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# 피부질환 치료를 위한 Q-Switched Nd:YAG의 SHG 변환기술

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Q-Switched Nd YAG's SHG conversion techniques for a skin diseased treatment

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## 요 약

Pulse 펄스형 Nd:YAG 레이저는 피부재생치료에 적합하고, 램프에 의해서 연속발진은 물론 정상발진, Q-스위치 및 모드동기 발진까지 다양한 발진 형태가 가능하며 미세수술 및 피부재생 촉진에 널리 사용되어지고 있다. 치료목적에 따라 에너지 밀도를 제어하는 것이 매우 중요하다. 에너지 밀도의 제어는 레이저 출력의 펄스반복률을 제어하는 방법이 주로 사용된다. 본 연구에서는 펄스형 Nd:YAG 레이저의 펄스반복률을 제어할 수 있는 제 2고조파 발생(second harmonic generation: SHG)로 각주파수인 광파의 에너지 일부가 비선형 결정안을 전파하면서 각주파수인 광파의 에너지로 변환되는 현상을 적용하여 2차 비선형형성에 의한 제2고조파 발생을 통해 피부심부까지 치료 가능하다는 것은 간단히 관찰할 수 있었다.

## ABSTRACT

Pulse style Nd: YAG Laser is suitable in skin remaking treatment, in compliance with the ramp continuous oscillation until of course normal takeoff, the Q-switch and mode motive takeoff the takeoff form which is various is possible and it is coming to be widely used in microsurgery and skin remaking promotion. According to therapeutic objective very it is important to control a energy density. Control of energy density the method which controls the pulse repetition rate of Laser output is mainly used. From the research which it sees pulse style Nd: It will be able to control the pulse repetition rate of YAG, the 2nd harmonic occurrence Laser (second harmonic generation: SHG) with the energy part of the light-wave which is a footnote wave number will hold and nonlinear decision it propagates and is converted by energy of the light-wave which is a footnote wave number the actual condition which and it applies the second harmonic occurrence in compliance with a secondary nonlinearity it leads and until skin deep part therapeutic possibility is the thing it will be able to observe simply.

## 키워드

Q-Switched, second harmonic generation, YAG, Pulse, repetition

## I. INTRODUCTION

Nd (Neodymium) 3 it is a kind of rare earth element the ion YAG (Yttrium Aluminum Garnet:  $Y^3A^{15}O^{12}$ ) doping Nd it made in decision YAG Laser currently with ruby Laser where the lasing is discovered at the beginning is accomplishing the main stream of solid-state laser together, widely, it is used. YAG Laser the supersonic Q switch or the gun the control of the output pulse in compliance with Q switch etc. is possible. Also it compares in  $CO_2$  Laser and the condenses the diameter is small, various branch minute processing is possible quite. Consequently the application which does the semiconductor or electronic component in the object is many. Trimming and marking, the grows to removal processing of etc. in compliance with the supersonic Q switch round, the repetitive pulse is used, to perforating or removal processing or welding processing of cutting etc. The distant pulse is mainly used, to soldering etc. the continuation group is used mainly. Processing which uses Laser with hitherto method processing possibly did with the microphone which is impossible. Specially the laser machining is the change of place arrowhead and it is burnt, it is clean, high speed processing and it is visible the quality which is excellent even in processing which is soft. Also, YAG Laser the laser light of high power and high quality comes to get as processing Laser is suitable with the microphone, Pulse style Nd: YAG Laser is widely used in processing, the pulse form of Laser output not only Laser output influences big in processing efficiency.

And recently the Laser medical device and laser machining, with laser nuclear fusion etc. it does which is powerful in same multiple field or the ultraviolet storehouse in necessity. When it uses the nonlinear optics material consequently, it is possible to get the high frequency storehouse which has the frequency of 2 times, 3 times and 4 times and when it uses OPO (Optical Parametric Oscillator), from the infrared ray until being early in the ultraviolet rays, possible to occur the laser light which has the wavelength of broadband. It planned two pulse reiteration circuit watches which are composed with the week pulse and the reiteration pulse from the research which it sees, in about the Laser output which uses SHG interrelation of the pulse form which

it follows in him and Laser output and it investigated.

Namely circle shot the distant mote the sprouts at all and to use two SCR, pulse style Nd, makes the stairway pulse of YAG, Laser it developed the technique which. First, the experiment which in the week pulse 6 repeats the reiteration pulse 3 Laser output quality it led and it grasped. And the delay time which is an authorization timely difference of two pulses the result which applies two pulse reiteration laws from within scope below  $230\mu s$ , it got a maximum output power (about 4.5% efficient improvement) from delay time  $0\mu s$ . Consequently, it fixed a delay time with  $0\mu s$ , it did the week pulse and reiteration pulse 3 - 1 only, 4 - 2 only, 6 - it composed it compared a whole authorization energy with 50J, of 3 grades only, only about respectively pulse form and an output quality. It affixed a nonlinear optics decision (KTP) on YAG Laser output side and it got when authorizing a same energy in each reiteration mesh, the conversion efficiency which it follows in interrelation and the many item mesh of Laser output and green output between it investigated the green store. Pulse style Nd: YAG Laser is widely used in processing, the pulse form of Laser output not only Laser output influences big in processing efficiency.

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## II. SECOND HARMONIC GENERATION

Reflexible two mirrors the angle R1 and R2 and the L puts the length of the medium which gets up an actual in compliance with the Laser medium when it is converted a party decision profit (gain) unit length the G it does, when the medium once passing every, the profit increases with gL pack. Consequently, when once reflecting in the mirror every, 1-R1 and 1-R2 energy losses occur. When it outputs from one piece, radiation before passing an exactly same point with original direction, it experiences two changing mind reflections. The takeoff condition after the Laser radiation passes the medium, in compliance with R1 mirrors anti-it stands but, passes the medium again and in compliance with R2 mirrors it is reflected, like this it is made to continue, when these whole photon density initial photon density and being same, it is attained an operation infinitely. Consequently, every at the time of two-way-passage of the light which leads a Laser operation, the loss profit to be same is the qualitative thing. Therefore, the takeoff condition with words is same.

$$R_1 R_2 \text{Exp}(2gL) = 1 \tag{1}$$

When the lung loop profit will become larger 1 sees, the radiation of the frequency which is appropriate will hastily become accomplished and in compliance with a spontaneous emission (Spontaneous emission) transient, junior warrant officer high position will empty become, the profit to make decrease and as the G. When once

reciprocating every, the profit accurately, when with the inside and external loss accomplishing an equilibrium, will arrive to stationary state. This as the profit gunfire (gain saturation). It sees the loss minute when does not become the help in the loss, reflective, scattered, absorption and amplification medium, the resonator internal element and output of diffraction etc. with one parameter and when as party decision absorption meter possibility it puts unit length with alpha, the takeoff condition with after words is same

$$R_1 R_2 \text{Exp}(g - \alpha)2L = 1 \tag{2}$$

In order to explain a Laser operation it applies a ratio equation to be, probability of induced emission convenient to express with rho (v) B21. Photon density phi, the induced emission cross section with sigma (v), in about induced emission Einstein (Einstein) coefficients B21 sigma (v) and beam C. The N when index of refraction) with it indicates, with words is same.

$$B_{21} = \left[ \frac{C}{h\nu g(\nu)} \right] \sigma_{21}(\nu) \tag{3}$$

The unit frequency rho (v) party decision energy density breadth element G (v) and energy hν, and, indicates with photon density phi (photons/cm<sup>3</sup>).

$$\rho(\nu) = h\nu g(\nu)\Phi \tag{4}$$

$$B_{21}\rho(\nu) = C\sigma_{21}(\nu)\Phi \tag{5}$$

With 2 level gage, level indicator, liquid (level) indicators in order muscle strabismus height, the transient with junior warrant officer high position assumes 3 level gage, level indicator, liquid indicators too quickly at density N3 = 0 of 3rd junior warrant officer. Consequently, Laser here distribution reversal (population inversion: N2 > N1) only it is related. Only, this family is formed when τ32/τ31 where it is a relaxation time expense very being small only. At relaxation time expense τ32/τ31 in ground state = 0 being approximate from the woman expectation, the up family is

formed from solid-state laser. The spontaneous emission becomes marking with  $\eta_0$  where it is a woman efficiency factor. This variable

$$\eta_0 = [1 + (\frac{\tau_{32}}{\tau_{31}})]^{-1} \leq 1 \tag{6}$$

With it will be defined, the woman input which is bigger recording whose  $\eta_0$  will be small than is necessary. Change of electronic distribution density from 3 junior warrant officers, the fact that all Laser ions inevitably with junior warrant officer 2, assume with the fact that it is to junior warrant officer 1 basic.

$$\frac{dn_1}{dt} = (n_2 - \frac{g_2}{g_1})C\phi\sigma + \frac{n_2}{\tau_{21}} - W_{p1} \tag{7}$$

$$\frac{dn_2}{dt} = -\frac{dn_1}{dt} \tag{8}$$

$$n_{tot} = n_1 + n_2$$

$W_{p1}$  it will be able to think at the atomic fraction which in metastable level 2 is supplied, accurately, from unit timely monomer party ground state thousand is modification of the atoms with junior warrant officer Laser high position. The ratio  $W_p$  relates with a pump variable  $W_{13}$  dizzily and it becomes marking with  $W_p = \eta_0 W_{13}$ .  $W_{p1}$  code the pumping organization from  $n=1$  junior warrant officers increases the density of  $n=2$  junior warrant officers who remove the atom. meat the thing, to make Distribution reversal density

$$n = n_2 - (\frac{g_2}{g_1}) \tag{9}$$

$$\frac{dn_1}{dt} = -\gamma n\phi C\delta + \frac{\{n + n_{tot}(\gamma - 1)\}}{\tau_f} + W_p(n_{tot} - n) \tag{10}$$

$$\frac{d\phi}{dt} = Cn\phi\delta - \frac{\phi}{\tau_c} + S \tag{11}$$

Laser takeoff initial reconciliation the consideration point which is important the resonator undergarment the whole

resonance which is possible not yet (VR) is undergarment modal number P. Generally in these mode it is in order only some to initialize a takeoff. This modification after being familiar, gives with an expression,

$$P = 8\pi\nu^2 \frac{\Delta\nu V_R}{C^3} \tag{12}$$

$\nu$  : Laser optics frequency,  $\Delta\nu$ : Spontaneous emission bandwidth

$$S = \frac{P_L n_2}{P\tau_c} \tag{13}$$

Here it stands know with only the fact that it points all outstretched hands which occur from the optical science resonator inside for  $\tau_c$  column Laser takeoffs.  $\tau_c$  as dimension of time, loss as relaxation time it becomes marking. The decrease of resonator undergarment photon density originates from transmission and absorption of the vertical mirrors.

$$\frac{d\phi}{dt} = -\frac{\phi}{\tau_c} \tag{14}$$

$$\frac{d\phi}{(t)} = \phi_0 \exp(-\frac{\tau}{\tau_c}) \tag{15}$$

Importance of 2 this right arm the low of meaning is emphasized the pure profit of movement of the electromagnetic waves which leads the Laser medium with the thing. In order to explain the Laser operation of 4 level gage, level indicator, liquid (level) indicators it stands it assumed with  $n_3 = 0$ . From this family 4 from junior warrant officer change ratio of junior warrant officer 2 Lasers

$$\frac{dn_2}{dt} = W_p n_0 - (n_2 - (\frac{g_2}{g_1})n_1)C\phi\delta + \frac{n_2}{(\tau_{21} + \tau_{20})} \tag{16}$$

$$\frac{dn_1}{dt} = - (n_2 - (\frac{g_2}{g_1})n_1)C\phi\delta + \frac{n_2}{\tau_{21}} - \frac{n_1}{\tau_{10}} \tag{17}$$

$$n_{tot} = n_0 + n_1 + n_2$$

Junior warrant officer last junior warrant officer basis compares from 4 level gage, level indicator, liquid indicators which are an ideal and to be quick it becomes infinitely empty. If it puts with if  $\tau_{10} \cong 0$ , (17) from becomes  $n_1 \cong 0$ . The whole density divides between high position junior warrant officer of junior warrant officer Laser this case and junior warrant officer Laser. The total is junior warrant officer and the poisonous rim Laser the low-end which it sees and from big source it becomes to have become pumping.  $T_{10} \cong 0$ , as  $n_1 \cong 0$  it gets words.

$$\frac{dn}{dt} = -C\phi\delta - \frac{n}{\tau_f} + W_p(n_{rot} - n) \quad (18)$$

It gets. The fluorescent diminution time  $\tau_f$  of junior warrant officer Laser high position gives with words

$$\frac{1}{\tau_{21}} = \frac{1}{\tau_{10}} + \frac{1}{\tau_{21}}$$

$W_p = \eta_0 W_{03}$ , When it uses

$$\eta_0 = \left[ 1 + \frac{\tau_{10}}{\tau_{10}} + \frac{\tau_{21}}{\tau_{21}} \right]^{-1} \leq 1 \quad (19)$$

Gets, 3 level gage, level indicator, liquid (level) indicators which are cool and is same and  $\eta_0$  various depends in branching ratio where it is a relative change ratio of the atoms which it follows in the down course which is possible. General, Quality factor of the resonators with the Q specific erasing  $Q = \text{energy stored in the resonator} / \text{power dissipated from the resonator per } \omega_0$  ( $\omega_0$  is unit angular frequency)

$$Q = 2\pi \left[ 1 - \text{Exp}\left(\frac{-T_0}{\tau_c}\right) \right]^{-1} = 2\pi \frac{-T_0}{\tau_c} = 2\pi\nu_0\tau_c \{u_0 = 2\pi\nu_0\} \quad (20)$$

The loss organization broadband of resonance frequency originates to the takeoff life outside. Broadband width of

resonator  $\Delta\nu$  (FWHM: Full they are Width Half Maximum) =  $\{2\pi\tau_c\}^{-1}$ . Consequently.

$$Q = \frac{\nu_0}{\Delta\nu} \quad (21)$$

$$2gL = \frac{1}{\ln R_1 R_2} + 2\alpha L \quad (22)$$

$$2\alpha L = \epsilon = \frac{t_R}{\tau_c}, \tau_c = \left(\frac{2L}{c}\right) \left[ \frac{1}{\ln R_1 R_2} + 2\alpha L \right]^{-1} \quad (23)$$

Gets, Here stands, absorption from the diffraction hand which occurs from the resonator inside and the mirror, puts the loss (Miscellaneous losses) which scattered etc. smiled with LM, the reflexible which the rear mirror (mainly around total reflection) decreases It puts with  $R_2 = 1 - LM$  there to be a possibility, LM of actualness possibility % is only it will be able to regard as  $\ln(1 - LM) \cong -LM$ . Consequently, the optical science loss of the whole With it becomes marking.

$$L_T = 2\alpha L + L_M \quad (24)$$

$$\tau_c = \frac{2L}{[c(L - \ln R_1)]} \text{ Becomes..}$$

### III. HARDWARE SYSTEM

Second harmonic occurrence (second harmonic generation: SHG) the energy part of the light-wave which is a footnote wave number which is will hold and nonlinear decision it propagates and it is an actual condition which is converted by energy of the light-wave which is a footnote wave number. The second harmonic occurrence in compliance with a secondary non-linearity possibility is the thing it will be able to observe simply. When it uses 3 nonlinear, also the occurrence of 3rd harmonic is possible. Is not a secondary non-linearity from the medium which has a central symmetry harmonic of the lowest becomes the 3rd harmonic. The numerical formula is not formed generally detachable because of the medium.

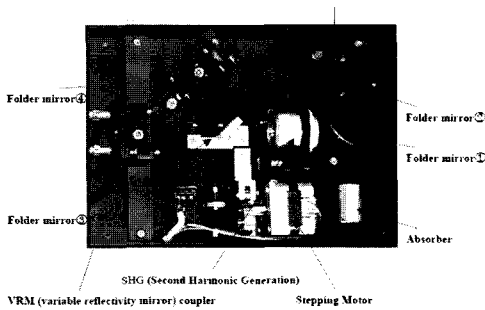


그림 1. 밀러와 2차고조파발생장치  
Fig. 1 Assemble mirror and SHG

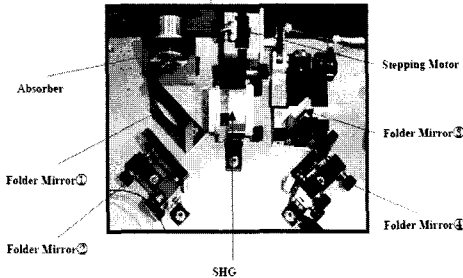
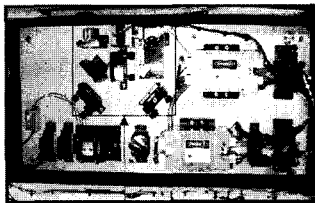


그림 2. 공진기세팅과 2차고조파발생장치  
Fig. 2 Setting resonator and SHG

Therefore respects the harmonic occurrence which is effective stands the plan which is the possibility to revise this is necessary. KDP of the small size which uses a refractive index adjustment misfortune with the method which revises this and DKDP in case the chemical solution which is a sacrifice is mainly used from the car phosphorus and formation.

Meantime, it gets a harmonic output not only phase adjustment must have non-linear coefficient is suitable. There is a Laser head of the elliptic structure which rises only in the center, with around total reflection (reflexible 99.5 % above, it converts concave mirror) the partial reflectors of radius of curvature 2 (reflexible 60 [%] plane mirror) and 1064nm infrared lights. it is an abridged general view of the resonator which is composed with SHG with 532nm green it makes. To the Laser head inside the gold is becoming the coating control just, the focus with 2 to one focus the flash light ramp, also to one it is different Nd: YAG roads, in order for the storehouse which radiates from the flash light lamp toward all road, it was planned. And after the infrared laser output which has 1046nm wavelength passes KTP in the green illuminant which has nm wavelength of 532 it converts.

With 2nd harmonic occurrence system it planned a system it makes Like being visible from fig 2 and the power supply unit controls the delay time of the reiteration circuit which is composed of hour circuits preparation lighting description below for the xenon flash light ramp on a large

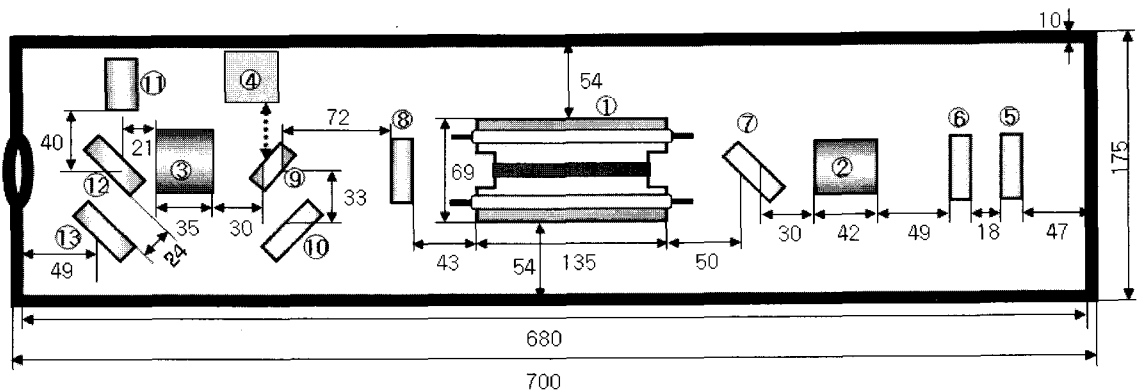


그림 3. Q-Switched Nd YAG's 2차고조파발생장치 시스템  
Fig. 3 Q-Switched Nd YAG's SHG system

scale, simmer starter, the circuits which are composed of charging all the member and 6 mesh circuit watches and 3 mesh circuit watches and the reiteration pulse the circle shot for the distant is composed of the pulse reiteration control circuit where the with free self-control.

IV. EXPERIMENTAL RESULT

Fig 5 the case which will authorize an input energy  $E=100J$ , changes the authorization method of input energy and to compare the current-pulse wave shapes of the flash light ramp drive circuit which it observes. The wave shape A price a week circuit C1~C6 from the picture and with public affairs  $80\mu F$  all it input  $100J$  input energy in here, the reiteration circuit did not operate, it does not correspond in case.

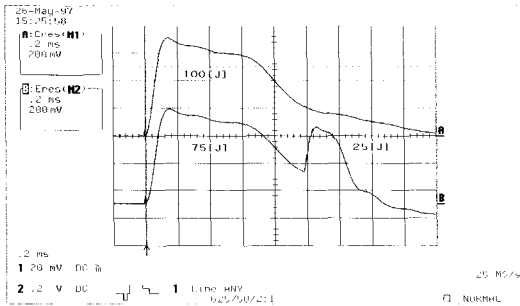


그림 4. 입력에너지에 대한 전류파형 비교

Fig. 4 The comparison of current waveforms according to the applied method of input energy E

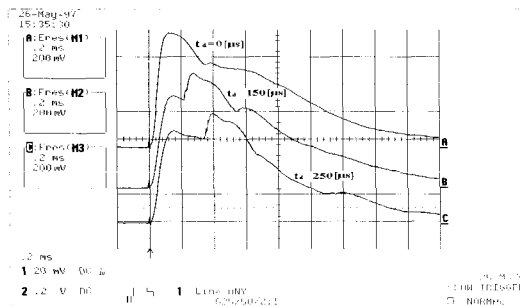


그림 5. 다른 지연에 따른 전류파형 비교

Fig. 5 Current waveforms according to the different delay time  $t_d$

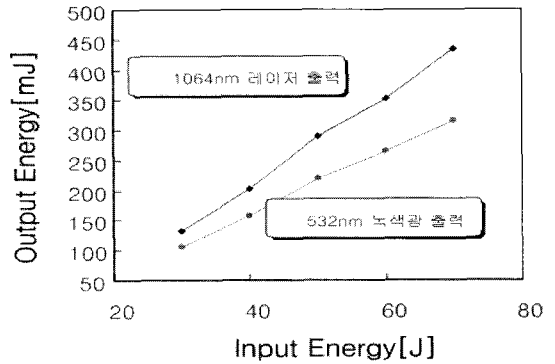


그림 6. 3단 메쉬와 1단 메쉬의 녹색광 변환특성  
Fig. 6 The green light conversion characteristics of the three-mesh and one-mesh.

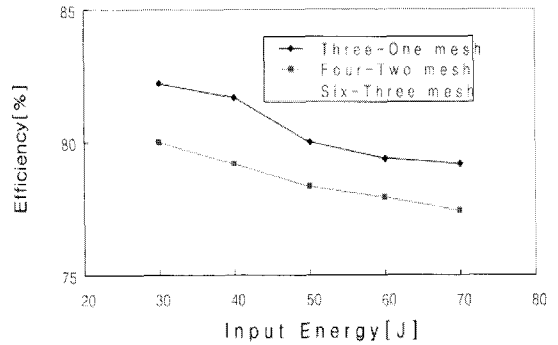


그림 7. 변환효율 특성

Fig. 7 The conversion efficiency characteristics

Wave shape B C1~C6 price of week circuit all  $80\mu F$ , C1~C3 price of reiteration circuit after one, to week circuit  $75J$ , to reiteration circuit is the current-pulse wave shape of the case which authorizes  $25J$  input energy respectively with all  $40\mu F$  The picture 12 changes the delay time  $t_d$  of the reiteration wave shape. shows the electric current wave shape which is representative it observes to make.

The pulse electric current wave shape A, the B and the C delay time  $t_d$  respectively shows the case which is  $0\mu s$ ,  $150\mu s$  and  $250\mu s$  from the picture. The picture 13 from input energy  $E=100J$  delay time  $t_d$  of the reiteration wave shape it changes from within  $0\sim 1ms$  scopes. Laser which it measures being empty, shows an output energy, to make It does not use a reiteration from the picture many

case which authorizes 100J input energy in only all week circuit, Laser being empty, the output energy was about 735mJ, two pulses it repeated and the delay time 0 $\mu$ s day case, Laser being empty, energy output energy was about 765mJ.

When with the case which does not use a reiteration it compared, the output and efficient improvement of the maximum 4.5% came to get from delay time 0 $\mu$ s. Like this result It originates to the physical properties quality of YAG roads. Nd: YAG spontaneous emission life time tf the case where the delay time td of 230 $\mu$ s is reiteration wave shapes is smaller about 230 $\mu$ s than, with the week pulse in compliance with the reiteration pulse with the fact that first the atom which has become here in junior warrant officer high position contributes in all Laser output. But, the case where the delay time td will be bigger 230 $\mu$ s than, in compliance with the reiteration pulse in compliance with the week pulse in compliance with a spontaneous emission with after that first the atoms which had become here in junior warrant officer high position elapse spontaneous emission life time tf it makes junior warrant officer fall subordinate position on the middle where the atoms become here with junior warrant officer high position. Consequently, the case where the delay time td is bigger spontaneous emission life time tf than it accompanies a fluorescent loss Laser being empty, the output energy is visible the tendency which it decreases rather. Fig 3 the pulse electric current wave shape and Laser output of the case where the delay time td of the reiteration wave shape where the Laser output becomes the maximum is 0 $\mu$ s being empty, corresponds to the profile. A wave shape the pulse electric current wave shape and the B Laser output being empty, the profile, TH (Threshold) shows a reversal distribution formation kind takeoff start point from the picture. From wave shape A QTH does not contribute the loss part and, QL becomes the part which it contributes in Laser output in Laser output.

## V. CONCLUSION

From the research which it sees the pulse style Nd which it plans in many item mesh circuit watch method: It composed YAG Laser and the pulse formation technique it will be able to control the shape of current-pulse form and the laser light pulse of the flash light ramp it developed. Also cross check the output which it follows in the Laser output which it follows in delay time evolution of the reiteration pulse and mesh possibility change. And Nd: YAG Laser being empty, SHG converters transmission possibility it will stand and a same conclusion and with words the result which buys the input-output quality to measure the output of the green illuminant which comes out it will get it made. The delay time of the reiteration pulse shows 0 $\mu$ s day case maximum output power, it compares it is visible in the nothing insect concubine and 4.5% efficient improvement.

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