Polarization switching in a continuous-wave Yb:$GdVO_4$ laser

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As laser hosts for the Yb-ion emitting at ~1 µm, the orthovanadate crystals YVO_4, $GdVO_4$, and $LuVO_4$, have recently attracted much attention because they have 2-3 times higher thermal conductivity in comparison with the currently popular potassium double tungstates $KY(WO_4)_2$, $KGd(WO_4)_2$, and $KLu(WO_4)_2$. In this respect, Yb:$GdVO_4$ is the most promising among them: Its thermal conductivity is at least comparable to or even better than that of Yb:YAG. Despite this, however, only one study has focused on the laser properties of Yb:$GdVO_4$, in which the maximum output power achieved in the continuous-wave (cw) regime under Ti-sapphire laser pumping was less than 0.5 W [1]. Here, we report on the characteristics of an efficient and compact Yb:$GdVO_4$ laser end-pumped by a high-power diode laser. Our results indicate that, in the absence of intracavity polarization selective element, the polarization of the laser field undergoes a transition from σ (|| *a* axis) to π (|| *c* axis) with increasing pump power; in an intermediate region between these two states the two polarizations coexist but the corresponding oscillation wavelengths are different.

The Yb:$GdVO_4$ laser consisted of a compact plano-concave resonator with a length of 25 mm arranged in a near hemispherical configuration. The 0.9 at. %, 2 mm thick uncoated Yb:$GdVO_4$ crystal was held in a water-cooled Cu block close to the plane mirror. The unpolarized pump source used at 974…979 nm was a 50-W high-brightness, fiber-coupled diode laser with a fiber core diameter of 200 µm and NA of 0.22. The absorption of the Yb:$GdVO_4$ crystal measured under non-lasing conditions was roughly 20%. Optimal operation was achieved using an output coupler with T=1%, for which the output power reached 4.0 W at an absorbed pump power of 6.6 W. The optical-to-optical and slope efficiencies in this case were 61% and 78%, respectively. Slightly lower slope efficiencies of 73% and 69% were obtained for T=0.5 and 2%, respectively. For all three coupling transmissions used, the laser output was π-polarized while operating at the highest power levels, whereas the emission wavelength shifted from 1045 nm (T=0.5%) to 1040 nm (T=1%) and 1031 nm (T=2%). With all three output couplers, characteristic bistable behaviour was observed at low powers, with different laser thresholds depending on whether the pump power was increased or decreased. The laser was σ-polarizated at both the “down” and “up” thresholds.

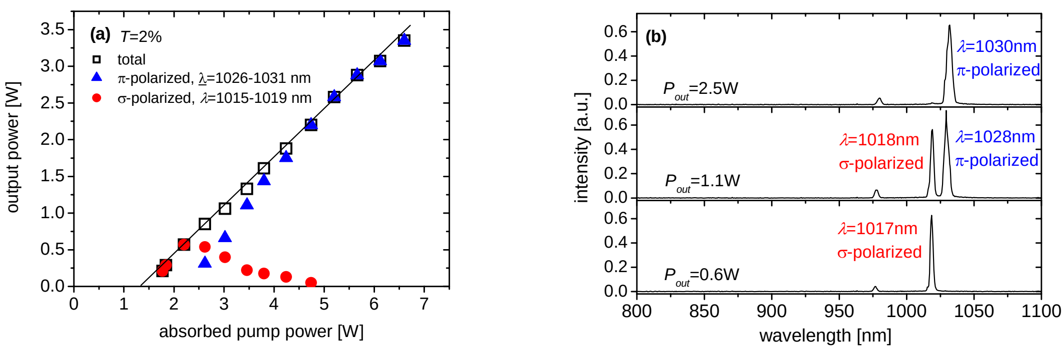

Fig.1: Variation of the σ- and π-polarized output power with the absorbed pump power for T=2% (a) and typical laser emission spectra (b) recorded in the three operational regimes.

The significant competition between the σ- and π-polarization states of oscillation distinguishes the Yb:$GdVO_4$ laser from its Yb:YVO_4 and Yb:$LuVO_4$ counterparts as illustrated in Fig. 1a for the case T=2%. At low pump powers the laser oscillated in σ-polarization. The π-polarized oscillation occurred at an absorbed pump power of 2.6 W and the laser entered a region in which the two polarization states coexisted at different oscillation wavelengths. This region extended up to 4.7 W in terms of absorbed pump power. Finally, only the π-polarization oscillated for absorbed pump powers exceeding 4.7 W. Figure 1b presents typical laser emission spectra recorded in the three regions. For σ-polarized oscillation the laser wavelength varied from 1015 to 1019 nm; for π-polarized oscillation, this wavelength range was 1026-1031 nm. The observed polarization switching can be explained by heating of the active volume which increases the reabsorption losses and changes the laser wavelength while depending on the laser wavelength, different polarization can provide higher gain cross section as can be concluded from the spectroscopic data.

1. J. Petit, B. Viana, P. Goldner, D. Vivien, P. Louiseau, and B. Ferrand, Opt. Lett. **29** (2004) 833.