論文
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A Variable pulsed Nd:YAG laser system adopted ZCC method
(영전압 제어 방법을 적용한 가변 펄스형 Nd:YAG 레이저시스템)

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ABSTRACT

For general laser power supply to control the laser power density, the secondary of the power transformer is connected to the rectifier and filter capacitor. The output of a rectifier is applied to a switching element in the secondary of the transformer. So power supply is complicated and the loss of switching is considerably. In addition, according to increasing pulse repetition rate, charged energy of energy-storage capacitor bank is not transferred sufficiently to flashlamp, and laser output efficiency decreases.

In this study, we have proposed the power supply in which the SCR was turned on at the zero point of input AC voltage by the method of zero cross control(ZCC). As a result of that, The new power supply employed ZCC are simple and compact in design. And laser output efficiency increased by the 3.5% other than conventional power supply (SCADC), when a repetition rate was increased by the 10pps. In 60pps, efficiency was increased by about 20%.

요 약

기존의 레이저통신용 스위칭 방식은 변압기 2차측에 정류부 및 평활용 콘덴서가 필수적으로 포함되어 있으며, 이렇게 얻어진 직류전압의 후단부를 스위칭하게 되므로 시스템장치가 복잡하다. 또한 스위칭에 의한 손실이 크고, 펄스반복율(pulse repetition rate)이 증가할수록 콘덴서에 저장된 에너지가 램프로 충분히 전달되지 못하여 레이저 출력 효율이 저감되는 단점이 있다.

본 연구에서는 스위칭에 의한 손실을 줄여 레이저의 출력 효율을 개선하고자 교류전압의 영점(ZERO)을 ZCC(zero cross control)방식으로 검출하여 변압기 2차측 교류전압의 영점에서 SCR을 턴-온(turn-on)시키는 레이저 시스템을 설계 및 제작하였다. 그 결과 기존의 평활용 콘덴서와 정류부를 사용한 레이저 시스템보다 펄스반복율이 10[pps]씩 증가할수록 레이저 출력 효율 약 3.5%씩 증가하여 60pps에서는 약 25%까지 상승하였다.

1. Introduction

The pulsed Nd:YAG laser is the most commonly used type of solid-state laser in many fields at present because of it's good thermal, mechanical properties, and easy maintenance. Since the transfer of laser beam was realized by optical fiber, communication and medical section has employed employed it.[1, 2]

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In resent studies of laser processing methods, the pulsed Nd:YAG laser, which has various advantages over the commonly used CO_2 laser, has been investigated energetically. It can be focused to a smaller point, due to its shorter wavelength, than the CO_2 laser, and can be easily adjusted to materials. Thereby it is broadly used in many application such as rangefinder, material processing, laser making and so on.[3-5]

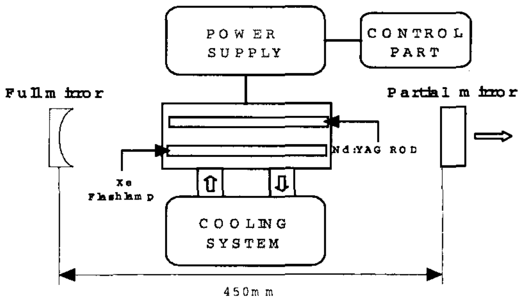
Its essential to make the efficiency of resonator and power supply better so that improvement in laser optical efficiency is accomplished. As of now, laser resonators for material processing and medical treatment make use of Fabry-Perot in which optical system becomes stable. However, for laser power supply, there is still something to make impro- vement.[6, 7]

In conventional laser power supply, the secondary of the power transformer are connected to the rectifier and filter capacitor and the filtered output is applied to a switching element in the secondary of the transformer, so that power system is complicated a little. According to increasing pulse repetition, now that charged energy of energy-storage capacitor is not transferred sufficiently to pumping source, laser output efficiency decreases and switching loss increases. These results cause the power system to be replaced by a PWM(pulse width modulation) control. In order to use a PWM switching as driving circuit of pumping source, the high switching frequency is required. But due to the switching loss at switches of system, the limitation is to reduce the switching loss by using the zero crossing control technique.

In this study, we will introduce a superior laser power supply using the ZPC method that dont make use of the rectifier and the filter capacitor. So the power supply is simple and competitive in price, and switching loss can be reduced. In order to investigate operational characteristics of our pulsed Nd:YAG laser system, we have carried out the laser output characteristic experiment as the function of pulse repetition rate.

2. Design

[Fig. 1] shows the schematic diagram of Nd:YAG laser system. In its basic configuration, a solid-state laser is comprised of a laser head which contains all the optical elements, a power supply to drive the pump source, and a cooling system. A flashlamp and a laser rod are placed at the focuses of elliptical pump cavity coated with gold. To perform the function of highly selective feedback element by coupling back in phase a portion of the signal emerging from the amplifying medium, the optical resonator in composed of two dielectrically coated mirrors which have a separation of 450mm. One has a concave curvature of 2m(reflectivity of over 99.5%), the other is flat(reflectivity of 85%). Mirrors are placed at the ends of the laser rod. In other to keep stable laser action, cooling of the rod and flashlamp is accomplished by circulating water.



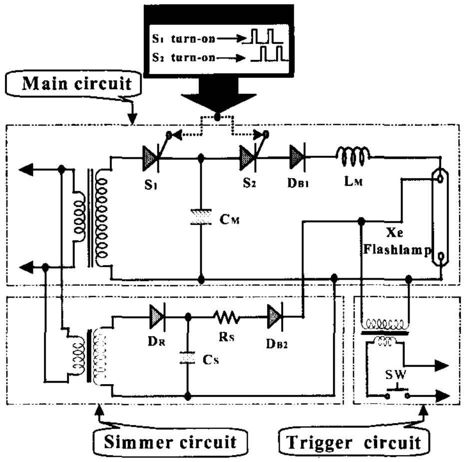
[Fig. 1] The schematic diagram of laser system unit.

A schematic diagram of power supply is shown in [Fig. 2]. This power supply is simple because the rectifier and filter capacitor could be removed. And it can reduce switching loss and noise because SCR is turned on at the zero point of AC voltage in secondary of transformer. The circuit operation is as follows.

① The simmer-trigger circuit creates an ionized spark streamer between two electrodes so that the main discharge can occur.

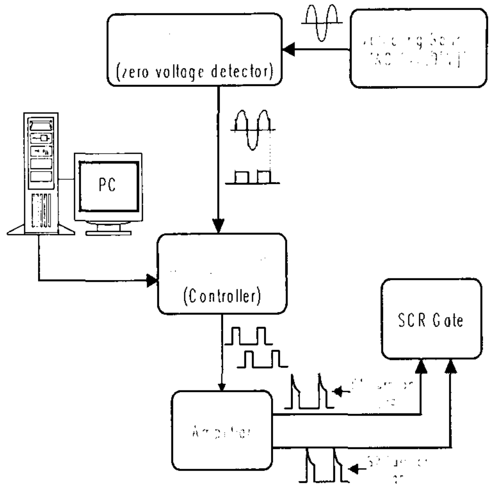
② SCR1 turned on at the zero point of AC voltage in secondary of transformer storage capacitor bank(CM) charged.

③ SCR1 turn-off SCR2 turn-on charged energy of storage capacitor transferred into flashlamp.(so called First charge and Last discharge technique adopted)



[Fig. 2] The laser power supply of ZPC method.

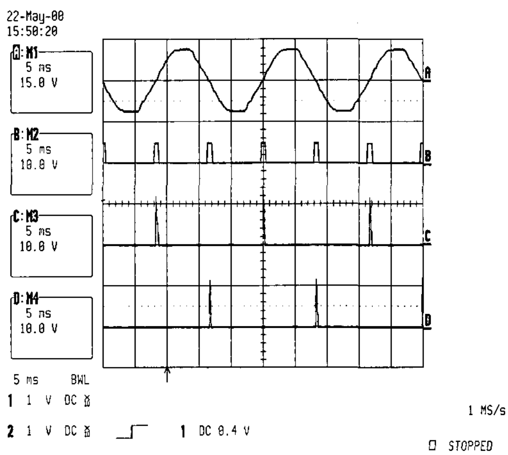
[Fig. 3] shows the block diagram of zero voltage detector and controller. From the line sample voltage by step-down transformer, the synchronization signal is obtained via a zero voltage detector, which evaluates the zero passages and transfers them to the one-chip microprocessor. By the controller, for every half wave of line voltage, a positive pulse of approximate 320s duration appears at the output of the controller. This output signal is a square pulse, so it is necessary to transform it into a different signal. Therefore, it does not have effect on the turn-off time of each SCR according to an increase in a pulse repetition rate. A differentiator transforms it into a specific signal with a short pulse width. This short pulse has such a low voltage and low current that it is difficult for the transformed signal to turn each SCR on. For this reason, an amplifier inserted plays a role in amplifying the current and voltage of the transformed signal.



[Fig. 3] The block diagram of zero voltage detector and controller

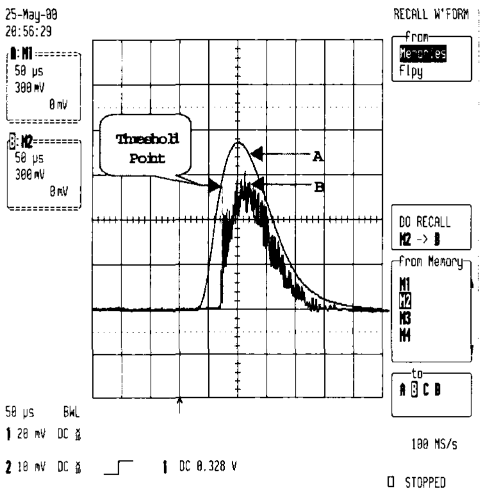
3. Output performance

[Fig. 4] shows the zero crossing signal detected by zero crossing detector and SCR turn-on signal at 60pps(pulse per second). Waveform A is synchroniz- ation signal. After output signal of zero voltage detector(B) is transferred to microprocessor, SCRs turn-on(C, D) are generated by an interval of about 8.4ms.



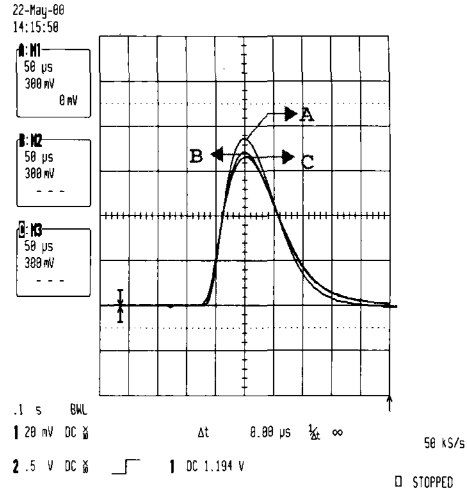
[Fig. 4] Zero voltage detector and SCR gate turn-on signal.

A current waveform of flashlamp and laser beam profile are shown in [Fig. 5] at a pulse repetition rate of 1pps and a capacitor bank voltage of about 850V. Current waveform was measured with a pulse current transformer(pearson electronics co. sensitivity of 0.001 V/A) and beam profile, with APD (avalanche photo diode, Model : hamamatsu C5331). Laser action reaches threshold at the 70% points of current waveform. In this figure, as you see, FWHM(full width at half maximum) is about 100μs.

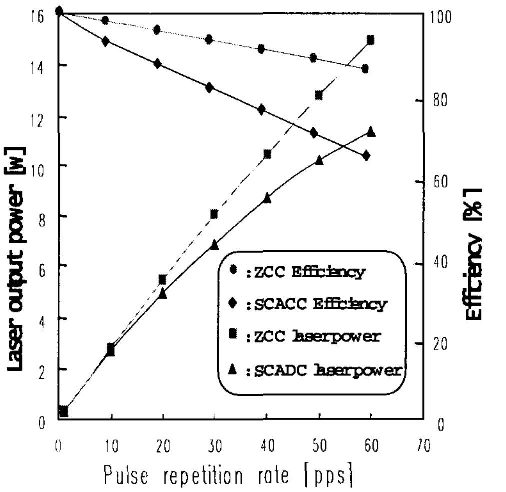


[Fig.5] A current waveform of flashlamp and laser beam profile at the pulse repetition rate 1[pps].

At a repetition rate of 1, 30, 60pps and a capacitor bank voltage of about 850V, flashlamp current waveform is shown in figure 6. The peak value of waveform A, B, C is 930, 860, 835A respectively. According to increasing pulse repetition rate, charged energy of capacitor is not transferred sufficiently to pumping source, so that peak value of measured currents tends to decrease a little.



[Fig. 6] A current waveforms of flashlamp at the pulse repetition rate 1, 30, 60[pps].



[Fig. 7] The characteristics of laser output vs. pulse repetition rate.

[Fig. 7] shows the laser output as a function of pulse repetition rate. According to increasing the pulse repetition rate in conventional power system (SCADC), the laser output efficiency decreased (for example, laser output of 11W at 60pps).[12] On the other hand, proposed power system in this paper displayed laser output of about 15W under same conditions. The output efficiency of ZPC supply system goes up much more than one of conventional system.

4. Conclusions

In this study, we designed and fabricated a new power supply adopted ZCC method to control the laser power density. We have performed experiments of output characteristics with our Nd:YAG laser. The obtained results are as follows.

① As SCR was turned on at zero point of AC voltage in secondary of transformer, switching loss can be reduced. The power supply was simple and economical because the rectifier and filter capacitor could be removed.
② It is known that the laser output is stable up to the 60pps without damage to any element of system by damping.
③ While in conventional power supply (SCADC) using rectifier and filter capacitor, laser output of 11W was obtained at 60pps, laser output of 15W in ZPC power supply was obtained under same conditions. Therefore the output efficiency of new power supply goes up to 20% compared to one of conventional system.

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