UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LASER ENGRAVING MACHINE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Electronic Engineering Technology (Industrial Electronic) (Hons.)

by

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This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electronic Engineering Technology (Industrial Electronic) (Hons.). The member of the supervisory is as follow:

……

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ABSTRAK

Ukiran laser ialah amalan menggunakan laser untuk mengukir atau menanda objek. Sistem kawalan CNC digunakan untuk mengawal pergerakan laser. Laser pengukir adalah alat yang boleh memotong kertas, mengukir kayu dan plastik. Menggunakan laser, proses ukiran yang tepat dan kemas boleh diperolehi. Projek ini adalah bertujuan untuk membina sebuah mesin yang boleh melakukan ukiran laser tersebut dengan kos yang minimum dengan sekurang-kurangnya boleh melakukan fungsi yang dinyatakan. Ia dikawal menggunakan "Raspberry Pi" yang merupakan pusat kawalan utama bagi mesin ini. Sampel ukiran dilampirkan kepada paksi x - jadi ia hanya bergerak dalam arah tersebut manakala laser dilampirkan kepada paksi y jadi ia hanya bergerak arah paksi y. Dua motor telah digunakan untuk menggerakkan kedua-dua paksi x dan paksi-y. Laser yang digunakan diambil dari dvd rom yang mempunyai kuasa keluaran 200 mW. Laser ini sesuai untuk projek ini kerana ia mampu mencapai objektif yang dikehendaki.

ABSTRACT

Laser engraving is the practice of using lasers to engrave or mark an object. A CNC control system is used to drive the movement of the laser head. Laser engraver is a device that can cut paper, engrave wood and plastic. Using laser, the engraving process will be very precise and clean can be achieved. This project was aim to build a machine that can do laser engraving with a minimal cost at least can do the stated function. It is controlled using a Raspberry PI which is the main control centre for the machine. The engraving sample is attached to x-axis so it only moves in x direction while the laser is attached to y axis so it only moves in y direction. Two stepper motor were used for moving both the x-axis and y-axis. A laser diode used was taken from computer dvd-rw that has output power 200 mW. From my findings, this low power laser diode is suitable for my project as it is able to achieve the objective. This laser engraver machine should be able to do marking that would have been done by other processes.

ACKNOWLEDGEMENT

Throughout the whole process of the final year project, I had gained a lot of knowledge and experience. Unlike the ordinary course subject, final year project are able to train us in independently and practically on handling a project. This is a very valuable and precious experience where it cannot be obtain in ordinary studies or books and it would be a good training for the undergraduate student before entering their career life. Hence, I would like to express my deepest gratitude to Mr Tengku Mohd Faisal bin Tengku Wook, my supervisor. During carrying out my project, Mr Tengku Mohd Faisal is a great source of support and guidance where he taught me on how to handle a project effectively, how to deal with problems, and idea with his optimism and humour. Next, I would like to express my gratitude to all my friends. Although we are handling different part in this project title, throughout the whole progress we are helping each other and learning together in order to bring a great success to this project.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AEL	-	Accessible Emission Levels
CAD	-	Computer Aided Design
CD	-	Compact Disc
CNC	-	Computer Numerical Control
CPU	-	Central Processing Unit
DVD-RW	-	Digital Versatile Disc Rewriteable
GPIO	-	General Pin Input Output
HDMI	-	High Definition Multimedia Interface
IO	-	Input Output
PCB	-	Printed Circuit Board
RAM	-	Random Access Memory
SOC	-	System on Chip
UART	-	Universal Asynchronous Receiver Transmitter
USB	-	Universal Serial Bus
UV	-	Ultra Violet

CHAPTER 1
INTRODUCTION

This chapter covers introduction to final year project. To outline the chapter, we will first discuss the background of the project. It is followed by the problem that is trying to be solved. Next, the objective will be presented. The remaining sections describe the work scope, short explanation on project methodology and the structure of this report.

1.1 Background of The Study

Laser engraving is one of the process that cut material through a thermal cutting process in higher quality and precision than any other thermal cutting process. Engraving is a process of incising a design into a hard surface normally a flat surface. The design on the surface is permanent and cannot be remove. The surface is burned using a precise laser which then create a sculpture effect as it were done using traditional method chisel and hammer.

This project uses laser as the main component for engraving purpose. A low power laser diode was used to do the specific task as paper cutting, wood engraving and plastic engraving. A laser is device that can emit light through a process of optical implication based on the stimulated emission of electromagnetic radiation. To be able for engraving purposes a suitable laser need to be chosen to carry out the specific task. There are many different types of laser and classification. The normal laser that normally used for pointer in the presentation is not same as the laser used in the dvd-rom to write data. There are also laser that used in medical field. Laser beam is very

bright and can be seen in the bright condition. It can damage eyes if point directly to eyes. Normally the laser pointer power is restricted to not exceed 5 mW. With this power, it cannot be used for engraving purposes. So for my project, laser diode is taken from computer dvd rom burner. It has power rated at about 200 mW and it is able to cut paper, engrave wood and engrave plastic.

The machine that will be built for this project included some component to function properly. The most important component is the laser diode. It is the medium to transfer the design virtually into a real design that can be touch and sees. This machine will have two stepper motor that will move the laser in x-axis and y-axis direction. The motor is control by Computer Numerical Control (CNC). CNC convert design produced virtually using computer into number. The number that was converted used as the coordinate for the movement of the motor. In this way, the CNC control the laser for the cutting or engraving purposes.

1.2 Problem Statement

The ideas for this project come after my finding to find a cheap laser engraving service. For a small quantity of engraving, the cost would not be cheap. By making a small machine that could do laser engraving with a small cost this project hope to solve this problem. Many of the part are taken from used part such as laser diode and motor. This would be reduced the cost to make the machine to the minimum as possible.

From this project, it will benefit user that want to do laser engraving at their convenience. As this machine is small, it is also portable and can be bring anywhere when there is a need. This machine does not suitable for a large quantity of item that need to be engraved. It still has some limitation that make it only suitable for small quantity and size of the item that need to be engraved. One of the limitation is the time. Time taken for the laser machine to start operating until finish engraving is too long. It is because the laser take time to burn the surface of an object. Using low power laser cause the engraving process longer. Since the laser diode only has a power of about 200 mW it can only engrave thin and soft object. The laser does not have enough power to cut thick and though object. To keep laser diode to working at its maximum capacity,

the surface of engraved object is preferred to be black so that it can absorb as much power of laser as possible. Due to the limit size of DVD drives that were used, the area of engraving is only limited to 36 millimetre by 36 millimetre. So it can only engrave on a little pieces of wood or plastic but not any larger than that size dimension.

1.3 Objective

There are several objective needed to be achieve in this project. The objective is as follow :

(a) To build a cheap machine for laser engraving.
Currently a laser machine does not come with affordable price for regular user. By using a used component taken from unused item the cost to build the machine will be reduced as much as possible.

(b) To do engraving on an object.
This machine should at least can do engraving on the surface of wood, plastic and acrylic. The surface of wood must be thin and soft to do the engraving. This low power laser cannot do engraving on thick and hard object.

(c) To build portable laser engraving machine.
The machine will be build small and lightweight. So it will be easy to bring this machine to anywhere. It is simple machine with its main component laser, motor and the raspberry pi.

1.4 Scope

The scope of this project is to build a machine that will function properly based on the objective and to solve problem faced. This project using a laser diode found in dvdrom or cdrom and motor that can be used to move x axis and y axis for engraving an object. The main part that control the movement of the laser diode is raspberry pi. With raspberry pi which is actually a small computer that has operating system using a linux, the design and control is handled fully within this device. Lastly, the final product need to be tested to make sure that it will function as stated in the objective.

In this project, it only focuses on low power laser diode. A laser diode used in dvdrom is about 200 mW. With this power it can be used for my project. From the dvd burner two laser diode can be found, one is infrared that is used to burn CD and red laser that is used to burn DVD. Light from infrared is invisible and cannot be seen by naked eyes while the laser used to burn dvd is visible to human eyes. Both of this laser diode are very dangerous to eyes. The light emit whether it is visible or invisible can cause injuries to eyes and may cause permanent damage. The beam from laser diode can cause burn of fire so it should be used with care to avoid any unintended fire. There are different classes of laser depending of their power and wavelength. The laser used in this project is in class IIIb. Laser in this class generally have power below 500mW. As mention earlier, the laser power taken from dvd burner is about 200 mW.

For controlling all the operation of the laser and motor, there is a brain that do all the processing. This machine control by computer numerical control. This means the design produced virtually using software converted into numbers as a coordinate to control the movement of the motor which move in x-axis and y-axis. For controlling the CNC, raspberry pi were used. This raspberry pi can support complete operating system to operate. So it actually a computer but in a small size and not very powerful compared to normal computer. But it is not about it performance to do normal routine such as a computer can do instead it is mainly used for electronic project. There are General purpose input output (GPIO) pin in this device to interface with physical. GPIO handle interfacing with the pins. Here the GPIO pins were used to move the motor based on the design which is then converted into numbers of coordinate.

CHAPTER 2
LITERATURE REVIEW

Literature review can be defined as a background study about the knowledge and information needed to develop a project. To develop a complete and functional project it is necessary to writing literature review to go through before starting project analysis and design. This chapter will focus on the theory of each part and software used in my project. The sources from theory are taken from book, journal, article and website that are relevant. Besides, methods and tools used to handle project are described and discussed.

2.1 Study On Laser Engraving

Mihaiela Iliescu states Holograms and holography become more and more important for nowadays life, especially because of their role in security and protection. Some research results on holograms laser engraving process parameters are evidenced by this paper. Application of holography and holograms is very wide, covering: security and product authentication, packaging - consumer goods brand protection, art and interactive graphics, etc. This paper is a study on hologram marks, more specifically, on hologram laser engraving process parameters. In order to obtain high resolution engraving results low speed, high frequency and small pulse duration of the laser beam should be used. (Mihaiela, 2010)

In an extensive study of Lin Li presents a review of the direct applications of high-power diode lasers for materials processing including soldering, surface modification (hardening, cladding, glazing and wetting modifications), welding,

scribing, sheet metal bending, marking, engraving; paint stripping, powder sintering, synthesis, brazing and machining. A review on high-power diode laser applications for materials processing has been carried out. These features include better surface finish, less heat-affected zone, better beam absorption, better morphological characteristics, more consistent and repeatable results, fewer cracks and less porosity generation. The weaknesses of the high-power diode lasers include high beam divergence (thus difficult to focus to a small beam size), beam absorption dependent on work piece colours and the difficulty to produce very high-peak-powered short-pulsed beam directly. (Lin, 2000)

Janez Diaci present a novel method for rapid and flexible laser marking and engraving of tilted, curved and freeform work-piece surfaces. A low power CW laser regime is used to measure the 3D shape of a work-piece surface while a high-peak power- pulsed laser regime is used for processing. This paper discusses key issues concerning an implementation of the method and presents typical examples of markings and engravings. A novel method is presented that allows rapid and flexible laser marking and engraving of tilted, curved and freeform work- piece surfaces. (Janez, 2011)

Li Mingwei in his study, bamboo lamina was engraved using various laser output power levels in conjunction with various feed speed ratios in order to understand the effects of feed speed ratio and laser output power on engraved depth and color difference. The results showed that the engraved depth became deeper for either higher laser power or a lower feed speed ratio. Moreover, the color difference values increased under a lower feed speed ratio and higher power, and resulted in a brownish color in the engraved zone. The average engraved depth and color difference values were 0.69–0.86mm and 46.9–51.9 pixels by different engraving parameters respectively. (Mingwei, 2008)

2.2 Laser

Laser is an acronym for Light Amplification by Stimulated Emission of Radiation. It is difference from ordinary light in that it consists of photons that are all the same frequency and phase. A laser emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. Lasers differ from other sources of light because they emit light coherently. Spatial coherence allows a laser to be focused to a tight spot, enabling applications like laser cutting and lithography (Siegman & Anthony, 1986). Spatial coherence also allows a laser beam to stay narrow over long distances, enabling applications such as laser pointers.

Laser light is very different from the kind of light that a regular lamp gives off. Ordinary light photons are emitted without any pattern but laser light is organized in a coherent manner so that each photon follows the same course as the other, like well-trained troops marching. Additionally, ordinary light is diffused without specific direction unlike light from a laser, which is compact and directional with a tight beam. Laser light is monochromatic (all one colour) because it is all one wavelength as determined by the amount of energy released

The laser allows the easy reproduction of a computer generated shape or image onto a material without physical contact with the surface. This allows complex shapes to be imprinted or cut from delicate and flexible materials such as paper and thin plastics allowing complex shapes to be created in fine detail (Steen, 1998). It is often used for architectural model making and even the cutting/engraving of fabrics. The other advantage of a laser cutter is that there is no physical cutting tool to be sharpened or replaced. Provided the optics are clean and focussed it will cut crisply every time.

Lasers are also used to cut metals and other solid materials but the power required is much more. With 60 watts, it have the ability to cut wood and plastic up to around 10mm, this vary according to the consistency of the material, some woods produce low quality result due to the release of the sap and resins in the timber burning and charring the surface (Zhou & Yusoff, 2006).

2.2.1 Type of Laser

2.2.1.1 Gas laser

Gas lasers use low density gaseous materials as active media. Line widths are much narrower as compared to solid state, dye and semiconductor lasers. Main broadening mechanism is the Doppler Effect. Due to narrow line widths, optical pumping would be very inefficient. Instead, electrical pumping (continuous, RF or pulsed) is used. The gas lasers can be made from neutral atoms (He-Ne, metal vapor etc), ions (e.g. Ar+) or molecules (e.g. CO2).

2.2.1.2 Semiconductor laser

Semiconductor lasers are one of the most important laser types today. They can be used directly in applications, as well as to pump solid state lasers. To work as laser active media, semiconductors must have a direct band gap so that elements like Si and Ge would not work. Emission wavelengths are in the range 630 – 1600 nm. Majority of semiconductor laser use compounds of III-V elements (Al, Ga, In ... – N, P, As, Sb ...). Other compounds are rare but possible. II-IV compounds yield shorter, IV-VI Wavelength yield longer wavelengths.

2.2.1.3 Solid state laser

Solid state laser use high density solid as active laser materials. Ions are introduced as an impurity into host materials, which can be crystalline or glass. Semiconductors are excluded since their energy levels are quite different. Ions of transition elements particularly rare earth elements or transition metal are most commonly used as dopants. They are typically electric dipole forbidden so they have very long lifetimes. Glasses are easier to fabricate but crystals have better thermal properties.

2.2.2 Component of Laser

As shown in figure 2.1, the three basic components of a laser are:

- Lasing material (crystal, gas, semiconductor, dye)
- Pump source (adds energy to the lasing material, e.g. flash lamp, electrical current to cause electron collisions, radiation from a laser, etc.)
- Optical cavity consisting of reflectors to act as the feedback mechanism for light amplification

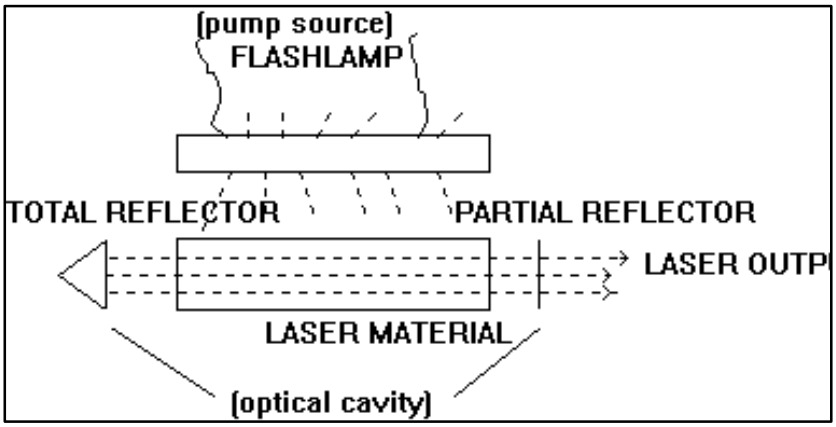

Figure 2.1: Solid state laser diagram

Electrons in the atoms of the lasing material normally reside in a steady-state lower energy level. When light energy from the flash lamp is added to the atoms of the lasing material, the majority of the electrons are excited to a higher energy level a phenomenon known as population inversion. This is an unstable condition for these electrons. They will stay in this state for a short time and then decay back to their original energy state. This decay occurs in two ways: spontaneous decay and stimulated decay. This stimulated transition will release energy in the form of photons of light that travel in phase at the same wavelength and in the same direction as the incident photon. If the direction is parallel to the optical axis, the emitted photons travel back and forth in the optical cavity through the lasing material between the totally reflecting mirror and the partially reflecting mirror (Townes & Homes, 1999). The light energy is amplified in this manner until sufficient energy is built up for a burst of laser light to be transmitted through the partially reflecting mirror.

As shown in figure 2.2, a lasing medium must have at least one excited (metastable) state where electrons can be trapped long enough (microseconds to milliseconds) for a population inversion to occur. Although laser action is possible with only two energy levels, most lasers have four or more levels.

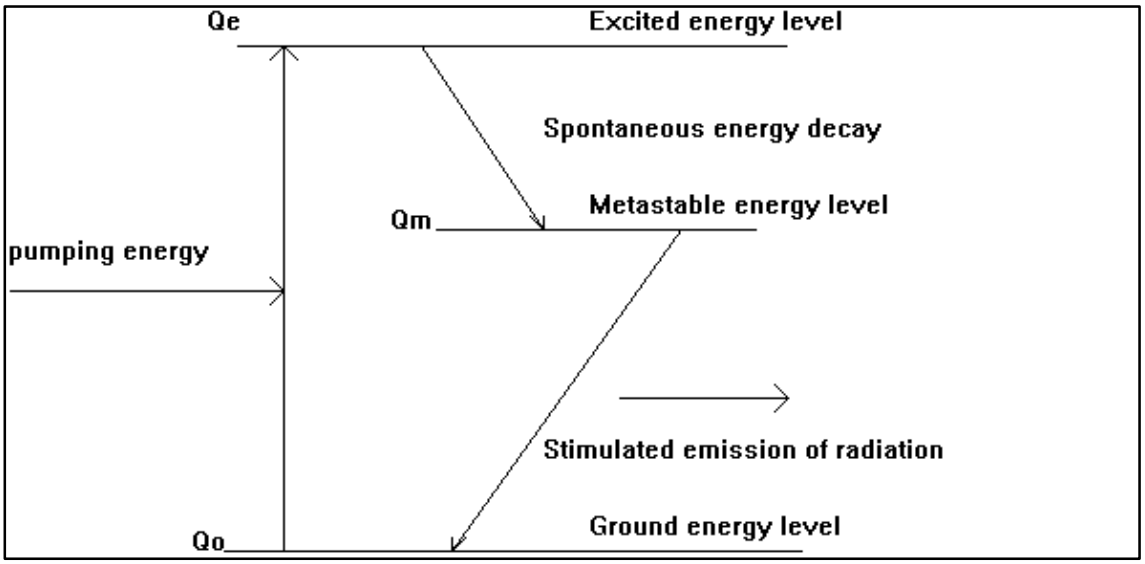

Figure 2.2: Three level laser energy diagram

A Q-switch in the optical path is a method of providing laser pulses of an extremely short time duration. A rotating prism like the total reflector in figure 2.2 was an early method of providing Q-switching. Only at the point of rotation when there is a clear optical path will light energy be allowed to pass. A normally opaque electro-optical device is now often used for a Q-switching device. At the time of voltage application, the device becomes transparent, the light built up in the cavity by excited atoms can then reach the mirror so that the cavity Quality, Q, increases to a high level and emits a high peak power laser pulse of a few nanoseconds duration (Bertolotti & Mario, 1999). When the phases of different frequency modes of a laser are synchronized, these modes will interfere with each other and generate a beat effect. The result is a laser output with regularly spaced pulsations called "mode locking". Mode locked lasers usually produce trains of pulses with a duration of a few picoseconds to nanoseconds resulting in higher peak powers than the same laser operating in the Q-switched mode. Pulsed lasers are often designed to produce repetitive pulses. The pulse repetition frequency, prf, as well as pulse width is extremely important in evaluating biological effects (Townes & Homes, 1999).