

DEVELOPMENT AND CHARACTERIZED OF MICROCONTROLLER BASED  
XENON FLASHLAMP DRIVER CIRCUIT

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*Dedication to my beloved father, mother, family, abang and friends...*

*Thanks for everything*

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## ABSTRACT

Optical pumping using flashlamp is the preferred technique in solid state laser. Xenon flashlamp is a device that emits large amount of spectral energy in short duration pulses. Xenon is generally chosen because it yields a higher radiation output (40% - 60%) for a given electrical energy than other noble gases. Triggering a flashlamp generally requires very high voltage pulse of a short duration. The objective of this project is to develop a programmable xenon flashlamp driver. Current set-up allows flashlamp to be triggered in a single mode. A fundamental study was carried out by varying the input energy from 4.48 J to 26.88 J across the flashlamp. The heart of the flashlamp driver is a PIC16F84A microcontroller that runs on a +5 V supply and clocked by a 4 MHz resonator. This microcontroller was connected to a personal computer, via serial port, acting as remote terminal. Initially, a TTL pulse output from PIC16F84A was sent out to drive a SCR. The SCR step-upped the TTL pulse to  $332 \pm 5$  volts pulse. Finally, a 1:2 transformer mixes the resulting  $740 \pm 10$  volt pulse with  $2 \pm 0.01$  kV DC voltage. The resulting voltage waveform is applied across a xenon flashlamp. Xenon gas ionizes for a brief period determined by the pulse width. This results in an electrical short circuit across the flashlamp's electrodes. A large amount of current is drawn across the electrodes. This causes a rapid increase in the current flow through the flashlamp and initiates the desired arc lamp discharges. A Rogowski coil was used to detect the pulse current waveform. Xenon flashlamp output was detected using IPL10050 photodiode. An OPHIR BeamStar CCD Laser Beam Profiler was employed to record a plasma spectral gradient. The peak pulse current was obtained in the range of 776 A – 982 A. The bandwidth and the amplitude of the xenon flashlamp pulse were found in good agreement with the input energy. The beam profiles and dimensions of the plasma were dependent upon input energy.

## ABSTRAK

Pengepaman optik menggunakan lampu kilat merupakan teknik yang dipilih dalam laser pepejal. Lampu kilat xenon merupakan peranti yang menghasilkan spektrum tenaga yang banyak dalam tempoh denyut yang singkat. Xenon umumnya dipilih kerana ia memancarkan pancaran yang tinggi (40%-60%) bagi tenaga elektrik tertentu yang dibekalkan berbanding gas nadir yang lain. Memicu lampu kilat umumnya memerlukan denyut voltan yang sangat tinggi pada tempoh yang singkat. Objektif projek ini ialah untuk membangunkan sebuah pemacu lampu kilat xenon yang boleh diprogramkan. Susunan sekarang adalah membenarkan lampu kilat dipicu dalam satu mod. Kajian fundamental dijalankan dengan mengubah tenaga masukan daripada 4.42 J hingga 26.88 J merentasi lampu kilat. Nadi pemacu lampu kilat ini ialah pengawal mikro PIC16F84A yang dijana bekalan +5 V dan penyalun 4 MHz sebagai jam. Pengawalmikro disambung kepada computer peribadi, melalui labuhan sesiri, bertindak sebagai terminal pengawal. Pada mulanya, output denyut TTL daripada PIC16F84A dihantar keluar untuk memacu SCR. SCR meningkatkan denyut TTL kepada  $332 \pm 5$  volt denyut. Akhirnya transformer 1:2 mencampurkan denyut  $740 \pm 10$  volt yang terhasil dengan voltan  $2 \pm 0.01$  kV DC. Bentuk gelombang voltan yang terhasil dibekalkan merentasi lampu kilat xenon. Gas xenon mengion dalam tempoh tertentu yang ditentukan oleh lebar denyut. Ini menyebabkan litar pintas merentasi elektrod lampu kilat. Jumlah arus yang besar terhasil merentasi elektrod. Ini menyebabkan pertambahan yang pantas dalam aliran arus melalui lampu kilat dan memulakan nyahcas lampu yang diperlukan. Gelung Rogowski digunakan untuk mengesan bentuk denyut gelombang arus. Output lampu kilat xenon dikesan menggunakan photodiode IPLIPL10050. OPHIR Beam Star CCD Laser Beam Profiler digunakan untuk merekod kecerunam spektrum plasma. Denyut arus puncak diperolehi dalam julat 776 A – 982 A. Lebar jalur dan amplitud yang terhasil didapati mempunyai persetujuan yang baik dengan tenaga masukan. Profil dan dimensi plasma juga didapati bergantung kepada tenaga input.

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## LIST OF SYMBOL

$v-i$	-	Voltage-current relationship
$V$	-	Voltage
$K_0$	-	Flashlamp impedance
$l$	-	Arc length
$p$	-	Pressure
$D$	-	Flashlamp bore diameter
AC	-	Alternating current
DC	-	Direct current
$C$	-	Capacitance
SCR	-	Silicon Controlled Rectifier
$C_T$	-	Total capacitance
PIC	-	Programmable Interface Controller
PIV	-	Peak Inverse Current
$I$	-	Current
$R$	-	Resistor
$OD$	-	Optical density
$T$	-	Transmission
$H$		Horizontal of the centroid of plasma
$V$		Vertical of the centroid of plasma
$i(h,v)$		Intensity at location (h,v)
$I$		Total intensity taken the total area
$Q$		Amount of charge stored in capacitor
$P$		Power
$E$		Energy

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Overview

There are many methods used in pumping process. Basically, for gas laser or semiconductor laser it used electrical injection as pumping method. Most solid state lasers are pumped with optical sources (Noriah, 2002). The goal in designing optical pumps for solid state laser is to match the output spectrum of the optical pump with that of laser pump bands. Optical pump sources can be divided into two broad categories. One category is black and greybody radiators, of which filament lamps are the best example. The other category is pump sources with line emission spectra, of which semiconductor lasers are the best example (Kuhn, 1998). Noble gas discharge lamps are compromised between blackbody radiators and line sources. They have significant blackbody component generated by recombination radiation from gas ions capturing electrons into bound states (free-bound) and from Bremstahlung radiation. Noble gas discharge lamps are typically designed so that the plasma completely fills the lamp.

Flashlamp excitation is an attractive method to initiate laser of lasing media (Winstanley, 1997). The first demonstration of laser action by Maiman was achieved in 1960 by using ruby laser, a crystalline solid system where flashlamp was used as

pumping source (Hecht, 1991). The flashlamp-pumped solid-state laser is now by far the most common pulsed laser system in the world with neodymium ions either in crystal or in glass as the preferred lasing medium (Shaw, 1997).

Pulsed flashlamps, particularly xenon filled flashlamps are used in variety of application. Besides used as pumping sources in laser application, there are many others application of flashlamp. These include light source for flash photography (Eloumi *et al*, 2004), copying, optical detection and optical ranging applications, in cosmetology, dermatology and other medical applications (Inochkin *et al*, 2004).

Ultraviolet light (UV) emitted by medium and high power flashlamp has been very useful tool for drinking-water treatment. Intense peak power associated with microsecond pulses of ultraviolet light generated by inert gas (xenon, krypton) flashlamps appears effective tool, against a broad range of pathogens, including *Cryptosporidium and Giardia* (Ganesh *et al*, 2003).

For the past few years, revolutionary new techniques in medical and aesthetic applications have been developed and they are taking the industry by storm. These techniques referred to as Intense Pulsed Light (IPL<sup>TM\*</sup>), Variable Pulsed Light (VPL), Controlled Pulsed Light (CPL), or Intense Flash Light (IFL) are essentially the same. The systems harness the energy from a pulsed flashlamp and deliver it directly to the skin. Thousands of systems are currently operating in Japan and Europe, and the Federal Drug Administration (FDA) has cleared them for use in the USA. This technique is providing highly effective in several treatment area (Attwood and Mehlmann, 2004). These include hair removal, skin rejuvenation, medical skin treatment and acne treatment.

## 1.2 Flashlamp Driver Circuit

Studies of triggering flashlamp as pumping sources have been investigated by many previous researchers. Thus, various methods and patterns of xenon flashlamp drivers have been designed.

Several generations of discharge circuit exists for driving flashlamp. The original discharge circuits used an in-line trigger transformer or a trigger coil on the lamp to initiate conduction. A series capacitor-inductor discharge would then occur to deliver the energy into the lamp. This circuits whilst very simple. Furthermore, has relatively high jitter between trigger and laser pulse and also reduces lamp lifetime. However, it is still used today for limited low repetition rate applications.

In order to improve the driver, the second generation of discharge circuits use an active simmer supply, which triggers lamp into conduction and keeps the lamp in conduction with a few hundred milli-ampere current flows through it. A semiconductor-switching device, such as a thyristor, can then be used to control the discharge into the lamp. This enables repetitive pulsed operation of the lamp. Jitter and lifetime are much improved and the circuit works well for most application.

The latest and third generation for discharge technologies is the use of an opening and closing switch, such as an IGBT in combination with a large capacitor bank. The energy storage must be greater than that to be delivered into the lamp. This gives a highly flexible technology, where both the pulse energy and pulse length can be controlled independently. Repetition rates of many kilohertz are possible and many different applications can be tackled by the same circuit implementation (Greenwood and Miler, 1999 )

Study of the designing single mesh circuit for driving xenon flashlamp was presented by Markiewicz and Emmet (1966). This single mesh circuit has been found accurate and useful. Pettifer *et al* (1975) reported a reliable 60 kV flashlamp triggering system. The triggering system has proved to be an efficient and reliable unit for simultaneously triggering a pair of heavy walled, water cooled quartz flashlamp. Recently, in 1998 a zero-current switching resonant converter as a power supply of a pulsed Nd:YAG laser was adopted to control the laser power density. This power supply was designed and fabricated suitable for the high frequency range and to reduce switching loss and noises (Kim *et al*, 1998). A new method of sequential charge and discharge circuit (SCADC) was proposed by Hong *et al* (1999). The power supply is composed of low frequency capacitors instead of very expensive high frequency capacitors. This method have been designed and fabricated based on a cheap and simple power supply.

Kim *et al* (2001) have proposed a new power supply for pulsed Nd:YAG laser adopting zero crossing control (ZCC) method which is simple and compact in design. In this power supply, SCR was turned on at zero point of input AC voltage by the method of zero crossing control (ZCC). In 2002, a new real time multi-discharge method (RTMD) was reported. This method uses real-time one-chip microcomputer that can turn on the flashlamp with a precision of up to  $1\mu\text{s}$  and thus can create diverse pulse shapes and strength, in addition to longer pulse (Hong *et al*, 2002).

A flashlamp driver for medical laser system was reported by McCarthy *et al* (2003). This driver circuit was employed IGBT device for power switching and use microprocessor in order to control laser pulse width. In 2004, Inochikin *et al* reported a power supply or driver circuit for a pulsed flashlamp. A high-speed semiconductor switch was employed in order to turn on and off of the flashlamp by a suitable control. DC simmer current source was connected across flashlamp to maintain discharge in the flashlamp.

### 1.3 Comparison of Rare-Gas Flashlamp

Rare gas is also known as noble gas. This noble gas is in Group 8A in the periodic list table. They include neon, argon, krypton, xenon and radon (David, 1982). It was found that in the past few years there has been increased interest in rare gas flashlamp, particularly with respect to their application in solid-state laser pumping and in high intensity illumination for photographic work. Substantially programs by a number of people have been carried out to investigate the characteristics of flashlamp.

Oliver and Barnes (1969) presented data on the spectral emission characteristics of xenon, krypton, argon and neon in the region where the emission line spectra make up a substantial portion of energy. From the spectra data in terms of both output power and emitted quanta, it was show that xenon is the most efficient of all the rare gases, a fact which has been reported previously by Barnes (1964).

Study of rare gas pumping efficiencies for Neodymium laser was reported in 1969 by Oliver and Barnes. The investigation was presented on the comparative pumping efficiencies of xenon, argon and krypton flashlamp. The results obtained confirm that krypton can be more efficient than xenon for driving Neodymium laser when run at low current density. Nevertheless, at high drive levels, xenon is superior to all the rare gases.

Fountain *et al* (1970) presented a study of comparison of Krypton and Xenon flashlamp for Nd:YAG laser. As demonstrated previously by Oliver and Barnes (1969), Krypton lamp was found generally superior to xenon for pumping Nd:YAG laser except at high current densities.

## **1.4 Problem Statement**

A flashlamp driver is the most important part in a solid state laser system. It is used as a pump source for laser material. This study is the initial stage to develop a flashlamp driver circuit for optical pumping. Hence, this driver can or will be used as a reference to develop a driver circuit that can be used as a pump source in the future.

## **1.5 Objective**

The main objective of this study is to develop a xenon flashlamp driver using PIC16F84A microcontroller and characterize the xenon flashlamp output. The use of PIC16F84A microcontroller is as a control element.

## **1.6 Scope**

In this study, a programmable flashlamp driver circuit was developed. Programmability is provided by a PIC16F84 microcontroller. The flashlamp driver used a series injection trigger mode as a triggering circuit. The current setup allows the flashlamp to operate in single shot. A Rogowski coil was used to detect the pulse current waveform. Xenon flashlight output is then recorded using a CCD laser beam profile and analyzed by using imaging software. A photodiode was employed to detect the output of the flash light.

## 1.7 Thesis Outline

This thesis is divided into eight chapters. In the first chapter, it reviews some of previous research on the development of flashlamp driver, and the application of the xenon flashlamp in various field of research.

Chapter 2 reviews the characteristics of the xenon flashlamp including the lamp design, optical and electrical characteristics of the lamp. Besides, the basic of the flashlamp driver, this chapter also discusses and the mode of triggering the mechanism of breakdown in gaseous.

Chapter 3 explains about the experimental methods and the techniques used in development flashlamp driver. This includes a series injection triggering technique and image processing software. A Rogowski coil is used to detect the current curve during the discharge. The calibration of a high voltage power supply that is employed in the system is described in Chapter 4.

The development of pulse generator using PIC16f84A microcontroller, which is interfaced to the personal computer using RS232 lines driver is discussed in chapter 5. This generator acts like a control element for the flashlamp driver. The development of flashlamp driver circuit is covered in Chapter 6. Series injection triggering mode was employed to trigger a U-shape xenon flashlamp. The pulse current during the discharge time was measured. The relation of the pulse current and peak power during the discharge time due to the capacitance value or input energy is also discussed.

The characteristic of flashlamp output is enlightened in chapter 7. The bandwidth of the flashlamp pulse at FWHM was measured using the IPL10050 photodiode. Plasma spectral gradient induced by xenon flashlamp was recorded with the aid of CCD Laser Profiler.

Finally, the conclusions of the project are noted in Chapter 8. These provide with the summarization of the whole project and also problems arisen during the period of study. Finally, a few proposal are suggested for future study.

## REFERENCES

- Alex D.M (1998). *Design Considerations for Triggering of Flashlamp*. USA: Perkin Elmer. Application note.
- Attwood, S and Mehlmann, C (2004). *Intense Pulsed Light for Aesthetic & Medical Application*. USA: Perkin Elmer. Application note.
- Benson,D (1997). *A Beginner's Guide to Using PIC Microcontrollers*. USA: Square 1 Electronics.
- David A.U (1982). *Basic for Chemistry*. New York: Academic Press.
- Elloumia; H, Zissisb, G, Berthierc, T and J.J Damelincourt (2004). Time-Dependent Behavior Of A Pulsed High Power Xenon Flashlamp. Application to the Mega-Joule Laser Pumping. *Quantitative Spectroscopy & Radiative Transfer*, 86: 361–369.
- Fountain, W.M., Osterink, L. and Foster, J. (1970). Comparison of Kr and Xe Flashlamps For Nd:YAG Lasers. *IEEE Journal of Quantum Electronics*. 6(11):684-687.
- Goody, R.W. (1995). *PSpice For Windows. A Circuit Simulation Primer*. USA: Prentice-Hall.
- Greenwood,M and Miller,D.W (1999). Power Electronics For Pulsed Nd:YAG Laser System. *IEE Colloquium on Power Electronics for Demanding Applications (Ref. No. 1999/059)*. 15 April 1999. London: IEE, 8/1-8/5
- Grob,B. (1997). *Basic Electronics*. 8<sup>th</sup> ed. New York: McGraw-Hill.

Hecht, J (1992). *Understanding Laser: An Entry-level Guide*. New York: IEEE Press.

Hee-Jee.Kim, Eun Soo Kim and Dong-Hoon Lee (1998). The Development of a High Repetitive and High Power Nd:YAG Laser by Using A Zero-Current Switching Resonant Converter. *Optics & Laser Technology*, 30:199-203.

Heraeus Noblelight GmbH, (2003). *The Lamp Book*. Germany.

Inochikin, Mikhail, Tagotav, Vychesley, V, Gnatyuk, and Peter O (2004). *Flashlamp Drive Circuit*. (U.S. Patent Application 20040085026).

Jaakko Hyvätti (2004). *Jaakko Hyvätti Picprog 1.7 Documentation*. USA: GNU General Public Licence.

Jalil bin Ali (1990). *Development & Studies of a Small Plasma Focus*. Universiti Teknologi Malaysia: Ph.D Thesis.

John,I, (2000), *PIC Microcontroller Project Book*. New York: McGraw-Hill.

Jung-Hwan Hong, Koo-Ryul Park, Byung-Gyun Kim., Whi-Young Kim., Dong-Hoon Lee, Hee-Je Kim., and Uk Kang (1999). A New Proposal Of High Repetitive Nd:YAG Laser Power Supply Adopted The Sequential Charge And Discharge Circuit. *Optics & Laser Technology*, 31:397-400.

Jung-Hwan Hong, Kum-Young Song, Hyun-Ju Chung, Jong-Han Jung, Whi-Young Kim, Uk Kang and Hee-Je Kim (2002). Long Pulse Generation Tecnology of Solid-State Laser Adopting a New Real Time Multi-Discharge Method. *Optics & Laser Technology*, 30:203-207.

Kelin J. Kuhn (1998), *Laser Engineering* . USA: Prentice-Hall, Inc.

Koechner W and Michael,B. (2003), *Solid State Laser Engineering A graduate Text*.  
New York: Springer-Verlag.

Koechner W. (1976), *Solid State Laser Engineering*. New York: Springer-Verlag.  
Laser Electro Optic Technology Series, (LEOT) (2001). *Laser Technology-Module:  
Flashlamp for pulsed Lasers and Flashlamp Power Supplies*. Texas: Cord  
Communications Inc.

M.S. Berde (1986). *Thyristor Engineering*. 4<sup>th</sup> Edition. Delhi:Khanna Publisher.

Markiewicz, J.P and Emmet, J.L (1966). Design of Flashlamp Driving Circuits. *IEE  
Journal of Quantum Electronics*. 2(11):707-711.

Maxim Integrated Products (2003). *MAXIM +5V-Powered, Multichannel RS-232  
Drivers/Receivers Datasheet*. USA: Datasheet.

McCarthy, Delwin K, Gregg, Robert H.II, Thompson, Rick, Yessik and Michael (2003).  
*Medical Laser System*. (U.S. Patent Application 20030108078).

Melles Griot Inc. (1997—98). *Optics, Fiber Optics, Table & Hardware, Lasers,  
Intruments and lab Accessories*. USA: Catalogue.

Merle N.H and H.J Oskam. (1978). *Gaseous Electronics*. Volume 1. New York:  
Academic Press.

Microchip Technology Inc. (2001). *PIC1684A Datasheet*. USA: Datasheet.

Microchip Technology Inc.(2002). *EEPROM Memory Programming Specification*.  
USA: Application note.

Motorola (1999). *Silicon Control Rectifier (2N6394 thru 2N6399)*. Datasheet. USA: Datasheet.

Nebojsa,M, (2000), *The PIC Microcontroller*. Book 1. Belgrade: Mikroelektronika .  
Newport (2004). *The Newport Resource 2004. Your Guide to Standard Product, Application Note, Tutorials*. USA: Catalogue.

Noriah Bidin (2002), *Teknologi Laser*. Malaysia: Penerbit Universiti Teknologi Malaysia.

Oliver, J and Barnes, F (1969). A Comparison of Rare-Gas Flashlamp. *IEEE Journal of Quantum Electronics*. 5(5):232 – 237.

Oliver, J and Barnes, F. (1969). Rare-Gas Pumping Efficiencies For Neodymium Lasers. *IEEE Journal of Quantum Electronics*. 5(5):225 – 231.

Ophir Optronics Ltd. (2003). *Beam Star CCD Laser Beam Profiler for Windows*. United State: User Manual.

R.A Capobianco (2002). *Application Note AN-103: UV Curing Equipment For Assembly Application*. USA: Xenon Corporation. Application note.

R.A. Capianco (1998). *Design Consideration for High-Stability Pulsed Light System*. USA: Perkin Elmer.

R.E.W Pettifer, R.G Flavell and G.A Robinson (1975). A Reliable 60 kV Flashlamp Triggering System. *Journal of Physics b: Scientist Instrument*. 8:875-877.

Raymond, R. (1973). *Power Electronics: Thyristor Controlled Power For Electric Motors*. London:Chapman and Hall Ltd.

Russell, L.M. (1999). *Foundation of Electronics*. 3rd ed. Albany: Delmar Publishers.

Shaw, M. J. (1997). Pulsed Power For Laser: Past, Present, Future. *IEE Colloquium on Pulsed Power '97 (Digest No: 1997/075)*. March 19. IEE, 7/1 - 7/2.

T.K.Elbell (1978). *Practical Electronics. Fundamentals For Industry*. Vol.5. USA: Buck Engineering Co, Inc.

Upadhyaya, G; Curry, R.D; McDonald, K.F; Nichols, L.M; Clevenger, T (2003). A Pulse Power Flashlamp System For Water Decontamination. *Conference of the 2003 Pulsed Power. Digest of Technical Papers. PPC-2003*. June 15-18. 14th IEEE International, 221 – 224.

Whi-Young Kim, Jung-Hwan Hong, Uk Kang, Guang-Zhao Wu and Hee-Je Kim. A simple pulsed Nd:YAG laser power supply adopted ZCC method (2001). *Proceeding of ISIE 2001 IEEE International Symposium on Industrial Electronics*. June, 12-16 2001. Pusan, Korea: IEEE, 942-946.

Winstanley, P.A. (1997). The Role of Pulse Power in Flashlamp Pumped Laser. *IEE Colloquium on Pulsed Power '97 (Digest No: 1997/075)*. March 19. IEE, 4/1 - 4/3.

Y.P Raizer. (1987). *Gas Discharge Physics*. Moscow: Springer-Verlag.

Z.Sari, K.Amgoud and M. Ait-Bouabdallah (1993). Design And Implementation Of A Microprocessor Based High Frequency Switching Mode Power Supply. *Proceeding of Fifth European Conference on Power Electronics & Application*. Sept. 13 – 16, 1993. Inelec, Algeria: IEEE, 334-337.