Efficient Yb:KGW lasers end-pumped by high-power diode bars

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Abstract: The generation of 12.4W of output power with optical-to-optical conversion efficiency of 47% and slope efficiency of 74% is demonstrated in Yb:KGW laser end-pumped with high-power diode bars. Thermal-lensing and laser tuning has been investigated.

OCIS codes: (140.3480) Lasers, diode-pumped; (140.5560) Pumping

Recently increased interest is shown to Yb^{3+}-doped double tungstates such as $Yb:KGd(WO_4)_2$ (Yb:KGW), $Yb:KY(WO_4)_2$ (Yb:KYW) and $Yb:KLu(WO_4)_2$ (Yb:KLuW) as the laser materials with the highest potential for efficient tunable continuous wave (CW) and mode-locked operation in diode-pumped arrangements. The advantageous features of these materials are low quantum defect and absence of parasitic effects, as well as acceptance of high doping concentrations without indication of serious quenching. This has enabled demonstration of high CW slope efficiencies in both, Ti:Sapphire and laser diode-pumped setups [1,2]. Possibility of large doping concentration is also beneficial for thin-disk laser designs. The thin-disk configurations, to a large degree alleviate the problems associated with thermal loading and relatively poor thermal conductivity in double tungstates.

End-pumping schemes, however, in most cases offer more compact and less expensive laser designs where the matching of the laser mode and the pump beam can be achieved relatively easy. This is an important issue considering three-level nature and corresponding reabsorption on Yb^{3+} transitions around 1 μm. The highest slope efficiencies have also been reported for end-pumped configurations [1,2]. Further, end-pumped configurations are more favorable for compact lasers or Q-switched lasers as they can offer more compact cavity designs. Recent analysis by Brenier et al [3] reveals that that these double tungstates should be the most promising Yb^{3+} hosts for end-pumped CW lasers.

In this work we aim at extending the generated power in the end-pumped Yb:KGW laser arrangements using diode bar pumping. Considering a strong asymmetry of the absorption cross section, thermal expansion, thermal conductivity and thermooptic coefficients in KGW, it is important to investigate different pumping configurations. Here we compare two different pumping schemes. In the first scheme, the pump is delivered through an optical fiber yielding a symmetric but unpolarized pump spot. In the second scheme the pump is delivered through an optical lens system yielding a polarized but asymmetric pump spot.

Throughout this work a 5 % Yb:KGW laser crystal, cut for propagation along the **b** axis, was utilized. The cavity consisted of a plane input coupler and a concave output coupler with 50 mm radius of curvature. The cavity length was adjusted for each pump source to give the highest output powers at maximum pump power. In the first pumping scheme, the pump laser was a fiber-coupled CW diode-bar. The pump wavelength varied between 973 nm and 980 nm by increasing power level, with a FWHM of ~5 nm. The maximum output power of the pump laser was 50 W at the end of the 200 μm fiber (N.A. = 0.22). The fiber output was imaged 1:1 in the center of the laser crystal. In the second pumping scheme, we used a CW diode bar without fiber coupling as a pump source. This diode bar from LIMO GmbH was 95 % linearly polarized in the direction parallel to the N_m principal optical axis. The output wavelength varied between 978-980 nm depending on power level, with a FWHM of ~2.5 nm. The laser diode consisted of 19 individual emitters that were stacked together by use of a lens system to form a focus of 100×75 μm (e^{-2} radius) width inside the cavity. The maximum output power incident on the microchip after the focusing system was 19.3 W.

The dependence of the laser output power versus the incident pump power for the two pumping schemes using different output couplers is given in Fig. 1. It should be also mentioned that here we use incident pump power to determine the laser efficiencies, as this parameter eventually is more relevant than the absorbed power for practical device performance.

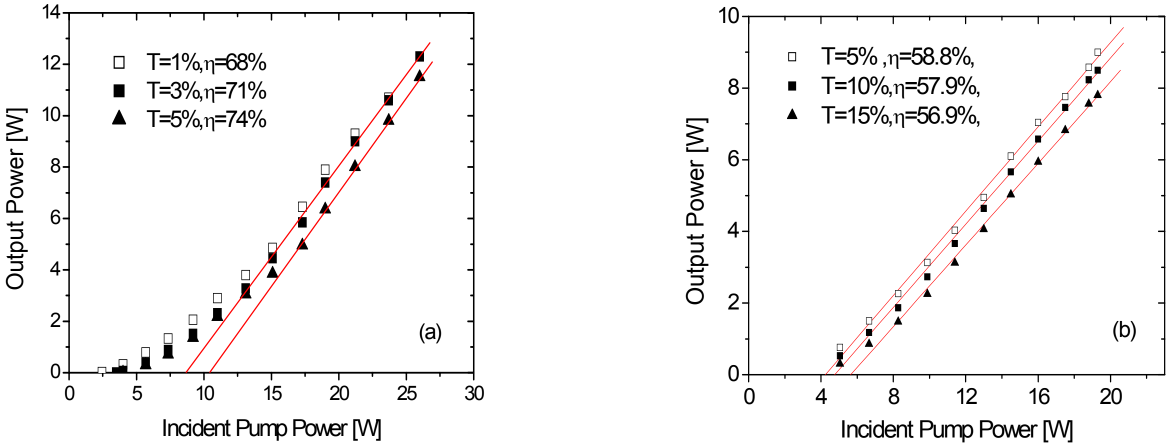

Fig. 1. Output power versus incident pump power for the fiber-coupled scheme (a) and the stacked emitters scheme (b).

In both pump configurations the highest slope efficiency was obtained using T=5% output coupler. So, for the polarized diode pumping the slope was about 59% while in the fiber-coupled diode case the slope was as high as 74%. Here the maximum output power of 12.4W has been generated. The higher slope in the latter case has to be associated primarily with the better overlap of the symmetric pump beam with the laser cavity mode. By increasing the pump power above 26 W, the laser crystal fractured due to thermal stress. This would give an estimate for the heat generation fluence of about 10 kWcm^{-2}, which would cause crystal fracturing in the end-pumped laser configuration. For further power scaling, a more homogeneous heat distribution is required, which can be achieved in the end-pumped configuration by using thinner laser crystal and elliptical pump beams and an appropriate cavity design to compensate for the astigmatism.

The dependences of the optical efficiency on the incident pump power for the laser configurations tested in this work are shown in Fig. 2. The optical efficiency is higher using the polarized non-fiber-coupled pump throughout the entire pump power interval.

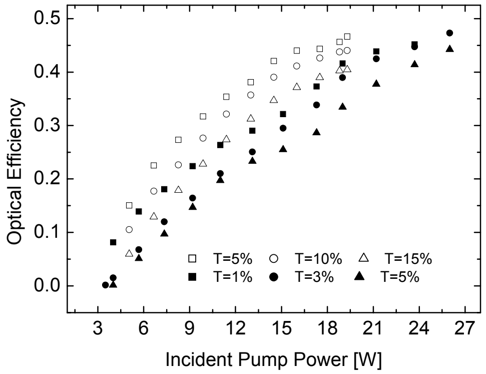

Fig. 2. Optical efficiency versus incident pump power for the fiber-coupled scheme (filled symbols) and the stacked emitters scheme (open symbols)

We have also investigated dependence of the thermal lens and M^2 parameter as a function of the pump power, which could be as strong as 30 m^{-1}, and its pronounced impact on beam quality. The output wavelength tuning between 1020nm and 1050 nm could be achieved in this laser system by using appropriate output couplers and intracavity etalon.

References

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