DEVELOPMENT OF LASER CUTTING AND ENGRAVING MACHINE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA

CERTIFICATE

This is to certify that the thesis entitled "Development Of Laser Cutting and Engraving Machine" submitted by Parinav (110ID0534) and Mukesh Kumar (111ID0508) in partial fulfilment of the requirements for the award of the degree BACHELOR OF TECHNOLOGY in INDUSTRIAL DESIGN at National Institute of Technology, Rourkela is an original work carried out by them under my supervision and guidance. The matter embodied in the thesis has not been submitted to any other university/institute for award of any other degree.

Date: 24/04/2015

Dr.B.B.Biswal

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ABSTRACT

Basically in laser engraving the laser beam burns the top layer of the surface to be engraved. The burnt area is left uncoloured which makes it appear different from the surrounding surface. While in laser cutting laser beam has to penetrate through the surface. This can be achieved by prolonging the beam on a particular area for a long period of time, duration being decided on the strength of material to be cut. We are still collecting data from different resources to know this topic more in depth.

In our project we have decided to develop working model of laser cutting and engraving machine. This machine is very useful in our department since it's a kind of rapid prototyping machine. It can cut out paper patterns and thermoplastic sheets to produce desired shape and patterns. Till now we have collected information on laser cutting, laser and what engraving is. Laser cutting is different from laser engraving, in case of engraving very low intensity laser torch is used as compared to laser cutting. We got a brief introduction on laser, how it works, what are its properties, how to generate it and how to control its intensity. The machine is made using a ~200mW red laser. It might nut cut through chunks of wood but surely burn the top layer.

Simulation analyses are performed in CAD software 'CATIA V6' in order to simulate each part of the machine. It was helpful for remodelling the moving bed or the job holder, if any errors found during the simulation. Additionally, experiments are performed for the develop laser cutting engraving machine.

Keywords: laser, cutting, engraving, portable, low intensity

CONTENTS

LIST OF FIGURES

1. Introduction

Laser stands for Light Amplification by Stimulated Emission of Radiation, was discovered in 1960. Laser light beam is different from normal light beam because of its high temporal and narrow spectral bandwidth. Here amplification of light is achieved by a laser active medium (gain medium). This medium is obtained by stimulated emission of photons from a lower energy state to a higher energy state previously populated by a pump source. In order to start the lasing active in the medium it must be in nonthermal energy distribution known as population inversion. Wavelength of photon is changed according to the need of active medium. The wavelength represents the colour and the amount of energy stored. It is important to feed back the generated photon into the active medium using a resonator, so that a large amount of identical photons builds up for further stimulated emission. Pumping action is required which ensures continuous feeding of energy into the laser active medium. This helps in sufficient emission is generated on a continuous basis. Lasers are classified into different ways i.e. according to their mode of operation or type of laser-active medium.

Diode Lasers. Laser diodes are made by sandwiching negatively(n-type) semiconductor with positively(p-type) semiconductor. The laser beam generated is only in boundary layer of the forward biased semiconductor diode. This layer is only few micrometres in size, mirrors are fixed to make very compact diodes. Different colours of diode can be made by varying the choice of semiconductor and the dopant used. In p-type and n-type semiconductor the major component is gallium arsenite[1].

Laser cutting

It has been long since the first diode application for material processing was as soldering a 15W medical diode laser. Now it has reached a considerable height as compared those days. The advantages of high-power diodes are its compactness, lifetime runtime, energy efficiency and low running cost. Currently CO_2 and Nd:YAG lasers are used in hardening and welding. The characteristics of high-power diode lasers which help it to stand out from other types of lasers are its wavelength, laser power, energy efficiency, beam formation, beam divergence and asymmetry[2].

Advantages of Laser cutting

1. Edges are clean with no burn and dust formation.

2. High level of precision and accuracy of cut line.

3. No material deformation due to contactless processing.

4. Low thermal influence.

5. Cutting of material of various thickness and combinations in one go.

6. No tooling cost.

Disadvantages of Laser cutting

1. Power use and capability depends on upon the method for the laser for cutting and the sort of zone that must be done, is used. Ordinarily joins the laser cut high usage of essentialness stood out from diverse advances used for cutting.

2. Creation rate is not dependable when laser cutting is used. It will depend by and large on the thickness of the workpiece, the kind of material used and the method for laser cutting.

3. Setting paying negligible respect to the division laser and the temperature can incite the ignition of specific materials. Several metals have a tendency to stain when the force of the laser section is over the top.

4. Laser cutting of plastic, can be extravagant because of plastic transmits gas when shown to warmth. Thusly, the whole arrangement of an all that greatly ventilated room, which can be amazingly unnecessary. Moreover, the gasses discharged amidst the method of being unsafe and can be dangerous.

5. Carelessness in altering laser division and temperature may provoke replicating of a couple of materials. Certain metals tend to stain if the power of the laser shaft is not as per need.

Laser Engraving

Engraving is a process of design onto a hard surface by cutting grooves into it, basically on flat surface oriented perpendicular to the processing beam axis. Engraving was very important method of producing image on paper like printmaking, in mapmaking and also for book and magazine. This is replaced by etching and other technique because of difficulty of learning the technique. Modern engraving technique such as laser engraving and

photoengraving have many important application. Laser engraving is one of the most suitable technologies to be used in wood engraving operation. In this method a laser beam is used to penetrate the solid material. The advantage of this laser is non-contact working, high scanning speed, high flexibility and high automation[3].

1.1 Motivation

With 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.

1.2 Problem statement

The new design development in this thesis is based on industrial laser cutting and welding machine. This approach consists of a mobile platform and a laser nozzle, in the arrangement the nozzle is equipped on top of mobile platform to provide the required manipulation capability (for proper laser cutting and engraving). The development of the scale down model of industrial cutter system covers mechanics of systems design and simulations, design of movable bed and cooling system to dissipate heat produced during cutting. The movable bed is controlled by stepper motor which in feed with input from Arduino and external power source.

1.3 Objective of the Work

The objectives of the work are:

a) To reduce the large scale industrial cutting machine to a small portable lab equipment.

b) To decrease the cost of making prototypes

c) To make it useable for cutting paper, polystyrene and thin sheets

d) Make the machine mobile.

e) Developing concept sketches and then reviewing it with the customers to find according to them what the shapes should be.

2. Review of Literature

2.1 Literature review

A laser cutting device has a cavity designed to provide a controlled environment while the laser beam is used to cut metals to reduce or eliminate heat energy and changes brought about by oxygen is termed as mechanical characteristics of the metal. A separate configuration is set up to provide gas to the controlled environment with the cavity, as well as a means for consuming gas and cutting out debris from the cavity is also described. A moving tool is used to provide the flow of a shielding gas and also provide an alternative means for dispersing laser beam before it produces any damage to the work piece[4].

The improvement gives a laser cutter to cutting sheet material that has been bent into a roll. The cutting means contains a laser, and then again a collimator, mounted in a settled edge for conveying a static laser shaft that is focussed onto the sheet material as it disregards a tubular roller. The cutting sample is controlled by an assistant head which mounts reflecting and focussing means and is flexible longitudinally parallel to the material support suggests for moving the inside motivation behind the column longitudinally of the material reinforce infers in synchronism with improvement of the material under the control of bi-directional material nourishment infers. In a favoured alteration, an optical sensor is mounted on the helper head for seeing stamps on the sheet material, the yield of the optical sensor being sent to a control PC which has a yield mode and a cut mode. The yield technique for the PC is specialists to prompt the associate head and the bi-directional sustenance infers in synchronism while the laser is murdered, so that the optical sensor inspects the shape or sample on the sheet material. The delayed consequences of the yield are taken care of in the PC to construct, in the PC memory, a fancied cutting route composed to the shape or illustration on the sheet material; and the cut system for the PC is specialists to enact the helper head and the bi-directional nourishment suggests in synchronism while the laser is ordered, to cut the looked for instance in the sheet material along the needed cutting way[5].

2.2 Background

The laser cutting machine was developed to cut the metal and other material also, the first production laser cutting machine was used to drill holes in diamond dies in 1965.This machine was made by western electric engineering research centre the British pioneered

laser-assisted oxygen jet cutting for metals in 1967[6]. In the early 1970s this technology was put into production to cut titanium for aerospace application at the same time CO_2 laser was adapted to cut the non-metals like textiles and lather because at that time CO_2 laser was not powerful enough to overcome the thermal conductivity of metals [7]. For cutting the metal work piece the sufficient intensity of laser beam needs to fall on the surface of work piece. For sufficient intensity of beam we use coherent laser source which are free from other source of disturbance. Presently highly developed laser cutting machine are mostly used in industrial area, where they are used for mass production. The laser cutting machine is more accurate and precise rather than mechanical cutting and plasma cutting. Earlier CO_2 laser were quite expensive and very few industries could afford them.

2.3 Different types based on laser used in cutting mechanism

There are basically three types laser used in laser cutting mechanism.

CO_2 Laser

This type of laser is generally used in cutting, boring and engraving purpose. The co_2 lasers are used in heavy industries for cutting material like mild steel, aluminium, plastic, stainless steel, titanium, wood and fabrics. A mixture of carbon dioxide, helium and nitrogen is flown out at high velocity by a blower. The laser generator and focus lens require cooling. Generally coolant or air is used for cooling. Water is commonly used for coolant and is circulated through a chiller or heat transfer system.

Fig: 2.1 CO_2 Laser

Laser microjet

This type of laser is a water-jet propelled laser in which a pulsed laser beam is blown at surface of object along with low pressure water jet. Basically it is used where focused cutting is required. The advantage of this type over the other is that no chipping and no micro cracks are developed, no heat affected zone as it is water cooled. Running cost of this laser is very low.

Fig: 2.2 Microjet laser

Fiber lasers

Fiber laser is a type of solid laser which rapidly growing in the metal cutting industry. It uses a solid gain medium as opposed to a gas or liquid. The laser beam produced is amplified within a glass fiber. The wavelength is of 1.064micrometer which produces an extremely small spot size making it ideal for cutting reflective metal materials.

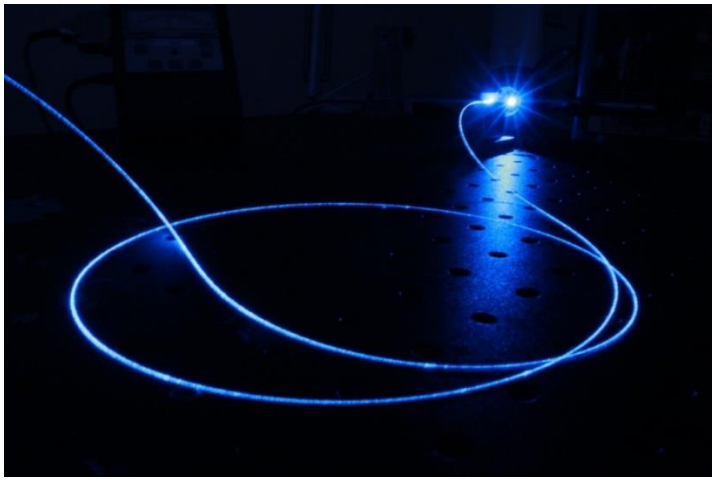

Fig: 2.3 Fiber laser

2.4 Different type based on method of cutting

There are five different type based on different types of cutting.

Stealth dicing of silicon wafers

It utilizes a pulsed Nd:YAG laser which has a wavelength of 1064nm which in turn is well adapted in electronic band gap of silicon. It used in preparing semiconductor devices from silicon wafers.

Melt and blow

It is also called fusion cutting that uses high pressure gas to blow molten material away from cutting spot which in turn greatly decrease the power requirement. This process of cutting requires first the metal to the melting point and then a gas jet blows the molten material away. It is generally used in metal cutting.

Reactive cutting

Termed as burning stabilized laser gas cutting or flame cutting. Reactive cutting is like oxygen torch cutting with laser beam as the ignition source. This is mostly used for cutting carbon steel with thickness over 1mm. it can cut very thick steel plates.

Industrial laser cutting machine

Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications, but is also starting to be used by schools, small businesses, and hobbyists. Laser cutting works by directing the output of a high-power laser most commonly through optics. The laser optics and CNC (computer numerical control) are used to direct the material or the laser beam generated. A typical commercial laser for cutting materials would involve a motion control system to follow a CNC or G-code of the pattern to be cut onto the material. The focused laser beam directed at the material, which then either melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high-quality surface finish. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials. The fig1 shows an industrial cutting machine.

Fig: 2.4 Industrial laser cutter

3. Methodology

3.1 Target population

The product is aimed for students, engineers and as well as common people. The product is designed as low cost easy maintenance lab equipment. The mechanism is kept simple so that even the common man can use the machine with full comfort, effectiveness and safety. The machine being small and portable it can be moved and setup at any place where the user wants.

3.2 Concept sketches

Sketch 1

This sketch here is of the main unit of the system it depicts the attachment where laser nozzle is placed. The laser nozzle consist of laser device which is mounted to a moveable attachment which in term is connected to a servo motor which provides movement to the laser nozzle. The laser used here is optical laser which provides enough heat to melt paper and plastic on which we are going to perform cutting and engraving operation. It is fitted with adjustment screw which helps in height adjustment. The most important component is the lens inside the laser gun.

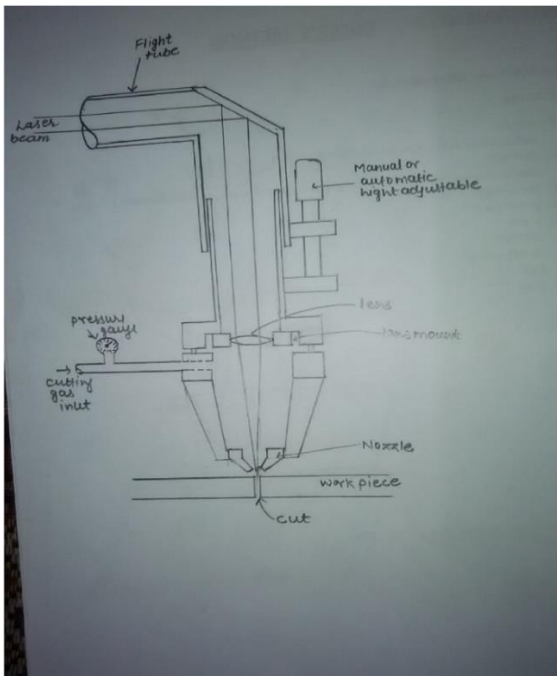

Fig: 3.1 Laser nozzle

Sketch 2

The work bench which is going to hold the material to be cut or engraved is a set of two movable beds which works in combination to one another to perform the desired manipulation required. Each bench is fitted with a servo motor which helps it to move in either x-axis or y-axis. One bed if fitted upon the next one onto which the other one glides while keeping the other bed stationary. The figure5 below show our work bench.

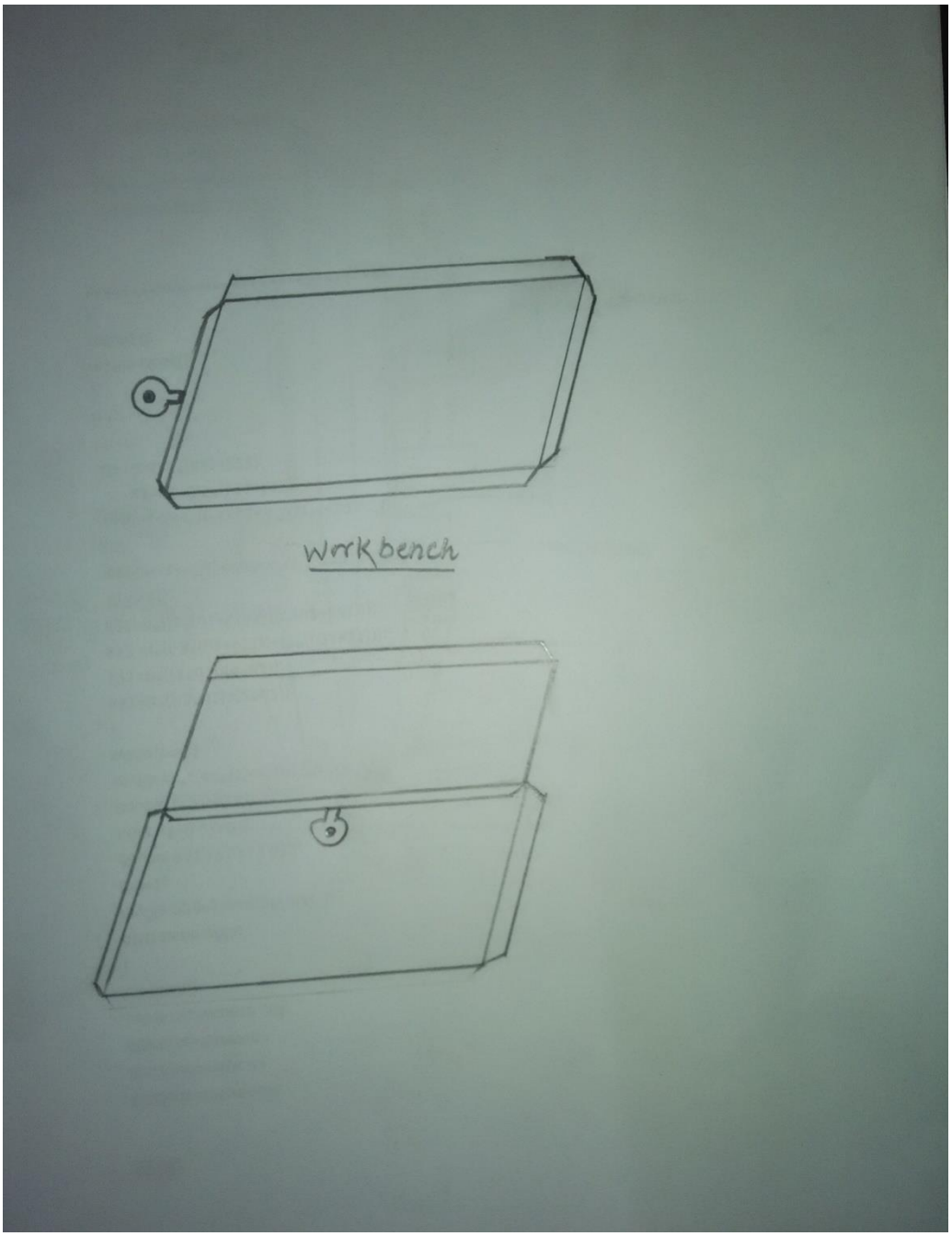

Fig: 3.2 Work bench

Sketch 3

After doing certain refinement in the previous concept and meeting with design restrains we decided to come up with a more improved and better design. In this the platform in modified for y axis movement. The platform is a movable disc tray connected to a stepper motor controlled by a microcontroller. Vertical stands are kept to accommodate laser so that it is perpendicular to the bed or platform. The laser is mounted with help of laser housing and socket securing. This design has more realistic look and stability. The fig below shows the cad model generated for it.

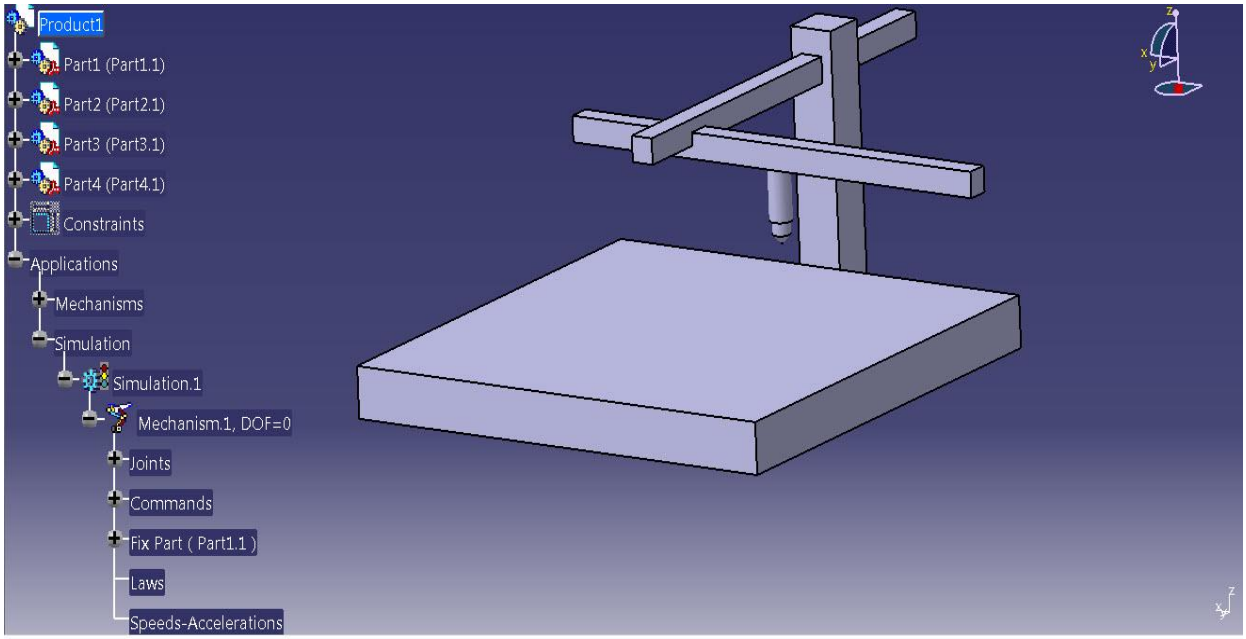

Fig: 3.3 Catia model of concept

3.3 Detail design

Mechanism

The laser beam is condensed by machining lens and while the laser beam thus condensed is being applied to a work piece the laser beam and work piece are moved relative to each other to cut the work piece. The work piece is fixed on the movable platform with help of fasteners or magnets. The movement is achieved from stepper motor attached to it which in turn is controlled by pulsed input from arduino and easy motor drive. The input to arduino is given from a DPDT switch which is used by the user to get the desired movement of the work bench or platform. The platform can move in “Y” axis only. The laser diode is mounted in a laser housing to prevent it from overheating and fro focusing the beam. Laser diode along

with the laser housing is mounted onto the vertical stand which provides movement in “X” axis with help on stepper motor. Here also the movement is controlled by the same as explained above. The code burnt in arduino is basic which involves producing high output when DPDT switch is pressed and the rpm is set once along with the rotation angle. The power is provide from two different power source one being of 3Volts and other being of 12Volts. The 5V power supply is used to provide supply to laser diode which utilises maximum of 3v in forward bias condition. The 12v power is consumed by 2 stepper motor which is used in movement of laser and platform.

3.4 Components used in prototyping

Laser

- The laser beam used in this case is semiconductor laser.
- A lens for guiding the laser beam, and photodiode detecting the light reflection from disc's surface.
- Initially, CD lasers with a wavelength of 780 nm were used, being within infrared range. For DVDs, the wavelength was reduced to 650 nm (red colour), and the wavelength for Blu-ray Disc was reduced to 405 nm (violet colour).
- On read only media (ROM), during the manufacturing process the groove, made of pits is pressed on a flat surface called land. Because the depth of the pits is approximately one-quarter to one-sixth of the laser's wavelength, the reflected beam's phase is shifted in relation to the incoming reading beam, causing mutual destructive interference and reducing the reflected beam's intensity. This is detected by photodiodes that output electrical signals.

Fig: 3.4 Diode laser

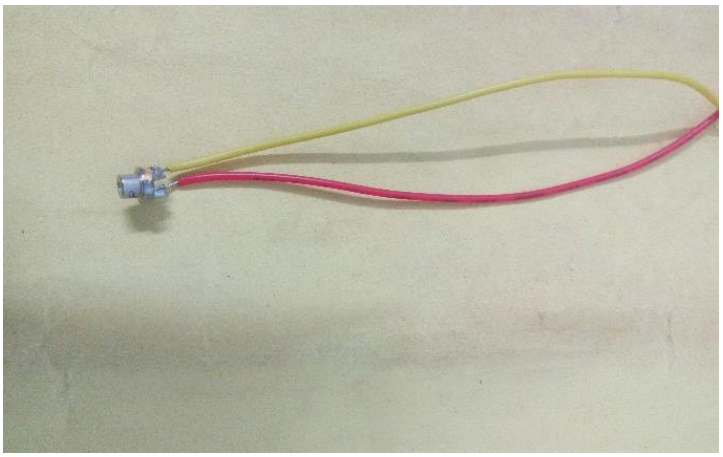

Fig: 3.5 Red diode laser

Stepper motor

A stepper motor is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor (an open-loop controller).

DC brushed motors rotate continuously when DC voltage is applied to their terminals. The stepper motor is known by its important property to convert a train of input pulses (typically square wave pulses) into a precisely defined increment in the shaft position. Each pulse moves the shaft through a fixed angle. Stepper motors effectively have multiple "toothed" electromagnets arranged around a central gear-shaped piece of iron. The electromagnets are energized by an external control circuit, such as a microcontroller. To make the motor shaft turn, first, one electromagnet is given power, which magnetically attracts the gear's teeth. When the gear's teeth are aligned to the first electromagnet, they are slightly offset from the next electromagnet. This means that when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one. From there the process is repeated. Each of those rotations is called a "step", with an integer number of steps making a full rotation. In that way, the motor can be turned by a precise angle.

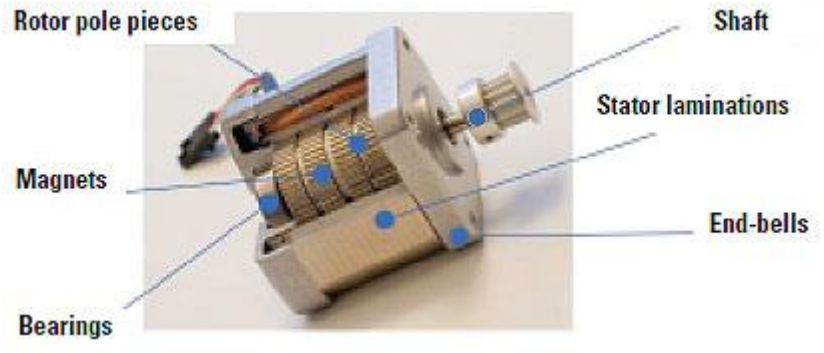

Fig: 3.6 Servo motor

Arduino

Arduino is an open-source computer hardware and software company, project and user community that designs and manufactures kits for building digital devices and interactive objects that can sense and control the physical world. Arduino boards may be purchased preassembled, or as do-it-yourself kits; at the same time.

Arduino programs are written in C or C++. The Arduino IDE comes with a software library called "Wiring" from the original Wiring project, which makes many common input/output operations much easier. Users only need define two functions to make an executable cyclic executive program.

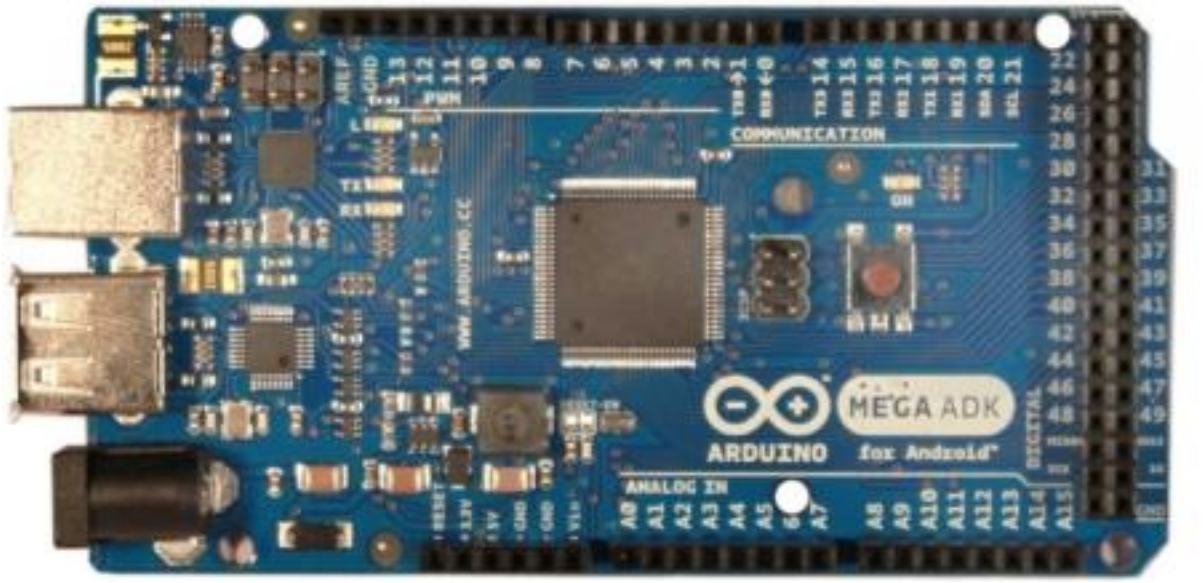

Fig: 3.7 Arduino board

Power supply for laser diode

A set of two AAA sized battery was used to achieve 3volts output for the laser diode. As laser has a limit of around 2.5 volts. The batteries were placed in a socket purchased from

outside. The output was then taken out with help of two soldered wires and directly feed to the laser diode passing through a control switch.

Fig: 3.8 3Volts power source

Power supply for stepper motors

It is DC power output device which converts AC current. The output can be regulated as desired by the user. A rectifier circuit converts AC input into varying DC output which in turn is passed through electronic filter to convert it into unregulated DC voltage. We need a power supply of 12volts for our two stepper motor. The voltage output can be changed by regulating knob.

Fig: 3.9 12Volts D.C supply

Motor driver I.C

L293D is a dual H-bridge motor driver IC which allows DC motor to drive on either direction. Motor drivers act as current amplifiers since they take a low-current control signal

and provide a higher-current signal. Enable pins 1 and 9must be high for motors to start operating. When an enable input is high, the associated driver gets enabled.

Fig: 3.10 Motor driver I.C

DPDT switch

DPDT stands for double pole double throw relay. Relay is an electromagnetic device used to separate two circuit electrically and connect them magnetically. They are often used to interface an electronic circuit, which work at low voltage to an electrical circuit which work at high voltage. There are two section in DPDT switch which are input and output. The input section consist of a coil with two pins which are connected to the ground and input signals. The output section consist of contractors which connect or disconnect mechanically.

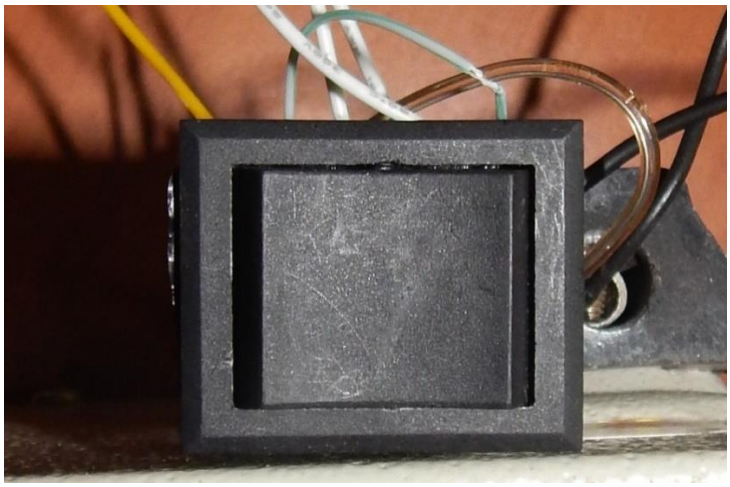

Fig: 3.11 D.P.D.T switch

Working platform

The platform was made from wood as it helps to absorb heat from work piece. The wooden platform is of dimension 30cms in length and 7.5cms in width. It will be better if we use a steel or any other material which has high resistance to fire to prevent it from burning during cutting.

Fig: 3.12Wooden platform

3.5 Prototyping

Following are the steps and method that should be followed for the construction of the prototype:

- The dimension of the frame is listed below. Material used is soft wood other materials can also be used to build the frame. Stainless steel is also used in some parts like support for movement of tracks.
- We will first consider building the basic frame of the prototype. The vertical and horizontal beams on which the steel support system will be screwed.
- The wooden beams are cut according to the dimension and then they are first glued together and the hammered with a medium size nail to secure them properly in their place.

Fig: 3.13 Cutting softwood for frame

- We will now attach the steel guide lines or steel support system to the vertical beams with help of a small drill made into the wooden beam by the help of hand drilling machine and then tightening the screw in its place. The same is then done with repeated with horizontal platform.

Fig: 3.14 Drilling holes for screw

- The support system consists of a steel platform on which a stepper motor is place which is attached to a shaft which drives the platform.
- After the support systems are fixed into position the laser housing is fixed with moving parts of vertical support system.
- Now we will attach our soft wood platform (working bed) onto the horizontal support system with help of some additive.

- We will connect of the stepper motor with 1st motor driver IC to the pin no (7&12) and the other stepper motor with 2nd motor driver IC to the pin (7&12).
- Laser is connected to the 3 volt battery supply with red wire being the positive end of laser to the positive terminal and the black wire which is negative end to negative terminal of the battery supply.
- Arduino is connected to both motor drivers and the external D.C supply of 12volts. The pin arrangement is set as (11-8) for motor driver1 and (7-4) for motor driver.
- Program is written in arduino burning software in computer and then the program is burned into the arduino chip.
- Movement is checked with the D.P.D.t switch.
- The prototype is now ready for use.

3.6 Dimensions

Vertical beam length = 18cms

Breadth of vertical beam = 1.5cms

Horizontal platform length = 21cms

Breadth of platform = 9cms

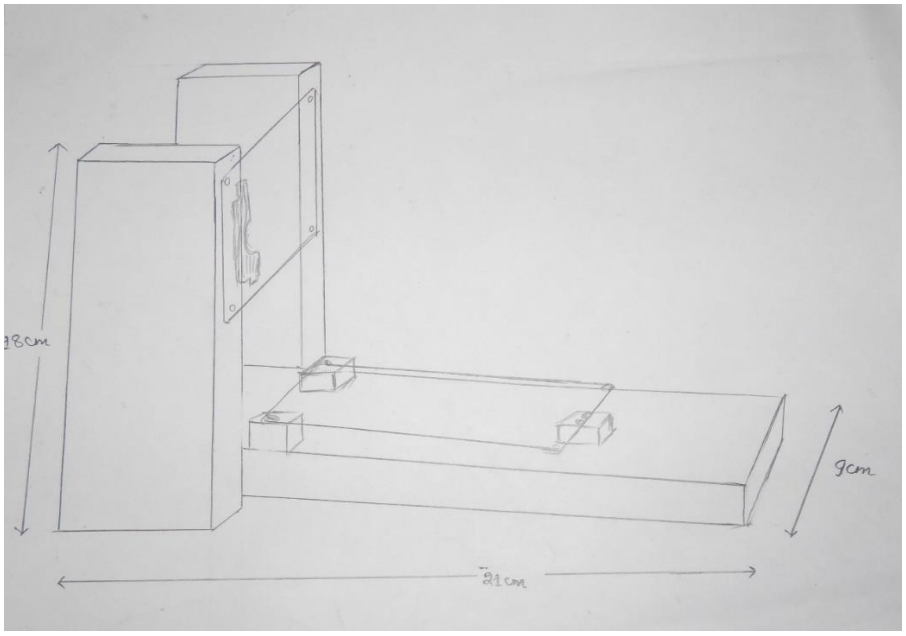

Fig: 3.15 Side view

4. Result and Discussion

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 burns 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 pocket. 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 cutter. It was not as easy task as it involved arduino programming and c code writing but with help of our supervisor and friend the desired prototype was made.

Advantage:

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

Disadvantages:

- Depth of penetration is low.
- Available for only soft material like polystyrene.
- Works only with D.C supply

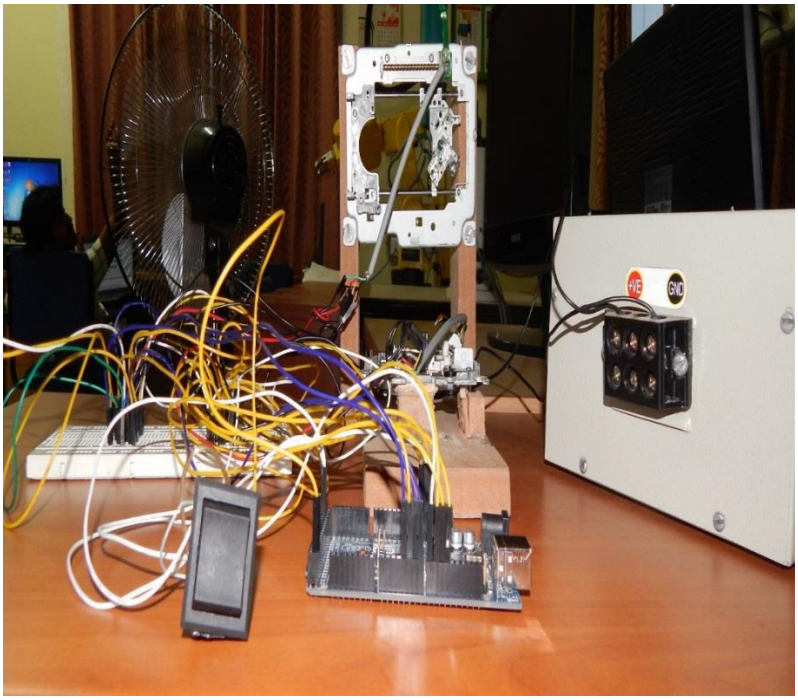

Fig: 4.1 Final product

5. Future Scope of Work

Present design can be modified in various ways as there is no end to innovation. The most important aspect to be worked upon is the control of laser movement, from manual to automatic or input to be feed from modelling software. This will help to achieve accuracy and increase the usefulness of the machine. As laser cutting is an exothermic process, a lot of heat is generated during the process so to reduce the heat a cooling system should be introduced to decapitate the heat produced. It was seen during the experiments that long working on laser causes the diode to stop working so better laser diode should be used. As there is no end to this modification, as need is felt the improvement work is carried on.

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