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$LiNbO_3$ Q-switch used as tuning element for flash-lamp pumped Cr-Tm:YAG laser*

SUN Xiao-quan, TONG Zhong-cheng, NIE Jin-song

(Department of Optical-electric Technology, Electronic Engineering Institute, Hefei 230037, China)

Abstracs: To minimize the elements inserted in the cavity of 2 μm band tunable laser and reduce the cavity loss, a special designed prism based on the disperse property of $LiNbO_3$ crystal was used as tuning and Q-switching element . Two faces cut at Brewster's angle make the prism work well as tuning element. In a flash-lamp pumped Cr-Tm:YAG 2 μm laser with the $LiNbO_3$ prism, active Q-switching operation was realized at room temperature, while the tuning range of 1.95 ~2.08 μm was obtained with the prism. The repetition rate of the Q-switched laser was 1~5 Hz. The experimental result shows that the Q-switching and tuning method is valid.

Key words: 2 μm laser; Cr-Tm:YAG laser; Q-switching; Tuning; $LiNbO_3$ crystal

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铌酸锂用于灯泵 Cr-Tm:YAG 激光器的调 Q 与调谐*

孙晓泉，童忠诚，聂劲松

(电子工程学院 光电系，安徽 合肥 230037)

摘要：为了简化激光器结构，减少腔内损耗，首次提出利用 $LiNbO_3$ 电光晶体较高的色散特性，实现 2μm 波段可调谐激光器的调 Q 与调谐。将 $LiNbO_3$ 晶体加工成单块特殊形状的棱镜，作为主动调 Q 器件，用于 2 μm 波段灯泵 Cr-Tm:YAG 激光器，以产生巨脉冲，该棱镜还同时具有调谐的功能。将该棱镜插入室温灯泵的 Cr-Tm:YAG 激光器中，实现了 1.95~2.08 μm 范围的调 Q、调谐运转，重复频率为 1~5 Hz。实验结果表明，所提出的方法可行。

关键词：2 μm 激光器； Cr-Tm:YAG 激光器； 调 Q； 调谐； 铌酸锂晶体

0 Introduction

Flash-lamp pumped Cr-Tm:YAG laser, with advantage of simple structure and reliability, is a useful wide band tunable laser source [1]. Since the first flash-lamp pumped Cr-Tm:YAG laser operating at room temperature was reported[2], acousto-optic elements[3] and saturable absorbers[4,5] have been used to increase the output peak power. However, all these works need additional elements to tune the lasers, which means more complexity in

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作者简介：孙晓泉(1962-)，男，教授，主要从事光电子学方面的研究。

schemes of the laser system.

The purpose of this paper is to demonstrate initially the Q-switching and tuning operation of a flash-lamp pumped Cr-Tm:YAG laser with a $LiNbO_3$ (LN) crystal prism, holding the promise of simplicity in scheme.

1 Experiment

The schematic of our experimental setup is similar to the traditional flash-lamp pumped solid state lasers, which is shown in Fig.1. The interval between the mirrors is 1050 mm. The concave total reflective mirror has a radius of 4 m, and the flat output mirror is coated with transmittance of about 20%~30% in 1.94~2.10 μm region. Two cerium-doped fused silica xenon flash-lamp and a Cr^{3+}-Tm^{3+} codoped (0.6% Cr, 6% Tm) YAG crystal are placed at the three focus-axes of an double-elliptic cylinder cavity. The internal surface of the cavity is coated with gold. The bore diameter and the length of the flash-lamps arc are measured Φ5 mm×65 mm, and the length of the cavity is 65 mm, which is designed for another laser system. A power supplied with capacitor-discharge produces flash-lamp pulses of 500 μs (FWHM) width measured with a PIN photodiode detector. Both the flash lamp and the crystal are cooled by deionized water of 15 ℃. The Cr-Tm:YAG crystal used in this experiment is fabricated with the size of Φ6 mm×52 mm, and the end faces are broadband antireflection coated.

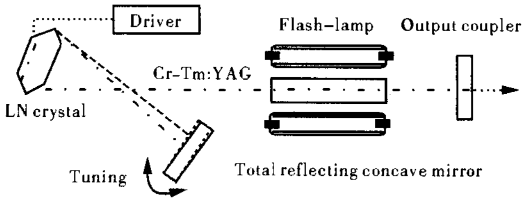

Fig.1 Cavity layout for Q-switching and tuning of flash-lamp pumped Cr-Tm:YAG laser

A prism made of LN crystal is inserted at Brewster's angle (64°48′) between the concave mirror and the Cr-Tm:YAG crystal. The LN crystal is hexagonal, with four polished faces, two of them (*a* and *b*) at angles of 45°57′ with the crystal axis of the prism. The faces (*a* and *b*) played the same role as the reflecting faces in standard double-45° LN Q-switch, as shown in Fig.2. When the half wave voltage was applied on, the prism worked as a Pockels cell for the light between *a* and *b*. The other two polished faces, at angles of 25° 12′ with the crystal axis of the prism, were designed in a way that they could refract the incident 2.01 μm light beam at Brewster's angle to the direction perpendicular to crystal axis of the LN prism. The length of the prism *L* is 45 mm, the width *W* is 15 mm, and the thickness of it (the distance between the electrodes of the crystal) is 10 mm. With the prism, the tuning of the laser could be achieved by deflecting horizontally the total reflect mirror as shown in Fig.2.

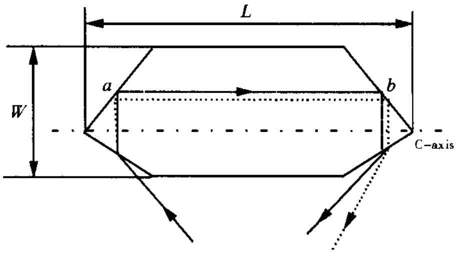

Fig.2 Schematic of electro-optic Q-switching and tuning prism made of $LiNbO_3$

For Q-switched operation, the half wave voltage, about 3.6 kV, was applied between the electrodes of the prism. The Q-switch opened when the applied voltage descended to zero rapidly. The opening time of the Q-switch was controlled by a delay generator, which could be tuned from zero to several milliseconds. The output energy was measured by a pyroelectric energy meter. The temporal profile of the Q-switched laser pulse was recorded using an InSb photo-voltaic cell (response time above 1 μs) and a Tektronix digitizing oscilloscope with a bandwidth of 100 MHz. The laser wavelength was measured by a monochromator and an InSb photo-voltaic cell.

2 Results and discussion

A typical Q-switched laser output pulse is shown in Fig.3. The output about 18 mJ in energy and 10 μs (FWHM) in duration was obtained with a flash-lamp input energy about 350 J, when the time delay of Q-switching was set at 970 μs after the triggering of flash-lamp pump. Because the Cr-Tm:YAG crystal used is of poor optical quality, exhibiting considerable scattering, the mismatch of laser crystal and the pump system in length, the laser threshold is very high, which is about 300 J. For free oscillation, there's no voltage applied on the LN prism,as shown in Fig.4,and an output energy of 40 mJ could be observed at the same pump level. The measured wavelength is 2.02 μm, and the Q-switching efficiency is about 45%.

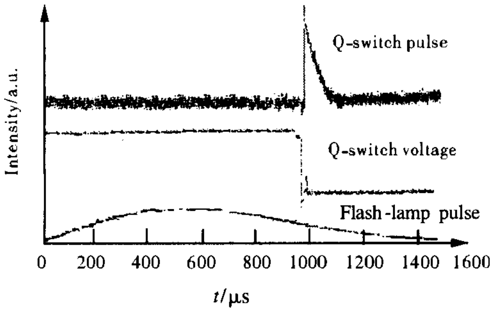

Fig.3 Temporal profiles of Q-switched laser output and flash-lamp pulse

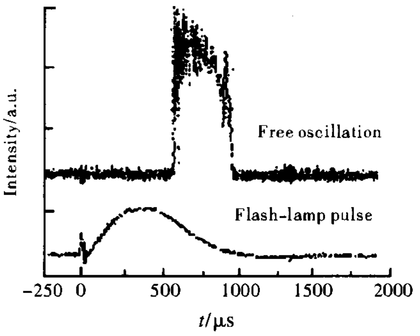

Fig.4 Temporal profile of free oscillation output without a voltage applied on LN and flash-lamp pulse

As we know, the Q-switch opening time is an critical parameter. Fig.5 shows three typical temporal profiles of laser output corresponding to different Q-switch delay time. The pump power is 350 J in all cause. It is obvious that the optimum Q-switch delay time is 970 μs .When the Q-switch delay time was shorter than the optimum one, multiple spikes were observed, which is by relaxation oscillation and Cr^{3+}-Tm^{3+} energy transfer process[3].

Q-switched laser pulses could be tuned over a wide range of wavelength, as shown in Fig.6. When the pump power was fixed at 350 J and the repetition rate of laser operation was 1 Hz, the tuning range reached 1.95~2.08 μm, and nearly the same tuning range was reached a repetition rate of 5 Hz. The maxi- mum output energy near 2.05 μm seems to contri- bute to the transmittance of the output coupler.

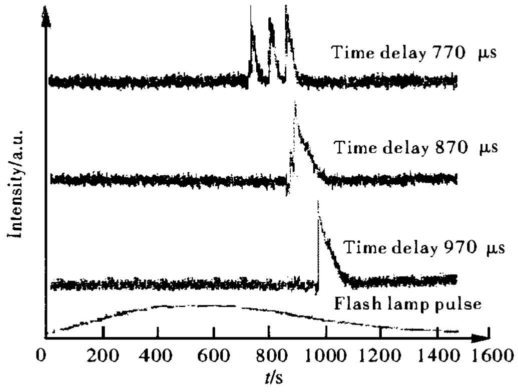

Fig.5 Temporal profiles of output laser corresponding to different delay time of 770, 870, 970 μs

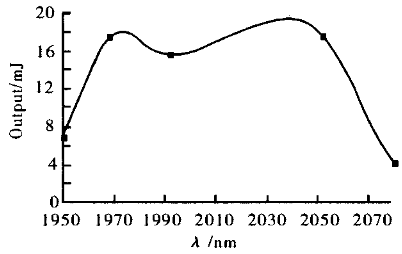

Fig.6 Tuning curve of Q-switched pulses with pump energy of 350 J. The repetition rate of the laser is 1 Hz

3 Conclusion

A simple solution was obtained for the Q-switching and the tuning operation of flash pumped Cr-Tm:YAG laser. The Q- switch is a special designed prism made of LN crystal. With the hexagonal prism, the Cr-Tm:YAG laser could be Q -switched and tuned over a quite wide wavelength range. The scheme seems also possible to be used in other kind of tunable lasers operating between 0.5~2 μm.

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