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RAPID COMMUNICATION

Laser diode corner pumped Nd:KGW slab laser

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Abstract This paper reports the continuous wave (CW) and Q-switched operation of a diode pumped KGd (WO_4): Nd (Nd:KGW) slab laser with a corner pumped geometry at the wavelength of 1067 nm. With an optical conversion efficiency of 38% and 34%, average powers of 23 and 20 W in CW and Q-switched modes were achieved respectively. The maximum pulse energy of 27 mJ was observed with a repetition rate of 840 Hz.

Keywords laser engineering, KGd (WO_4):Nd (Nd:KGW) laser, diode-pumped slab laser

1 Introduction

KGd (WO_4):Nd (Nd:KGW) laser crystals are low lasing threshold and high efficient material suitable for remote sensing applications. The efficiency of Nd:KGW lasers is several times higher than that of Nd:YAG crystal because Nd:KGW laser medium is suitable for laser operation at low pump powers within the range of few watts. The crystal has a high melting point of 1075°C and a transmission range of 0.35–5.5 μm. The $^4F_{3/2} \rightarrow {}^4I_{11/2}$ transition with life time of 120 μs evolves 1067 nm laser radiation. The doping concentration can be varied from 2% to 10% with absorption looses less than 0.005 cm^{-1}. This lasing crystal has a wide temperature range of operation and can be designed for end-pumping or side pumping from a rod shape to a slab crystal.

Other diode pumped lasing crystals [1–10] and Yb:KGW also have applications in mode locked lasers, such as Ti:sapphire laser. The crystal has an emission spectrum from 1020 to 1070 nm, and can be pumped with diode lasers at 800 or 980 nm. Diode-pumped Yb:KGW lasers have been used to generate femtosecond pulses at an output wavelength of 1048 nm and can be used in oscillator amplifier configurations.

In literature, the operation of Nd:KGW laser directly under diode pumping was reported for several times. The Q-switched operation of Nd:KGW laser in both active and passive modes was shown with a pulse energy of 2.7 mJ and a duration of 8 ns [11]. A passively modelocked operation using a Cr:YAG crystal in a V-shaped cavity was also demonstrated in Ref. [12]. The comparative output performance of Nd:KGW and Nd:YAG at 1.3 μm was also analyzed in Refs. [13] and [14]. The effect of Nd ion concentration on the laser performance at 1064 nm was considered in Ref. [15], during which 5% Nd ion doping was found to be the most efficient.

The continuous wave (CW) operation of Nd:KGW compared with other laser crystals such as Nd:YAG, Nd:BEL and Nd:YVO_4 was observed in Ref. [16]. The use of Nd:KGW crystal as an efficient raman medium was established in Refs. [17,18].

In this paper, we presented the operation of CW and Q-switched operation of a Nd:KGW laser in a 30 cm long plane-plane resonator under corner pumped configuration. The maximum of 23 W power was produced in the CW mode and maximum pulse energy of 27 mJ was obtained at 1067 nm.

2 Experimental setup and results

Figure 1 illustrates the experimental setup related to the diode pumped Nd:KGW laser. Four conductively cooled 15 W laser diodes along with focusing optics at an emission wavelength of 808 nm are used to pump through the corners of the slab laser crystal. The lower surface area of lasing crystal is attached with a copper heat sink using indium foil. A plane-plane resonator of total length 30 cm is formed in order to achieve good output beam quality and to get Q-switched pulses of stable temporal duration. All

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the pumping lasers are operated with a single power supply with variable current.

The composite slab crystal Nd:KGW/KGW is a thermally bonded combination of undoped KGW and 4.5% doped Nd:KGW. To improve the absorption efficiency of incident light all the four ends of slab are antireflection coated at 808 nm, whereas the two edges along the optical axis are antireflection coated at 1067 nm. However, the internal reflection losses of pump light between the Nd:KGW and the undoped KGW crystal are minimized by a 400 μm thick SiO_2 coating at the interface, this may further improve the efficiency of system.

The pump sources are four 15 W conductively cooled diode lasers with central wavelength at 808 nm, along with 5 cm focusing lenses in front of the spacing is adjusted such that to insert maximum light inside the slab. These laser diodes are workable in CW and quasi continuous wave (QCW) mode at an efficiency of about 40% with an output beam diameter of 7 mm × 0.3 mm. The operating conditions are 2 V and a typical current of 9 A each. The slab utilized has dimensions of 25 mm long, 14 mm wide and 6 mm thick with a doped portion of 6 mm wide. To provide the optical feedback, a flat rear mirror high reflection (HR) coated at 1067 nm is utilized, whereas a variety of flat output coupler with transmissions 5%, 10% and 15% are tested to choose the best.

The operation of laser is tested in CW mode and with an optical efficiency of 38%, a maximum of 23 W average power is recorded for 5% transmission of output coupler. A Cr^{4+}:YAG crystal anti-reflection (AR) is coated at 1067 nm, clear aperture 6 mm with initial transmission 95% is placed inside the cavity near the output coupler to achieve Q-switched pulses at 1067 nm. In this way, the laser is operated in Q-switched mode with the temporal duration of 80 ns.

Figure 2 shows the measured average power of the laser with increasing pump power (808 nm) up to 60 W. The output couplers with variable transmissions at the laser wavelength are used, which are 5%, 10% and 15%. The output response is linear with maximum CW power of 23 W at 5% transmission of output coupler. The same is used

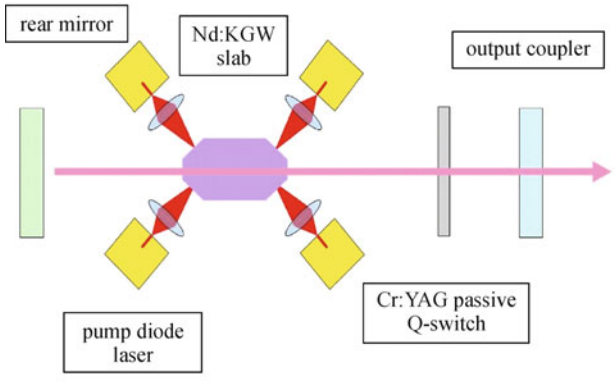

Fig. 1 Pumping scheme and Nd:KGW laser resonator

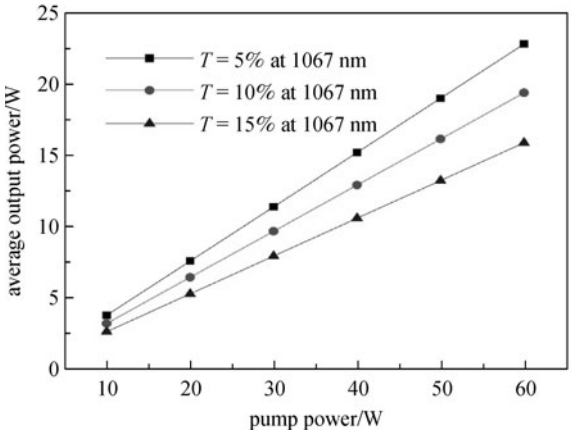

Fig. 2 Pump power versus CW mode operation of Nd:KGW slab laser without Q-switch using different output couplers

for Q-switched operation of laser, for which the input current of laser diode driver varies upto 36 A, the threshold current is 6 A, extendable upto a maximum of 36 A at which 27 mJ pulses are observed as revealed in Fig. 3. Further, the operation of this laser is confirmed for a one hour operational time during which the average output power is measured after each 10 min as obtained in Fig. 4. The plot initiates from 23 W and remains a bit stable with a maximum fluctuation of 0.32 W, whereas the Q-switched operation has a varying response with the most difference of 0.95 W. The reason of this variation can be the thermal gradients inside the laser crystal during the Q-switched operation, where peak power is very high, so to remove this variation cooling system must have to be improved, and preferable TEC cooling or micro-channel cooling can be arranged.

3 Conclusions

In conclusion, a medium size and high output pulse energy (27 mJ) Nd:KGW slab laser was reported in this paper. The laser provides pulses duration of 80 ns with a peak power of 337 kW at 840 Hz. The high output pulse energies are comprised due to the use of Cr:YAG passive Q-switch. In future, the cooling requirement for lasing crystal will be improved to minimize the power fluctuations and to get stable repetition rate. To improve the laser beam quality in some extant using this plane-plane resonator, a variable circular aperture can be placed inside the resonator towards the rear mirror and its effect on the output can be observed by varying its opening. However, if improvement is specifically required in the *y*-axis, then the shape of aperture has to be modified accordingly, i.e., elliptical. Further, the operation of this lasing medium in other cavity configurations, such as asymmetric and off-axis resonator as described in Ref. [19], can also provide good beam quality.

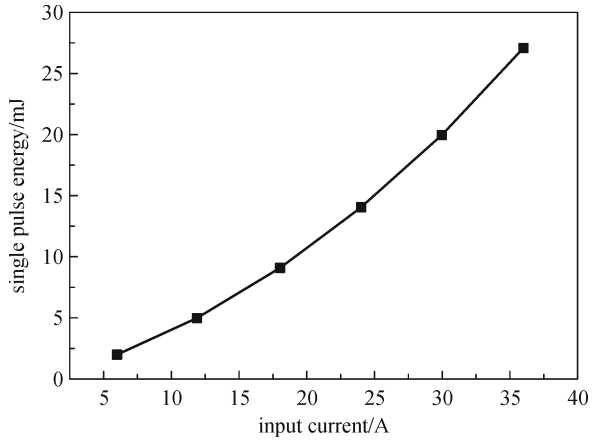

Fig. 3 Input current versus single pulse energy at the output

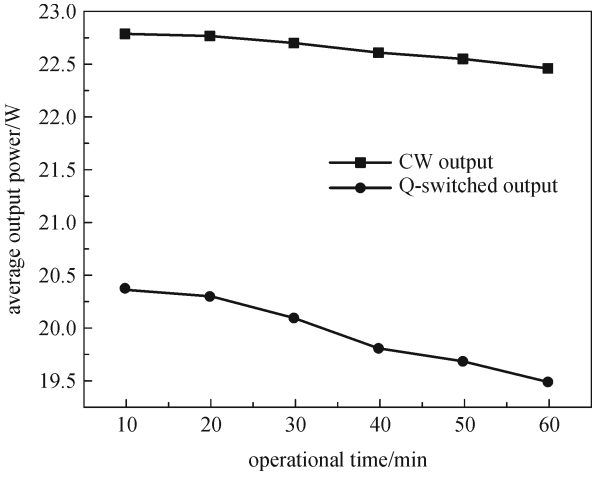

Fig. 4 Operational time versus average power in CW and Q-switched mode

References

1. Zhu L, Gao C, Wang R, Gao M, Wang X, Eichler H J. Resonantly pumped 1645 nm Q-switched Er:YAG laser with a ring cavity. Frontiers of Optoelectronics, 2012, 5(4): 400–402
2. Lin Z, Gao C, Gao M, Zhang Y, Zhu L, Zheng Y. Diode-pumped single-frequency Tm:YAG NPRO laser by using different pumping spot sizes. Frontiers of Optoelectronics, 2009, 2(4): 410–413
3. Li J, Yang A, Zuo L, Lai J, Sun Y. Optical sampling system using periodically-poled lithium niobate waveguide and nonlinear polarization rotation mode-locked fiber laser. Frontiers of Optoelectronics, 2012, 5(2): 208–213
4. Zhao M, Guo Y, Wang T, Shen X. Short cavity single-frequency all-fiber Er/Yb co-doped laser. Frontiers of Optoelectronics, 2009, 2(1): 81–85
5. Liu Y, Zhang H, Yan Y, Zhang H, He J, Xin J. A 123 W Nd:YVO_4 slab laser with high beam quality output. Frontiers of Optoelectronics, 2009, 2(4): 407–409
6. Zhang Y, Gao C, Gao M, Zheng Y, Wang L, Wang R. A speed measurement system utilizing an injection-seeded Tm:YAG laser. Frontiers of Optoelectronics, 2011, 4(4): 411–414
7. Xu J, Dong X, Leng J, Zhou P, Hou J. Efficient, 62.5 watts all-fiber single-mode 1091 nm MOPA laser. Frontiers of Optoelectronics, 2011, 4(4): 426–429
8. Zhao Y, Liang Y, Zhu X. Applications of scanning femtosecond laser-induced ionization microscopy in biological imaging. Frontiers of Optoelectronics, 2008, 1(3–4): 201–204
9. Zhang X, Xie S, Zhan Z, Zhao H, Guo J, Ye Q. Evaluation of Er,Cr:YSGG laser for hard tissue ablation: an in vitro study. Frontiers of Optoelectronics, 2010, 3(2): 163–168
10. Wang B, Jiang H, Jia X, Zhang Q, Sun D, Yin S. Thermal conductivity of doped YAG and GGG laser crystal. Frontiers of Optoelectronics, 2008, 1(1–2): 138–141
11. Karlitschek P, Hillrichs G. Active and passive Q-switching of a diode pumped Nd:KGW-laser. Applied Physics B, 1996, 64(1): 21–24
12. Liu M, Liu J, Liu S, Li L, Chen F, Wang W. Experimental study on passively Q-switched mode-locking diode-pumped Nd:KGW laser with Cr^{4+}:YAG. Laser Physics, 2009, 19(5): 923–926
13. Musset O, Boquillon J P. Comparative laser study of Nd:KGW and Nd:YAG near 1.3 μm. Applied Physics B, 1997, 64(4): 503–506
14. Kushawaha V, Yan Y, Chen Y. Efficiency of diode-pumped 1.35 μm laser from Nd:KGW. Applied Physics B, 1996, 62(5): 533–535
15. Kushawaha V, Michael A, Major L. Effect of Nd concentration on the Nd:KGW laser. Applied Physics B, 1994, 58(6): 533–535
16. Demidovich A A, Shkadarevich A P, Danailov M B, Apai P, Gasmi T, Gribkovskii V P, Kuzmin A N, Ryabtsev G I, Batay L E. Comparison of cw laser performance of Nd:KGW, Nd:YAG, Nd:BEL and Nd:YVO_4 under laser diode pumping. Applied Physics B, 1998, 67(1): 11–15
17. Bai Y, Chen X M, Guo J X, Zhang H L, Bai J T, Ren Z Y. Kilohertz high power extracavity KGW yellow raman lasers based on pulse LD side-pumped ceramic Nd:YAG. Laser Physics, 2012, 22(3): 535–539
18. Lisinetskii V A, Grabtchikov A S, Demidovich A A, Burakevich V N, Orlovich V A, Titov A N. Nd:KGW/KGW crystal: efficient medium for continuous-wave intracavity raman generation. Applied Physics B, 2007, 88(4): 499–501
19. Lu B D, Cai B W, Feng G Y, Xu S F. Beam quality improvement of slab lasers. In: Proceedings of International Symposium on Optoelectronics in Computers, Communications, and Control. International Society for Optics and Photonics, 1992, 265–273