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SELF-Q-SWITCHED CR,ND:REVO4 (RE=GD, Y) CRYSTAL LASERS

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Self-Q-switched Cr,Nd:$ReVO_4$ (Re=Gd, Y) crystal lasers

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Abstract

Self-Q-switched Cr,Nd:$ReVO_4$ (Re=Gd, Y) crystal lasers are demonstrated. The spectroscopic and self-Q-switched laser properties of Cr,Nd:$ReVO_4$ are studied. Polarized absorption spectra were measured at room temperature, which showed that the absorption bands display polarization character and an absorption band of Cr^{5+} ions at 1110 nm enables the crystals to be self-Q-switched laser materials. The maximum pulse energy are achieved to be 1.12 μJ with Re=Gd, and the shortest pulse width is 85.8 ns with Re=Y. The results show that Cr,Nd:$ReVO_4$ crystals are new potential self-Q-switched laser materials.

Introduction

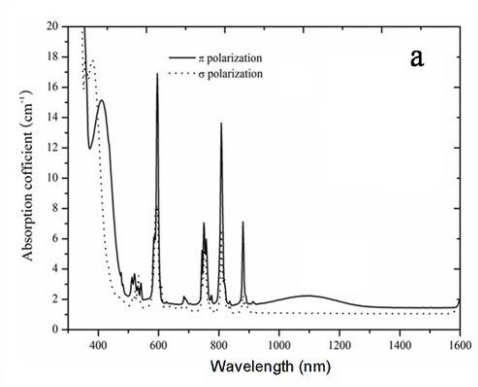
In recent years, multifunctional laser crystals, such as the self-frequency-doubling, self-Raman conversion, self-mode locked, and self-Q-switched laser crystals, have been paid a lot of attention, because of their compactness, low loss, and simplicity in the laser design and application [1-3]. In the self-Q-switching regime, neodymium (Nd^{3+}) and chromium (Cr^{4+}) co-doped YAG crystals has been investigated in detail and identified to be an excellent self-Q-switched laser material. However, due to the substitution of Cr^{4+} ions for a fraction of Al^{3+} ions at Al-ion sites in this crystal, Ca^{2+} or Mg^{2+} ions should also be co-doped to keep the balance of the charge, which brings some complexities in the crystal growth and problems in the applications. So it is significant to search for new self-Q-switched laser materials. Nowadays, the crystals doped with $3d^N$-ions in the arrangement of tetrahedral symmetry have found potential applications as saturable absorbers for near- and mid-infrared lasers [4]. With the electronic configuration of $3d^1$, the Cr^{5+} ion with a vanadate crystal as the host material should also have broad absorption in this waveband. Beside, because Cr^{5+} substitute for V^{5+} ions in those Cr^{5+} doped vanadates, no balancing charge is needed. Here, we report the growth, characterization and laser performance of Cr, Nd:$ReVO_4$ (Re=Gd, Y) crystals.

Experiments and results

By the Czochralski method, the Nd, Cr:$ReVO_4$ crystal was grown from the melts of mixed polycrystalline material $NdVO_4$, $GdVO_4$ and $GdCrO_4$ for Re=Gd, and $NdVO_4$, YVO_4 and $YCrO_4$ for Re=Y, under a nitrogen atmosphere containing 2% oxygen (v/v) in an iridium crucible. Figure 1 shows the as-grown Nd, Cr:$ReVO_4$ crystal boules with dimensions of about Φ30 mm×20 mm. Observed under He-Ne laser, no light scattering is obtained, which means that the as-grown crystals have excellent quality and are suitable for the application in the laser experiment.

Figure 1. (a) As-grown crystal Nd:Cr:YVO_4 boule (b) As-grown crystal Nd:Cr:$GdVO_4$ boule

The polarized absorption spectra of Nd, Cr:$ReVO_4$ were measured with Hitachi U-3500 spectrophotometer at the wavelength of 400 nm-1500 nm at room temperature. The incident light was perpendicular to the face of the crystal during the absorption spectra measurement. The polarized absorption spectra are shown in Fig. 2. Due to the strong absorption of Nd^{3+} ions at about 680 nm (transmission of $^4I_{9/2}$ to $^4F_{9/2}$) for π polarization, that of Cr^{5+} ions at 642 nm ($^2A_1$ to ^2E) which is only allowed for σ polarization (E⊥ c) is not evident. The absorption band of Cr^{5+} ions at 1110 nm, with the width (FWHM) of about 250 nm, is generated by the transmission of $^2A_1$ to $^2B_2$ [4-7] which is electric dipole allowed only for π polarization, and is not overlapped with that of Nd^{3+} ions at 808 nm. From the broad absorption bands near the 1100 nm for π polarization enable the crystals to be a self-Q-switched laser matrix.



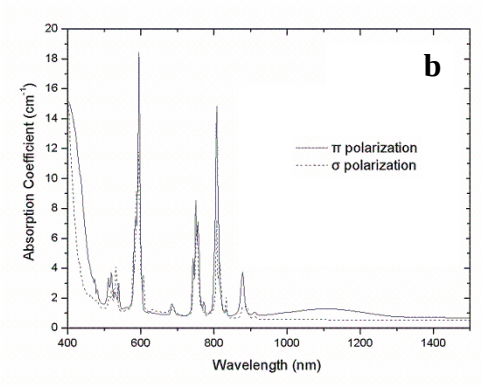


Figure 2 (a) Polarized absorption spectra of Nd:Cr:YVO_4 (b) Polarized absorption spectra of Nd:Cr:$GdVO_4$

The pulsed laser experimental setup is based on a two-mirror resonator with the length of about 30 mm. The pump source employed in the experiment was a fiber-coupled laser-diode with the central wavelength around 808 nm. Through the focusing optics (N. A.=0.22), the output of the source was focused into the crystal with a spot radius of 0.256 mm. For Re=Y and the output coupler (OC) of 40%, the maximum average output power of 120 mW was achieved with the incident pump power of 6.23 W. The threshold of the pulsed laser was measured to be 3.94 W. At the maximum pump power, the Q-switched pulse with the width of 173.5 ns and repetition rate of 151.4 kHz were obtained. The energy of single pulses was 0.79 μJ. Using the pulse energy and width, the peak power was calculated to be 4.57 W. For OC = 10%, the pumping threshold is 1.53 W and the maximum output power of 103 mW was achieved at the incident pump power of 3.47 W. At the maximum pump power, the Q-switched pulse with width of 85.8 ns and the repetition rate of 293 kHz were obtained. The energy of single pulse was about 0.35 μJ much smaller than that with OC = 40% shown above. By the pulse energy and width, the peak power was calculated to be 4.09 W. The pulse width of 85.8 ns is shown in Fig. 3(a). The inset of this figure presents the pulse trains of 293 kHz. For Re=Gd, the maximum output powers of 243 and 265 mW were obtained with OC=40% and 30%, respectively, at the incident pump power of 3.2 W. The thresholds were achieved to be 1.87 and 1.43 W, and the slope efficiencies were 18.3% and 15.3%, with OC=40% and 30%, respectively. The minimum pulse widths of 230 and 362 ns were obtained with OC=40% and 30%, respectively, under the incident pump power of 2.92 W. The maximum pulse energies were gotten to be 1.12 μJ and 0.9 μJ with the two output couplers, respectively, under the respective corresponding incident pump powers of 2.6 W and 2.33 W. By the pulse energy and width, the peak power can be calculated. The highest peak power of 3.82 W was achieved with OC=40%. The pulse train with 60.2 kHz is shown in Fig.3 (b). The inset of this figure presents the pulse profile with a pulse width of 230 ns.

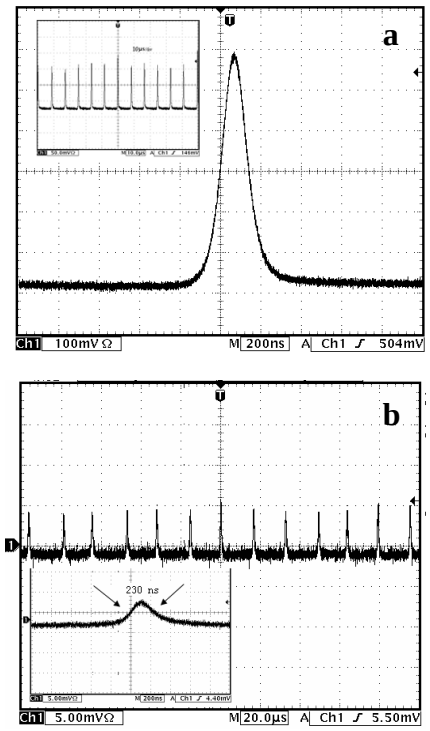


Figure 3. (a) Pulse profile for Nd:Cr:YVO_4 (b) Pulse profile for Nd:Cr:$GdVO_4$

Conclusion

In conclusion, self-Q-switched Cr,Nd:$ReVO_4$ (Re=Gd, Y) crystal lasers are reported. The absorption band of Cr^{5+} ions at 1110 nm enables those crystals are self-Q-switched laser materials. With the Nd:Cr:$ReVO_4$ crystal, the self-Q-switched laser performance was demonstrated. All the results and discussions show that Nd, Cr:$ReVO_4$ are new potential passively self-Q-switched laser materials.

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References

1. A. A. Danilov, V. L. Evstigneev, N. N. Il'ichev, A. A. Malyutin, M. Yu, Nikol'skiĭ, A. F. Umyskov, and I. A. Shcherbakov (1987) , Compact GSGG:Cr^{3+}:Nd^{3+} laser with passive Q switching, Sov. J. Quantum Electron, 17, 573-574.

2. B. X. Jiang, Z. W. Zhao, X. D. Xu, P. X. Song, and J. Xu (2005), Study of the effects of Cr ions on Nd in self-Q-switched laser crystal Cr^{4+},Nd^{3+}:$Gd_3Ga_5O_{12}$, Proc. SPIE, 5627, 167-171.

3. J. Dong and K. Ueda (2006), Observation of repetitively nanosecond pulse-width transverse patterns in microchip self-*Q*-switched laser," Phys. Rev. A, **73**, 1-7 (053824).

4. S. Suck (2001), Laser-related spectroscopy of ion-doped crystals for tunable solid-state lasers, Appl. Phys. B **72**, 515–562.

5. H. H. Yu, H. J. Zhang, Z.P. Wang, J. Y. Wang, Y. G. Yu, W. L Gao, X. T. Tao, J. H. Liu,X. Y. Zhang, and M. H. Jiang (2007), Cr^{5+}:$GdVO_4$ as a saturable absorber for a diode-pumped Nd:$Lu_{0.5}Gd_{0.5}VO_4$ laser, Opt. Express **15**, 11679-11684.

6. H. Yu, H. Zhang, Z. Wang, J. Wang, Y. Yu, W. Gao, X. Tao, and M. Jiang (2007), Growth and passively self-Q-switched laser output of new Nd^{3+},Cr^{5+}:$GdVO_4$ crystal, Opt. Express 16, 3320-3325.

7. Z. Pan, B. Yao, H. Yu, H. Xu, Z. Wang, J. Wang, H. Zhang (2012), Growth and characterization of self-Q-switched Nd:Cr:YVO_4 crystal, Opt. Express, 20, 2178-2183.