 Applications of Lasers

Lasers are being widely used in different fields in our day to day life. Lasers are seeing their application in multiple areas. Some of the main ones are:

A. Laser/ Fiber optic communication systems

Laser communication systems are used to transfer information from one point to a distant point. The information may be an audio conversation, a stream of data from one computer to another, or several simultaneous television broadcasts. The distance may range from a few feet to thousands of miles. Modern optical communication systems use semiconductor lasers that transmit light through optical fibers. Such systems have become widely used for telecommunications.

i. Semi conductor lasers

Semiconductor lasers are basically PN junction diode. Conduction band plays the role of excited level. Valence band plays the role of ground level. Population inversion requires the presence of large number of holes in valence band. A simple way to achieve population inversion is to make a semiconductor in the form of a PN junction diode from heavily doped P and N type semiconductors. Direct conversion method is used for pumping

ii. Construction of Ga-As laser

The gallium arsenide laser is designed in such a way that a piece of N type GaAs material is taken and a layer of natural GaAlAs is pasted, and a third layer of P type GaAs material is pasted over it. The two ends(length wise)

are polished in order to amplify the light by cross reflection. Here one end is partially polished from where we get the laser beam.

iii. Working of a GaAs Laser

The forward Bias Voltage causes the carrier pairs (i.e. electron in n region and hole in p region) to inject into the junction region, where they recombine by means of stimulated emission.

When a p-n junction is forward biased, the electrons will be injected into conduction band along and side, and the number of holes are produced in the valence band along the p-side of the junction. Thus, there will be more electrons in the conduction band than that in the valence band. Hence, population inversion is achieved.

When forward biasing is applied, a current flows. Initially at low current, there is spontaneous emission in all the directions. Further, as the bias is increased , a threshold current is reached at which the stimulated emission occurs. Due to plane polished surfaces , the stimulated radiation in the plane perpendicular to the depletion layer builds up due to multiple reflections in the cavity formed by these surfaces and a highly directional coherent radiation is emitted.

iv. Working of communication system

A basic fiber-optic telecommunication link is shown in Figure . The laser output is modulated to yield a digital pulse-code-modulated (PCM) signal, that is, a series of ones and zeros. The input signal drives the laser power supply (the driver), which in turn pulses the laser on and off. The light from the laser is coupled into the fiber. The end of the fiber is positioned by a connector to maximize the input. This part of the system constitutes an optical transmitter.

The fiber carries the light toward the receiver, where the light is detected and the digital signal is recovered. But the link may be long, perhaps many kilometers. Absorption, scattering and dispersion in the fiber may degrade the signal. Optical amplifiers are needed to regenerate the signal every 50 to 100 km. Early fiber-optic telecommunications systems included signal

repeaters that consisted of a detector, amplifier, and a signal regenerator that restored the shape and intensity of the pulses. In the more modern networks, the repeater system is replaced by an optical amplifier which consists of laser gain material and replicates and reinforces the signal optically.

B. Medical uses of Laser

Over the past half-century, lasers have found their way into and many areas of medicine and biomedical research. Lasers are being used in many different fields of medicine like, Dermatology, ophthalmology, cardiology, gynecology, urology, gastroenterology etc. The special properties of lasers make them much better than sunlight or other light sources at targeting medical applications. Each laser operates within a very narrow wavelength range and the light emitted is coherent. They can also be very powerful. The beams can be focused to a very small point, giving them a high power density. These properties have led to lasers being used in many areas of medical diagnosis and treatment.

i. Laser in Dermatology

Lasers have become an important part of the dermatologist's arsenal for the treatment of skin diseases.

Port wine stain - PWSs with an incidence of about 0.4% of new-borns are benign vascular birthmarks consisting of superficial and deep dilated capillaries in the skin resulting in a reddish to purplish discoloration. Flashlamp-pumped pulsed dye laser (PDL) is the treatment of choice with wavelengths from 585 to 600 nm KTP laser at the shorter wavelength of 532nm with the advantage of causing less purpura.

Laserresurfacing – It is a facial rejuvenation procedure that uses a laser to improve the skin's appearance or treat minor facial flaws. It can be treated with ablative or non-ablative laser treatments. It can be used to treat Fine wrinkles, Age spots, Uneven skin tone or texture, Sun-damaged skin, Mild to moderate acne scars.

Treatment of pigmented lesions and tattoos-Treatment of tattoos with Q-switched lasers fragments the ink particles and selectively kills pigment-containing cells, with resultant ink particle release.

ii. Laser in Ophthalmology

ophthalmology was perhaps the first subspecialty in medicine to use laser light to treat patients.

<u>laser tissue interaction</u>

Photocoagulation - uses the thermal energy of a laser to seal leaking blood vessels.

laser light -> target tissue -> generate heat -> deneturues proteins (coagulation)

Photodisruption - uses the mechanical energy of a laser to create micro-explosions, expanded plasma formation, acoustic waves, and cavities to cut intraocular structures with minimal thermal damage.

laser light-> optical breakdown->miniature lightening bolt->vapor->quickly collapses->thunder clap-> acoustic shockwaves-> tissue damage

Photoabalation - laser ablation can be used as phototherapeutic keratectomy to remove superficial corneal opacifications in scars and dystrophies and to close the epithelium in non-infectious corneal ulcers

iii. laser eye surgery

PRK-Photo refractive Keretectomy :

with this method of laser eye surgery, the superficial cornea is removed layer by layer, used for treating shortsightedness as well as far sightedness.

lasik-laser assisted in-situ keratomileusis :

with the lasik method, the cornea is cut into with a precision knife or a femtosecond laser, and a very fine flap is lifted. Then, analogous to the prk method, tissue is removed accordingly and the cornea flap is closed again.

Laser in surgery for brain tumors :

Laser surgery aims to direct the laser beams at the cancer and destroy it with heat. because the light beams cannot penetrate bone, the laser can be

used only during surgery. lasers destroy tumor cells by vaporizing them. lasers are chiefly used in the treatment of tumors that have invaded the skull base or are deep within the brain, with hard tumors that cannot be removed by suction, or with tumors that break apart easily.

Uses of laser in dental problems :

laser beam is used to remove benign and malignant tumors in the oral environment. A laser beam is used to treat gum disease and adjust its appearance. Treatment of dental pigmentation due to the effectiveness of the laser in teeth whitening and restore the brightness of the surface. Dental caries can be treated by shedding laser beams on infected areas.

iv. Laser in gynecology :

one of the first lasers they used was the co2 laser, which they found tremendously effective in treating patients with erosion of the cervix.the laser is also found useful for cutting, coagulating, and vaporizing during intra abdominal procedures.

Laser in medicine - potential advantages for both surgeons and patients; reduced blood loss,reduced oedema and pain yielding, more rapid recovery of the patient.

limited fibrosis and stenosis, limited damage of the adjacent tissue (for a few tens of micrometers) ,precision , reduced postoperative pain

No evidence of causing genetic damage or cancer.

C. Cutting and Welding of Metals

Cutting and welding of metals :

Material processing

• Material processing involves cutting,welding,drilling ,surface treatment

•types of laser for material processing

-High power CO_2-laser with continuous waves or pulsed waves.

-Nd YAG laser

• When the material is exposed to laser light, then light energy is converted into heat energy. due, to heating effect, the material is heated then melted and vapourised.

Laser Instrumentation for material processing

• The light output from laser source is incident on a plane mirror. after reflection, the laser light passes through a shutter to control its intensity.

•There is a focusing lens assembly to get a fine beam. further, there are shielding gas jet and powder feeder.

• The shielding gas is used (i) to remove the molten material and help vaporization. (ii) to provide cooling effect.

• For different material, different gases are used.

• The powder feeder is used to spray the metal powder on the substrate for alloying or cladding.

Laser Cladding

• In this process, a laser beam melts a very thin layer of work piece.This thin layer mixes with the liquid cladding alloy and form metallurgical bonding between the cladding and substrate.

•advantages: (i) heat treatment of metals using laser radiation is very fast. (ii) compared to other methods of heating, lasers are able to localize thermal treatment even to spots inaccessible by other methods.

Laser welding : Welding is joining of two or more metal pieces into a single unit.

• For welding of two metal plates, the metal plates are held in contact at their edges and laser beam is allowed to move along the line of contact of the edges

.•the laser beam heats the edges of the two plates to their melting points. metas fuse together where they are in contact.

•advantages : (i) it is a contact-less process and hence, there is no possibility of impurities into joint.(ii) the heat affected zone is relatively small because of the small spot size of laser beam.(iii) laser welding can be done even with very small pieces without any difficulty. (iv) The

welding is done at very high rates. (faster) (v) any dissimilar metals can be welded.

Laser Cutting: The principle of laser cutting is the vaporization of the material at point of focus of the laser beam.

• When laser beam is incident on the material, due to heating effect the material is melted and vaporized at the point of incidence.

•the vaporized material is removed with the help of a gas jet.

•advantages : (i) laser cutting can be done at room temperature and pressure without preheating and vacuum condition.(ii) the microstructure of surrounding layers are not affected since heat affected zone is very narrow.(iii) higher cutting speed van be achieved.

Surface detect detention: One of the important industrial and engineering applications of laser.

• High intensity laser beam is used to study the surface defectsin material such as ics, aircrafts, etc.

• The laser beam reflected from the surface of material under investigation and also directly obtained from the source as a reference are used to produce interference between the two laser beam.

• Information about the material is obtained by forming the interference pattern.

• A high intensity laser beam from the source *s* falls on the converging lens L_1 focuses the laser beam on the object *O*. the optical diffraction pattern of the image is focused on the photographic plate (p) or photodiode (d).

•the photodiode senses the light and converts the light energy into electrical signals, using the signal analyser along with necessary software, the image of the defect is obtained.

•thus surface defects in material can be studied.

D. Surveying and Ranging

Helium-neon and semiconductor lasers have become standard part of the field surveyor's equipment. A fast laser pulse is sent to a corner reflector at the point to be measured and the time of reflection is measured to get the distance.

Some such surveying is long distance. The Apollo 11 and Apollo 14 astronauts put corner reflectors on the surface of the moon for determination of the Earth-Moon distance. A powerful laser pulse from the MacDonald observatory in Texas had spread to about a 3km radius by time it got to the Moon to Texas within about 15cm, a nine significant digit measurement. A pulsed ruby laser was used for this measurement.

i. Apollo 11

On the afternoon of July 20, 1969, Apollo 11 astronauts Neil Armstrong and Edwin "Buzz" Aldrin explored the surface of the Moon for two and a half hours, collecting samples and taking photographs while Michael Collins orbited in the command module Columbia.Scientists from various institutions who analyze the data from the lunar laser ranging experiment have observed, among other things, that the Moon is moving away from the Earth and has a fluid core, and that Einstein's Theory of Relativity is accurate.

The experiment consists of an instrument called the lunar laser ranging reflector, designed to reflect pulses of laser light fired from the Earth. The idea was to determine the round-trip travel time of a laser pulse from the Earth to the Moon and back again, thereby calculating the distance between the two bodies to unprecedented accuracy. The Apollo 11 laser reflector consists of 100 fused silica half cubes, called corner cubes, mounted in a 46-centimeter (18-inch) square aluminum panel. Each corner cube is 3.8 centimeters (1.5 inches) in diameter. Corner cubes reflect a beam of light directly back toward its point of origin; it is this fact that also makes them so useful in Earth surveying

ii. Ruby Laser

The ruby laser is the first type of laser actually constructed, first demonstrated in 1960 by T. H. Maiman. The ruby mineral (corundum) is aluminum oxide with a small amount (about 0.05%) of chromium which gives it its characteristic pink or red color by absorbing green and blue light. The ruby laser is used as a pulsed laser, producing red light at 694.3 nm. After receiving a pumping flash from the flash tube, the laser light emerges for as long as the excited atoms persist in the ruby rod, which is typically about a millisecond. A pulsed ruby laser was used for the famous laser ranging experiment which was conducted with a corner reflector placed on the Moon by the Apollo astronauts. This determined the distance to the Moon with an accuracy of about 15 cm.

iii. LIDAR

Lidar is a method for determining ranges (variable distance) by targeting an object with a laser and measuring the time for the reflected light to return to the receiver. Lidar can also be used to make digital 3-d representations of areas on the earth's surface and ocean bottom, due to differences in laser return times, and by varying laser wavelengths. it has terrestrial, airborne, and mobile applications. *lidar* is an acronym of "light detection and ranging" or "laser imaging, detection, and ranging". lidar sometimes is called 3-d laser scanning, a special combination of a 3-d scanning and laser scanning.

2. 5 LASER SECURITY SYSTEM (Model Work)

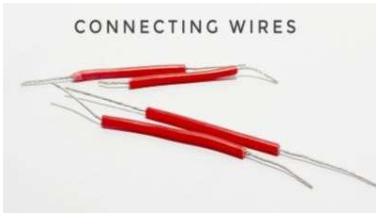
A laser alarm system operates by projecting a beam of invisible laser light across a doorway or window opening. When the light is broken, it activates a buzzer or alarm. A laser security alarm is a system designed to detect intrusion – unauthorized entry – into a building or area. They are also called security alarms, security systems, alarm systems,

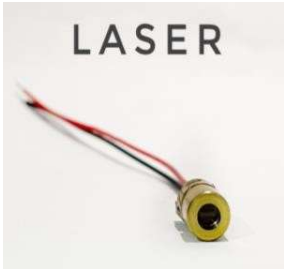
intrusion detection systems, perimeter detection systems, and similar terms. Burglar alarms are used in residential, commercial, industrial, and military properties for protection against burglary (theft) or property damage, as well as personal protection against intruders. Car alarms likewise protect vehicles and their contents. Prisons also use security systems for control of inmates.

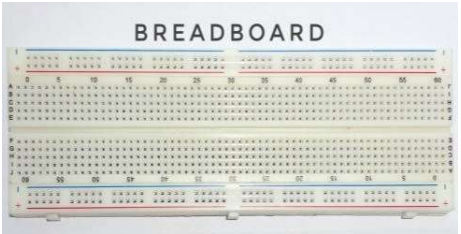
Objective: To make and study the functions of a Laser Security System.

Theory: This system for security uses the combination of LASER light and LDR. The LDR module has an onboard potentiometer to adjust the sensitivity of LDR, so that it only senses laser light falling onto it. In normal conditions, where there is always laser light falling on the LDR, the LDR module always gives a high signal to microcontroller. When someone crosses this laser light, it will behave as an obstruction between the LDR module and laser light, resulting in no light falling on LDR. In such cases LDR module gives a low signal to the microcontroller, which indicates it to switch on an alarm.

Materials required:

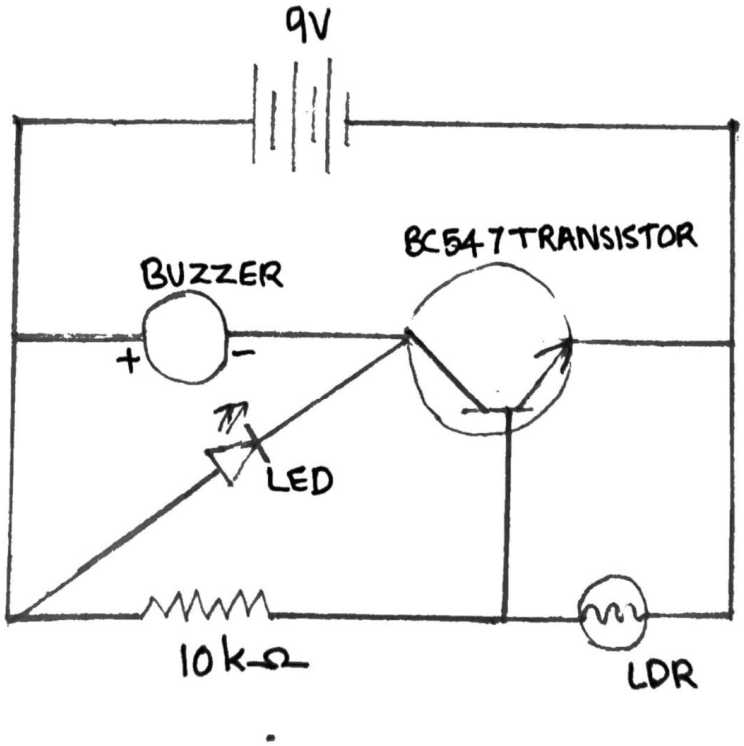






Procedure:

1. Take the breadboard and mark its two extreme sides, any one as positive and other as negative.
2. Use the circuit diagram and make the connections as follows.
3. Punch in the transistor on the breadboard.
4. Connect the emitter of the transistor with negative side of breadboard using a wire.
5. Connect the LDR with base of transistor and negative side of breadboard.
6. Connect the buzzer with collector of transistor and positive side of breadboard.
7. Now connect the 10k ohm resistor with base of transistor and positive side of bread board.
8. Now connect the battery and at this time the buzzer would be ringing.
9. Now drop the laser light upon the receptive surface of the LDR and the buzzer stops ringing.



Circuit diagram of the model

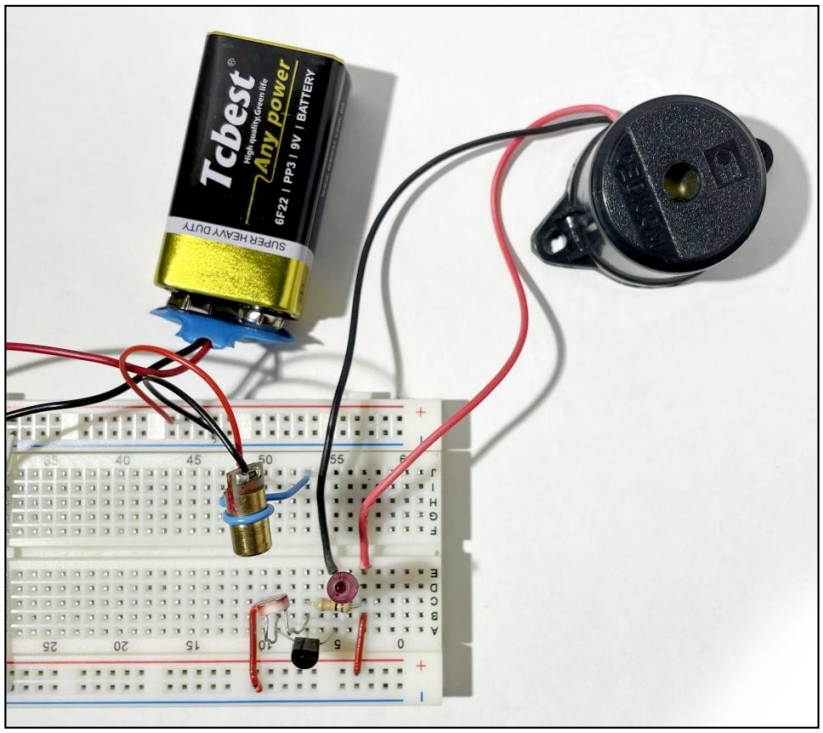


Image of the Circuit

Working:

• This circuit is based on LDR (Light Depended Resistor), variable resistor in which the resistance varies according to the light intensity falling on it.

• LDR and resistor R1 forms a potential driver network which is the main part of the alarm circuit.

• The voltage drop across the LDR is used to drive the transistor switch. When the voltage drop is above cut in voltage (0.6v), the transistor is turn ON.

• LDR has low resistance in the presence of light and high resistance in the absence of light.

Make the laser light point to the LDR.

• In this situation the resistance offered by LDR is too low .Since the LASER light is continuously allowed to fall on the LDR surface.

• Thus the voltage drop across the LDR is also low, which is insufficient to turn ON the transistor, so the transistor remains off state.

• When a person makes a blocks to the continuously flow of LASER beam, the light falling on LDR gets blocked.

• While resistance increases voltage drop also increases when this voltage drop exceeds cut in voltage of NPN transistor, it will turn ON.

• Then current from vice starts flowing to ground via the buzzer and transistor, which makes the beep sound.

• The beep sound from the security alarm gives the indication of some security failures.

3. RESULTS AND DISCUSSIONS

In our project Laser and LDR is the core of the laser security system. The circuit is all about when the laser beam falling over the LDR continuously is interrupted by the object in the field of laser net. Hence the LDR develops an output voltage and the alarm rings showing the sign of any intruders. In this way it can reduce the problem of thefts and intruders in our day-to-day life and it also helps in reducing manual works as this circuit is automatically operating one. The Laser Security System has been successfully designed and developed. The buzzer is turned on as the laser beam falling on the LDR is interrupted. The experimental model was made according to the circuit diagram and the results were as expected. The LDR has to be placed in such a way that is remains uninterrupted by any other light source except the laser beam. This helps the circuit to work faster and properly. This is beneficial for the advanced protection of very small objects. The circuit consumes lots of energy to work and thus implanting this system with AC connection using transformer and rectifier circuit would give better performance. Also using of infrared laser could make the laser net invisible to human eye. Use of microcontroller could give better result for the laser security system.

4. CONCLUSION

The laser is one of the most fantastic and versatile tool invented recently, although its story began with luminescent phenomena, which have been always at the center of curiosity of mankind since ancient times. This project explored various aspects of Lasers. Ranging from its properties to its working principle and then to its applications, all the basic information one needs to know about lasers has been included in this project. It is no secret that Lasers have eased our work. They have simplified processes of cutting and welding of metals and have proven to be a boon to our medical sector. Easing processes of surgeries with minimal invasion and less damage has been an advantage with their introduction. Security systems also have proven to be highly effective in setting a parameter alarm and providing security. Lasers complete jobs to a high standard and have changed the world.

By doing this project we learnt about the various applications of lasers and how it affects our day to day activities. We also saw the making of a simple circuit security alarm system and explored its working. Laser security system provides us the security against any crime, theft in our day-to-day life and so people are installing them in order to stay safe, secure and sound. Various electronic security systems can be used at home and other important working places for security and safety purposes. It is a great opportunity and source of saving man power contributing no wastage of electricity. The "Laser Security System" is an important helping system. Using this system robbery, thefts & crime can be avoided to large extent. Avoiding thefts results in the safety of our financial assets and thereby this system provides us protection against all. The Laser & LDR system is highly sensitive with a great range of working. The system senses the light emitted by the Laser falling over the LDR connected with the circuit. Whenever the beam of light is interrupted by any means, it triggers the alarm or siren. This highly reactive approach has low computational requirement; therefore, it is well suited to surveillance, industrial application and smart environments. Laser security systems have many advantages. They are simple to install and can be used effectively inside or outside a home. The system can be used as a highly effective perimeter alarm for property boundaries or even for pools, where customers can have the lasers set to detect when small children come within a set number often from the edge of the water. Indoors, the sensors utilize normal power outlets and telephone jacks; outdoors, the sensors can be hidden beneath plants and bushes which will not harm lawns or other vegetation. However, laser security systems can be prohibitively expensive. While some security system plans allow for customers to target one room, plans that protect large amounts of land or an entire house will cost much more and can be difficult for many customers to afford. If we talk about the future prospects of lasers, we are sure that they are going to be used extensively as the time which is to come will the technological age. A car might have a few beams of lasers to monitor any upcoming collisions. Or maybe streets have lasers to turn on CCTV by motion sensing. Lasers will be used in making a 3D map of the surrounding world. By projecting a single beam of laser many times and capturing the returned intensity and location of laser, we can map the surroundings, and by using Infrared or visible or UV maps, we can know far more than a 2D image. The application of lasers in the field of assembling and controlling robots will be endless. If we are able to leverage the speed of light in optical computers, and somehow be able to make every part of a computer using optical logic units, then we can have a computer that runs on light. With some intelligent light filters, it can run directly using sun's light that will save millions of cost, and megawatts of energy and will be a greener solution to our computing.

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