

A study on Intention Pulse Forming Network Generation of Pulse Nd:YAG Laser adopting Multi-Alienation Discharge

(다중분할 방전방식을 적용한 펄스형 Nd:YAG 레이저의 임의 펄스성형 연구)

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ABSTRACT

In this study, a solid-state laser system adopting a new real time multi-discharge (RTMD) method in which three flashlamps are turned on consecutively was designed and fabricated to examine the pulse width and the pulse shape of the laser beams depending upon the changes in the lamp turn-on time. That is, this study shows a technology that makes it possible to make various pulse shapes by turning on three flashlamps consecutively on a real-time basis with the aid of a PIC one-chip microprocessor.

With this technique, the lamp turn-on delay time can be varied more diversely from 0 to 10 ms and the real-time control is possible with an external keyboard, enabling various pulse shapes. In addition, longer pulses can be more widely used for industrial processing and lots of medical purposes

요 약

펄스형 Nd:YAG 레이저는 연속형에 비해 효율이 높고 높은 침투출력이 가능하므로 가공에 있어서 여러 가지 장점이 있다. 더구나 레이저 펄스모양을 가변시키는 기능은 펄스형 Nd:YAG 레이저로 가공하기 힘든 특수분야에까지 가공을 가능하게 하였다. 본 연구에서는 3개의 플래쉬 램프를 순차 점등시키는 방식의 레이저시스템을 설계, 제작하여, 램프 점등시간의 변화에 따른 레이저빔의 펄스 폭과 펄스 세기를 조사하였다. 즉 PIC-Onechip microprocessor를 이용하여 실시간으로 3개의 플래쉬 램프를 순차적으로 점등시켜 보다 다양한 펄스모양을 만드는 기술을 개발 하였다. 위 방식의 장점은 램프의 점등 지연시간을 0~10ms까지 다양하게 변화 시킬 수가 있고, 외부의 키보드로 실시간 제어가 가능하므로 보다 편리하게 펄스모양을 변화 시킬 수가 있다. 또한, 긴 펄스를 만들 수가 있어 산업용 가공이나 의료용으로 널리 사용될 수가 있을 것이다.

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1. 서론

Recently laser applications are being widely used in a variety of fields including material processing, industrial instrumentation and medical equipments. [1, 2]

In the area of material processing, the application scope of the laser processing technologies is increasingly expanding as more refined and precise processing is required in industrial sites. The laser types that are widely used in material processing include Nd:YAG, CO₂ and Excimer. In terms of the output type, pulsed, CW and Q-switching types are popular. Each of these lasers has an independent area of application depending upon its characteristics.[3-5]

The pulsed Nd:YAG laser has various advantages over the continuous laser as it has a greater efficiency and a higher peak power. Moreover, the function to vary the laser pulse shapes makes it possible to process even special areas whose processing was impossible with the conventional pulsed Nd: YAG laser.[6]

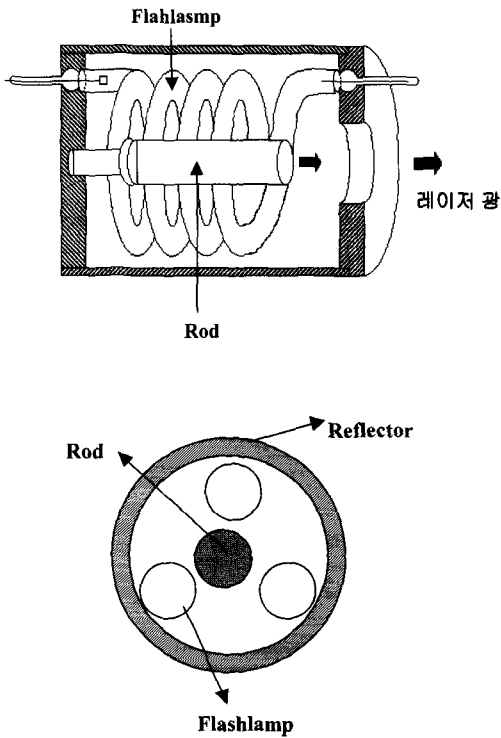
The classical laser output pulse shape usually takes on a rectangular form in a two-dimensional structure having the output strength and the output pulse width. At this time, the variation of the pulse shape refers to the variation of the output strength and the output pulse width within a single output pulse. Therefore, the shapes of the output pulse can take on very complicated forms depending upon processing materials, instead of the rectangular form. [7, 8]

The laser output pulse variation involves two parameters of the output strength and the pulse width. When the laser is condensed and applied to a workpiece, the workpiece absorbs the laser light, causing the temperature to rise locally. At this time, the temperature rise differs according to the applied laser strength and the material characteristics of the workpiece while the temperature rise required differs depending upon the processing needs. Accordingly, a more delicate processing is possible by properly

controlling the temperature rise through the adjustment of the output pulse strength. With respect to the variation of the laser output pulse width, long pulses (around 2~20msec) are needed to ensure sufficient welding in the case of laser welding while pulses ranging 0.1~3msec are needed for hole drilling. Thus, the pulse strength and width vary depending upon the types of processing materials and therefore the traditional rectangular laser pulse shape has limitations in carrying out various processing needs. These limitations of the rectangular pulse shape can be overcome if the laser output strength and the pulse width can be varied freely.[4, 9]

There are two traditional pulse variation methods: variation of capacitance or inductance and change in the switching time of the switching element (IGBT, SCR, FET, etc.). In these methods, the variation of the pulse shape and width is limited and the switching element control system is complicated and its operation is somewhat difficult.[10-11]

Therefore, this study suggests a new RTMD method that can vary the pulse width in accordance with the consecutive turn-on of flashlamps. Using a real time one-chip microcomputer, this method turns on the flashlamps consecutively with a precision of up to 1mÅ and thus can create diverse pulse shapes and pulse strength, in addition to longer pulses. Therefore, this method can be used in various applications including medical equipment and special processing needs.



[Fig. 1] Schematic diagram of laser cavity system unit.

2. Design

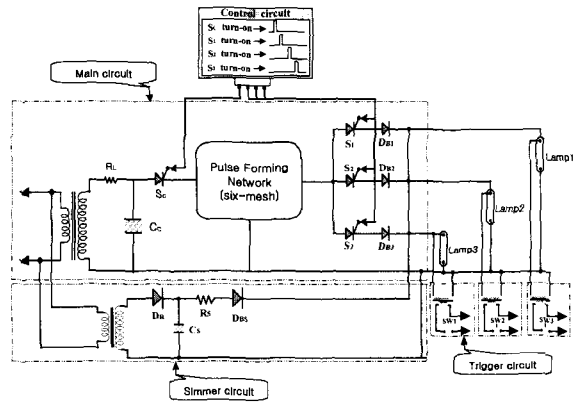
1) Laser system unit

[Fig 1] represents a schematic diagram of a laser system unit. There is a circular-type laser head in the center of the oscillator and on both sides of the head there are two mirrors for laser oscillation: a total reflector (a concave mirror with a reflectivity of over 99.5% and a curvature radius of 2m) and a partial reflector (a plane mirror with a reflectivity of 85%) that constitutes a stable resonator. The laser cavity by the optical pumping was made in a round form with use of optical glass causing diffused reflection in order to deliver the light radiated from the lamp efficiently to the rod. The laser head

comprises the rod in the center of the circular cavity and three flash lamps around the rod at an interval of 120°.

2) power supply

[Fig 2] shows a laser power supply of a new RTMD type using the PFN. It consists of a 6-step mesh to make the laser output pulse a rectangular form. In the experiment, the capacitance C, inductance L and the charging voltage of the capacitance were set at 3330µF, 1200µH and 400V, respectively. At this time, the input energy is calculated at 266J, about 4ms from formulas (1)



[Fig. 2] Laser power supply of an RTMD method using the PFN

and (2).

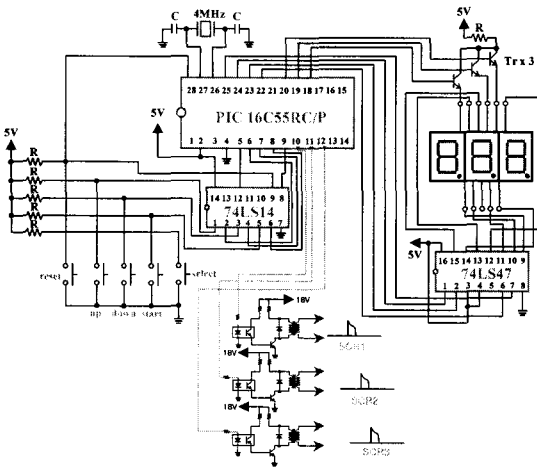
$$E_0 = 1/2 CV^2 \quad (1)$$

$$td = 2iL \quad (2)$$

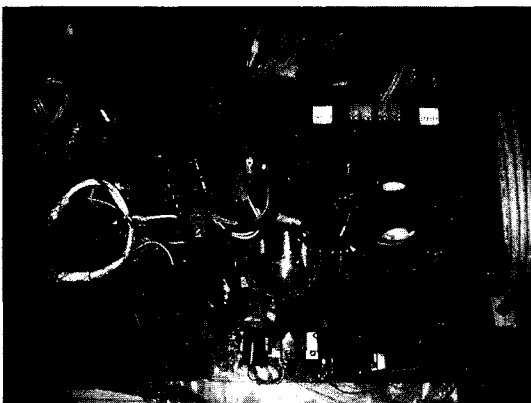
The operating principle of the above circuit can be summarized as follows:

- (1) Authorize DC 1[kV] to both ends of the flash lamp with the simmer power supply, turn on the switch of the trigger pulse circuit and then the streamer discharge is sustained in the flashlamp.

(2) When SCR Sc is turned on, the energy is charged in the capacitance of the PFN, and then SCR S1, S2 and S3 are turned on consecutively. At this time, the energy stored in the capacitance of the PFN is delivered and the lamp is turned on.



[Fig. 3] Turn-on delay time control circuit of the SCR comprising a PIC one-chip microprocessor. .



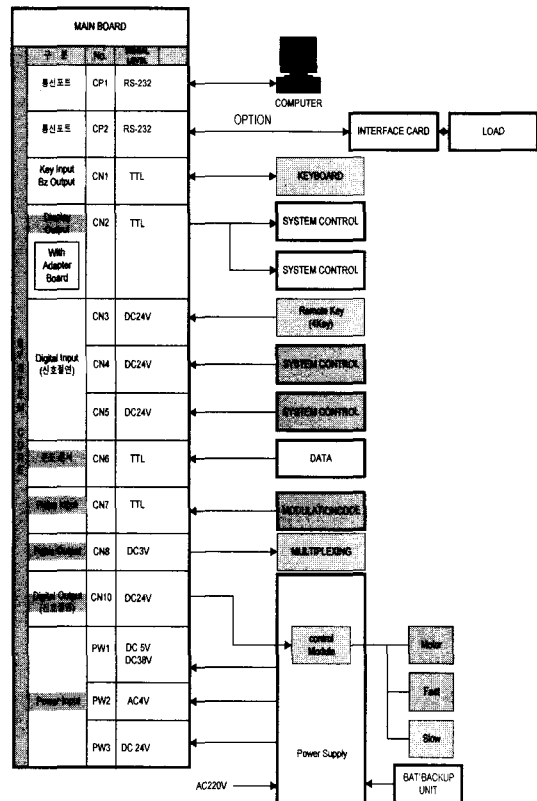
[Fig. 4] Main controller.

3) Control circuit

[Fig 3] represents the turn-on delay time control circuit of the SCR comprising a PIC one-chip

microprocessor. This control circuit consists of four parts: the keyboard that enters the delay time; the FND (Multi-segmented LED Displays) display; the PIC microprocessor which is the most key part of the control circuit; and the amplification circuit to turn on SCR.

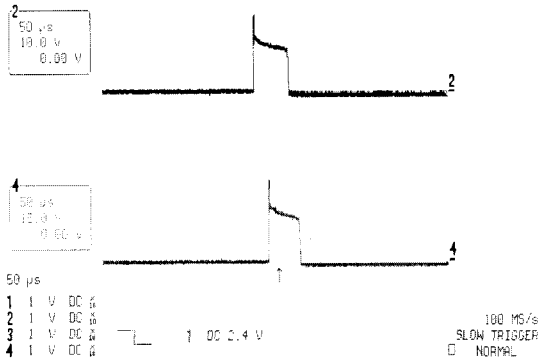
In this control circuit, the delay time information is entered by the keyboard, and this input is conveyed to the PIC which in turn outputs four different signals in accordance with the predetermined program. But these signals are too weak to turn on the SCR and therefore the current and voltage are amplified with use of a transistor for high-speed switching. These amplified signals first turn on SCR Sc and then turn on SCR S1, S2 and S3 consecutively with a precision of up to 1 μ s. [Fig 4] shows Main controller and [Fig 5] represents the Flow chartt.



[Fig. 5] Flow chartt.

3. Experimental results

[Fig 6] shows the gate trigger signals of SCR Sc ~ S3. Signal 1 is triggered after SCR Sc is triggered and signals 2, 3 and 4 are triggered at a certain delay time interval by $10\mu\text{s}$ each, turning on SCRs consecutively. At first, our controller perceives the trigger signal of SCR Sc. And then the rectangular waveform signals of SCR S1 ~ S3 was applied the each SCR gate with an adjusting delay time by a PIC one-chip microprocessor.

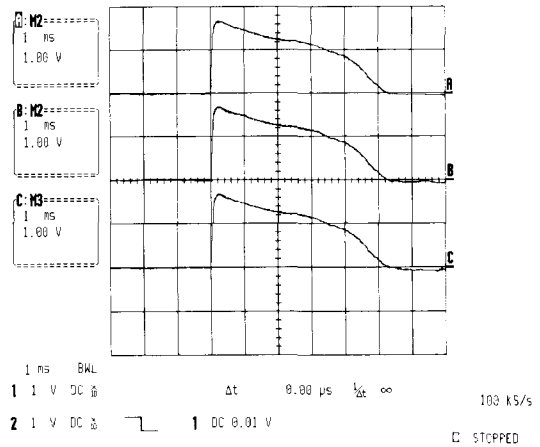


[Fig. 6] Gate trigger signals of SCR Sc ~ S3 .

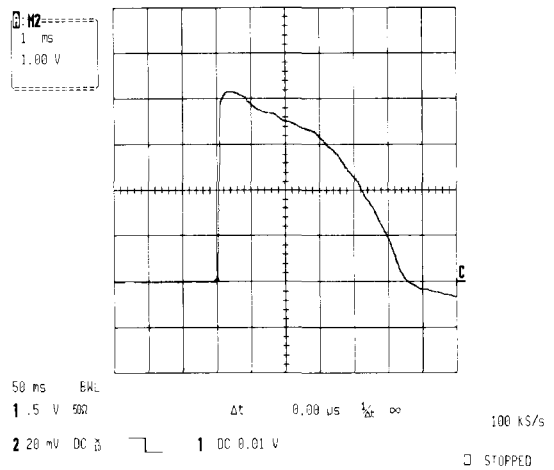
[Fig 7] shows the laser beam profiles at a time when the three flash lamps are turned on respectively. At this time, the FWHM is around 4ms. These waveforms obtained at the input energy of 266[J]. And the laser output energy was obtained about 3[J]. The laser beam profile of flashlamp is nearly the same one.

[Fig 8] indicates the laser beam profile when the delay time is set at $0\mu\text{s}$ (when the lamps are turned on simultaneously). At this time, the FWHM is about 4ms and the peak value is about 2.7 times greater than that of a single flashlamp. In this case, the typical laser beam profile was obtained by

multi-pulse superposition technique stemmed from two-pulse superposition technique.[11]



[Fig.7] The laser beam profiles at a time when the three flash lamps are turned on respectively



[Fig. 8] The laser beam profile when the delay time is set at $0\mu\text{s}$.

[Fig 9] shows the laser beam profiles when the three lamps are turned on at the delay time interval of 1ms. Here, the FWHM stands at about 5ms and the peak value is two times greater than that of a single flashlamp. The typical laser beam profile was

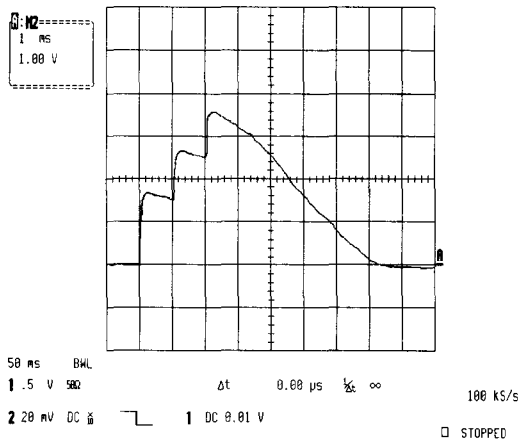
generated a step-like waveform caused by adjusting a delay time of each SCR consecutively.

[Fig 10] represents the laser beam profile when the delay time is set at 2ms. In this case, the FWHM is about 8ms. This generated waveform was nearly the same one caused by the above mentioned.

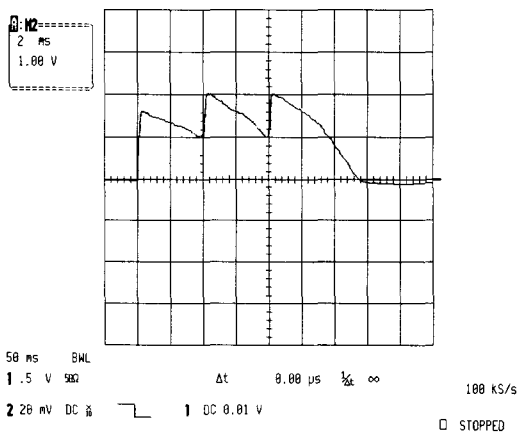
4. Conclusion

In a wide range of material processing, the various pulse shapes will be able to enhance the processing efficiency. We have generated various pulse shapes by adopting the new RTMD(real time multi-discharge) method which turns on many flashlamps consecutively.

In this study we have proposed the new technology of long pulse generation adopting the each SCR gate with an adjusting delay time by a PIC one-chip microprocessor. By doing this new technique, various pulse shapes will be able to generated. Especially the longer pulse shapes up to 20ms can be generated more precisely and easily which has never been applied.



[Fig. 9] The laser beam profiles when the three lamps are turned on at the delay time interval of 1ms.



[Fig. 10] The laser beam profile when the delay time is set at 2ms.

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