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고전압과 고주파수형 공진형 DC-DC 콘버터를 이용한 펄스형 Nd:YAG 레이저의 디지털제어 구현

김 휘 영**

동주대학 컴퓨터정보통신계열

The Digital Controlled Implementation of the Resonant DC-DC Converter with High Voltage, High Frequency For Pulsed Nd:YAG Laser

Whi-Young Kim

School of computer information & communication,. DONGJU COLLEGE

E-MAIL: ndyag@dongju.ac.kr

요 약

This paper is mainly concerned with the state of the practical developments of a constants PWM bridge type resonants DC-DC suitable converter for Nd:YAG Laser with a Microprocessor.(PIC16C54 & 8051)

The use of IGBT power supply with feedback control of flashLamp currents imparts a advantages to Nd:YAG Laser for materials processing. these include the alility to tailor the pulseshape and modify pulse parameters on a pulse- by pulse basis. And Correct choice of pulseshape can enhance the repeatability of the process. as higher power IGBT became available, active pulseforming power supplies will find greater user in deep hole drilling machine. By Using certain control tecniques, utililized in designing Pic16C54 from Microchip technology and Intel 8051, also Mornitoring from Microsoft Visual Basic 5. And it allowed us to designed and fabricate ahigh repetition rate and high power(HRHP) pulsed Nd:YAG laser system. As a result of that, the current pulsewidth could be contorlled 200s to 350s(step 50s), and the pulse repetition rate could be adjusted 500pps to 1150pps. In addition, in the case of one laser head consisting of a Nd:YAG laser rod and two flashlamps, the maximum laser output of 240W was produced at the condition of 350s and 1150pps, and that of about 480W was generated at the same condition when two laser heads were arranged in cascade.

1. Introduction

In a most resonant power supplies, the DC-to-DC Converters are driven by equivalent DC voltage sources obtained from peak rectifying circuits connected to the ac mains as shown in Fig.1.

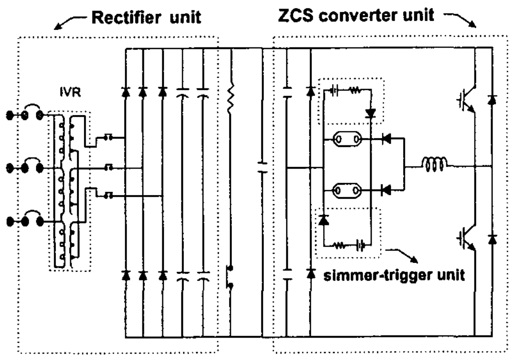

Fig.1. Schematic circuit of the pulsed Nd:YAG laser systems.

Due to a large filter capacitor C at the output of the bridge rectifier, the rectifying circuit draws power from the ac line only in small time intervals, resulting in pulsating input current with a high peak value. pulsed Nd:YAG Laser have the attraction of high efficiency relative to their continuous wave counter part. they also used the opportunity to choose the peak power to achieve the required process whilst independently choosing the average power to meet the through- put requirement. the facility to control the pulse shape this benift in a wide range of applications.. By Using certain control tecniques, utililized in designing PIC16C54 from Mi
crochip technology and Intel 8051, also Mornitoring from Microsoft VisualBasic 5.

The Pic16c54 from Microchip trchnology is a family of low-cost, high performance, 8-bit, fully static, EPROM/ROM-based CMOS microcon troller s.it employs a RISC architecture with only 33 single cycle (200ns) except for program branches which take two cycles. the easy to use and easy to remember instruction set reduces developments time significantly. Fig.2. shows the schemetic structure of Nd:YAG Laser system.. The Nd: YAG Laser system mentioned above consists of a Controller as AC/DC Rectifier, Simmer, a resonants inverter to converter DC input voltage into high -frequency, high voltage to increase the inverter output voltage,a full bridge high voltage and lamp as a load which can be represented by a resistance load model. equivalents resistance can be varied by means of lamp current controller connected to the cathode of lamp, Pic16c54 from Microchip technology . The trially-produced setup using new power semiconductor devies/modules for Nd:YAG Laser power is investigated including

And there by it is broadly used in many applications such as microm achining, holography, range finding, materials processing and so on3-6. Among other things, in materials processing, suitable laser power density is required for the specific process, and the laser power density can be controlled by current pulsewidth and pulse repetition rate, which are known to be major factors for particular property of materials7,8.

2. SYSTEM DESCRIPTION

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

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).

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.

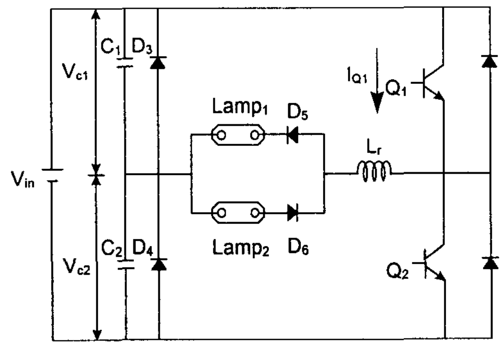

Fig.2. Electrical circuit of the ZCS resonant converter

In Fig. 2, the pulse forming network(PFN) applied ZCS series resonant converter consisted of switch devices(*Q1*, *Q2*), a resonant inductor(*Lr*), and resonant capacitors(*C1*, *C2*). The switching loss was zero in principle, and it is adequate in high repetion rate operation because the current through *Q1*, *Q2*, *C1*, and *C2* was forced to the sinusoidal wave, and the switch' devices turned on/off at zero current. The output of ZCS series resonant converter is

$$Pout = 2\,f\,C\,Vin2 \quad (1)$$

where f is the repetition frequency, C the capacitance of charging capacitor, and *Vin* the input voltage. According to this formular, it is found that there are two ways to control the power density of the resonant converver. One is to vary the input voltage *Vin* at a constant pulse width 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 *Vin*.

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 Vc1 of capacitor *C1* is initially charged to input voltage *Vin*, the voltage *Vc2* of capacitor *C2* zero, switch devices *Q1*, *Q2* turned off, and the simmer-trigger circuit is turned on.

Mode 1 ($t0 \leq t < t1$) : Mode 1 starts with the Q1 turning on at time t0. The equivalent circuits are shown in Fig. 3(b). The resonant current IQ1 flows through *C1*→*Q1*→*Lr*→*D5*→

lamp1→*C1* path and *Vin*→*Q1*→*Lr*→*D5*→lamp1 →*C1* path. The resonant capacitor voltage *Vc1*, *Vc2* and the input voltage *Vin* at time *t1* both are equal to zero. And then the current through resonant inductor *Lr* flows through *Lr* →*D5*→lamp1→*D3*→*Q1*→*Lr* path. As a result of that, *Vc1* and *Vc2* are clamped at zero and also *Vin* at zero.

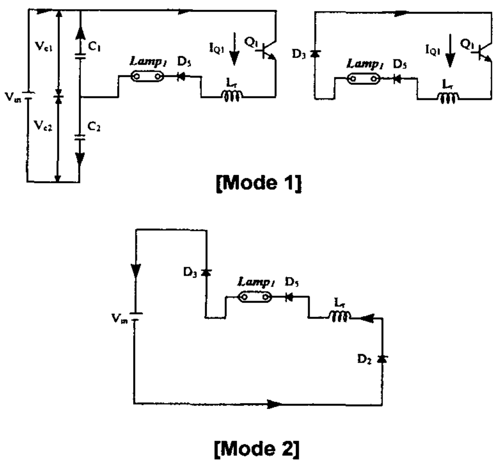

Fig.3. Equivalent Circuit waveforms of operation modes for the ZCS modes

Mode 2 ($t1 \leq t < t3$) : The equivalent circuit is shown in Fig. 3(b). Even though the switch *Q1* is turned off at time *t2*, the resonant current is continuously flowing to *Lr*→*D5*→lamp1→*D3*→*Vin*→*D2*→*Lr* path due to the stored energy in the resonant inductor *Lr*. During these mode 1 and mode 2, lamp 2 is blocked

by *D6*, so the energy is only provided with lamp1. Here, *ID3* 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.

Input vlotage (*Vin*) : DC 540V
Resonant capacitor(*C1*, *C2*) : 40F
Resonant Inductor(*Lr*) : 46H
Switching Freqency(*f*) : 1150Hz
Current Pulsewidth : 300s

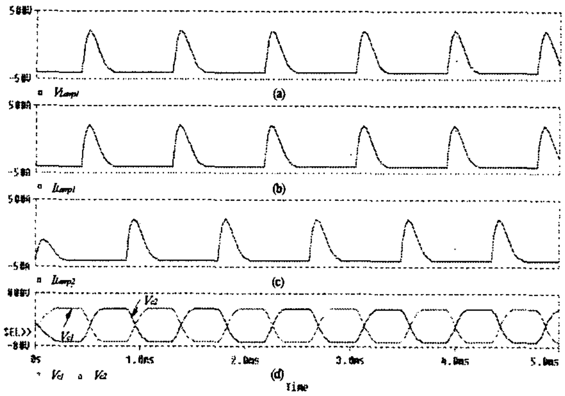

Fig.4. Circuit waveforms of operation modes for the ZCS

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 mm2 nickel wire is wrapped around the flashlamp for easy triggering.

Laser Controller

The pic16c54 series fits perfectly in applications ranging from high -speed automotive and appliance

control to low-power remote transmitters/ receivers, pointing devices and telecom processors...

A variety of frequency ranges and packaging

options are available. these devices have EPROM program memory and operate over the standard voltage range.
the availablity of OTP devices is especially useful for customers expecting frequent code changes and updates.. In order to realize low cost, more high-power density and improve power conversion efficiency and output dynamic response characteristics, a constant

Laser resonator

A laser head was composed of a Nd:YAG laser rod 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 laser rod. In the case of one laser head, they had a 50cm separation. And the total mirror had the reflectivity of over 99.5% and the concave curvature of 2m.

Fig.5. A general block diagram of the systems.

The half mirror had the reflectivity of 85%. In addition, in order to maintain a stable laser operation, the laser rod 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.

3. Results and discussion

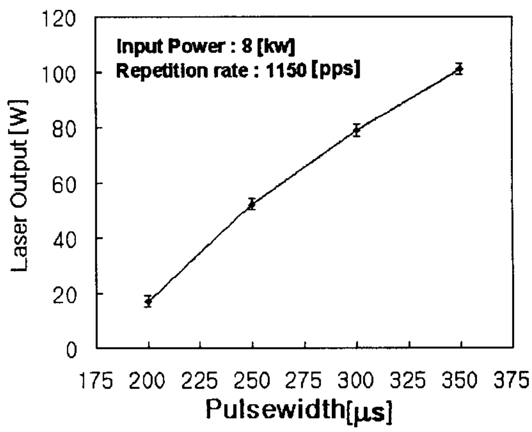

Fig.6. Laser output as a function of current pulsewidths at a repetition frequency of 1150pps

In the case of one laser head, Fig. 5 shows laser output obtained by varying a pulse repetition rate at the fixed current pulse width of 350s and the input power of 8kw. As a result, the highest output was
obtained at 1150pps. It means that laser output per second rises with increasing a repetition rate. In this experiment, the repetition rate was restricted to 1150pps because of the properties of Xe flashlamp made in ILC. Fig. 6 shows

laser output gained by adjusting a current pulse width at the repetition frequency of 1150pps and the input power of 8kw. The longer pulse width is, the higher laser output is.

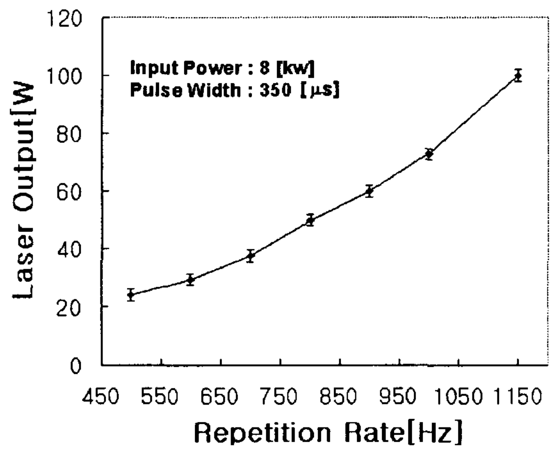

Fig.7. Laser output as a function of pulse repetition rates at a fixed current pulsedwidth of 350uS.

The maximum laser output was 240W at the input power of 12kw. And the laser output as a function of electrical input power is shown in Fig. 7.

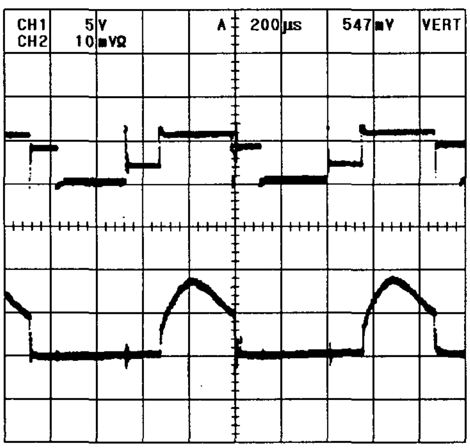

Fig.8. voltage and current waveforms across the switch devices during a switching period of the ZCS series resonant converters

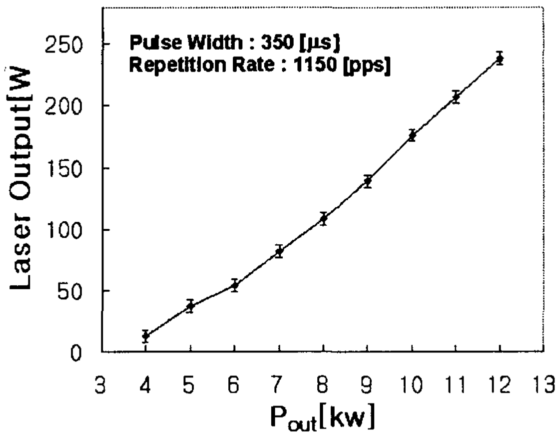

Fig.9. laser output as a function of electrical input power at a current pulsewidth of 350uS

As we can see, it rises linearly from the electrical
input power of about 4kw, 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. 8, 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 half mirror was changed from 85% to 80%. The maximum average output was about 480W.

4. CONCLUSIONS

The zero-current switching(ZCS) resonant converter as the power supply of a pulsed Nd:YAG laser 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) pulsed Nd:YAG laser system applied the ZCS resonant converter. In this study, in order to find out operational characteristics of the HRHP pulsed Nd:YAG laser system, the experiments have been performed by adjusting the current pulsewidths of 200s to 350s(step 50s) and the pulse repetition rate of 500pps(pulse per second) to 1150 pps. As a result, in the case of one laser head with a Nd:YAG laser rod and two flashlamps, the maximum laser output of 240W was obtained at the current pulsewidth of 350s and the pulse repetition rate of 1150pps. And that of about 480W for two laser heads was gained at the same condition.

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