Design of Long Pulse Width Laser Power

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Abstract. This paper designs a half-bridge IGBT inverter switch solid laser power. This power has realized great energy work for more than 20 hours in succession. It is reliable and steady. Its switch frequency is in about 25 kHz. We have adopted the modules to design, have strengthened the interchangeability of the unit circuit, the interconnected system and computer interface when there is outside. It is convenient to operate and safeguard with high repetition frequency, high reliability, etc..

Working Principle of the Power

The entire power signal transformation from input to output is AC→DC→AC→DC. The input of the AC220V power is rectified, and a DC voltage is formed on the filter capacitor after a soft start. After preignition for the pulse xenon lamp, the power gives a signal to the control board. If there are no such failures of the main circuit with under-voltage or over-current and the laser without water, the control panel allows the main power to work and produces about 25 kHz oscillation signal to the drive plate. Driven by the driving signal, the DC voltage is converted into an alternating voltage of 25 KHz. After high frequency transformer and high frequency rectifier bridge, the alternating voltage is boosted and rectified. It is finally sent to the charging energy storage network. When the energy storage capacitor is charged to the rated voltage, the control board gives a stop signal and the inverter circuit stops working. Under the system signal drive, the storage capacitor discharges through the xenon lamp. The power principle is shown in Fig.1.

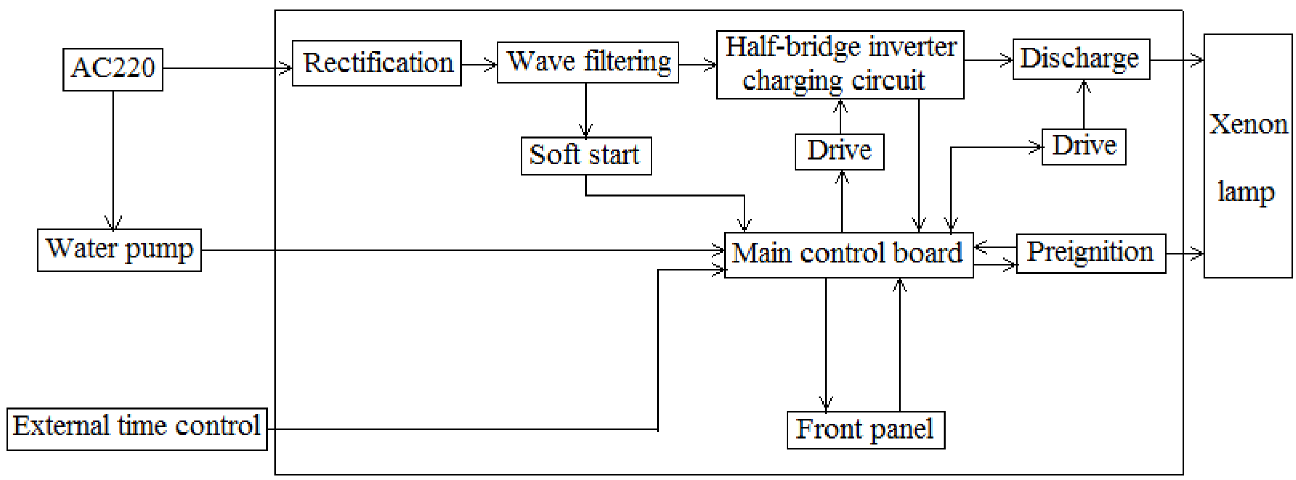

Fig. 1 The schematic diagram of the power

The technical index of the pulse width tuning solid-laser power：
Output power: 800W
Working mode: Pulse
Repetition rate: 0.5 Hz, 1 Hz, 3Hz, with the external time control
Continuous adjustable voltage: 0 ~ 680V
Power: AC220 V, 10A, 50 / 60Hz
Continuously tunable pulse width: 100μs ~ 1.5ms

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Effective capacity: 20000 μF
Continuous working hours: >20 hours

Power Design

Half-bridge Inverter Charging Circuit. The half-bridge inverter charging circuit is shown in Fig.2. Switches T_1 and T_2, capacitors C_1 and C_2 are respectively used as the four arms of the bridge. The voltage U_i is input into the diagonal ends of the bridge. Another two ends are connected high-frequency transformer T_r as power output. Usually $C_1 = C_2$, so the voltage of each capacitor is $U_i/2$.

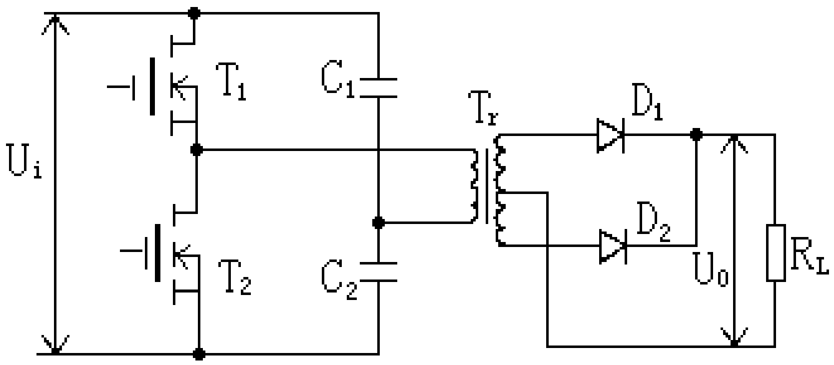


Fig.2 The half-bridge inverter charging circuit

Bipolar Power Transistor. The core of pulsed laser power is the charging circuit of energy storage capacitor [1]. In the actual use, there are some certain limitations in the power's volume, weight, heat, power, etc.. Therefore a small size and high efficiency charging circuit is the key to the power design. The inverter IGBT has the advantages of both VMOS and high power transistors.

It has the characteristics of high speed, high reliability, high accuracy, low power consumption and so on. And it can make full use of electric energy and save space, so we use IGBT in the charging circuit of the power. The equivalent circuit and electrical symbol of IGBT are shown in Fig.3.

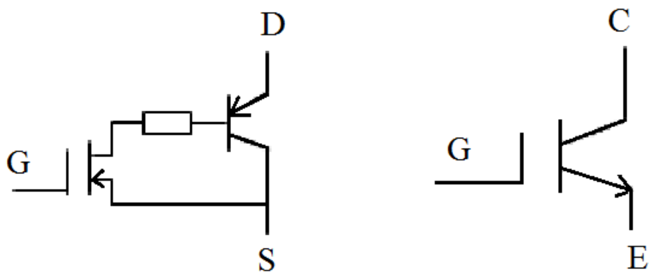


Fig.3 The equivalent circuit and electrical symbol

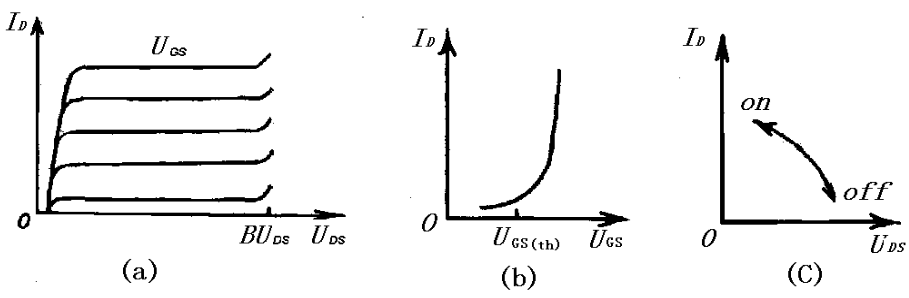


Fig.4 The volt-ampere characteristics of IGBT

The static characteristics of IGBT include the volt-ampere characteristics, the transfer characteristic and the static switching characteristics. The volt-ampere characteristics of IGBT are shown in Fig.4 [2-3]. Fig.4 (b) represents the transfer characteristics of IGBT, which is the same as that of VMOS. In most of the drain current range, I_D has a linear relationship with U_{GS}. Only when the gate voltage is close to the threshold voltage，t hey have a nonlinear relationship. At this point the leakage current is quite small. When the gate-source voltage is less than $U_{GS(th)}$, IGBT is in the off state. IGBT static switching characteristics are shown in Fig.4 (C).When the gate source voltage is greater than the threshold voltage, IGBT is in a state of conduction.

The conduction voltage $U_{DS(ON)}$ is as follows:

$$U_{DS(on)} = U_{J1} + U_{dr} + I_D R_{on} \tag{1}$$

In the formula，U_{J1} ———J1 forward voltage drop, about 0.7 - 1V;

U_{dr} ———The voltage drop on the extended resistance R_{dr}

R_{on} ———Channel ohmic resistance

Chopper-type Discharge Circuit. The capacitor discharge causes a xenon lamp light, so the capacitor discharge time will directly affect the xenon lamp pulse width, and xenon lamp pulse width will also influence the laser pulse width. The time constant of a capacitor is τ=RC. In order to make a long pulse laser output, a large capacitor must be used to discharge xenon lamp, namely the time constant of the capacitor must be longer than the pulse width tuning range of xenon lamp. In order to make the laser pulse width tuned, we choose IGBT to control the conduction time of the main discharge circuit [4]. The pulse width tuning range of xenon lamp is from 100μs to 1.5ms. IGBT chopper type discharge circuit principle diagram is shown in Fig.5.

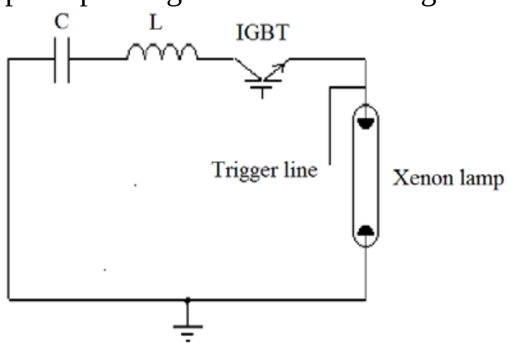


Fig.5 IGBT chopper type discharge circuit principle diagram

External Control Circuit. A 555 oscillators is shown in Fig.6,that is a rectangular wave generator circuit.

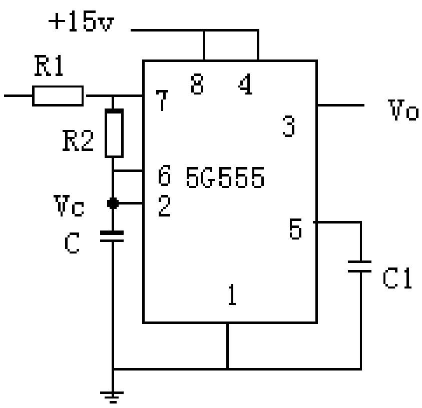


Fig.6 555 timer rectangular wave generating circuit

According to the law of the capacitor charging and discharging, we can obtain:

$$T_h = 0.7(R_1 + R_2)C \tag{2}$$

$$T_l = 0.7R_2C \tag{3}$$

$$T = T_h + T_l = 0.7(R_1 + R_2)C \quad (4)$$

The resistance change of R_1 and R_2 can change the oscillation frequency. In Fig.6, C_1 is connected to Pin 5 of the chip, values of 0.01 μf. So we can maintain a constant dc voltage on the resistances R_1 and R_2.

Under-voltage and Over-voltage Protection. Under-voltage and over-voltage protection is also very important in laser power. If under-voltage, a large current must be input for the rated power output. If over-voltage, the power has high input voltage spikes, increasing the reverse voltage of IGBT power switch in the inverter bridge, which could easily lead to over-voltage breakdown. Therefore, in order to ensure the stability of the system the circuit must contain under-voltage and over-voltage protection circuit. The circuit diagram is shown in Fig.7. By using the sampling resistors R, R_1, R_2, and adjusting potentiometer R_w, the input voltage is limited to allow the change of AC220 ±10%

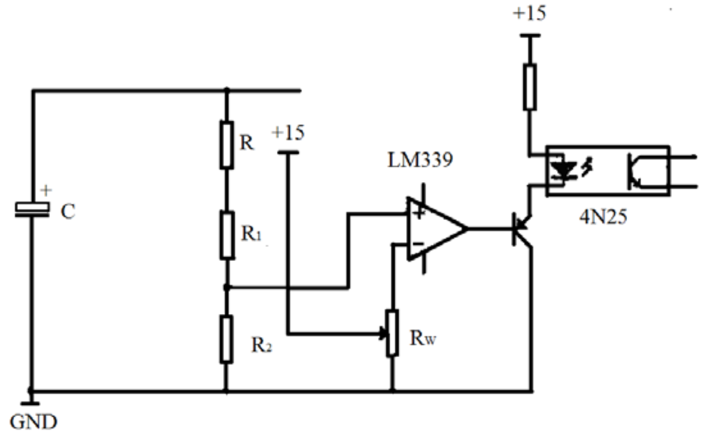


Fig.7 The over-voltage protection circuit diagram

Over-current Protection. Setting over-current protection circuit is mainly to solve the following two problems: One is that in a variety of strong interference environment, inverter failure in the charging circuit will not cause the power switch (IGBT) over the rated current value damaged.

The second is to ensure that the pulse power to charge and discharge, once the xenon lamp with arc fault, due to over current the main circuit will be cut off, so as to realize protection. Over-current protection circuit is shown in Fig.8 [5].

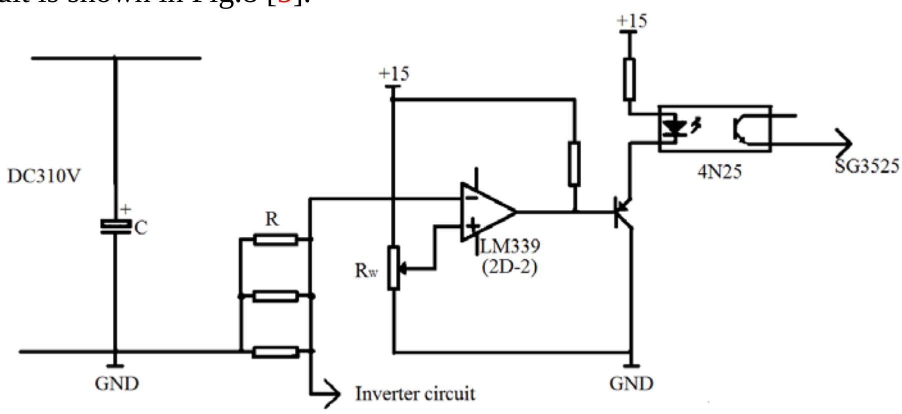
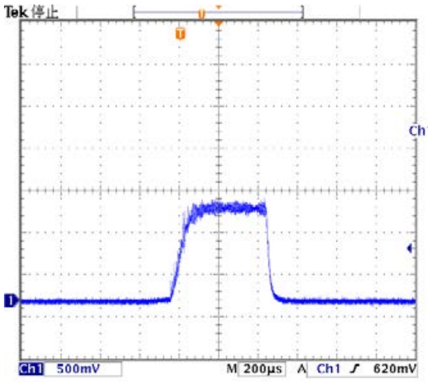


Fig.8 Over-current protection circuit

Combined Experiment for Power and Laser System

Used in the experiments is a dual elliptical cavity, in which two xenon lamps and a laser rod are installed. The cavity length is 72mm. Nd:YAG laser rod diameter is 9mm and its length is 75mm.Pulse xenon lamp diameter is 7mm and two xenon lamp spacing is 90mm.

The first group of experiment: when working voltage is 600V and the input pulse width is 500μs, the xenon lamp waveform and laser waveform are as shown in Fig. 9 and Fig.10.



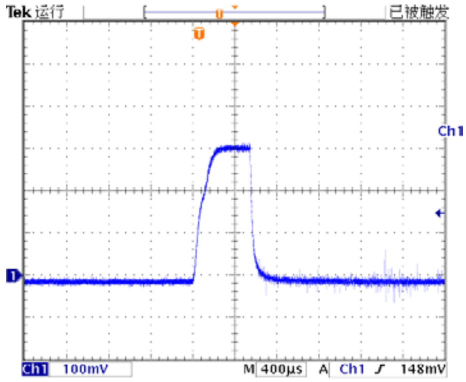
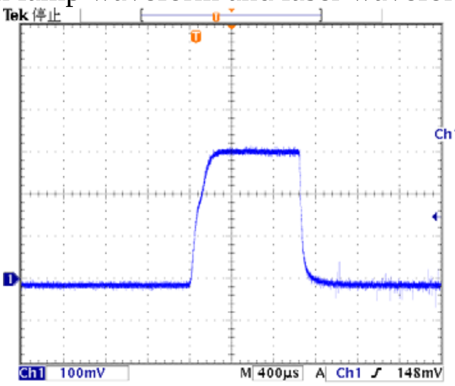


Fig.9 Pulse xenon lamp waveform figure

Fig.10 Static laser pulse diagram

The second group of experiment: when working voltage is 600V and the input pulse width is 1ms, the xenon lamp waveform and laser waveform are as shown in Fig.11 and Fig.12.



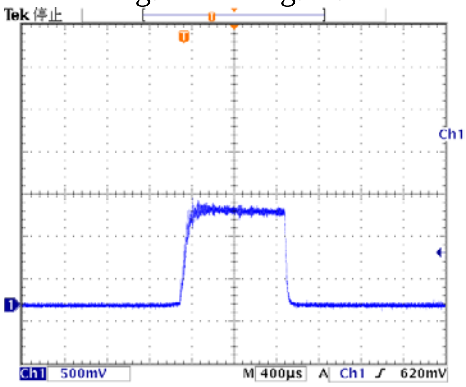
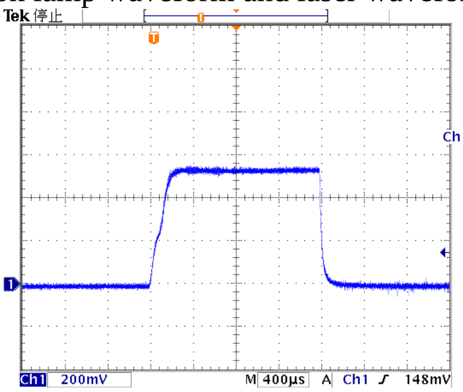


Fig.11 Pulse xenon lamp waveform figure

Fig.12 Static laser pulse diagram

The third group of experiment: when working voltage is 600V and the input pulse width is 1ms, the xenon lamp waveform and laser waveform are as shown in Fig.13 and Fig.14.



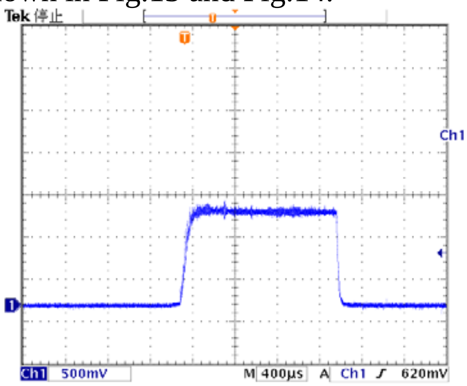


Fig.13 Pulse xenon lamp waveform figure

Fig.14 Static laser pulse diagram

In the above three groups of waveforms, only the third group near square wave. And the xenon lamp waveform in the first two groups is not complete square wave, its pulse front is a certain inclination to rise. In the three photos can be seen that the laser pulse width is narrower than the xenon lamp pulse width and laser amplitude is much lower than that of the xenon lamp.

Summary

When the width is smaller, the capacitance charging will take time and the energy for the capacitor discharge will increase or decrease with the charging time, so the xenon lamp waveform reflects a certain slope upward trend. When the input pulse width is broadened, the released energy by the capacitor increases and the discharge time is lengthened. In a certain operating voltage, the capacitor discharges, the amplitudes of the output xenon lamp and laser will decrease with time. If the increase of capacitance, it can make the xenon lamp and laser output waveforms present square wave shape.

The formation of laser pulse is based on the accumulation of inversion population, while the accumulation of a certain number of particles will take some time. Therefore, the laser pulse width is narrower than that of pulse pumped xenon lamp. In the process of xenon lamp pumped to the laser output, due to the existence of various energy loss, the laser amplitude decreases more significantly than that of xenon lamp.

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