DESIGN AND DEVELOPMENT OF LOW COST MINI LASER ENGRAVER MACHINE

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I HEREBY RECOMMENDED THAT THE THESIS PREPARED BY **SAMAYAN MAZUMDER** ENTITLED **"DESIGN AND DEVELOPMENT OF LOW COST MINI LASER ENGRAVER MACHINE"** UNDER MY SUPERVISION BE ACCEPTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF TECHNOLOGY IN LASER SCIENCE & TECHNOLOGY DURING THE ACADEMIC SESSION 2021-2023.

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

The author hereby declared that this thesis contains original research work by the undersigned candidate, as part of this MTECH **in LASER SCIENCE AND TECHNOLOGY** studies during academic session 2021-2023.

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PREFACE

In this report discusses the Laser and the Laser machining processes mainly Laser engraving. This Laser engraving technology has revolutionized the field of personalization and customization by offering precise and versatile engraving capabilities on a wide range of materials. This abstract provides an overview of laser engraving technology and focuses specifically on small laser engraving machines, which have gained popularity due to their compact size, affordability, and accessibility.

Laser engraving is a non-contact process that utilizes the intense energy of a laser beam to remove material from a surface, creating permanent markings or engravings. The laser beam interacts with the material, vaporizing or ablating it to leave behind a precise and detailed engraving. The versatility of laser engraving allows for the customization of various materials, including wood, acrylic, glass, leather, metals, and plastics.

Small laser engraving machines are compact devices that bring laser engraving capabilities within the reach of individuals, small businesses, and hobbyists. These machines typically utilize various types of lasers, each with its own advantages and applications. Diode lasers are suitable for engraving organic materials like wood and leather, while fiber lasers excel at marking metals and plastics.

The benefits of small laser engraving machines include their ease of use, low maintenance requirements, and high precision. With user-friendly software interfaces and intuitive controls, even beginners can quickly learn to operate these machines effectively. Additionally, small laser engraving machines offer high-resolution engraving with intricate details, enabling the creation of personalized gifts, promotional items, signage, and artistic designs.

Furthermore, small laser engraving machines have found applications in various industries, including jewelry making, electronics manufacturing, woodworking, and signage production. Their compact size and portability make them ideal for small-scale production, prototyping, and customization tasks. They also provide opportunities for entrepreneurs and creative individuals to start their own laser engraving businesses with minimal investment.

Here laser engraving technology has transformed the art of personalization, and small laser engraving machines have played a pivotal role in making this technology accessible to a wider audience. The compact size, affordability, and versatility of these machines have empowered individuals and businesses to explore their creativity and fulfill their engraving needs with precision and efficiency. As technology continues to advance, small laser engraving machines are expected to evolve further, opening up new possibilities for customization and innovation.

CHAPTER -1

FUNDAMENTALS OF LASER

1.1. Introduction

LASER, the letters in the word stand for **Light Amplification by Stimulated Emission of Radiation**. A laser is different. Generally Lasers do not occur in nature. However, we have figured ways to artificially create this special type of light. Lasers produce a narrow beam of light in which all of the light waves have very similar wavelengths. The laser's light wave's travel together with their peaks all lined up, or **in same phase**. This is why laser beams are very narrow, very bright, and can be focused into a very tiny spot. So we can say that a laser is an unusual light source. It is quite different from a light bulb or a flash light. A laser produces a very narrow beam of light that is useful in many technologies and instruments. Although like other electromagnetic lights, lasers also have particle and wave properties.

But commonly Laser is known as a device because that emits a beam of coherent light through an optical amplification process. So later in this thesis the laser will be written as a device. So, we can say Laser is a Device which can convert any kind of energy (Optical or Electrical etc) to highly directional light or narrow beam.

Here we created a laser engraver machine that is a type of tool used to engrave or mark various materials using a laser beam. The laser beam is generated by a laser source and directed onto the material using a series of mirrors and lenses, creating a high-precision and high-contrast marking or engraving. Total process is done by CNC automation process. For control the whole process we need various types of sensors, drivers, motor etc.

1.2. HISTORY OF LASER

The laser is an a suggestion given by Albert Einstein in 1916 that under the proper circumstances atoms could release excess energy as light beam or electromagnetic wave ,either spontaneously or when stimulated by light. After that German physicist Rudolf Walther Ladenburg first observed stimulated emission in 1928, although at that time laser have no practical use.

In 1951 Charles H. Townes, then at Columbia University in New York City, thought of a way to generate stimulated emission at microwave frequencies. At the end of 1953, he demonstrated a working device that focused “excited ammonia molecules in a resonant microwave cavity, where they emitted a pure microwave frequency. Townes named the device a maser, for “microwave amplification by the stimulated emission of radiation.” Aleksandr Mikhaylovich Prokhorov and Nikolay Gennadiyevich Basov of the P.N. Lebedev Physical Institute in Moscow independently described the theory of Maser operation. For their work all three shared the 1964 Nobel Prize for Physics.

An intense burst of maser research followed in the mid-1950s, but masers found only a limited range of applications as low-noise microwave amplifiers and atomic clocks. In 1957 Townes proposed to his brother-in-law and former postdoctoral student at Columbia University, Arthur L. Schawlow that they try to extend maser action to the much shorter wavelengths of infrared or visible light at Bell Laboratories. Townes also had discussions with a graduate student at Columbia University, Gordon Gould, who quickly developed his own laser ideas. Townes and Schawlow published their ideas for an “optical maser” in a seminal paper in the December 15, 1958, issue of *Physical Review*. Meanwhile, Gould coined the word *laser* and wrote a patent application. Whether Townes or Gould should be credited as the “inventor” of the laser thus became a matter of intense debate and led to years of litigation. Eventually, Gould received a series of four patents starting in 1977 that earned him millions of dollars in royalties.

The Townes-Schawlow proposal led several groups to try building a laser. The Gould proposal became the basis of a classified military contract. Success came first to Theodore H. Maiman, who took a different approach at Hughes Research Laboratories in Malibu, California. He fired bright pulses from a photographer’s flash lamp to excite chromium atoms in a crystal of synthetic ruby, a material he chose because he had studied carefully how it absorbed and emitted light and calculated that it should work as a laser. On May 16, 1960, he produced red pulses from a ruby rod about the size of a fingertip. In December 1960 Ali Javan, William Bennett, Jr., and Donald Herriott at Bell Labs built the first gas laser, which generated a continuous infrared beam from a mixture of helium and neon. In 1962 Robert N. Hall and coworkers at the General Electric Research and Development Center in Schenectady, New York, made the first semiconductor laser.

While lasers quickly caught the public imagination, perhaps for their similarity to the “heat rays” of science fiction, practical applications took years to develop. A young physicist named Irnee D’Haenens, while working with Maiman on the ruby laser, joked that the device was “a solution looking for a problem,” and the line lingered in the laser community for many years. Townes and Schawlow had expected laser beams to be used in basic research and to send signals through air or space. Gould envisioned more powerful beams capable of cutting and drilling many materials. A key early success came in late 1963 when two researchers at the University of Michigan, Emmett Leith and Juris Upatnieks, used lasers to make the first three-dimensional holograms.

Helium-neon lasers were the first lasers with broad commercial applications. Because they could be adjusted to generate a visible red beam instead of an infrared beam, they found immediate use projecting straight lines for alignment, surveying, construction, and irrigation. Soon eye surgeons were using pulses from ruby lasers to weld detached retinas back in place without cutting into the eye. The first large-scale application for lasers was the laser scanner for automated checkout in supermarkets, which was developed in the mid-1970s and became common a few years later. Compact disc audio players and laser printers for personal computers soon followed.

Lasers have become standard tools in diverse applications. Laser pointers highlight presentation points in lecture halls, and laser target designators guide smart bombs to their targets. Lasers weld razor blades, write patterns on objects on production lines without touching them, remove unwanted hair, and bleach tattoos. Laser rangefinders in space probes profiled the surfaces of Mars and the asteroid Eros in unprecedented detail. In the laboratory, lasers have helped physicists to cool atoms to within a tiny fraction of a degree of absolute zero.

Now a day’s increase in rapid prototyping and 3D printing techniques, it has become mandatory for every industry to have one of the prototyping techniques in its laboratory for better presentation of its idea in realistic form. In laboratories every engineers need to present his thoughts and the various projects that he /she undertakes to take a solid form so that he/she can get into more of its detail and specification. The large laser cutting machines makes it impossible for a student engineer to utilize the machine for any purpose suitable for small hand held projects. In case of 3D printing the cost of producing a model is considerably high as compared to daily use. So to make it possible for every student and any person for easy and low cost usage this small laser cutting and engraving machine can be to great use.

1.3. PROPERTIES OF LASER LIGHT

- The light emitted from a laser is monochromatic in nature, the meaning of it is one color/wavelength. In contrast, ordinary white light is a combination of many colors (or various wavelengths) 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, is emitted in many directions away from the source.
- The light from a laser is said to be coherent, which means that the wavelengths of the laser light are in phase in space and time. Ordinary light can be a mixture of many wavelengths.

1.4. BASICS OF LASER OPERATION THEORY

Laser energy is generated from the energy of photons, which are particles of light. In a laser, a population inversion is created in the active medium, which is usually a gas, liquid, or solid material. This means that there are more atoms or molecules in an excited state than in the ground state. When a photon of the appropriate wavelength interacts with an excited atom or molecule, it triggers stimulated emission, in which the excited atom or molecule releases its excess energy as another photon. The emitted photon has the same wavelength, phase, and direction as the incident photon, creating coherent light. As the emitted photons move back and forth between the mirrors in the laser cavity, they stimulate more atoms or molecules to emit photons, amplifying the light and creating a beam of laser energy. This process is called stimulated emission and is responsible for the high intensity, coherence, and directionality of laser light. The energy of the laser photons is determined by the wavelength of the light, which depends on the specific properties of the active medium and the optical cavity. The energy of a photon is proportional to its frequency, and inversely proportional to its wavelength. Shorter wavelength photons have higher energy, while longer wavelength photons have lower energy. Overall, laser energy is generated from the energy of photons, which are produced by stimulated emission in a population inverted medium, and are amplified and directed by the laser cavity.

1.4.1. SPONTANEOUS EMISSION:

When an isolated atom is excited into a high-energy state, it generally remains in the excited state for a short time before emitting a photon and making a transition to a lower energy state.

1.4.2. STIMULATED EMISSION:

This is the process by which atoms release energy in the form of photons (light) when they are hit by a photon of the same frequency. The released photons (two) are in same phase and move in the same direction, leading to coherent light.

1.4.3. POPULATION INVERSION:

This is the condition in which more atoms are excited to a higher energy level than are in a lower energy level. This is necessary for stimulated emission to occur and for laser amplification.

1.4.4. ABSORPTION:

An atom in a lower level absorbs a photon of frequency hν and moves to an upper level. Spontaneous emission: An atom in an upper level can decay spontaneously to the lower level and emit a photon of frequency hν if the transition between E2 and E1 is radiative. This photon has a random direction and phase.

1.4.5. OPTICAL CAVITY:

This is the physical structure of a laser that contains the active medium (usually a solid, liquid, or gas), mirrors to reflect the light back and forth, and sometimes additional optical elements such as lenses or polarizer's.

1.4.6. PUMPING:

This is the process by which energy is added to the active medium to excite the atoms to a higher energy level, creating a population inversion.

1.4.7. THRESHOLD:

This is the point at which the amplification of the laser light is enough to overcome losses in the optical cavity and produce a sustained output.

1.4.8. ENERGY SYSTEM:

Actually to study laser system need to know quantum mechanics and molecular spectroscopy. For both the cases energy system is an important thing for laser fundamentals. Three-level and four-level laser systems refer to the energy levels of the active medium in the laser. In a three-level laser system, there are three energy levels involved in the laser operation: ground state, excited state, and metastable state. The metastable state is a long-lived excited state that is used for laser operation. The population inversion necessary for laser operation is achieved between the ground state and the metastable state. Three-level laser systems have lower efficiency than four-level systems because the population inversion is more difficult to achieve. In a four-level laser system, there are four energy levels involved in the laser operation: ground state, lower laser level, upper laser level, and metastable state. The population inversion is achieved between the lower laser level and the ground state, while the upper laser level serves as a transition state for stimulated emission. Four-level laser systems have higher efficiency than three-level systems because the population inversion is easier to achieve. One advantage of three-level lasers is that they can operate at lower pump energies and can be more compact than four-level lasers. However, four-level lasers are more efficient and can produce higher output powers. The choice of a three-level or four-level laser system depends on the specific application and the desired output characteristics. Both types of laser systems have their advantages and disadvantages and are used in a variety of applications.

1.5. BASIC COMPONENTS OF LASER

A Laser consists of three main components:

2. A Lasing Medium (Medium to be excited).
3. A Pumping Device.
4. An Output Coupler & Mirror setting.

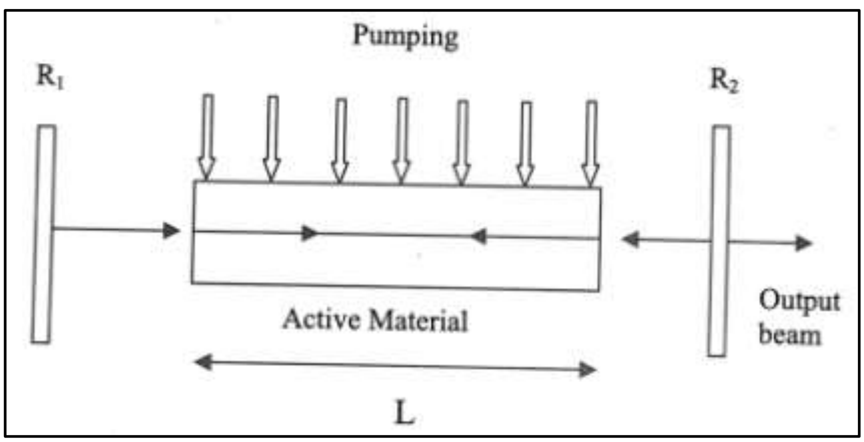


Fig.1.1.Elements of laser

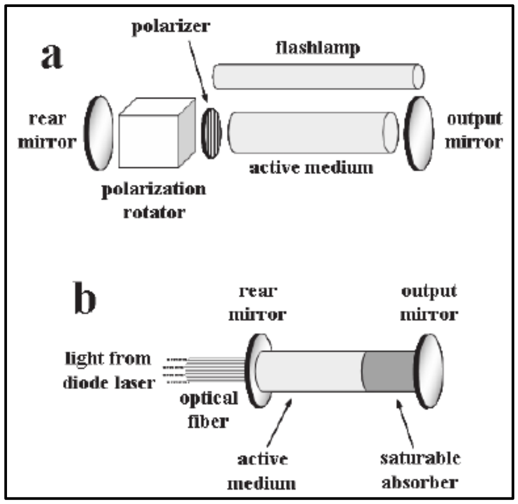


Fig.1.2. Components use in laser

1.6. CLASSIFICATION OF LASERS

Lasers systems can be divided on the basis of

- Density of gain medium
- The state of matter of the active medium: Solid, Liquid ,Gas
- On the basis of output of laser beam, continuous wave (CW) or pulsed
- On the basis of region of wavelength: X-ray, Ultraviolet, Visible or Infrared.
- The number of energy levels which participates in the lasing process: three levels or four levels
- The pumping method of the active medium: Optical pumping, Electrical
    a. Types and operation of Pumping (angle, direct etc)

1.6.1. Density of Gain Medium

The laser systems may be grouped on the basis of density of gain medium: low gain and high gain medium.

Low Gain Medium:

A gas laser comes under this category. Example of low gain medium laser are Neutral atom lasers (for example He-Ne laser, He-Cd laser), Ionic lasers for example Argon ion, Krypton ion lasers, Molecular lasers for example carbon di-oxide laser, nitrogen laser, excimer laser (for example XeF, XeCl etc.), Far infrared lasers, chemical lasers (for example HF laser), X-ray lasers, Free electron lasers, Atom lasers (for example, rubidium atom) etc.

High Gain Medium:

This can be further classified into solid state lasers, semiconductor lasers and liquid lasers

Solid State Lasers

Solid state lasers include lasers based on paramagnetic ions (for example ruby laser, Nd:YAG, Ti:Sapphire, Cr^{3+} in BeAl2O4 etc.), organic dye molecules and colour centres in crystalline or amorphous hosts (for example F_2* centre in LiF).

Liquid Lasers

In this kind of lasers the active medium is in the form liquid. The examples are dye lasers

Semiconductor Lasers

These **lasers** are solid-state lasers based on semiconductor gain media, where optical amplification is usually achieved by stimulated. It is widely used in fiber optic communication .It is used to heal the wounds by infrared radiation.

1.6.2. State of Matter

The lasers may be divided on the basis of state of matter, whether they are solid, liquid or gases

Solid State Lasers

The examples are Ruby laser, Nd:YAG laser, Nd: Glass laser, Ti: sapphire etc.

Gas Lasers

They are further classified as neutral atom lasers (for example He-Ne); ionic excimer gas lasers etc.), chemical lasers (for example HF laser)

Liquid Lasers

In this kind of lasers the active medium is in the form liquid. The examples are dye lasers

1.6.3. Output of laser beam

A laser may be classified as operating in either continuous wave (CW) or pulsed mode, depending on whether the power output is essentially continuous over time or whether its output takes the form of pulses of light. The examples of continuous wave lasers are: He-Ne laser, Nd:YAG laser, Argon ion laser. The examples of pulsed lasers are: Ruby laser, Nitrogen laser, Excimer laser, Copper vapour laser. Some of the lasers can operate both in CW as well as made to operate in pulsed mode.

1.6.4. Region of Wavelength

The lasers can also be classified on the basis of spectral range of wavelength.(a) X-ray region for example $C2^{1+}$ (b) Ultraviolet: examples are Excimer laser, Nitrogen laser (c)Visible Region: for example Ruby, He-Ne, Dye, etc. (d) Infrared region: for example Nd:YAG laser, Carbon di oxide laser etc. The range of wavelength for a laser cannot be accurately fitted to a spectral region as some lasers emit wavelength in visible as well as in the infrared region for example He-Ne laser, some lasers emit radiation in the visible as well as ultraviolet region, for example He-Cd laser. Where the most commonly used wavelength in Raman spectroscopy is 785 nm. We know that spectroscopy is the study of the absorption and emission of light and other radiation by matter. It involves the splitting of light (or more precisely electromagnetic radiation) into its constituent wavelengths (a spectrum), which is done in much the same way as a prism splits light into a rainbow of colors.

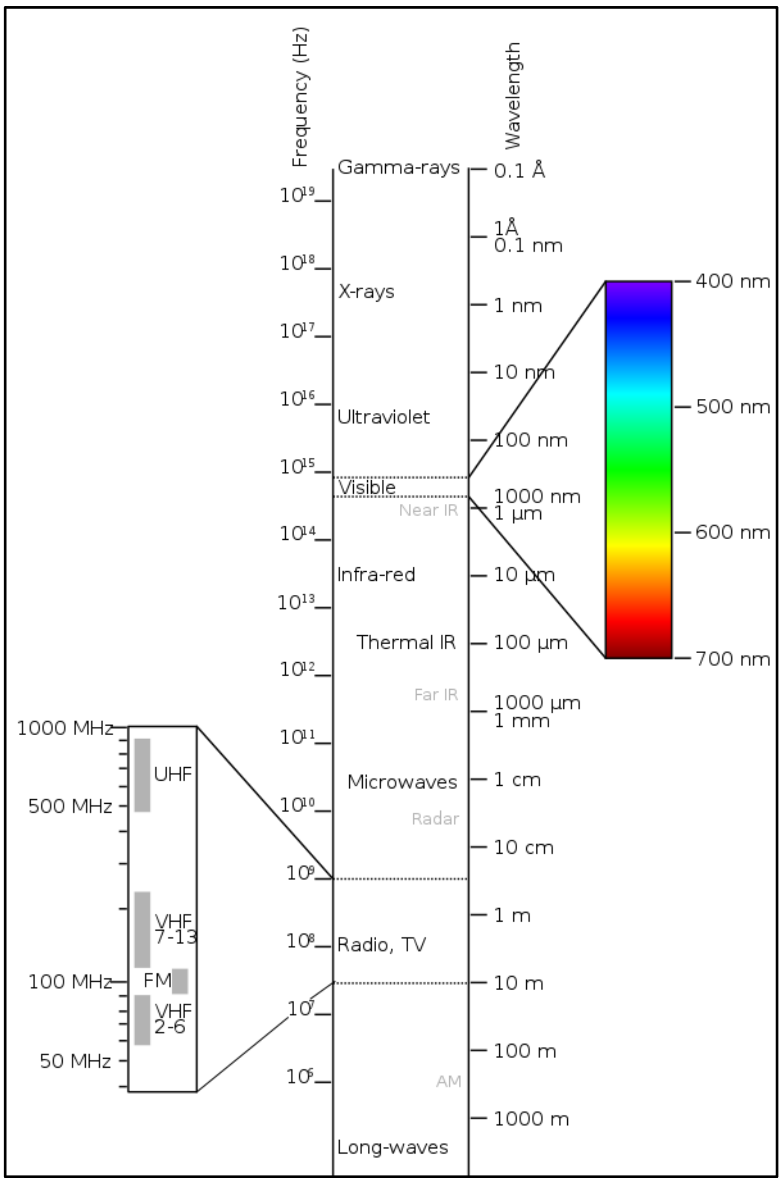


Fig.1.3.Electromagnetic spectrum

1.6.5. The number of energy levels which participates in the lasing process

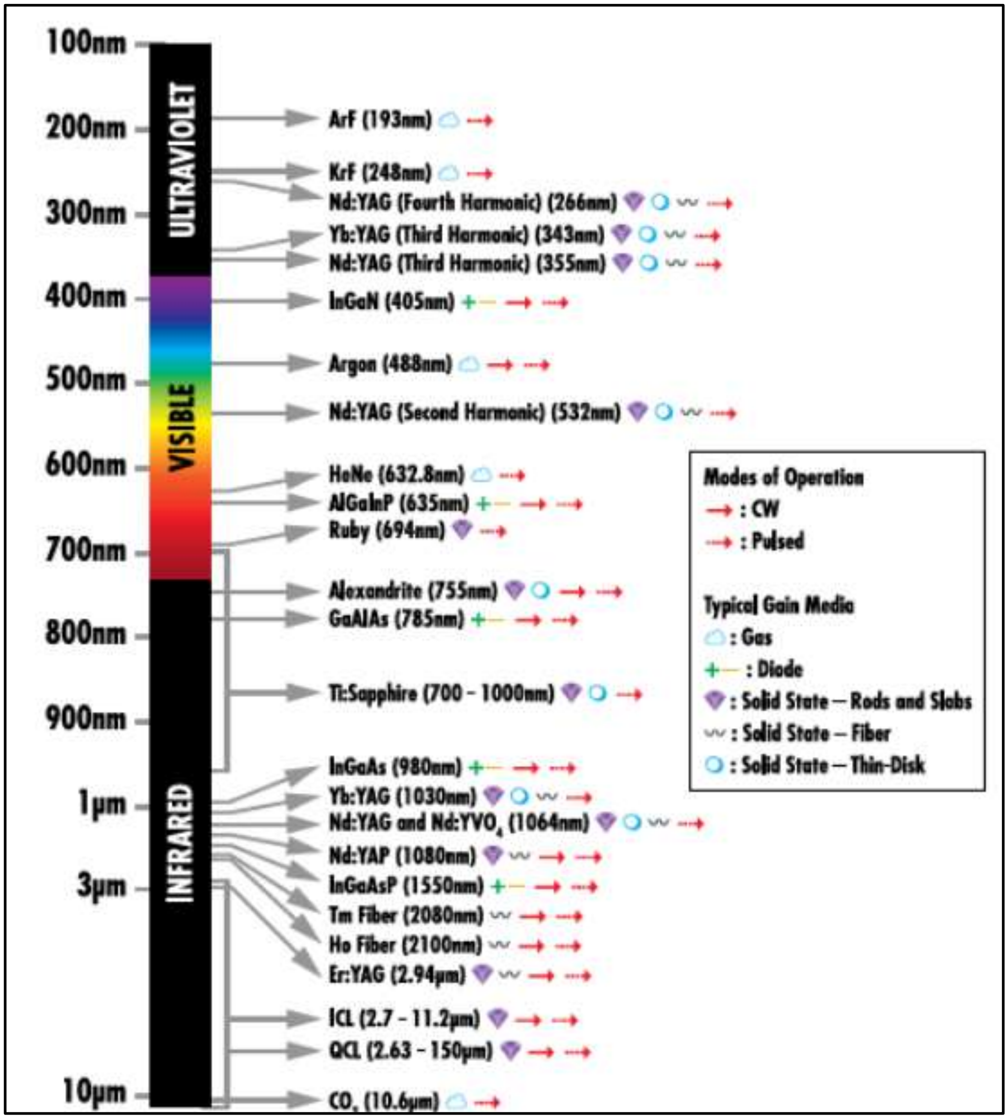


Fig.1.4. Overview of Common Industrial Lasers

The lasers can also be classified depending on the number of energy levels which participates in the lasing process. This can be grouped into two categories, three level lasers and four level lasers. The example of three level lasers are ruby laser, copper vapor lasers etc. while the example of four level lasers are He-Ne, Argon ion laser, Dye laser, Nd: YAG laser, CO_2 laser etc.

1.6.6. The pumping method of the active medium

The lasers can also be classified on the basis of pumping used

Electrical pumping: the examples are He-Ne laser, CO_2 laser, Argon ion laser, Excimer lasers etc

Optical pumping: Ruby Laser, Nd :YAG laser, Dye laser etc.

Chemical pumping: the examples are HF

Also Nuclear pumping, Thermal pumping, Heavy ion pumping, Free electron pumping etc mainly used.

1.7. APPLICATIONS OF LASERS

Lasers have a wide range of applications in various fields. Here are some examples of laser applications:

INDUSTRIAL MANUFACTURING: Lasers are used in cutting and welding materials, **engraving**, marking, etching, sintering and drilling. For example, CO2 lasers are commonly used for cutting metals and plastics, while fiber lasers are used for high cost marking and engraving on metals, plastics, and other materials.

MEDICAL PROCEDURES: Lasers are used in a variety of medical procedures, including eye surgery, skin therapy or dermatology surgery like vascular lesions, hair removal, pigmented lesions, laser ablation, wound healing, acne treatment, tattoo , scars and wrinkles removal, dental procedures, and cancer treatment. For example, laser eye surgery uses a laser to reshape the cornea and correct vision, while laser ablation is a minimally invasive procedure used to remove cancerous or precancerous cells.

SCIENTIFIC RESEARCH: Lasers are used in scientific research for a variety of applications, including spectroscopy, microscopy, and laser cooling. For example, lasers can be used to study the properties of materials at the atomic and molecular level.

TELECOMMUNICATIONS: Lasers are used in fiber-optic communications to transmit data over long distances with minimal loss of signal. Fiber lasers are also used in manufacturing fiber-optic cables.

ENTERTAINMENT: Lasers are used in entertainment for laser light shows, laser pointers, and laser-based visual effects in movies and television. Defense and security: Lasers are used in defense and security applications, including target designation, missile defense, and non-lethal weapons. For example, high-energy lasers can be used to disable drones or other unmanned aerial vehicles.

Overall, lasers have a wide range of applications and continue to be an important technology in various fields.

1.8. DIFFERENT CLASSES OF LASER FOR SAFETY

All above mentioned that laser is very dangers for human being (mainly eye and skin), if not we use the laser in a controlled way. That's why **ANSI Z136. 1-2014**: American National Standard for Safe Use of Lasers sets recommended guidelines for specifies both the environment in which the laser is being used and around the path of the beam. Never allow a laser beam to escape from its designated area of use. Remove all unnecessary reflective objects or white objects from the area near the beam path. This may include watches, jewelry, or tools. Position the laser so that it is well above or below eye level (both standing and sitting). In many jurisdictions, organizations that operate lasers are required to appoint a laser safety officer (LSO). The LSO is responsible for ensuring that safety regulations are followed by all other workers in the organization.

The tables are given on the next page.

Table-1 CLASSES OF LASER FOR SAFETY

CLASS	POWER	HAZARD
CLASS-1	Few microwatts	Non-hazardous.
CLASS-1M	Greater than class-1	Safe as long as additional optical instruments are not used.
CLASS-2	Upto 1mW	Safe for accidental exposure < 0.25s. The natural reflex blink will prevent this from damaging the eye.
CLASS-2M	1-1.5mW	Safe for accidental exposure < 0.25s as long as optical instruments are not used.
CLASS-3R/3A	1-5mW	Momentarily hazardous
CLASS-3B	5-500mW	Hazardous. Viewing of diffuse reflection is safe.
CLASS-4	≥500mW	Hazardous, Viewing of diffuse reflection is also hazardous .Fire risk

It is important to note that the laser safety classification system is not the only factor that determines the safety of a laser. Other factors, such as the beam divergence, beam profile, and exposure duration, also play a role in determining the potential hazard level associated with a laser. It is essential to always follow appropriate safety procedures and guidelines when using any type of laser to avoid any potential harm to yourself or others.

CHAPTER-2

2.1. LITERATURE REVIEW-

Micro laser engraver machines are a type of laser engraving equipment that allows for precision engraving on small objects. These machines use a laser beam to etch designs onto surfaces, which can include metal, plastic, glass, and wood. In this literature review, we will examine several studies and articles that have been published on micro laser engraver machines.

"Design and fabrication of a mini micro laser engraving machine for metallic molds" (M.S. Ravi et al., 2019)

This study focuses on the design and fabrication of a small laser engraving machine for metallic molds. The machine was designed to have high precision and accuracy, with a resolution of 0.001 mm. The researchers used a 50 W CO_2 laser for the engraving, and they were able to successfully engrave fine patterns on metallic surfaces.

"Laser engraving for biomedical applications" (K. Breault et al., 2017)

This article discusses the use of laser engraving for biomedical applications, such as creating mini-fluidic devices and microstructures on medical implants. The authors describe the advantages of using laser engraving for these applications, including the ability to create precise and complex structures.

"Laser engraving of plastics: a review" (G. Balasubramanian et al., 2018)

This review article examines the use of laser engraving for plastics, including the types of lasers and plastics that are commonly used. The authors discuss the advantages of laser engraving for plastics, such as the ability to produce high-quality and detailed engravings, as well as the challenges associated with the process.

"Laser engraving of wood: a review" (Y. Zhang et al., 2019)

This review article focuses on the use of laser engraving for wood, including the types of lasers and wood that are commonly used. The authors discuss the advantages of laser engraving for wood, such as the ability to produce intricate and precise engravings, as well as the challenges associated with the process.

A study by Chen et al. (2020) evaluated the performance of a laser engraver machine in terms of engraving depth and resolution. They found that the machine produced high-quality engravings with a resolution of up to 10 microns and an engraving depth of up to 30 microns.

In another study by Huang et al. (2018), the authors investigated the effects of laser parameters such as power, speed, and frequency on the quality of engravings produced by a laser engraving machine. They found that optimizing these parameters can improve the precision and quality of the engravings.

A review by Lee et al. (2019) discussed the use of laser engraving machines in the jewelry industry. They highlighted the advantages of using these machines for personalized jewelry engraving and customization, as well as for branding purposes.

In a study by Jiang et al. (2020), the authors developed a laser engraver machine that uses a low-power laser diode for engraving. They found that the machine was able to produce high-quality engravings on various surfaces, including metal and glass.

Another study by Chen et al. (2019) focused on the use of a laser engraver machine for fabricating micro fluidic devices. They found that the machine was able to produce precise patterns on the surface of the devices, which can be used for various applications in the biomedical and production field.

Angshuman Roy *et al* have used response surface methodology to design, experiment and optimise the input parameters, laser power, scanning speed and pulse frequency of laser beam with marking width and marking depth as output parameters of a marking of stainless steel process with an Nd:YAG laser.

Lyubomir Lazov *et al.* have discussed and systemised different methods of laser marking in this thesis. In today's world of advanced technologies, DPM (Direct Marking of Products) is used in various mechanical engineering applications like automobile and aerospace industries, for identification of the final industrial product. A graphical comparison of electrochemical etching, dot peening, continuous ink jet and laser marking shows that, laser engraving meets requirements for speed, quantity, quality, as well as price.

Alexander Stepanov *et al* have experimented with concept paper material like wood fibre-based paper materials like, dried pulp, copy paper, paperboard, cardboard, corrugated board. A study of interaction of laser with various paper materials, paper chemicals, fillers and mineral coatings are shown in this paper. Laser cutting of materials are done by CO_2 lasers having 10.6µm wavelength which are well absorbed by the main constituents of wood fibre which are cellulose.

M. Pazner *et al*. did laser ablation experiments by excimer laser, Nd:YAG laser & CO_2 lasers are carried out on wood surfaces. It was found that thermal effects like melting and carbonisation of cellulose were found for IR- & UV-laser wavelengths. Although damage was weaker for excimer laser because of the high absorption of wood in ultraviolet, middle infra-red spectral ranges.

Halah A. Jasim in this paper laser paint removal was studied with ns-pulsed fiber laser on the combination of 20μm thick, white polymeric paint and alloy substrate. Emission spectroscopy was used to monitor the process. Spectral characteristics were linked to layer change as well as machining depth.

Longjun Gu *et al.* in this paper has proposed a low-cost micro-fabrication method on six types of thermoplastic substrates , of reducing the feature size and minimising the bulges formed by CO_2 laser engraving by using the method of sacrificial layer assisted laser engraving . Micro-channel width as small as~ 40μm was achieved and inherent bulging issue has been solved.

L. D. Laude in this paper have addressed the physics of the polymer structure ablation with a pulsed excimer laser. The ablation takes place at and above a given value of pulsed energy density (fluence, J/cm2), the ablation threshold ε0. Above threshold ablation appears to increase at a constant rate X(J/cm3) and tend to saturate at further increased fluence setting ablation per pulse z0, and the relationship between these variables are shown.

Subhashish Nath *et al* [18] have laser incised commercial wood species with 10.6μm wavelength CO2 laser. Laser focal length focal point positioning and laser pulse duration of CO2 laser have been analyzed.

Mohammad Hosein Rahimia *et al*. [1] in this work have dealt with the study of laser engraving process of Al-SiC composite by Q-switched Nd:YAG laser. A central composite design method was used to design experiments based on the response surface methodology (RSM). A feed forward back-propagation neural network (FF-BPNN) was used and accuracy of BPNN method was compared with mathematical models based on RSM mode.

Overall, the literature review suggests that although a good number of research studies have been made in the field of laser engraving but most of the work has been done on optimization techniques (RSM or TAGUCHI method). Also most of the work has been done on expensive laser engraving machine but only a few number of research studies have been reported on low cost mini laser engraving machine. Most of the machines are very high cost not below two lacs. Very very less number of research studies has properly been made on development of low cost laser engraving machine setup. In fact there is almost no low cost laser engraving machine available in Indian market.

2.2. OBJECTIVE

As already pointed out that in spite of potential applications, till date cheap, mini desktop laser engraving machines are not readily available in the Indian market. There is a need for developing such small desktop laser engraving machine that can be used for small scale industry, laboratory classes and other similar applications. In view of the above the prime objective of the present research study is to design and develop a low cost mini CNC laser engraving machine.

2.3. SCOPE

In order to design and develop the mini low cost laser engraving machine the following research activities will be carried out.

- To study various laser engraving techniques in order to explore the various options of low cost hardware for developing mini low cost laser engraving machine.
- To design and develop the support structure with a suitable frame.

- To integrate low-cost X and Y axis slide systems along with motor with the main support frame.
- To connect a microcontroller and driver with the motors of the mini two axis drive systems.
- To install the laser source in the X axis drive system and job piece with the Y axis.
- To flash and configure the microcontroller with an appropriate firmware in order to enable the G code control of the X and Y axis movement.
- To develop a power control module for the laser source in order to engrave various kinds of materials.
- To use appropriate software for converting the image file into a G-Code file suitable for mini laser engraving machine.
- To study the actual performance proposed mini machine for engraving of different materials.

CHAPTER-3

LASER ENGRAVING

In the field of Advance manufacturing industries laser play major role the operation like cutting, forming, ablation, additive manufacturing or material treatment. Laser engraving is also a manufacturing process where we use a laser beam to mark, etch or engrave a design onto a material's surface. It is a precise and efficient method of creating permanent marks on a wide range of materials, including wood, glass, metal, plastic, ceramics and more. During the process of laser engraving, the laser beam impinges on the material, exposing it to a great deal of heat. Depending on the exposure time, the color changes and creates a contrast, or the material evaporates or burns. The resulting laser engraving is permanent and very resistant to abrasion. The laser beam vaporizes or melts the material's surface, creating a cavity or depression in the shape of the design. The laser beam acts as a chisel, incising marks by removing layers from the surface of the material. The laser hits localized areas with massive levels of energy to generate the high heat required for vaporization. Laser engraving is a popular choice for creating personalized gifts, promotional items, and industrial parts. It is often used in industries such as signage, jewelry, and medical devices.

Laser engraving machines come in various sizes, from small desktop models to large industrial-grade machines. The process of laser engraving is computer-controlled, making it highly accurate and repeatable. The design is created using software that converts digital images into vector graphics, which are then sent to the laser machine for engraving. Laser engraving offers several advantages over traditional engraving methods, such as the ability to engrave highly detailed designs and the ability to engrave on a variety of materials. It is also a non-contact process, which means there is no physical contact between the laser and the material being engraved, resulting in less wear and tear on the machine.

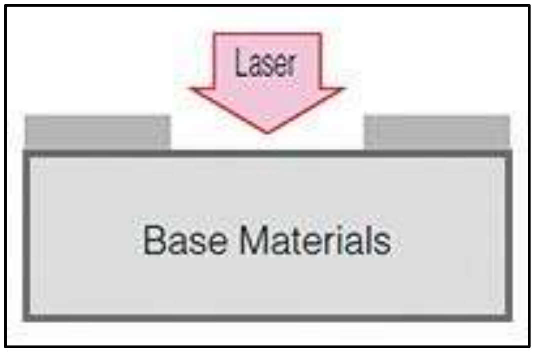


Fig.3.1.Laser operation

So we can say that, laser engraving is a versatile and effective method of creating high-quality, permanent marks on a wide range of materials.

3.1. FUNDAMENTAL ASPECTS OF LASER ENGRAVING:

Laser engraving machines: A laser engraving machine consists of a laser, a controller, and a surface to engrave. The laser emits a high-powered beam of light that is focused by a lens onto the material's surface, causing it to heat up and vaporize, leaving behind a permanent mark.

Materials: Laser engraving works on a variety of materials, including wood, plastic, leather, metal, glass, and more. The type of material used will affect the depth and quality of the engraving.

Design: The design is created in a computer-aided design (CAD) software and converted into a format that the laser engraving machine can read. The machine's controller then directs the laser to engrave the design onto the material.

Engraving settings: The laser engraving machine's settings, such as the laser power, speed, and depth, are adjusted based on the material being engraved and the desired outcome.

3.2. PROPERTIES

Laser engraving offers several properties that make it a popular choice for creating permanent marks on materials. Some of these properties include:

Precision: Laser engraving is a highly precise process, allowing for intricate and detailed designs to be engraved with accuracy and consistency. The laser beam can be controlled to produce marks as small as a few microns.

Versatility: Laser engraving can be used on a wide variety of materials, including metals, plastics, wood, glass, and more. The laser can be adjusted to engrave different materials, making it a versatile method for a variety of applications.

Durability: Laser engraving creates permanent marks that are resistant to wear and tear, making it a popular choice for industrial applications and products that require long-lasting identification marks.

Speed: Laser engraving can produce marks quickly and efficiently, making it a cost-effective option for high-volume production runs.

Non-contact: Laser engraving is a non-contact process, meaning that there is no physical contact between the material and the laser beam. This reduces the risk of damage to the material and the machine, and also minimizes the need for maintenance.

Customization: Laser engraving allows for customization and personalization of products, making it a popular choice for creating unique and personalized gifts and promotional items.

3.3. HISTORY OF LASER ENGRAVING

In the production engineering or the manufacturing industries this are the very important techniques .The history of laser engraving can be traced back to the invention of the laser in the early 1960s. The first laser was created by Theodore Maiman in 1960, and it was initially used for scientific and military purposes. However, as laser technology improved, it became possible to use lasers for industrial applications, including laser engraving. The first laser engraving machine was developed in the late 1960s by the Western Electric Engineering Research Center. This machine was used to engrave text and images on metal surfaces for industrial applications. However, the machine was large and expensive, and it was not until the 1980s that laser engraving became more widely available.

In the 1980s, laser engraving machines became smaller and more affordable, and they were used for a variety of applications, including engraving on plastics, wood, and other materials. These machines used CO_2 lasers, which produced a high-intensity beam of light that could be focused to create precise engravings.

As laser technology continued to improve, new types of lasers were developed that were better suited for engraving on specific materials. For example, Nd:YAG lasers were developed for engraving on metals, while fiber lasers were developed for engraving on plastics and other materials.

Today, laser engraving is used in a wide variety of industries, including automotive, aerospace, electronics, and jewelry making. It is a versatile and precise technology that allows for detailed engravings on a wide range of materials, making it an essential tool for many businesses and industries.

3.4. DIFFERENCE BETWEEN LASER MARKING, LASER ENGRAVING, AND LASER ETCHING

Laser marking, engraving, and etching are almost same but they have some difference, all processes that use laser technology to create permanent marks or designs on a variety of materials. However, there are some differences between the three mentioned methods:

Laser marking: This process uses a laser beam to create high-contrast marks on the surface of a material. The laser interacts with the surface of the material, causing a chemical or physical change that creates a visible mark. Laser marking is often used for part identification, barcoding, and branding.

Laser engraving: This process uses a laser beam to remove material from the surface of a material, creating a permanent mark or design. The laser removes material to a precise depth, creating a visible contrast between the engraved area and the surrounding surface. Laser engraving is often used for creating designs, text, or images on a variety of materials.

Laser etching: This process uses a laser beam to melt the surface of a material, creating a permanent mark or design. The laser melts the material to a precise depth, creating a visible contrast between the etched area and the surrounding surface. Laser etching is often used for creating high-quality images or designs on metal, plastic, and glass surfaces.

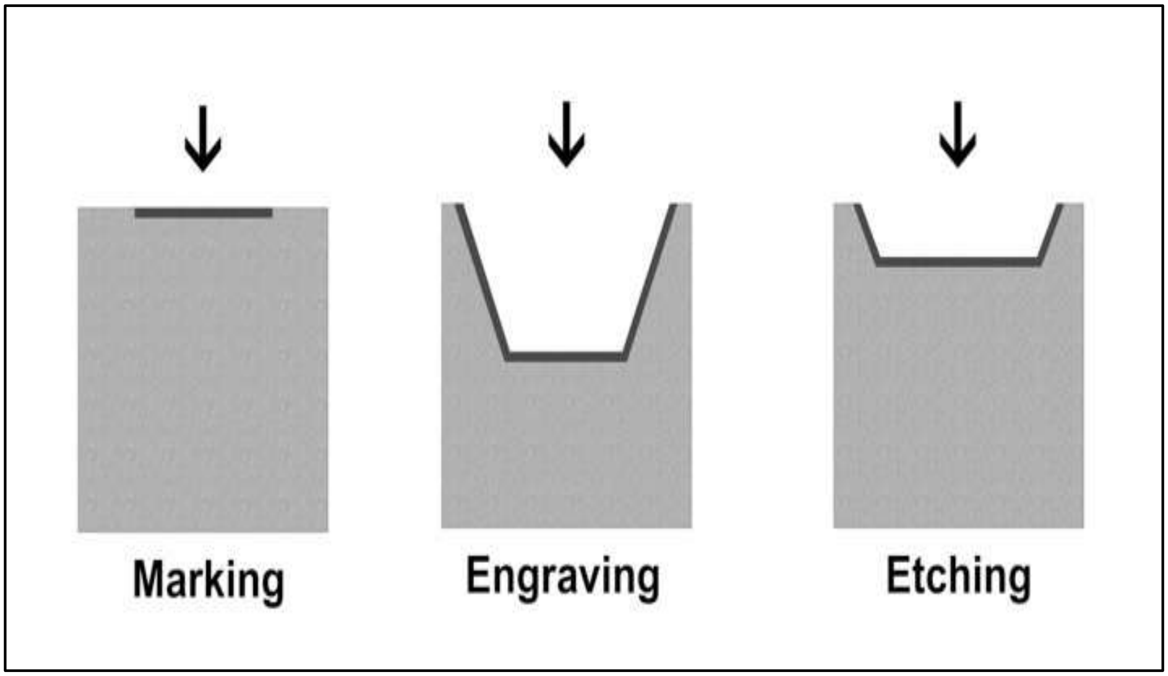


Fig.3.2.Laser marking, engraving& etching

Table-2 Difference between laser marking, engraving& etching

Parameter	Laser Marking	Laser Engraving	Laser Etching
Working Depth	Surface Phenomenon	0.001"-0.125"	0.001"
Material Removal	No	Yes	Yes/No
Laser Power	Low-power	High Power	Moderate Power
Speed	High	Low	Low
Abrasion resistance	Low	High	Low

Applications	Serial number, Barcodes, Bath number, etc.	Wood carving, leather items, ceramics etc.	Name plaques on trophies and awards, etc.

So, we can say laser marking creates high-contrast marks, laser engraving removes material to create a design, and laser etching melts the surface to create a design. The choice between these methods depends on the desired outcome, the material being marked, and the intended use of the marked item.

3.5. TYPES OF LASER ENGRAVING

There are generally two main types of laser engraving processes:

- Vector engraving: This type of engraving uses a vector file to guide the laser beam, which cuts into the material to create precise, clean lines. Vector engraving is commonly used for creating text, logos, and other designs that require crisp edges and fine details. It is often used for engraving on materials such as wood, acrylic, and metal.
- Raster engraving: This type of engraving uses a bitmap image to guide the laser beam, which vaporizes the material in a controlled manner to create a series of dots that form the desired design. Raster engraving is often used for creating images, photographs, and other designs that require shading and gradients. It is commonly used for engraving on materials such as glass, stone, and ceramic.

In addition to these two main types of engraving, there are also hybrid techniques that combine elements of both vector and raster engraving. These techniques can be used to create more complex designs with a combination of fine details and shading.

3.6. APPLICATION

Laser engraving is a versatile technology that can be used in a wide range of applications. Here are some common applications of laser engraving**,** including personalizing items such as jewelry, creating signage, engraving awards and trophies, and creating intricate designs on products:

Industrial marking and branding: Laser engraving is widely used in industrial settings to mark products with logos, serial numbers, and other identifying information.

Personalized gifts and trophies: Laser engraving can be used to create customized gifts and trophies, such as engraved jewelry, plaques, and crystal awards.

Signage and labels: Laser engraving can be used to create high-quality signage and labels for businesses, schools, and public spaces.

Art and design: Laser engraving is a popular technique used by artists and designers to create intricate designs and patterns on a variety of materials.

Electronics and components: Laser engraving can be used to mark electronic components and circuit boards, ensuring that they can be easily identified and tracked.

Medical devices and implants: Laser engraving can be used to mark medical devices and implants with important information, such as lot numbers, serial numbers, and manufacturing dates.

Packaging and branding: Laser engraving can be used to create intricate designs and logos on product packaging, helping to distinguish products from competitors.

3.7. ADVANTAGES

Laser engraving is a popular technology used for creating precise and intricate designs on various materials. Some of the advantages of laser engraving include:

Precision: Laser engraving is a highly precise technology that can create intricate and detailed designs on various materials with high accuracy and consistency.

Versatility: Laser engraving can be used on a wide range of materials, including wood, metal, plastic, leather, and more.

Speed: Laser engraving is a fast process that can create designs quickly and efficiently, making it ideal for large-scale production runs.

Customization: Laser engraving allows for customization of designs, making it possible to create personalized products with unique designs or logos.

Durability: Laser engraving creates permanent designs that are highly resistant to wear and tear, making it ideal for applications that require longevity.

Non-contact Process: Laser engraving is a non-contact process that does not require any physical contact with the material being engraved. This makes it less likely to damage the material or affect its structural integrity.

Environmentally Friendly: Laser engraving is an environmentally friendly technology that does not generate any harmful waste or by-products.

3.8. LIMITATIONS

Although, but Laser engraving is a versatile technology used to create precise and intricate designs on various materials. However, there are some limitations to the laser engraving process:

Material Limitations: Laser engraving works best on certain types of materials, such as wood, acrylic, leather, and some types of metal. Some materials, such as glass or stone, are more difficult to engrave and require specialized techniques. White surfaces are not engraved by the laser until or unless apply oxide layer on it.

Depth Limitations: Laser engraving is limited in the depth that it can achieve. While it can create shallow engravings, it is not suitable for creating deep engravings or 3D designs.

Size Limitations: The size of the material that can be engraved is limited by the size of the laser machine. Large materials may not fit inside the machine, and even if they do, they may require multiple passes to achieve the desired result.

Color Limitations: Laser engraving can only create designs in a single color, depending on the material being engraved. It cannot create multi-colored designs or gradients.

Cost Limitations: Laser engraving machines can be expensive, making it less accessible for small businesses or individuals.

Safety Limitations: Laser engraving involves the use of high-powered lasers that can be dangerous if not used properly. Laser engraving can produce hazardous fumes and smoke. Proper ventilation and safety equipment are required to prevent harm to the operator and the environment.

CHAPTER-4

CHEAPEST LASER ENGRAVEING MACHINE DESIGN & DEVELOPMENT

A laser engraver machine is a type of tool used to engrave or mark various materials using a laser beam. The laser beam is generated by a laser source and directed onto the material using a series of mirrors and lenses, creating a high-precision and high-contrast marking or engraving. Total process is done by CNC automation process. For control the whole process we need various types of sensors, drivers, motor etc.

Laser engraving machines have become increasingly popular due to their ability to produce high-quality and precise engravings on a variety of materials, including metal, wood, plastic, and glass. They are commonly used in the manufacturing of electronic components, such as circuit boards and microchips, as well as in the production of custom signage, personalized gifts, and jewelry.

The technology behind laser engraving machines is based on the principles of optics and photonics, which involves the manipulation of light for various applications. The laser beam is produced by exciting atoms within a laser source, which emits light of a specific wavelength and intensity. The beam is then directed onto the material using a series of mirrors and lenses, which focus the beam onto a small spot, creating a precise and detailed engraving.

Laser engraving machines are capable of producing a wide range of engravings, including text, images, logos, and barcodes. They are highly versatile, and the engraving can be adjusted in terms of depth, width, and intensity. They are also highly efficient, with the ability to produce multiple engravings simultaneously.

Here a micro laser engraver machine is a tool used to engrave or mark very small details on various materials using a laser beam. This technology has been widely used in industries such as electronics, medical devices, and jewelry making. In this thesis, we will explore the various aspects of micro laser engraving machines and their applications.

Firstly, we will examine the design and components of a micro laser engraver machine. This will include an overview of the laser source, optics, and control system. We will also discuss the different types of lasers used in micro engraving, including fiber, CO2, and diode lasers. Additionally, we will cover the various types of optics, such as mirrors and lenses, and their functions in the engraving process.

Next, we will explore the materials that can be engraved using a micro laser engraver machine. This will include metals, plastics, ceramics, and even biological materials. We will discuss the properties of these materials that make them suitable for laser engraving, such as their ability to absorb or reflect the laser beam. Furthermore, we will analyze the different applications of micro laser engraving machines. This will include their use in the manufacturing of electronic components, such as microchips and printed circuit boards, as well as the engraving of jewelry and medical devices. We will also discuss the use of micro laser engraving in the production of high-security features such as anti-counterfeiting measures and product identification.

Finally, we will examine the advantages and disadvantages of micro laser engraving machines. This will include their high precision and accuracy, as well as their speed and versatility. However, we will also address the potential health risks associated with laser exposure and the need for appropriate safety measures.

4.1. MAIN PARTS OF LASER ENGRAVER MACHINE

A laser engraving machine consists of three main parts: a laser, a controller, and a surface. The laser is a drawing tool: the beam emitted from it allows the controller to trace patterns onto the surface.

4.2. PARTS AND MATERIALS REQUIRED FOR THIS MACHINE

- Wooden Base and Metal stands with rubber stand (For folding design)
- Arduino Uno Micro controller (with USB cable)

Fig.4.1.Arduino Uno

- CNC V3 shield driver

Fig.4.2.CNC V3 Shield

- **POTENTIOMETER (10 K Ohm)**

- 2x DVD drive stepper mechanism (SM15DD STEPPER MOTOR)
  (The motor used in CD machine)

Fig.4.3SM15DD Stepper motor

- 2x A4988 stepper motor driver modules (or GRBL shield)

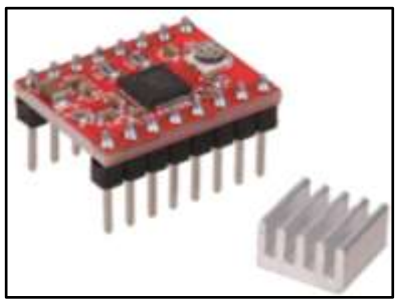


Fig.4.4. Stepper motor driver

- 500mW and 2500mW Laser with adjustable lens (or above)

Fig.4.5.(a) 500 mW laser module

Fig.4.5.(b) 2500 mW laser module adjustable lens

- 12v 2Amps power supply minimum

Fig.4.6. Dc power supply

- N-CHANNEL MOSFET (IRFZ44N / IRF520N MOSFET DRIVER)

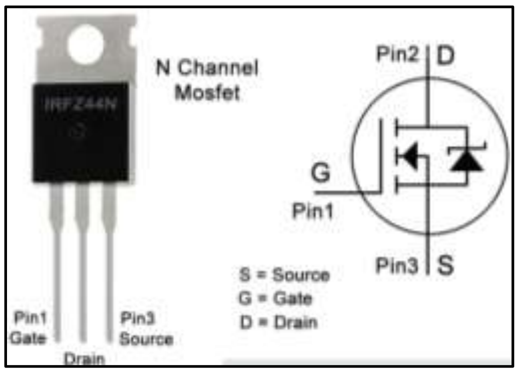


Fig.4.7. Mosfet

- 1x 10k resistor and 1x 47ohm resistor

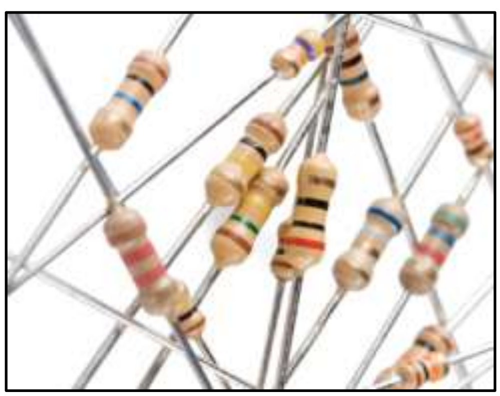


Fig.4.8. various resistor

- Male and Female connector
- 2.5mm JST XH-Style

- 2pin male connector
- Micro jumper short circuit connector (For micro stepping)

Fig.4.9. Micro jumper

- 1x 1000uf 16v capacitor Jumper cables

Fig.4.10.Jumper cable

- 1x 2pin plug in screw terminal block connector
- Zip ties (100mm)
- Super Glue
- 6x M3x12 screws
- 8x M2x5 screws
- Laser Safety Glasses (Green glass goggles)

Fig.4.11.Green goggles

Table-3 PRICE OF BASIC COMPONENTS

SL. NO.	COMPONENT NAME	PRICE (/piece)	NO.OF COMP -ONENT	TOTAL (with GST)
1.	ARDUINO UNO	349.00	1	349.00
2.	CNC v3 SHIELD	130.00	1	130.00
3.	A4988 MOTOR DRIVER	85.00	2	170.00
4.	JUMPER WIRE	6.00	10	60.00
5.	MINI JUMPER	1.50	6	9.00
6.	SM15DD STEPER MOTOR & BED (FROM SCRAP CPU)	0.00	2	0.00
7.	WOOD (23×18 cm) SCRAP	0.00	1	0.00
8.	METAL STAND (SCRAP BROKEN TABLE)	0.00	2	0.00
9.	MOSFET DRIVER	37.00	1	37.00
10.	POWER SUPPLY (SCRAP SMPS)	0.00	1	0.00
11.	LASER SOURCE (500mW)	287.00	1	287.00
12.	LASER-SOURCE (2500mW)	6500.00	1	6500.00
13.	MALE-FEMALE CONNECTOR	25.00	2	50.00
14.	GREEN GOGGLES (SAFETY PURPOSE)	838.00	2	1676.00
	TOTAL			9268.00

4.3. METHODOLOGY-

The methodology used to create this a mini laser engraver machine for the specific machine model. However, here are some common steps that may be involved in the manufacturing process:

4.3.1. **DESIGN AND PLANNING OF FRAME:** The first step to creating a mini laser engraver machine is to design and plan the machine's frame, specifications and components. This includes determining the size of the machine, the type of laser to be used, the control system, and other key components. All design has drawn in Freecad software.

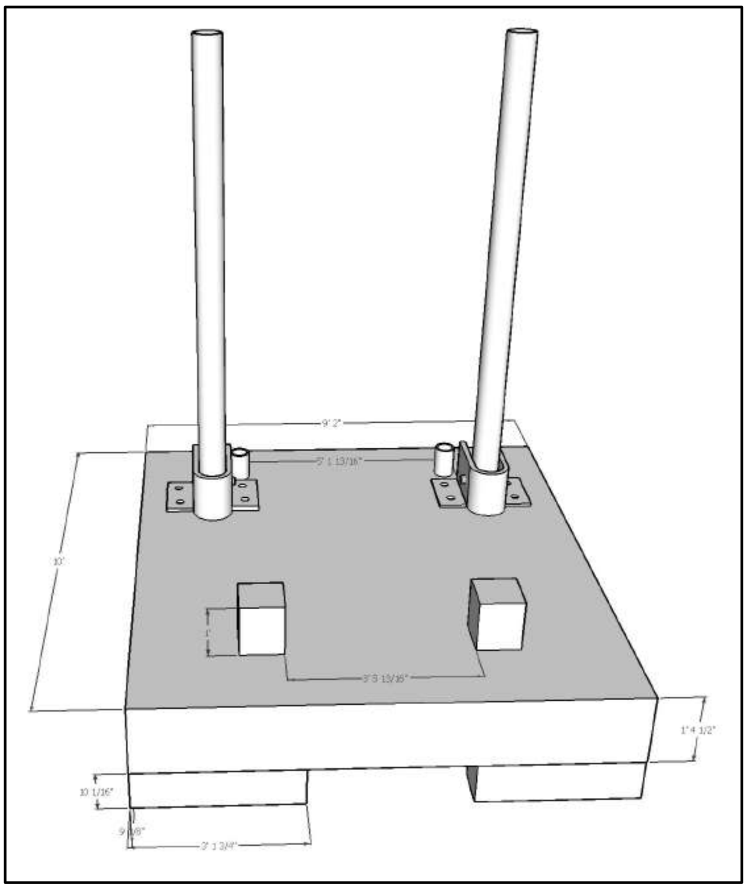


Fig.4.12.(a)Front view of CAD design

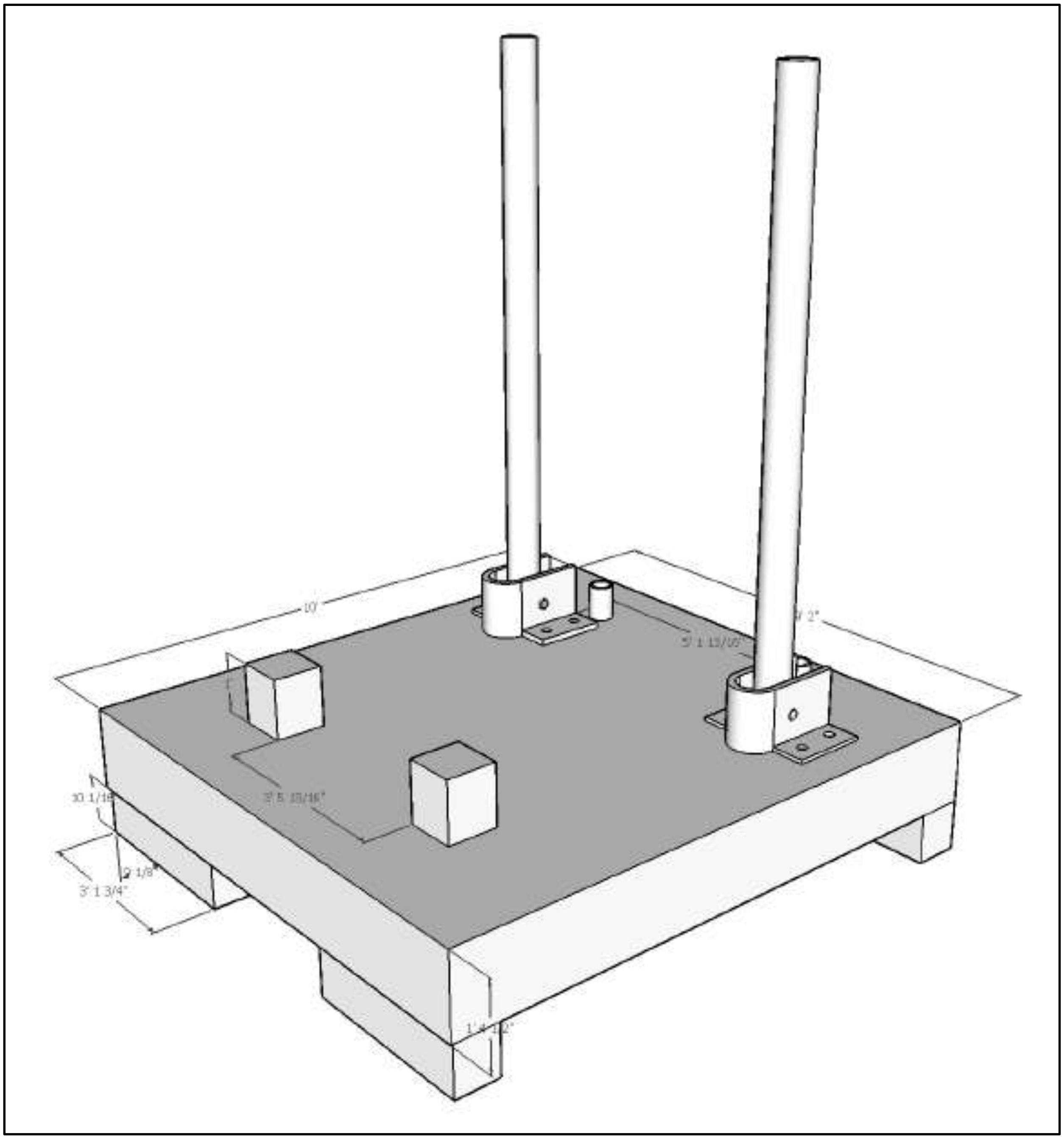


Fig.4.12.(b)Side view of CAD design

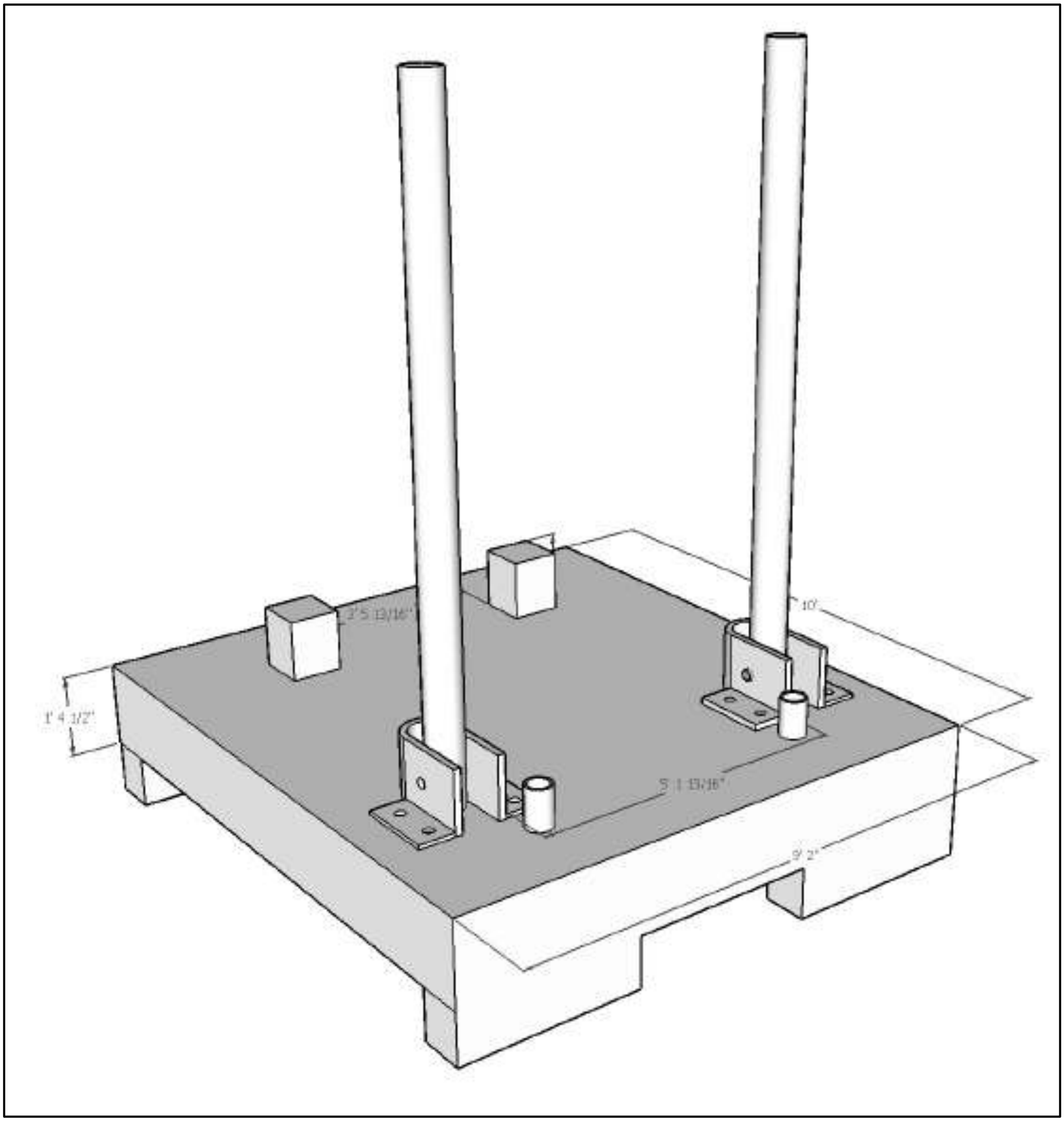


Fig.4.12.(c)Back view of CAD design

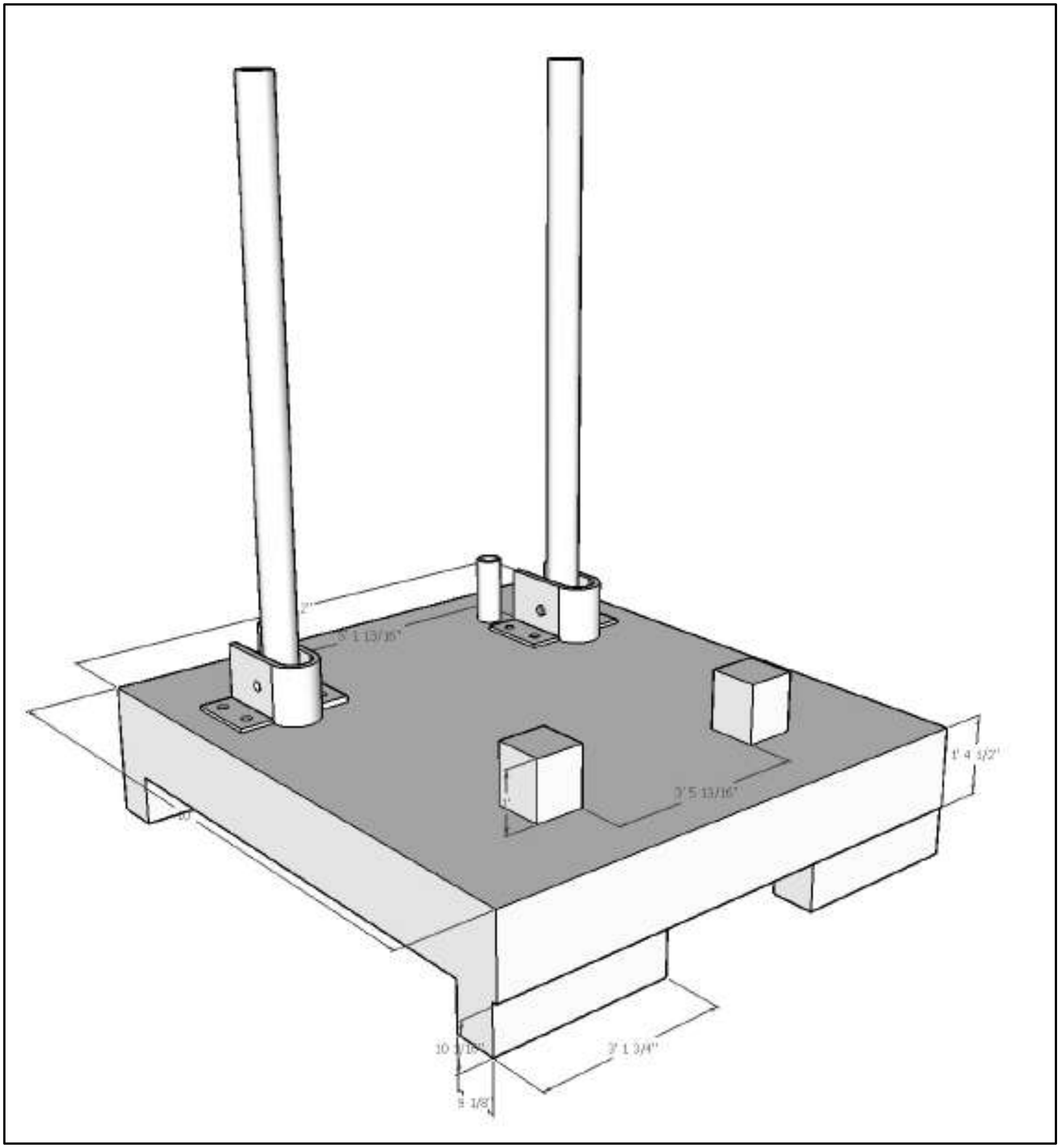


Fig.4.12.(d) Side view of CAD design

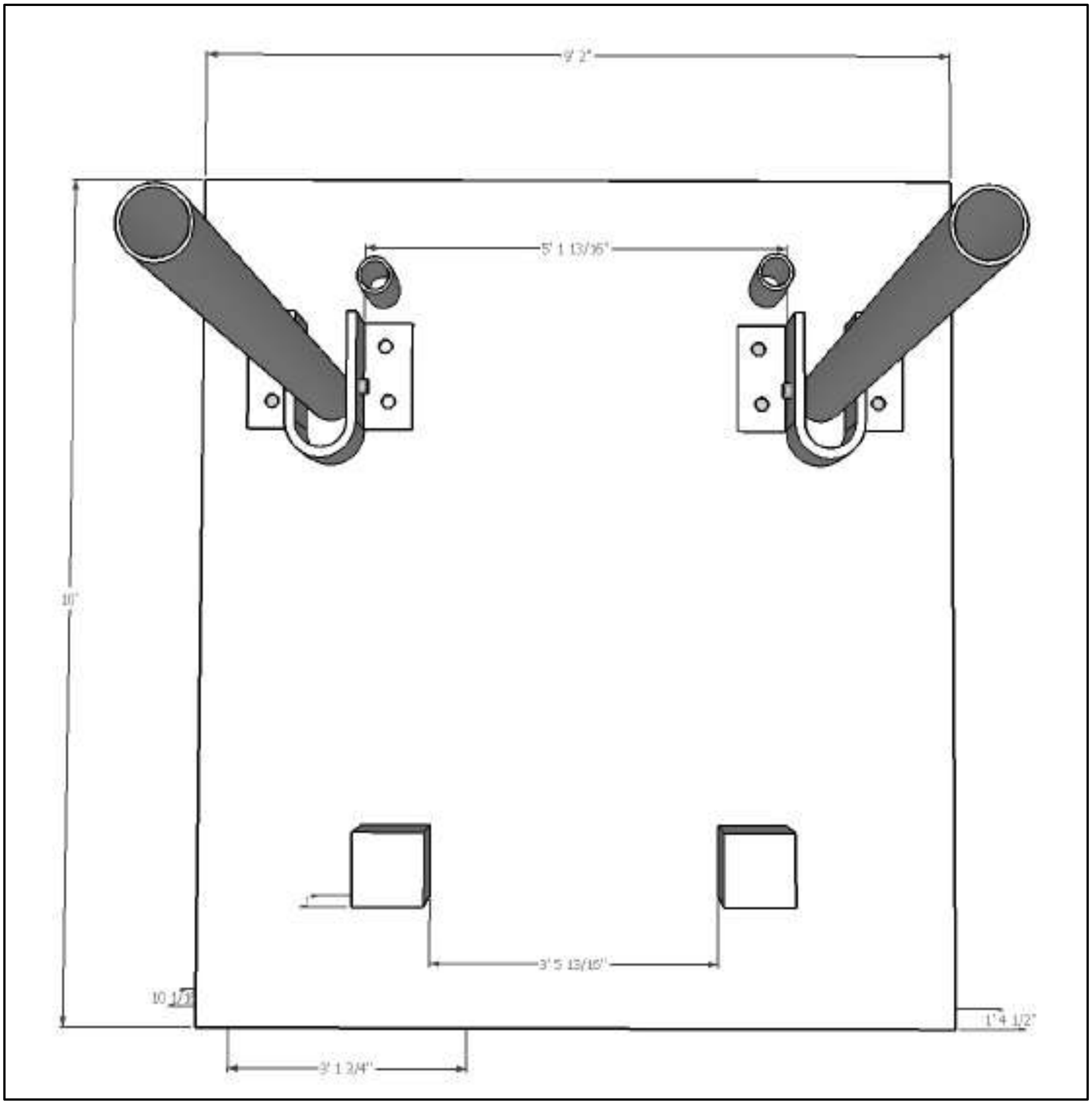


Fig.4.12.(e)Top view of CAD design

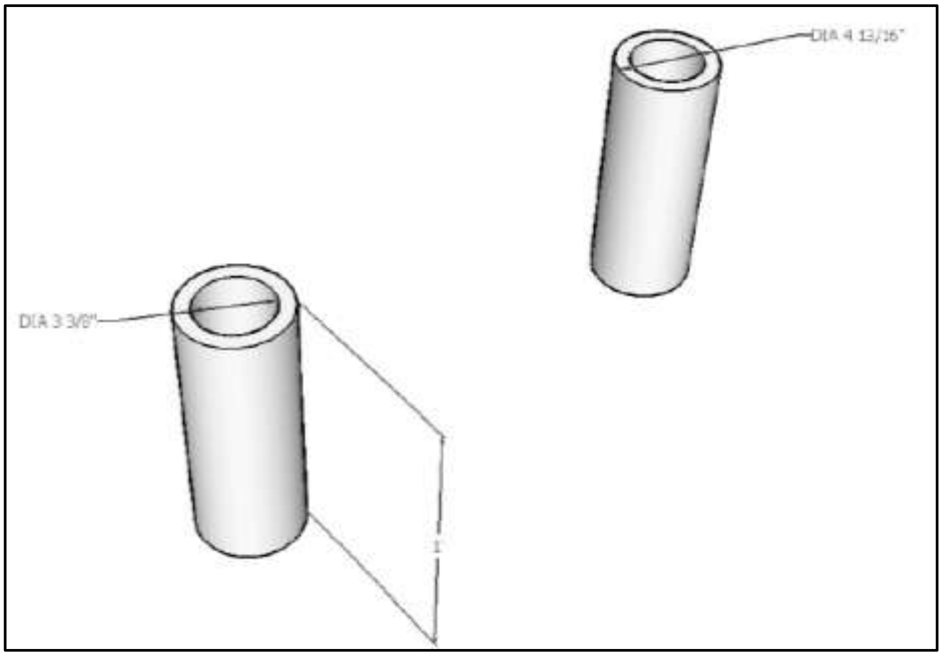


Fig.4.12.(f)Back fitting part CAD design

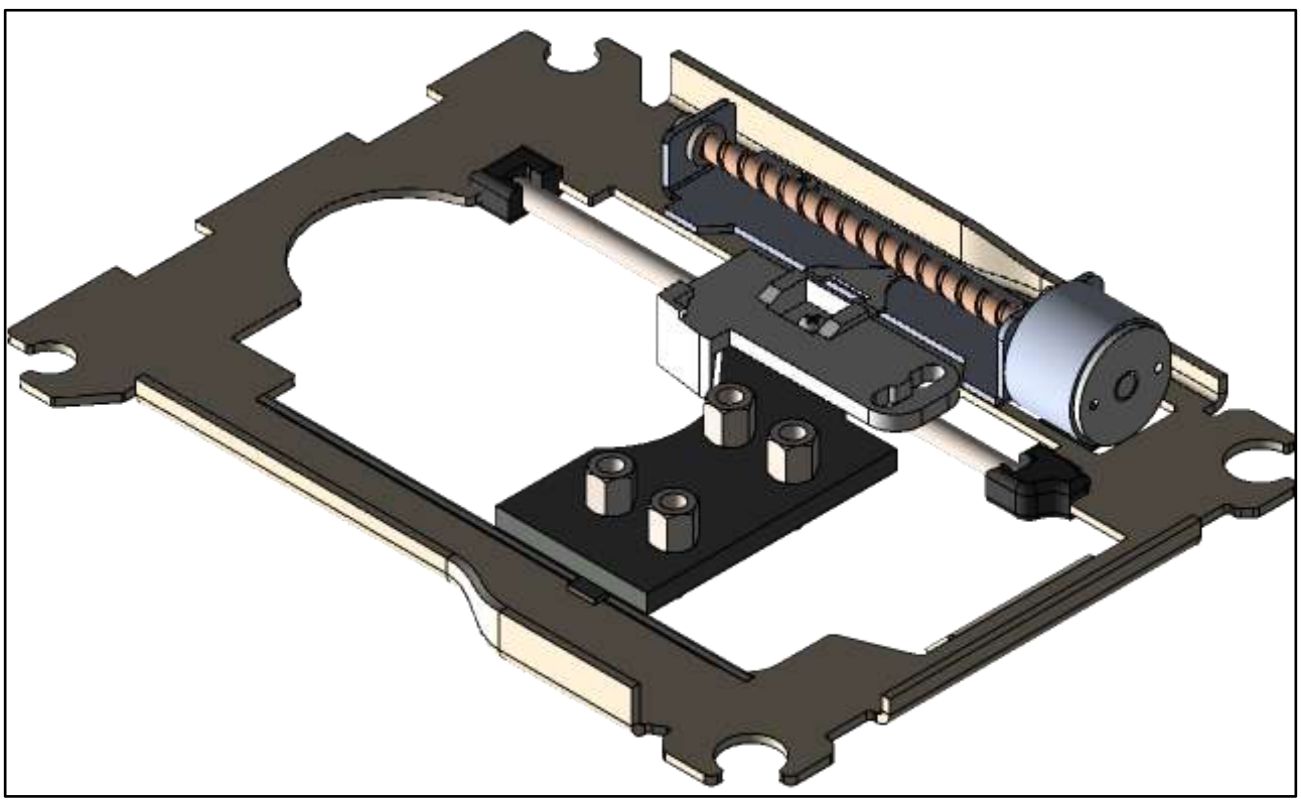


Fig.4.12.(g)Motor and job holder bed CAD design

Fig.4.12.(h)Motor lead screw (40cm x 40cm maximum working area)

Frame Design I made a **CAD** model of the machine to make sure that everything would fit, and to figure out the dimensions of the parts. Some screenshots of the machine's CAD model are above. As this is totally a fold-able machine that's why two hinge joints are basically made in this diagram.

4.3.2. Component assembly:

Once the design and planning are complete, the components of the mini laser engraver machine are assembled. This may involve sourcing various parts from different suppliers, such as the motor, bed of work, motor connection, laser head, and other mechanical components. The steps of fitting are listed below:

Steps:

1. Collect a piece of ply-wood of (230x180x 1) mm^3.Clean the surface properly and connect both two pipe hing join mechanism in a line and a distance of 100 mm gap at the upper section of the wood. Then screw up properly.
2. Two small wooden pieces connect by glue in the front part for the bed holder. The end part of bed is connected by two removable metal pipes.
3. After the motor wiring is done fit both the two bed and motor mechanisms bed with the structure. One is used as job holder bed (y axis) screws all four nuts with the wooden area. Another bed and motor mechanism bed is used

as laser head holder and connected with the upper pipe section. The motor lead screw can travel maximum 40 cm [shown in Fig.3.12. (h)], but here I used 37cm x 37cm as safe working area. Finally connect the 0.5 watt or 2.5 watt laser head with the upper bed. The total mechanisms work as a fold-able laser engraver machine.

After complete the Basics hardware connection the structure is like this.

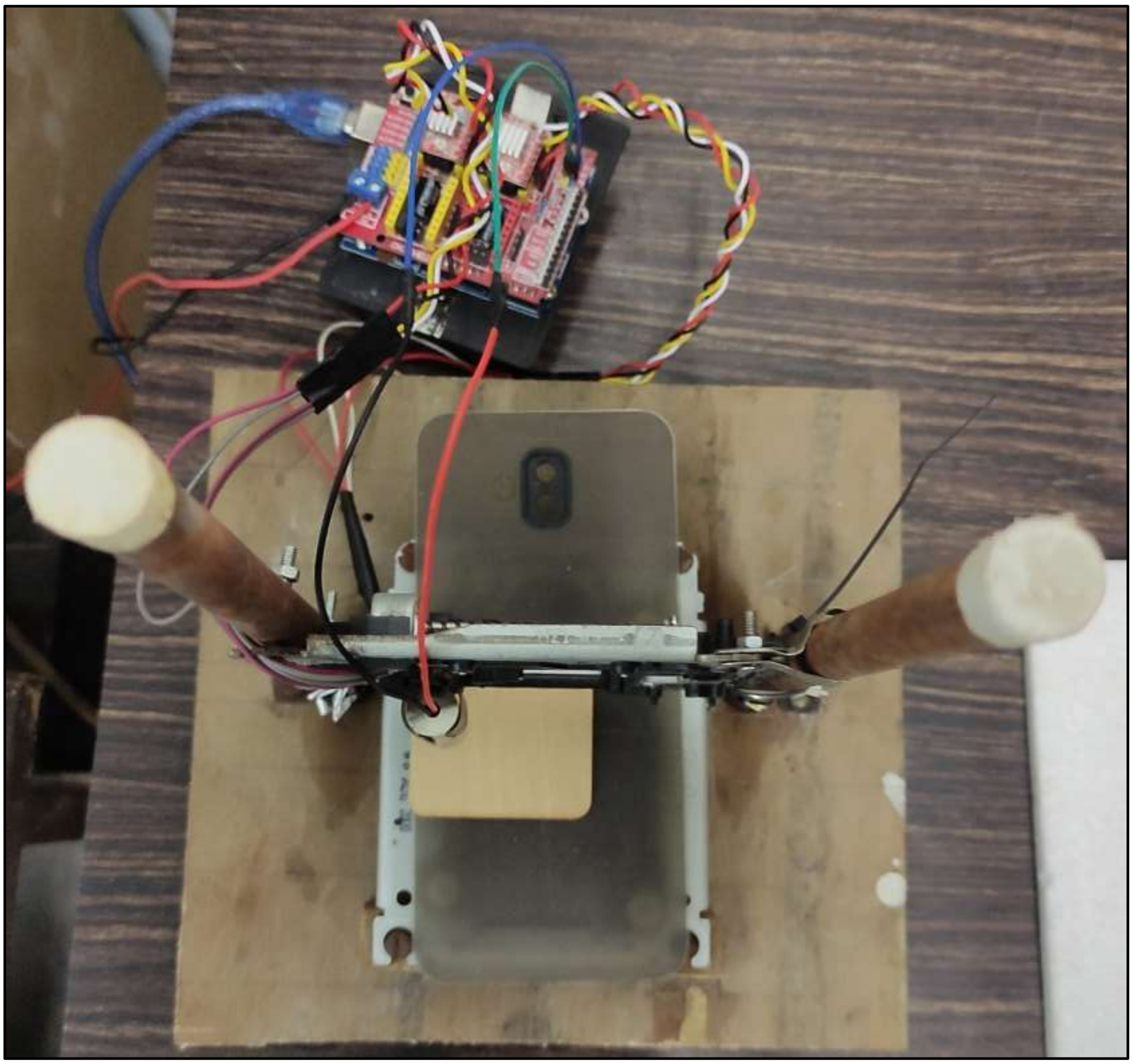


Fig.4.13.(a)After connect with 0.5 watt setup (top view)

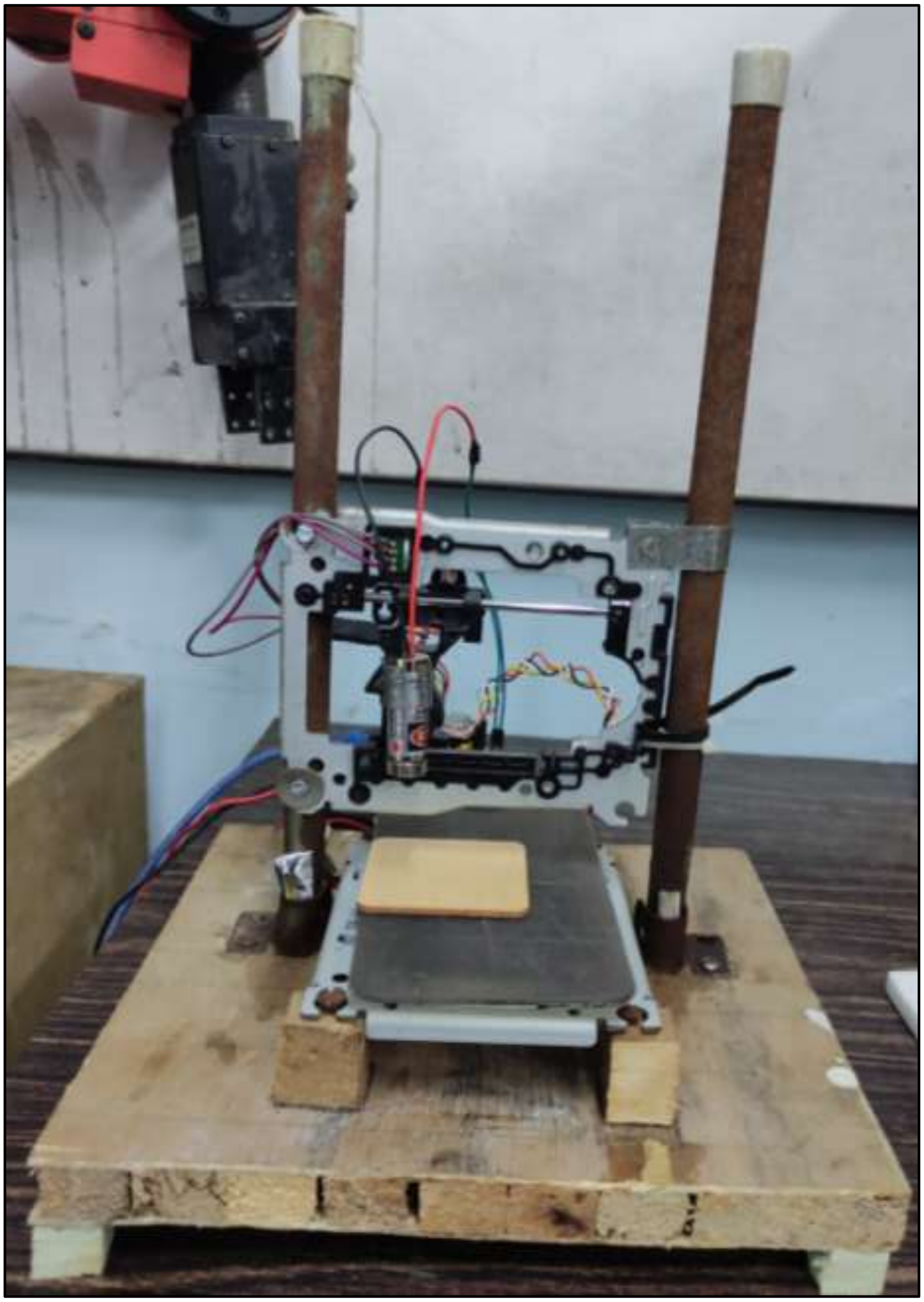


Fig.4.13.(b)After connect with 0.5 watt setup (front view)

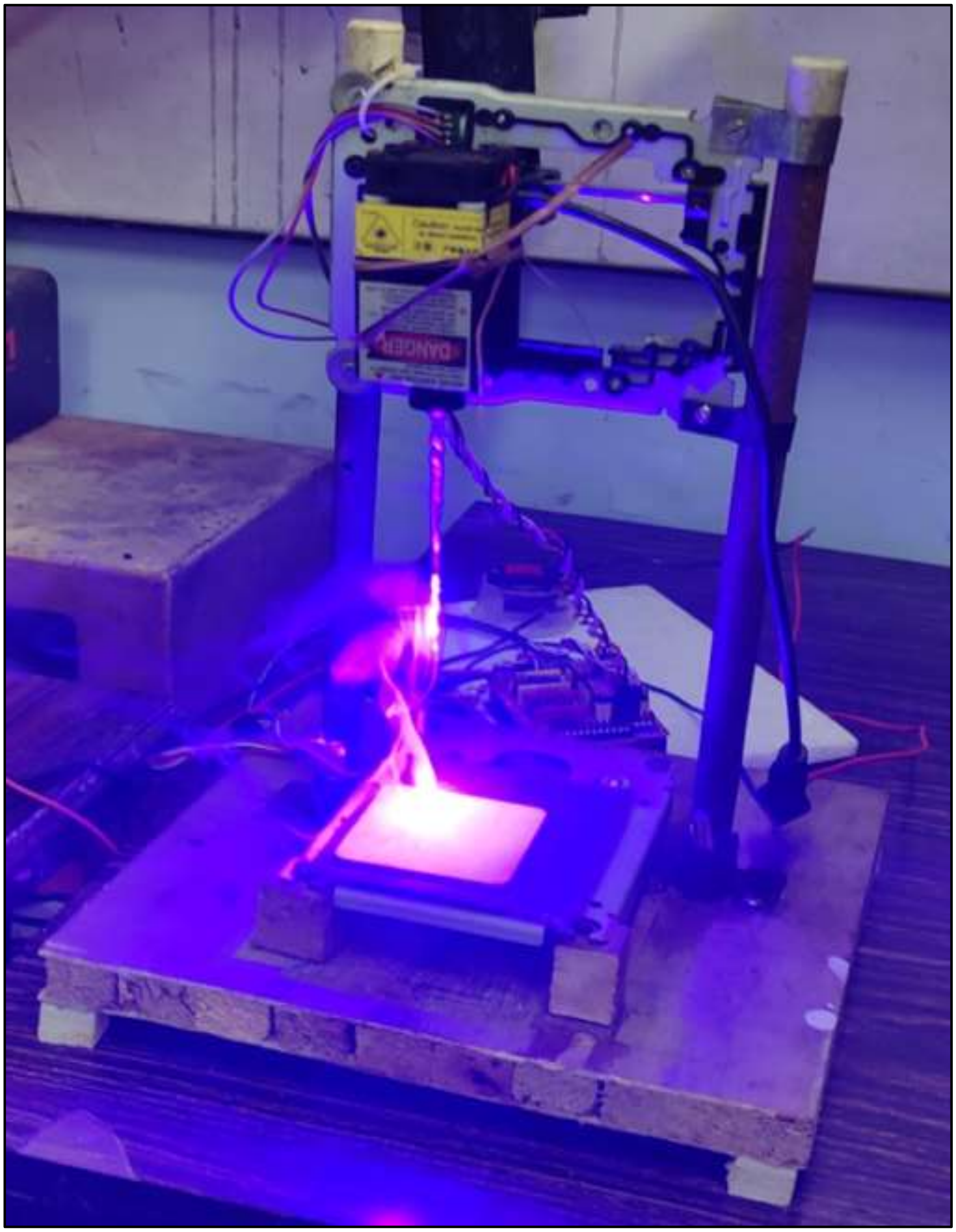


Fig.4.13.(c)After connect with 2.5 watt setup (front view)

4.3.3. Electrical & Electronics Circuits Design:

Mentioned above all parts connected to follow the below mentioned circuit diagram. Here I basically designed two circuits, first one is for 0.5 watts laser source and the second one is for 2.5 watts.

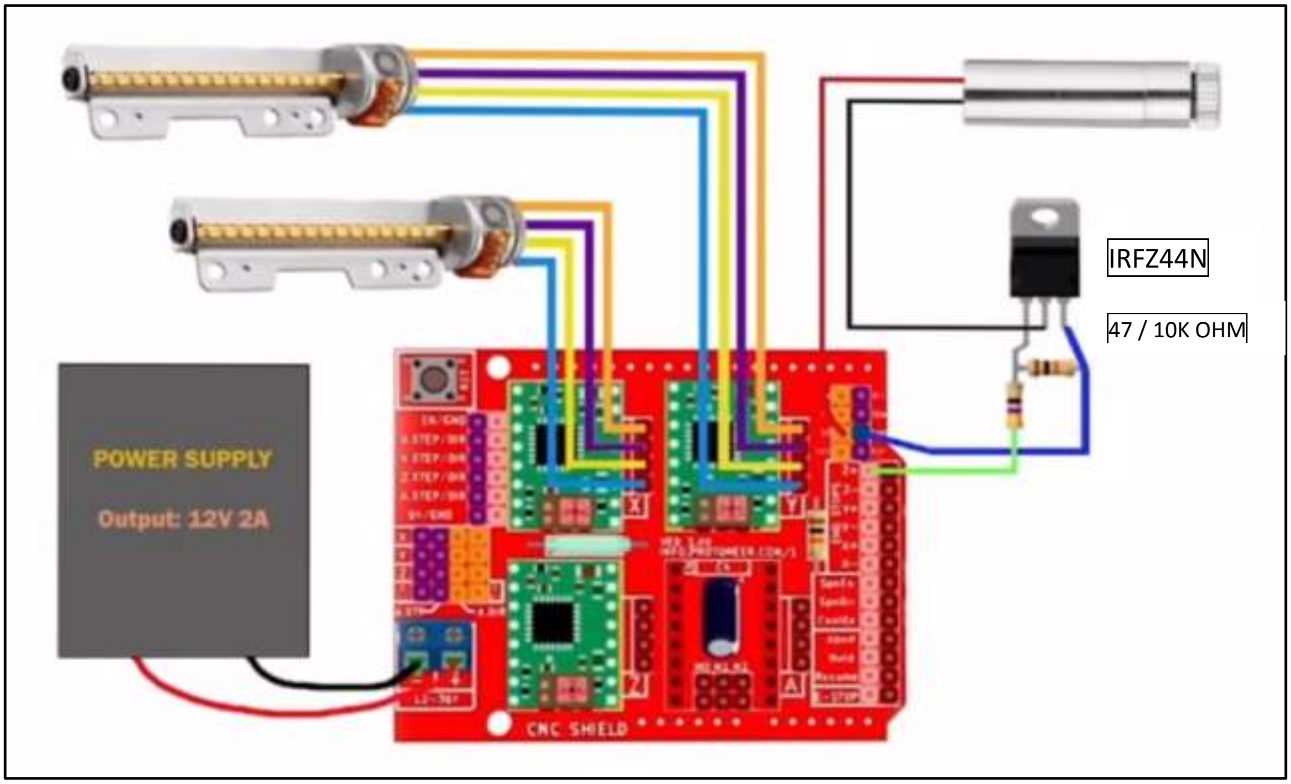


Fig.4.14.(a) Laser Source (0.5 watt & 5 volts) circuit diagram

For the above circuit connection the positive terminal of laser diode is connected to any one of the 5v pin present in CNC v3 shield, and the negative wire to N channel MOSFET drain pin, common source connected with GND pin. Mosfet gate pin is connected with Z+ (signal) pin presented in CNC v3 shield. But for the 2.5 watt laser module (below circuit) connect the positive terminal of laser diode to direct 12v power supply, and the negative wire to N channel MOSFET drain pin, source connected with GND pin. Finally Mosfet gate pin is connected with Z+ (signal) pin presented in CNC v3 shield. For every cases 10K resistance is connected with gate and source pin of the mosfet.

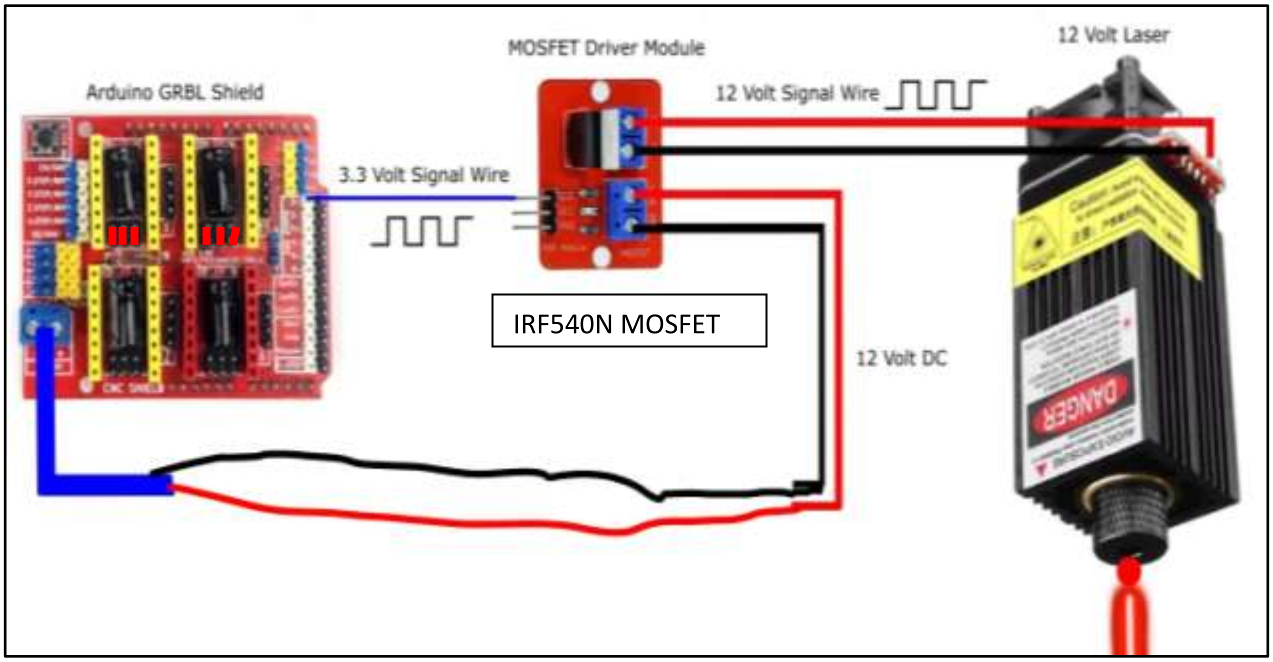


Fig.4.14.(b) Laser Source (2.5 watt & 12 volts) circuit diagram

As per the above two diagram,

The CNC V3 shield is connected on the Arduino Uno, where the supply pin for the both board are present in the same direction. Press the cnc shield on the arduino Uno. To connect the A4988 driver on the cnc shield always match A4988 Driver EN pin with the enable pin present in cnc v3 for both the X and Y axis motor. Connect four micro jumper for each case, creating micro stepping up-to 1/64 of a single step. If micro stepping is not done then the entire machine will suffer, like lots of sound coming from stepper motor, also huge vibrations will be generated may damage the motor as well as the circuit of machine.

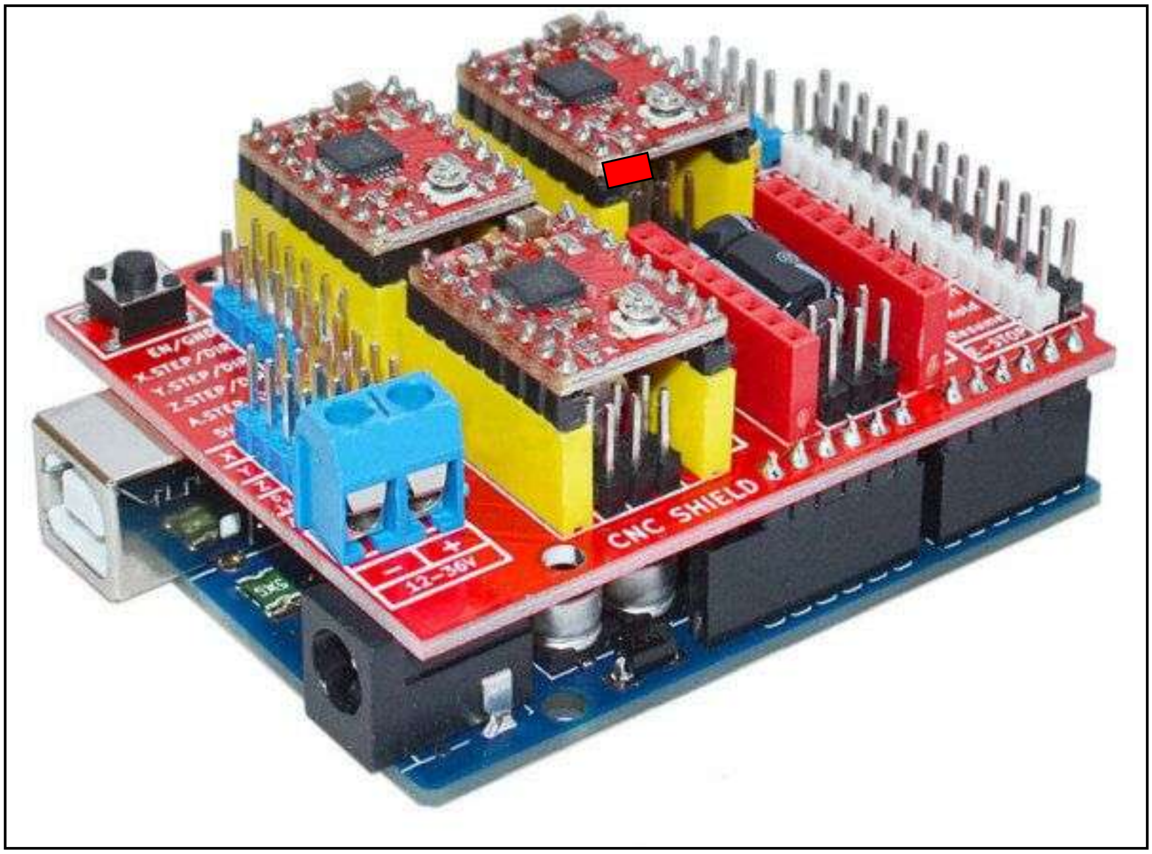


Fig.4.15.Arduino, CNC v3 shield & A4988 driver connection

CNC Shield V3.0 can be used as drive expansion board for engraving machine, 3D printer and other devices. There're 4 slots in the board for stepper motor drive modules, can drive 4 stepper motors, and each step stepper motor only need two IO port, that is to say, 6 IO ports can quite well to manage three stepper motor, it's very convenient to use. After insert CNC Shield V3.0 into OSOYOO Basic board, and installed GRBL firmware then you can quickly DIY a CNC engraving machine.

Board Layout

GRBL Pin Layout:

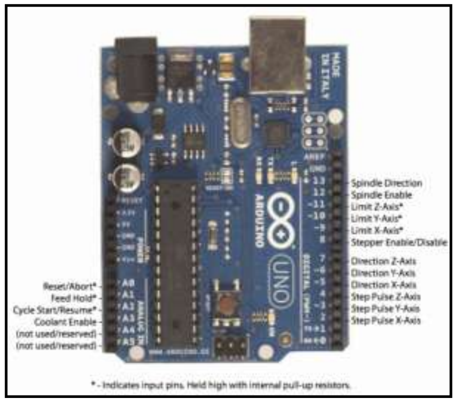


Fig.4.16.Arduino Pinout

GRBL Pin Layout

In addition to have all the GRBL function pin, Arduino CNC Shield V3.0 also have some additional pins to achieve more features:

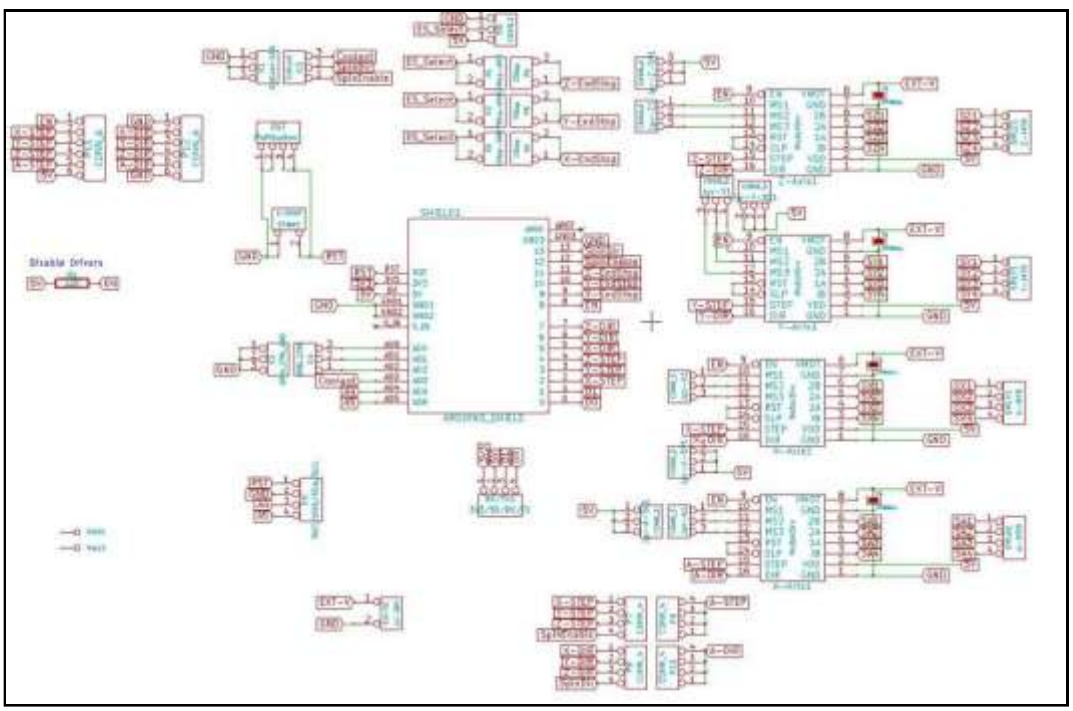


Fig.4.17.(a)CNC v3 Shield pinout

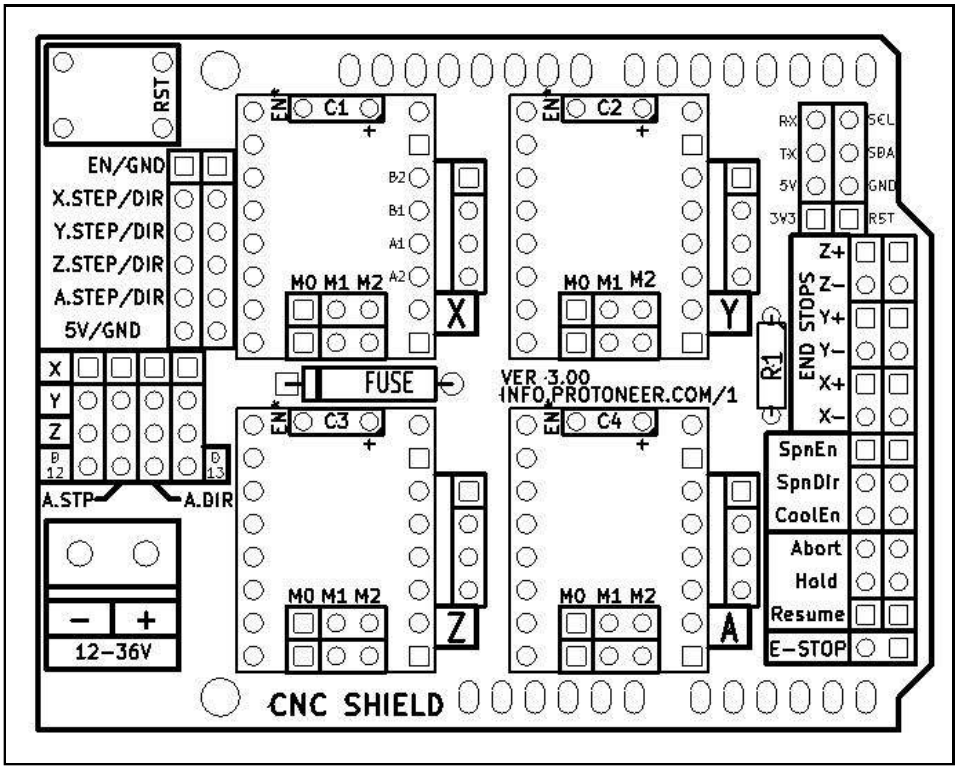


Fig.4.17.(b)CNC v3 Shield pinout

Extra pins:

- Limit switch pins have been doubled up so that each axis has a "Top/+" and "Bottom/-". This makes it easier to install two limit switches for each axis. (For use with a normally open switch)
- EStop – These pins can be connected to an emergency stop switch. This does the same as the RESET button on the Arduino board. (We do advice that an extra emergency button also be installed that cuts power to all machinery. **A REAL EMERGENCY BUTTON**)
- Spindle and coolant control has their own pins.
- External GRBL Command Pins have been broken out allowing you to add buttons for Pause/Hold , Resume and Abort.

- Serial Pins (D0-1) and I2C Pins (A4-5) have their own break out pins for future extensions. I2C can later be implemented by software to control things like spindle speed or heat control.
- Version 3.00 of the board added a jumpers to configure the 4th axis(Clone the other axis's or run from Pin D12-13), Comms Header(RX+TX , I2C) and a Stepper Control Header(All Pins needed to run 4 steppers)

Laser source-

High power laser for Engraving and Cutting comes with LASER Light power of 2.5 Watts and having the wavelength of 445nm. You can engrave plastic, wood, acrylic, PVC, PCB, on behalf of the wood and other materials. This module does not contain pictures on the bracket and power supply. Shown in **Fig.3.5.(b) 2500 mW laser module adjustable lens.** Technical specifications and Features are given below:

- Laser Wavelength: 445nm (Blue).
- Spot Type: Dotted (Adjustable).
- Light Power: 2.5 watts (2500mW).
- Millisecond pulsed laser.
- Drive Mode: ACC Constant Current Drive.
- Cooling Method: Forced Air Cooling.
- Input Voltage: 12V DC
- Input Current: 0.22 Amps.
- Input Method: 2.1 DC Seat Line.
- Can engrave: plastic, wood, PVC, PCB, on behalf of the wood and other materials.
- Unable to engrave: White/transparent material, Aluminum without oxide layer.
- 1 x High Power Laser 2.5W 445nm for Engraving and Cutting.

4.3.4. Hardware Installation:

Connect the components according to the actual situation, such as motors, limit switches, lasers, motor drives and so on.

When installing the hardware, please pay attention to the following points:

1) Incorrect connection of +/- may destroy your devices, even cause fire.

2) Please make sure to insert drivers in correct direction, or it may burn the mainboard and drivers, specific installation direction please integrating Arduino CNC Shield V3.0, refer to the data sheet of motor drive. The picture shows the connection of A4988 motor drivers and Arduino CNC Shield V3.0.

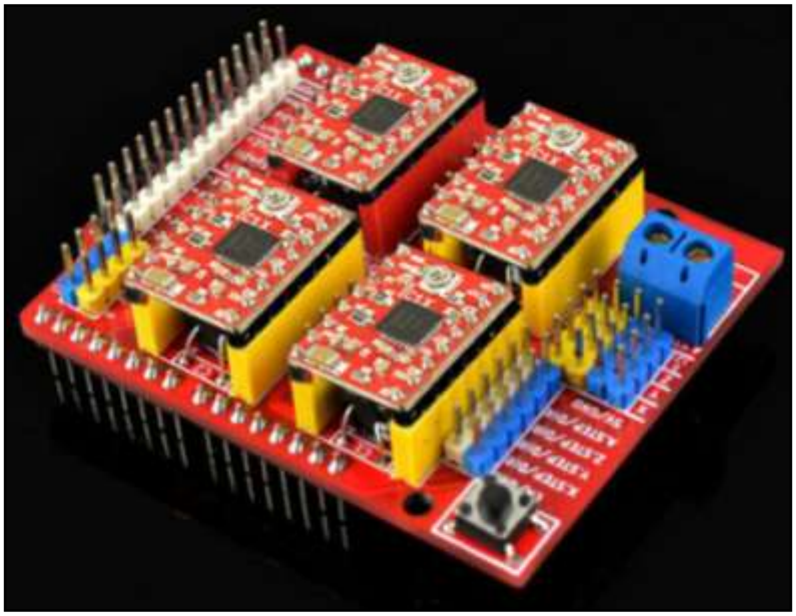


Fig.4.17.(c)CNC v3 Shield pinout

In the case of A4988 driver, it has various support segment like support 1 segment, 1/2 segment, 1/4 segment, 1/8 segment, 1/16 segment. Each segment is set by the M0, M1, M2 pin header in the Arduino CNC Shield V3.0, cover the jumper cap to the pin header represents high level, do not cover the jumper cap represents low level.

In order to improve the precision of engraving, use 1/16 segment, it needs 3 jumper caps to cover M0, M1, M2. As shown in picture:

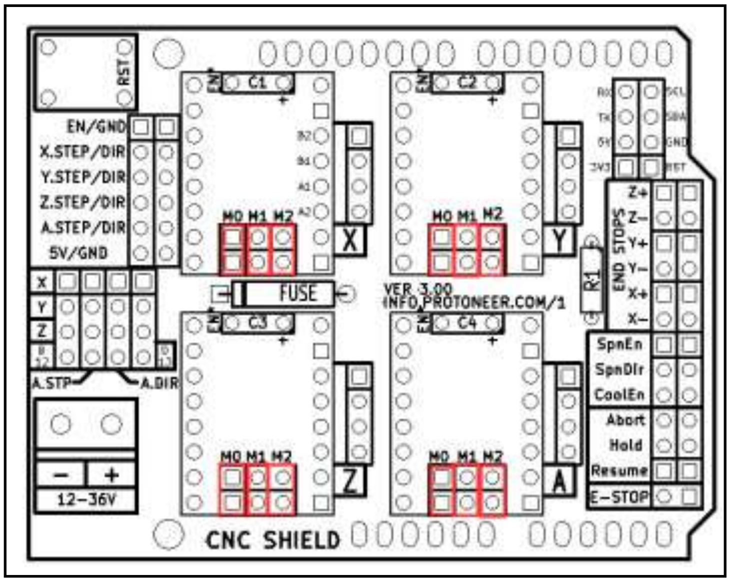


Fig.4.17.(d)CNC v3 Shield pinout

3) The input voltage of Arduino CNC Shield V3.0 is DC 12V-36V, do not input more than 36V voltage. Although the input voltage supports power supplies up to 36V, does not mean that you can use 36v under any circumstances, because some motor drivers supply voltage (VMOT) is less than 36V, such as A4988, its supply voltage is 8-35V, if you use 36V power supply, it will burn the motor driver. So when you select the power supply, please refer to the corresponding the motor driver's data sheet. Here are a few supply voltage parameters for commonly motor driver:

A4988 Driver Pinout

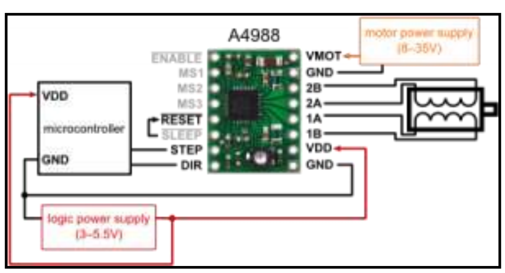


Fig.4.18.A4988 Pinout

Minimum operating voltage: 8V, Maximum operating voltage: 35V, Continuous current per phase: 1A, Maximum current per phase: 2A (with heatsink), Minimum logic voltage: 3V,Maximum logic voltage: 5.5V, Micro-step Resolutions: 1, 1/2, 1/4, 1/8, 1/16, Size: 0.6″ × 0.8″, Weight: 1.3g

Here we get a potentiometer in the driver, to properly set the coil current on the A4988 drivers you first must know the value of the sense resistors on the board to insert into the formula,

$$V_{ref} = 8 * I_{max} * R_{cs}$$
$$=8 * 0.6 *0.1$$
$$=0.48 \text{ volt}$$

Where, V_{ref} is the desired reference voltage to set, I_{max} is the coil current and R_{cs} is the value of one current sense resistor.

LASER DRIVER MODULE OR SWITCH

This driver module uses IRF520N Power MOS, we can adjust the output PWM. It fits to drive up to 24V allows the load, such as LED lights, DC motors, miniature pumps, solenoid valves. An LED indicator provides a visual indication of when your load is being switched.

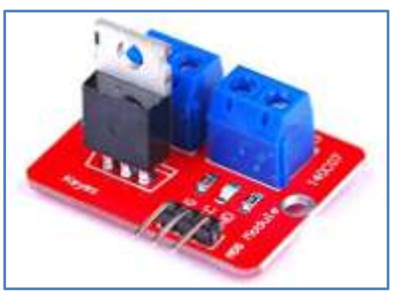


Fig.4.19.(a)Robocraze IRF520N Mosfet Driver

Same driver we can make by the help of IRFZ44N MOSFET, 10K Ω and 47 Ω resistors.

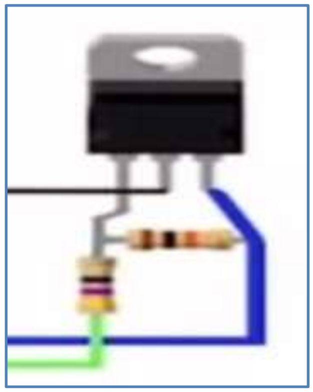


Fig.4.19.(b) Handmade IRFZ44N Mosfet Driver

Both are almost same but an IRF520N has a threshold voltage in the range of 2 to 4 volts, so it's entirely possible a 3.3 v Arduino gate drive will not do the trick. The IRFZ44N, on the other hand, has a range of 1 to 2 volts, so an Arduino will reliably turn it on. The IRFZ44N is 60V, and 50amp at 25^0C and the IRF540N is 100V and 28amp at 25^0C.

4.3.5. Software integration:

After the machine components are assembled, the software is integrated with the control system. The software may include a user interface, firmware, and other programs that allow the machine to operate and communicate with a computer.

- **GRBL Library Installation**

Download and unzip grblmain.zip, put it to libraries folder of Arduino IDE installation directory. Open Arduino IDE, choose File->Examples->grblmain->GRBL to Arduino, then you'll open a grbl sample program, select the port and board type, burn this grbl sample program to Arduino UNO.

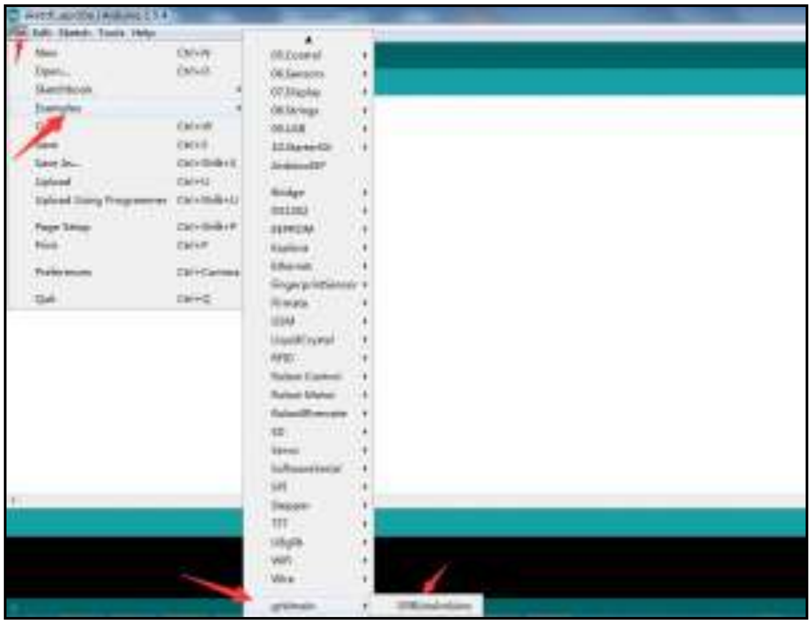


Fig.4.20.(a) Arduino IDE installation step-1

Thus these tasks must be done consecutively before installing Laser GRBL

Fig.4.20.(b) Arduino IDE installation step-2

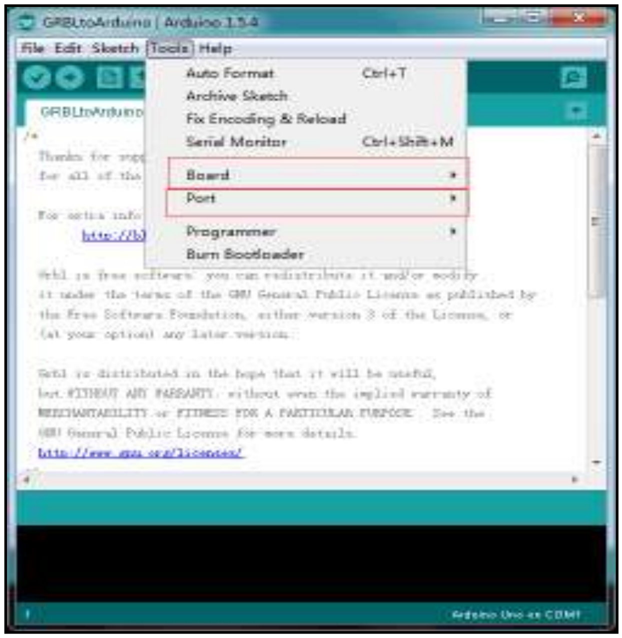


Fig.4.20.(c) Arduino IDE installation step-3

- **Install GRBL Controller**

Download and install Grbl Laser , open it, interface as shown in picture:

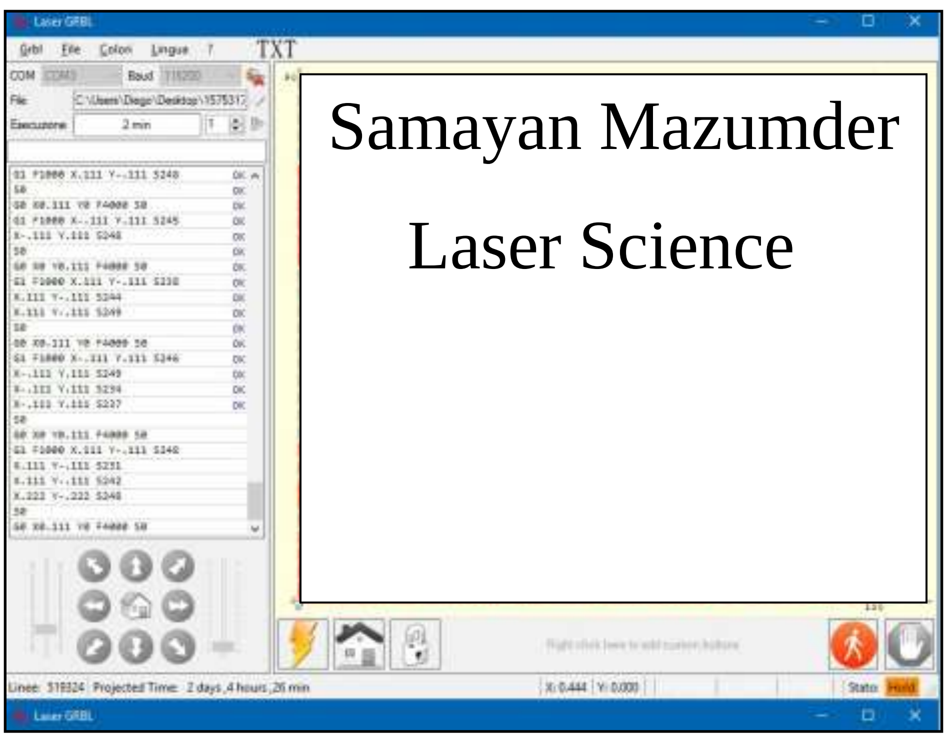


Fig.4.20.(d) Laser GRBL installation

Complete all configurations as required,

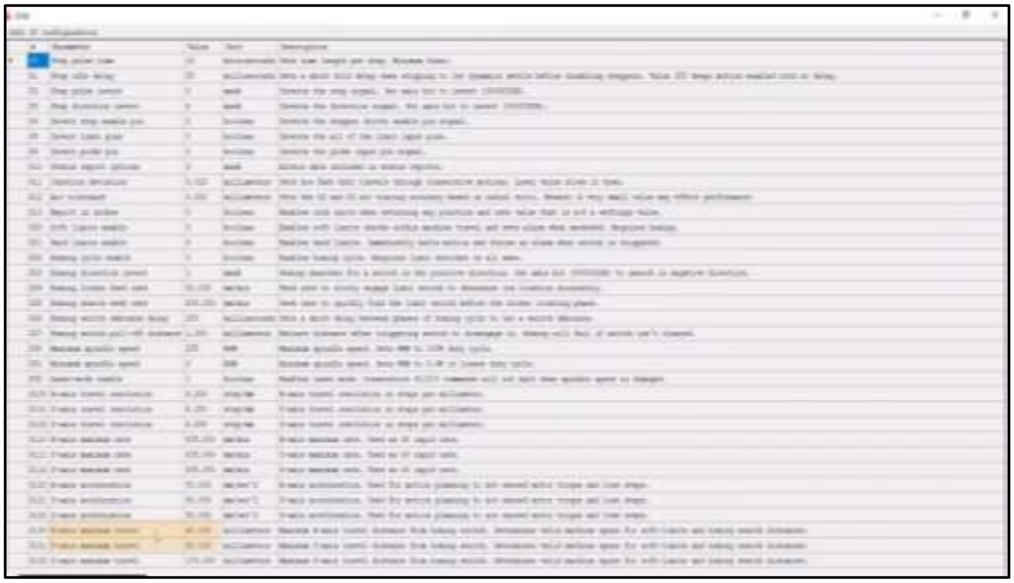


Fig.4.20.(e) Laser GRBL configurations

Use the USB cable to connect your PC and Arduino UNO, select the port and select the baud rate as 9600. Click “Open”, if it connected, “Open” will be “Close/Reset “, the background is red. Click “Choose File” to choose the graphy you want to engrave, after selected click “Begin” to engrave.

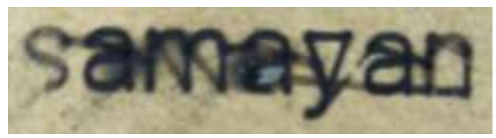
4.3.6. Quality control testing:

Once the mini laser engraver machine is assembled and the software is integrated, it undergoes a series of quality control tests to ensure that it is functioning correctly. This may include testing the laser's power output, checking the accuracy of the engraving, and verifying that the machine is safe to use.

4.4. SOME APPLICATION DONE BY THIS MACHINE

At this power level of 2500 W, We could burn through paper, cut thin foam sheets, and mark wood, cardboard, ceramics and possibly melt or burn plastic.

Table-4 ENGRAVE PRODUCTS

SL.NO.	ENGRAVE MATERIAL	ENGRAVE PRODUCT
1.	PAPER (2.5W blue Laser)	 **Fig.4.21.(a) paper engraving**
2.	PITCH BOARD (2.5W Blue Laser)	 **Fig.4.21.(b) pitch board engraving**
3.	MASONITE BOARD (2.5W Blue Laser)	 **Fig.4.21.(c) masonite board engraving**

4.	PLYWOOD (2.5W Blue Laser)	 **Fig.4.21.(d) plywood engraving**  **Fig.4.21.(e) plywood engraving**
5.	WOOD (2.5W Blue Laser)	 **Fig.4.21.(f) Balsawood engraving**

6.	SUN-MICA (2.5W Blue Laser)	 **Fig.4.21.(g) Sun-mica engraving**
7.	HARD PLASTICS (2.5W Blue Laser)	 **Fig.4.21.(h) Hard white plastics engraving**  **Fig.4.21.(i) Hard black plastics engraving**

8.	MUD BRICKS (2.5W Blue Laser)	 **Fig.4.21.(j) Brown mud cup engraving**
9.	TILES (2.5W Blue Laser)	 **Fig.4.21.(k) Brown tiles engraving**  **Fig.4.21.(l) off white tiles engraving**

4.5. RESULTS AND DISCUSSIONS-

The concept was converted into reality along with all its components. Working prototype was made with help of different components acquired and purchased. It was found out during the conducted experiments that the laser being used is only for few cuts and as it burn out after several use. We have to be very careful during the connection as diode works only in forward bias condition and under a particular range of voltage. The platform here can accommodate only small objects which can be kept in small begs. The size of platform or bed can be increased for bigger projects in future. The basic aim was achieved that was to build a scale down model of industrial laser engraver.

4.5.1. Advantage:

- Low weight.
- Easily transportable.
- Low cost
- Easy setup

4.5.2. Disadvantages:

- Depth of penetration is low.
- Available for only soft material.
- Small (40cm x 40cm) maximum working area.
- Not applicable for white object unless oxidized.
- Works only with D.C supply.

CHAPTER-5

5.1. SUMMERY & GENRAL CONCLUSION-

In the present research study a low cost laser engraving machine has been developed mostly by scavenging different items from old abandoned computers. The stepper motors (SM15DD) of CD ROM drives of old computers have been used and integrated with the developed support structure. Arduino UNO was used as microcontroller and CNC V3 shield was used to connect A4988 motor driver with the two axis drive system. The driver was connected with DC 12 volt power supply and a laser module along with MOSFET switch in this laser engraving setup. Unused old computer SMPS was used here as power supply to further minimize the cost. In order to enable G code control, the microcontroller has been flashed with the GRBL laser firmware and subsequently configured for this specific hardware setup. In this machine (2.5 Watt Blue, 445 nm) laser source is installed along with the X axis and job holding table was mounted on the Y axis slide. Ink-scape software was used for converting the image file into a G-Code file suitable for mini laser engraving machine. After successful fabrication, the machine was directly used for engraving/marking applications and it was observed that the developed engraving set up was giving very satisfactory result. Based upon the present research studies the following observations can be made;

i. It is possible to develop a mini laser engraver machine as low as within one thousand Rupees (excluding the price of laser source) only. Most of the things like the power supply and stepper motors etc. have been scavenged from old computers. This approach is extremely useful for not only cost reduction but extremely helpful for reduction of e-waste.

ii. The small stepper motor drive systems of CD ROM of old computer are very well capable and giving very satisfactory response.
iii. This machine is totally portable and occupying a very little amount of space.
iv. This engraving/marking setup is extremely useful for small scale engraving/marking applications like drawing paper, pitch board, masonite board, plywood, wood, sun-mica, hard plastics, rubber, mud bricks, tiles etc. They gave a very satisfactory result and can complete the work instantly within a few seconds.
v. This small handy machine can be used in laboratories and small scale industries for various desktop engraving/marking applications.

Still there are lots of scopes to further upgrade the machine. There is a possibility to incorporate Z axis drive system in order to automate the focusing. For continuous operation of the machine a better cooling system may be developed. For ease of operation limit switch can be installed. The machine may further be designed to install interchangeable laser head adapter in order to install different laser sources for engraving of various materials.

Finally, it may be stated that this kind of mini laser engraver machines are valuable tool in modern manufacturing industries for developing customized/personalized products. They offer high precision and versatility in producing engravings on various materials. Their use is likely to increase in the coming years as technology continues to advance and new applications are discovered.

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