Experimental Study on $LiNbO_3$ as Q-switched crystal in 1319nm laser

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Abstract. It is usually with Q-switched technologies in order to obtain the peak power of laser pulses[1].This paper analyzes the characteristics and the electro-optic effect of $LiNbO_3$(LN) crystal. We use LN as Q-switched crystal of 1319nm infrared laser and estimate its required voltage. The corresponding experimental study is conducted for LN applications and some parameters are obtained such as the delay time and the ratio of dynamic to static laser output.According to the results,we analyze the experimental characteristics of LN and put forward the measures of improvement.

Introduction

LN is an important material on optical and waveguide applications . It is a synthetic crystal.In the field of laser,it is primarily as a frequency doubling crystal in low-power infrared lasers [2][3].The greatest feature of LN crystal is the birefringent properties that can be artificially controlled [4].We can change the size or orientation of the electric field to effectively control the intensity, the polarization direction and state of emitted light, in order to achieve an electro-optic modulation deflection and Q-switch.

LN Voltage Estimation

There are two ways of transverse and longitudinal uses for LN.In the transverse use,the total phase delay is not only proportional to the applied voltage,but also related to *l/d* [5].Therefore, the half wave voltage can be greatly reduced with the increase of *l* or decreasing *d* .In this paper,we take transverse voltage mode.Figure 1 is the schematic diagram of transverse voltage mode.

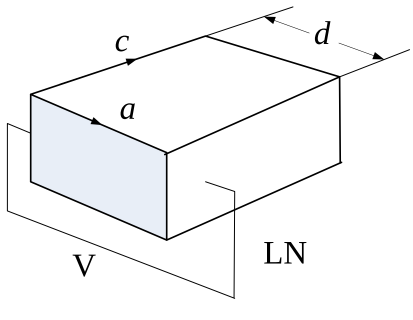


Fig.1 Transverse voltage mode of LN

Light propagates along the *c* axis of the crystal.If the polarized light parallels to the *a* axis as well as the applied electric field, the 1/4 wavelength voltage is:

$$V_{\frac{\pi}{2}} = \frac{\lambda d}{4\gamma_{22} n_o^3 l} \tag{1}$$

In the formula, *l* is the crystal length along the *c* axis, *d* is the distance between electrodes along the *a* axis, γ_{22} is the electro-optic coefficient.We can see that the voltage is related to the crystal size.In this paper, the crystal size is 10 × 10 × 20mm.

For pulsed Q-switched operation, the required voltage is higher by 30% to 40%.Compared with the direct current operation, γ_{22} in pulse operation is smaller.This is because of the fact that when the existence of electrostatic field, the total electro-optic effect is equal to the electro-optic effect inherent and that caused by piezooptical effect.

$$\gamma_{22} = \gamma'_{22} + P_{2k} d_{2k} \qquad (2)$$

When the voltage is turned on or off quickly,the piezooptical effect will not be produced.So $P_{2k} d_{2k} = 0$, $\gamma_{22} = \gamma'_{22}$ and γ_{22} has the smaller value.

For 1064nm light waves, electro-optic coefficient of LN is $\gamma_{22} = 5.61 \times 10^{-6} m/V$ (n_0=2.237).

V_{1064nm}=2753.14～2964.92 V

For 1064nm light waves, $V_{1319nm} \approx \frac{1319}{1064} V_{1064nm}$=3412.96～3673.5 V.

Through the above analysis, the voltage value can be reduced by designing the size of LN.Such LN has much smaller voltage than other crystal.It is an absolute advantage of LN in this respect.

Experimental Device

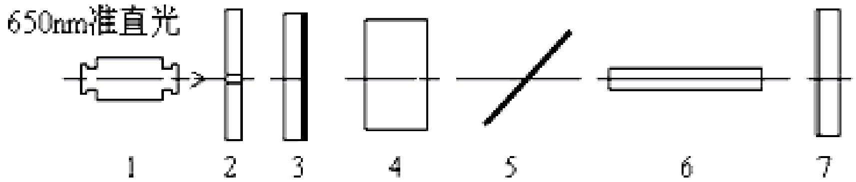


Fig. 2 Schematic diagram of the experimental system structure

Experimental system structure is shown in Figure 2.The parameters of each element is as follows:

(1) Collimation system:

1.collimated light:650nm semiconductor red laser, 2.diaphragm: Φ1

(2)Resonant cavity: flat-flat cavity

3.Totally reflecting mirror:Φ20mm,R=99.8%@1319nm,T>95%@1064nm;

7.Output mirror:Φ20mm,T=35%@1319nm,T>60%@1338nm,T>95%@1064nm

(3)Q-switched devices:

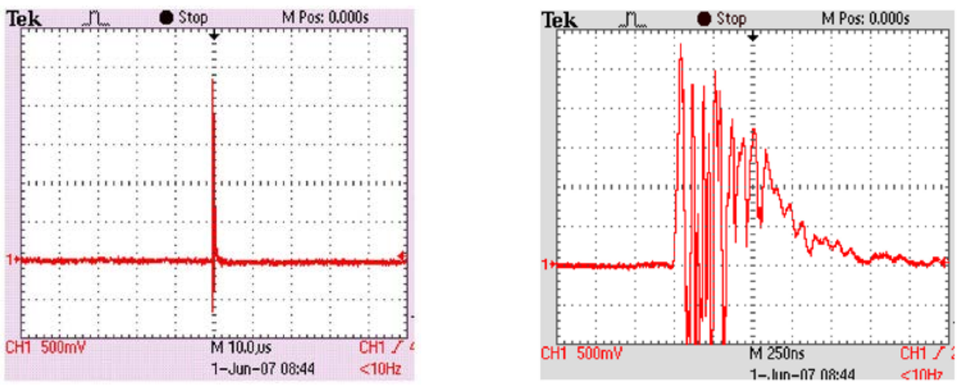
4.Q-switched crystal:LN,10×10×20mm;5.Polarizer:Φ20mm

(4)Working substance:

6.Nd^{3+}:YAG solid-state laser rod:Φ6×100mm,Film parameters: R<0.2@1064nm&1319nm

Test Results

After adjusting the instrument,we use a pulse detector to measure static laser pulse width, and then use InGaAs detector for measuring dynamic pulse width.



(a) (b)

Fig.3 Dynamic output pulse waveform

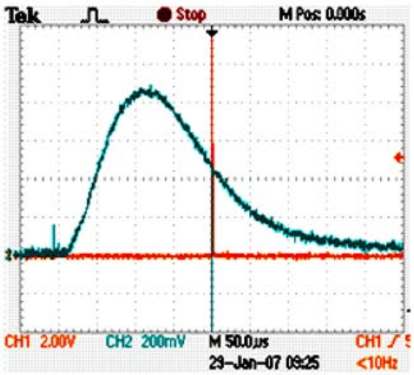


Fig.4 Laser waveform output waveform relative to the position of xenon lamp

Tab.1 Experimental measurement parameters

Input voltage(V)	Static energy(mJ)	Dynamic energy(mJ)	Dynamic to static ratio
600	50.8	32.4	63.75%
620	63.5	37.5	59.03%
640	76.2	43.3	56.79%
660	85.7	46.9	54.72%
680	100.3	63.3	63.18%
700	113.0	67.6	59.83%
720	124.4	77.1	61.94%
740	138.1	83.9	60.74%
760	152.4	90.4	59.35%
780	161.9	96.8	59.76%
800	180.0	106.0	58.84%

Dynamic to static ratio is the ratio of dynamic energy and static energy measured after adding the value of the polarizer and Q-switch crystal.From the above data,dynamic to static ratio will decrease as the input energy increases.It is believed that the peak power of laser pulse at high energy input (Q-switch pulse) is increasing, but the pulse energy is reducing.

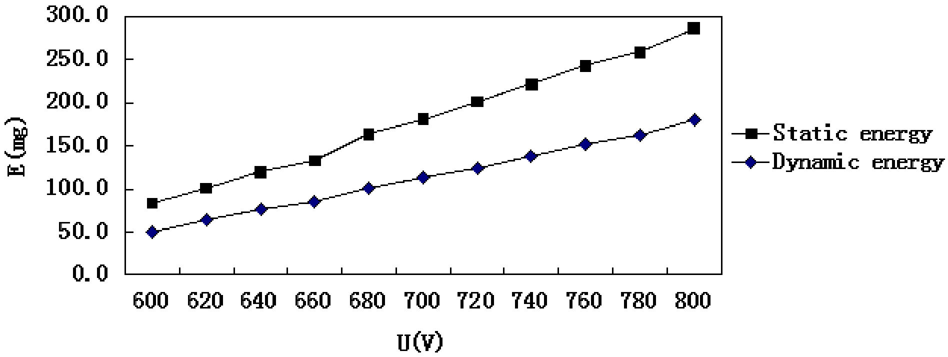


Fig.5 Input and output energy curve

Figure 3 is the laser dynamic waveform.It can be seen that dynamic laser output presents multi pulse condition after the Q-switch pulse width modulation is compressed. In practice, the inhomogeneity of birefringence intensity and crystal can lead to multiple pulse as well as crystal mechanical fastening. Figure 4 is a laser waveform relative xenon lamp light wave output position.The laser output is realized at the half power point output of xenon light wave.At this moment, the voltage on LN is returned on.Experiments prove that this moment is the best time of laser output, for that the highest peak power is achieved.Because inverted population of the operation material is accumulated to the maximum value.

Conclusion

LN crystal has a high transmittance for 1319nm and is chosen as Q-switch crystal.We estimate the voltage value of LN that about 3500 volts.Such the delay time is determined.The problems of the system:(1) There is no coating for 1319nm on LN crystal, thus it causes the energy loss in the resonator increasing.(2) The piezoelectric effect of the LN makes dynamic laser appear in the case of a multi-pulse, and thus affect the peak power and frequency doubling efficiency of the laser output. Improvements:(1) to the LN crystal coating.(2) try to add voltage gradually on LN for reducing the effect of piezoelectric on pulse.(3) use the multistage amplifier form to effectively improve the laser energy with consideration of LN crystal anti-damage ability.Through the improvement, the overall performance of the laser will be further improved.

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