

STUDY OF SINGLE-MESH LC FLASHLAMP DRIVING CIRCUIT FOR XENON FLASHLAMP

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ABSTRACT

This paper is reporting the estimation of flashlamp driving circuits for xenon flashlamp as an optical pumping for solid-state laser. A linear xenon flashlamp with dimension 69 mm length and 4 mm bore diameter was employed. The circuit with combination capacitor and inductor used as pulse forming network (PFN) to control explosion energy given into the flashlamp. The determination of LC combination is important to transfer optimize energy between PFN and flashlamp. With flashlamp impedance 22 Ohm Amps^{0.5}, storage capacitor energy of 50 Joules and 58 μ H inductor, a calculated value for peak current and discharge duration was determined. The peak current and discharge current were 635 Amps and 227 μ s respectively.

Keywords: xenon flashlamp, single-mesh LC circuit, pulse forming network (PFN)

INTRODUCTION

Flashlamp was well known as an optical pumping source since it has output spectrum cover broad band from UV to IR which closely to white light. In Nd:YAG laser rod usually employed xenon flashlamp as a pumping source. The selection base on its efficiency to convert electrical input energy to radiation in the range of 0.2 to 1.0 μ m regions which match with the absorption band of Nd:YAG [1-3].

Many pulsed flashlamps are operated from inductor or capacitor single mesh pulsed forming networks (PFN's) or electronic switching. For PFN operation, the values of inductance (L), capacitance (C), and capacitor charging voltage (V_0) are chosen to give a critically damped pulse of the desired duration and energy with a given lamp impedance (K_0) [3]. Several techniques can be used in designing driving circuits to operate flashlamp and it can be done according to the user needs. One of the famous driving circuits for flashlamp was invented by Markiewicz and Emmett in 1966 using single mesh flashlamp discharge circuit [4] as shown in Figure 1. The single mesh flashlamp discharge circuit is a combination of a capacitor and an inductor. In this study, the single mesh flashlamp circuit is used as a PFN to control the explosion energy given into the flashlamp.

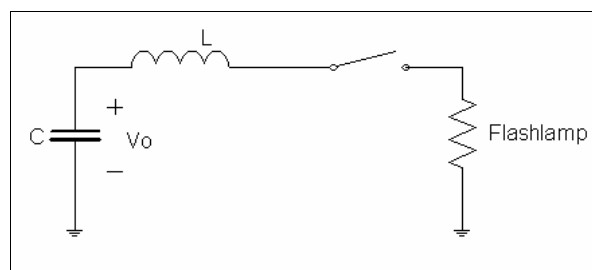


Figure1: Single mesh discharge circuit

It is generally desirable to operate lamp or PFN's under conditions of critical damping. The pulse shape under conditions of critical damping will have a near Gaussian profile. This will ensure the maximum energy transfer between lamp and PFN, also maximizing lifetime. For a given pulse width, energy and lamp impedance there is only one value of C , L and V_0 that result in critical damping. The term conventionally is taken to describe the pulse shape and is normally chosen to be 0.8 for critical damping like mention by Markiewics and Emmett (1966). If the lamp operate over a wide range of input energies, with C and L fixed (V_0 varied to alter E_0), the circuit should be designed for critical damping at the maximum energy; the circuit will then become over damped when V_0 is reduced.

CALCULATION FOR SINGLE-MESH LC PFN

First step towards the development of optimum flashlamp driving circuits is to know the impedance of flashlamp used as pumping source. Impedance of flashlamp, K_o depends on its geometry and several flashlamp parameter. It depends on the arc length, l and bore diameter d of flashlamp. Other parameters are gas type and gas fill pressure, p . The estimation of the xenon flashlamp impedance is given by equation (1) [5].

$$K_o = 1.28(p/450)^{0.2} l/d \quad (1)$$

To simplify the calculation of flashlamp driving circuits, value of storage capacitor and charging voltage are chosen by using one constant value. By knowing storage capacitor (C), charging voltage (V_0) flashlamp impedance (K_o) and damping parameter (α) value, the inductor values can be calculated using equation (2)[4].

$$L = \left[\left(\frac{K_o}{\alpha} \right)^2 \times \left(\frac{1}{V_0} \right) \right]^2 \times C \quad (2)$$

Several important electrical parameters can be determined after the calculation of LC single-mesh flashlamp driving circuit value. The important electrical parameters related to the flashlamp driving circuit are [3-9];

1. The energy given to flashlamp,

$$E_0 = \frac{1}{2} CV^2 \quad (3)$$

2. Flashlamp Driving Circuits impedance,

$$Z_0 = \sqrt{\frac{L}{C}} \quad (4)$$

3. Discharging time, one third from full discharge process,

$$T_{\frac{1}{3}} = \sqrt{LC} \quad (5)$$

4. Flashlamp resistance,

$$R_t = \rho \frac{l}{A} \tag{6}$$

5. Discharge peak current,

$$i_{ip} = \frac{V_0}{(Z_0 + R_t)} \tag{7}$$

6. Peak current density inside flashlamp,

$$i_{pkD} = \frac{i_{pk}}{A} \tag{8}$$

These parameters are very essential to characterize the flashlamp driving circuit for laser application. Every laser crystal needs deferent input energy and pumping duration depends on its energy level characteristic. For example, Nd:YAG laser crystal usually will be pumped with discharge duration between 200 μ s to 500 μ s and sometimes reach in milliseconds range especially for medical application.

RESULT AND DISCUSSION

In this study, a linear xenon flashlamp with dimension 69 mm length and 44 internal bore diameter was employed. It filled with xenon gas and pressure of 450 torr. This flashlamp was energized through a 100 μ F storage capacitor and 1000 Volts charging voltage. Using Equation (1) to (7), the appropriate for our flashlamp driver can be determined. Electrical properties of flashlamp driver also can be estimated. This estimation is value was very important in order to develop flashlamp driver which offer an optimum energy during optical pumping process. Table 1 shows the computational of inductor and electrical properties using previous equations with neglecting circuit's losses through parasitic resistor, inductor and capacitor.

Table 1: Estimation of single-mesh flashlamp driver parameters

Parameters	Value
Storage capacitor, C	100 μ F
Maximum Charging voltage, V_0	1000 Volt
Flashlamp impedance, K_o	22.00 Ohm Amps ^{0.5}
Damping parameter, α	0.8
Inductance, L	57.19 μ H
Input energy (max), E_0	50 Joules
Circuit impedance, Z_0	0.7562 Ohm
Discharge duration (full discharge),	227 μ s
Flashlamp resistance, R_t	0.8186 Ohm
Peak current, i_{pk} ($V_0 = 1000$ volts)	635 Amps
Peak current density, i_{pkD} ($V_0 = 1000$ volts)	5051.7 Amps cm^{-2}

CONCLUSION

Optimum parameter for single-mesh flashlamp driving circuit was successfully calculated. Using linear xenon flashlamp and selected input energy, inductor for shaping discharge process signal was determined. The electrical parameters of flashlamp driving circuit output with neglected circuit losses are successfully estimated.

ACKNOWLEDGEMENT

The authors like to express their thanks to the government of Malaysia through IRPA grant vote 74531 and to Universiti Teknologi Malaysia for supporting this project.

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