

## Nd:YAG Laser를 위한 포켓셀 Q-스위칭특성 연구

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### 요약

Q-스위칭은 셔터나 다른 광학소자를 레이저 광 공진기 내에 넣어 광이 공진기 내에서 발진하는데 손실을 유발하고, 충분한 반전분포가 활성 매질 내에서 생성되면 순간적으로 셔터를 열어 공진기 내에 축적된 에너지가 매우 강한 빛으로 방출되게 하는 것이다. 이와 같이 Q-스위칭은 레이저 공진기의 Q-factor를 감소시켰다가 갑자기 증가시키는 것이다. 레이저 Q-스위칭의 방법에는 mechanical switching 방법, electro-optic switching 방법, switching by saturable absorber 방법, acousto-optic switching 방법 등 크게 4가지가 쓰이고 있다. 이들 중 전기광학적인 효과에 의한 전기적인 전환은 짧은 펄스폭의 Q-스위칭 펄스를 생성할 수 있기 때문에 널리 사용되고 있다. 따라서, 전기광학효과의 특성을 가진 Pockel cell은 Q-switch로 사용하기 적합한 것으로 알려져 있다. 본 연구에서는 포켓셀 Q-스위칭용 구동 장치를 스위칭 소자인 FET와 PIC 마이크로프로세서 및 펄스 트랜스로 설계, 제작하고, 펄스형 Nd:YAG 레이저 시스템에 적용하여 Q-스위칭의 동작 특성을 조사, 연구하였다. 또한, 이 Q-스위칭을 통하여 출력된 Nd:YAG 레이저 빔의 측정치를 이론적 계산에 의해 구해진 예상치와 비교하여 Q-스위칭 된 레이저 빔의 특성을 분석하였다.

## A study on the characteristic of Pockel cell Q-switch for Nd:YAG laser

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### Abstract

The Q-switching the shutter or the different optical science element puts in within the laser light resonator and the storehouse departs from the within the resonator it loses the mortar and the reversal distribution which when is sufficient creates from within the active medium, opens the shutter instantaneously and it is to do to be made to emit with the light where the energy which is accumulated within the resonator is strong very. Like this Q-switching of laser resonator--It decreases factor increasing suddenly to make. To method of Laser Q-switching mechanical switching methods, electro-optic switching methods and switching by saturable absorber methods, acousto-optic switching method etc. 4 kind are being used on a large scale. In these people the conversion which is electric in compliance with the effect which is electrooptics is widely being used the Q-switching pulse of short pulse width because being it will be able to create. Consequently, Pockel cell where it has the quality of electrooptics effect) the Q-it is become known that it is suitable it uses with switch. From the research which it sees FET and one-chip microprocessor where it is a switching element and pulse transformer to plan and produce pockel cell Q-switch driving gears, pulse style Nd: It applied in YAG Laser system and it investigated and researched the operating characteristic of the Q-switch. Also, the Q-switch leads and Nd where it is output: YAG with forecast in compliance with a theoretical calculation it comes to buy laser beam side politics it compared and laser beam qualities which had become Q-switching it analyzed.

Keywords : Q-switch, pulsed Nd:YAG laser, Q-factor, pic-microprocessor, pockel cell

## 1. INTRODUCTION

The dependancy which generally is a time of Laser output is important from Laser application. Specially, pulse length and the output le

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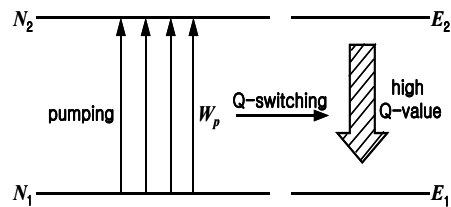
vel which it follows in him is very the factor which is important from material processing in compliance with Laser. Consequently, there is to Laser output and with higher peak power getting a shorter pulse, the pulse creation technique for comes to be demanded, like this pulse creation technical middle Q-switching methods are used[1]. The Q-switching the shutter or the different optical science element puts in within the laser light resonator and the storehouse departs from the within the resonator it loses the mortar and the reversal distribution which when is sufficient creates from within the active medium, opens the shutter instantaneously and it is to do to be made to emit with the light where the energy which is accumulated within the resonator is strong[2]-[5]. Like this Q-switching Q of laser resonator--It decreases factor increasing suddenly to make. To method of Laser Q-switching mechanical switching methods, electro-optic switching methods and switching by saturable absorber methods, acousto-optic switching method etc. 4 kind are being used on a large scale. In these people the conversion which is electric in compliance with the effect which is electrooptics is widely being used the Q-switching pulse of short pulse width because being it will be able to create. Consequently, Pockel cell where it has the quality of electrooptics effect the Q--It is become known that it is suitable it uses with switch. From the research which it sees the gun FET and PIC E which are a switching element with the crow processor and the pulse lance to plan and produce the Q-switch driving gear which it will count, pulse style Nd: It applied in YAG Laser system and it investigated and researched the operating characteristic of the Q-switch. Also, this Q-switch leads and Nd where it is output: YAG Laser being empty, with forecast in compliance with a theoretical calculation it comes to buy a side politics it compared and Laser which has become Q-switching being empty, a quality it analyzed.

## II. Q-SWITCHING

When the R is small from RLC-oscillator circuit and the electric oscillation is continued during long time. The R is big in opposition, it digs up with Joule-heating and the electric energy which is accumulated in the plaque seat is consumed at ten, the take off decreases rapidly[6]-[7]. Case of the electron, we say and that of the oscillators is big, stands the light-wave the bird freezes at the laser resonator outside, or, it is in order to go, like this resonator it Q-hits. There is not a possibility the Laser operation happening efficiently from low-end Laser resonance. With muscle privacy it shows a Laser operation with 2 junior warrant officers. It refers to the principle of Q-switching and when explanation it tries, it raises an if N1 with junior warrant officer E-2C, population inversion

$$N = N_2 - N_1 > 0 \text{-----(1)}$$

It becomes accomplished, when become threshold  $N=0$  the Laser operation happens and the N starts it decreases. This as raises in the place which is high the water bottle and it puts and when closing the cock of the water bottle, with the fact that the water flows new slowly it is same. It will ask in the water bottle which is to the high place and after filling plentifully, in the lower part which it will ask all at once it flows and to through under should have been boiled the fact that rightly is aim of Q-switching[8]-[9].



(Fig. 1) Principle of Q-switching

When it authorizes the strong battlefield in the material, the optical science nature of that material changes. The decision of KD<sub>2</sub>PO<sub>4</sub> (D KDP) and LiNbO<sub>3</sub> etc. when the optical science anisotropic decision which shows a birefringence and, in these people it authorizes the battlefield from the outside, according to the burglar of the battlefield which the refractive index authorizes has the nature which changes[10]. In compliance with the battlefield together the refractive index changes actual condition electrooptics effect (electro optic effect). Among those from the decision where the reversal symmetry is not it is proportionate in the burglar of the battlefield and the gun which is an actual condition where the refractive index changes first electrooptics effect it comes the solid body of inversion symmetry adult decision and the amorphism, fluid etc. in case in square of the battlefield to be proportionate and it is an actual condition where the refractive index changes to be big there is a effect (secondary electrooptics effect).

The indicates the principle of the Q-switch which uses a effect in First, off-switching methods of in the Laser rod investigate the woman storehouse and when here making, in nonlinear decision voltage the assault they put[11]. Then, the nonlinear decision makes the duty of  $\lambda/4$  delay petals do. The storehouse which occurs first from part of the road leads and the polarized light person when it becomes the rectilinear polarized light and this passes a decision, it becomes the circular polarized light. This storehouse will reflect from the mirror and when again it passes a decision, the rectilinear polarized light which tilts and the first rectilinear polarized light and  $90^\circ$  the polarized light person it will become it will not be able to pass. It says again and the loss of the resonator makes come to be small, the Q price comes to be high and the takeoff happens. Second, on-switching methods of compared to insert  $\lambda/4$  delay polarized light self-acknowledgment p

olarized light people P2 in off-switching methods of and it composes, when voltage assault support being in nonlinear decision, from off-switching methods the voltage the assault like falling and operates to nonlinear decision. Namely, from the condition which does not inflict a voltage in nonlinear decision it investigates in the Laser road and here it makes. Then, the store which occurs from the spontaneous material the rectilinear polarized light passes polarized light person P1 and it becomes. After that, the voltage assault support passes the nonlinear decision which is not like that and  $\lambda/4$  delay polarized light self-acknowledgment polarized light people P2 it leads and the circular polarized light it becomes. It reflects from the mirror and the storehouse which returns passes polarized light person P2 again and the first rectilinear polarized light and  $90^\circ$  in polarized light person P1 it becomes it absorbs the rectilinear polarized light which tilts. Then, in compliance with polarized light person P1 the storehouse which becomes the rectilinear polarized light leads these  $\lambda/2$  delay petals and the first rectilinear polarized light and  $90^\circ$  becomes the rectilinear polarized light which tilts, this storehouse is reflected in the mirror and again it passes  $\lambda/2$  delay petals and becomes the rectilinear polarized light which agrees with the first rectilinear polarized light and it makes polarized light person pass P1. When it becomes like that and the Q price of the resonator increases, the Laser takeoff happens. with NaCl decisions must conduct a coating with same water solubility, or, they must use from inside refractive index adjustment misfortune, the absorption, scattered and distortion etc. LiNbO<sub>3</sub> is not a deliquescence, low voltage the Q-switch is possible, high temperature there is a feature it will can use, but receiving a storehouse damage from thorn territory, it is easy and it accomplishes storehouse dispersion to deep-sea large output · high energy Laser system it is not suitable to the storehouse power density above w

high degree.

### III. POCKEL CELL

This the electric market the birefringence which is induced to walk namely in the voltage to walk the first is proportionate fan-shaped electrooptics effect because is. The accidentally these people same 20 types show a piezoelectric effect as well. Therefore the many decisions and all liquids do not show a fan-shaped electrooptics effect. It says the principle of operation of this organization simply, in compliance with the electric market the double refraction it is exchanged electronically. Then it wants a phase lag and as there to be a possibility of changing, depends hereupon and there is a possibility of changing the polarized light condition of the fan-shaped polarized light group which joins. This system does the duty of the polarized light modulator with same method. The initial systems have and this hydrogen phosphoric acid ammonium (NH<sub>4</sub>H<sub>2</sub>PO<sub>4</sub> and ADP) it comes with this hydrogen monopotassium phosphate (KH<sub>2</sub>PO<sub>4</sub>) which becomes known as a KDP it made, but this two they are widely used yet. The very big progress becomes accomplished with introduction of the duplex hydrogen monopotassium phosphate (KD<sub>2</sub>PO<sub>4</sub> and KD\*P) single crystal but this an identical phase lag at price below half of the voltage which is necessary to a KDP makes. This process which implants a deuterium in decision is a possibility with growth of making this decision from the heavy water solution. Today KD\*P or CD\*A (cesium dideuterium arsenate; The duplex hydrogen scattering salt cesium) with the gun which it comes to make it will count it is used. Until a now it puts absurd effort in electrooptics crystalline research and it comes but, few thing example of the materials which are developed like this the wild person cotton,

Like this the system the usual unit operates only from low voltage, (approximately it will

be equal and [e] it will count big and 5 to 10 times which it sees it is small,). This is not also a problem which is caused by with fan shape and of course poisonous liquid. The decrease which KDP the unit 10 ns it sees reaction time only shortly typically, it will be able to modulate the beam until of about 25 Ghz (namely, 25×10<sup>9</sup>Hz). The electric market to walk respectively horizontality or perpendicular is in electronic direction, according to yes or no with width (transverse) two which with the bell (longitudinal) it shows it is general and there is an arrangement method which it will count. In order for the beam to pass the electrode the electrode the usual transparent oxidation metal (example: SnO, it makes with InO and CdO) coating, the metallic foil, watch (grid) or the ring. In order for if decision that oneself is not the external market and generally the electronic direction and the optical axis of shortening and beam to agree, it lines up.

$$\Delta\phi = 2\pi n_o^3 \gamma_{63} V/\lambda_o \text{-----(2)}$$

Here stands  $\gamma_{63}$  the electrooptics constant which it shows with m/V (electro-optic constant) and,  $n_o$  to be normal index of refraction, the V the electric potential difference which it shows at volt and,  $\lambda_o$  is wavelength from the vacuum inside which it shows at meter. Decision on the nature according to direction changes because is anisotropic, must describe in the protest group which as 2 total electrooptics tensors  $\gamma_{ij}$  calls generally. The woman rare book this ingredient public opinion one, namely,  $\gamma_{63}$  10,002 is necessary, these prices are coming to give to ticket.

### IV. Q-SWITCH Nd:YAG LASER

Q-switching which it uses on a large scale to divide, there are two kind drive methods of off-switching methods and on-switching meth

ods, on- switching methods from the research which it sees and it adopted system the operational at the time of height atlas. here is by a Laser drive which becomes Q-switching electrodynamics and according to the decisive material, geometric structure and storehouse wavelength it is necessary from 1.5kV voltage electrically from 15kV scope switching. And the count possibility kV insect has the ten pF dosage which can discharge, the electric current of  $10^{-20}A$  degree flows inside possibility . This in order to come true with the simple structure the gun of existing the Q-switch handler which it will count compared to FET and PIC E which are a switching element plan and produced with the crow processor and the pulse lance. The  $\lambda/4$  voltage the ambient temperature  $1^{\circ}C$  rises according to about 50V and, operating this the fact that it will rise with about 3.6kV the last  $\lambda/4$  voltage for room temperature and  $24^{\circ}C$  standard it decided. Operation of circuit commercial business all the member 220V it will pass by 2 back pressure circuits and it will make to C3 where it will reach and it will charge in compliance with FET turn-on the pulse lance it will lead and boosts the voltage and the high tension pulse which the gun it will count to make deliver it is becoming with about 600V DC. This pulse lance will use the core (toroidal core) which expressing will take, the volume number expense will do at the 1:6, the possibility which it will get 3.6kV  $\lambda/4$  voltage successfully it was. This time, FET turn-on times pulse style Nd: It has a schedule delay time (delay time) in about lighting of the Xe-flash light ramp (flashlamp) of YAG Laser system. The control of this delay time PIC E used the crow processor and it embodied. PIC E which are used from the research which it sees the crow processor used PIC16C55.

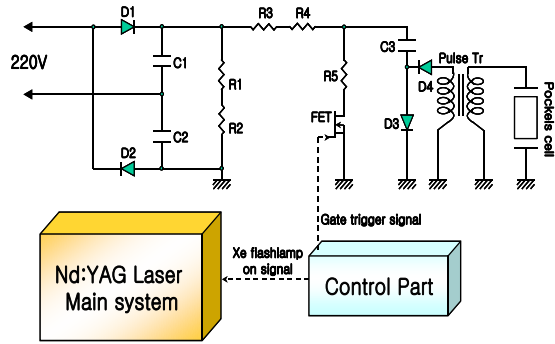


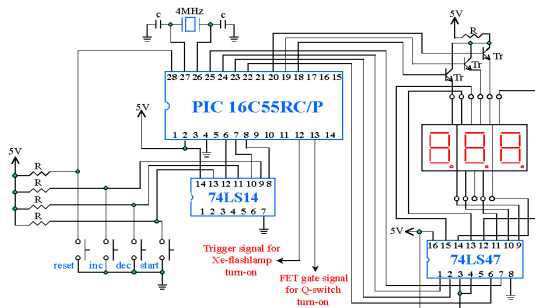
Fig. 2 Circuit of driver for the Pockel cell Q-switch

### V. EXPERIMENT RESULT

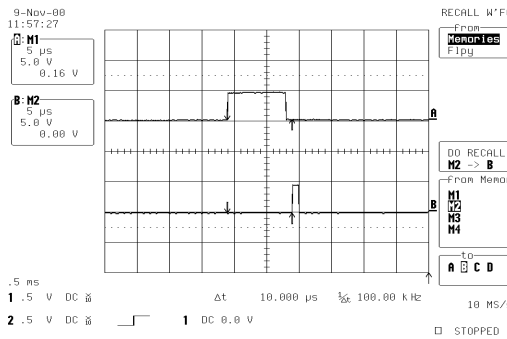
PIC, it shows the delay time control circuit where E are composed of the crow processor. This control circuit is composed of 3 parts on a large scale. The one the keyboard which is input the delay time which it will operate and, one it is different FND (Multi-segmented LED Displays) display (display) parts which indicate the delay time which is input and, remaining one from this control circuit most is strong with PIC microphone ropes which are a core part. The operation of this control circuit with words is same. When delay timely information to lead was input the keyboard in first time, this was delivered in PIC, PIC made in compliance with the program which it comes to decide three kind outputs a different signal.

One signal while giving a signal which is output from PIC FND display signal and, different one signal pulse style Nd: It is a lighting trigger (trigger) signal of the Xe-flash light ramp of YAG Laser system. And the remaining one signal operates the Q-switch. is  $\lambda/4$  voltage authorization trigger signals for, making FND display signal leads and in order to be a display the delay time which is input in FND 74LS47 decoders it is delivered. Xe-flash light ramp lighting trigger signal pulse style Nd of picture 3-4: While YAG Laser system power supply unit it is delivered in SCR gates of we

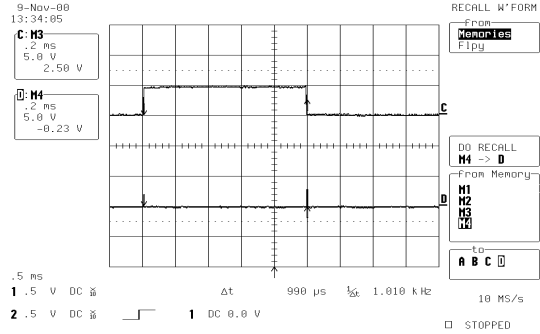
ek circuit, (main circuit) after that as the delay time which is input it is operated the Q-switch after last in FET gates which have  $\lambda/4$  voltage authorization trigger signals for by Q-switch drive circuit of (fig 3) delivering. Delay time the variable in order to be possible, PIC E program do the crow processor, but the variable scope until  $990\mu s$   $10\mu s$  it will be able to increase in order from  $10\mu s$ , from the research which it sees. Operating characteristic of Q-switch handler PIC E show a crow processor output signal. At the time of  $10\mu s$  day which is a delay timely



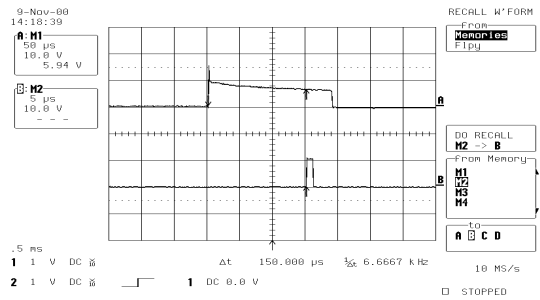
(Fig. 3) Control circuit of delay time



(a) Waveform at  $10\mu s$  delay time



(b) Waveform at  $990\mu s$  delay time  
(Fig. 4) Output signal of PIC micro-processor



(Fig. 5) Operating waveform of delay time control circuit

smallest control time at the time of  $990\mu s$  day which is an output signal wave shape and a delay timely maximum control time it is an output signal wave shape. The wave shape A is delivered on SCR trigger circuits, the wave shape B is delivered on FET trigger circuits.

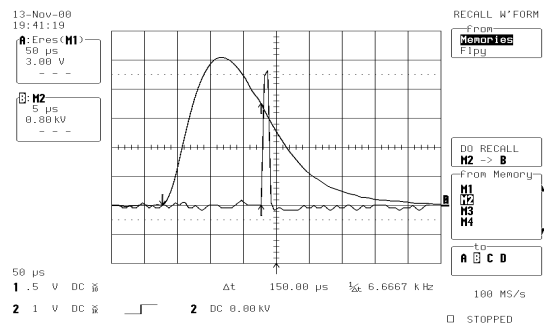
It put out the last operational wave shape of the control circuit which is rough like this SCR trigger circuits and FET trigger circuits indolently in (fig 2) At the time of delay timely  $150\mu s$  day to be an operational wave shape of control circuit, the wave shape The Xe-flash light ramp in order lighting: pulse style Nd making input with YAG, SCR gate trigger signal and the wave shape B which Laser system power supply unit authorize  $\lambda/4$  voltage are FET gate trigger signals which are input on the drive circuit for in Pockel cell.

In compliance with wave shape A after the Xe-flash light ramp lights, as the delay time

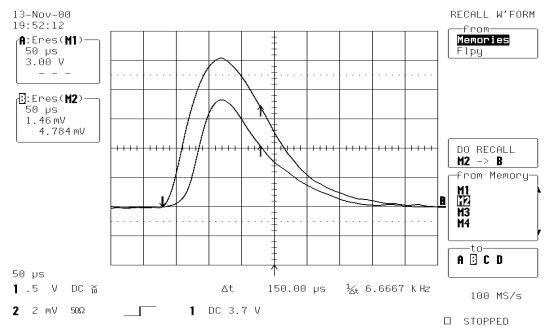
which is input it will be delayed and in compliance with wave shape B the gun will count  $\lambda/4$  voltage to be authorized, the Q-switch operates. Pulse width of FET gate trigger signals of wave shape B it does with  $1\mu s$ , but this pulse width is FET on hours, also count  $\lambda/4$  voltage authorization is the time when it is maintained. This for the Q-switching of high speed is pulse width of the smallest PIC microprocessor will be able to output from the crow processor. In order to prevent the output of multiple mode stands a shorter authorization maintenance time necessity but, to be strong from  $1\mu s$  is the limit with PIC microphone ropes which are used from the research which it sees. Is like this, in compliance with SCR gate trigger signals and FET gate trigger signals of control circuit the gun which is operated] output voltage and pulse style Nd of the Q-switch handler which it will count: It put out the electric current wave shape of the Xe-flash light ramp of YAG Laser system indolently Input energy increases according to the delay time which departs with a first decreasing the input energy departs highly according to the burden Laser which has become Q-switching in the smallest pumping energy for to arrive, more quickly in order is. The maximum output power energy from each charging voltage at the time of 400V day was output from delay time and  $190\mu s$  until  $220\mu s$ , at the time of 450V day it was output until  $220\mu s$ , at the time of 500V day it was output until  $220\mu s$ , from 550V it was output until  $220\mu s$  it was maintained from  $130\mu s$  and from  $140\mu s$  and from  $180\mu s$ .

Like this the maximum output power energy identically from each voltage, it decreases from delay time  $230\mu s$ , starting Nd: Life time of junior warrant officer high position of YAG Laser selfish because of  $0.23 \times 10^{-9} \text{sec}$  from  $230\mu s$  first, it is in order for the atoms which have become here to start a spontaneous emission. it will count it is thought with the fact that it is a limit. With the theoretical output ene

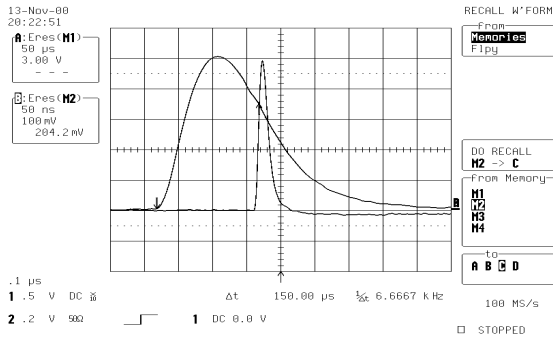
rgy which calculates the peak energy which is output from each voltage from before to compare. Sees this in compliance with an experiment the energy which is output agrees to the energy which is calculated theoretically rationally from bar graph. This time, at the time of input energy  $15.125 \text{J}$  (charging voltage  $550 \text{V}$ ) one with theoretical calculation the gun which it explains from the front experimental will count in about storehouse power density about because and also input energy



(Fig. 5) Waveform of Pockel cell  $\lambda/4$  voltage and Xe-flashlamp current



(Fig. 6) Waveform of non-Q-switched laser beam and flashlamp current



(Fig. 7) Waveform of Q-switched laser beam and flashlamp current

15.125J of limit the theoretical energy use ratio was calculated with 98%, this it does not correspond in experimental condition of the actual resonator, is the difference which occurs because not being. It is a graph which compares the Laser output which had not become Laser output energy and the Q-switching which had become Q-switching. In about the Laser output which does not become Q-switching of the Laser output which had become Q-switching from each charging voltage ratio at the time of 400V day The Laser output which most efficiently had become Q-switching was input energy 12.5J (input charging voltage 500V), at the time of delay timely 150μs day.

That time, it put out the laser light wave shape which does not become the electric current wave shape and Q-switching of Xe - flash light ramps indolently, the laser light wave shape which had become the electric current wave shape and Q-switching of the Xe-flash light ramp put out indolently. The wave shape A is the electric current wave shape of the Xe-flash light ramp, wave shape B has not become Q-switching a Laser output storehouse wave shape which it is, the Laser output broad pulse width which has not become Q-switching of wave shape B is about 105μs (FWHM). Also, the wave shape B is the Laser output storehouse wave shape which becomes Q-switching, the Laser output broad pulse width which has become

this Q-switching is about 15ns (FWHM).

## VI. CONCLUSION

From the research which it sees FET and PIC E which are a switching element with the crow processor and the pulse lance to plan and produce the Q-switch driving gear which it will count, pulse style Nd: YAG Laser system. It applied system and with after words the result which it investigates and researches the operating characteristic of the Q-switch a same conclusion it got. The gun which is output from driving gear  $\lambda/4$  voltage for the operation of the Q-switch which it will count pulse width 1μs, was peek voltage 3.6kV, the delay time (from flash light ramp lighting time interval until of  $\lambda/4$  voltage authorizations) until 990μs was controlled from 10μs. storehouse power density of the Q-switch which it will count at the time of input energy 15J day, input energy 12.5J, the Q-switch operation of optimum happened from delay time 150μs. Laser which has become Q-switching being empty, in compliance with a theory with the output energy which is calculated it was under agreeing, in compliance with the Q-switch operation of optimum pulse width 15ns, it got the Laser output which is cusp 8.73MW.

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