

INDUSTRY 4.0 INDIUM GALLIUM NITRIDE DIODE LASER ENGRAVER

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Abstract

Laser engraving is an advanced technology in material processing that involves removal of material layer by layer. The aim of this research paper is to obtain digitally designed patterns and pictures on materials using InGaN (indium gallium nitride) laser module and to measure certain characteristic features of this advance laser technology. A novel tabletop CNC laser milling machine is specially built up to for using the laser engraving. The time taken to complete the engraving operation is measured using different techniques for different resolution in the design. The adaption of internet of things and Industry 4.0 featured a low-cost CNC laser engraver is special useful for learners to explore further research on the laser field.

Keywords: CNC, laser engraver, InGaN laser, portable engravers.

1. Introduction

Planck has given the idea of quanta in 1900 in 1920 it was all around acknowledged that separated from wavelike attributes of light it additionally shows molecule nature while collaborating with issue and trade energy in the structure of photons. The underlying establishment of laser hypothesis was laid by Einstein who has given the idea of animated discharge. Townes and Schawlow (1957) delivered the first laser known as Ruby laser.

Laser (Light Amplification by Stimulated Emission of Radiation) is basically a device which generates, amplifies radiations in the region of the electromagnetic spectrum. Lasers come in variety of forms with variation in different laser material used, different atomic system and the different kind of pumping and excitation techniques. Laser beams have properties like remarkable intensity, directionality, and spectral purity. Laser consists of medium of appropriate collection of atoms, ions, molecules or in some cases a semiconducting crystal. There is a pumping process which excites these atoms or molecules or ions to a higher

quantum-mechanical energy level. There is an optical medium which helps in laser amplification, or which helps in laser oscillation.

There are different of lasers using non-identical components configuration which produces discrete wavelengths, and these wavelengths are acceptable for different materials. A diode laser is a semiconductor device, like LED. This uses p-n junction to release light wherein all the waves are in the same phase and frequency. And since it uses p-n junction, it is called as laser diode. Laser diodes are dominating the market at consumer-level due to their availability, portability and can be fixed on different machines. However, they cannot engrave all the materials. Some reflective or translucent materials are ineffective to work with this laser. But engraving can be done on these materials with some modifications. Since laser diode operates under visible light spectrum, shielding the machine is not compulsory but a safety eye glass is mandatory for continuous operation.

The second type of laser is CO₂ LASER. CO₂ lasers are very flexible. This uses high power to engrave the material. This can easily cut designs on wood and other materials. The CO₂ operates in the infrared region which means the light is invisible and harmful as well. The machine must be in the enclosure while operating. These lasers tend to heat when used for a long time hence they require a coolant which can help in heat dissipation. They can produce results quickly due to their high power. The third type of laser is fibre laser. This is mostly used in industries for cutting and engraving. This being multifaceted, proves to be more efficient than other types of lasers. Its efficiency is good because of the microscopic focal diameter and good intensity. Conventional engraving technique includes hand engraving which is considered to be one oldest and most daunting method. It requires skilled artisans and an engraving tool of required size. It is obvious the fact that the final product that is obtained using this technique is not as accurate as done by a CNC machine and since a skilled artisan is required it is easily the most expensive technique that is available. It also includes rotary Machine Engraving which involves a tool controlled by a machine to create the desired engraving. CNC laser engraving on the other hand is an advanced form of engraving. It involves the removal of material from the top layer of a material surface down to a specified depth based on requirement. Today CNC technology incorporates networking and open-source technology by which researchers can redesign the existing machines for any other manufacturing applications.

Gallium nitride (GaN) laser diodes are becoming popular sources not only for lighting but for applications ranging from communications to quantum and to laser engraving. This paper presents the use of a commercial, off-the-shelf InGaN laser diode, with an emission wavelength of 445 nm.

InGaN (indium gallium nitride) laser is a diode laser which emits blue light, and it is grown on a GaN buffer on a transparent substrate. Using the 445nm and 2W variant of this laser module. This laser diode is relatively unaffected to operating temperatures compared to other high-power semiconductor lasers and has case operating range of -10°C to 75°C. It produces a continuous beam, has a dot beam shape and it has a lifetime of 10000 hours.

2. Review of CNC laser engraving

Dharmesh K. Patel et al. [1] have investigated the parametric optimization of laser engraving process for different material in which it was found that the laser engraved depth became deeper for either high powered laser or a lower feed speed ratio. F. Agalianos et al. [2] have studied the industrial application of laser

engraving technique and found that the surface roughness strongly depends on the frequency and the scan speed used. S. Genna et al. [3] have inferred the fibre laser machining of C45 steel and the influence of process parameters on material rate and roughness. C.Leone et al. [4] inspected wood engraving using Q-switched diode in which it was found that an accurate selection of wood type and the process parameters is necessary to obtain deep engraving without carbonization and a homogenous carving. Cheng-Jung et al. [5] examined the effects of speed ratio and laser power on engraved depth and colour difference of Moso Bamboo lamina in which it was found that the either of the power or the feed speed is varied inversely with respect to each other can have a better burnt surface or more depth. Mohd Ashraf B et al. [6] explored CO2 laser engraving of stainless steel 304 and studied the effect of various parameters on the characteristics of engraving in which it was found that the characteristics differ despite using the same parameters combination.

The review of the literature reveals that a number of researchers have worked on different materials using different laser modules and materials; studies were conducted on the effects of various parameters on the materials. In the present paper a low-cost CNC laser engraver machine is built using internet of things and the features of Industry 4.0 aspects. InGaN Laser diode is directly procured and used to study the engraving operation by varying the design parameters.

3. Methodology

In the present paper the CNC machine is constructed in three stages: (a) building mechanical frame, (b) assembling electric system and (c) installing control and computing unit. The mechanical frame is made using PVC sheets which are cut using Shopbot PRSalpha Gantry milling machine. The other components such as the guide rods and lead screws are cut according to the dimensions of the frame. The InGaN laser is fixed to the z-axis and is not intended to traverse along it as it may disturb the focus of the laser leading to poor finish. So, stepper motor is omitted from this axis. However, a lead screw and t-nut are fixed which gives the z-axis extra stability by mitigating any vibration produced by the other motors. The working table which holds the material to be engraved is a movable bed which moves along the y-axis, whose motion is completely controlled by the stepper motor. The vertical stand also called as the gantry, which holds the laser is perpendicular to the moving bed. The laser engraver is constructed in a way that all the 3-axis movements are attained by utilizing the guide rods and linear bearings. The motors are the source of motion as they act according to the control signal produced from the electronics circuit. Each motor is combined with the lead screws which carry a nut known as T-nut, coupled with coupling bush. This screw and the nut positioning are accountable for converting rotational motion to linear motion. In each axis, the linear motion is transferred away evenly by the guide rod and the linear bearing. In each axis, the controlled motion is attained directly by managing the number of turns done by the stepper motor. The assembled CNC machine for Laser engraving is shown in Figure2.

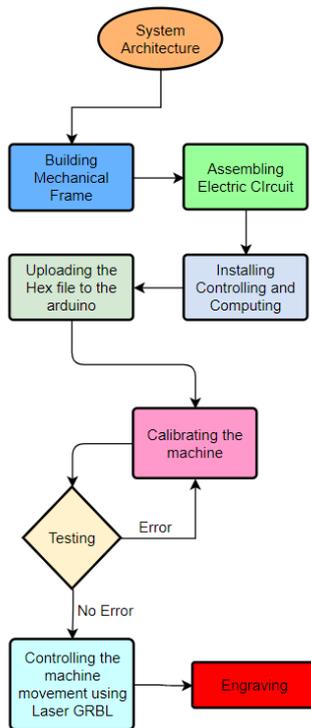


Figure 1: Flow chart representation of the methodology

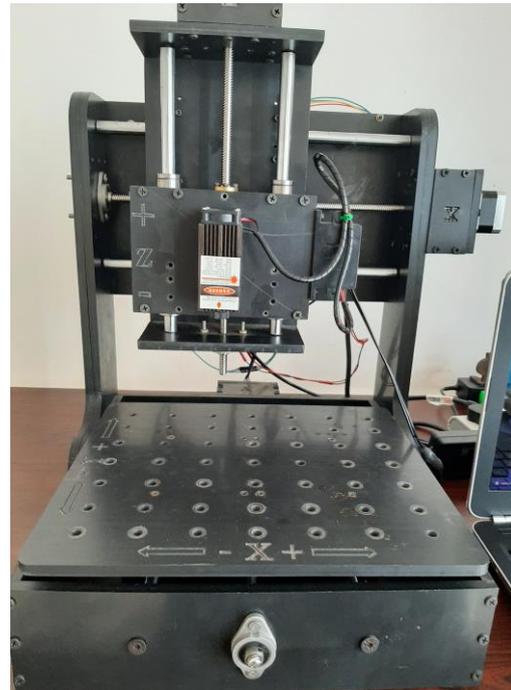


Figure 2: CNC Laser Engraver

The electronic hardware used are Stepper motor NEMA 17, Stepper motor driver TB6560, Switched-mode Power Supply (SMPS), Arduino Uno AT mega 328p, Bluetooth module HC-05. Arduino is an open-source gadgets stage dependent on simple to-utilize equipment and programming. Arduino can understand inputs like light on a sensor, a finger on a catch, or a Twitter message - and transform it into a yield. The yield can be actuating an engine, turning on a LED or distributing something on the web. Arduino board can be guided by sending a bunch of directions to the microcontroller on the board.

The stepper motor driver is an integral part of the setup. It provides the stepper motor the required voltage and current for smooth functioning of the motor. The DC power supply is associated between +24 V and Ground, and the engine Phase A (B) windings are associated among A+ and A- (B+ and B-). The associations with CLK+ and CLK-pins control the venturing movement (known as heartbeat, PUL, in some different drivers), while the associations with CW+ (counter-clockwise) and CW-(clockwise) pins control the course of movement. The EN+ (handicap) and EN-(empower) show the enable pulse connections, however it is not important to utilize them on account of Arduino program-based control.

The slide changes SW1 to SW3 regarding plunge switch S1 are utilized for controlling the running current from 0.3 A up to 3A. Switch S2 is utilized to control the stop current (ON: 20%, OFF: half), S3 and S4 are utilized to set the excitation mode (from entire to 1/16 stages), and S5 and S6 are utilized to control the decay setting.

The arrangements of switches in the stepper motor driver in a certain way is very important because when not arranged according to the data sheet, the current sent to the motor is not apt and hence, the motor tends to produce irregular movement during movement. Figure-3 shows the configuration of the stepper motor driver that has been utilized in the current machine based on the data sheet of the stepper motor.

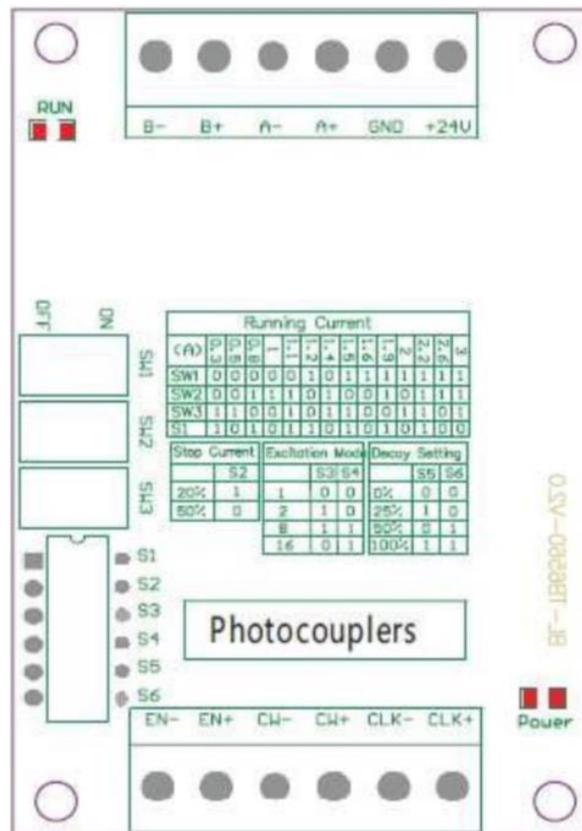


Figure 3: Configuration of stepper motor driver

4. CNC Engraver Control Software

For engraving purpose, an open-source software called LaserGRBL is used. It has a rich set of tools which allow engraving with different resolution on the specimen. LaserGRBL utility window is shown in. This

software directly instructs the engraving machine to engrave. It first needs to be connected to the CNC engraving machine by providing the COM port number. After this the Baud range to set the laser intensity. The saved picture that is to be engraved on the specimen is opened using the software; a suitable tracing tool is then selected. All the parameters related to engraving like feed rate, tracing tool type are selected appropriately. The software then generates the G-codes, and the tool movement which can be visualized on the software as shown in Fig-4.

The G-codes are sent to the Arduino via USB. The Arduino with the grbl firmware interprets and translates and consequently drives the stepper motor, controls the movement of the laser and laser power modulation.

Prior to starting the actual engraving operation, the machine must be calibrated for accuracy. This can be done by using the concept of travel in millimetre corresponding to the rotation of the motor. To calculate the following formula is used, Steps per mm = [(steps per/rev)/mm per rev]/ micro step fraction. The distance travelled is physically measured with a scale and compared with the input given. If the measured value matched the input value, then the machine is said to be calibrated and if not, the procedure is repeated. Now once this is done, the official settings need to be altered by entering the respective axis (step/mm) in command and changing its pre-set value. This procedure is repeated for each axis.

Once the machine is calibrated, it can be used for engraving purposes. The engraving can be obtained on the specimen by following all the procedures from generation of G-codes of the image to engraving. Materials which are not lustrous and non-metallic are preferred for engraving using this laser unit. The specimen is firmly clamped on to the bed before the operation is started. The engraving is then started, and the pattern is obtained on the specimen. There are various ways of realization of laser engraving on the surface of products like Line-to-tracing, dithering tool, Vector edging.

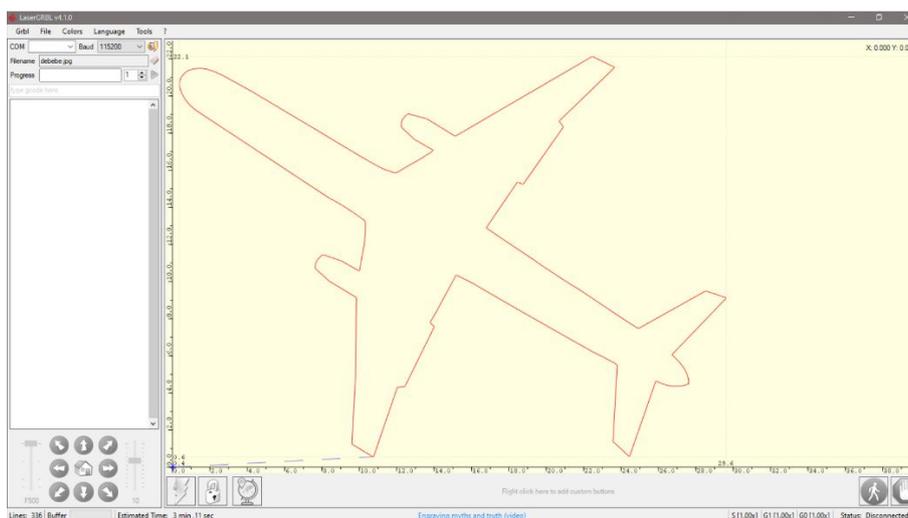


Figure 4: A representation of vector edging

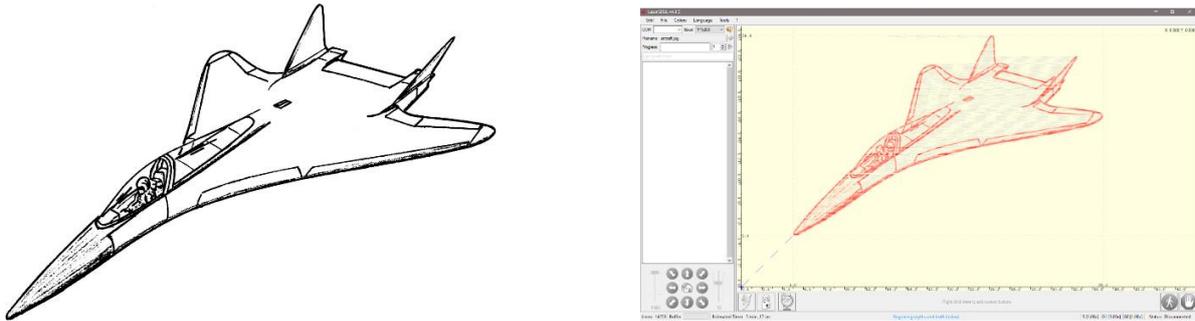


Figure 5: Comparison between original image and Line-to-Line tracing

Certain materials do not react linearly to the laser, for such materials we use dithering tool. This technique involves reproducing the shades of grey by pixelating images of very short dots. The resolution produced is not as good as line-to-line tracing but it a good bargain since this technique takes less time.

Vector Edging: Unlike line-to-line tracing, vector edging is a technique that involves tracing the edges of the design onto the surface of the material. It works well with raster design since it creates areas which look distinct; it also works well for outlines and areas which do not need any filling.

For execution of laser engraving, it is important for material to retain a bigger measure of energy in the zone of the preparing than when executing laser checking. Expulsion of material by vanishing happens simultaneously. With this strategy, the engraved channel is obtained in the specimen as shown in figure- 6. The fundamental benefit of laser engraving is that it can be done at high speed. Albeit this technique seems, by all account, to be the liveliest laser checking method, it cannot be seen shading the treatment zone because of the interaction. Laser engraving can be determined by touch or low power microscope. Laser engraving is not suggested for use on parts with thickness less than 2.5mm.

4. Conclusion

With the advancement of technology, it is now possible to build CNC machine that are more portable and are available at a very low cost so much so that even the public can afford it apart from the researchers. In a comparison done among the tracing tools it is found that line-to-line tracing takes more time followed by vector edging followed by centreline tracing, also the resolution of line-to-line tracing is much better than vector edging and centreline tracing. Laser engraving can also be included in curriculums of institution which deal with art and crafts and even in institutions which deal with material processing to teach the students about laser engravers. Students can learn how to transfers digital designs to different materials. Getting an exposure to these technologies can help the students combine art and technology.

Laser engraving proves to be a viable option as an alternative to the various conventional printmaking and décor technique. InGaN laser head promises to give economic CNC laser engraver for research work. This research includes the mechanical assembly, the electronics assembly, the software integration, real time simulation and finally the realisation of the print on the specimen. In the future work it is possible to use more powerful laser which will have the ability to cut through steels or engrave on lustrous materials or lasers which

support power modulation. In addition to that, machine learning and artificial intelligence concepts can be incorporated with the CNC which would enhance the performance.

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