고효율의 Intese Pulse Light에 특성연구

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Study on intense pulse lighting with high efficiency

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요 약

장비의 리액터브 성분의 물리적 크기를 저감하고 동특성을 개선하기 위하여 동작스위칭 주파수를 증가 시키는 것이 우수하나 이러한 방식은 발열과 스트레스로 인한 전력소자의 파괴, 스위칭손실 증가로 인한 효율 감소등 다양한 문제가 발생하게 된다. 따라서, 본 논문에서는 이러한 문제점을 해결하기 위해 보조장치를 응용한 기동전류 회로를 적용한 하프브리지 방식의 Intense Pulse Light를 제안 하였다. 시뮬레이션 및 실험결과를 통해 20% 향상을 가져와 환자에게 보다 더 질적인 측정을 할 수가 있다고 확인하였다.

ABSTRACT

the equipment increase switching frequency in order to achieve small size, a low noise, and light weight. however, the power switches have high power losses and switching stresses as the switching frequency is increased. In order to solve like this problem point from the present paper it proposed Intese Pulse Light of the half bridge methods which apply the start current circuit which applies the auxiliary equipment. Simulation and experimental result it leads and it brings is more qualitative there is 20% improvement and it confirmed that a possibility of measuring to the patient.

키워드(switching frequency, power switches, half bridge, Simulation, half bridge, Intese Pulse Light)

Ⅰ. Introduction

Intese Pulse Light is the most commonly used type of lasers in many fields at present because of its good thermal and mechanical properties and easy maintenance. In the recent studies of Intese Pulse Light processing methods, the Intese Pulse Light which has various advantages over commonly used CO_2 laser has been investigated energetically. It can be focused to a smaller point due to its short wavelength than CO_2 laser and can be easily reacted to patients. And thereby it is broadly used in many applications such as skin, bone, cure, materials processing and so on. Among other things, in skin processing, suitable laser power density is required for the specific process, and the Intese Pulse Light power density can be controlled by current pulsewidth and pulse repetition rate, which are known to be major factors for particular property of body.

In this study, a zero-current switching(ZCS) resonant converter as the power supply was adopted to control the Intese Pulse Light power density. And we have designed and fabricated a high repetition rate and high power(HRHP) Intese Pulse Light system applied the ZCS resonant converter. In order to investigate operational characteristics of the HRHP Intese Pulse Light system, the experiments for the laser output as function of current pulsewidth and pulse repetition rate have been carried out.

Ⅱ. Power supply

The power supply was designed and fabricated to be suitable for the high frequency range and to reduce switching loss and noises. It consisted of three components such as a ZCS resonant converter unit, a rectifier unit, and a simmer-trigger unit, as shown in Fig 1. Especially, the ZCS resonant converter was used to decrease the loss occurred by the tailing current generated on turning off an insulated gate bipolar transistor(IGBT).

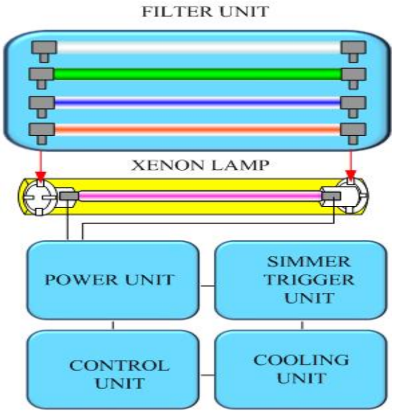


Fig. 1 Equivalent circuits of operation modes for ZCS Intese Pulse Light divided into two modes

The rectifier unit consisted of a three-phase interchanging voltage regulator(IVR), a three-phase bridge diode rectifier, and a smoothing condenser as shown in Fig.1. Because of the over-peak current which came from the resonant converter, the high power DC capacitor with a good frequency response and a smoothing condenser were connected in parallel. The change of input voltage depending on the load change could be adjusted slightly by the three-phase IVR. In Fig. 2, the pulse forming network(PFN) applied ZCS series resonant converter consisted of switch devices(s1, s_2), a resonant inductor(L_r), and resonant capacitors(C_1, C_2). The switching loss was zero in principle, and it is adequate in high repetion rate operation because the current through s_1, s_2, C_1, and C_2 was forced to the sinusoidal wave, and the switch devices turned on/off at zero current. The output of ZCS series resonant converter is

$$P_{out} = 2 f C V_{in}^2 \tag{1}$$

where f is the repetition frequency, C the capacitance of charging capacitor, and V_{in} the input voltage. According to this formular, it is found that there are two ways to control the power density of the resonant convercer. One is to vary the input voltage V_{in} at a constant pulsewidth and frequency, and the other is to adjust the switching frequency f. In the latter case, low frequency switching causes noises and instability. Therefore, we adopted the control method to vary the input voltage V_{in}.

Ⅲ. Operation of the ZCS converter

In this paper, the proposed ZCS converter circuit is shown in Fig. 2. The circuit operation can be divided into two modes, whose waveforms and equivalent circuits for the modes are shown in Fig 3. To simplify the analysis, the initial states of the circuit are assumed as follows : the voltage V_{c1} of capacitor C_1 is initially charged to input voltage V_{in}, the voltage V_{c2} of capacitor C_2 zero, switch devices s_1, s_2 turned off, and the simmer-trigger circuit is turned on.

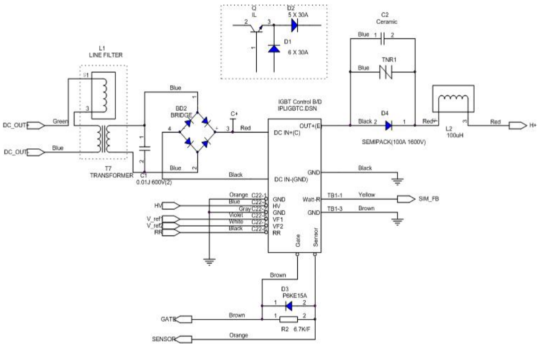


Fig. 2 Schematic circuit of the Intese Pulse Light which consists of three components such as a ZCS resonant converter unit, IGBT driver

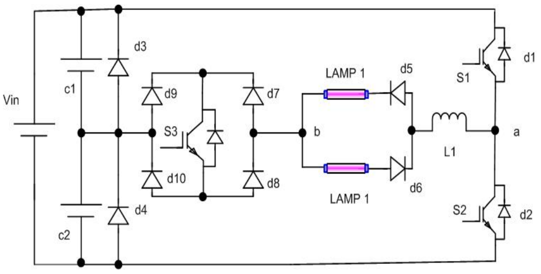


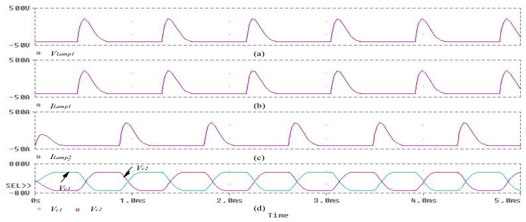
Fig. 3 Electrical circuit of ZCS resonant converter which consists of switch devices(s_1, s_2), a resonant inductor(L_r), and resonant capacitors(C_1, C_2)

Mode 1 ($t_0 \le t < t_1$) : Mode 1 starts with the Q_1 turning on at time t_0. The equivalent circuits are shown in Fig. 3(b). The resonant current I_{Q1} flows through $C_1 \to s_1 \to L_r \to D_5 \to$ lamp1 $\to d7 \to s3 \to d10 \to C_1$ path and $V_{in} \to s_1 \to L_r \to D_5 \to$ lamp1 $\to d7 \to s3 \to d10 \to C_1$ path. The resonant capacitor voltage V_{c1}, V_{c2} and the input voltage V_{in} at time t_1 both are equal to zero. And then the current through resonant inductor L_r flows through

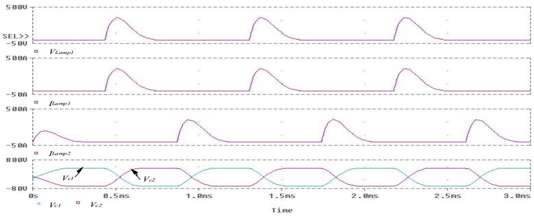
$L_r \rightarrow D_5 \rightarrow$ lamp1 $\rightarrow d7 \rightarrow s3 \rightarrow d10 \rightarrow D_3 \rightarrow s_1 \rightarrow L_r$ path. As a result of that, V_{c1} and V_{c2} are clamped at zero and also V_{in} at zero.

Mode 2 ($t_1 \leq t < t_3$) : The equivalent circuit is shown in Fig. 3(b). Even though the switch s_1 is turned off at time t_2, the resonant current is continuously flowing to $L_r \rightarrow D_5 \rightarrow$ lamp1 $\rightarrow D_3 \rightarrow d7 \rightarrow s3 \rightarrow d10 \rightarrow \rightarrow V_{in} \rightarrow D_2 \rightarrow L_r$ path due to the stored energy in the resonant inductor L_r. During these mode 1 and mode 2, lamp 2 is blocked by D_6, so the energy is only provided with lamp1. Here, I_{D3} is a freewheeling current.

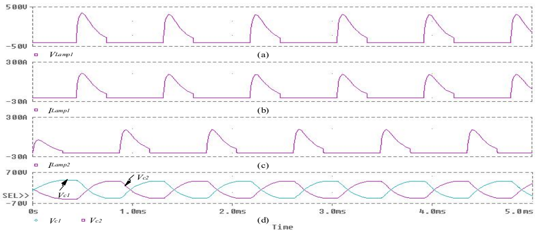
The modes for lamp 2 can be also divided into two modes, and these operation are just the same with the case of lamp 1. The simulated circuit waveforms of this ZCS series resonant converter are shown in Fig. 4. The simulation parameters were as follows.



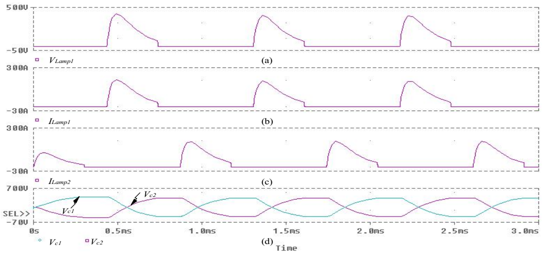
Lamp (1Ω, 0 ~ 5ms)



Lamp (1Ω, 0 ~ 3ms)



Lamp (2Ω, 0 ~ 5ms)



Lamp (2Ω, 0 ~ 3ms)

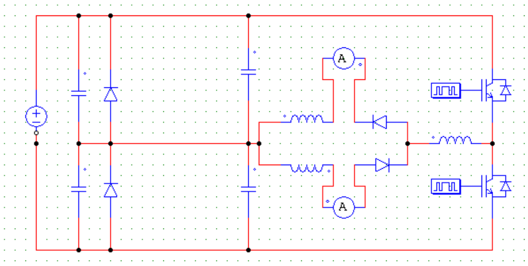
Fig. 4 Simulated current and voltage waveforms of ZCS resonant converter.

The simmer-trigger circuit is to create an ionized spark streamer between two electrodes so that the main discharge can occur. In order to generate the strimmer, the simmer current of about 20mA to a few A(ampere) is required, and it is restricted by resistance. A 0.3 mm^2 nickel wire is wrapped around the flashlamp for easy triggering.

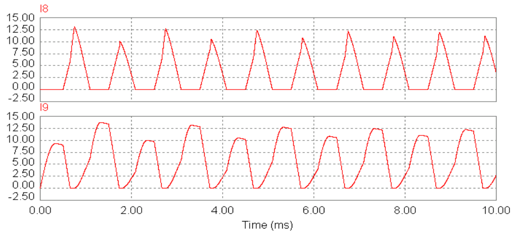
Ⅳ. Intese Pulse Light resonator

A laser head was composed of a Intese Pulse Light and two flashlamps. The double elliptical cavity inside was coated with gold, and two mirrors were dielectrically coated. In general, in a double elliptical cavity, all rays emanating from the pumping source are transformed into the Intese Pulse Light. In the case of one Intese Pulse Light head, they had a 50cm separation. And the total mirror had the reflectivity of over 99.5% and the concave curvature of 2m. The reflectivity of 85%. In addition, in order to maintain a stable laser operation, the Intese Pulse Light and flashlamps were liquid-cooled by circulating pure water as a coolant in flowtubes which surround these elements. And we used two water pumps of 35[liter/min]. One cooled a flashlamp and a rod, and the other did the rest lamp and parts of surrounding a reflector.

Ⅴ. Experimental Results



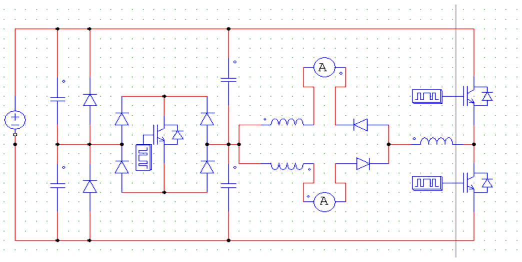
a) General ZCS



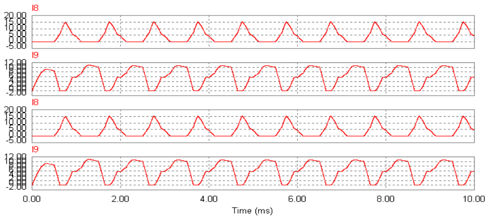
b) voltage and current

Fig. 5 Voltage and current waveforms applied across the switch devices during a switching period of ZCS series resonant convertes

In the case of one Intese Pulse Light head, Fig. 4 shows Intese Pulse Light output obtained by varying a pulse repetition rate at the fixed current pulse width of 350μs and the input power of 8kw. As a result, the highest output was obtained at 50pps. It means that Intese Pulse Light output per second rises with increasing a repetition rate. In this experiment, the repetition rate was restricted to 50pps because of the properties of Xe flashlamp made in ILC. Fig. 5 shows laser output gained by adjusting a current pulse width at the repetition frequency of 50pps and the input power of 8kw. The longer pulse width is, the higher laser output is. The maximum Intese Pulse Light output was 240W at the input power of 12kw. And the laser output as a function of electrical input power is shown in Fig. 6. As we can see, it rises linearly from the electrical input power of about 400w, which is the oscillated point, to input rating. Consequently, it is expected that more laser output can be generated by increasing input and having a better cooling device. In Fig. 6, the voltage waveform and the current waveform, which were applied across the switch devices during a switching period of ZCS series resonant convertes, are shown. There are no sudden peak voltage and ringing. The current waveform became a sinusoidal wave by series resonance. In addition, we arranged two laser heads in cascade and the reflectivity of the mirror was changed from 85% to 80%. The maximum average output was about 480W.



a) proposal start current & ZCS



b) voltage and current

Fig. 6 Voltage and current waveforms applied across the switch devices during a switching period of ZCS series resonant convertes

Ⅵ. Conclusion

In materials processing, the power density control of laser beam has been considered to be significant. In this study, a zero-current switching(ZCS) resonant converter as the power supply of a Intese Pulse Light was adopted to control the laser power density which depends on flashlamp current pulsewidth and pulse repetition rate. And it allowed us to designed and fabricate a high repetition rate and high power(HRHP) Intese Pulse Light system. As a result of that, the current pulsewidth could be contorlled 200μs to 350μs(step 50μs), and the pulse repetition rate could be adjusted 50pps(pulse per second) to 1150pps. In addition, in the case of one laser head consisting of a Intese Pulse Light and two flashlamps, the maximum laser output of 240W was produced at the condition of 350μs and 50pps, and that of about 480W was generated at the same condition when two laser heads were arranged in cascade. The zero-current switching(ZCS) resonant converter as the power supply of a Intese Pulse Light was adopted in order to control the laser power density which has been considered as the major factor in materials processing. And we have designed and fabricated a high repetition rate and high power(HRHP) Intese Pulse Light system applied the ZCS resonant converter. In this study, in order to find out operational characteristics of the HRHP Intese Pulse Light system, the experiments have been performed by adjusting the current pulsewidths of 200μs to 350μs(step 50μs) and the pulse repetition rate of 50pps(pulse per second) to 1150 pps. As a result, in the case of one laser head with a Intese Pulse Light and two flashlamps, the maximum Intese Pulse Light output of 240W was obtained at the current pulsewidth of 350μs and the pulse repetition rate of 50pps. And that of about 480W for two Intese Pulse Light heads was gained at the same condition.

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