Long Pulse Generation Technology of an Alexandrite Laser System for Hair Removal

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Abstract - In this study, an Alexandrite laser system for hair removal adopting a multi-discharge 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. Specifically, this study demonstrates a technology that makes it possible to formulate various pulse shapes by turning on three flashlamps consecutively on a real-time basis with the aid of a PIC (program integrated circuit) one-chip microprocessor.

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

Keywords: Hair removal, Multi-discharge, PIC one-chip microprocessor, Long pulse, Pulse shape

1. Introduction

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, CO_2 and Alexandrite. In terms of the output type, pulsed, CW (continuous wave) and Q-switching types are the most popular. Each of these lasers has an independent area of application depending upon its characteristics. [3-5]

The pulsed Alexandrite 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 shape makes it possible to process specific areas whose processing was previously impossible with the conventional pulsed Alexandrite laser. In particular, the long pulse Alexandrite laser ranging from 5 to 10ms is being widely used for hair removal in the administration of medical treatment. The 755nm alexandrite wavelength makes the laser well-suited for hair removal as it penetrates deeply into the dermis with lengthy active times. [6-8]

The classical laser output pulse shape usually takes on a rectangular form in a two-dimensional structure having the output power and the output pulse width. Currently, the variation of the pulse shape refers to the variation of the output power 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. [8, 9]

The laser output pulse variation involves two parameters of the output power and the pulse width. When the laser is focused 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 1~20msec) are needed to ensure sufficient strength for hair removal. 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 the various processing needs. These limitations related to the rectangular pulse shape can be overcome if the laser output power and the pulse width can be varied freely. [4, 11]

There are two traditional pulse variation methods: variation of capacitance or inductance and change in the switching time of the switching element [IGBT (insulated gate bipolar transistor), SCR (silicon -controlled rectifiers), FET

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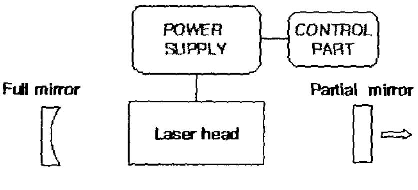
(field effect transistor), etc.] In these methods, the variation of the pulse shape and width are limited and the switching element control system is complicated with a somewhat difficult manner of operation. [12-13]

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

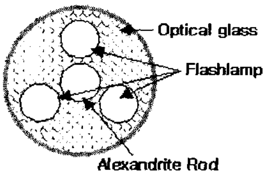
2. Design

2.1 Laser system unit

Fig. 1 represents a schematic diagram of a laser system unit. There is a circular-type pump cavity in the center of the oscillator and on both sides of the pump. There are two mirrors for laser oscillation: a total reflector (concave mirror with a reflectivity of over 99.5% and a curvature radius of 2m) and a partial reflector (plane mirror with a reflectivity of 80%) constituting a stable resonator. Photo 1 shows our practical laser system. The pumping cavity was composed in a circular form with the use of optical glass causing diffused reflection in order to deliver the light radiated from the lamp efficiently to the rod. The pump cavity comprises the rod in the center of the cylindrical cavity and three flashlamps around the rod at an interval of 120°.



(a) Laser system



(b) Laser head

Full mirror(radius of curvature : +2m, $R > 99.5\%$)
Partial mirror(flat, R≈80%)
Alexandrite rod(concentration of Cr^{3+}: $BeAl_2O_4$ atoms :
1.1%, length : 76.5mm diameter : 6mm)
Xe Flashlamp(arc length : 63.5, diameter : 6mm)

Fig. 1 Schematic diagram of laser system unit

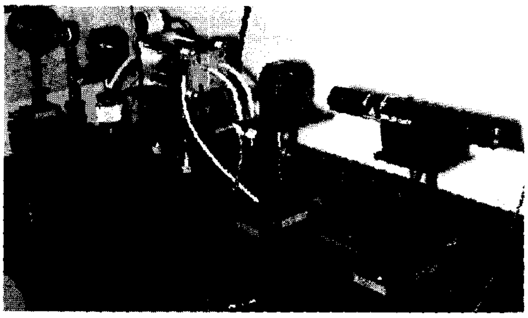
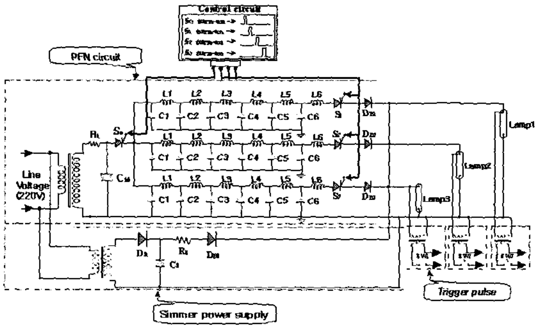


Photo 1 Laser optical system

2.2 Power supply

Fig. 2 shows a multi-discharge type laser power supply using the PFN (pulse forming network). It consists of a 6-step mesh to make the laser output pulse a rectangular form. In the experiments, the capacitance C, and the inductance L were set at 1200 μF and 840μH respectively. At this time, the input energy was calculated at 384J (the charging voltage was set at 800V), about 2ms from formulas (1) and (2).



L1~L6 = 140 μH C1~C6 = 200 μF R_L = 5 Ω
Cs = 10 μF Rs = 15 kΩ

Fig. 2 Laser power supply of a multi-discharge method using the PFN

$$E_0 = 1/2\, CV_0^2 \tag{1}$$

$$t_d = 2\sqrt{LC} \tag{2}$$

Photo 2 shows our laser system adopting a multi-discharge method with 6-mesh PFN.

Photo 2 Total laser system of multi-discharge method

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

(1) Authorize DC 1[kV] to both ends of the flashlamp using the simmer power supply, turn on 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.

2.3 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 used to enter the delay times; the multi-segmented LED displays; the PIC one-chip microprocessor, which is the most significant part of the control circuit; and the amplification circuit to turn on SCR. Photo 3 shows the the SCR turn-on delay time controller.

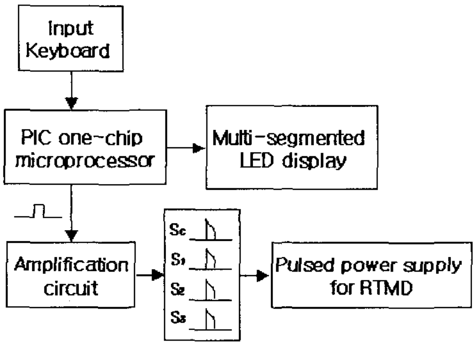


Fig. 3 Block diagram of turn-on delay time control circuit for a real time multi-discharge technique.

Photo 3 SCR turn-on delay time controller

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. However, these signals are too weak to turn on the SCR and therefore the current and voltage are amplified by the 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 μs.

3. Experimental Results

Signal 1 triggers SCR Sc and signals 2, 3 and 4 trigger SCRs at a certain delay time interval by 10 μs each, turning on SCRs consecutively as shown in Fig. 4. At first, our controller perceives the trigger signal of SCR Sc. And then the rectangular waveform signals of SCR S1 ~ S3 were applied to each SCR gate with an adjusting delay time by a PIC one-chip microprocessor.

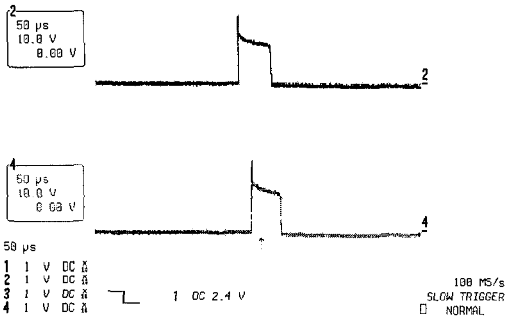


Fig. 4 Gate trigger signals of SCR Sc ~ S3

Fig. 5 shows the temporal laser profile when a single flashlamp is turned on. At this time, the FWHM (full width at half maximum) was approximately 2ms. These waveforms were obtained at the input energy of 384[J] and the laser output energy was obtained at about 1[J]. The temporal laser profile of the flashlamp was almost identical.

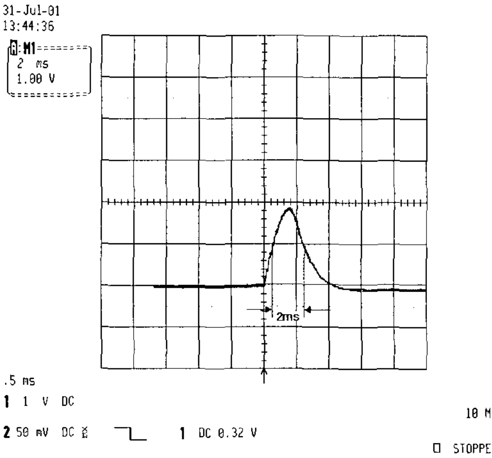
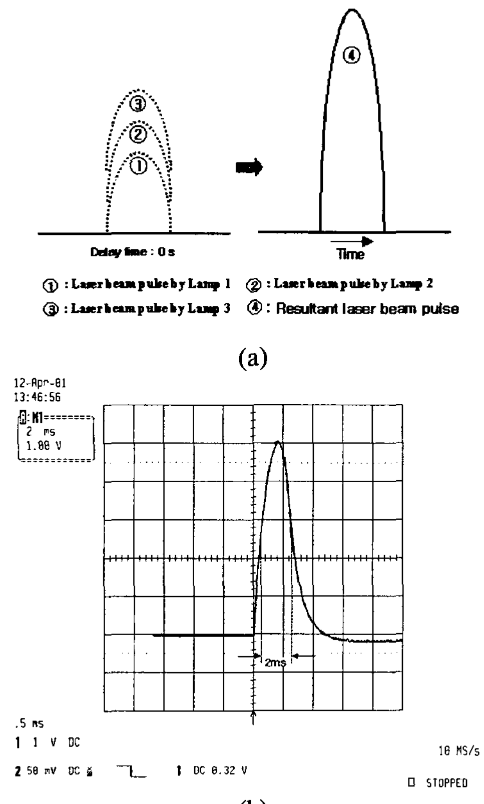


Fig. 5 The temporal laser profile at a time when a single flashlamp is turned on.

Fig. 6 indicates the temporal laser profile when the delay time is set at 0 μs (when the lamps are turned on simultaneously). At this time, the FWHM is about 2ms and the peak value is about 2.6 times greater than that of a single flashlamp. In this case, the typical temporal laser profile was obtained by multi-pulse superposition technique derived resulting from the two-pulse superposition technique. [13]

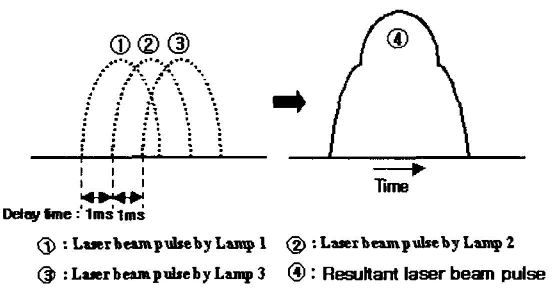


(a)

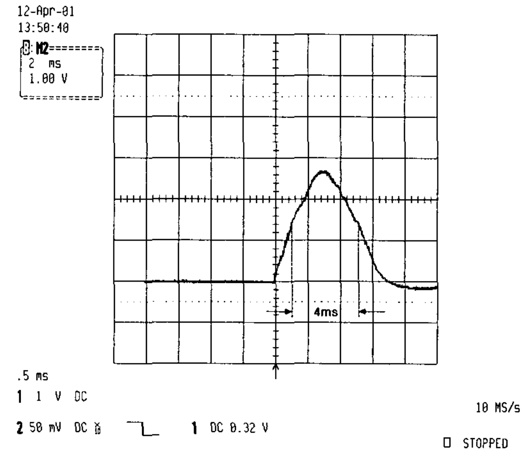
(b)

Fig. 6 (a) Principal diagram and (b) temporal laser profile when the delay time is set at 0 μs.

Fig. 7 shows the temporal laser profile when the three lamps are turned on at the delay time interval of 1ms. Here, the FWHM stands at about 4ms and the peak value is about 1.5 times greater than that of a single flashlamp. The typical temporal laser profile was generated in a step-like waveform caused by adjusting the delay time of each SCR consecutively.



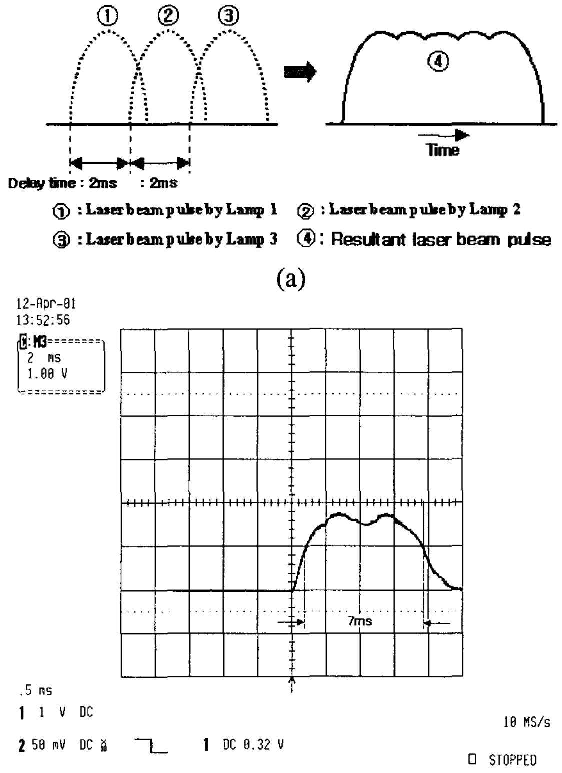
(a)



(b)

Fig. 7 (a) Principal diagram and (b) temporal laser profile when the three lamps are turned on at the delay time interval of 1ms.

Fig. 8 represents the temporal laser profile when the delay time is set at 2ms. In this case, the FWHM is about 7ms. This generated waveform was almost equivalent to the one mentioned above.

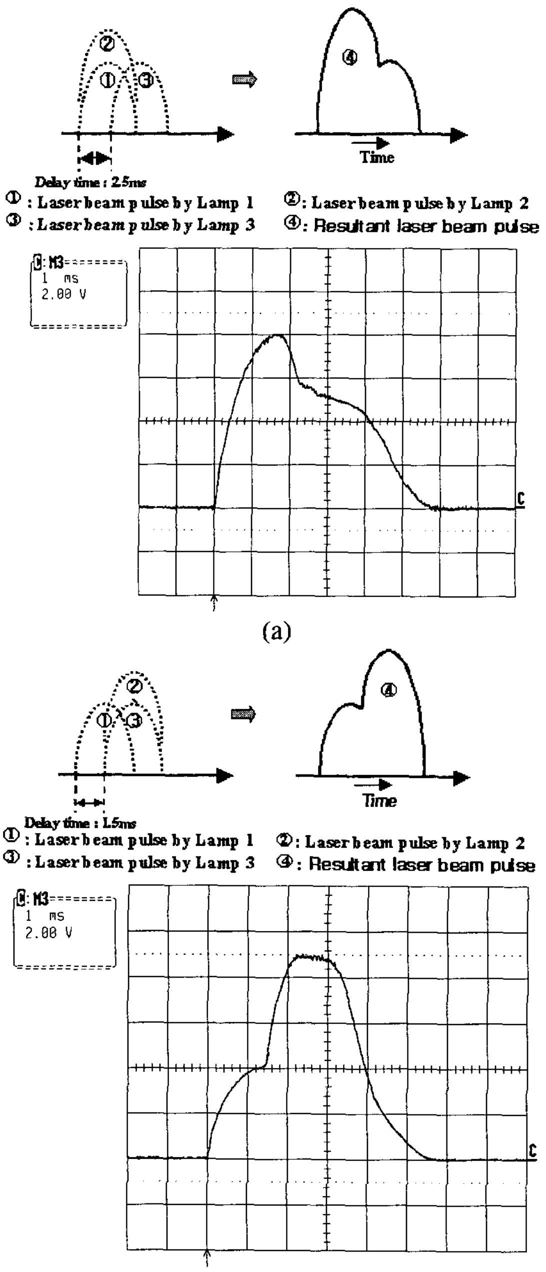


(a)

(b)

Fig. 8 (a) Principal diagram and (b) temporal laser profile when the delay time is set at 2ms.

The temporal laser profile with a singular peak position caused by adjusting a delay time of each SCR consecutively is depicted in Fig. 9. Fig. 9-(a) represents the temporal laser profile when the three lamps are turned on at the set delay times of 0s and 2.5ms, respectively. The temporal laser profile shows a pre-peak pulse shape with the FWHM at approximately 3.7ms. Fig. 9-(b) represents the temporal laser profile when the three lamps are turned on at the set delay times of 1.5ms and 0s, respectively. This temporal laser profile shows a post-peak pulse shape with the FWHM at approximately 2.5ms.



(a)

(b)

Fig. 9 (a) temporal laser profile when the delay time is set at 0s and 2.5ms, respectively. (b) temporal laser profile when the delay time is set at 1.5ms and 0s, respectively

4. Conclusion

In a wide range of hair removal processing, the various pulse shapes will be able to enhance the processing efficiency. We have generated various pulse shapes by adopting the multi-discharge method, which turns on many flashlamps consecutively.

In this study we have proposed innovative technology for long pulse generation allowing each SCR gate to have an adjusting delay time by a PIC one-chip microprocessor. Using this new technique, various pulse shapes will be able to be generated. In particular, the longer pulse shapes up to 10ms can be generated more precisely and easily, which have never been able to be applied before.

Acknowledgements

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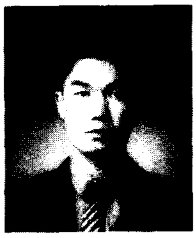

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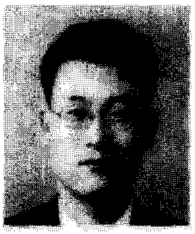

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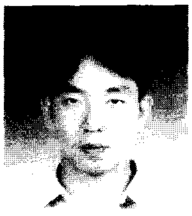

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